GOVERNMENT OF INDIA
MINISTRY OF IRRIGATION AND POWER

REPORT
OF
POWER ECONOMY COMMITTEE

March, 1971
NEW DELHI

APPOINTMENT OF COMMITTEE AND TERMS OF REFERENCE

The Power Economy Committee was constituted by the Government of India in the Ministry of Irrigation and Power by their Resolution No. EL.I.32(84)/68, dated the 27th May, 1969 (Appendix I) as a High Power Committee of Experts in the field of electricity development. The terms of reference with subsequent amendments, are as follows:

1. to review the pattern of utilisation of available plant capacity during the past 5 years and their operational efficiency and fuel consumption, to consider the scope of improving economy in power generation together with specific measure for attaining them;
2. a review of the economics of power generation from different sources, hydro, thermal and nuclear sources under prevailing conditions and expected future trends to indicate the factors which must prevail in the choice of schemes for expansion of generation and supply in each Region of the country in future;
3. to review the conditions of power supply including reliability, voltage fluctuations and the extent of transmission losses, to be followed by specific suggestions to improve the conditions of supply and reduce transmission losses to the minimum extent possible;
4. to review the causes of delay in the execution of the power projects, to suggest measures for improving the manner of implementation of power projects and reducing construction periods;
5. to review and examine the technical and economical aspects of rural electrification, particularly with a view to enabling the State Electricity Boards and Electricity Authorities to undertake a massive programme of rural electrification and making electricity available at an economical rate.

2. The following were appointed as Members of the Committee :—

(1) Shri K. L. Vij, *Chairman*
Retd. Vice-Chairman, C.W. & P.C.,
New Delhi.

(2) Shri H.V. Narayana Rao,
Adviser (Power), C.B.I. & P.,
Bangalore.

(3) Member (Commercial), C.W. & P.C. (PW),
Shri Ipe Mathai,
later succeeded by
Shri P. P. Gangadharan,
New Delhi

(4) Shri B. N. Ojha,
Chief Engineer & Technical Member, Bihar State Electricity Board, now Member (Thermal), C.W. & P.C. (PW).
New Delhi.

(5) Shri K. B. Rao,
Adviser (I. & M.), Planning Commission, now Director General, Technical Development,
New Delhi.

(6) Shri K. M. Chinnappa,
Jt. Managing Director, Tata Electric Companies,
Bombay.

(7) Shri M. W. Goklany,
Chief Electrical Engineer, Damodar Valley Corporation, *Calcutta.*

(8) Dr. K. Venugopal,
Minerologist, National Council of Applied Economic Research, *New Delhi.*

(9) Shri B. V. Deshmukh,
Member (Technical), Maharashtra State Electricity Board, now Chairman, Bhakra Management Board, *Chandigarh.*

(10) Shri M. N. Chakravarti,
Project Administrator, Tarapore Atomic Power Plant Project, now Adviser (Power), Department of Atomic Energy, *Bombay.*

(11) Shri S. N. Vinze, *Member-Secretary*
Director, Central Power Research Institute, Bangalore, now Joint Secretary (Power), Ministry of Irrigation and Power, *New Delhi.*

It was proposed to have two Experts from U.S.A.—one from the Tennessee Valley Authority and the other from the Detroit Edison Electric Company. For various reasons, this did not materialise. However, the assistance of the American Experts was availed in other ways. Mr. Walker Cisler, Chairman of the Board of Directors of the Detroit Edison Electric Company, who is also currently Chairman of the International Executive Council of the World Energy Conference and Mr. Tyler Wood of U.S. AID, Washington attended the first meeting of the Committee held in New Delhi in August/September, 1969. Again U.S. AID, on the advice of Mr. Walker Cisler made available, at their cost, the services of 5 American Experts who visited a number of power installations, manufacturing units etc. in November/December, 1969 and gave their expert advice in their fields of specialisation to the Committee. In March, 1971, two American Experts viz. Mr. William Clapp and Mr. Harold C. Reasoner visited India for about 2 weeks each and gave their suggestions on the draft reports of the Committee and its Study Groups. The U.K. Government made available under the Colombo Plan, the services of Prof. E. A. G. Robinson, a well-known Economist for about 3 weeks in February/March, 1971.

3. In its first meeting held in August/September, 1969, the Power Economy Committee formed five Study Groups, one for dealing with each of the aforesaid terms of reference. The work of the Power Economy Committee was mainly carried out in the res-

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pective Study Groups and the Chairman and the Member-Secretary fully participated in the work of all the Study Groups throughout. The names of Conveners and Members of the Study Groups are given in Appendix-2. The Study Groups co-opted from time to time additional top level experts in the respective fields. The reports of all the five Study Groups form an integral part of the report of the Power Economy Committee.

4. A number of studies were undertaken in different appropriate organisations for furthering the work of the Committee. Notable among these are (i) the detailed studies of costs and benefits of power generation from fossil-fuel, water power and nuclear power sources by discounted cash flow method undertaken by the National Council of Applied Economic Research at the instance of the Planning Commission; (2) studies carried out by the Tata Electric Power Companies on behalf of Study Groups 2 and 5; (3) a sample study regarding distribution losses undertaken by the Mysore State Electricity Board and (4) vast amount of data collection and processing work carried out by the concerned units of the Central Water and Power Commission.

5. **Acknowledgements.**—The Power Economy Committee is grateful to :—

(1) Dr. K. L. Rao, Minister of Irrigation and Power, for his active interest and guidance in the work of the Committee from its inception.

(2) Vice-Chairman and Members of the Power Wing of the Central Water and Power Commission, who participated actively in the work of Study Groups and the deliberations of the Committee. They also very kindly made available to the Committee the services of different technical Directorates to assist it in its work.

(3) U.S. AID for (a) the visit of M/s Walker Cisler and Tyler Wood in August/September, 1969; (b) making available the services of 5 American Experts at their expense in November/December, 1969; (c) participation of M/s D. C. Woody and Dale C. Calhoun, the local engineers of U.S. AID in the meetings of the Committee; and (d) services of M/s William Clapp and Mr. Harold C. Reasoner in March, 1971.

(4) The Government of the United Kingdom for making available the services of Prof. E.A.G. Robinson under the Columbo Plan.

(5) The Tata Electric Companies for carrying out some of the detailed technical studies and making available the services of their officers and staff for the work of the Committee. In this connection, special mention is made of the valuable contribution made by Shri V. P. Thakor in the preparation of the report of Study Group-2.

(6) The Member-Secretaries of the Regional Electricity Boards for their participation in the work of the Committee and the different Study Groups and assistance in data collection in the respective regions.

(7) Shri B. N. Baliga, Chief (Power), Planning Commission for actively participating and making useful contribution in the work of the Study Groups and that of the Committee.

(8) The Rural Electrification Corporation for their valuable assistance in preparation of the report of Study Group-4 dealing with rural electrification.

6. The Committee would like to place on record its appreciations of the valuable work done by the Member-Secretary, Shri S. N. Vinze. In this, he was ably assisted by Shri S. P. Jain, Deputy Director, Shri Harkirat Singh, Deputy Director and Shri Priti Pal, Assistant Director, whose services were very kindly placed at the disposal of the Committee by the Vice-Chairman, C.W. & P.C.

APPENDIX I

RESOLUTION SETTING UP THE POWER ECONOMY COMMITTEE

MINISTRY OF IRRIGATION AND POWER

Dated the 27th May, 1969

RESOLUTION

No EL. I. 32(84)/68.—Under Section 18 of the Electricity (Supply) Act, 1948, the State Electricity Boards are charged with the general duty of promoting the co-ordinated development of the generation, supply and distribution of electricity within the State in the most efficient and economical manner. Power demand has outstripped its supply and the cost of electricity supply in the country has been rising despite large scale technological development.

2. In order to efficiently utilise the limited resources of the country to take up required schemes for generation, transmission and distribution of power which are largely capital intensive in nature, it is necessary to implement measures for bringing down costs of power development. This would require a detailed review of measures taken by Government to ensure utmost expediency in the construction of power projects, better utilisation of existing generating facilities, planning of future schemes to utilise the most economic energy sources in each Region and reduction in transmission losses.

3. It has, therefore been decided to set up a High Powered Committee consisting of experts in the field of electricity development. The Committee shall consist of :—

Chairman

(i) Shri K. L. Vij, Retd. Vice-Chairman, C.W. & P.C., *New Delhi.*

Members

(ii) An Expert from the Tennessee Valley Authority, *U.S.A.*

(iii) An Expert from the Edison Institute of *U.S.A.*

(iv) Shri K. B. Rao, Adviser (I&M), Planning Commission.

(v) Shri H. V. Narayana Rao, Malleswaram, *Bangalore.*

(vi) Shri Ipe Mathai, Member (Commercial), C.W. & P.C. (PW), *New Delhi.*

(vii) Shri B. N. Ojha, Chief Engineer and Tech. Member, Bihar State Elecy. Board, *Patna.*

(viii) Shri K. M. Chinnappa, General Manager, Tata Hydro Electric Power Projects Ltd., *Bombay.*

(ix) Shri M. W. Goklany, Chief Electrical Engineer, D.V.C., *Calcutta.*

(x) Dr. K. Venugopal, Senior Technical Officer, National Council of Applied Economic Research, *New Delhi.*

(xi) Shri B. V. Deshmukh, Member (Technical), Maharashtra State Elecy. Board, *Bombay.*

(xii) Shri M. N. Chakravarty, Project Administrator, Tarapore Atomic Power Plant Project, Department of Atomic Energy, *Bombay.*

Member-Secretary

(xiii) Shri S. N. Vinze, Director, Power Research Institute, C.W. & P.C. (PW), *Bangalore.*

The Chairman and Secretary of the Committee will be full-time members of the Committee.

4. The terms of reference of the Committee are :—

(i) to review the pattern of utilisation of available plant capacity during the past 5 years and their operational efficiency and fuel consumption, to consider the scope of improving economy in power generation together with specific measure for attaining them;

(ii) a review of the economics of power generation from different sources, hydro, thermal and nuclear sources under prevailing conditions and expected future trends to indicate the factors which must prevail in the choice of schemes for expansion of generation and supply in each Region of the country in future;

(iii) to review the conditions of power supply including reliability, voltage fluctuations and the extent of transmission losses, to be followed by specific suggestions to improve the conditions of supply and reduce transmission losses to the minimum extent possible;

(iv) to review the causes of delay in the execution of the power projects, to suggest measures for improving the manner of implementation of power projects & reducing construction periods;

(v) to review and examine the technical and economical aspects of rural electrification, particularly with a view to enabling the State Electricity Boards and Electricity Authorities to undertake a massive programme of rural electrification and making electricity available at an economical rate.

5. The Committee will submit its report within a year.

K. P. MATHRANI

Secretary

Ministry of Irrigation & Power

Notes :

Para 3 (iv) : *Added* by Resolution of even number, dated 29-8-1969.
Para 3 (xi) : *Added* by Resolution of even number, dated 19-6-1969.
Para 4 (v) : *Added* as per Resolution of even number dated 5-11-1969.

APPENDIX II

NAMES OF CONVENERS AND MEMBERS OF THE STUDY GROUPS

STUDY GROUP 1

"To review the pattern of utilisation of available plant capacity during the past 5 years and their operational efficiency and fuel consumption, to consider the scope of improving economy in power generation together with specific measure for attaining them."

Convener

SHRI M. W. GOKLANY, Chief Electrical Engineer, Damodar Valley Corporation

Members

SHRI B. V. DESHMUKH, Chairman, Bhakra Management Board.

SHRI B. N. OJHA, Chief Engineer & Engg. Member, Bihar State Electricity Board, now Member (Thermal), CW&PC.

SHRI B. N. BANERJEE, Chief Engineer, West Bengal State Electricity Board.

SHRI K. A. DAVE, Vice-Chairman, Central Water & Power Commission.

SHRI K. L. VIJ, Chairman, Power Economy Committee.

SHRI S. N. VINZE, Member-Secretary, Power Economy Committee.

STUDY GROUP 2

"To review the conditions of power supply including reliabilty, voltage fluctuations and the extent of transmission losses, to be followed by specific suggestions to improve the conditions of supply and reduce transmission losses to the minimum extent possible."

Convener

SHRI K. M. CHINNAPPA, Joint Managing Director, Tata Electric Companies

Members

SHRI B. R. R. IYENGAR, Member (Hydro-Electric), Central Water & Power Commission

SHRI P. P. GANGADHARAN, Member (Commercial), Central Water & Power Commission

SHRI H. V. NARAYANA RAO, Adviser, Central Board of Irrigation & Power

SHRI C. K. CHANDRAN, Member-Secretary, Northern Regional Electricity Board.

SHRI V. P. THAKOR, Chief Load Despatcher, Tata Electric Companies.

DR. K. R. PANDIT, Dy. Chief Engineer, Tata Electric Companies.

SHRI B. N. BALIGA, Chief (Power), Planning Commission.

SHRI K. L. VIJ, Chairman, Power Economy Committee.

SHRI S. N. VINZE, Member-Secretary, Power Economy Committee.

STUDY GROUP 3

"A review of the economics of power generation from different sources, hydro, thermal and nuclear sources under prevailing conditions and expected future trends to indicate the factors which must prevail in the choice of schemes for expansion of generation and supply in each Region of the country in future."

Convener

SHRI IPE MATHAI, Member (Commercial), Central Water and Power Commission
succeeded by

SHRI P. P. GANGADHARAN, Member (Commercial), Central Water and Power Commission.

Members

SHRI C. K. CHANDRAN, Member-Secretary, Northern Regional Elecy. Board.

SHRI K. B. RAO, Adviser, Planning Commission.

SHRI B. V. DESHMUKH, Chairman, Bhakra Management Board.

SHRI K. M. CHINNAPPA, Joint Managing Director, Tata Electric Companies.

SHRI B. N. OJHA Member (Thermal), Central Water and Power Commission.

SHRI M. N. CHAKRAVARTI, Adviser (Power), Department of Atomic Energy.

SHRI H. V. NARAYANA RAO, Adviser, Central Board of Irrigation and Power.

DR. K. VENUGOPAL Minerologist, National Council of Applied Economic Research.

SHRI K. L. VIJ, Chairman, Power Economy Committee.

SHRI S. N. VINZE, Member-Secretary, Power Economy Committee.

STUDY GROUP 4

"To review and examine the technical and economical aspects of rural electrification, particularly with a view to enabling the State Electricity Boards and Electricity Authorities to undertake a massive programme of rural electrification and making electricity available at an economical rate".

Convener

SHRI B. N. OJHA, Member (Thermal), Central Water and Power Commission (Formerly Chief Engineer & Technical Member, Bihar State Elecy. Board).

Members

SHRI L. B. DUDHANE, Technical Member, Maharashtra State Electricity Board.

SHRI N. TATA RAO, Technical Member, M.P. Electricity Board.

SHRI A. C. BANDYOPADHYAY, Managing Director, Rural Electrification Corporation.

SHRI P. A. RAMAN, Technical Director, Rural Electrification Corporation.

SHRI A. P. SEETHAPATHY, Officer on Special Duty, Rural Electrification Corporation.

MR. LYLE M. ROBINSON, Rural Electrification Specialist, AID/Co-operative Programme.

SHRI K. B. MATHUR, Director (R.E.), Central Water & Power Commission.

SHRI B. M. SAFIULLA, Member-Secretary, Southern Regional Electricity Board, (Since retired).

SHRI K. L. VIJ, Chairman, Power Economy Committee.

SHRI S. N. VINZE, Member-Secretary, Power Economy Committee.

STUDY GROUP 5

"To review the causes of delay in the execution of the power projects, to suggest measures for improving the manner of implementation of power projects and reducing construction periods".

Convener

SHRI B. V. DESHMUKH, Chairman, Bhakra Management Board.

Members

SHRI M. W. GOKLANY, Chief Electrical Engineer, Damodar Valley Corporation.

SHRI K. M. CHINNAPPA, Joint Managing Director, Tata Electric Companies.

SHRI M. N. CHAKRAVARTI, Adviser (Power), Department of Atomic Energy.

SHRI B. N. BALIGA, Chief (Power), Planning Commission.

SHRI K. C. KRISHNAMURTHI, Deputy Secretary, Ministry of Irrigation & Power.

SHRI K. L. VIJ, Chairman, Power Economy Committee.

SHRI S. N. VINZE, Member-Secretary, Power Economy Committee.

I. AMERICAN EXPERTS WHO VISITED INDIA IN NOVEMBER/DECEMBER, 1969 IN CONNECTION WITH THE WORK OF POWER ECONOMY COMMITTEE.

COMMITTEE

1. MR. HAROLD C. REASONER, Assistant Vice-President and Manager of Engineering and Interconnections, Detroit Edision Company.
2. MR. A. HOEFLE, General Manager (Retd.), Toledo Edison Company.
3. MR. ROBERT ALLEN, Vice-President (Retd.), Allis-Chalmers Company.
4. MR. ROBERT HATFIELD, Vice-President (Retd.), Combustion Engineer Company.
5. MR. WILLIAM CLAPP, Chairman of the Board of Directors, Florida Power Company.

II. Prof. E.A.G. Robinson, Professor of Economics, Cambridge University, England.

INTRODUCTION

When India became independent in 1947, the nation possessed only some 1363 MW of capacity in the electric supply utilities, the annual total of energy sold was 3360 million kWhrs. In 1968-69, we had 12960 MW of capacity and the sales of energy were 37,350 Million kWhrs. The capacity has increased 9.3 times, the energy sold 11.1 times. Over the twenty-two years, capacity has grown by an average of 10.7% a year and energy sold by 11.6%. During the eight years (60-61 to 68-69) capacity has grown by 13.6% a year and energy sold by 13.1%.

2. Yet today, despite this stupendous expansion, we are faced with shortages of electricity, interruptions of supply, poor voltage conditions, and rising costs and charges. Why should this be? Electricity supply is the life blood of development. Without it, we cannot create and operate our industries; without it, we cannot multiply the number of tube-wells that are bringing about a revolution in agriculture; without it, we cannot achieve the improvements of life in our towns and villages that are brought by light for our houses, power for our activities, the fans and air-conditioning that are beginning to mitigate some of the severities of our climate. It is essential that this life-blood shall flow to every limb of the body. In U.S.A., less than 7% of the population engaged in farming not only produces enough food for the country, but also a lot surplus which is exported. In Germany, a relatively small labour force in the agricultural sector produces so much food that they are nearly self-supported. On the other hand, in India, about 80% of the population work directly or indirectly in the agricultural sector but the out put of farming is low. Generally, it does not rise above low level subsistence farming except a few areas like Punjab where green revolution has recently taken place. The reasons, for this are many but one important factor as to why the productivity of farming is low is that energy and motive power on large scale are not applied for farming as in the developed countries. In order to increase the food production and improve the standards of living of villagers, who constitute about 80% of the population, and to give them a psychological effect that they are members of the modern age, electricity will have to be applied in rural areas on a very large scale. The Committee has, therefore, given special attention to this subject and analysed the socio-economic benefits of rural electrification and the measures that should be taken for reduction in cost etc. so that with the available funds, maximum amount of electrification can take place in rural areas.

3. Today consumption of electricity per head is very different in different parts of India. It is vitally important that, where States are lagging in development and in their use of electricity, added supplies shall be available when industrial and agricultural development begins to create a demand, and that the temporary backwardness of some States shall not be aggravated by shortages of electricity supply. It is equally important that this energy shall be supplied as economically as possible at prices which are within the reach of those who need the electricity. This can be achieved only if the industry is operated as efficiently as possible and on the basis of the cheapest sources of fuels that are available.

4. India is not rich in energy resources. As compared with the vast resources of North America, Europe, the U.S.S.R., our resources of primary energy in the form of coal, oil, water resources are limited and concentrated in particular areas. From a long term point of view, we are more fortunate in respect of nuclear fuels and are likely to have good reason to be grateful for the foresight which led us to begin early to experiment with these new sources of energy.

5. It was not accident that industrial development began earlier and grew more rapidly in some of the countries that were rich in energy. Like Japan, and like some of the countries of Europe, India will have to build a modern energy-intensive industrial economy. But today our present energy resources are very unequal to the needs of an industrially advanced country.

6. To keep up with the rapid growth of demand for electricity, massive further investment in generation, transmission and distribution will continue to be needed. Since planned development began in 1950/51, some Rs. 4,000 crores have been invested directly in the electricity supply industry, apart from the additional investment in the coal industry and in transport facilities to carry the coal to the power stations. This report does not attempt to forecast or plan such further investment. It is concerned, however, with a different but extremely urgent and important issue. If the volume of the necessary investment is to be kept within the limits of our national resources and if the costs and charges for electricity supply are to be kept from rising up the inflationary spiral (as has happened elsewhere) it is necessary to rationalise the operations of the power supply industry in its varied areas of activity and press into service every modern technique of scientific management as well as of the science and technology of power generation, transmission and distribution. This is the only way in which the most can be made of the limited available capital resources and the benefits maximised with as low running and operation charges as possible. The Power Economy Committee has been able to identify a large number of areas in which substantial savings are possible and a number of such instances of prospective savings have been indicated throughout the reports of its Study Groups on the basis of factual data and studies based thereon. A few instances of

such savings are given below by way of illustration. The immediate utility of these in improving the resources position needs hardly any stress:

(1) **Integrated Operation**

In Southern region, a saving of Rs. 8.27 crores in fuel charges alone would have been possible in the working in 1968-69 if adequate facilities for integrated operations were available. Even on the basis of the transmission system already on the ground the savings would have come to Rs. 1.5 crores. For the expected conditions of 1973-74 the savings would amount to Rs. 8.33 crores per annum.

If fully integrated operation of the power systems throughout the country could be achieved by 1980-81 a net saving of capital expenditure to the extent of Rs. 300 crores would be available.

(2) **Proper Mix of Energy Sources**

If adequate advance action by way of necessary investigations of hydro schemes and arrangements for fuel supplies, transport etc. had been taken at appropriate times, it would have been possible to achieve the most economic mix of energy sources with necessary hydro capacity as brought out in the Report of Study Group No. 3. If this had been achieved, it would have been possible to generate additional revenues of the order of Rs. 180 crores at the prevailing tariffs during the Fourth Plan.

(3) **Reduction of losses**

A reduction of 1 per cent in power system energy losses would have made 538 million kWh of additional energy available at the level of 1969-70 operations. This would be equivalent to an additional revenue of over Rs. 5 crores (on the basis of 10 paise per unit) for every 1 per cent reduction in losses.

(4) **Improvement in Plant Availability**

It is estimated that availability of thermal power plant can be improved to the extent of 8 to 10 per cent if the quality of fuels (abrasiveness, ash content, etc.) as well as the operation and maintenance could be improved. Further improvement by another 5 per cent or so should be available by modifying the boiler regulations to permit biennial statutory overhaul instead of annual. If the plant availability is thus improved to the extent of about 15 per cent in an all-thermal system of about 4 million kW installed capacity, the benefit are equivalent to about Rs. 6.0 crores annually.

(5) **Reduction in transport costs**

Introduction of unit trains for power stations burning over a million tonnes of coal per year would roughly reduce the fuel transportation costs for these power stations to about 50 per cent after taking the cost of special arrangements into account. Three such stations are expected to come up by 1973-74.

(6) **Rural Electrification**

There are several measures for economising in the cost of rural electrification by adopting standardisation of designs, specifications, materials and construction practices. It has been estimated that this could bring about a saving of 5% in the capital cost. An investment of Rs. 1800 crores has been estimated for the rural electrification during the period 1974-81 which would mean a saving of Rs. 270 crores or in other words additional benefits with the same investments.

7. This same problem of preventing a rise of electricity prices in a world of inflation has been facing other countries also. To some extent in all countries, it has been possible in the past to offset increases of costs of labour, fuels and other inputs through the lower capital costs per KW of large units as compared with smaller units and through higher thermal efficiencies and reduced fuel consumption per kWh. But above all, other countries have found it possible to make very significant savings in the amount of generating capacity needed to meet given demands, partly by reducing the number of involuntary stoppages of their generating plants, partly by reducing the time in each case for which equipment needs to be stopped for given repairs or maintenance, but to an even greater extent by reducing the margins of inactive capacity that are needed to provide a given service with a given degree of security. If electricity systems are small in area and load, each must possess a margin of capacity above its peak demand sufficient to deal with the risks that some of its units may be out of action. If a group of small systems are integrated into a single whole, the necessary margins are reduced, since the peaks of demand are unlikely to occur simultaneously, since involuntary stoppages are statistically very unlikely to occur at the same moment, and since the largest units, against whose involuntary stoppages reserves must be held, will represent a smaller proportion of the integrated than of the separate systems. At the same time, the larger integrated system can more readily absorb and use efficiently the very large units which greatly reduce the cost of capacity per kW and offer greater possibilities of reducing fuel consumption per kWh.

8. In Indian conditions, electricity can ordinarily be supplied more cheaply from hydro than from other sources. Where these are limited, it may be more economical to reserve the hydro for use to meet peak-load demands. There are areas in which there is little available hydro. In these areas, coal-burning stations and nuclear stations may provide the lowest cost supplies or be used to carry the base load while conserving the hydro for peak use. But in general, the Committee is of the opinion that the first priority should be given over the next few years to further development of hydro, but that such development should always be designed on the basis that, as total load builds up, the hydro can increasingly be reserved for use to meet peak demands at low load factors.

9. During the past twenty years, Indian engineers have successfully tackled the formidable tasks of building and operating the large new electricity systems that now exist in all the States of India. It is not surprising that there remain certain respects in which, using the experience that has been accumulated in this country and the experience of other countries in addition, more can still be done to improve the performance of the industry, to reduce involuntary stoppages, to improve fuel consumption and to make it somewhat more possible to balance rising input costs by improved performance

and efficiency. It is with the detailed technical problems of achieving these objectives that this report is primarily concerned. They are summarised in the main report and dealt with in more detail in the reports of the expert Study Groups appointed to examine them. The report deals very frankly and objectively with all the techno-economic reasons why there have been difficulties and delays in completing and commissioning the plants, why there have been occasional breakdowns and involuntary outages and why repairs and maintenance have taken longer than is desirable. In all these cases, the reports of the Study Groups suggest the technical solutions that seem likely to be the best in Indian conditions. These represent improvements on present performance that it is most desirable to achieve. But in contemplating the record of the past, any reader should be aware that this is at present an industry of extremely rapid technical progress in which new design concepts necessarily run far ahead of operating experience and that similar difficulties of operation and maintenance have arisen, not only in other developming countries, but also in the advanced countries where the new technical developments have been originated.

10. There remains one major issue, part technical, part administrative, part political, with which the Committee, like others who have considered these problems in recent years, found itself confronted. When national electricity development began in the 1950s, the immediately urgent problem was to interconnect the multitude of small local independent systems that then existed and to unify them into effective and more efficient State systems, which could achieve many of the economies that were then in reach. Over the past twenty years, this large task has been achieved to the very great gain of all consumers of electricity. But already in 1965 when the Energy Survey of India Committee reported, it was recognised that the State was becoming too small a unit for the effective planning and operation of electricity systems. In that year the Government of India introduced a system of Electricity Regions in which each region comprised a group of neighbouring States which together appeared to constitute a satisfactory unit for the collective development of electricity supply.

11. As this report brings out, since 1965, a great deal has happened to reinforce the conclusion that the State is now too small a unit for satisfactory planning and operation in electricity. The size of units of generating plant has steadily increased. Whereas in 1965, most of the new units were of some 50 MW, today units of 200 MW are beginning to be constructed and units of 500 MW are in sight and are actually installed in other countries. The total installed capacity of most Indian States is of the order of 500 MW to 1500 MW. In a system of that size, an addition of 200 MW is too large for each absorption into the system. It requires an uneconomically large reserve of capacity, aiainst its occasional voluntary or involuntary stoppages for maintenance and repairs, and an uneconomically large daily spinning reserve of capacity lest the system shall collapse if it is lost. At the same time, the uncertainties of load growth cannot cancel out in so small a unit as the State. Some States have overestimated load growth and have had temporary surpluses of capacity. Some have grown faster than forecast and have had temporary shortages. It has not always been technically possible to offset the shortages in some places from the surpluses elsewhere.

12. More important in any efficient electricity system there are a variety of needs, best met in a variety of different ways. There is the need to provide cheap base-load electricity at a high load factor which will permit a station with a high capital cost per kW of capacity to produce at comparatively low unit cost. There is the need to provide peak-hour supplies where the paramount need is to secure that the cost per kW of capacity, to be operated on a low load factor for a much smaller number of hours per year, shall be as low as possible. These two needs can be best met from very different types of equipment, the latter will probably be best met by use of hydro capacity, the former may be best met by nuclear or thermal capacity. The two types of capacities are complementary rather than competitive. Thus an integrated regional system, which possesses within it both hydro capacity and nuclear or low-cost thermal capacity, is likely to be more efficient and more economical than a single system primarily dependent on any one source of electricity.

13. The Regions created in 1965 have hitherto not been operated on a Regional base. They have been valuable organisations for the exchange of information and technical experience. But they have not been units either of responsible planning of development or of day-to-day operation. The Committee is convinced that the time has come when, in the interest of economy of costs and security of service, the Regions should be made into effective operating and planning bodies. By intensive study of certain Regions, the Committee has satisfied itself that the potential economies of operating and planning on the basis of close integration of Regions are very large indeed. If it is assumed that the entire country would be fully integrated, then capacity saving of about 2000 MW can accrue by 1980-81. In terms of savings in investments, this can mean about Rs. 300 crores. If a similar total of investment were permitted under conditions of integrated operation, that given total would provide much more energy with much less likelihood of shortage and interruption.

14. The Union Ministry of Irrigation and Power should consider as to how exactly a closer regional co-operation and operational integration should be secured administratively. The Indian Constitution gives the States and the Centre a concurrent responsibility for electricity supply. The States have been mainly responsible for expansion of power supply facilities and this is being done with the necessary consultation with the Planning Commission, Ministry of Irrigation and Power and the Central Water and Power Commission in respect of the financing. However, there are problems to supply power in the most economical manner in view of the uneven distribution of resources and limited capacities of most of the State Power Stations. In some foreign countries, including the United Kingdom, similar problems have been solved by central ownership and control of the planning and operation of all power stations and high tension transmission facilities, leaving regions to handle the important local tasks of distribution and sale of electricity. The Com-

mittee, therefore, feels that the time has come when the Centre should play a vital role in establishing major generating stations and bulk transmission systems. However, under the present conditions in India, this may take considerable time. In the interim period, the Committee has, therefore, thought it right to draw attention to the very different solution that has been commonly adopted in the United States. In that country electricity supply has, in all except a few instances, been the responsibility of individual private corporation, each with its separate franchise area, operating under State supervision and State price regulation. These individual corporations, like the State Electricity Boards in India, have increasingly found themselves too small for efficient planning and operation under modern technical conditions. They have, on the other hand, been anxious to preserve their individual identities. They have, therefore, sought and have effectively developed arrangements between a group of legally separate individual systems which have permitted them to cooperate so closely that they behave in all essential respect like a single integrated system. The Committee believes that this experience of the United States may provide useful precedents and suggestions for the solution of the very similar problems of the voluntary co-operation of a group of States in India in order to secure, so far as possible, all the economies of Regional rather State planning and operation. The Committee has, therefore, set out in complete detail in the report of Study Group No. II and briefly in the summary report the principles on which such collaborations should be worked out.

15. The problems of bulk tariffs for the sale and purchase of electricity are not the only problems which need to be solved before there can be close co-operation in five Regions into which the national system is divided. At present, the inter-connections between State and State are wholly inadequate for integrated working. The despatch centres for the control of operations within each single State are currently being completed, but the regional despatch centres that will be necessary are at present only at the design stage. Without them and without the systems of telecommunication that are necessary for the effective hour-by-hour and day-by-day operation of an integrated system, no regional organisation can become fully effective. We have satisfied ourselves that the relatively small investments required for these purposes will repay themselves in the savings that they will make possible.

16. Above all, it is necessary that it should be widely recognised that all parties can benefit by closer collaboration. It is as much to the benefit of a State with a short-term surplus of unsaleable hydro or thermal capacity to be relieved of a large part of the burden of a temporarily unprofitable investment and to be reimbursed for its use as it is to the benefit of a State in which industrial or agricultural development is held up by lack of electricity to be allowed to purchase it from a neighbour. This is emphatically not a case in which a gain to one part implies a loss to the other party, but a case in which both can simultaneously gain.

17. Whatever form a strengthened regional organisation may take, there is a distinct need for central planning and co-ordination on a national scale. In all forms of energy planning, but in particular in the case of electricity, it is necessary to start thinking and preparation some fifteen years ahead of the actual date at which plant should be commissioned. The broad strategy of development needs to be worked out on a national scale in order to ensure that the industries producing equipment shall be planned on a scale sufficient to meet total national needs. The main lines of development and even the main sites need to be identified and preparatory work started, in consultation where necessary, with the State and Regional authorities. It will be important, moreover, to see that the whole national development is flexible and adaptable enough to handle the problems that may arise if demands in some regions are over-estimated and in other are underestimated. However well the Regions may be integrated, it will not only remain very important that there shall be adequate provision and transmission facilities for assistance and interchange of electricity in emergencies between region and region. It will be important also, in a country as short of energy resources as is India, to ensure that it shall be possible to use the best and cheapest available resources to keep to develop those States which are at present seriously deficient and backward.

18. In the past the responsibility of preparing long-term perspective plans and for working out broad long term development strategies has been divided between the Planning Commission, the Central Water and Power Commission (Power Wing), the Ad Hoc Committee for Irrigation and Power Projects and the Ministries of Irrigation and Power and Finance. This division of responsibility has not led to desired results. Planning has lacked a unified and purposeful direction. Resources have been unsatisfactorily divided between the needs of generation, transmission and distribution. The Committee is convinced that some reorganisation is urgently needed. It recommends that this should take the form of activating the Central Electricity Authority already created under the Electricity (Supply) Act of 1948 but never fully constituted with the functions and responsibilities implied in that Act. It is proposed that, within limits of funds to be determined by the Planning Commission and the Ministry of Finance, the C.E.A. should determine the technical strategies and programmes on which electricity development shall be planned.

19. The Committee recognises that these are major issues which can be solved only by careful and convinced prolonged consultation. The P.E.C. is convinced that the economic development of India must depend on adequate, rapidly growing and less frequently interrupted supplies of electricity, produced as cheaply as can be made possible by the fullest use of all available technical knowledge and experience and the most economical use of the capacity that is available. These can be achieved only if a workable solution, acceptable in Indian conditions, can be found for the problems of closer collaboration between States in electricity supply and a more effective direction can be given at the Centre to the Planning of the technical strategy of electricity development.

20. The Committee envisages the need for stepping up power development programme all over the country

and considers it necessary to make every effort to have about 50 m.kW of installed capacity in the country by the end of this decade. This programme will involve investment of about Rs. 8000 crores on generation, transmission, distribution and rural electrification during the Fifth Five Year Plan period alone. The Committee was not required to examine this problem but would like to indicate that this is an aspect which is important because availability of finances will ultimately shape the power development policy and programme.

The success of this ambitious venture, the Committee would like to impress, would depend largely upon the State Electricity Boards and other organisations building up adequate expertise, know-how and implementation capability to match the larger investment programme contemplated. Its success will also depend on the ability of the public and private sector manufacturing units for producing and delivering in time plant and equipment for generating stations, transmission lines, grid substations and rural electrification. Availability of raw materials such as steel, aluminium, cement, etc., will also have to be ensured in adequate quantities. The programme for the Fifth Plan and onwards is expected to include additions of large thermal capacities. Coal raising capacity and transport arrangements (where necessary) will have to be ensured for feeding these stations.

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CHAPTER 1

COST OF ELECTRIC POWER

1.1.1. The Resolution setting up the Power Economy Committee states that "The power demand has outstripped its supply and the cost of electricity supply in the country has been rising despite large scale technological development." It is stressed that, in order to efficiently utilise the limited resources of the country it is essential to implement measures for bringing down costs. Electricity is a basic industry on which depends in a large measure, the economic and social development of the country; the infrastructure required for the industrial development can be built up only a sound and extensive network of power supply; the process of "green revolution" can be speeded up with rural electrification in facilitating more effective methods of irrigation and farming; lastly, electricity supply is a service, which is most crucial to the amenities programme in both urban and rural life of the country. Electric power should be always available at economic prices everywhere it is needed under proper voltage and supply conditions to be arranged by the electric supply industry which should work efficiently with imagination, initiative and drive making full use of the modern technology and scientific development to fulfil the overall targets of the objectives set out in the national plans.

1.1.2. The matters of short-fall in power supply and rising costs of electric power are a result of the interplay of large number of complex factors. These have been analysed and considered at length by the Power Economy Committee in all their aspects. The close inter-relation between these aspects has also to be recognised. The rise in cost reduces the benefits that can be derived from capital investment and restricts the programmes of power development on account of limited resources available. On the other hand, the shortfall in power supply further boosts the costs. Electric power is an essential input for industries and in recent years, also for agriculture and the emergency measures necessitated by power shortage are costly and lead to increases in the cost of power supply.

1.1.3. Table (1) shows the position obtaining in India during the last six years. It is seen therefrom that the cost of electric energy has generally been rising. The differences in the trends seen in the different States are due to a number of local factors including initial size of the power system and subsequent rate of growth in each State. The type of resources available, leading

TABLE 1

OVERALL REVENUE PER UNIT OF ELECTRICAL ENERGY SOLD BY DIFFERENT STATE ELECTRICITY BOARDS IN RECENT YEARS

Sl. No.	State Electricity Boards	Years					
		1964-65	1965-66	1966-67	1967-68	1968-69	1969-70
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1.	Andhra Pradesh	13·4	13·8	16·3	17·1	17·1	16·1
2.	Assam	22·8	20·5	18·0	19·4	15·1	14·4
3.	Bihar	11·3	11·9	11·1	11·1	15·5	15·7
4.	Gujarat	14·5	12·1	12·1	12·0	12·4	12·6
5.	Haryana (Counted from 3-5-67)	—	—	—	6·2(a)	7·6(a)	8·6
6.	Kerala	7·7	8·7	8·4	7·1	7·8(a)	7·7
7.	Madhya Pradesh	11·6	11·8	12·4	11·3	12·4	12·8
8.	Mysore	6·5	7·7	8·3	8·4	8·4	8·7
9.	Maharashtra	6·7	7·0	7·0	7·8	8·6	9·5
10.	Orissa	6·3	6·3	8·0	7·4	6·9	7·0
11.	Punjab	5·5	6·1	6·6	6·3	7·9	7·6
12.	Rajasthan	12·8	14·2	16·1	19·1(a)	12·3(a)	12·5
13.	Tamil Nadu	9·5	9·9	11·4	10·6	10·9	11·5
14.	Uttar Pradesh	13·8	9·2	10·0(a)	11·1(a)	12·4(a)	13·7
15.	West Bengal	9·3	9·7	11·2	11·9	11·5(a)	11·8
16.	D.E.S.U.	12·0	12·7	12·7	13·4	13·9(a)	14·7

The figures in case of Punjab for the period 1964-65 to 1966-67 are for the combined Punjab and the subsequent period for the bifurcated Punjab.

(a) Board's figures as given in the physical statistics or annual Survey reports. The figures of ASFR are indicated by (a). All others are as the Physical Statistics.

Source:—SEB's as furnished to CW&PC.

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to predominance of Hydro-electric or fossil-fueled power generation is a very important factor in the differences in costs from State to State. By and large, the main reasons for the increase are (1) the increase in the cost of equipments, materials, labour and fuel and (2) the State Electricity Boards aiming at more realistic revenue to give a reasonable return on the capital than was done previously. Earning of reasonable return is important as every State Electricity Board should be able not only to meet all its liabilities including interest, depreciation, working expenses etc. but also, in addition, to earn a small profit (as recommended by Venkataraman Committee and the Ministry of Irrigation & Power) so as to generate funds for further power development. If the element of increase in the cost of energy owing to unrealistically low older rates being now charged, is discounted, it would be seen that the increase in the cost of electrical energy is substantially less than the general rise of price levels in the country. This is mainly due to the economies secured by operation on increasingly larger scale and economies due to technological advances. In this connection, it would be of interest to see the corresponding figures of over all revenue from electric energy obtaining in the UK.

1.1.4. The cost of electric energy in U.K. has also been rising in a manner similar to our experience in India, but it is now reported by CEGB in their annual report of 1968-69, that they have now been able to arrest the upward trend (which had been going on for the past decade) of cost of electricity. They state that the CEGB had hoped to reach this turning point sooner and would have done so but for delays in securing reasonable performance of new plant. During most of the years of the sixties, the CEGB's over-riding concern was to eliminate the risk of major power cuts. Last year, the emphasis has been changed and CEGB's first concern is now to get costs down. It will be seen that the situation in India is also similar. Arresting the rising cost of electricity, in the face of general trend of price increases is no doubt a very difficult task. However, the experience in the countries like U.S.A. and Canada shows that given the possibility of economies of scale and scope for modern technological advances such costs reductions are indeed possible. In U.S.A., in spite of general rise in the price level, the overall rate for sale of power has been brought down from 2.06 cents per kWh in 1940 to 1.81 cents in 1950 and 1.69 cents in 1959. In Canada, the revenue per kWh has been brought down from 1.9 cents. In Australia this figure has been held almost constant at 1.9 cents from 1964 to 1968.

1.1.5. The cost of electrical energy is broadly composed of two main components, one dependent on the capital cost and the other on the running costs. In the case of Hydro-electric stations as well as for transmission and distribution system, it is capital cost that determines the cost of power supply. On the other hand, in the case of Thermal Power Stations, the running costs generally predominate. Capital costs for all types of power generation are greatly influenced by the technical parameters adopted (such as size of generating units, voltage of transmission, quantum of power handled etc.) as well as the construction methods and delays in project implementation, margins required as system reserves etc. The running costs include the wage bills and in the case of thermal power stations, the cost of fuel. The cost of fuel is the largest single item affecting the cost of power from thermal power stations.

1.1.6. The total capital investment on electricity supply undertakings in the country now aggregates to over Rs. 4000 crores, and the investment proposed on Fourth Plan schemes amounts to Rs. 2513 crores. The Inter-Ministerial Working Group on power for the Fourth Plan set up in 1968 had recommended that to maintain the historical rates of growth necessary to meet anticipated load demands, the Fourth Plan should aim at a target of 26 million kW and had set the capital requirement for this at Rs. 3462 crores including Rs. 500 crores for adequate advance action on economic Fifth Plan schemes. Chiefly owing to shortage of resources, the physical targets and the capital allocations for electricity expansion have been lowered. It is, therefore, necessary to consider and suggest measures for (a) achieving maximum benefits from built-up generating capacity and for enabling limited capital resources to carry the power supply industry the farthest distance, and (b) restoring the perspective approach to economic power development.

1.1.7. Costs of electricity production from hydro, thermal and nuclear sources have been discussed and analysed in this country during the past 15 years. Most of the past work of analysis of alternative sources of power supply has, however, been based on preliminary estimates of costs and expectations of benefits at the time of proposal or sanction of individual projects. A similar analysis was not carried out so far of the actual costs of production and supply at the operational stage. Study Groups 1 and 3 of this Committee have carried out such an analysis and the results are very interesting. From Table-2 of the Report of Study Group 3, it would be seen that the actual cost of energy generation in 1968-69 at hydro stations systems, for which data was available, generally varied from about 1.7 paise to about 4 paise per kWh. Table 3 of this Study Group gives the actual cost of energy generation in 1968-69 at thermal stations/systems for which data is available; and it would be seen that the cost generally varied from 5 paise to 10 paise per kWh. Table-2 gives the actual pooled cost of generation in 1968-69 for 11 different systems.

1.1.8. During 1968-69, electricity supply utilities generated 47,350 million units from a total of 12.974 million kW of installed generating capacity. Supply

TABLE 1-A

*1964-65	1965-66	1966-67	1967-68	1968-69
1·652	1·737	1·775	1·848	1·914 pence/kwh
12·39	13·03	13·31	13·86	14·36 paise/kwh*

*based on post devaluation rates.

TABLE 2

POOLED COSTS OF GENERATION (1968-69)

Systems	Type of Grid	Energy generated million kWh	Pooled cost p/kWh
1. Bhakra Power System	Pure Hydro	4343	1·66
2. Koyna Hydro Grid (Ma)	Pure Hydro	2990	1·68
3. Kerala Grid	Pure Hydro	1623	3·38
4. Mysore Grid	Pure Hydro	2539	2·65
5. Tamil Nadu Grid	Mixed Hydro-Thermal	3353	3·40
6. Andhra Grid	Mixed Hydro-Thermal.	2276	5·6
7. U.P. Grid	Mixed Hydro-Thermal.	4371	6·4*
8. West Bengal S.E.B.	Pure Thermal	1167	6·37
9. Gujarat S.E.B.	Pure Thermal	2172	6·72
10. Madhya Pradesh	Predominantly Thermal	1859	7·22
11. Vidarbah Grid (Ma)	Pure Thermal	1169	8·54

*The pooled cost of generation is for 9 major hydro and thermal stations which contributed almost 75% of the total generation. (Source:SEB's as furnished to CW&PC).

to ultimate consumers aggregated to 37,452 million units of which about 80% was sold by the State Elecy. Boards. The average rates at which this power was distributed is given in Table-3 arranged in ascending order of average tariffs. The percentage return on the average capital base earned by the State Electricity Boards is also given.

TABLE 3

AVERAGE TARIFFS FOR POWER IN 1968-69

Sl. No.	State Elecy. Board	Units sold	Average* Tariff (Paise)	Percentage return on average capital base (of the Board portion only)
(1)	(2)	(3)	(4)	(5)
1.	Orissa	1250	6·9	6·7/4·3
2.	Haryana—			
	Sales to Common pool Consumers	630	2·4	8·4
	Sales to other Consumers	662	12·5	
3.	Kerala	1366	7·8	3·8
4.	Punjab—			
	Sales to Common Pool Consumers	782	2·4	
	Sales to other Consumers	922	12·6	7·6
5.	Mysore	2118	8·4	5·9
6.	Maharashtra	3955	8·6	2·9/8·1
7.	Tamil Nadu	4282	10·9	7·7
8.	West Bengal	1606	11·5	8·6
9.	Madhya Pradesh	1586	12·4	7·5
10.	Gujarat	1752	12·4	7·2
11.	Uttar Pradesh	3563	12·4	6·6
12.	D.E.S.U.	957	13·9	9·0
13.	Bihar	1354	15·5	1·1
14.	Assam	176	15·1	(—)0·8
15.	Rajasthan—			
	Sales to Common Pool Consumers	271	3·7	4·4
	Sales to other Consumers	652	15·9	
16.	Andhra Pradesh	1638	17·1	7·8

*Obtained by dividing total revenue realised by the State Electricity Board by the units sold.

The rate of return given in Col. 5 is for the operations of the Board only excluding the operations of the Govt. projects (Durgapur projects in case of West Bengal).

(SOURCE: SEB's as furnished to CW&P C

1.1.9. Tables 2 and 3 make a very interesting reading. When this data is considered after notionally equalising the percentage return obtained by the different State Electricity Boards, it is clearly seen that purely hydro systems have the lowest tariff, the mixed hydro thermal systems come next and the highest tariffs prevail in purely thermal systems. This is seen to happen in spite of the fact of extensive transmission systems being necessary for utilisation of hydro-power. These matters are discussed at length in the report of Study Group 3.

1.2. Features and costs of different sources of Power Supply

1.2.1. While planning for future, the above experience of actual generation costs has to be kept in view.

1.2.2. Hydro, thermal and nuclear power stations have widely differing features giving them distinctive economic characteristics. As alternatives—hydro, thermal and nuclear stations have to be evaluated in future both on their intrinsic economy reckoned on individual basis under prevailing conditions—and also by their effective or economic contributions to our emerging regional power grids. The choice among alternatives for expansion of power generation facilities is really assessing at each stage what the integrated power systems actually need to ensure the fullest utilisation of built-up generating capacity and the lowest possible overall costs of electricity supply, and then determining the best possible combination of hydro, thermal and nuclear sources to serve this specific purpose.

1.2.3. Costs of hydro energy generation vary from site to site depending on the nature of civil works, magnitude of power potential and the period and speed of construction. Besides, at each developed site, they will vary from year to year depending upon the actual river flows and degree of utilisation thereof. In general, the costs of hydro energy vary almost directly in proportion to the investment involved. The investment cost on the hydel projects completed during the last decade in the country ranged from Rs. 1000 to Rs. 1,500 per kW of installed capacity. An assessment of the expected cost of energy generation from existing and recently completed hydel installations and those under construction has been made on the basis of actual up-to-date estimates of capital outlays and firm energy outputs. It is seen that the expected cost of energy generation from hydro stations generally vary from 2 to 3 paise per kWh.

1.2.4. The costs of energy generation of thermal power stations and thermal power system vary with (a) investment cost (b) cost of fuel (c) thermal efficiency (d) transportation costs from collieries/sources of fuel (e) changes in the load factors (to which, unlike, hydel schemes, they are very sensitive) (f) operation and maintenance and (g) machine parameters. In a purely thermal power system, the possible energy generation is seldom more than 4000 kWh per kW installed due to firstly, the margins required to be maintained over peak capability to cover longer periods of scheduled maintenance and forced outages, spinning reserves, etc. and secondly the limitations on energy generation imposed by the system load curves. In a properly designed mixed hydro-thermal power system, where all the effective on-line thermal capacity can be operated almost continuously at base load, the energy output of thermal stations can be increased to about 6000kWh/kW installed on the average.

1.2.5. The capital outlays on thermal installations are generally well established and should not be subjected to large variations during periods of construction if estimates have been prepared with due care. However, the cost of energy generation from them vary substantially over the life of the plant, tending to increase steadily on account of decrease in operational efficiency, increases in the cost of fuels and their transport costs with time. During the decade prior to devaluation, the capital outlay of thermal power stations employing 50/100 MW units was about Rs. 1000 to Rs. 1200/- per kW installed based on imported equipment. Current investment costs on new thermal installations taking into account the increases due to devaluation and indigenous manufacture are of the order of Rs. 1700/- per kW installed. In some cases, it has been as high as Rs. 2000 per kW installed even for units in the range of 100/120 MW. At these higher investment costs, the corresponding cost of energy generation would be about 6.2 paise per kWh at the collieries. Generation cost at sites remote from the collieries will be more, depending upon the distance of haulage of coal.

1.2.6. In the case of nuclear stations, their investment costs are relatively high though incremental fuel costs are low requiring base load operation as an essential pre-requisite for competitive electricity generation. Maximum benefits from nuclear stations can, therefore, be derived in a grid with hydro and thermal generating stations and not as an independent source of supply. At present only one nuclear power station of the Boiling Water Reactor Type is in operation in the country at Tarapur. The capital outlay on this station is about Rs. 68.3 crores (Rs. 1630 per kWh installed) and the fuel used is slightly enriched uranium. The average cost of energy generated at the station works out to about 4.21 paise per kWh assuming depreciation on sinking fund basis. The present strategy for development of atomic power in the country aims at reliance on natural uranium reactors during 1970-80 and from 1980-85, simultaneously developing thermal and fast breeder concepts based exclusively on thorium cycle. The capital cost of such like power stations has roughly been worked out at about Rs. 300 per kW installed. Two such power stations one at Ranapratap Sagar in Rajasthan and the other at Kalapakkam in Madras are currently under construction. The cost of energy generation at these power stations has been worked out at about 6 paise per kWh, the net fuel cost being about 0.83 paise kWh.

1.2.7. Cost of generation from thermal and nuclear power stations are at their lowest when the power stations are operated at high load factors on base loads. On the other hand, hydro energy generation is relatively insensitive to large changes in load factor. Hydel station can therefore conveniently be assigned the most difficult function of dealing with fluctuating peak demands on electrical power systems. Mixed power systems emerge usually under conditions of scarcity of cheaper hydel energy resources and are basically intended to take advantage of the above facts although there are several other advantages also.

CHAPTER 2

ENERGY RESOURCES A

2.1.1. The availability of energy and its utilisation have the greatest influence on economic growth. The economic development of the industrialised countries is characterised by a steadily increasing use of energy. Indeed, the vital key to the growth process, to industrialisation, mechanisation and thereby to higher living standard was the sufficient supply of energy. At the middle of the last century in Europe, about 95% of the total energy consumption was made up by energies of low efficiency such as human and animal tractive power, fire wood, coal, etc. Agriculture and small workshops for a number of handicrafts formed the basis of the economies and limited the income per capita. With the invention of mechanical tractive power for transport and industry, this picture changed rapidly and completely. Commercial forms of energy obtained from mineral fuels or water power were increasingly used. Today human and animal tractive power and other non-commerical forms of energy play only negligible role in European economies. Electricity, especially, contributed largely towards the introduction of automation in industry. Its use extensively replaced manual labour and put man in control of vast amount of productive power.

2.1.2. The choice of the economic and social goals in any country is greatly dependent on the energy policy. The developed countries use a higher ratio of energy per capita as compared to the developing countries as would be explained in what follows.

2.2. World Energy Resources and Utilisation

2.2.1. The importance of a sufficient supply of energy if a modern economy is to be created in a developing country needs no emphasis. Energy supply is essential both for industrial expansion and for the increase of agricultural production in the normal commercial forms; coal and coal products, petroleum products, natural gas and electricity. But if we compare the different countries of the world, they differ widely both in the reserves of energy resources that they possess and in their present annual consumption of energy. At the present time, out of a total world consumption of the commercial forms of energy amounting to 5,611 million tonnes of coal equivalent a year, 85% is consumed by less than 30% of the world's population. This can be seen in Table-4, which presents the consumption in 1967 of commercial energy in the world as a whole and in the countries in which the bulk of the world's present energy consumption occurs.

TABLE 4

CONSUMPTION OF PRIMARY ENERGY

Country	Population 1967		Consumption of primary energy in Commercial forms 1967-in million tonnes coal equivalent					Percentage of world total
	In million	Percentage of world total	Coal & Lignite	Oil	Natural gas	Hydro and Nuclear Electricity	Total of commercial energy	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
U.S.A.	199·1	5·8	440	791	697	29	1957	34·9
Canada	20·4	0·6	22	79	47	17	165	2·9
U.S.S.R.	235·5	6·9	434	279	208	11	932	16·6
Countries in Europe other than USSR	452·0	13·2	761	598	75	45	1479	26·4
Japan	99·9	2·9	76	139	3	9	227	4·1
Total of above	**1007·0**	**29·4**	**1733**	**1886**	**1030**	**111**	**4760**	**84·8**
Other countries in the world	**2413·0**	**70·6**	**440**	**333**	**58**	**20**	**51**	**15·2**
World Total	**3420·0**	**100·0**	**2173**	**2219**	**1088**	**131**	**11**	**100·0**

2.2.2. The bulk of the energy consumption in the world is in the more advanced countries. Their annual per capita consumption of energy in commercial forms averages about 4,750 kg. of coal e[illegible] vear against a world average of 1[illegible] vanced and developing cou[illegible] the per capita consumption of the commercial forms of energy is only 350 kg. of coal equivalent. Table-5 shows the same data as in Table-4 on the basis of consumption per head.

2.2.3. During the past twenty years, there has been throughout the world a shift in the pattern of the consumption of final energy away from the cruder forms of energy, and particularly from coal, and towards the greater use of the more convenient forms of energy, and particularly towards petroleum product, gas and electricity. This shift has been especially evident in the more developed countries, as can be seen in the data for a number of European countries presented in Table 6.

TABLE 5

CONSUMPTION OF ENERGY PER HEAD
(1967)

Country	Total consumption of commercial energy per head (Kg. per head).	Percentage of World Average of consumption per head
1	2	3
U.S.A.	9830	599
Canada	8090	493
U.S.S.R.	3960	241
Countries in Europe other than USSR	3270	199
Japan	2270	138
Average of above	**4730**	**279**
Other countries in the world	**350**	**21**
Total World average	**1640**	**100**

TABLE 6

TOTAL FINAL CONSUMPTION OF MAIN FORMS OF ENERGY IN CERTAIN EUROPEAN COUNTRIES

Country	Year	Solid (a) Fuels 10^3 tons coal equivalent.	Liquid Fuels 10^3 tons petroleum equivalent	Gaseous fuels 10 Kcal	Electricity 106 Kwh.
(1)	(2)	(3)	(4)	(5)	(6)
Francs	1950	42,715	7,962	15,755	28,877
	1967	35,785	46,612	84,139	102,690
	1967 as % of 1950	84	585	534	711
Italy	1950	8,325	3,894	7,971	12,974
	1967	8,523	42,899	74,853	86,500
	1967 as % of 1950	102	1,012	939	701
Sweden	1950	6,518	3,637	n.a.	15,784
	1967	2,128	17,773	n.a.	46,528
	1967 as % of 1950	33	479	n.a.	295
U.K.	1950	133,142	12,928	68,645	44,386
	1967	67,401	52,603	127,840	173,459
	1967 as % of 1960	51	407	186	391
West Germany	1950	62,308	2,445	55,301	37,834
	1967	60,619	68,976	170,256	157,643
	1967 as % of 1950	97	2,759	308	417

*Direct final use only, i.e., excluding solid fuels used to generate electricity or to manufacture gas.

2.2.4 Consumption of electricity in all countries of the world has been increasing very much more rapidly than consumption of energy in total. In 1967 over 25% of total final consumption of energy was in the form of electricity, in 1960 the proportion was 20%. Electricity plays an increasingly important part in the energy economies of all the advanced countries. It accounts today for almost one-third of all energy consumption in North America and Europe other than U.S.S.R. The discrepancies between the levels of consumption of electricity by the advanced countries and by the developing countries are even wider than they are for energy in total. As can be seen in Table 7, 22.5% of the world's population accounts for almost 90% of the world's electricity consumption, with an average consumption per head of 4450 kWh a year. Japan had in 1967 an electricity consumption of 2377 kWh a year. The comparable figure for the total of the developing countries was about 175 kWh a year, and that for India only 72 kWh a year.

2.2.5. Table 8 shows the known world resources of all the conventional forms of energy in all countries developed and developing. It will be seen that the bulk of these resources are concentrated in the U.S.A. and the U.S.S.R. where large volumes of energy are consumed annually. On the other hand, the regions which contain 70% of the world's population possess only some 20% of the world's known coal resources and only about 25% of the world's estimated hydro resources. They possess a considerably large proportion of the world's proved reserves of oil approximately 76% of the total. But a large propertion of these resources are in sparesely populated countries, far removed from the main centres of population, and many of these are ill-endowed with the energy resources necessary for the development of a modern economy.

2.3. The Energy Position in India

2.3.1. While the energy situation in the world is of importance, in that it provides standards of comparison by which to measure the situation of any one country, we are directly concerned only with the problems of energy supply in India. The Energy Survey of India of 1965 brought out the fact that in India more than half the energy consumption is in non-commercial forms—firewood and animal and agricultural waste, and that, as a result of the substitution of commercial forms of energy for these non-commercial forms, the growth of total consumption of commercial energy was faster in India than in the developed countries.

2.3.2. This trend has continued. During the past decade, the consumption of commercial forms of energy in India increased by about 6% per annum as against an average of 4.2% for the world as a whole and about 4.7% for the advanced countries. On the other hand, the growth of consumption of non-commercial fuels has increased by only about 3.0% a year. At the same time there has been the same shift in India towards the more convenient fuels (liquid and gas fuels and electricity) than there has been in other countries. Thus, while the direct final consumption of coal increased by about 3.6% a year during the past decade, the consumption of oil rose by about 10.5% a year and that of electricity by about 12.8%. The high rate of growth of electricity consumption is particularly significant.

2.3.3 The annual consumption per head in India of the commercial forms of energy in terms of coal equivalent is estimated to have been about 200 kg. in 1967—measured in this way, Indian energy consump-

TABLE 7

CONSUMPTION OF ELECTRICITY

Country	Electricity Consumption (1967)		Per capita Consumption (1967)	
	10^9 Kwh	% of world total	KWH	% of world average
(1)	(2)	(3)	(4)	(5)
U.S.A. ..	1317	34·2	6612	585
Canada	166	4·3	8111	718
Countries of Europe other than USSR	1713	44·4	2500	221
Japan	238	6·2	2377	210
Total of above	**3434**	**89·1**	**4450**	**394**
Other countries in the world ..	422	10·9	175	15
Total WORLD	**3856**	**100·0**	**1130**	**100**
India	**37**	**1·0**	**72**	**7**

TABLE 8

WORLD KNOWN CONVENTIONAL ENERGY RESOURCES

Country	Hydro (Thousand Million Kwh)	Coal (Thousand million Tonnes)	Brown Coal & Lignite (Thousand Million Tonnes)	Petroleum proved reserves (Thousand Million Tonnes)	Oil in Shable & Bituminous Sands (Thousand million tonnes)	Natural Gas (Measured Reserves (Thousand million on cu. m.)	Total Energy (Coal equivalent Thousand Million Tonnes)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
U.S.A.	1063	1100·0	406·0	6·5	83·5	8194·0	1364
Canada	1143	61·0	24·1	1·03	65·5	1534·0	158
USSR	3820	4121·6	1406·4	5·2	—	4381·5	4838
Countries other than USSR in Europe	87	153·0	91·9	0·6	0·9	3350·7	190
Japan	—	19·2	1·7	0·01	—	159·5	20
Iran, Iraq, Kuwait, Libya, Saudi-Arabia and Trucial Oman ..	—	1·0	—	36·3	—	6738·0	65
Venezuela	233	—	—	2·4	5·6	826·2	12
Rest of the World	2354	1255·7	111·3	4·6	48·9	6114·0	1374
Total World	**9420**	**6711·5**	**2041·0**	**56·6**	**204·4**	**31297·9**	**8021**

tion per head in 1967 was about 12% of the world average (*See* Table 5 above). It was less than 9% of the consumption per head of Japan in that year. But these figures are in important respects misleading. In India, in 1967 approximately 53% of all energy took the form of non-commercial energy. In most of the advanced countries, consumption of energy in non-commercial forms represents less than 2% of total energy consumption. There is a second discrepancy also. The conventional measurements in terms have been nearer to 600 kg. per head. But, however, measured, it falls very far below the average of the the effective consumption of energy in India may that different fuels are normally used in India and of coal equivalent make no allowance for the fact elsewhere with markedly different thermal efficiencies. In India it has been customary since the work of the Energy Survey to make allowance for this by estimating total use of energy more accurately in coal replacement units; this method attaches a somewhat higher valuation to the consumption of petroleum fuels. If allowance is made for both these factors, developed countries, when similarly adjusted.

2.3.4. If we are to reach a reasonable stage of development of our economy, the consumption of conventional forms of energy should at least reach 1000 kg. per head—about five times the 1967 level. The achievement of this will unquestionably require stupendous efforts and very large investment both in the sector producing primary energy and in those converting the primary energy into more usable forms of final energy.

2.3.5. The first question that arises is whether India possesses the natural resources of the conventional forms of commercial energy necessary to support a level of energy consumption comparable to that of an advanced country.

2.4. **Basic Energy Resources—need for review now.**

2.4.1. In 1965, the Energy Survey Committee dealt exhaustively with the availability of basic energy resources—coal, water, oil/gas and nuclear fuels—available for conversion to electricity. Broadly, their conclusion was that for the foreseeable future, there would be adequate energy resources for conventional methods of electricity generation all over the country, that in particular there would be very large surpluses of by-product coals constituting a basic problem of utilisation and finally that decision on implementing nuclear alternatives must be based purely on economic considerations. The main changes since 1965 need to be noted.

2.5. **Hydel Resources**

2.5.1. The CW&PC's preliminary assessment of our hydel resources was carried out during 1953-60 and they (*a*) included only firm potentials and (*b*) were estimates of economically utilisable hydel resources on prevailing economic considerations. It excluded seasonal potentialities and the potential in years of average and heavy rainfall. It also excluded sites considered uneconomic according to standards of investment costs at that time.

2.5.2. Studies and surveys carried out subsequently notably in the Indus system have indicated that the firm hydro potentials would be substantially greater than the earlier estimates. For instance, the hydro potential located in Himachal Pradesh was placed at 3 million kW under the earlier Hydro Electric Survey, but subsequent development have pointed to the fact that these would be of the order of 8 million kW. Similarly, the potential of the Chenab was indicated as 3.26 million kW on the basis of permissible storage under the Indus Water Treaty. It is this conservative figure which is included in the early surveys of CW&PC. Investigations carried out indicate that this figure would increase to 4.0 million kW and, if storages can be increased in future, under international agreement, the figure of firm potential can well increase to 6.5 million kW.

2.5.3. In the central Himalayas, the hydro-electric potential of the Sarda-Karnali system was assessed at 4.5 million kW, that of the Karnali Valley in Nepal adjoining U.P. being set at about 2.75 million kW. Detailed surveys carried out subsequently under the auspices of the United Nations have increased the potentials of the Lower Karnali to 5 million kW at 60% load factor at 3 sites, and that of the entire Karnali Valley to about 7 million kW of installed capacity. This potential lies in Nepal. The assessed power potential of the Sarda Valley has been substantiated by subsequent investigations.

2.5.4. On the Deccan River systems there is an reason to warrant any increase in the estimate of firm potential of 14 million kW at 60% load factor. However, recent technological trends of pumped storage developments through installation of reversible pump-turbines have opened up possibilities of developing a number of sites, where economic hydel generation on a seasonal basis would be possible. This energy potential can either be firmed up by co-ordinated grid operation or utilised for saving in costs of coal at existing thermal stations. These seasonal potentials, which have not been dealt in the hydro-electric survey report, may increase earlier figures of energy potential by about 30%.

2.5.5. The map (attached at Annex VIII of the report of Study Group No. 3) indicates the location of the country's hydro-electric resources and the Table 9 (given below) indicates the extent of utilisation in each region by the end of the Fourth Plan. On the basis of the latest information regarding hydel energy resources, and their economics of development, it is estimated that it would be possible to install about 80 to 100 million kW of hydel capacity on our river systems during the next two to three decades as required for efficient operation of our power stations and grids.

TABLE 9

CONVENTIONAL ENERGY RESOURCES AND THEIR REGIONAL DISTRIBUTION

Region	Total coal reserves 10^6 metric tons	Total Lignite reserves 10^6 metric tons	Hydro resources (MW) at 60%LF		Total oil reserves 10^6 metric tons	Total natural gas reserves 10^6 cubic metres
			Total	Developed and Under-development		
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Southern	5,515·00	2032·00	8097·0	3220·5 39·70		
Western	22,887·00*	11·10	7168·9	941·5 (13·12%)		
Northern		20·30	10731·5	2450·7 (22·80%)	153·87	63,600
Eastern	74,227·50	..	2693·7	574·0 (21·30%)		
North-Eastern	3,629·60	—	12464·4	37·5 (0·30%)		
Total	106,259·60	2,063·40	41,155·5	7,224·2 (17·60%)	153·87	63,600

Note:—The Hydro resources are based on CW&PC's Hydro-Electric Survey.

*For Western and Northern Regions.

2.6. Coal

2.6.1 In 1953, the coal reserves of India upto a depth of 609 metres (2000 ft.) had been estimated at about 128,000 million tonnes and this figure had been indicated to the Energy Survey of India Committee. This figure was revised to 87,000 million tonnes in 1967, the main reductions being at Singrauli and Talcher coal fields where the estimates of reserves were revised to about 8,000 million tonnes each from the earliest estimated figures of 30,000 million tonnes each. The estimates in 1968 placed the country's coal reserves at about 100,000 million tonnes upto a depth of 609 metres (2000 ft.) in the case of the most of the coal fields and 1219 metres (4000 ft.) in the case of some of the collieries specifically Raniganj and Jharia.

2.6.2 It would be recalled that the Energy Survey Committee had indicated that 12, 33 and 53 million tonnes of by-product coals would be available in 1970-71, 1975-76 and 1980-81 respectively. Assuming that surplus washery by-products would otherwise be wasted and are potentially available to be used at zero cost they observed that "a low coal-cost thermal station such as can be constructed to burn by-product or waste coals at the coal field, if operated at a plant factor of 60% or better would provide the cheapest rates of generation of power". Against these, the availability of by-product coal during 1969-70 was only of the order of 3.69 million tonnes and at the end of the 4th Plan (1973-74) the availability is now estimated at 6 million tonnes In view of this, conventional thermal power generation would have to rely mainly on non-coking high ash content coals mined specifically for the purpose.

2.7. Oil/Gas Resources

2.7.1 Under prevailing conditions in this country oil/gas resources have an insignificant effect in the total picture. No major variations from the trends indicated by the Energy Survey Committee, have been reported.

2.8 Nuclear Fuels

2.8.1 In 1965, the Energy Survey Committee pointed out that, even assuming a burn up of 10,000 MWD/tonne of fuel, the then estimated reserves of Uranium (in Bihar) would be sufficient only for the operation of one million kW of nuclear capacity during its useful life. They noted that the Department of Atomic Energy had since indicated the possibility of increasing the figure five-fold. The AEC monograph 1 on "Nuclear power in developing countries (1970)" indicates that the reserves of uranium available may sustain 5000-10000 MW of Nuclear plant for their lifetime.

2.8.2 In view of these limitations, the Energy Survey Committee pointed out to the reserves of 500,000 tonnes of thorium—described as being equal in magnitude valued to all the world's uranium ore containing 0.1% and above with the reservation that thorium could be used for production of nuclear energy only after solution of a number of problems. They also believed that the conversion of thorium could best be done in a breeder type reactor and that only when these processes have been developed and, especially when suitable breeder type reactors are commercially available, could the country regard itself as being richly endowed in nuclear fuels.

2.8.3 An extract from "Uranium Resources—Revised Estimates December, 1967"—A joint report by the European Nuclear Energy Agency and the International Atomic Energy Agency which presents the position of our resources as of December, 1967 is appended as Annexure-X in the report of Study Group No. 3.

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2.9 It will be seen that the bulk of our resources is in the form of coal. Our known reserves of oil and natural gas are extremely limited. Unless our explorations reveal substantially larger reserves than are at present known, use of oil and gas are likely to be restricted to sectors which cannot use any alternative fuel. Our resources of coal are in most cases of poor quality and present considerable problems both in mining and in use. Assuming that 50% of the coal resources can be recovered economically our conventional energy resources, as at present known, can sustain an annual energy consumption of 1000 kg. per head of coal equivalent for about 75 years.

2.10 It would be seen that in view of the lack of adequate oil and gas resources the country would have to rely on electricity more and more to reach a reasonable figure of energy consumption. In this context the nuclear energy has an important role in our future energy economy. We are fortunate in having adequate reserves of uranium to support a modest nuclear programme in the immediate future and abundant reserves of thorium to meet our longer-term needs. And thanks to the vision of Dr. H. J. Bhabha and the enthusiastic support that he and his colleagues received from our former Prime Minister Shri Jawahar Lal Nehru, we launched a nuclear programme well in advance. Our progress in this field has already been notable.

CHAPTER 3

PLANNING FOR FUTURE

3.1.1 Though the rates for sale of power in India have been increasing due to very valid reasons given in Chapter 1, every effort has to be made to control and reduce the costs of energy generation, transmission and supply as has been happening in U.S.A. Full utilisation of generating facilities already built up has to be ensured and we have also to ensure that limited capital allocations to the power supply industry go the farthest distances in meeting our estimated deficits. The first and the foremost thing that is required to be done is that there must be a long term plan—say for a period of 15 years—and the schemes which provide the least costs of power generation selected out of this plan at different times for implementation. This plan should be based on optimal mix of hydro, steam and nuclear generation with adequate transmission system, taking into account the regional power system conditions from time to time. This would help to reduce costs of power generation to the minimum possible.

3.1.2 At the instance of Planning Commission, the Central Water and Power Commission (Power Wing) in 1961 prepared a perspective plan for power development for the period upto 1980 indicating the clear order of priority, the hydro, thermal and nuclear power stations to be constructed with their precise location. This plan was prepared on regional basis. The regional frame-work was also adopted by the Power Survey Committee in 1962 for the first of the current series of All-India Power Surveys. For power planning the country has been divided into five regions, viz. Northern, Southern, Western, Eastern and North-Eastern. In the perspective plan the CW & PC had emphasised that :—

"In view of the above capital cost comparisons, the far lower foreign exchange components required for hydro schemes, their much lower costs of generation, and the fact that there is no depletion of natural resources, it is obvious that, on purely economic considerations hydro power should be resorted to wherever feasible and thermal (including nuclear) resources developed to a complementary extent to meet the expected deficits. This, therefore, has to form the basic principle for a perspective plan for future power development during the net two decides."

The Energy Survey Committee (1965) stated :—

"In the light of these estimates, it seems clear that India will be well advised to continue to exploit hydro resources wherever there are suitable sites available."

The recommendations of the Working Group on Power for the Fourth Plan (1968) were :—

"As power generation has to be planned on the basis of the most economic schemes, both in capital investment and in recurring costs, it is inevitable that a greater part of the additional capacity (required in the Fourth Plan) would have to come from hydro schemes."

3.1.3 Both CW & PC's perspective plan for most economic development of power supply and the Energy Survey Committee's report (1965) had recommended—with indications of exact sites to be developed—that 52% of the total capacity during 1969-74 should be of hydel installations. Actually they account instead for just 40% of the total now. Failure to develop the country's hydel resources at a faster pace during the past decade and the resort instead to large scale thermal generation, especially, in areas within economic reach of hydel potential and remote from our collieries, have resulted in higher generation costs in such areas. Study Group No. 3 has analysed the position in detail that if the admittedly more economic path of lowest cost developments suggested earlier had been followed and the schemes completed in time, at prevailing tariffs, the power supply industry would be generating additional revenues surplus of the order of Rs. 180 crores during the Fourth Plan. This figure of cost benefit would increase during the Fifth Plan if steps are not immediately taken to put the country's power development plans back on the path of lowest cost developments.

3.1.4 The relative costs of energy generation from hydro, thermal and nuclear alternatives have been discussed in Chapter 1. Hydel schemes have established themselves as undoubtedly the cheapest source of electricity generation in India involving in the past decade comparable and in many cases even lower capita outlays per kW of effective capacity. Their energy generation costs generally range from 1.8 to 3 paise per kWh. Hydel developments over the next 2/3 decades are expected to be about the same levels of intrinsic economy as prevailing at present and it has been indicated that our river systems are capable of providing 80-1000 million kW of hydel capacity at favourable sites compared to the 7 million kW installed today.

3.1.5 Thermal stations with generating units of 110/120 MW involve a capital outlay of about Rs. 1600-1800 per kW installed. The generation costs from such thermal stations generally varies from 5 to 10 paise per unit. The generation cost from thermal stations is likely to increase further under conditions of indigenous manufacture and rising costs of coal and labour. In order to reduce the generation costs, the larger sized units have to be adopted. This question is discussed in detail in Chapter 10.

3.1.6 The cost of generation at the nuclear stations existing and under construction are estimated at about 5 to 6 paise per kWh. It has been estimated by the Atomic Energy Commission that with the adoption of larger units of the order of 500 to 600 MW the cost of generation will get reduced significantly. More detailed studies are required to establish a realistic picture of cost of nuclear power from stations with bigger units and adopting advanced reactor concepts. Nevertheless it has to be noted that even the cost of energy generation from 200 MW natural uranium type reactors at about 6 paise per unit would be competitive with prevailing costs of thermal generation at most of our thermal stations which are remote from collieries, even after allowing for the necessary standby provisions.

3.1.7 Our aim is to create the maximum amount of generating capacity with the funds available and to generate power at as cheap a rate as possible. To achieve these objectives, it is recommended that during the Fifth and Sixth Plans, the bulk of new generating capacity to be added should be derived from hydro sources, both of the energy intensive and peaking categories, as laid down most recently by the Inter-Ministerial Working Group on Power for the Fourth Plan (1968) which took into account the requirements of the Fifth Plan. The balance of new generating capacity should be derived from supersteam power stations, employing the largest possible units sizes and located at the coal washeries/coal mines since this alternative is bound to be cheaper in the immediate future and in the long run than locating the thermal stations far away from the collieries. The largest size of steam generating unit presently installed is 150 MW and the nuclear power plant at Tarapur as well as those under construction have generator ratings of the order of 200 MW. In the present schedule of manufacture of M/s HE and BHE, the largest unit is rated at 120 MW and it is expected that 200 MW would also be included in the manufacturing programme shortly. 200 MW unit in most of the regional power systems should be installed now. The Tata Consulting Engineers had made recently a study of relative economics of extension at a thermal station in Bombay with a 300 MW unit and a 500 MW unit. The detailed budgetary costs worked out for the entire project on the basis of prices obtaining in U.S.A. have shown that the capital cost installation of a 500 MW unit is cheaper by about 17% than a 300 MW unit. We should, therefore, plan for installation of units much larger than 200 MW at as early a date as the power systems can admit. The manufacturing programmes take considerable time to mature and make indigenously made generating units available. Taking this development period into account it is felt that the size of the largest generating units available from our manufacturers would have to be revised upwards immediately so that units of large rating than presently contemplated can become available to the power systems sufficiently early to enable them to derive the full benefits of the larger unit size. The installed capacity in each of the four regions excepting the North-Eastern Region would be of the order of 10 million kW before the end of the decade. A generating unit of 500 MW would thus constitute only about 5% of the regional installed capacity and it should therefore be quite feasible to instal such units in all the four regions of the country. Plans for manufacture, collaboration, import, installation etc., will take about 6 to 7 years. Action in connection with the installation of larger sized units needs to be initiated immediately. The arrangements for transport by rail/road of such large sized units should also be examined and made well in time. This matter is discussed in detail in Chapter 7. Detailed studies regarding the installation of larger sized units may be carried out carefully by the Central Water and Power commission in consultation with the Regional Electricity Boards and their recommendations adhered to by the manufacturers and the users. Nuclear power generation should be resorted to preferentially at all points which are remote from collieries and involve long haulage of coal, in steadily increasing measure. The above provides the broad guidelines for future power supply to ensure utmost economy in power generation for the foreseeable future, according to the current costs and trends in the fields of hydro, thermal and nuclear generation.

3.2 Longterm perspective plan and agencies for its preparation

3.2.1 The long-term economic perspective plan would have to be drawn up independently for the power sector and co-related and fitted into the overall economic plants. As future power development cannot be organised rationally and economically on a state-basis, the perspective plan should be prepared on a regional basis. The Fourth Plan, recognises this as a basic feature of future planning which has been accepted by the National Development Council.

3.2.2 The long-term plan would have to be reviewed at regular intervals, which may correspond with the periods for which the perspective plans of the Planning Commission are prepared, and in any case should be reviewed every year on a basis of uptodate information available. The long-term perspective plan should provide sufficient flexibility for changes which may be required to meet the short-term requirements of the over-all economy but must always be such as to ensure power supply ahead of demand. Once finalised, however, there should be a firm commitment to implementation of this perspective plan at the desired rate, at the Central/State levels. No uneconomic schemes should be considered as adhoc individual additions thereafter.

3.2.3. It is now well recognised that the grouping of projects by plan periods of 5 years has resulted in a jerky progress which is highly uneconomical. The planning and execution of power projects should, therefore, be a continuous process wherein the picture of the targets to be achieved, say, 15 years hence is always available in outline and the details are filled in as the years progress. The perspective plan for the next 15 years should be available at any point of time and every year such plan should be up-dated and extended to cover the future 15 years. Advance action in respect of preliminary investigations and designs and estimates should be on a more definite basis and indicate the specific project to be undertaken their time-table of the major stages. The plans and estimates for the first 5-7 years should be on a very definite basis at any time and prepared after detailed investigations so that any material change in estimates is avoided.

3.2.4 Each Electricity Board should have a planning Cell which will be capable of taking into account the long range needs for electric energy as well as utilisation of the resources in the best possible manner. Similarly, long range planning cells should also be organised in Regional Electricity Boards in order to make the planning wider-based utilising the resources of energy in the best possible manner. These should be able to co-ordinate and correlate the plans prepared by the State Cells. The projections of the Annual Power Survey should be taken into account in addition to the working of the Regional Electricity groups on an integrated basis. The projects should be identified in respect of geographical locations, power potential and the time when they are required to be commissioned for meeting the needs of the region. The needs of the transmission net-work should also be identified and spelt out.

3.2.5 *Planning at the Central Level*: At the central level, the responsibility for planning, at present, is divided between the Planning Commission, Central Water & Power Commission (Power Wing), *Ad Hoc* Committee for Irrigation & Power Projects, the Ministries of Irrigation and Power, Finance, etc. The Committee feels that this division of responsibility is not conductive to a unified and purposeful objective which is so essential now for economic planning in the power supply industry. It feels that the entire work of preparing long-term perspective plans should be entrusted to a single centralised agency which is competent to carry it out and ensure that the above objectives are achieved. The work involved, being primarily of a technical nature, the main question to be decided is whether this central responsibility should be discharged by the C.W. & P.C. (Power Wing) or the Central Electricity Authority.

3.2.6 The C.W. & P.C. (Power Wing) has been set up primarily, as a high-level consultant body to function at the request of States and other organisations. It has no statutory authority for carrying out investigations which seem to be the biggest bottleneck in the implementation of economic plans. Notwithstanding the major contributions, *i.e.*, National Hydro Electric Surveys (1953-60), preparation of the First Perspective Plan for Power Development (1962) and other important contributions to planning and designs of power projects, CW&PC (PW) was not entrusted with the work of investigation of 62 hydel sites—this work being taken up with the assistance of the United Nations Special Fund. The position is best summarised by Dr. Bhagvantham, Chairman, CW&PC Re-organisation Committee in March, 1969, in his letter of transmittal of the Committee's Report:

"By and large, the CW&PC had during the course of its existence over the last two decades discharged its functions satisfactorily, *commensurate with the Status given to the organisation*, and the responsibility devolving on those at the top levels. Nevertheless, the Committee feels that it could have done much better had it been given *adequate powers* to deal with the problems at a national level."

3.2.7 The Central Electricity Authority, on the other hand, even now enjoys statutory status and has the responsibility, *inter alia*, to develop a sound, adequate and uniform national power policy, and to co-ordinate the activities of the various planning agencies in the country, to carry out such investigations, as are necessary and to collect and record all data concerning generation, distribution, and utilisation of power and the development of power resources. These powers, it may be noted, were vested in the Central Electricity Authority, on the basis of recommendations of the Select Committee appointed by the Constituent Assembly to consider the Electricity Supply Bill—which, ultimately, became the Electricity (Supply) Act, 1948, which deliberately widened the scope and functions of the Authority. They had felt even then that non-statutory institutions would not serve the purpose even of discharging the duties of Electricity (Supply) Act, 1948. The Indian Atomic Energy Act of 1962, while empowering the Central Government "to develop a sound and adequate national policy in regard to atomic power", also lays down that the Central Government should co-ordinate such policy with the C.E.A. This Act, further directs that (a) the Central Government should fix rates for and regulate the supply of electricity from atomic power stations with the concurrence of the C.E.A.; and (b) in case of differences of opinion between the Central Government and any State Electricity Board in regard to provision of necessary transmission lines (for inter-State supply of power from nuclear power stations), the matter shall be referred to the Central Electricity Authority whose decision shall be binding on the parties concerned. It is clear from the above that the required status to ensure that the work of planning for power development is carried un-impeded, already vests in the C.E.A., in principle. The views of the Government of India on the Gokhale Committee recommendations regarding the C.E.A. are reproduced below:

"The Central Electricity Authority is charged *inter alia* with the development of a sound, adequate and uniform national power policy and particularly with the co-ordination of the activities of the planning agencies in relation to the control and utilisation of national power resources. In view of the heavy programme of power development in the country *any change in the Constitution of the*

Central Electricity Authority and reduction of its functions to a mere Arbitration Board *would be a retrograde* step."

This was the view then communicated by the Ministry of Irrigation & Power to the Estimates Committee of Parliament in 1963.

3.2.8. In this connection, the Committee feels that when a statutory authority like the C.E.A. is already in existence, is fully vested with power to undertake all the power planning programmes on rational considerations, and it is admitted that it is lack of this statutory status which has been inhibiting the work of the C.W. & P.C., it is obviously not necessary to look for another agency to carry out this task. There appears no point in introducing or attempting fresh legislation merely for taking away functions from the Central Electricity Authority and entrusting it to another Commission.

3.2.9 The Committee feels tha tthe over-all responsibility for planning for power, including investigations and processing of schemes, right up to the stage of initiation of construction should be centralised with the C.E.A. This will mean activisation of the C.E.A. which has never been set up as a full-time body and is, therefore, not adequately equipped now to discharge its responsibility. The C.W. & P.C. has been carrying out this responsibility on a *de facto* basis. The CW&PC (PW) or the units thereof, which are engaged on this work could be reconstituted as the Central Electricity Authority, and the Authority further strengthened on a technical and administrative plan to discharge these and other centralised functions.

3.2.10 The Committee realises that the implementation of schemes, included by the C.E.A. in the perspective plan would always depend on the availability of funds and that the Planning Commission are essentially concerned with this aspect. It would be necessary for the CEA to ascertain the position of availability of funds from the Planning Commission and to adjust the development programmes accordingly. The Committee, therefore, feels that the Planning Commission may be requested to advise the CEA of the extent of funds available in a particular Five Year Plan or a particular year for the development of power and the C.E.A. may then communicate sanction to schemes within the limits of available funds. It would improve matters further if a representative of the Planning Commission functions on a part-time basis as a Member of the Authority. It may be mentioned that the Ministries of Irrigation & Power, Finance and Law are already represented on the C.E.A. in that capacity. Further in view of the fact that nuclear generation on a large scale would have to be resorted to in future, a representative of the Atomic Energy Commission may also be appointed as a part-time member of the C.E.A. On the basis of these sanctions of the C.E.A., the Regional authorities, the State Government and Electricity Boards may then proceed to issue final sanction and execute projects.

3.2.11 It is felt that the time has come when the original jurisdiction of the C.E.A. for carrying out the investigations and overall planning in the best regional and national interests should be invoked to remedy the prevailing difficulties. For long-term regional planning, advantage could be taken of the existing institutions at regional/State levels to evaluate new schemes for expansion of power themselves and supply in the best way for region as a whole. They should be encouraged to take the help of CW&PC/other consultants in preparing feasibility reports as needed to expedite work. These feasibility reports should be forwarded to the CEA who should fit them into their overall perspective plan. After the inclusion of schemes in the perspective plan, detailed designs for projects selected at a regional basis may be arranged. In this connection, either the help of CW&PC Designs Organisation or of consultants already working in the field, as may be necessary, may be utilised.

3.3 Period of construction

3.3.1 It has been emphasised in the foregoing that if power is to be generated at the cheapest possible rates, during the 5th and 6th Plans, the bulk of new generating capacity to be added should be derived from hydro sources both of the energy intensive and peaking categories. A feeling seems to prevail in certain quarters that construction of hydro electric projects takes comparatively much longer time than thermal projects. This topic was considered by the Working Group on Power of the Fourth Plan and has further been considered in detail by Study Groups Nos. 3 and 5 of this Committee. The gestation period of new schemes involves (a) the period of investigations right from the concept of the scheme to its clearance for construction and (b) the actual period of construction of the Projects. In regard to (a) above there were no doubt inordinate delays ranging from six years onwards but on the basis of actual experience of the speed of construction of different projects during the past two decades it has been seen that once a scheme has been investigated in detail and sanctioned, the actual period of construction of hydro and nuclear power schemes was about the same, *i.e.*, 5 to 6 years, (In many cases of relatively simple projects like Kundah, Periyar etc., hydel schemes, have in fact been constructed as fast as in four years) whereas coal-fired thermal stations could be built generally in 5 years and sometimes even in 4 years.

3.3.2 The above excludes obviously time-consuming large projects like the Bhakra Project, the Beas Link etc., which involve works of large civil engineering features requiring longer gestation periods. Study Group No. 3 has given actual record of construction of hydro and thermal power plants (Tables 6 and 7 of the Report). The essential point to be noted is that in hydro projects the time factor of actual construction *i.e.*, excluding the periods of investigation upto the clearance for construction would largely depend on the kind of project. In practically all cases, where natural drops are available and the power station and the water conductor system and the storage works form separate constituent units, and work can be simultaneously accelerated on all of them, the schemes can easily be commissioned within four to five years of start of construction. A large number of our projects fall in this category. Table No. 6 of the Report of the Study Group shows that hydro projects in the above category were completed within a period of 5 to 7 years, the first units having been commissioned even in a period of 3 to 5 years. As regards thermal projects, some of these were completed within a period of 4 to 5 years but others took much longer. It is only in a few cases of hydro projects where the heads have to be artificially created by construction of large dams, *e.g.* Bhakra, Hirakud, etc., that long gestation periods are involved. Other factors which tend to increase construction periods are (i) when work is commenced on schemes in which foundation conditions have been inadequately explored and give rise to uncertainties during the stage of construction leading to major changes in designs and estimates of costs; (ii) where adequate financial provisions are not made in time for executing the project with all possible speeds.

3.3.3 Studies show that in India it is the initial period of investigation and pre-construction activities relating to sanction which is unduly prolonged. This, therefore, is what has to be controlled through all round concerted action. The need for advance action on investigations of hydel projects has been voiced in different forums for the last 15 years. The importance of investigations has been most powerfully expressed by the Estimates Committee of Parliament in their 30th Report (1962-63):

"As it is an established fact that Hydel is the cheapest source of power in India the Committee would urge the Government to investigate and prepare blue prints of all the remaining hydro-electric schemes so that they can be readily available for being taken up to meet the increasing demands. This is all the more desirable as India has all the requisite experience for undertaking investigations and preparation of project reports as also the implementation of hydel-schemes."

3.3.4 The CW&PC had also laid great emphasis in their perspective plan for power development in 1961 on the need for investigations of all kinds of power projects, particularly hydel projects. Subsequently, with the assistance of the United Nations special fund, investigation of 62 hydel projects in the country was taken up and the assistance of United Nations was dispersed to the various State Organisations along with equipment as decided by the Planning Commission/Central Ministries. Most of this work is still incomplete. Out of the 62 projects, detailed project reports on 12 have been prepared and further 6 projects have been reported upon in a preliminary manner. This again would be seen to be an unfortunate situation calling for immediate remedial measures. It is important that the project proposals and estimates are prepared in a manner as would not involve any significant variations in cost or time when action regarding their implementation is decided.

3.3.5 Once the time involved in investigation and sanction of projects is controlled (i) by organising proper institutions to undertake such work with stream lined procedures on a thorough and uniform basis and (ii) by a proper perspective approach to sanctioning projects on a continuing basis and as part of a total programme rather than on an individual basis as at present, the time factor in actual construction of projects would not be materially different in the different alternatives under consideration, *i.e.*, hydro, nuclear or thermal. In any case, the margin of difference would not be such as cannot be easily taken care of in a perspective plan.

3.3.6 It has been already suggested that the Central Electricity Authority which enjoys statutory status should be constituted as a full time organisation to develop a sound, adequate and uniform national power policy, prepare perspective plans and to coordinate the activities of the various planning agencies, in the country. The CEA when constituted in the above manner should see that the investigation work is organised all over the country in the desired manner. The actual work could be carried out in different ways by a Central Organisation, by State Organisations or even in the case of river valleys like the Chenab in India and the Godavery which have very lage power potentials at a number of sites, separate River Valley Authorities could be set up for the purpose of investigations and implementation of these schemes. The CEA will have to coordinate all this work and ensure that it is carried out in a proper manner within a time schedule.

3.3.7 *Proposals for the 5th Plan and early 6th Plan Periods*: Cost of generation from hydro, thermal and nuclear plants have been discussed in the Reports of Study Groups Nos. 1 and 3. It is found that the cost of hydel power has generally been found to be the cheapest, thermal and nuclear power costs being more. However, in each type of generating project, only the most economic, well-conceived and thoroughly investigated projects have produced low cost power and therefore the crucial factor in the power economy is that in the selection of projects, utmost care and scrutiny for the choice of the economic projects should only be made. In future, the energy requirements would be increasingly larger and larger in this country. The strategy for planning power development should therefore be based on both for meeting the energy as well as capacity requirements and naturally an optimal combination of hydro-steam power generation would be the most economic. Keeping the above in view, proposals for additional generating capacity for deriving benefits in the 5th Plan and early 6th Plan period have been considered by the Committee in Consultation with the Central Water and Power Commission. The schemes regionwise for deriving these benefits are given below. It is important that necessary steps for authorisation and implementation of all the schemes are taken without any loss of time so that the benefits from the same are derived in a phased manner. After realisation of benefits from all these schemes the total installed capacity would increase to about 46 million kW. In other words for achieving total installed capacity upto 46 million kW the pattern of development indicated below should be adopted and all efforts made to implement the same as early as possible. Further, hydro schemes on which investigations should be initiated and completed quickly for benefits in sixth Plan, have been indicated in Appendix 5 of the Report of Study Group No. 5.

GENERATION SCHEMES FOR BENEFITS DURING THE FIFTH PLAN AND EARLY SIXTH PLAN

NORTHERN REGION

I. Continuing Schemes from the Fourth Plan

Scheme	State	Installed capacity (MW)
Hydro		
1. Dehar	Punjab/Haryana/ Rajasthan	495
2. Pong	Punjab/Haryana/ Rajasthan	240
3. Yamuna Stage II	Uttar Pradesh	120
4. Maneri Bhali Stage I	Uttar Pradesh	105
5. Ramganga	Uttar Pradesh	60
6. Yamuna Stage IV	Uttar Pradesh	20
7. Lower Jhelum	Jammu & Kashmir	96
8. Salal	Central Scheme in J & K	270
	Total Hydro	**1406**
Thermal		
1. Bhatinda	Punjab	110
2. Panki	Uttar Pradesh	110
	Total Thermal	**220**

Total benefits from schemes continuing from the Fourth Plan 1626

II. New Schemes

Scheme	State	Installed capacity (MW)
Hydro		
1. Shanan Extn.	Punjab	50
2. U.B.D.C. Extn.	Punjab	45
3. Thein	Punjab/J & K	420
4. Nangal R. B.	Punjab/Haryana/ Rajasthan	150
5. Vishnu Prayag	Uttar Pradesh	200
6. Maneri Bhali Stage II	Uttar Pradesh	200
7. Gangbal	Jammu & Kashmir	60
8. Sonamarg/Kangan	Jammu & Kashmir	50
9. Pakal Dhul	Jammu & Kashmir	260
10. Kishtwar Stage I	Jammu & Kashmir	200
11. Seawa	Himachal Pradesh	100
12. Rishikesh/Hardwar	Uttar Pradesh	100
13. Dehar Extn.	Punjab/Haryana/ Rajasthan	330
14. Parvati*	Himachal Pradesh	500
15. Lakwa Byasi	Uttar Pradesh	250
	Total Hydro	**2915**
Thermal/Nuclear		
1. Bhatinda Extn.	Punjab	220
2. Badarpur Extn.	Delhi (Central Project)	400
3. Obra New Station	Uttar Pradesh	600
4. Nuclear	Central Project	600
	Total Thermal/Nuclear	**1820**

*Investigations to be expedited and project report to be prepared at the earliest.

WESTERN REGION

I. Continuing Schemes from the Fourth Plan— Nil

II. New Schemes

Scheme	State	Installed capacity (MW)
Hydro:		
1. Kadana	Gujarat	240
2. Tilari	Maharashtra	60
3. Bhira (Tailrace)	Maharashtra	80
4. Pench	Maharashtra	160
5. Narmada Sagar	Madhya Pradesh	500 } (Part I pumped storage)
6. Navagam	Gujarat	500 } (Part I pumped storage)
7. Bodhghat	Madhya Pradesh	240
8. Budhsagar	Goa	30
9. Chitrakot	Madhya Pradesh	100
	Total Hydro	**1910**
Thermal/Nuclear:		
1. Nuclear in Western Region	Central Project	[illegible]0
2. Ukai Thermal Extn.	Gujarat	[illegible]00
3. North Gujarat	Gujarat	[illegible]40
4. Wanakbori	Gujarat	220
5. Koradi/Pench Nasik/Chanda	Maharashtra	2000
6. Satpura Extn.	Madhya Pradesh	400
	Total Thermal/Nuclear	**3860**

In view of the very large thermal/nuclear capacity that will be installed in this Region by the end of 5th Plan, it is important to have hydro peaking capacity so as to economise on costs of power generation. With this object, the proposals for pumped storage hydro schemes for a total installed capacity of 600/700 MW should be evolved and implemented. Investigations for this purpose should, therefore, be taken up without any loss of time.

SOUTHERN REGION

I. Schemes continuing from the Fourth Plan;

Scheme	State	Installed capacity (MW)
Hydro:		
1. Lower Sileru	Andhra Pradesh	400
2. Srisailam	Andhra Pradesh	440
3. Pandiar Punnapuzha	Tamil Nadu	100
4. Idikki (3rd Unit)	Kerala	130
	Total Hydro	**1070**

II. New Schemes

Hydro

1. Upper Sileru Extn. .	Andhra Pradesh	120
2. Lower Sileru Extn. . .	Andhra Pradesh	200
3. Nagarjunasagar Pumped Storage . . .	Andhra Pradesh	100
4. Kadamparai . .	Tamil Nadu	200
5. Cholatipuzha. . .	Tamil Nadu	60
6. Suriliar . . .	Tamil Nadu	35
7. Upper Thambraparni .	Tamil Nadu	30
8. Idikki Extn. . . .	Kerala	390
9. Silent Valley . . .	Kerala	120
10. Idamalayar . . .	Kerala	50
11. Kalinadi Ist Phase . .	Mysore	260
12. Kalinadi (further development) . . .	Mysore	650
13. Warahi . . .	Mysore	300
14. Sharavathi Dam and Tail Race . . .	Mysore	300
	Total Hydro	**2815**

Thermal/Nuclear

1. Kothagudam . .	Andhra Pradesh	400
2. Neyveli New Scheme .	Tamil Nadu	400
3. Nuclear . . .	Central Scheme	600
	Total Thermal/Nuclear	**1400**

EASTERN REGION

I. Schemes continuing from Fourth Plan:

Scheme	State	Installed Capacity (MW)
Hydro :		
1. Subarnarekha . .	Bihar	65

II. New Schemes :

Hydro

1. Koel Karo (Ist Stage) .	Bihar	720
2. Kolab. & other Pumped Storage . . .	DVC/Bihar	300
3. Upper Klab. . .	Orissa	150
4. Upper Indravati . .	Orissa	300
5. Sankh . . .	Bihar	600
	Total Hydro	**2070**

Thermal :

1. Patratu Extn. . .	Bihar	220
2. Thermal in North Bihar .	Bihar	120
3. New Station . .	D. V. C.	400
4. Thermal in W. Bengal .	West Bengal	600
5. Talcher Extn. . . .	Orissa	240
6. Tenughat . . .	Bihar	400
	Total Thermal	**1980**

NORTH—EASTERN REGION

(I) Schemes continuing from Fourth Plan—Nil

(II) New Schemes

Scheme	State	Installed capacity (MW)
Hydro :		
1. Loktak Extension .	Manipur	35
2. Kameng . . .	N.E.F.A.	300
3. Kardamkolai . .	Meghalaya	60
4. Umkhen . . .	Meghalaya	200
	Total Hydro	**595**

CHAPTER 4

REGIONAL OPERATION OF POWER SYSTEMS

4.1.1 In Chapter-1 recommendations have been made for generation of power at the lowest possible cost. Power supply industry is highly capital intensive and after generating facilities become available at huge costs, it is important that they are utilised in an optimum manner, as this would result in lower costs of generation and transmission. This can be done best by having integrated operation of neighbouring power systems, so that as far as possible, maximum energy generation takes place from thermal/nuclear stations and maximum energy and capacity are utilised from the hydro stations. This can be achieved only by very close integrated operation of different power systems. The State power systems are operating in isolation and cannot be utilised to the maximum advantage. Therefore, it is necessary that systems of different States are interconnected to yield maximum benefits. For this purpose, the country has been divided into five regions as follows.—

(i) Northern Region : Comprising States of Haryana, Punjab, U.P., Rajasthan, Jammu & Kashmir, Himachal Pradesh and Union Territories of Chandigarh and Delhi.

(ii) Eastern Region : Comprising States of Bihar, West Bengal and Orissa and power system of Damodar Valley Corporation.

(iii) Western Region : Comprising States of Gujarat, Maharashtra and Madhya Pradesh and Union Territories of Diu, Daman and Goa.

(iv) Southern Region : Comprising States of Tamil Nadu, Kerala, Mysore, Andhra Pradesh and Union Territory of Pondicherry.

(v) North-Eastern Region : Comprising States of Assam, Nagaland, Meghalaya and Union Territories of Manipur, NEFA and Tripura.

4.1.2 It is intended that the energy resources of all regions should be developed in the most economic manner for producing power and that all power systems within the region should be operated in a co-ordinated manner to obtain minimum costs of power generation.

4.2.1 *Benefits of Integrated Operation* : The interconnected or pooled operation of a large number of generating stations offers overwhelming economic benefits resulting in large savings in capital investment and operating costs. While these are fairly well-known and accepted, they are briefly enumerated below.

(i) The simultaneous peak load demand of group of systems is almost always less than the sum of their separate non-coincident peaks owing to differences in types of loads served, diversity in seasonal variation of loads and differences in lighting up times. Thus the peak demand of an interconnected system would be lower resulting in considerable savings in total installed capacity.

(ii) In view of the natural diversities which often exist between the basic characteristics of energy resources of different power stations/power systems, the total firm load carrying capacity of common grid as a whole would be greater than the sum of the individual firm capacities of each constituent power system.

(iii) By sharing reserve capacity through interconnections, a group of systems can reduce the combined reserve for unscheduled outages or errors in load forecasting. The U.S. National Power Survey (1964) estimated that such reserve capacity requirements in U.S. can be reduced from 17% to 8% by 1980-81 with the same reliability if a fully co-ordinated operation of all the country's resources was carried out. In India also the reserve capacity requirements can be considerably reduced by having fully coordinated operation.

(iv) Large systems are able to absorb large-sized generating units since they can operate in a suitable manner even under a sudden loss of such a unit. If regional development is fully integrated, addition of 200/300 MW thermal units by 1974-75 and 500 MW units by 1980-81 should be easily feasible. Such a measure would result in saving in capital cost of thermal capacity per installed kW by about 15%.

(v) When regional power systems are fully co-ordinated, selection of new schemes for power development can take place by selection of the lowest cost generation schemes in the region instead of their being confined to State basis.

(vi) Peaking capacities can be planned on a joint basis in large interconnected systems so that the peak loads of combined system can be carried at a much lower cost than what is possible with small individual systems.

(vii) Large economies in operation cost are possible by carrying out fully coordinated despatching which would allocate total load of the combined system among individual units in the most economic manner.

(viii) Maintenance of generating units if properly coordinated in a region would result in reduction in standby capacity.

(ix) In case of emergency, neighbouring systems can come to the assistance of one another.

4.2.2 The users of power in the country have a right to demand electricity at the most economic rate possible irrespective of the barriers of political boundaries of the States or ownership pattern. It is with this objective that the policies of development of power resources in the country should be planned. Substantial economies in the cost of power generation can be achieved by developing well-integrated regional power grids, leading to the evolution of a national power grid. There is an urgent need to recognise measures which would promote development of such grids. Sanction for future schemes should be on Regional and not on State considerations. If integrated operation is to be achieved special attention is required on (a) transmission line planning, (b) interstate contracts to promote interchanges of power and (c) operation management including load despatching. These are discussed subsequently.

4.2.3 *Adequacy of Transmission Lines and Criteria for Planning*: (i) Detailed review of existing and proposed interconnection facilities between States and systems has been carried out by Study Group No. 2 of this Committee. It has shown that considerable progress will be made in the interconnections of different State systems to form regional systems. Also some inter-Regional ties are planned. The review also shows that most inter-State and inter-Regional ties will be of a capacity around 150/200 MWs being mostly single circuit lines. It has been already observed above that the economy in the cost of power generation can be achieved by operating systems closely integrated. The available interconnection capacity in 1969-70 was far from adequate for such an operation. The planning for 1973-74 also does not seem to be adequate for achieving integrated operation of resources to obtain maximum economy. The inter-regional ties are planned with limited capacity like S.C. 220 kV or 132 kV lines. It is desirable to review the planning of all regional grids and inter-Regional ties. The following criteria for planning are recommended.

(ii) In a developing economy like the Indian economy, unforeseen disparities between the planned load growth and actual load growth is inescapable. It is likely that the development of generating capacity in one State may lead the load growth while that in a neighbouring State may lag behind the demands. Due to such factors, one State may have surplus generating capacity while the other may suffer shortages. The only remedy for such a situation is to provide for transmission lines between States of adequate capacities to be able to transfer surplus of one State to another. While each situation will demand a solution based on its own characteristics, it appears that inter-State ties with capacities of less than 10% of the size of the systems that are tied together are not likely to be adequate since they will not take care of a load slip of even one year. This criterion may appear to be somewhat extravagant at a first glance, but considering that a tie of this type may cost Rs. 2/3 crores while a State like Maharashtra lost industrial production to the tune of Rs. 100 crores in power shortage extending for six months in 1969 due to absence of ties with Mysore, and Madhya Pradesh, liberal planning seems to be justified. There is an acute power shortage in the States of Punjab, Haryana & Uttar Pradesh at present. This is partly due to the loads having been built up beyond the firm capacity available and because the run off in the Bhakra Reservoir this year has corresponded to that of a dry year. A surplus capacity of over 180 MW at Satpura Thermal Power Station in Madhya Pradesh which is jointly owned by Madhya Pradesh and Rajasthan States is available at the moment but unfortunately due to lac of interconnecting transmission facilities, this power cannot be utilised in the States of U.P., Punjab, Haryana, etc. If the Satpura surplus power could have been utilised, losses worth several crores of rupees (in Punjab alone the loss is estimated at about Rs. 100 crores), which are occuring and will occur in industrial and agricultural production due to non-availability of power in other States could have been avoided, as the Satpura surplus power would have mitigated the shortage to a very large extent. This example alone would be sufficient to indicate as to how important it is to arrange for interconnections between different power systems. Once such ties exist they will provide a fillip to economic scheduling of generation.

(iii) It should be borne in mind that inter-State and integrated ties are required to be utilised for the economic operation of resources of the interconnected systems. This implies that even if two systems are self-sufficient in their needs of power generation, power transfer will take place from the State having lower cost of generation to the State having higher cost of generation till costs are equalised. The cost of production of electricity is a dynamic concept in the sense that it is continuously changing in a power system from hour to hour, depending on the source of generation. Also one State may be able to produce electricity cheaper at certain times of the day but may be more expensive at other times. Hence exchange of economy power will involve a continuously varying pattern of power transfer which can be of a large magnitude. Thus to revert to the example of Maharashtra and Madhya Pradesh, it is possible that Madhya Pradesh can feed cheap thermal power from idle pithead plants to Maharashtra during peak periods and Maharashtra, on the other hand, can feed spill hydro-energy in monsoon to Madhya Pradesh during low load periods at small costs. This aspect of system operation should be fully studied at the planning stage so that uneconomic generation utilisation does not take place. Even transfer of power from one thermal source to loads in the neighbouring system having its own thermal generation should take place if sufficient cost differential between the two exist. In the planning of inter-State ties, these aspects have to be kept in view.

(iv) The third function of inter-State ties is to permit (a joint planning of maintenance schedules of the generating units between the States and (b) permit sharing of emergency reserve. The saving in the capital investment due to reduction in the quantum of gross reserve required in the systems are very large.

(v) In order to illustrate the principles of integrated operation, an indicative study of the benefits of integrated operation of four systems in the Southern Region was carried out by Study Group-2 and the detailed report in this respect is attached in Annexure 2-3 of the report of the Study Group. This shows that the power systems could have saved about Rs. 8.27 crores in fuel charges alone in 1968-69 if principles of economic generation scheduling were applied to all resources. Nearly 2692 million units of thermal generation in Tamil Nadu could have been substituted by zero cost surplus hydro generation from Sharavathi Hydro electric Project, Mysore. The study for the anticipated operating conditions in 1973-74 also shows that savings of similar magnitude, *viz.*, Rs. 8.33 crores can be achieved if coordinated generation scheduling is carried out. Also the study for 1973-74 conditions reveal that a large capacity saving can be achieved if systems are planned and operated in an integrated manner.

4.3.1 *Capital Outlay for Transmission and Distribution* : (i) Earlier the inadequacy of transmission lines for inter-State and inter-Regional interconnections has been brought out. The outlay on power programme in India from 1951 to 1968-69 is given in the following Table :—

TABLE 10

OUTLAY ON POWER PROGRAMME INDIA

(Figures in Crores of Rupees)

Sl. No.	Year	Generation	Transmission and Distribution	Rural Electrification	Miscellaneous	Total
1	2	3	4	5	6	7
1.	1951-56 .	105·0	132·0	8·0	15·0	260·0
2.	1956-61 .	250·0	115·0	75·0	20·0	460·0
3.	1961-66 .	774·0	301·0	153·0	24·0	252·0
4.	1966-67 .	240·0	83·2	73·4	7·2	403·8
5.	1967-68 .	221·3	103·2	74·8	6·6	405·9
6.	1968-69 .	215·7	105·5	88·7	4·7	414·6
Total outlay as on	31-3-1969 .	**1806·0**	**839·9**	**472·9**	**77·5**	**3196·3**

Outlay on transmission and distribution as percentage of total outlay . $\frac{840}{3196} \times 100 = 26{\cdot}2\%$

Outlay on rural electrification as percentage of total outlay $\frac{473}{3196} \times 100 = 14{\cdot}3\%$

Outlay on transmission and distribution and rural electrification as percentage of total outlay $\frac{1313}{3196} \times 100 = 41{\cdot}0\%$

SOURCE : Planning Commission.

(ii) The above Table shows that the capital outlay in transmission and distribution facilites has been considerably lower than the norms adopted in other countries. The report of Study Group No. 2 incorporates data of investments in generation, transmission and distribution in U.S.A., Canada, Japan and European countries. The investment in transmission and distribution in India during the years 1966-67 to 1968-69 was only 23.8% of the total outlay in power sector whereas the corresponding figures in U.S.A., Canada, Japan and European countries ranged from 39.5% to 58.3%. (Table No. 2.5 of the report of Study Group No. 2). The investment of 14.3 per cent in the rural electrification sector in India is separately shown since it has no real counter part in other countries. Since the rural loads constitute only 10% of the total loads in the country, it is clear that this investment is not available to 90% of the consumer loads or for interconnections.

(iii) The lack of adequate investment in the field of transmission and distribution is chiefly responsible for inadequacy of inter-connection, high transmission/distribution losses, unsatisfactory voltage conditions and low reliability of supply in various power systems in the country. In view of this, it is important that plans for augmentation of transmission and distribution systems and optimum utilisation of generating capacities should be planned as an integral part of tne plans for increase in generating capacity. The allocation of funds for generation, transmission and distribution facilites should be separately made and suitably matched. The provision for transmission and distribution in the Fourth Plan is Rs. 721 crores against a provision of Rs. 1255 crores for generation schemes and Rs. 444 crores for rural electrification. There is already a lot of back log in transmission, and distribution which would be seen from the fact that investment in the first three Plans was much less than required, but then during the period 1966-67 to 1968-69, it was only 23.8 per cent of the total outlay on power. If the above deficiencies are to be rectified, it is apparent that provision for transmission and distribution in the Fourth and subsequent Plans shall be considerably increased.

(iv) It is understood that Rs. 22 crores have been sanctioned by the Planning Commission for construction of inter-State and inter-Regional tie lines during the Fourth Five-Year Plan against the fact that the transmission facilities proposed so far by CWPC up to 1973-74 would cost Rs. 37.2 crores. Details of these transmission lines are listed in Annexure 2.1 and 2.2 of the report of Study Group No. 2. In view of the inadequacy of the transmission system already existing, it is desirable to sanction more inter-system ties and provide additional funds for the same as this will help integrated operation of the systems.

4.3.2. *Criterion for Transmission Planning* ; (i) The review of existing and proposed inter-State and inter-Regional transmission lines in the country has brought out that the transmission capacity has been utterly inadequate in the past to permit efficient use of resources. It has also revealed that the proposed additions up to 1973-74 would not remedy this situation to any large extent. It is concluded that there is need for a complete change in the strategy of planning and inter-system tie lines and need for allocation of more investment for this purpose.

(ii) The long range planning strategy should be based on the fact that in the next 10 years or so, not only the State systems should completely integrate to form regional grids but also that the regional grids should get adequately inter-connected to form a national grid. In such a complex, the selection and setting of power projects could be done purely on the basis of minimum cost criteria and the operation of resources could be done with a view to optimising the use of national wealth.

(iii) It has been already pointed out that in a developing economy like that of ours, it is likely that the development of generating capacity in one State may lead the load growth while that of any neighbouring State may lag behind the demand and due to such factors, one State may have surplus generating capacity while the other may suffer shortages. The remedy for such a situation is to provide for transmission lines between States of adequate capacities to be able to transfer surplus of one State or region to another. Each regional grid excepting the North-Eastern Regional Grid, would have an installed capacity in excess of 5 million kW in the next 3 years. It is then easy to conceive power transfer between the regions of the order of 500/700 MW over distances up to 1,000 Km. in the interest of economic utilisation of resources. Transmission lines have to be planned on long-term basis—say for a period of 15 to 20 years. In 1980 the installed generating capacity is proposed at about 50 million kW and will be much more thereafter. Each regional power system by 1980 would have an installed capacity of over 10 million kW. In view of what has been stated above, it appears that inter-State ties with capacities of less than 10% of the size of the systems that are tied together are not likely to be adequate since they will not take care of a load slip of even one year. We have, therefore, to plan for an inter-change of over one million kW between the different regional power systems. Such power transfer would need extra high voltage lines with voltages of 400 or 500 kV. At present, not a single inter-State or inter-Regional tie with such capacity is proposed nor have any feasibility studies been carried out. It is desirable to initiate studies to evolve the concept and plans for a national grid immediately if it has to be a reality in the next 10 years. All short-range plans should be made to fit into such a long-range perspective plan.

(iv) The maximum voltage in use at present in India is 220/230 kV. It is quite clear that 220 kV. level would be totally inadequate when inter-Regional planning is considered. The 400 kV or 500 kV lines which have been proposed for 2 or 3 schemes in the country have been selected purely on considerations of power transfer from a generating station to the load centre. If the results are to be achieved within the required time, a decision on the next higher voltage *i.e.*, 400 or 500 kV has to be taken without any further loss of time. This question has been under discussion in the country for some time now. It is suggested that a study group should be set up to evaluate the need of the country over the next 10/15 years and recommend suitable voltage levels above 220 kV for development in the country.

4.4. System operation management:

4.4.1. In the previous paragraphs, it has been shown that operation of power resources in an integrated manner can provide large savings both in capacity and fuel cost. In order to achieve optimum utilisation of resources, and at the same time ensure reliability and continuity of power supply, proper institutional and technical set up has to be created. This function is referred to as System Operation Management. The objective of this is to ensure safety of operations, reliability and continuity of power supply, and the optimum overall efficiency by fullest coordination between generation, transmission, distribution and inter-connection facilites. The cost of power to the ultimate consumer should be the minimum that can be achieved by the most efficient management of power system operations. All the benefits arising out of careful power system planning, advanced equipment design, available generation resources etc. will be lost if operation management does not ensure minimum cost of power to be realised.

4.4.2. The operation management of power systems can be achieved by the performance of the following functions:

(a) Forward operation planning
(b) Operation execution
(c) Processing the operational data and reports
(d) Inter-system coordination
(e) Inter-region coordination.

The power system management is closely connected with the system operation, maintenance and construction organisations in a power utility. Further it has to coordinate the commercial, engineering and the broad policy laid down for the region. It is desirable that in an efficient operation management, the flow of decisions and information between the participating organisations is free and unrestricted, to evolve a final dynamic operation policy and its execution.

The above problems have been discussed in detail in Chapter 4 of the report of Study Group No. 2.

4.4.3. The first step in operation management involves the preparation of a long range plan of power system operation with the available and known resources. Plan so envisaged should ensure that it is optimum for the region and should also consider inter-Regional transfers to enable economy and emergency transfers. Such a long range plan, which may extend to a period of 4/5 years would enable the construction, engineering, commercial and policy making organisation to foresee the future operational trends and make necessary changes in their plans. The participation of these agencies in the evolution of the long range operational management assures that engineering, commercial and construction decisions are made well in advance so that no handicaps are experienced in the final execution of operation plans. The inter-connected operation plan should be evolved for each region by the technical coordination committees to ensure safety, security of the regional power system and optimisation. The preparation of operating philosophy for a period of 4-5 years can only be possible by computer studies which can simulate operation of generation, transmission and distribution facilities of an electric power system to evaluate future operating costs. It is then possible in a very short period to compare a number of alternative operational plans which take into account different valuable factors. It is imperative that long-range operation plans so developed are cleared early through the various policy making bodies in each region so that they are released to the regional and State load despatch organisations for execution well in advance. The approved operation plans are translated into day to day operations by the various multi-tyre load despatch organisations *viz.*, regional, States and area load despatch centres who are ultimately charged with the responsibility of coordination of the generation, transmission, distribution and inter-connection facilities.

4.4.4. The objective in inter-connected operation of the region has to be approved at the policy level. It is recommended that this function be performed by the Regional Electricity Boards comprising representatives of various constituents of the regions having major generating capacities, at the level of Chairman. This Board should have full time Member-Secretary and should be assisted by a Technical Co-ordination Committee and a number of technical groups consisting of specialists in various fields.

4.4.5. Operating Committee, which will be at lower level as compared to policy level, will decide broad operational plans and targets in line with the operating philosophy laid down by the Regional Electricity Board. Operating Committee should be responsible for technical aspects of system of operation. These will improve coordination of maintenance schedules, monthly generation scheduling for dry seasons and monsoon to obtain maximum overall economy in the region, coordination of protection, determination of operating criteria and procedures to maintain desired reliability and quality of service. The Operating Committee may have to meet every month. Operating Committees should have representatives (at the level of Chief Engineer) from the constituents of the region having major generation capacities. Such representatives will be incharge of individual system operations and will have the authority to take operational decisions.

4.4.6. Execution of the operational plans and targets laid down by the Operating Committee are executed in day to day operations by multi-tyre load despatch organisations. It is necessary that each system in a region has a separate load despatch centre which will monitor detailed operations within the system. State and Regional load despatch centres to coordinate and act as a clearing house for transactions between systems is desirable. Coordination of day to day operation is carried out at regional level by regional load despatch centre and State level by State load despatch centre. The execution is carried out by area load despatch centres.

4.4.7. Functions and duties of these load despatch centres have been outlined in the report of Study Group No. 2. It is desirable that use of modern on-line digital computer control techniques is employed at various levels to achieve desired standard of operation.

4.4.8. Load despatch tools for effective system operation have been described in detail in the report of Study Group No. 2, which gives the various functions, communication facilities, controls etc. required in a load despatch station. It has also emphasised that inter-connection manuals to acquaint the operating staff for normal and emergency operations should be prepared and these should give in detail the operations to be carried out on the inter-connections. Another point to be noted is that the load despatching work is being taken up in the country on the planned scale for the first time. It is, therefore, necessary to train the load despatching personnel suitably. Some time back the Ministry of Irrigation and Power had a proposal of setting up a load despatch training institute. It is recommended that establishment of such an institute should be expedited.

4.5 Conclusions

4.5.1. The rapid pace of inter-connection between power systems can greatly improve the continuity, security and integrity of power supply only if it is associated with a sound mechanism for monitoring and control. In its absence, instead of achieving "Perfect Service Standard", it is likely to result into deterioration of the existing standards. The analysis and recommendations pertaining to the black-out in the North-Eastern part of United States in November, 1965, emphasised the need to provide effective inter-system coordination and to provide the various Load Despatch Centres with adequate modern tools for monitoring and control of the power systems. The Central Electricity Authority was formed by an Act of the Parliament to exercise such functions and perform such duties under the Electricity (Supply) Act, 1948 and in such manner as the Central Government may prescribe or direct and in particular to—

(i) develop a sound, adequate and uniform national power policy and particularly to coordinate the activities of the planning agencies in relation to the control and utilisation of national power resources. In order to achieve these objectives, it is recommended that the Central Electricity Authority takes active part in Technical Coordination Committees and forward Power System Planning Cells at Regional levels. It should also play active role in Regional Load Despatch activities with respect to power system control and optimum utilisation of national resources.

(ii) act as arbitrators in matters arising between the State Government or the Board and a licensee or other person as provided in the Electricity (Supply) Act, 1948.

Since system coordinations is reqired between various States at regional level, it is suggested that the Central Electricity Authority acts as technical judiciary between the States for disputes regarding operation and control.

(iii) carry out investigations and to collect and record the data concerning the generation, distribution and utilisation of power and the development of power resources.

It is suggested that the Central Electricity Authority should carry out investigation and make reports outlining system operating practices and security criteria in various systems.
and

(iv) make public from time to time information secured under the Electricity (Supply) Act, 1948 and to provide for the publication of reports and investigations.

It is recommended that the Central Electricity Authority should investigate and publish reports regarding major power supply failures for information of the public.

4.5.2. In order to achieve all these functions actively, it would be necessary to have full-time members and Chairman for the Central Electricity Authority. The activisation of the Central Electricity Authority has also been emphasised for rational power planning, investigation and for expediting construction of power projects. Also the Regional Electricity Boards should be strengthened to perform the functions of System Operation Management at the Regional level.

4.5.3. The Load Despatch Centres at State and Regional levels should be expeditiously set-up. It is desirable to have them all functioning before the end of the Fourth Five Year Plan if the full benefits of the large investments being made in the power field, are to be obtained. The amount of money spent on setting up such centres would be small compared to other investments and would undoubtedly be repaid many times over within a few years.

4.6 Reliability of power supply

4.6.1. There have been many complaints from consumers from various parts of the country that the power supply arrangements are far from satisfactory from the point of view of quality and continuity. The Central Water and Power Commission have conducted special studies in a number of instances where supply interruptions had become inordinately large. These reports of CW&PC have provided a valuable data in determining the basic deficiencies in supply arrangements. Eight such reports of CW&PC have been studied by Study Group No. 2 of the Committee. Due to rapid development in power supply facilities, the standards of operation and maintenance have tended to be diluted in many systems. The reliability can be improved by careful application of the well-known principles of power supply planning, operation and maintenance. Vigorous measures are necessary for this purpose. Large voltage variations, sustained low or high voltages, voltage fluctuations, frequency fluctuations etc. result in low quality of supply and low reliability. In many instances, these become equivalent to interruptions as far as the effect on consumers is concerned. The subject has been dealt within detail in Chapter 5 of the report of Study Group No. 2 and the measures for improving reliability outlined by it. Briefly these are :

1. Generation Reserve : It is necessary to have sufficient generating capacity to meet the loads at all times as well as to have sufficient emergency reserve capacity so that tripping of generating units does not result in frequent load shedding. Calculations in the Maharashtra system in 1973 indicates a reserve requirement of about 14 to 18 per cent for this purpose. Similar studies should be carried out for all systems and adequate reserve provided while planning generation capacities.
2. Adequate transmission system has to be provided and the system should be so operated as to ensure that tripping of one transmission line does not result in a severe disturbance due to over loading and cascade tripping of other lines and/or transformers. During adverse weather conditions, the operation may also have to be organised to cover tripping of two lines on one tower or lines on one right of way. The load flows on various lines and major transformers should be monitored on a continuous basis and the generation schedule so arranged as to take into account the security aspects. The relay settings for overloading tripping of various transmission lines should be periodically reviewed and adjusted to suit the changing loading conditions in the system.
3. The protective relaying system should be sensitive as well as discriminatory. Protection on various elements like generators, bus-bars, transmission lines, transformers etc. has to be fully coordinated so as to perform the dual function of isolating the faulty equipment with high speed and at the same time being insensitive to faults outside its own area of protection.
4. Instances of shortage of generating capacity may occur due to forced outage of large magnitude. In such instances load relieving in the system would be necessary. The use of underfrequency relays would permit relief of lowest priority loads and such relays should be installed especially in large urban distribution systems.
5. Existence of a well-organised load despatch centre is necessary in order to restore a system

to normalcy after a disturbance in as quick a time as possible.

6. In order to continuously improve system reliability, it is necessary that all tripping and disturbances are fully investigated and necessary steps taken to avoid recurrence.

7. Other measures for this purpose are (i) provision of written operating instructions for all elements in the system which convey to the operating staff the switching procedures and other precautions for operations. (ii) Provision of adequate number of recording instruments at all major receiving stations. (iii) Provision of disturbance recorders which can record several quantities simultaneously so that sequence of tripping in case of complex occurrences can be analysed at all important generating stations and inter-connection points.

8. On long transmission lines and especially on major system inter-connecting lines, it is desirable to provide on-line fault locating equipment which can indicate faulty sections within a few spans and save patrolling time.

9. For proper voltage control, reactive generation in the system should be adequate both on the leading and lagging side so that the system voltages are maintained within very close limits at all bullk receiving points.

10. For all important and large industries or consumers, duplicate feeders with circuit breakers and bus sectionalising switches should be provided. All important loads should have main and alternate sources of supply so that outage of one source does not result in long interruptions.

11. In distribution system for supply to important consumers, protection on the feeders should be properly coordinated.

12. Provision of auto-reclosing relays on feeders can help to reduce interruptions since a large percentage of faults on feeders are of a transient nature. These should be provided on all important feeders.

13. A large number of interruptions are caused by bird faults. In the locations subject to bird faults, distribution lines should be designed with adequate clearances to obviate this difficulty.

14. A large number of failures occur due to failure of clamps. The clamps should be properly designed, procured from reliable suppliers and erected with necessary care. Also periodical inspection is desirable.

15. Frequency of feeder tripping can be reduced by periodic inspection of lines, inspection of lines after every trip out, practice of tree cutting in time, cleaning of insulators prior to onset of unfavourable weather conditions, etc. Comprehensive preventive maintenance procedures should be provided and issued for the guidance of the maintenance staff.

16. Instances of frequent failures of cable joints and cable boxes have been reported which are due to (i) sub-standard quality of material used in making the joints and (ii) poor quality of workmanship. These are avoidable by proper quality control and supervision.

17. Tripping of circuit and/or transformers due to overloading has to be avoided. For sustained overloads, it is better to trip feeders by overload relays rather than trip a transformer which results in interruptions to entire areas or a large group of consumers.

18. Insulator flashover also causes many line trippings. While this cannot be eliminated, precautions like periodic check of tower footing resistance, proper maintenance of grounds and provision of lightning arresters would reduce the frequency of flashovers of insulators. Live line washing techniques should be used to reduce outage requirements.

19. Many interruptions in large chemical plants have occurred due to the failure of the designer of the plants to take into account the characteristics of the system feeding the plant. The type of equipment installed in the plant and protective gear provided are required to be coordinated with the supply conditions.

20. It is important that time required to restore supply after a fault is reduced. Provision of good communication between substations and consumers facilitate quick restoration. Also providing vehicles to the line crew for quick patrolling is essential.

21. All disturbances on a distribution system should be fully reported and properly analysed and classified. It is only by keeping good records and carrying out an analysis of the causes that steps to improve reliability can be continuously initiated.

CHAPTER 5

INTER-REGIONAL & INTER-STATE EXCHANGES OF POWER

5.1. Difficulties in power exchanges

5.1.1 The need for integrating power systems in the country has been brought out in the foregoing. In India, there are numerous instances where interchanges of power, integrated operation of power systems and economy exchange of power is not taking place though transmission capacities exist. Interconnection between Mysore and Tamil Nadu could be cited as an example. Table No. 3.1 of the report of Study Group No. 2 gives the position regarding availability of energy in Mysore, energy requirements of Tamil Nadu, etc. In 1968-69 alone, over 2,000 million units were generated in Tamil Nadu from the thermal stations involving fuel cost of 1.85 to 5 paise per kWh at Neyveli and Basin Bridge stations, the latter being old and comparatively inefficient. On the other hand, over 2,000 million units of zero incremental cost hydro energy in Mysore remained unutilised. Considerable savings in fuel charges of Tamil Nadu could have been made if Mysore's hydro energy was utilised instead. Another example, which has been already mentioned, is the inter-connection between Gujarat and Maharashtra. The two States systems are tied with Double Circuit 220 kV lines through the Tarapur Nuclear Station. But the inter-State ties are used mainly for the purpose of sharing Tarapur Power and not for exchange of economy power or rendering emergency assistance to each other on a regular basis. There are cases notably Tatas and Railways in Bombay where principles of equichange transfers, secondary energy sale and peaking assistance are translated into practice. Also there are instances of exchange of emergency assistance as in the Eastern Region. However, such instances are exceptions. Many instances of power transfer are dictated by compulsion of circumstances rather than being results of pre-planned agreements. One of the main reasons for this inadequacy is lack of commercial contracts between the concerned parties and lack of principles of costing of power in inter-system trnasactions.

5.1.2. *Tariffs and Commercial Agreements for Inter-State Exchanges*: Study Group No. 2 of the Committee took up for special consideration the question of tariffs for inter-State supplies of power. Based on the recommendations of the Venugopalan Committee, constituted earlier by the Ministry of Irrigation and Power, the Ministry have notified in their Resolution dated 27th November, 1969 guidelines for the above purpose. The Study Group came to the conclusion that these guidelines do not adequately meet the requirements of the situation and this is one of the chief reasons for there not having been any progress on inter-State exchanges even after the recommendations of the Venugopalan Committee and its acceptance by the Government of India. The Venugopalan Committee divided inter-State supplies into six categories and stated that the cost of inter-State supply should be based on the pooled cost of generation and the appropriate cost of transmission. The only distinction sugested between the different categories is in regard to the elements of profit chargeable over and above the pooled cost of generation and the cost of transmission. Study Group No. 2 has given considerable thought to this problem.

5.1.3. The pooled cost of generation represents the average cost of generation from all the facilities in the particular supply system and is to be worked out according to the principles laid down in the 8th Schedule to the Electricity (Supply) Act, 1948 which provides for inclusion of all fixed and operating charges. Under integrated operation, where the object is to achieve utmost economy of system operation, inter-State exchanges would be called for (a) to meet deficits in certain systems as they arise and (b) to utilise low cost energy supplies in some of the systems in place of high cost energy in other systems, thus achieving overall economy. As an example of the latter category, old and high cost thermal units at Delhi could advantageously be backed-down during the long periods of secondary power availability in the Bhakra/Beas hydro systems. Similarly when spilling takes place over storage dams in projects like Sharavathi, Sabarigiri and others, thermal power stations in neighbouring systems can be backed down. Even high cost thermal stations in some States could advantageously be backed down if more economic thermal generation (and supply) can be arranged from neighbouring systems. In such cases, tariff based on pooled cost, which includes fixed costs, would not provide the necessary incentive to promote inter-changes which lead to more efficient use of generating facilities and energy resources. The tariff for such supplies would have to be based on the incremental (mainly fuel) cost of supply to the selling system and the actual economy effected in the buyer system by availing of this supply *i.e.*, decremental cost of buyer system. These will not include fixed and overhead costs.

5.1.4. In the case of firm supply to be made under pre-arranged contracts, what is relevant is not the pooled cost of generation of supply system but the cost of only those supply facilities which actually enter into this tranaction. This is particularly true when the seller has to build new facilities for the purpose of a long term firm supply arrangement. In such cases, the tariff should take into account the cost of these facilities which the selling State would have to incur and the investment which the buying State would defer in view of this inter-State supply.

5.1.5 Experiences of tariffs in other systems where independently owned facilities are operated to a high degree of inter-connection or integration are relevant for our purpose. The Legal Advisory Committee of the Federal Power Commission of the U.S.A. on "Rate Regulation and Power Pooling Agreements" in the year 1963 recommended specifically that regulatory agencies in so far as they have occasion to judge the justness and reasonableness of power pooling contracts, should not generally use *fully distributed costs* as the yardstick.

NOTE : The term "fully distributed costs" in U.S. Parlance corresponds to the term pooled costs as in current usage in this country.

More recently (in 1965), the Task Force interconnection arrangements of the Edison Electric Institute in a report on methods of owning and selling generating capacity made the following observations :

"Fully distributed costs are not an accurate measure of the fairness of price and secondly a rate based on such costs could prove to be a complete obstacle to the successful completion of a desirable firm power arrangement."

5.1.6. The above references are being quoted mainly to indicate the limitations of the guidelines which have been laid down so far and to evolve a more constructive approach which would promote integrated operation through inter-system power exchanges.

5.1.7. The Study Group No. 2 recognised that principles have to be evolved based on the following primary considerations :—

(i) that in regard to sales of electricity between independent supply systems, the seller as well as the market are equally important;

(ii) that tariff principles must provide incentive and equity to both parties, if the power resources developed at huge costs are to be utilised with optimal economy.

(iii) In economy interchanges, the position of seller and buyer are interchangeable and hence the tariff structure should be reversible.

(iv) The tariff principles must provide the necessary incentive to both the seller and the buyer, to generate extra power and even to install extra facilities in the case of the former and to purchase this power in the case of the latter, forgoing the alternative of self generation, the sole object being the promotion of overall economy in operation and planning of the combined systems.

5.2.1. The Study Group has come to the conclusion that for proper costing of power supply the transactions should at least be classified under the following broad classifications :—

(i) Firm supply;
(ii) Economy Interchange;
(iii) Emergency Interchange;
(iv) Inadvertent Interchange,

5.2.2. *Firm Supply* : It covered situations when one of the parties is surplus in generating capacity and is in a position to enter into a firm commitment to supply power and energy on a firm basis to another State which is deficit in capacity and energy. The term 'firm' implies that the seller must always keep the committed capacity available to the buyer at all times except under "force majeure" conditions and make the supply as per the buyer's schedule to the extent of the commitment made. Firm supply can be of two kinds, *viz.* (i) on a short-term and (ii) on a long-term basis. The criterion for deciding whether a supply is a long-term one, is whether the arrangement is made by the buyer as a cheaper alternative to investment in additional plant. Since no additional capacity can be added in less than three years, long-term supply will range from three years upwards. All other cases of supply may be termed as short-term. Thus short-term arrangements would take care of situations where an unforeseen delay in commissioning additional generating or transmission capacity creates a deficit in one State necessitating import of power from a neighbouring system. Similarly, major deviations in load forecasting cause shortages or excesses of a short duration necessitating interchange of power.

5.2.3. *Long-term Supply* : As mentioned above long-term supply on a firm basis may range from three years upwards. Need for such agreements would arise primarily on account of scarcity in economic power resources in some States and availability of more economic resources in others. The costing of such exchanges should be based on the relative investment and operating costs of the schemes from which supply is proposed to be made and the cost of alternatives available to the buyer. The interchange will be governed by a two-part tariff which would have to take into account the cost of generation at the seller's generating station, or a group of stations if the supply is from such a group, and the cost of bulk transmission to the point of interconnection. The generation cost will consist of two components *viz.* (i) the annual fixed charges like interest, depreciation, taxes and insurance, fixed elements of operation and maintenance etc. and (ii) the variable charges like fuel cost, variable elements of operation and maintenance, auxiliary consumption and losses. The cost of bulk transmission will include the relevant fixed charges as well as operation and maintenance charges. Since, however, in case of transmission lines, the operation and maintenance charges do not vary with the quantum of energy transmitted, the entire transmission cost may be considered as a fixed cost to be covered by the demand charge in the tariff. The cost of bulk transmission should be computed in respect of the particular line or lines utilised for effecting the supply. If, however, due to the nature and configuration of the interconnection, it is not possible to identify the transmission lines which can be considered to have been utilised for making the supply, the transmission cost may be determined on the basis of the average annual charges per kilo-watt of bulk transmission line network in the seller's system. In computing the average cost of generation and bulk transmission to the seller, the costs applicable to the immediately preceding year should be taken into account. Suitable adjustment may, however, be made if it is found that the costs in the preceding year are substantially different from those of the earlier years. The interchange tariff should also take into account what it would cost the buyer to generate an equivalent quantum of power if he were to put up his own thermal plant. Hydro and nuclear alternatives are not considered because economic hydro stations would or should, in any case, be developed by the buyer State and nuclear stations are being developed by the Atomic Energy Commission. Having thus established the cost to the seller and the likely cost to the buyer, it only remains to fix a tariff which takes into account both these. It is felt that the buyer and seller may negotiate a tariff within these limits and that where there are difficulties in reaching a negotiated rate, the arithmetic mean of the two may be adopted for the purpose. If this principle, *viz.*, that the buyer and the seller should both more or less equally share the economic advantage in the transaction is accepted, then it would promote such power development from the most economic sources all over the country.

5.2.4. *Short-term Supply*: In the case of short-term supply, the buyer purchases power from the seller not as a cheaper alternative to investment in additional plant but because no other alternative is really available to him for maintaining the supply to his consumers. In such a case, there is, therefore, no question of deferring any investment or of relating the purchase rate to the likely cost of power from alternative sources. Different costing principles may, therefore, govern such cases. Here also two limits may be set between which a negotiated rate may be evolved. The lower limit may be the seller's cost of generation and bulk transmission as in the case of long-term supply. The upper limit may be the average selling rate of the buyer to its H. T. consumers at the voltage nearest to that at which the inter-State supply is made. Where there are difficulties in reaching a negotiated rate, the arithmetic mean of the two may be adopted for the purpose. This approach is proposed as it is considered equitable to both the parties and has also the merit of simplicity.

The case of "off-peak firm energy assitsance" can also be treated in the same manner as short-term supply for costing purposes. In this case a system having surplus energy in the off-peak periods (say Delhi) supplies energy to a neighbouring system which is able to conserve its hydro resources for use in the peak period (say Bhakra System). The sharing of benefits would be equitable if such a transaction is treated at par with short-term firm energy supply for costing purposes.

5.2.5. *Economy Interchange*: Economy interchange relates purely to interchange of surplus energy between two systems. In such a transaction there is no intention of capacity assistance, it being understood that each system has adequate capacity to meet its own load. The price for such an interchange should be based on the incremental/decremental cost of production and transmission in the participating system. An equitable rate would be the average of the two costs. That is, if the incremental cost of generation in State 'A' is 3 paise per unit and the decremental cost in State 'B' is 5 paise per unit then 4 paise may be charged by State 'A' to State 'B' for backing down the generation of State 'B'. Thus the overall saving in generation cost is equally shared by the two systems, while permitting utilisation of the most economic source of generation, irrespective of the ownership.

For executing such transactions, it will be necessary to have cost data of the two systems readily available and freely circulated. The operating people on either side can then be authorised to execute such transactions.

5.2.6. *Emergency Interchange*: When systems are inter-connected, each system expects to be helped by the neighbouring system in case of any trouble provided the neighbouring system has a capability to do so. Even if sustained assistance is not possible, short-term assistance is unavoidable since trouble in one system is automatically reflected in the other system. Thus emergency assistance may be of two kinds:

(a) Short-term capacity assistance lasting for a few minutes, or for a few hours at no cost, since this is unavoidable. It assumes pooling of reserves by the participating systems.

(b) Sustained assistance with the consent of the helping system (at the request of the system in trouble), which should be charged in terms of energy charges only. The assistance may be returned in kind or be paid for at the cost of the helping system. This principle would be equitable if the cost of sharing of spinning reserve is also agreed separately.

5.2.7. *Inadvertent Interchange*: It should be recognised that electric inter-changes are subject to inadvertent or uncontrollable transfers from one system to another. Such unintentional interchange should be adjusted in kind as far as possible between the two systems and any balance at the end of the year may be paid at a mutually agreed rate, which could be the same as that agreed for the type of transaction in which the inadvertence occurs *i.e.* firm or economy.

The definitions of terms used in this section are given in Annexure 3.3 of the Report of Study Group No. 2.

5.3.1. The Study Group, in order to illustrate the principles of costing suggested above, have carried out a detailed case study for costing of power between the two States and this is given in detail in Annexure 3-4 of their report.

5.3.2. *Costing of other Service*: There are two other categories of services for which costing should also be carried out and incorporated in the co-ordination agreements.

(i) *Costing of Spinning Reserve*: The party carrying more reserve than its share should be compensated. The deficit party should be penalised. The cost structure should be such as to encourage the participants to maintain adequate reserve.

(ii) *Frequency Regulation Service* : It should be recognised that when a system carries out the function of frequency regulation, it has to maintain certain reserve for this service. Costing of this service and payment for it should be carried out.

5.3.3. *Participation Agreement* : Previous paragraphs covered the costing principles for power purchases between utilities owning their own generating facilities. There is one more category of agreement termed as "Participation Agreement" which deserves special mention. This covers the cases of jointly owned plants or centrally owned plants put up within a State for the benefit of several States. In case of a jointly owned plants, the capital is put up by participants and the benefits are shared in the ratio of their respective capital participation. In case of centrally owned plants, like Tarapur, Neyveli, etc., it is desirable to specify the percentage allocation of benefits to all constituents in advance. The participants should then share the fixed charges of the plant in the ratios of their share and pay for the energy charges as per usage. It is recommended that such contracts should precede the construction of centrally owned projects.

5.4. **Conclusions**

5.4.1. It is desirable to spell out all the objectives of inter-connected or integrated operation in unambiguous terms in the agreements between parties which should necessarily precede construction so that all issues subsequently can be judged with these criteria. A co-ordination agreement between interconnected systems should preferably precede interconnection.

5.4.2. Highly complex agreements involving all the concepts outlined above are in force in many advanced countries particularly the U.S.A. which has shown that independent utilities would voluntarily surrender their individual authorities to a common pool for economic advantages. There is no reason why similar conditions cannot be created in India.

In this field the Central Electricity Authority should take a lead and help various systems in the country to evolve and conclude agreements based on sound operating and costing principles. It is to be desired that no power systems that are interconnected should operate without properly conceived and comprehensive commercial agreements. Since the incentive for achieving economic benefits is one of the strongest of all incentives for human endeavour, it is strongly felt that agreements designed to share economic gains derived from integrated operation of power systems will accelerate the pace of development of Regional and the National Grids, with attendant economic gains to the community at large.

CHAPTER 6

TRANSMISSION AND DISTRIBUTION LOSSES

6.1. The total electrical energy generated is not available for productive use. Consumption of energy in electricity industry is broadly in two categories—first, the energy consumed by the auxiliaries of the power station and second, energy lost in the process of transmission, transformation and distribution. Transmission and distribution losses are mainly in the form of heat but in some cases theft is also of considerable magnitude.

6.2.1 Transmission and distribution losses in India are on the whole high as compared to other industrially advanced countries. The following Table gives the transmission and distribution losses in different States during the years 1966-67 to 1968-69.

TABLE 11

LOSSES IN TRANSMISSION, TRANSFORMATION DISTRIBUTION AND ENERGY UNACCOUNTED FOR EXPRESSED AS PERCENTAGE OF ENERGY AVAILABLE FOR TRANSMISSION

(Taking the total generation of a jointly-owned project against the State having maximum share)

State/Union Territory	Year		
	1966-67	1967-68	1968-69
1	2	3	4
Andhra Pradesh	26·57	25·2	25·7
Assam	24·10	25·6	20·9
Bihar (excluding D.V.C.)	10·46*	18·4	18·6
Gujarat	11·88	14·2	14·2
Haryana	**	16·6	28·4
Jammu & Kashmir	13·52	23·9	29·3
Kerala	20·42	15·8	16·7
Madhya Pradesh	12·64	13·1	10·1
Maharashtra	14·29	11·7	12·4
Mysore	16·54	16·6	13·5
Nagaland	6·24*	7·6	22·3
Orissa	14·21	9·8	9·9
Punjab	13·88@@	10·9(2)	12·3(2)
Rajasthan	25·93	30·7	22·8
Tamil Nadu	17·06	18·2	18·0
Uttar Pradesh	19·37	20·1	22·4
West Bengal (Excluding D.V.C)	9·16	11·6	11·8
D.V.C.	4·67(3)	6·2(3)	4·9(3)
Union Territories			
Delhi	12·83	15·6	13·1
Andaman & Nicobar Islands	15·97@	16·0@	(4)
Chandigarh		n.a.	(4)
Dadra & Nagar Haveli	9·68	9·7	(4)
Goa, Daman & Diu	17·95	10·3	11·3
Himachal Pradesh	11·41@@	21·5	(4)
Laccadive, Minicoy & Amindivi Islands	9·43	9·2	(4)
Manipur	26·60(1)	29·2(1)	n.a.
Pondicherry	14·63	12·4	15·2
Tripura	19·501	8·0*	15·3(1)
All India	15·9	16·5	16·7

*Provisional.

**Included in Punjab.

@Estimated.

@@Estwhile Punjab & Himachal Pradesh.

(1) Data received do not appear to be very reliable.

(2) Due to intensive consumption in Nangal Fertilizer, the figure works out low.

(3) The element of distribution on network is small.

(4) Combined figure for other Union Territories roughly estimated at 26·4

6.2.2. The reasons for excess in losses in some State like Andhra Pradesh, Uttar Pradesh, Haryana have been discussed in the report of the Study Group No. 2.

6.2.3. In advanced countries the losses are comparatively much less as would be seen from the following Table

TABLE 12

PERCENTAGE TRANSMISSION & DISTRIBUTION LOSSES IN VARIOUS COUNTRIES DURING 1967 AND 1968

Sl. No.	Country	Transmission and Distribution energy losses (Percentage)	
		1967	1968
1	2	3	4
1.	Austria	9·6	9·9
2.	Czechoslovakia	7·8	8·1
3.	Finland	8·3	7·7
4.	France	7·6	7·4
5.	Hungary	9·3	10·3
6.	Ireland	11·2	10·6
7.	Italy	10·1	9·1
8.	Norway	10·4	10·15
9.	Poland	8·7	8·6
10.	Sweden	12·1	12·5
11.	Switzerland	8·2	8·1
12.	West Germany	5·9	5·7
13.	Yugoslavia	11·9	11·1
14.	U.S.A.	—	10·0

SOURCE: "Annual Bulletin of Electrical Energy and Statistics Publication" 68 for Europe-U.N. Publication.

6.2.4. The total energy sent out from the power stations in 1969-70 in India was 53868 million kWh. If the losses were to be reduced even by 1%, the savings in energy would be 538 million kWh. Taking an average overall revenue by sale of electricity as 10 paise per kWh, the savings due to 1% reduction of losses are worth more than Rs. 5 crores. This additional revenue could have been available from the energy generated without any additional cost whatsoever. The importance of minimising the energy losses is, therefore, self-evident.

6.2.5. The question of reduction of transmission and distribution losses has been examined in detail by Study Group No. 2 and it is discussed in Chapter 6 of their report. It has been already brought out in para 2.10.0 that investment in transmission and distribution facilities in India has remained considerably lower than the desired level and as has been the experience in other countries, this is one of the chief reasons contributing to higher percentage of losses. This could also be due to a variety of other causes such as technical deficiencies in design, construction, operation and maintenance etc. More investment in transmission and distribution does not necessarily mean construction of additional transmission and distribution lines alone. Use of higher transmission or sub-transmission voltages, adequate size of conductors, integrated operation of power systems, use of synchronous condensers/ shunt capacitors etc. are factors which help substantially in reducing the transmission losses. It is essential that development of these facilities keep pace with the development in generating facilities.

6.2.6. There are no norms for transmission and distribution losses. They depend to a large extent on the configuration of the transmission and distribution systems. The loss would be small when generation is well distributed over an area and near the utilisation point and the number of transformation stages are small. The losses are small in systems where load densities are high *i.e.*, in compact systems. The commercial lighting and domestic lighting sales in India constitute only about 15% of the total against 47% in U.K., 53% in Australia, and 69% in New Zealand, Our industrial loads account for about 70% of the sales. Our agricultural loads account for about 7 to 8% of the total sales. The above pattern of load results in lower power factor and hence more losses.

6.2.7. The main reasons for higher transmisison losses in India are (a) transmission and distribution of energy over long distances and large number of transformation stages, (b) inadequate sizes for conductors, (c) loads being predominantly industrial and agricultural which have low power factor, (d) lack of proper interconnections/integrated operation, (e) unauthorised tapping of energy without being metered. Generally speaking reduction in energy losses due to transmission and distribution involves greater capital investment. Therefore, savings effected by reduction in energy losses and extra investment required by the system for reducing energy losses have to be balanced and it may not be economical to reduce the energy losses beyond a certain limit. In other words, losses should be reduced to an optimum value after making a techno-economic study.

6.2.8 Study Group No. 2 has studied the matter in detail and outlined various measures for reduction of losses. Briefly these are :

(1) Efficiency of operation has to be watched continuously. It is therefore necessary to equip the system with the necessary instruments for continuous monitoring and improvement of its performance. Proper instrumentation and documentation is required for all sub-systems.

(2) Energy meters should be installed on all generating units and their station and unit auxiliary services, stepdown transformers at the bulk receiving stations and interconnection points, consumer substations.

(3) MW and MVAR indicating instruments should be installed on all HV lines of 66 kV and above. The sub-station designs should be such that it is easy to introduce more elaborate instrumentation facilites for any particular lines required.

(4) Each Divisional Engineer should be made responsible for watching and reporting the performance of the system under his control in respect of losses. Periodic comparisons should be made of the performance of different divisions in this respect in order to promote healthy competition.

(5) The transmission and distribution networks have to be strengthened. There has been an imbalance in the investments in the electric power supply industry and this has to be rectified. The strengthening of the network would involve provision of additional circuits, choice of appropriate voltage level etc.

(6) Improvements in the transmission and distribution system design :

(a) Selection of transformers with reference to expected load cycle so as to obtain minimum total of fixed and variable losses—use of low iron loss transformers, particularly, for rural areas and areas of low load factor.

(b) Avoiding excessive corona losses in EHV lines by proper choice of conductor size.

(c) Reduction in the number of power transformation stages.

(d) Improvement of power factor—installation of capacitors etc. at appropriate locations.

(e) It has come to the notice that the losses in some of the LT feeders are of the order of 15 per cent. This points out to the need of constructing LT feeders keeping in view their lengths and loads required to be carried, if necessary the number of distribution transformer stations should be increased suitably.

(7) Integrated operation of power systems including reactive scheduling.

(8) Elimination of theft of energy.

(9) Elimination of miscellaneous losses by improved operation and maintenance.

(10) Continuous monitoring of system performance and introduction of corrective actions at the Divisional level.

6.3. Theft

It has been noticed that in some States energy losses on some of the 11 kV feeders are as high as 30% to 60%. These lead to the inference that considerable theft is taking place on such like feeders. Study Group No. 2 has studied this matter in detail and their suggestions regarding the steps that should be taken to minimise the theft of energy are given in Annexure 6.2 of their report. The Committee would recommend adoption of the measures suggested therein by the State Electricity Board/Electric Supply Undertakings.

CHAPTER 7

DELAYS IN CONSTRUCTION OF PROJECTS

7.1. Introduction

7.1.1 The Fourth Five-Year Plan provides an outlay of Rs. 2,530 crores on power development programmes (Public and Private Sectors) and envisages that the installed capacity in the country will increase from 14.29 GW in 1968-69 to 23.0 GW at the end of the Plan period (1973-74). The power plan also lays emphasis on development of transmission and distribution systems and on formation of grid systems on a scale commensurate with the increase in power generating capacity for enabling maximum utilisation of generating capacity and also for improving power supply conditions in the country. A large scale programme of rural electrification is contemplated for supporting food production programme and also for providing the infrastructure for development of agro-based small scale and rural industries.

7.1.2 The schemes expected to provide benefits during the Fourth Plan are mostly those schemes which were approved during the Third Five-Year Plan or earlier. It may be recalled in this connection that in the erstwhile Draft Fourth Plan (1966-71), a target of 20 GW was adopted. As against this, however, it is anticipated that only about 16.2 GW would be in operation by the end of 1970-71. Thus, there would be a shortfall of about 4 GW in the targets anticipated in 1966. Again in 1969-70, the first year of the Plan, a target of 1.63 GW was fixed raising the total installed capacity in the country to 15.92 GW. The actual achievement, however, amounted to only 1.19 GW.—a shortfall of about 0.5 GW. In 1970-71 the target for additional installed capacity is 1.32 GW but according to broad indications available now, the additional installed capacity during the current year is likely to be only about 0.7 GW.

7.1.3 It would be seen from the above that continuously there have been short-falls in achievements. The position thus is serious. Delays result in increased capital outlays and higher interest charges. Electric power being one of the principal members in the infrastructure of a developing country like India, adequate importance has to be attached to power development and achieving of targets laid down for the purpose. Any power shortages in any part of the country carry with them a frightfull prospect of serious retardation of industrial and agricultural growth. The problem has, therefore, to be tackled in right earnest and the obstacles which are coming in the way must be removed.

7.2. Causes of delays

7.2.1 The relevant term of reference of the Power Economy Committee sets out the task as—

"To review the causes of delay in the execution of the power projects, to suggest measures for improving the manner of implementation of power projects and reducing construction periods."

The causes of delays in the execution of power projects were earlier examined by a Committee under the chairmanship of Shri K. P. S. Nair in 1967 and have again been examined by Study Group No. 4 of this Committee. The causes of delays are as follows:—

1. *Thermal*

(i) Lack of adequate project data.

(ii) Inadequate investigation before finalising technical project report.

(iii) Major changes in scope of work.

(iv) Delay in site selection and land acquisition.

(v) Delay in issue of authorisation by Central and/or State Authorities.

(vi) Delay in foreign exchange tie up.

(vii) Deficiency in organisation for planning and engineering the project.

(viii) Delay in appointment of consultants wherever required.

(ix) Delay in procurement of equipment due to:

(a) late issue and late finalisation of tenders;

(b) processing of foreign exchange release by Govt. of India.

(x) Delay in levelling and dressing at site due to—

(a) inaccessible nature of site;

(b) delay in procurement of construction equipment.

(xi) Late receipt of erection drawings.

(xii) Delay in procurement of construction equipment like tower crane, gantry crane etc.

(xiii) Shortage of Cement and Steel, welding rods, explosives, etc.

(xiv) Late arrival of erection specialists.

(xv) Delay in delivery of equipment due to:—

(a) failure of supplier to keep up schedules;

(b) lack of ships, port strikes, etc.

(c) over carriage of equipment;

(xvi) Difficulties in transporting equipment to site—

(a) in moving over dimensional packages on railway due to restrictions imposed by bridges, tunnels etc.;

(b) due to lack of suitable rolling stock etc.;

(c) due to difficult terrain and lack of proper access routes.

(xvii) Delays in getting replacement for items of equipment damaged or lost in transit.

(xviii) Lack of proper planning and co-ordination of various construction schedules and failure to anticipate delay in case of critical phase of construction activities in advance.

(xix) Labour strikes and civil disturbances.

(xx) Unprecedented rains and floods.

(xxi) Difficulties experienced due to change in the course of lean water flow in river.

(xxii) Change in top personnel in the course of implementation of project.

2. *HYDRO*

(i) Inadequate investigation before finalising technical project report.

(ii) Major change in the scope of work like :

(a) change in the location of dam;

(b) change in design of dam foundation;

(c) change in design of water conductor system;

(d) change in location of power station and switch yard;

(e) change in generator capacity.

(iii) Delay due to inter-State aspects.

(iv) Delay in issue of authorisation by Central and/or State authorities.

(v) Delay in foreign exchange tie-ups.

(vi) Change in key personnel in the course of advance planning and execution.

(vii) Delay in procurement of equipment due to:—

(a) late issue and late finalisation of tenders.

(b) processing of foreign exchange release by Government of India.

(viii) Delay in procurement of construction equipnent.

(ix) Shortage of cement and steel, welding rods explosives, etc.

(x) Shortage of spare parts for construction equipment.

(xi) Late arrival of erection specialists.

(xii) Delay in delivery of equipment due to failure of supplier to keep up schedules.

(xiii) Difficulties in transporting equipment to site—

(a) in moving over dimensional packages on railway due to restrictions imposed by bridges, tunnels, etc.;

(b) due to difficult terrain and lack of access roads.

(xiv) Unprecedented rains and floods.

3. *NUCLEAR*

(i) Protracted negotiations have been generally necessary before finalising the various agreements.

(ii) Long delivery period in the supply of equipment and machinery, both by the Indian and Foreign suppliers.

(iii) Locating Indian suppliers of equipment to meet standards and other requirements in the fabrication of the various equipments to achieve maximum indigenisation.

(iv) Technical improvements which had become necessary during the construction phase.

7.3 The measures which should be adopted for avoiding delays in the construction of projects within the scheduled time have been discussed in detail in the report of Study Group No. 5 and are briefly summarised below :

7.4 **Planning & Investigation**

7.4.1 If power is to be made available at the most economical rates, a long term plan—say for the next 15 years—should be available at any point of time and a fairly large programme of construction should be in hand all the time in order to provide adequate generating capacity for meeting the anticipated load growth. It has also been emphasised in Chapter 5 that planning for electric power should be organised on a Nation-wide basis and that the over-all responsibility for planning including investigations and processing of schemes right up to the point of execution should be centralised with the Central Electricity Authority. In order to ensure planning on the right lines, each State Electricity Board should have a planning cell and similar long-range Planning Cells should also be created in the Regional Electricity Boards. At the Centre, till the responsibility is transferred to the Central Electricity Authority, the Planning Commission, Ministry of Irrigation & Power and the Central Water & Power Commission should keep in constant touch with the work and progress at the State and the Regional levels and a long term power plan should be evolved continuously.

7.4.2 The question of investigations has been already discussed in Chapter 5 of this Report and also dealt with in detail in Chapter 7 of the Report of Study Group No. 5. In brief, a massive continuous programme of field investigations is needed immediately in each region of the country so that the needs of the Fifth and Sixth Plan periods for investigated projects can be fulfilled. There is an urgent need for strengthening the Civil Engineering Organisation in each Electricity Board in order to cope with the large programme of investigations, planning and construction, especially for hydro-electric projects. It is suggested that an experienced Chief Engineer (Civil) should be appointed in each State Electricity Board especially to look after the work of Hydro Electric Projects.

7.5 **Financing**

7.5.1 After the project is sanctioned for execution, it is necessary to prepare not only the year-wise construction programme, but also a programme for financing. The latter actually dictates the pace of the former. It is necessary to provide the required finances including the foreign exchange for the construction programme as per schedule. However, one disturbing fact has also to be considered. The actual spending in the past Plans has been far in excess of the provisions asked for—some times as high as 30%. At the same time, however, the achievement of physical targets has slipped back by as much as 25% or more in many cases. Thus paucity of funds has inhibited the progress of projects in many cases only in the sense that it has not been possible to execute these projects with the cost estimated originally. These would point to the imperative need of framing estimates accurately. The excess expenditure as well as slippages in the achievements of targets have been mainly due to (i) under-estimation of costs at the time of preparation and sanction of the project report and (ii) rising costs of materials, labour and other services in the course of project execution. The under-estimation of cost can mostly be traced to inadequate investigations, designs and engineering, and due to incomplete information on anticipated costs and rates. The rising costs are now a common feature not only in India but all over the world and it is the practice of some of the leading consultants in other parts of the world to provide for the rise in costs by provision of a definite margin in the project estimates. In India, this practice is being followed by the Atomic Energy Commission.

7.5.2 It is in the interest of the Central and State Authorities that the cost estimates are prepared on a realistic basis and checked thoroughly. Presently, these are scrutinised as a part of the technical examination of the projects by the Central Water and Power Commission before these projects are processed through the Technical Advisory Committee of the Planning Commission for approval. It is recommended that the C.W. & P.C. should be charged with thorough scrutiny and a measure of responsibility for the accuracy of the time and cost of project execution. If the projects are properly investigated, it should be possible for C.W. & P.C. to check and ensure that the basic designs of the different components of the project as well as the type and manner of construction, etc., are correctly provided for and the estimates are realistic. The C.W. & P.C. should organise and equip itself for this work without any delay.

7.6 **Procurement**

7.6.1 Procurement procedures affect the construction programme seriously. This subject has been dealt with in detail in Chapter 10 of the Report of Study Group No. 5.

7.6.2 There have been considerable delays in the past in the supply of generating plant and equipment by the manufacturers. In so far as turbines and generators are concerned, these are now to be supplied chiefly by the two heavy indigenous electric manufacturing factories, *viz.*, M/s HEL, Bhopal and M/s Bharat Heavy Electricals. It is suggested that the Ministry of Irrigation & Power should ensure that there is a smooth flow of orders suiting the capacities and stages of development of the two manufacturing units from time to time. The Ministry should plan the major items of plant and equipment for each project suitably on these manufacturing units, taking into account the requirements of the project in respect of similar units, schedule of construction etc. Sometimes considerable time is lost in negotiating prices with the above two Public Sector Undertakings. It is a fact that the prices of turbo-generators and other equipments supplied by these undertakings are comparatively much higher than the imported plant and equipment. One of the main reasons for this is that we are dependent on foreign designs and technology and have to import some of the most basic components of the plant. This would point out to the urgent need of organising design sections in the public heavy electrical manufacturing undertakings so that we should be able to evolve our own designs rather than be dependent on the collaborators for designs for all times. It is suggested that the Ministry of Industrial Development and Internal Trade should look into the matter immediately and if necessary appoint a High-Level Committee to examine the prevailing status of designs work and to suggest steps so that it may be possible to produce designs for all types of generating plant and electrical equipment indigenously at the earliest possible date. It is suggested that firm deliveries should count from the date of the letter of intent issued to the manufacturer, if necessary with advance payment after finalising the broad technical particulars. Finalisation of prices etc., can be done later with the assistance of the High-level Committee appointed by the Government of India for this purpose, if necessary. Further, the above two indigenous manufacturers should make their quotations thorough and business-like from the beginning by furnishing detailed lists of all the equipment and accessories that they would be in a position to supply so that the project authorities may take action for procurement of the balance items. Choice as far as possible should be only of the standard articles rather than non-standard ones.

7.6.3 Apart from this, a new element has come in the comprehensiveness of procurement action on account of supply of generating units from M/s. H.E.L. and M/s B.H.E.L. They supply equipment as per the standard practice of their collaborators. As a result of this, some of the essential auxiliaries/equipment of generating plant are not included in their offer. The extent of such items can presently be known only after the receipt of the detailed schedules of supply for the generating units from the manufacturers. This is very unsatisfactory and considerable amount of avoidable confusion and hardship is caused in the work of the project authorities. It is, therefore, recommended that both M/s H.E.L. and M/s B.H.E.L. should be asked to make their quotations thorough and business like from the beginning by furnishing detailed lists of all equipment and accessories that they would be in a position to supply and the balance equipment that the project is expected to procure from elsewhere. Further the quotation for the entire scope of supply of these manufactures should be binding, although they will continue to include a number of bought out items in future also in keeping with the general practice all over the world. As it is, they go on varying prices and deliveries for bought out items included in their scope of supply. It may be mentioned that bought out items include important basic components like cylinders of steam turbines. It is generally accepted commercial practice all over the world for the manufacturers to give a firm quotation for their entire scope of supply and adoption of this as well as proper definition of the scope of supply would eliminate many avoidable controversies and delays in engineering.

7.6.4 As regards other items of electrical and mechanical plant such as, transformers, circuit breakers, etc., there is no monoply in the indigenous supply. The Project Authorities can advantageously arrange procurement of the balance plant and equipment on their own instead of going through The Directorate General of Supplies & Disposals (DGS&D). In regard to certain items, advantage can also be taken of the rate contract arrangements made by the D.G. S. &D.

7.6.5 Good many items of plant and their ancillaries and other items have been standardised, therefore, while preparing specifications for such items, choice as far as possible should be only of the standard articles rather than non-standard ones. This will help in reducing the time of procurement and also result in economies.

7.6.6 Tender specifications should be drawn up with as many details as possible, including listing of all the information such as technical data, requirement of firm deliveries, contractual and financial requirements, etc., required of a tenderer. At the time of invitation of tenders, sufficient time should be allowed to enable the tenderers to furnish all the technical and financial particulars. The examination and acceptance of tenders must be completed within the validity period and occasions for extension of validity should be only exceptional. One of the main reasons for delay in placing orders for the equipment is the time taken to reconcile the commercial terms with those specified in tender specifications. A model "*general conditions of contract*" applicable to public and, if possible to private sector manufacturers, binding on all the parties, would go a long way to reduce the time between the receipt of the tender and placing the orders. Such a model agreement should be evolved with joint consultations between the Central Water and Power Commission, State Electricity Boards and manufacturers, including the public sector undertakings. While placing contracts, due consideration should be given to ensure that the tenderers are in a position to meet the requirements, technically, financially and within time.

7.7. Construction contracts

7.7.1 Work on a number of projects in the past had been delayed because of disputes and difficulties arising with the contractors. The ability to control a construction project, most elements of which are given on contract, depends largely on the soundness of the contract documents themselves. A loosely defined contract may create considerable dissensions between contractors and project management due to individual interpretations of the intent as well as contents of the contract. Disputes regarding advance payments and correct form of bank guarantee from the contractor have often delayed commencement of construction work. Similarly, serious delays have occurred in completion and acceptance of design drawings. The contracts usually specify certain exchange of drawings between the two parties and their mutual approvals. This is often treated lightly at the stage of drawing the contract when the nature and significance of these drawings is not properly foreseen. Extensive changes in the designs and drawings at a later stage naturally lead to dissensions,—project cost rise and delays. The practical solution for these problems lies in developing the overall project schedule as well as the desired schedules for the contract in question before inviting tenders and in any case before awarding the contract. The dates for supply of designs, drawings, approval of contractors drawings, assistance in respect of construction equipment etc. need to be clearly defined, so that the disputes on this account later on are avoided.

7.7.2 One important point is that the contract should be awarded only to those contractors who are considered capable of execution of the job in every possible way. The tender enquiry should require the contractor to submit details regarding his resources in men, materials and equipment that will be used in the contract. There is a need to evolve some system of compiling and evaluating information on past performance of the likely contractors. The performance record of contractors should be a very important consideration in their selection. It is recognised that acceptance of a bid other than the lowest can lead to criticism of the project authorities and in such cases the course of action needs to be documented thoroughly. In addition to the overall performance, it is, of course, desirable to examine some of the details such as the ability of the contractor's staff—supervisory, technical etc., prior experience on similar projects, availability of special tools and construction plant.

7.7.3 Recently, difficulties have arisen in arranging the execution of the complex generating plant and equipment through the equipment suppliers as in the past. Formerly, the suppliers used to be keen to have even a 'turn-key' job and were, in any case, prepared to carry out the complex erection and installation of equipment supplied by them. The supply of plant and equipment is now practically a monoply of M/s Heavy Electricals (India) Ltd. and M/s Bharat Heavy Electricals Ltd. They are, however, struggling with so many problems in manufacture of plant and equipment that they are neither equipped nor willing to undertake erection work of even their own equipment.

7.7.4 On the other hand, with the rapidly increasing tempo of new additions, each Electricity Board is likely to have certain amount of work regarding erection and commissioning of plant and equipment available at one project or another, continuously. It is, therefore, in the interest of the Electricity Boards to build up suitable teams that can undertake the work of installation and commissioning of plant and equipment, electrical transformers and switchgear and power plant auxiliaries. Building up such teams would also be of great value to the organisation in arranging overhaul and proper maintenance work and in case of any breakdown. It would then be necessary only to have one or two persons from the manufacturers during the installation work in order to ensure that there is no difficulty with equipment guarantees.

7.7.5 Recently, some organisations in the private sector have been building up the expertise for undertaking erection and commissioning works. Their services can also be availed of.

7.7.6 Where enough sustained activity is expected the departmental construction and erection work yields very substantial benefits. It is likely to be more economical and, being under the direct control of the project organisation, a first rate job can be obtained according to the exact specifications.

7.7.7 It is necessary to carry out a number of quality control tests on materials as well as sub-assemblies and the assemblies of the plant and equipment in the course of manufacture. The organisation in the Government as well as in private sector, active in the field of consultancy services for power projects, should build up the necessary expertise and capacity for rendering the service to the project authorities.

7.8. PROJECT ORGANISATION AND MANAGEMENT

7.8.1 It is highly advisable to adopt modern management methods for execution of the project. The project organisation should be such that the responsibilities at every level are well identified. A specific person should be responsible for proper completion of each specific item of work. It is essential that every project should be organised from the beginning under a suitably qualified and experienced project manager, who is in overall charge of the project and is vested with adequate financial and administrative powers. A surprisingly large number of projects have suffered badly for want of this obvious arrangement for power stations. Construction-in-charge stationed at site is necessary from the very beginning.

7.8.2 There has been a rapid development in rationalisation and improvement of management methods in the recent years mainly for meeting the needs of complex, defence, astronautical and nuclear development projects and these can now be adopted in the power projects very beneficially. In essence, these methods are based on the "Systems" approach to the question of project management and control. Proper planning of the project work at all stages, marshalling of all the resources (material as well as human) in appropriate combinations at every stage, proper intermeshing of the vast number of different activities by different agencies and monitoring and control of the project by watching the progress of physical achievement as well as spending of funds in a rational manner are the main techniques by which an optimum efficiency and speed is sought to be achieved.

7.8.3 These methods comprise performance budgeting, network techniques, management and information systems etc. These have been exhaustively dealt with in Chapter 17 and Appendices 6, 7 and 8 of the Report of Study Group No. 5. It is suggested that an organisation like C.W. & P.C., Indian Institute of Management or Planning Commission should organise advance training courses and seminars on the subjects frequently so that the concerned officials of the State Electricity Boards/Project Organisations get acquainted with the same and then able to introduce these in the works under their control.

7.9. IMPORTANCE OF DESIGN WORK

7.9.1 Experience has shown that wherever a construction project was backed by a strong Designs Organisation, the pace of work was much faster. Appropriate design engineering support must be provided at each level and at each stage. Where the project organisation or the Electricity Boards are not adequately equipped for this purpose, it is advisable to retain the services of an experienced consulting engineering organisation such as the Specialised Organisation of the Central Water and Power Commission or other Consulting Engineers available in each specialised field. With the increasing scale of operation required to meet the exponential rising demands for power, the resources of the State Electricity Boards etc. in respect experienced man-power for projects execution is bound to spread out thin. At the same time with the use of larger and larger sizes of generating units and higher transmission voltages, the power projects are rapidly increasing in complexity. This points to the need for encouraging development of specialised groups of consulting engineers in the country.

7.10. MARSHALLING OF RESOURCES

7.10.1 In view of the ever increasing scale of project execution in the field of power and considering the relatively small industrial base available in India, compared to more advanced countries, there is the danger of saturation of our resources for project execution and throttling our progress thereby. This can occur in respect of technical man-power, important materials like steel and cement, manufacturing capacity for power plant and equipment, capacity for civil construction work and above all, design and engineering capability. This matter, therefore, requires urgent attention at the National level. Proper material/resource balances need to be worked out to identify areas where action is required for enhancing our capabilities in the light of overall requirements. Proper planning and programming to dovetail the requirements of different projects into our capabilities is also essential.

7.10.2 Need has also developed for organisations which can take up erection work of the complex plant and equipment for power projects. Formerly, this used to be done mainly by the equipment manufacturers who would undertake either the complete erection and commissioning of the plant and equipment or at least complete supervision and guidance of erection. The new indigenous manufacturers like M/s Heavy Electricals (India) Ltd. and M/s Bharat Heavy Electricals

Ltd., have, however, their hands full with problems of organising manufacture of the plant and equipment which is their primary function. So far, they do not appear to be organised to take up erection of the plant and equipment even or the overall supervision of erection to the extent that foreign suppliers used to do. There is, therefore, an urgent need for organisations (contractors) who could undertake such work. Fortunately, a number of erection contractors have started coming up in the last few years and if this trend continues, there would be no difficulty in this regard.

7.10.3 There is also the urgent need of developing the technical man-power resources. It is something of a paradox that while there is growing concern about increasing unemployment of technical men, there is scarcity of adequately trained and experienced personnel to man a number of important jobs at all levels. At the level of technicians, there is the present scarcity of experienced welders and instrument mechanics. Scarcity in respect of other skills may also occur and adequate steps to forestall these are advisable.

7.10.4. *Scarce materials* : It will be an important task of the Design Organisations to take note of materials likely to be in short supply and to develop designs to get around such problem areas. This will also present many challenging and rewarding tasks to the Research Organisations. Close collaboration of the Designs and Research Organisation on such matters is highly desirable.

7.11 Miscellaneous Bottlenecks

7.11.1 There are a number of miscellaneous causes of delays which have to be taken care of. Among these are land acquisition, rehabilitation of displaced persons, transport facilities, labour strikes, shortages and breakages in equipment etc. The project authorities should be well aware of these difficulties and timely action should be taken for tackling these matters at the appropriate level so as to obviate any delay.

7.12. Working of Electricity Boards

7.12.1 Presently, it is the States that are playing the main role in the matter of power generation and transmission. In the area of planning, field investigations and preparation of projects, there is an immediate need for accelerating the tempo of the work many times over partly to make up for the lag in this work in the past years and partly to keep up with the larger requirements of the future years. Presently, the State Electricity Boards are engaged in multifarious activities embracing operation and maintenance of the generation and transmission works, co-ordinating o&m of distribution networks and rural electrification which make heavy demands on the time of the Chairman, Technical Member and other technical personnel. It is not possible for them to devote enough attention to the long-term problems of planning for the future as well as construction, as the demand of present day problems regarding system operation, rural electrification and the like are urgent. Action on the following lines is, therefore, considered an urgent necessity in the State Electricity Boards.

7.12.2 The top management needs to be strengthened and organised so that they are in a position to give greater attention to planning, investigations, projects preparation and project execution. This is a very big task and demands intimate knowledge of all aspects of power engineering. There is also the need to adopt latest technological advances in a practical manner. A stage has, therefore, been reached when each State Electricity Board should be headed by an experienced power engineer as the Chairman of the Board. All technical work should be put directly under the charge of another technical member. The Electricity Supply Act should be suitably amended to implement this.

7.12.3 It has been the experience in a number of places that at the lower technical levels, it is difficult to ensure continuity of experience and service in a sufficient measure for more technical work such as in generation projects. The personnel from the generation projects get dispersed on other work and it is difficult to find persons with adequate experience and training for the highly technical work involved. It is, therefore, suggested that as already recommended in the report of Study Group-1, a separate generation cadre should be formed. Within the cadre, it would be desirable to have considerable mobility of persons between the different functions such as operation and maintenance, designs, planning, etc.

7.13. Delegation of Powers

7.13.1 According to the present procedure followed by many State Electricity Boards, the power for purchase of stores, materials for stock/execution of works etc., vest in the Board or Chief Engineer and there is only limited delegation of powers to lower rungs in the ladder. This concentration of powers at the higher levels tends to make the process of decision making slow in view of the various levels through which the cases are processed before final approval is accorded. Since delays in purchase of stores for stock/works, approval of necessary essential deviations in construction works, etc., impede the progress of works which ultimately affect the targets fixed, it is necessary that there should be proper delegation of powers to appropriate lower formations. This aspect would require careful consideration for suitable delegation of powers. It is suggested that the Ministry of Irrigation and Power may appoint a Committee comprising Administrative, Technical and Financial Experts to examine the matter and make suitable recommendations in this behalf.

CHAPTER 8

HYDRO-ELECTRIC POWER STATIONS—UTILISATION AND AVAILABILITY OF PLANTS

8.1.1 The very first term of reference of the Power Economy Committee enjoins upon it "To review the pattern of utilisation of available plant capacity during the past five years and their operational efficiency and fuel consumption to sonsider the scope of improving economy in power generation together with specific measures for attaining them."

8.1.2 A comprehensive examination of this aspect has been made by the Study Group-1 of the Power Economy Committee and is detailed in Volume—I of the Report. Power generation in the country is derived mostly from Hydro-electric and conventional Thermal (steam) power stations. Only one Nuclear power station (Tarapur) is in operation and has an installed effective capacity of 400 MWe. A small part of generation is derived from diesel and gas turbine installations. The total installed capacity of electric power generating plant in the country in 1969-70 was 15.5 GW of which 39.2 per cent was in hydro-electric plant and 55 per cent in thermal plant.

8.2.1 The basic function of electric power plant and equipment is to generate electrical energy. The two factors limiting the generation of electrical energy from a plant are fluctuations in load demand and inability of generating equipment to give the output either due to outage or malfunctioning of components. Because of these factors, the cost of generation increases. Therefore, studies regarding availability have become an important activity in the management of power generation facilities. The aim must be to achieve the highest availability.

8.2.2 In the case of hydro-electric power stations, the availability of water acts as a constraint on the energy potential. Thus the plant availability of hydro station is in a different class from that of the thermal power station. The examination of the question whether a power plant has operated efficiently forms a complex task. Power generation facilities have to be provided to meet the maximum power demand. The demand, however, fluctuates during the course of the day and at various times of the year. The efficiency and proper operation of power plant cannot, therefore, be judged from any simple factors such as total hours of operation and suitable yardsticks have first to be established. This subject is comprehensively discussed in Section 1 of Chapter 2. The criteria that would apply have been considered and compared with data available from other countries. It is seen that generally the overall plant utilisation has risen continuously till about 1964-65. This has been the result of the inter-play of a number of factors such as inter-connected/integrated operation enabling higher system demand to be met from the same installed capacity; reduction in the need for standby plant, the effect of the preventive maintenance practices yielding better plant availability etc. It is, however, concluded that there is an urgent need to improve power plant availability and utilisation. For this, integrated operation of the power system in every region for improvement in the availability of thermal power plant is necessary. The need for modern methods of scientific management, quality control in operation and maintenance, improving of fuel efficiency etc. is self evident. Modern methods of scientific management, particularly operation analysis should be introduced to improve the quality of preventive maintenance and reduce the plant outage time for maintenance. Separate technical cells for quality control in operation and maintenance, and fuel efficiency should be set up in each organisation directly under the Chief Engineer or Technical Member.

8.2.3 The importance and urgent need of collection of statistical data and statistical engineering analysis of data regarding plant availability in the context of increasing integration of operation is discussed in Section 2 of the Chapter 2. This can form a very powerful tool for establishing norms of availability, future planning, monitoring of performance and formulation of basic policies. It is emphasised that the work needs to be centralised and organised on a comprehensive basis. Suggestions are made for collection of data in a digitalised form to facilitate analysis. The importance of promoting exchange of operation experience of various stations, formation of data banks etc. for improving economy in power generation is brought out. It is suggested that in the first instance, the arrangements in this regard may be made on voluntary basis. But if experience shows that this method is not working satisfactorily, statutory regulations making compilation and supply of such information obligatory should be made.

8.3. Hydro-electric Power Stations

8.3.1 Chapter 3 of the Report of Study Group No. 1 presents a review of hydro-electric power stations as well as various factors which affect economy and reliability in this source of generation. Hydro-electric generation in India which constituted about 42 per cent of the installed capacity in the country in 1968-69 and provided about 40 per cent of the energy is responsible for providing a far greater proportion of country's energy supply than in the case in many advanced countries. This position is likely to be maintained for a considerable time on account of many attractions offered by it in regard to initial cost, foreign exchange cost, operation cost etc. and the fact that a large number of favourable sites still remain to be exploited.

8.3.2. Utilisation of water power started very early in this country. The initial development of power grids in India was also centered round hydro-electric projects. The taking up of multi-purpose river valley projects and with integration of power systems, planning and operation of hydro-electric power stations has been increasing in complexity. Careful attention is required to be devoted to a multiplicity of hydraulic as well as other operating conditions to derive optimum benefits from this source. Hydro-electric power stations have a major role not only in providing an economic source of energy but also in improving the operation of systems by meeting the highly variable requirements of the system loads at various times and various places and performing various regulatory functions. These reasons make it important to design, construct and operate the hydro-electric installations in a highly reliable manner obtaining a full measure of the flexibility and economy of operation.

8.3.3 A review of the present hydro-electric developments is presented in Section 2 of this Chapter. At the time of Independence, the total installed capacity came to about 500 MW distributed over 11 power stations and about 49 generating units. Since then, about 195 generating units totalling a capacity of about 5,728 MW have been installed and commissioned (July, 1970). The range of hydro-electric installations covers practically the entire spectrum of hydro-electric development and there are with us power plants of almost every well-known manufacturer in the world. The heads range from 4 metres to 867 metres. In the maximum rated flow handled by a single turbine, it is 170 cubic metres per second which will shortly be overridden by one of 180 cubic metres per second. The charts and figures presented with this Section show the addition of units, over time period and other significant information.

8.3.4 When giving consideration to the economic operating problems and reliability of hydro-electric generation, it is necessary to take account of the entire work of the Project including the hydraulic works for storage and conveyance of water, the regulation features as well as the power station installation. The initial cost as well as operational features and problems are greatly influenced by factors of topography, geology and hydrology of a site. Section 3 of the chapter brings out certain generalised considerations which apply to power plants located in various geographical regions of the country. The economic considerations applicable are discussed in Section 4. It is a peculiarity of hydro-electric power developments that the cost of working these installations is practically independent of the amount of energy produced. Only in rare cases, the water used for power generation is required to be paid for on the basis of rate of flow or quantity used. Otherwise, in almost all water power developments, the cost of water is included in the capital cost of the project. The cost of power generation is, therefore, made up of simply the interest, depreciation and operation and maintenance charges. Typically, the interest charged amounts to about 60 per cent, the depreciation about 22 per cent and the operation and maintenance about 18 per cent of the annual cost of the hydro-electric installation. It is, therefore, evident that the lowest cost of energy will be attained when (i) the maximum possible amount of energy is generated at a given site; (ii) when the annual charges are reduced to a minimum and (iii) when working in an inter-connected system, it can contribute optimising the working of the system by contributing the high price peak energy, thus enabling better utilisation of thermal power plants.

8.3.5 It will be seen from the above considerations that adequate and competent planning and design are of overwhelming importance in ensuring economy of hydro-electric generation. The various factors affecting this aspect are discussed in the Report. The important factor which has a bearing on the subject now under consideration is the cost of indigenously produced plant and equipment. Although the cost of plant and equipment forms a relatively small proportion of the total capital cost, it affects the cost of energy to a greater extent than the cvil works cost because of the relatively higher depreciation and its greater share of the cost of operation and maintenance. After analysing the prevailing cost of indigenous equipments, it is pointed out that the high prices of indigenous manufacture will be an important factor in increasing the cost of water power.

8.4. **Modernisation**

8.4.1 As mentioned previously, some of our hydro-electric sites were explored in the early years of this century. The plant installed at these places is quite old and outmoded in design as well as capacity and performance features. It has been suggested that modernisation of such power stations utilising new and improved plant could contribute to improved and more economical utilisation of these sites.

8.4.2 Optimum and proper utilisation of energy potential of hydro-electric sites is intimately linked with proper water management. This fact is often overlooked leading to adverse conditions. The need for close attention being paid to this aspect is emphasised in Section 6 of the Chapter 3. It is not generally appreciated that the constraints on generation at a particular hydro-electric plant are normally set by availability of water and not by the capacity of the plant as is the case with fuel burning plant. The generation of energy with the available water and given regulation facilities has to be carefully anticipated and programmed. Serious difficulties not merely of non-availability of energy but of serious impairment of generating capacity and system regulating facilities can arise if due attention is not paid to water management. On the other hand, continuous attention to this problem may enable improving of utilisation of water at many sites as the system demand grows, resulting in improved economics for the hydro power station.

8.5. Plant availability & utilisation

8.5.1 As would be evident from the foregoing (and as disccussed in detail in Chapter 2 of the Report of Study Group No. 1) availability of hydro-electric plant can only be judged against a reference frame set by its designed operating conditions. Basically, the availability of the plant should be considered satisfactory if it is available for operation whenever required. The amount of energy generated or the hours of operation do not form proper criteria for considering availability. As the power stations would be designed for operation at certain usually low load factors and the energy potential at the site limited by the water available, would be a primary constraint. The plant availability and utilisation can be considered deficient only to the extent that the plant was not available for power generation when required, or its capacity was short of plant requirements at that time or the total utilisation of energy in the period of study fell short of the planned utilisation. Extensive information regarding energy generation and potential, hours of actual operation and maintenance and forced outages has been collected for hydro-electric power stations and analysed. This study covers a total of 350 unit-years in 119 units with aggregate rated capacity of 3928 MW. The turbines of all the principal types, *viz.*, impulse, reaction and fixed as well as movable blade propeller, have been covered. The power stations include both storage and run-of-the-river types. This is presented in various tables and bar charts included in the report and is discussed in Section 7 of Chapter 3. It is seen that hydro-electric stations have, by and large, been quite successful in exploiting practically the entire energy potential at each place. In many cases, the actual energy generation has exceeded designed firm energy potential quite substantially. This would substantiate that the availability of plant has been well above that required for exploiting the designed firm potential.

8.5.2 The available data also shows that there have been no significant cases of hydro-electric capacity not being available when required for use except when there was also a simultaneous shortage of energy. More intensive studies of plant availability of some major hydro-electric power stations over a period of three years are presented as bar charts. New as well as very old power stations are covered. It is seen that mostly, the forced outage hours have been very small. Even these are also generally due to causes not pertaining to the power plant but mostly arising from mal-tripping of electrical protective relays and such like occurrences. While some exceptionally high period of maintenance outages have occasionally been reported, the most common value appears to lay under 1000 hours. In many cases, however, the maintenance outage hours appear to be considerably more than what would actually be required. While this may be due to the fact that there was no particular reason for hurrying up the maintenance work, it is felt that in the context of increasing inter-connections, maintenance practices should be made more systematic. Attention should also be given to the improvement of protective systems to minimise forced outages.

8.5.3 The reliability of plant availability of hydro power plant is important to the system well in excess of the proportion of energy contribution of such plant to the system. This is mainly dictated by its capacity contribution. The importance of this will increase further as hydro-electric plants of the future are required more and more to supply the high cost peak energy and are operated at low load factors. Closest attention needs to be paid to the reliability of hydro-electric power plant covering both the plant and equipment as well as the civil and hydraulic works as discussed in Section 8. It has been recommended that a "Dams Safety Service" as being proposed by the Ministry of Irrigation and Power should be set up early and that the scope of such service should be extended to cover works such as tunnels, penstocks, etc.

8.6. Importance of adequated proper design

8.6.1 The discussions in various Sections of Chapter 3 of the Report of Study Group No. 1 pointedly bring out that adequate and proper design is one of the most important factors for safe, reliable and economic working of hydro-electric installations over long years. As already mentioned, the cost of energy generation at hydro-electric plant is primarily derived from the initial investment costs. Close attention to optimise the design features would evidently lead to minimising of energy generation cost. In this matter, however, a number of long range considerations also need to be borne in mind as, damage to the machines through erosion, possibility of rupture of pressure pipe lines, reliability of civil works components, etc. from major items of civil works which cannot easily be attended to in case of damage or failure by the small contingent of personnel available at the operation site. It is also highly important to provide reliable communication facilities for ensuring safe and efficient operation. Abnormal conditions likely to occur over the life time of the plant should be taken into consideration. A major factor which has come into lime-light recently is the effect of earthquakes.

8.6.2 Hydro-electric equipment is, by and large, very robust and reliable and the data collected and analysed have shown its performance and availability to have been generally satisfactory. Confidence in the inherent robustness has, however, sometimes led to neglect with consequent costly damage to plant. The necessity of proper operation and systematic maintenance practices is to be emphasised. Careful operation and timely maintenance of hydro-electric equipment yield long years of trouble-free and economic operation. It is also important to operate the plant carefully and within its designed range. Some important aspects of operation and maintenance which require attention are discussed in Section 10 of Chapter 3 of the Study Group No. 1 Report.

8.7. Monitoring of performance

8.7.1 Section 11 of the Report of Study Group 1 discusses an aspect which is found to receive inadequate attention at the present time, viz., monitoring of performance. The simplicity, dependability and robustness of hydro-electric plants lead to some neglect of the power stations and lack of attention to their state of fitness. It is, therefore, necessary to institue arrangements to monitor the performance of hydro-electric power stations. This will (i) obviate development of emergency conditions and (ii) enable timely action to forestall reduction in plant efficiency and deterioration of performance. Many slowly-occurring effects of wear and tear such as, enlargement of sealing gaps, pitting of surface, etc. accumulate over the time and result in poor performance. Broadly speaking, the efficiency of the plant can serve as a good overall indicator for judging its state. Various methods could be employed for this purpose. One of the commonest methods of monitoring performance during operation is the use of index methods. Other recently developed methods such as, thermodynamic method or ultrasonic method of measurement of efficiency could also be applied without disturbance to normal working. It has, therefore, been recommended that each new generating unit should be provided with adequate means of continuous monitoring of its performance. Measures should also be introduced in existing power stations to ensure monitoring of performance continuously or at least at short intervals.

CHAPTER 9

THERMAL POWER STATIONS—UTILISATION AND AVAILABILITY OF PLANTS

9.1.1 The very first term of reference of the Power Economy Committee enjoins upon it "To review the pattern of utilisation of available plant capacity during the past 5 years and their operational efficiency and fuel consumption, to consider the scope of improving economy in power generation together with specific measures for attaining them."

9.1.2 Power supply industry is highly capital intensive. The costs per kilowatt of installed capacity in thermal power stations now works out to about Rs. 1700/- to Rs. 1800/- against about Rs. 1,000/-1200/- that prevailed some years back. It is, therefore, all the more important that the power stations are so maintained and operated so that optimum generation is derived from the same.

9.1.3 Initially, coal-based steam power stations comprised small load centre installations supply urban requirements of power at Calcutta, Madras, Kanpur and other cities and towns. The installed thermal capacity prior to World War II was 540 MW, all of which was established and operated by private licensees. The first major step in development of economic thermal power through advantageously located large mine-mouth installations was taken when Damodar Valley Corporation inaugurated the work on the installation of the Bokaro Thermal Station with 3 generating units of 57.5 MW each in 1948-49. The total installed capacity of thermal plant in the country increased to 1.547 GW in 1956 at the end of 2nd Plan and stood at 8.5 GW at the end of March, 1970. There have been some important major changes in thermal power development in recent years. Firstly, although the larger urban centres of power generation have continued to grow, there has been a decided trend of setting up large thermal power stations at pit heads utilising directly the output of the collieries or of the coal washeries. The latter had been set up for supplying coking coal to the large steel plants and large quantities of washery by-products are being utilised as fuel in thermal power plants. Notable examples of such installations are Pathratu, Chandrapura, Durgapur, Kothagudam, Bokaro etc. Unlike their predecessors, these large mine-mouth power stations also involve development of large inter-connected transmission systems. While the older developments were almost entirely in the private sector, these recent developments which require very sizable investments are being carried out in the public Sector either by the State Electricity Boards or by organisations like D.V.C., Neyveli Lignite Corporation etc. The question of construction of some of the large power stations directly by the Central Government is under consideration in view of the huge outlays required and the benefits extending beyond boundaries of individual States.

9.1.4 In 1969-70, the energy generated by the steam power stations amounted to 31,535 million kWh out of the national total of 56,190 million kWh of electrical energy from all sources. In other words, the steam power stations accounted for 55% of the total installed capacity and contributed about 56% of the total energy.

The operational data for the last 5 years (1964-65 to 1968-69) was collected for a number of thermal power stations in the country. At the request of the Committee, the organisations in charge of these power stations furnished complete details regarding number of hours each generating unit was actually in service, was shut down for scheduled maintenance and emergency outages, causes located for failures of different components of plant and equipment etc. This data has been useful in examining the various aspects, about operation of the power plants. The matter has been examined in detail by the Study Group-1 of this Committee. In particular, sample survey of equipment availability and utilisation has been carried out by the Study Group for 14 thermal power stations divided into 3 groups.—

(i) Group I comprises of units in the range of 15 to 36 MW with stoker fired boilers. The study has covered 7 units, 11 boilers and 145 MW of installed capacity—in all 34 unit years.

(ii) Group II comprises of units in the range of 15 to 100 MW non-reheat with pulverised fuel boilers. This study has covered 23 units, 28 boilers with a total installed capacity of 1324 MW—95 unit years have been covered. The power stations covered in this group include Bokaro, Durgapur (DVC), Korba, Neyveli etc.

(iii) Group III comprises of reheat units with pulverised fuel boilers. The study covers 8 generating units and 8 boilers with an installed capacity of 920 MW. These include Trombay, Chandrapur, Bandel and Durgapur (DVC).

9.1.5 The parameters of all the power stations studied are given in Table 4-4 of the Report of Study Group No. 1. The results of equipment availability and utilisation (unit-wise) for the power stations studied are incorporated in Tables 4-5 to 4-7 of the Report of this Study Group. It would be seen thereform that capacity* factors of different units in Group I have been quite low, ranging from about 21% to about 67%. In the case of power stations under Group II, the capacity factors have generally ranged from 17% to 86%. In some of the cases, the periods for maintenance (scheduled and force) have been quite high. For the power stations in Group III, the capacity factors have generally ranged from about 13% to about 81%. Here again, for some of the units, scheduled and forced outage periods have been quite high. The detailed analysis is described in Section 8 of the Report of this Study Group. It is seen that the availability in the Indian power stations is below the United States' standard. It is true that in U.S.A., fuel used is either oil, gas or coal of very much low ash content but even taking these advantages in U.S. power stations into account, it may be stated that there is a large scope for improvement in availability of our thermal generating plant.

9.1.6 The study carried out was somewhat hampered because of the fact that the data received was not on uniform basis. A uniform basis of reporting plant availability and plant outage is essential for scientific analysis. Introduction of statistical and engineering analysis will enable a number of very useful studies leading to :—

(i) Establishment of norms of availability (including partial availability) for each type of equipment;

(ii) Continuous monitoring of the performance of the operation and usage of equipment in different power stations;

(iii) Evaluation of new technological innovations or procedures, apparatus, etc. in regard to their effectiveness in improving the performance of power installations;

(iv) Identification of problems faced by the various units of power supply industry on a broad national base, leading to formulation of the most economical and reliable solution;

(v) Evaluation of the efficacy of integrated operation and system load despatch procedures in use;

(vi) Provision of basic data for formulating the policies regarding spares inventories, technical manpower requirements, special T & P etc., and

(vii) Provision of basic data for planning of future programme of power development.

9.1.7 In this connection, it would be worthwhile to profit by the experience gained by the Edison Electric Institute and its vast network of constituent companies in the U.S.A. Under a Research Project of the Institute (Project No. 76) the data collection and analysis system for availability information has been under study for expanding the analysis and dissemination capability of the EEI Equipment Availability System. The past few years have seen a tremendous growth in demand for availability information for the various purposes already recounted above. This led to the development of numerous data collection and analysis system by different groups in the electrical industry. As a result of the above research project, new reporting instructions have now been devised to accommodate all the modern types of generating plant and equipment and to reduce ambiguity as well as preparation time for the data wherever possible. Study Group No. 1 has examined the system in detail and suggested that this should be adopted by our power system also. The Committee is in agreement with this view. The details of the system are given in Table 2-3 and Figure 2-2 of the Report of this Study Group.

9.1.8 One important factor for the success of such work is the feeling of purposefulness. The persons responsible for furnishing the data have to appreciate and understand the purpose and importance of the same. It is, therefore, necessary to have clear-cut definitions for all the terms to be used and detailed instructions must be drawn up regarding the manner in which the data is to be furnished. It is recommended that every State Electricity Board/Project Organisation should have a Technical Cell for critical examination of the operational data and to suggest ways and means of effecting improvements. Similarly, at the Central Level a Cell should be set up in CWPC where the data from all over the country should be collected and analysed. The results of the studies should be made available to the organisation contributing the data. Such feed-back of the results to the Electricity organisations throughout the country will help in creating an awareness of the use and purpose of this work and will greately assist timely collection of the requisite data. This will also facilitate in promoting exchange of operating experience of various power stations. Generally, "exchange of operating experience" will help in :

(a) reduction of occurrences or accidents;

(b) reliability of operation;

(c) economy;

(d) development of power plan technology; and

(e) most important of all, improvement in the understanding of operating personnel.

9.1.9 These can be achieved by convening conference of senior staff of various power stations to discuss their operating experience with an open mind. Further, each of them can put forth problems which may be hampering their plant operation and may

Capacity factor is the ratio of the number of units actually generated in a year to the number of units that would has been generated if the plant were to work at the rated capacity throughout the year.

find from one of the other participants a suitable solution. Such a Conference should be conducted by an agency such as CWPC. All participants should earlier give details of problems solved and problems for which they seek an answer. These should be circulated to all the participants so that suitable solutions can be obtained.

9.2. Problems in operation of steam power stations

9.2.1 As stated earlier, Study Group I of this Committee has examined in detail the information and data furnished by the various power stations regrading outages, their causes etc. The principal problems in operation of boilers, generating units auxiliary equipment etc. have been identified and necessary remedial measures have been suggested. The details are incorporated in Section 16 of Chapter IV of the Report of this Study Group. Briefly these are :—

9.2.2 Pilferage of coal especially from open box wagons, tramp iron accompanying coal causing damage to conveyor system and other equipment, spontaneous combustion in coal bunkers due to fire and wet coal being received, dust nuisances in coal handling system, experience with different types of pulversing mill systems and methods of firing, flame failure caused by coal feeding defects, furnace explosions with resultant damages, slag formation in furnace, erosion due to fly ash, problems of leakages in glands, leakages in pressure parts, problems with stoker fired plants with coal grading not being of the desired quality, problems with electorstatic precipitators have been highlighted. In the case of turbo generators, cases of fires caused by turbine oil leaking on to hot parts have been reported, failure of governing system, sticking of valves, wear of exciter commutator, chattering of control valves, deposits on turbine blades leading to capacity reduction, problems in condenser operation such as fouling of tubes, corrosion, erosion have been touched on. Failure in boiler feed pumps on account of use of sub-standard material in construction has been reported from several power stations. The fact has been brought out that there should be shaft mounted oil pumps to take care of the emergency of total power failure. Alternative emergency DC driven oil pumps should be employed. The necessity for oilless air supply where pneumatic controls are to be used has been brought out.

9.3. Maintenance and repair facilities in steam power stations

9.3.1 The necessity to take into account maintenance of the various items of plant and equipment at the design stage of the power station has been highlighted by the Study Group and suggestions made as to the type of such facilities considered desirable. At the time of developing the plant layout, the positioning of equipment and the maintenance facilities such as cranes, hoists should be taken care of, to provide for convenient maintenance of equipment.

9.4. Efficiency of energy generation

9.4.1 The following table gives distribution of steam power stations in terms of overall thermal efficiency :—

Overall Thermal Efficiency	Number of generating stations	Aggregate installed capacity (MW)	Energy generated by the group (GWh)
1	2	3	4
Year 1962-63			
Under 10%	24	115·61	172·00
Above 10% but below 15%	34	719·29	2076·71
Above 15% but below 20%	14	537·95	1,726·65
Above 20%	11	1,167·50	6,201·50
-rand Total . .	83	2,536·35	10,176·86
Year 1967-68			
Under 10%	18	114·29	205·23
Above 10% but below 15%	31	640·06	1,765·48
Above 15% but below 20%	11	547·71	2,205·63
Above 20% but below 25%	7	767·50	3,394·60
Above 25% but below 30%	17	19,89·60	6,877·93
Above 30%	7	1,901·50	7,783·88
Grand Total . .	91	5,960·66	22,232·75

NOTE: 3 Power Stations with aggregate capacity of 14·75 MW not taken in the analysis for 1967-68 due to no generation or want of data.

The thermal efficiencies shown above are the actual overall efficiencies achieved in the power station operation. These are based on the actual consumption of coal of different grades, fuel oil etc., the respective calorific values of the fuels and the gross electrical energy generated. It would be seen that the number of generating stations in the lower efficiency brackets has progressively reduced while that in the higher efficiency brackets has increased. In many cases, this is due to the addition of larger high efficiency generating units in existing power stations, resulting in the higher overall efficiency. In 1962-63, there were 11 power stations in the country, operating at efficiencies better than 20%. This number increased to 31 in 1967-68. In 1967-68, about 65% of the electrical energy generation in steam power stations was from generating units operating at an efficiency of 25% or better. The national overall efficiency worked out to 23.13% in 1967 against 27.99% in U.K. (Central Electricity Generation Board). It is noteworthy that the highest efficiency achieved in any one station during 1967-68 was at Chandrapura (DVC)—34.2% against the highest of 34.6% reported in U.K. at Ferry-bridge 'C' Station. The main reason for prevailing higher efficiencies in U.K. is that there has been a large scale addition of large sized units and this has contributed to the increase attained. The efficiency level in India is also expected to rise with additions of large units with higher parameters.

9.4.2 With the steam power stations contributing nearly 56% of the total production of electrical energy in the country, it is obvious that improvement of the overall efficiency of these power stations is of vital importance in reducing the cost of electrical energy. Any point on the curve (Figure-4-2 appended with the Study Group I Report) shows the installed capacity in the country and the corresponding minimum overall efficiency. It is seen that about 3,000 MW of installed capacity operated at an efficiency of 28% or better while an equal installed capacity operated at efficiencies lower than 28%. The installed capacity involved in efficiencies under 12% is of the order of 200 MW. Shutting down these plants and giving power supply at those points from the grid fed from high efficiency power stations would obviously yield very considerable savings. The question of taking similar action later on for power stations operating at efficiencies below 20% which cover less than ¼ of the present installed capacity can be considered later. If the power systems are suitably integrated, energy requirements could be derived from the generating units operating at higher efficiencies and the generating units with lower efficiencies could be assigned the functions of peaking till such time as sufficient additional generating capacity can be added to enable replacement of the older low efficiency plants.

9.4.3 Figure 4-3 appended with the report of the Study Group shows the energy generation of each of the 91 plants in 1967-68 against the efficiency at which the energy was generated. It would be seen that the energy generation at practically all the large high efficiency stations, namely Trombay, Neyveli, Chandrapura, Durgapur and Bandel has inrceased substantially in the year 1968-69. In this process, however, the efficiency at some of these power stations has reduced. Such reduction in efficiency with increased energy production is not what would normally be expected and it would be worthwhile to investigate the reasons for the same. In 1967-68 and 1968-69, the largest single sources of electrical energy (Thermal power Stations) in the country were Neyveli, Trombay and Chandrapura. Even these stations could not be utilised to the full energy potential which is taken as 6,000 kWh per kW installed in the Annual Power Surveys. It may be mentioned that in 1969-70 about 18,000 million kWh or about 72% of the total generation in steam plants were generated at efficiencies of 25% and above.

9.5. Utilisation of by-products from coal washeries in thermal power stations

9.5.1 The Government of India have laid down a policy that the boilers of the Public Utilities should use inferior coals and those tied to the coal washeries should use middlings or by-products having an ash content of upto 45%. This policy was adopted firstly to conserve good metallurgical coal and secondly to use by-products left over after washing medium quality metallurgical coal for use in the steel plants. This was based on the presumption that boilers were capable of burning inferior coals and, therefore, should utilise the left overs. The authorities of the power stations which have been using middlings and by-products from the washeries have been stating that they have been implementing the above policy of the Government of India but the operation of their thermal power stations has been badly suffering on this account.

9.5.2 It is true that boilers can be designed for burning inferior coals but burning of such coals without affecting plant availability is another matter. The abrasive ash has severe eroding effects resulting in tube failures or fire going out in case of loads lower than full loads.

9.5.3 A case study of the Chandrapura Power Station of the D.V.C. has been made. This power station designed to utilise Dugda Washery middlings was the first one to be planned to use middlings with high percentage of ash and every care was taken to see that the boilers were suitably designed. The first unit in this power station was commissioned in November, 1964, second in May, 1965 and the third in July, 1967.

9.5.4 Dugda-I Washery (3 stage) owned by M/s. Hindustan Steel have been supplying Chandrapura about 0.36 million tons of middlings and rejects with an ash content of about 35 per cent. Dugda-II Washery which is only a 2 stage washery was commissioned in September, 1968 and the supply being received is about 0.7 million tons of by-products with an ash content of 40 per cent. The quality of the by-product fuel received from Dugda Washeries and used at the station was as given below. (Upto September, 1968 when Dugda-II was commissioned, the washery products were insufficient. The station fuel was a blend of raw coal with a somewhat lower ash content).

Year	Dugda By-products,	Ash Station Coal, Ash
1964-65	34·94%	34·92%
1965-66	35·63%	33·70%
1966-67	35·06%	33·39%
1967-68	36·23%	33·86%
1968-69 (Upto end of Aug. '68)	34·86%	34·28%
1968-69 (Sept. '68-March, '69)	37·20%	36·80%
1969-70 (April-Dec., 69)	37·75%	37·75%

The above figures are averages for these periods. Monthly averages have been upto 41.6 per cent and daily averages have been even higher. The quality of fuel has thus progressively deteriorated.

9.5.5. The effect of use of by-product having such high ash content has been :

(1) Inability of the generating units to carry full load due to sharp fall in the capacity of pulverising mills.

(2) Increase in the coal mill outage for maintenance of mill parts like bullring, rolls and exhaust fans.

(3) Appreciable burner erosion resulting in instability of fire. Unit No. 3 was put on commercial operation on August 1, 1968, but by July, 1969, it showed appreciable burner erosion. On the other hand, Units 1 and 2, with station coal having around 33 per cent ash could carry on without comparable erosion on burners for two years. The instability of fire has resulted in unit outage with considerable system disturbances despite use of expensive oil support during low load periods. There were 36 outages due to fire-out on units 2 and 3 during 1969.

(4) Increase in the quantity of ash handled. The abrasion on ash handling plant has created problems of ash disposal resulting in ash build-up in the dust collector and consequent poor performance.

(5) Increase of wear on I.D. fan. This has reduced the capacity of the units from time to time. Unit No. 2 has had shut down at I.D. fan on 8 occasions from April, to October, 1969 and Unit No. 3 on three occasions. (Unit No. 1 was out for some other reason).

(6) Serious progressive deterioration in overall plant efficiency. The annual efficiency figures are given below :—

1965-66—35.8 per cent
1966-67—35.15 per cent
1968-69—34.55 per cent
1969-70—31.81 per cent (8 months)

Drop in efficiency of about 3.34 per cent means increase in fuel consumption by about 10 per cent.

(7) The statutory overhaul of Boiler No. 1 in 1965-66 was done in 789 hours and of Boiler No. 2 in 1966-67 in 1036 hours but overhaul of Boiler No. 1 in 1967-68 took 2241 hours and of Boiler No. 2 in 1968-69 as much as 2482 hours. Thus the overhaul period has increased by one month *i.e.* about 8 per cent. In other words, 8 per cent of more generation capacity has to be provided (on account of lower plant availability) in order to be able to meet the same load demand. In a system with 4 million kW of installed capacity this would mean about 300 MW, the cost of which would be about Rs. 54 crores.

(8) The additional installations and lower efficiencies also mean additional costs on fuel raising, transport and ash disposal. Huge additional investments will thus be necessary if we are not able to operate our thermal stations in a better manner.

9.5.6 This matter has been discussed with the West Bengal State Electricity Board also in connection with the operation of their Bandel Thermal Power Station. Previously Bandel was taking about 300,000 tons of by-products from Patherdih, Jamadoba and Lodna washeries (all 3 stage washeries) with an ash content of about 30 per cent and they were in addition using about 200,000 tons of coal with an ash content of about 22 per cent. Even with the above, they found that the performance was not good. Recently, therefore, they have reduced their intake from the above washeries to only 180,000 tons and are using about 500,000 tons of coal. With this, the plant performance is far better now.

9.5.7 Experience at Renusagar power station of M/s Hindustan Aluminium has also shown that the ash with abrasive materials like silica and alumina has been the cause of most of the outages either due to erosion of the economiser elements or that of I.D. fans.

9.5.8 Utilisation of coal washery by-products is a necessity from the larger national view point both for improving the economics of coal supply and for disposal of the large volume of by-products. The abrasive content of the ash however, plays havoc in the boiler plant and equipment. Unless effective steps are taken for removal of stones and other abrasive materials and to reduce the percentage of ash content to 32 per cent of the by-products, it may become extremely difficult for the washeries which are owned by the Central Government to dispose of their by-products. In any case, the State Electricity Boards and other consumers would ask for substantial reduction in the cost of these fuels which would result in increased cost of coal for the steel industry.

9.5.9 It is, therefore, necessary that (a) the future washeries should be only 3 stage with adequate arrangements for removal of stones and other abrasive material and (b) in the existing washeries steps should be taken to reduce the abrasive material and to ensure that the ash content does not exceed 32 per cent.

9.5.10 It is recommended that a practical time table for taking the corrective actions referred to above should be established immediately jointly by all concerned. The factors responsible for erosion damage to the boiler plant and equipment have so far eluded scientific identification. Research work for this should be initiated immediately. Design, construction and materials in the boiler plant, appurtenant plant and equipment require considerable further attention for devising ways and means of living with washery by-product fuels. Existing power plant installations can be fully utilised for making field trials of different new innovations or designs of equipment for this purpose. The equipment requiring attention is the coal mills, ID fans, layout and arrangement for superheater and economiser tubes, ash handling disposal systems, design and arrangement of burners etc. It is recommended that our nascent boiler plant manufacturers and manufacturers of appurtenant equipment approach this problem earnestly in collaboration with the organisations owning and operating the existing power stations so as to evolve the necessary Indian technology.

9.6. Pricing of coal and washery by-products fuels

9.6.1 The cost of fuel constitutes about 30 to 65 per cent of the cost of each kWh generated and is, therefore, by far, the most important element of energy cost. The cost of fuel is composed of the cost of coal or washery by-product at the source and the cost of transportation and handling. The power supply industry is given very little freedom in choosing the fuels for the different power stations. In the colliery areas, the large power stations are mostly linked to specific collieries or washeries and even the power stations situated far away from the collieries are usually tied to certain sources of coal, the choice in this being further narrowed down by the transport policy in regard to routing of coal traffic decided by the Railways from time to time. In consonance with the national policy of conserving better coal for metallurgical and other purposes, the power supply industry is obliged to use the inferior coals and the washery by-products. The low calorific value of these as well as the highly abrasive ash content necessitates costlier installations of boiler plant and auxiliary equipment as well as very heavy charges of operation and maintenance and replacement of parts. These factors have to be kept in view in formulation for coal prices.

9.6.2 It is of interest in this connection to take note of the fuel policy formulated in the United Kingdom (U.K.) where the fossil fuels are now inadequate. In the Fuel Policy White Paper (November, 1967), Her Majesty's Govt. has accepted the Power Industry's argument that the cost of special measures to support the use of uneconomic fuels in power stations should be borne by the Exchequer and not by the Electricity Consumers. In terms of the coal industry Act, 1967, the cost reimbursible to the CEGB towards supporting the protection of coal industry amounted to £ 3.4 million for the period 1-8-1967 to 31-3-1968.

9.6.3 The question of pricing of coal and washery by product fuels has been discussed in Section 9 of Chapter 4 of the Report of Study Group No. 1. In so far as pricing of coal is concerned, it has been suggested that it should be related to the heat value of the coal.

9.6.4 **In the case of washery by-products, the** position is different because the price does not depend on tendered rate and free play of competition, as the washeries are almost entirely under the NCDC and HSL. In the past, the prices were subject to bilateral agreements which were based on the controlled rates for coal. One of the largest consumers of middlings/by-products paid for these on the equivalent in terms of coal of Grade III-B containing up to 35% ash less Rs. 2.50 per tonne. The equivalent in terms of middlings was calculated in the following manner :—

The ash content of the rejects and middlings was taken as 55 and 35 per cent respectively. Then the formula used was :

middling content :

$$\text{(Total Tonnage of mixture)} \times \frac{(55\text{—ash \% in the mixture})}{20},$$

The denominator, 20 represents the difference between the percentage ash content of rejects and middlings.

9.6.5 Thus it would be seen that the price of middlings/by-products was being fixed in terms of Grade III-B coal without making any allowance for the extra cost to the Power Station on account of deleterious effect of the high ash fuels and the higher cost of transport and ash disposal. As already discussed in the foregoing, these factors must be taken into account. The Energy Survey Committee of India which submitted its report in 1965 had considered the washery by-products as zero cost fuels. Even if this is not found acceptable by NCDC and HSL in actual practice, there is a clear case for a lower price for these. This can be worked out taking into account the loss of efficiency, plant availability and plant capability in power stations using such fuels. For middlings having ash content less than 32%, it may be reasonable to fix the price at a rate equivalent to that for coal of the same heat value less Rs. 2.5 per tonne. In order to improve the operation of the thermal generating units it is considered that the ash content of **the fuel burnt in the boilers, should not exceed 32%.** For this purpose blending will be required to be done when either coal or washery by-products with ash content of more than 32% have to be utilised. When therefore washery by-products with ash content of more than 32% are supplied by the washeries, further necessary adjustments in price will need to be made to cover the expenses on account of blending arrangements. It is also recommended that the cess on middlings/by-products should be waived. These are the minimum incentives that the power industry must insist on to maintain its viability and to compensate for the lack of freedom to choose its fuel according to its best interests.

9.6.6 The sizes of power stations are increasing continuously and the requirements of coal are growing. There would, therefore, be an increasing trend to tie certain collieries to specific power stations on a long term basis. Under these circumstances, it would be economical to have long-term coal contracts between the power stations and coal suppliers. The guarantee of a large steady market for the coal raisings will enable higher degree of mechanisation and rationalisation in coal production. While earmarking the collieries for power stations, planning of alternative sources will also have to be kept in view, particularly in view of the possibilities of colliery shutdowns due to labour troubles or break-down of rail transport facilities. These coal contracts should ensure that the prices as well as the quality of fuel (chemical composition as well as size) are stable. The stability of the price and quality of fuel will greatly facilitate progressive increase in the efficiency, dependability and working of the power stations.

9.7. Transport of coal to thermal power stations:

9.7.1. At the end of the Second Plan, there were very few large thermal power stations in the country. The coal consumption was also comparatively small and was also not linked with any particular colliery. During the course of the Third Plan, construction of a number of thermal power stations with unit sizes of 50 and 100 MW was taken up and a number of these power stations have now been completed and more are under construction. The coal consumption of some of these stations will be of the order of one million tonnes per year. Most of these stations have been linked with particular mines. This will, therefore, involve constant movement of coal between two points. Such large quantities are best transported by means of unit trains instead of wagon loads. These power stations are now in a position to take continuously a rake load of coal and the railways will not have to marshal wagons to form rakes everytime at the junction stations.

9.7.2. In the unit train concept, normally the train uses bottom discharge type of wagons, so that, after coming to the station, it moves very slowly over the hoppers and the bottom-dump wagons are discharged one by one without stopping the train. At the mine also, the train does not stop, but is continuously loaded by chutes while the train is moving at a slow speed. No tippler is required at the power station for unloading purposes and there is no waiting time at the station. The reduction in time, therefore, at the power station and the mine considerably increases the turn-round of the wagons and hence reduces the capital investment on the rolling stock. On unloading at the destination, the train would immediately proceed back to the mine, load and return. In addition to dispensing with the wagon tipplers, the space requirement for marshalling yard at the station and the length of railway track are considerably reduced. It is also no longer necessary to employ shunting locomotives at the station.

9.7.3. The concept of unit train was introduced in the USA where the thermal power stations were utilising gas and oil in addition to coal for power stations. In the face of competition between different fuels, the unit train concept came into being in order to reduce the cost of transport of coal, so that the railways did not lose the traffic which was so valuable to them. It has been estimated that in U.S.A. unloading by wagon load lots costs about 4½ cents per ton whereas unit train unloading costs about one cent per ton. In spite of the rising cost of labour and materials in U.S.A., the average cost of transport of coal has come down.

9.7.4. In U.K. also, all movement of coal at present at the various stations is being done by bottom-discharge type wagons and merry-go round unit trains. Storage sidings at the power stations have been practically eliminated and the total lengths of track at the station reduced from an average of 26 Kms. to 7 Kms. significant benefit also accrued to British Railways from this development as wagon building programme was cut to half and the utilisation of locomotives and train crews increased. This resulted in new reduced tariff for transport of coal in 1962.

9.7.5. The Energy Survey Committee (1965) had suggested that close circuit unit trains for movement of coal should be investigated for certain large power plants which were contemplated for locations away from the coal fields. The savings in transport of coal had also been indicated. The matter has been again examined by the Study Group-1 of this Committee. They have worked out the comparative cost for transport of fuel in wagon load lots of close circuit unit trains and transport of energy by EHV transmission lines. The results are tabulated in para 3.3 of Section 12 of Chapter 4 of the Report. It is seen that EHV transmission of energy is cheaper than transport by rail by conventional method *i.e.* by wagon load lots for all the distances whereas transportation of energy by rail by unit train is even cheaper as compared to EHV transmission of energy. Keeping in view overall national interest, we must adopt ways and means which would bring down the overall cost of transportation of coal. Savings in this regard could be suitably shared by the railways and power supply industry to mutual advantage.

9.7.6. In view of the importance of the subject, the Power Economy Committee took up the matter with the Railway Board and requested them to have it examined thorougly. It is understood that matter is receiving the attention of the Railway Board. The Ministry of Irrigation and Power and the Central Water & Power Commission may further pursue the matter with the Railways and ensure that steps are taken at the earliest to introduce the unit train system for transport of coal for large thermal power stations. It may be mentioned that Table 4-12 of the Report of Study Group No. I gives region-wise requirements of coal transport for power stations by 1973-74. Rough estimates worked out by the Study Group indicate that savings on this account may be of the order of Rs. 10.00 crores annually by 1973-74.

9.8. Rationalisation of freight structure over short distances

9.8.1. The railways at present have a fixed tariff for transportation of coal for short distances upto 40 Kms. For some of the power stations which are located within 50 Kms. from the source of coal, an average rate of Rs. 10/- per tonne is being paid for transport to the railways. It is seen that usually it does not cost more than Rs. 5/- per tonne for short distance haulage by other means like belt conveyors, aerial rope-way, etc. Obviously, the freight being paid by the various power stations is on the high side. It is, therefore, suggested that the railways should rationalise the tariff structure for short distances. Different State Electricity Boards and the concerned project authorities may take up the matter with the Railway Board with the assistance of the Ministry of Irrigation and Power.

9.9. Instrumentation of power plants

9.9.1 In a thermal power plant, instrumentation plays a very important role, on which depends the efficiency, availability, security and safety of a power plant. With the growth of power demand, bigger units are being installed and it is very essential that these units must run very efficiently and economically. The outage of a large unit will upset the system and the indirect losses due to interruption of power to industries will be enormous. It is, therefore, essential that the generating units run smoothly and uninterruptedly. To achieve this, the controls and instruments in a thermal power station have to be very well-planned, efficient and reliable. In view of the large integrated networks which are now coming up, the instruments and controls have to be fast operating. This, therefore, deserves adequate attention.

9.9.2 It has often been observed that sophisticated instrumentation is provided in the station designs; but it is not fully utilised for want of proper maintenance. Many troubles and failures in power stations can be traced to parts of the instrumentation system being out of commission. The power stations have to work with proper functioning of instruments for all systems. It is suggested that special instrumentation Cells and well-equipped instrument laboratories should be put in each large power stations as well as for the power system as such. These Cells should be manned with specially trained and experienced staff and no obstacle should be placed in the procurement of spare parts for the instrumentation and controls already in operation in the power station.

9.10. Training of personnel for operation and maintenance of Steam Power Stations

9.10.1 The Fourth Plan envisages installation of additional 4.53 GW of thermal power. Consistent with the above increase in generating capcity, it has been estimated that about 1500 engineers and diploma holders and 4,500 technicians would be needed to cater to the requirements of operation and maintenance of new thermal power plants to be installed. Besides, availability of trained personnel for the existing installations is also not satisfactory, as a result of which it has not been possible to operate the various power plants under the optimum conditions.

9.10.2 The Central Water and Power Commission has recently established three training institutes at Neyveli, Durgapur and Delhi. The type of facilities available at these institutes are given in Section 22 of Chapter 4 of the Report of Study Group No. 1. Apart from the above institutions, some of the electric supply undertakings like DVC, Tatas, U.P. State Electricity Board, Gujarat State Electricity Board, Maharashtra State Electricity Board etc. are having the training facilities to a moderate extent.

9.10.3 The C.W. & P.C. and the Union Ministry of Irrigation and Power have shown commendable initiative in setting up the above training institutes. These facilities are, however, grossly inadequate particularly on account of institutes not being properly equipped with staff as well as equipment and other training facilities. Since the main beneficiaries are the State Electricity Boards and other major Electricity Undertakings in each region, it is desirable that the Regional Electricity Boards themselves should organise and operate adequate training facilites in their respective regions. As the institutes grow up they should install sophisticated simulators for training control room operators/engineers and shift engineers who are vital for safe operation of large units. Simulators are dynamic and can be used for training personnel to handle all plant emergencies. Any length of in-plant training will not substitute the above training as emergencies cannot be created on running units.

9.10.4 When adequate training facilites are set, it is recommended that it should be made obligatory for all technical personnel to be employed in operation and maintenance to have proper competency certificates issued by the training institutes or by the respective Governments before they are posted for these duties. If necesary, adequate legislation may be passed for the purpose. It should also be made necessary for the personnel already employed to undergo some prescribed formal training before obtaining further promotions. It is essential to run these institutes in a well-organised well-equipped and efficient manner in order to inculcate a proper sense of discipline and technical know how which are both very necessary for safe and efficient working of the power systems. The expense of imparting proper training to the o & m personnel is really an indispensable input for economical and reliable generation of electrical energy. Partly, it is also in the nature of insurance premium for the costly plants and equipment. Better operation of the power plants mean better conditions of power supply to the industry and agriculture which in turn would mean better production and prosperity.

9.10.5 It is suggested that middle level engineers should also be sent for a few weeks at a stretch to the works of large manufacturers or instrumentation factory at Kota for proper understanding of the plant and equipment.

9.11. Staffing for steam power stations

9.11.1 Study Group-1 has worked out a staffing pattern for steam power stations (Table 4-16) for 2 units, 4 units and 6 units power stations. This may be of assistance to the concerned organisations, while deciding about the staff required for their power stations. A more important point is that the staff required for operation and maintenance should be sanctioned and positioned at least 18 months before the expected date of commissioning of the different generating units. The whole of the o & m staff should be given initial training of six months in some institutes and then posted at the power plant during the construction phase so that they can get training on the specified plant by watching or participating in the installation, testing and commissioning works. During this period the o & m staff should be assigned definite responsibility and task.

9.11.2 It is understood that the various power supply systems are experiencing difficulty in staffing of personnel for thermal stations. On the transmission and distribution side, the personnel enjoy various facilities like city comforts. public conveniences etc., whereas the personnel engaged on the thermal power plant cannot enjoy such like facilities on account of location away from the cities. It is, therefore, suggested that proper incentives should be given to the personnel engaged on the operation and maintenance of thermal stations so as to invite sufficiently good talent to handle the various sophisticated and expensive equipment installed at the power stations. In this connection, the practice being followed by the Maharashtra State Electricity Board would be of interest. They have created a new generation cadre in which all the categories of staff are given some generation allowance and some categories are also given an advance increment in their scale of pay in addition to the generation allowance. The incentives offered to the personnel would be over compensated by the benefits derived in the form of better operation of power stations and lessening of outages which would in turn mean more revenues etc.

9.12. Import of spares for operation and maintenance of power stations

9.12.1 Non-availablity of adequate spare parts in time has figured as an important element in reduced availability of power plants and equipment as well as operation in an inefficient and at times unsafe manner. Almost all the plant and equipment presently in commission is imported. The spare/replacement parts for these are, therefore, mostly of proprietary nature and have to be imported. The indigenous manufacturers have tight delivery position even for the supply of the main plant and equipment and therefore show little interest in making odd bits of spare parts. As a result even a number of minor and fast moving spares are not being procured indigenously.

9.12.2 The subject has been discussed in detail in Section 2 of Chapter 5 of the Report of Study Group-1 and the reasons which in the past have held the supply of spare parts have been discussed therein. In order to reduce time for procurement of spares, the following suggestions are made.

9.12.2.1 The clearance of applications from indigenous angle should be done by Central Water & Power Commission itself. For this purpose, the Directorate General of Technical Development should equip the Central Water and power Commission with all the information about indigenous availability of spare parts, auxiliaries etc. The Electricity Boards/Project Authorities should adopt modern methods of inventory control for dealing with their replacement of spares. In any case, the position regarding spares should be reviewed by them at least every quarter and anticipatory action taken, so that the time normally required for release of foreign exchange, issue of import licence etc., does not come in the way of proper operation of the power installations or execution of projects. A special Cell should be created in the Central Water & Power Commission and the concerned officer should be provided proper facilities for conveyance etc.

9.12.2.2 Where a number of identical power plants have been installed in the country, some additional emergency spares, such as a spare thrust bearing may be obtained and kept in common reserve. Such common pool of spares, financed co-operatively by the different power station authorities may go a long way in reducing the loss of energy generation due to forced outages.

9.12.2.3 The Chief Controller of Imports & Exports should give necessary facilities to the Liaison Officer of the Central Water & Power Commission for expediting the cases of issue of import licence for spares. This can be done by placing an officer of the Central Water & Power Commission in the Office of the Chief Controller of Imports and Exports for carrying out liaison work. After release of foreign exchange and indigenous clearance Regional Joint Chief Controller of Imports & Exports should be authorised to issue import licences.

9.12.2.4 Revalidation of import licences in cases on which project authorities have entered into commitments, after clearance of the Directorate General of Technical Development, should be done as a matter of routine by the Chief Controller of Imports & Exports within a week. Any back reference by the Chief Controller of Imports & Exports should be addressed to the Central Water & Power Commission and not to the project authorities.

9.13. Ash disposal

9.13.1. The rapid increase in installed capacity in thermal power plants all over the country is certain to bring to a head the problems of ash disposal. The national policy of making maximum use of low grade coal and washery by-products will aggravate conditions in this regard very fast. The total annual consumption of fuels presently (1968-69) is about 12.5 million tonnes of coal and 2.6 million tonnes of lignite. This is expected to rise to 23.6 million tonnes of coal and 4.2 million tonnes of lignite by the year 1973-74. This indicates that at present about 4 million tonnes of fly ash is already being produced in the country annually and this quantity is likely to be doubled in the next few years. The disposal of such huge quantities of ash is a tremendous problem. The dumping of ash will gradually choke the available spaces around the power stations. The dumping of ash without return on account of non-utilisation of ash imposes a heavy burden on the economies of power supply industry. This is a serious matter that will affect the economy of power plants in a number of ways and various aspects of the problem must be considered rationally without any further loss of time.

9.13.2 The ash disposal itself presents two-fold problems, viz.

(1) Pollution

(2) Ash disposal

The above aspects have been discussed in detail in section 20 of Chapter-4 of Report of Study Group No. 1.

9.13.3 *Pollution* : There is already growing consciousness in the country about the pollution and it is expected that alongwith the laws and regulations controlling disposal of industrial wastes, regulations prohibiting or regulating dumping of ash will be promulgated in the coming years. These regulations, alongwith the cost of ash disposal, would make it an urgent necessity for the power plant authorities to explore ways and means of finding uses for the ash. The fly ash in power stations also possess serious threat of air pollution. The various aspects of air pollution are discussed in the above report. Tables 4.14.1 and 4.14.2 give useful information regarding the air pollution levels, stack heights exit velocity, characteristics of the fly ash extraction plants etc. in respect of 21 thermal stations in the country.

9.13.4 *Ash Disposal* : Considerable studies have already been carried out on the subject. In India various research organisations notably, the Central Building Research Institute (CBRI), the Central Road Research Institute (CRRI) and Cement Research Institute (CRI) have done considerable work in developing ways for the utilisation of fly ash. A number of uses have been developed; of these the following are important :

(i) In road construction using lime-fly ash-soil mixtures;

(ii) In the manufacture of portland pozzolana cement;

(iii) In making sintered light-weight aggregate for use in light-weight concrete, concrete blocks or slabs, etc.

(iv) As a fine aggregate in mortars, concrete, concrete blocks, cinder concrete bricks, sandlime bricks, etc;

(v) In the manufacture of cement;

(vi) In the manufacture of aerated concrete;

(vii) In making bricks from clayey soils;

(viii) As a filler in rubber, paint, bituminous concrete and bituminous products;

(ix) As a raw material for glass;

(x) In soil stablisation;

(xi) In sand blasting in place of sand for cleaning turbine blades;

(xii) As a filler layer under pavements;

(xiii) In oil well sealing.

9.13.5 The Central Water and Power Commission and construction authorities are generally well seized of the problem and the possibilities of use of fly ash in large mass concrete or masonry structures as pozzolana are usually explored. Difficulties however, do occur due to inadequate appreciation of the problem of fly ash by certain local authorities. In the case of one Dam prospects of use of 2-3 lakh tonnes of fly ash as pozzolana were explored. The proposal for use of fly ash had to be given up as the power station authorities insisted on a price of Rs. 40/- per tonne for the fly ash and this price together with the rail transport charges made use of fly ash uneconomical. Disposal of ash costs money at each power station. It will, therefore, be reasonable to expect that the power station authorities should make ash available freely for any civil engineering uses at a nominal price. This should in no case exceed the cost of coal at the power station multiplied by the proportion of ash content. Considerable amount of further research and development work may be useful. The Central Building Research Institute, Roorkee, have intimated the Power Economy Committee that they could undertake investigations on the uses of fly ash in making bricks from expensive soil such as black cotton soil and for silicate bonded high strength building bricks, if such a project is sponsored. It is also understood that Cement Research Institute, New Delhi, would be prepared to undertake work regarding analysis and assessment of fly ash of different power stations and participate in any applied research and development work in this regard.

9.13.6 Apart from these developments, it is now necessary to take practical measures for ash utilisation even on the basis of the presently known possibilities. The power station authorities are normally fully engaged with planning, construction and operation of the power generating stations and transmission and distribution works. It is, therefore, very difficult for them to carry out any effective research and development work or promotional activities on their own. Such efforts would also mean wasteful duplication in the different power systems. It is, therefore, strongly recommended that in each region, the Regional Electricity Board or the State Electricity Boards co-operatives should set up a non-profit Corporation for this purpose. The power stations should make all the ash available to the Corporation free of charge and the Corporation should take all possible actions for marketing and utilising all the ash. The Corporation will promote further research and development on necessary capital equipment, preparation of national standards and specifications for ash disposal and actively pursue the use of ash in the large number of areas in civil engineering.

9.14. Modification of Indian Boiler Regulations and Indian Boilers Act

9.14.1 According to the Boilers Act, the boilers are required to be shut down for overhaul and inspection at least once in a year. This is a factor unnecessarily limiting the availability of large and costly modern boiler installations. Necessary modification of this will improve the availability of boiler plant leading to more economical operation. The boiler regulations were originally designed to deal with smaller boilers, specially of the Lanchashire type used in small process industries and vertical type in the coal mines. The boilers used to be fed with water which was available and without regard to its quality, such waters could leave sufficient scales on the boiler surfaces to cause accident due to overheating of plants. Maintenance of water level was neither automatic nor fool proof. Therefore, the statutory laws were promulgated for the safety of the fire attendants and people working in the near premises. The modern boilers do not work under such conditions. Before there is even a remotest chance of pressure part explosion, they will be a tube failure. The tube failure acts as a built in safeguard and a compulsive factor to keep the boiler in a tip-top condition. Therefore, so far as the statutory requirement to ensure the safety aspect by subjecting the modern boiler to annual overhaul and inspection is concerned, is not relevant in the present day context. Earlier it is modified to suit the modern conditions, better it would be for the economy of the electricity undertakings. The Study Group-1 has dealt with the subject in Section 19 of Chapter 4 of the Report. The Power Economy Committee agrees with the recommendation of the Study Group that the period of inspection should be extended to 2 years. It is understood that the question of biennial inspection is under active consideration of the Central Boilers Board and it is very likely that the inspection every two years would be accepted by the Board for large thermal power station boilers.

9.14.2 It is also statutorily required to subject a boiler to a hydrostatic test before the inspector in case of failure of a tube or work on any pressure part. Since due to limitation on the time of the inspectors who have a very wide jurisdiction, it is not easy to get them on a short notice, as a result of which unplanned outage time gets prolonged. Also as a result of this difficulty, hydrostatic test is carried out twice, once to make sure that the boiler stands the hydrostatic pressure before the inspector comes and the other time after the inspector comes. With big units in operation any prolongation of outage means a lot of financial loss to the Electricity Boards and inconvenience to the consumers due to the resulting power shortage. The Power Economy Committee agrees with the recommendations of the Study Group No. 1 that statutory provision should be waived for between the annual or the suggested biennial inspections. The Power Station Engineers are sufficiently competent and they can be entrusted with the responsibiltiy of the care of the boilers and their safe operation. Boiler Inspector has to play an important role during the construction stages and for initial certification of boilers before commencement of operation.

9.14.3 Some of the leading technologists are of the view that the hydrostatic test of boilers during the annual or the suggested biennial inspection need only be at the operating pressure and only once in 4 years, need the boiler be subjected to 1.25 times the working pressure. This needs consideration of the Central Boilers Board. In this connection, it is mentioned that the test pressure to which fusion welded boilers have to be subjected has been reduced from 1.5 times the working pressure to 1.25 times the working pressure. Therefore, in any case subjecting the boiler to 1.25 times the working pressure during biennial inspection should be quite in order. The question of further relaxation needs serious consideration.

9.14.4 *Modifications in Indian Boiler Regulations in the light of Modern Technological Advances* : The Central Boilers Board reviews the Indian Boiler Regulations from time to time and has been making a number of relaxations in specific cases so that the Indian Boiler Regulations do not come in the way of adoption of modern technological advances. The review of installations of large steam power plants in recent years shows that a definite trend has been established in installations of large pulverised fuel fired reheat generating units. The manufacturing technology to be accopted in this country for such units is also fairly well defined by now. It is therefore recommended that suitable amendments in the IBR to take into account the modern technological advances should be made. The Study Group-I has suggested various modifications to the Indian Boilers Regulations i.e. to cover use of alloy steels and austenitic materials for high pressure, high temperature plants; elimination of feed regulating valve in case hydraulic couplings are provided; regarding design pressures for boiler feed discharge piping; annual hydraulic test of steam lines; boiler headers; list of recognised inspectors; list of recognised steel makers; code for unfired pressure vessels.

As stated above, the Central Boilers Board may incorporate suitable amendments in the IBR taking the above in view.

CHAPTER 10

SELECTION OF NEXT HIGHER STEAM GENERATING UNIT SIZES

10.1. It is now widely accepted that the growth of electricity has to be planned at a very much faster rate than hitherto and in 5th Plan and the succeeding Plans, this country should go in for large generation and large high tension system for ensuring this faster growth of power development and for ensuring stability and security of power supply as also economic generation on an integrated basis initially through the regional grids and then through the all-India national grid system.

10.2. Obviously, the total cost of generation and transmission constitutes a very important part. Therefore, we are of the view that it is very necessary to carry out the optimisation studies keeping in view the "security or reliability" criteria which is determined by the availability of the reserve capacity of the system both in regard to generation and transmission capacities. The other important factors which also play important role are the sizes of the large Central Steam Stations, availability of peak units such as pump storage or gas turbines or two shift operation thermal plants, etc. The optimum structure of the transmission and inter-connection systems, and the optimum spread of voltage levels and security that can be made available from the same, are equally important.

10.3. From the operation point of view, the reliability considerations demand that the system should have the required reserve capacity equal to the loss of generation caused by an outage to be met from its generating stations together with the emergency assistance it can possibly draw from interconnected neighbouring systems. This is also to be considered in the background that larger generating units have a comparatively higher forced outage rates than those of the smaller units and thereby necessitating a larger reserve capacity. Thus the economy which is gained by the larger units to a certain extent may be lost by the necessity of creating larger reserve capacity. Studies reveal that from all these considerations the size of the largest generating unit in a system normally in the more advanced countries like Europe and U.K. is generally of the order of 3 to 4 per cent of the system peak and in exceptional cases it has gone upto 7%. Obviously the main advantage obtained by adopting a large generating unit in a system is the economics of the larger units in meeting the energy requirements and running the unit under a maximum plant factor condition upto 70 to 80% and thereby reducing the overall cost of the generation from different power stations in that system.

10.4. In the U.S.A. the larger generating unit size constitutes a higher percentage of the integrated system capacity than in Europe and these figures generally vary to the extent of anything from 3 to 7 per cent and sometimes even 10%. Comparatively higher generating units may be attributed to the minemouth thermal power stations with economic advantage of the larger units steam parameters and also the existence of a comparatively larger nuclear generation requiring larger units for economic generation. It may also be mentioned that in the U.S.A. inter-connections are used for sharing of reserves besides economic inter-change of transfer of power between the different grid systms like in Europe. A table showing the maximum unit sizes against the anticipated maximum demand in the Fourth Plan period is given below. The maximum unit size to the total maximum demand of a regional inter-connected system on an average comes to 5.5%. This would necessarily mean that under an outage condition of 3% a reserve capacity of about 15 per cent would be required.

Region	Max. Unit size planned by 1973-74 (MW)	Anticipated max. demand in MW by 973-74	Maximum Unit size as % of maximum demand
Northern . . .	220 (nuclear)	4112	5·4
Western . . .	210 (nuclear)	3711	5·7
Southern . . .	235 (nuclear)	4060	5·8
Eastern . . .	140 (thermal)	2923	4·8

10.5. Increasingly, the overall efficiency of thermal generation has been improved by application of automatic supervision of power production by online performance computors including computor control for start-up and shut-down of plants. These computerised monitors have reached a very high standard of perfection and have permitted not only the reduction of outage but also a higher degree of safety and reliability. Obviously, such costly computerised control could be provided only with large size generating units in super thermal power projects. The cost of power from large units on an average has progressively gone lower than the existing low capacity thermal generating units. According to the estimates the cost of a 500 MW generating unit located at mine-mouth having a large installed capacity of 1000 MW or more will be of the order of only 4 paise/kWh for a coal price of Rs. 33/- per Tonne with calorific value of 5900 K. Cal/Kg. as per the comparative statement enclosed *vide* Appendix 10-1.

The question of selection of unit size for the future large thermal power stations is primarily dependent on the following :—

(a) At what intervals shall new plants be built

(b) What shall be their output ?

(c) What type of plants will be mostly built, nuclear or thermal, (coal fired, oil fired or gas fired) ?

(d) What principles and processes would be utilised for the operation of these plants (automatic, computorised, semi-automatic or manual)?

10.6. In a developing country like ours, it is not an easy task to forecast a precise solution to all these factors. The solution could, however, be considered if the process is reversed and the timing of the introduction of new generating units be stipulated in advance as will be seen from the consideration of security or reliability criteria to system capacities, besides other considerations such as financial considerations with regard to investments on the reserve capacity, integrated operation transmission facilities for bulk transfer of power, the limitations of manufacturing concerns, the limitations of know-how available and the limitation of development of metallurgy for production of high pressure units etc. For the economical selection of larger units sizes at different stations in different systems, various possible alternatives have to be studied. The data and information required for such studies have to be arranged for in order that detailed and accurate studies could be made and correct decision would be the technical and economical data of the existing plants, possible new plants of about 500 MW or 600 MW or of even higher capacity, estimate of the net work-loadings, other economic data for the intended period of extension, etc. However, decisions regarding expansion of a net-work or the determination of the maximum size of the generating unit should not be determined by economics alone. Other factors which are equally important such as research, metallurgy of metals required for the manufacture of the Turbo-generators, boilers and auxiliaries, the cost of materials and the rising cost of labour, the know-how of designing, manufacturing, erection, commissioning, and operation would constitute important considerations in the selection of the unit size. Simultaneous development of the transmission capacity, voltage levels, problems of transportation, right of way problems of H.T. lines, transportation of large parts of equipments from factories to the power station sites, the degree of development of other auxiliaries, technological development of other industries, such as, instrumentation, micro-electronics, manufacture of high voltage and high capacity switchgear, degree of interconnected and integrated operation in the regional and national power systems should get due consideration while determining the unit size.

10.7. The increase in the unit size of the superthermal power stations can bring in a saving to the extent of 10 to 15% in the total capital cost on the investment on thermal power generation in the 5th and succeeding plans. The other advantages are :—

(1) The design office needs approximately the same time for preparing a detailed project of a superthermal power station of 1 million KW consisting of 5×200 MW as for a smaller power station having 500 MW capacity with 5×100 units.

(2) Much more can be saved at the time of erection comparatively on MW basis both in regard to the construction time as well as in regard to locating skilled personnel for such specialised erection jobs.

The efficiency of the existing thermal power stations in this country vary from 10 to 35%. In the case of large generating units, the efficiency will be of the order of 35 to 40%. A statement of efficiency of the existing units is given below :

Sl. No.	Name	Total installed capacity	Unit capacity	Efficiency	Remarks
1	2	3	4	5	6
1.	Chandrapura (DVC)	280	140	34·19	Efficiency figures are for year 1967-68
2.	Renusagar (UP) .	62·5	62·5	33·98	
3.	Bandel . . . (West Bengal)	330	4×82·5	32·9	
4.	Indraprashtha Extension (Delhi) .	187·5	3×62·5 1×150·0	32·46	
5.	Trombay . .	337·5	3×62·5	31·60	
6.	Neyveli . . .	400	6 × 50 1 ×100	30·41	
7.	Durgapur (DVC) .	290	2×75 1 ×140	30·72	

10.8. Technical limitations for ensuring satisfactory solution of system stability problems throughout the period of this rapid development of the system capacity and growing voltage level are also determined by the unit size and generator para-meters. A significant development in this direction is the rapid advancement made in the manufacture of improved circuit-breakers. For having a protection for generating stations having an output capacity of 1000 MW or more, it is essential that the outages of out-going feeder should not have adverse effects on the type of the station which is necessarily to be maintained on the remaining out-going feeder circuits. The presence of a very large generating unit size alongwith a comparatively smaller unit size in the same power station without adequate transmission facilities may, therefore, not be acceptable from the point of view of 'stability or reliability' criteria on the same consideration in the power systems in this country. In the various power systems in this country, the problem of reserve capacity requirement is perhaps one of the most important considerations to determine the unit size and the capacity conditions required for future. Needless to repeat that if too much capacity is added or large unit sizes are added and also if the additions are made too soon, the hydel capacity reserves have to be high-thereby which necessarily, involve a high cost and may result in bad economy. If too little capacity or too smaller sizes be added after a longer period, there will, necessarily, be shortages, interruptions load-shedding resulting in loss of production and retarding the growth of overall economic development of the country besides serious public criticism caused by the inconvenience of five regions, i.e. Northern, Eastern, Western Southern and North-Eastern. At present regional grids are being developed in this country with a view to improving the stability and economy of the operations and costs and to reduce the reserve capacity in each regional system. For this purpose, 220-KV inter- connecting lines between individual power systems of the Electricity Boards and creation of regional central load despatch station have been accepted and are being implemented with loan assistance by the Centre. From the various studies that have already been made, it would appear that the reserve capacity in the various regions would vary from 10 to 15% (12% for the whole country). This will automatically be reduced as the integrated operation comes into force gradually. However, it is to be borne in mind that a larger reserve capacity is needed for reduced outages. On the whole, it appears necessary that the level of reserve capacity in each system may continue to be 15% or so and that there should be a gross margin of 30% overall to meet the peak requirements in the regional system. This means that if there is an outage of the largest generating unit of the system, even then the peak demand of the system can be met without imposing load shedding in the integrated power system of the region. Reliability criteria" however, is also closely related to the consumers' service requirements; whereas somewhat lower reliability would be acceptable to rural loads a very high reliability criteria would be acceptable for continuous process consumers in the petro-chemical, rayon, fertilizers chemical, iron and steel, cement and metallurgical industries. In a country like ours, with predominance of rural bias where large investments are needed on several sectors at the same time, it is necessary to economise in the capital investment and so it would perhaps serve the need of the people if the larger unit size of a system be now limited to 5% to 7% of the peak demand thereby assuming a certain amount of load restrictions in case of an outage of the largest unit. The need of load-shedding could, however, be avoided in the regions which have the hydro-steam combination and availability of enough hydel capacity could be available for emergency assistance in case of an outage of a largest thermal generating unit. Thus, in the regions having hydro-steam optional combination, larger unit sizes which cost much less per kW could be installed and additional reserve capacity for the same may not be required. The Table* (below indicates the system reserve required for different size units for different forced outage rates in a system of 3 million kW capacity with existing smaller units of 100/150 MW capacity:

Size of Unit †	Reserve† required forced outage	For Rates
	1·5%	3%
4%	10%	14%
7%	15%	21%
10%	19%	26%

†As percentage of system capacity.

Three alternatives have been calculated for the same reliability index. It will be observed that the larger size units require more reserve at the same outage rate. The decrease in the cost per kW for larged units has to be balanced against the increase in the reserve cost.

10.9. As power demands and systems have grown progressively, larger unit sizes and large central power stations have proved to be economically feasible and technically desirable as would be evident from the statements under Study Group I. It has been demonstrated that the trend is definitely pointing towards the higher sizes of units raising from 30 MW or below unit sizes before the independence to 5/62 MW sizes followed by 100, 110 and 120 MW unit sizes and now 200/300 MW sizes.

10.10. In this sub-continent of India, the resources of power generation are varied and the distances between the locations which are suitable for hydro-power generations are generally situated far away from the locations of mine-mouth thermal power stations. The load centres are also away from the generating stations. While the hydro-electric power might be cheaper, the time taken in the investigation and construction of these projects is much longer and the total initial investment is higher. Naturally, the loss of power production and correspondingly industrial and agricultural production in an exclusive programme of hydro-electric could be very much which could be obviated if a suitable hydro-steam combination with large thermal generating units at the mine-mouth locations could be developed during 5th and subsequent plans.

10.11. As already mentioned above, apart from various other aspects and studies that are necessary to determine the economic unit sizes, the limitations of design and manufacture of larger unit turbo-generator sets by the various manufacturing undertakings such as BHEL, HEIL, etc. are considered to be of great importance for determining the unit sizes of the turbo-generators. From this point of view, the Government of India have already decided to accept the ready-made design documentation for a sophisticated turbo-generator unit of 200 MW capacity to be manufactured by BHEL with Russian collaboration at the Hardwar Plant. Collaboration with the International Combustion Engineering of U.S.A. has also been made by BHEL for manufacture of boilers to match this 200 MW unit and even for larger units at the Boiler Plant at Trichy. From the general studies that have been made it also appears proper that 200 MW unit size definitely fits in economically in the regional systems to meet the peak demands and energy requirements in all the four regions, *i.e.* Western, Northern, Southern and Eastern. As a matter of fact, Western, Northern and Southern regions are capable of even accepting 275/300 MW unit size immediately. About 10 million MW of installed capacity of steam plants will be required to be added by about 1980. It would not be at all possible for BHEL's Hardwar Plant to meet the requirements of all the larger units for the above generation within this time limit, when 200 MW unit is just being developed in 1971-72. Therefore, it is considered advisable and expedient that HEIL should also enter into certain collaboration with the foreign firms to develop a reliable

*From a paper on "Operations Research Applications by Mr. F. C. Kohli, G.M., Tata Consultancy Services."

275/300 MW generating unit for the steam stations. However, it is to be mentioned that this size would remain economical until 1975-76 beyond which the system will develop to a much larger capacity for meeting a peak of about 10,000 MW or above when, perhaps, the maximum unit size could go up to 500/600 MW. From the consideration of both manufacturing and design it appears proper and economical that the BHEL should concentrate on the 200 MW unit size and also develop 500 MW unit within the next 7-10 year but with sub-critical steam pressures and one or two such large units could be put in operation in one of the regions in order to obtain experience on the proto-type so that these large units could be put into operation in other regions also from 1981 onwards. Similarly, HEIL should immediately arrange for collaboration with the foreign firms for manufacturing 275/300 MW unit simultaneously alongwith their 120 and 110 MW units in order to be able to supply the same to various regions to meet the requirements of these regions during the Fifth Plan period. HEIL should also simultaneously take into consideration the manufacture and development of a 600 MW unit by about 1980 so that the same could be used in the latter half of the 7th Plan and therefore, comparative statements of heat rates and economics of generation from larger units upto 500 MW unit size are enclosed at Appendix 10-2.

APPENDIX 10-1

COMPARISON OF 200 MW, 300 MW & 500 MW UNITS

Sl. No.	Station capacity MW	1×500	2×300	3×200
1.	Cost per KW installed Rs.	1180*	1300*	1380
2.	Heat rate-Kcal/KWhr at a back pressure of 0·085 0·085 kg/cm² abs.	1940*	1960*	2020
3.	Annual generation/kW installed kWhr assuming six weeks outage and 90% availablity.	6900	6900	6900
4.	Auxiliary consumption %	8	8	8
5.	Units sent out per year per kW installed kWhr.	6348	6348	6348
6.	Assumed Boiler efficiency %.	86	86	86
7.	(a). Fuel consumption in kg/kWhr assuming coal of 3500 kcals/kg. (Grade III).	0·6446	0·6511	0·6711
7.	(b) Fuel consumption in kg/kWhr assuming coal of 5900 kcal/kg (Grade I).	0·3824	0·3863	0·3981
8.	Coal consumption per year/kW installed in kg.			
	(a) with coal of 3500 kcal/kg.	4448	4493	4631
	(b) with coal of 5900 kcal/kg.	2640	2665	2747
9.	Annual coal cost per kW installed.			
	(a) At Rs. 30/tonne for coal of 3500 kcal/kg.	133·44	134·79	138·93
	(b) At R.s 33/- tonne for coal of 5900/- kcal/kg.	87·12	87·94	90·65
10.	Operation & maintenance charges /kW installed @ 1·75%.	20·65	22·75	24·15
11.	Fixed charges per kW installed @ 9% of cost/ kW (5% interest) +4% depreciation) Rs.	106·20	117·00	124·20
12.	Total running & fixed charges per kW installed capacity.			
	(a) At Rs. 30/tonne for cal of 3500 kcal/ kg.	260·29	274·54	287·28
	(b) At Rs. 33/ tonne for coal of 5900 kcal/ kg.	213·97	227·69	239·00
13.	Cost/kWhr generated paise/kWhr.			
	(a) At Rs. 30/- tonne for coal of 3500 kcal/kg.	3·77	3·98	4·16
	(b) At Rs. 33 tonne for coal of 5900 kcal/kg.	3·10	3·30	3·46
14.	Cost/kWhr sent out paise/ kWhr			
	(a) At Rs. 30/ tonne for coal of 3500 kcal/kg.	4·10	4·32	4·53
	(b) At Rs. 33/ tonne for coal of 5900 kcal/kg.	3·37	3·59	3·76

*Project Values.

APPENDIX 10-2

COMPARATIVE STATEMENT OF MAIN CHARACTERISTICS OF UNITS

	60 mw	100 mw	110 mw	130 mw	200 mw	300 mw	500 mw
1. Pressure Kg/sq. cm. (abs)	90	90	130	127·5	130	240	240
2. Temperature °C	525	535	535	538	565	570	570
3. Reheated steal Temp. °C.	—	—	535	538	565	570	570
4. Back Pressure ata.	0·0918	0·098	0·095	0·104	0·035	0·035	0·035
5. Heat rate K cal/Kwhr	2334	2310	2155	2061	1937	1860	1840
6. Heat rate 0·095g. /Cm² B.P.		2304	2155	2050	2047	1951	1930

CHAPTER 11
NUCLEAR POWER STATIONS, SCOPE OPERATIONS & COSTS

11.1. Demand for electrical energy

11.1.1 An estimate of the growth of installed capacity in India by the end of the Fourth Five-Year Plan i.e. 1974 puts it at a total 23,000 MW; the growth rate during the first three plan periods works out to 12.7% per annum. It is well understood that the economic penalty involved in pessimistic planning of electrical capacity is many times greater than the penalty arising from optimistic planning. Even assuming for the future a more conservative growth rate, the country will need by 1980 about 50,000 MW of installed capacity.

11.1.2 In the year 1968-69, according to a Planning Commission Paper* ? 42 per cent of commercial energy consumed in India was based on coal and lignite, 49 per cent on oil and 9 per cent on electricity. By 1973-74, the proportion of these three forms is anticipated to be 35 per cent, 55 per cent and 10 per cent respectively. If this trend is accepted, the consumption of oil will go up from 84 million tonnes of coal replacement to 152 million tonnes of coal replacement. In the context of our dependence on foreign imports of crude, inspite of development on a high priority of domestic sources which are as yet limited, this will result in major import of petroleum feed stock involving a substantial drain of foreign exchange. The only way of avoiding this situation is to increase the dependence on electricity as a source of energy. While in areas close to coal mines the generation of energy can and should for the time being be based on coal, large regions of the country are remote from deposits of coal by more than 800 Kms. These regions constitute 35% of the country by area and 30% by population. They include the principal communities engaged in activities needing energy in rapidly increasing quantities for industry as well as for agriculture. The transport of coal to these areas involve major investments on the transport system, for which the requirements of capital are large and the recurring economic penalty is substantial. In all such areas, where suitable sites for hydro power development are not readily available, atomic power would clearly provide the most advantageous solution.

11.2. Need for Nuclear Power

11.2.1 As indicated elsewhere, the per capita electrical capacity and energy consumption in India is one of the lowest in the world and this highlights the very unsatisfactory energy situation which needs to be advanced at a very high rate. India's need for electrical capacity should be considered keeping this in view. Today the generation of electricity is mainly from hydro and thermal based on coal. In the years to come, even if all the economical hydro stations are exploited and large proportions of the coal raisings are burnt for the generation of electricity, there would still remain a large gap to be made up by newer sources of generation in the country. It is in this background that practically all the countries in the world have taken advantage of the latest technical developments and nuclear power is making an important contribution in meeting the growing electricity demands.

11.2.2 It is worthwhile comparing the role of nuclear power in India according to the revised proposals at the Atomic Energy Commission of 2700 MW of nuclear power by 1980, with the position anticipated in some of the developed countries.

NUCLEAR POWER AS PERCENTAGE OF TOTAL INSTALLED CAPACITY

Country	1975	1980
United Kingdom	15	27
United States of America	21	29
Japan	15	22
India	5	6

Even with the revised Indian target implemented by 1980, India would still be lagging behind other countries in taking advantage of this new source of energy.

11.3. Preparatory steps

11.3.1 The Government of India in the Department of Atomic Energy had taken preliminary steps as far back as 1954, to prepare themselves for a large atomic power programme in the future. They started with experimental reactors, thereby building up a band of scientists, engineers and technicians well up in specialised field of nuclear sciences and engineering. With this programme of training, India was able to muster enough technical manpower to embark on a conservative programme of nuclear power.

11.3.2 In 1964, work was started on the first atomic power station at Tarapur, near Bombay, with an installed capacity of about 400 MW, based on slightly enriched uranium as fuel. This has been followed by another station in Rajasthan, near Kota (RAPP), which is nearing completion. Work on the third one at Kalapakkam, in Tamil Nadu (MAPP), has also started. Both these stations are based on natural Uranium as fuel, using heavy water as moderator; a type that has been developed in Canada and is commonly known as CANDU type.

*'A Plan for Energy Development in India'—February, 1970.

11.3.3 When the Tarapur Project was taken up in 1960, there was in the country, as there is even now in some quarters, considerable argument about the relevance of nuclear power in India on economic considerations. Global tenders were, therefore, invited for the construction of Tarapur reactors to demonstrate the point that was held by the Atomic Energy Commission that even on cost considerations, nuclear power could be competitive with the power from fossil fuel in Western India. Tarapur was approved with the full knowledge that being based on enriched Uranium for fuel and with a domestic programme which at that time did not contemplate the establishment of enrichment of facilities, fuel would have to be imported from abroad throughout the life of the station unless of course plutonium re-cycle in such reactors became a practical proposition and plutonium from subsequent natural uranium reactors was diverted to fuel Tarapur. Operations since the commissioning of Tarapur in October, 1969 have fully borne out the economic viability of atomic power in Western India.

11.4. Nuclear programme to safeguard the future

11.4.1 Nuclear power stations based on natural uranium of the CANDU type, have relatively high investment costs, about Rs. 3,100 per KW of installed capacity for a twin 235 MW unit station, as against Rs. 1,700 to 1,800 for conventional thermal power stations (see para 9.1.2). The incremental cost for fuel in the case of such nuclear stations is very low, of the order of about one paisa per KWH as against a much higher fuel cost of conventional thermal stations situated away from the coalfields. The relative economics of any one type of power plant should perforce be decided not only by the straight economic factors of other types of plants, but also by consideration of other features such as the demand for power in the area and the available means for meeting it. A large number of factors will thus have to go into the decision for expanding the electric power system covering a large area over a period of time.

11.4.2 Although the initial investment needed for nuclear power stations may be somewhat higher today than for thermal power stations of the same size, this additional capital investment will have to be considered necessary for the large purposes of meeting the demands for power in the future, than for power production at any point of time. A major fraction of the nuclear power capacity in India in the immediate future will be installed in natural uranium power reactors which are dual purpose stations producing power on the one hand and plutonium on the other. Plutonium is a concentrated fuel which is not available from outside as a commercial commodity and its production is essential in order to enable the country to set up breeder power stations using thorium and depleted uranium for the next stage of its programme. Such power stations would have lower capital cost than the present ones and the indications are that power from these may be even competitive with power from conventional power stations close to the coalfields. It will not be possible for India to take advantage of these new developments in the future unless steps are taken now to set up dual purpose power stations for producing plutonium.

11.4.3. The significance of the production of plutonium for the ultimate power programme of India is thus one of the major considerations for launching a power programme based on the use of natural uranium. It is estimated by the Atomic Energy Commission that to support a programme of one new 400-500 MW fast breeder reactor every other year during the 1980s, it would be necessary to have approximately 900 Kgms of plutonium per year. For this amount, it is necesary to have roughly 2700 MW of installed capacity of CANDU type reactor working at 75% plant factor.

11.5. Nuclear power programme

11.5.1 The development of nuclear power programme in the country is proposed to be divided into three stages.

Stage 1 involves the establishment during the present decade of natural uranium fuelled and heavy water moderated thermal reactors which could provide adequate annual production of plutonium to fuel commercial fast breeder reactors contemplated in the next decade. Simultaneously, proto-type advanced thermal reactors as well as fast breeder test and proto type reactors would be constructed to gain experience of a new technology.

Stage 2 from 1980 to 1985 would involve the breeding of U-233 from thorium in thermal and fast breeder reactors so as to have an inventory of U-233 to go over to a thorium breeder cycle in the third stage. Simultaneously, thermal and fast breeder concepts based exclusively on the thorium cycle would have to be developed to a prototype stage.

Stage 3 beyond, 1985, there could be four types of reactors simultaneouly in operation, namely, natural uranium fuelled thermal reactors, advanced thermal reactors, plutonium fuelled fast breeders and breeders using the thorium cycle.

11.6. Operation of Tarapur

11.6.1 As mentioned before, Tarapur station is now the nuclear power station operating in India, and this has an installed capacity of 420 MW, comprising of two units of 210 MW each, supplying power, on a commercial basis since October, 1969, to the combined Maharashtra and Gujarat systems. This capacity constitutes about 20% of the combined Maharashtra and Gujarat systems installed capacity. Appendix 11-1 gives information regarding total energy generated, net energy sent out, one hour peak load, availability factor etc. The average online availability for the calendar year 1970 was more than 82% taking into account the planned outages and other short-term stoppages, and this compares favourably with similar stations even in the United States of America.

11.6.2 The station has supplied a large part of the total power requirements of Maharashtra and Gujarat and the effect of this has been apparent in that no power-cut had to be imposed in Maharashtra even when Koyna lake was depleted. The station has demonstrated large-scale commercial utilisation of atomic energy in India over a fairly prolonged period.

11.7. **Rapp and mapp stations**

11.7.1 The Rajasthan Station is being built by Indian engineers with the assistance of Canadian Consultants. In the setting up of Kalapakkam project a major step towards self-reliance has been taken. There will be no foreign collaborators in respect of this project. The cost of foreign exchange component is about 60% for RAPP-1 and 40% for RAPP-II and for MAPP this will be around 20% only. As regards fuel, only 50% of the first stage of RAPP-1 will be imported from Canada. Except for this all the fuel requirements will be met from Indian sources. The requirement of heavy water initially will be obtained on lease from Canada. Additional heavy water for future stations will be met from Indian sources.

11.7.2 With the transfer of know-how of design and engineering from Canada, self-sufficiency is being achieved by gathering experience and first hand knowledge in construction—a sole responsibility of the Department of Atomic Energy. This has brought in its wake abundant problems like procurement of equipment, utilisation of available materials, and adopting modern techniques for maximising the utility of these materials both in manufacture and during construction with guaranteed assurance leading to safety. Most of the problems that have arisen have been overcome satisfactorily including a large scale indigenisation programme and has effectively set the pace in India for further nuclear power stations.

11.8. **Cost Factors**

11.8.1 The cost of power generation at Tarapur and the estimated costs at Rana Pratap Sagar and Kalapakkam stations have been worked out strictly on the lines suggested by the Power Economy Committee, so that comparisons could be made with the costs of power from thermal stations given in the Report. These costs are indicated in Appendices 11-21(A) and (B). With the adoption of larger unit sizes of the order of 500-600MW, which is under investigation, it has been estimated by the Atomic Energy Commission that a reduction of about 33% in capital cost can be achieved. Nevertheless, it will be noted that the cost of energy generation from a 235 MW CANDU type reactor at about 6 paise per kWs would be competitive with the prevailing cost of generation at most of our thermal stations, which are situated remotely from the coal fields, even after allowing for stand-by provisions. We are, therefore, undoubtedly on the right path of low-cost generation, in depending on nuclear power stations as cheaper of the alternatives, in places where hydro power is readily available and coal has to be carried over long distances.

11.8.2 At the request of this Committee the Atomic Energy Commission has furnished to it a break-up of the capital costs of Rana Pratap Sagar and Kalapakkam Power Stations, which is enclosed as Appendix 11-3. It will be seen that the engineering inspection and commissioning costs in the case of Rana Pratap Sagar are about Rs. 21 crores and in the case of Kalapakkam, about Rs. 10 crores. The first reaction would be that the sum of Rs. 21 crores to cover the charges referred to above is too much on the high side. The reason is apparent. When technology has to be imported, the country has to pay a very high price for it. One of the chief reasons for comparatively much higher costs of the generating plant and equipment manufactured by the indigenous manufacturing industry is that designs and some of the basic components have to be imported by these factories and for which heavy payments have to be made to the collaborators. This points to the need of attaining self-sufficiency in the fields of engineering and design.

11.9. **Enrichment of Uranium**

11.9.1 The use of slightly enriched uranium in thermal reactors involving the use of boiling light water in the coolant circuit while still using heavy water as moderator will result in savings in capital costs. The fuelling costs are also likely to reduce. So far, the enrichment of U-235 was considered out of question for India due to its high costs as well as enormous electric power consumption. This analysis was based on gaseous diffusion technology. With the marked progress now, however, of the gas centrifuge technology, which is less expensive, the Department of atomic Energy is entrusting itself with serious developmental works towards it, which involves not only sophisticated chemistry and machine technology but also production materials which are strong and corrosion resistant and is time consuming.

APPENDIX 11-1

TARAPUR ATOMIC POWER STATION—UTILISATION AND PLANT AVAILABILITY

Installed capacity—420 MWe (Two Generating sets rated 210 MWe each)

Period	Total energy generated MU	Net energy sent out (Million Units)			One hr. peak generation MW	Availability Factor			Plant Factor %
		MSEB	GEB	Total		Unit 1 %	Unit 2 %	Combined %	
1	2	3	4	5	6	7	8	9	10
November 1969	166·126	75·732	78·114	153·846	314	98·1	92·2	95·15	54·94
December 1969	151·487	69·393	70·111	139·504	312	88·4	79·0	83·70	48·49
January 1970	174·407	75·318	85·936	161·254	304	91·2	96·2	93·70	55·81
February 1970	165·243	75·630	77·206	152·836	320	96·4	94·4	95·40	58·55
March 1970	213·416	115·145	83·649	198·794	367	95·0	86·7	90·85	68·30
April 1970	220·692	120·064	85·314	205·378	420	95·6	84·1	89·85	72·98
May 1970	241·648	129·139	95·938	225·077	420	95·3	96·5	95·90	77·30
June 1970	154·313	73·966	68·193	142·159	338	97·6	86·0	91·80	51·00
July 1970	131·038	59·105	60·914	120·019	226	43·1	90·4	66·75	41·90
August 1970	127·539	58·992	57·399	116·391	251	6·96	98·5	52·73	40·80
September 1970	123·434	58·562	56·381	114·943	249	98·1	3·33	50·72	40·80
October 1970	153·839	72·283	70·046	142·329	310	100·0	32·96	66·50	49·20
November 1970	216·990	95·270	105·672	200·942	373	89·4	98·52	93·96	71·75
December 1970	254·975	112·970	124·614	237·584	390	100·0	100·0	100·0	81·60
January 1971	267·727	126·400	124·049	250·449	402	99·5	100·0	99·75	85·66

NOTES: 1. Unit I on annual inspection/maintenance from July 14 to August 29, 1970.
2. Unit II on annual inspection/maintenance from September 2 to October 21, 1970.

TARAPUR POWER COST

1. Installed capactiy . . . . . 420 MWe
   Nett capacity . . . . . 396 MWe (on Station 220 Kv bus)

2. Capital outlay exclusive of fuel cost and interest during construction, but inclusive of bonus paid as per station contract due to additional electrical output, etc. established over the warranted value . Rs. 68·3 crores
   Cost per KWe installed . . . . Rs. 1630

3. Cost of first fuel load
   (a) excluding customs duty . . Rs. 18·2 crores
   (b) customs duty paid . . . . Rs. 5·2 crores

4. Interest during construction (National.) . . . . . . Rs. 8·6 crores

5. Annual Operations and Maintenance costs. . . . . . . Rs. 0·7 crores

6. Fuelling cost—
   exclusive customs duty. . . . . 1·63 p/kWh
   incidence of customs duty. . . . 0·41 p/kWh

   2·04 p/kWh

7. Cost of energy. . . . . .

   A. **Basis**

Life	25 years
Interest Rate	6% per annum
Depreciation	1·82% (Sinking Fund)
Annual Plant Factor	75%

   B. Annual charges and cost in paise /kWh:

	Annual charges Rs. crores	Power cost p/kWh
Interest on capital	4·1	
Depreciation @ 1·82%	1·2	
Operations & Maintenance	0·7	
	6·0	
Fuelling cost		2·04
Cost of energy generation		4·21
Cost of energy sent out		4·34

NOTE 1. *Fuelling cost*—The unique features of nuclear fuel give rise to technical and costing problems not applicable in conventional stations. The special cost problems arise from the variety of fissionable materials used, necessity of complex fabrication and handling problems for usage, fuel scheduling *i.e.* the method of approach to equilibrium and the suffing of the fuel in the reactor, possible value for the fissile material of the spent fuel, processing of the spent fuel for recovery of the fissile materials it may contain and the credits due to this. The considerable initial investments and accounting correctly for the variable fuel expenditure and credits during the plant life, as also the financial and technical conditions under which the fuel is obtained add to the problem. Fuel consumption costs allowing for possible credits will differ from the consumption costs for the equilibrium years. The significance of this variation will depend on the length of equilibrium period and plant life. The plant life is also a relevant fuel cost parameter since the initial loading is amortized for the entire life of the nuclear installation.

The fuel cost is also critically dependent upon the fuel performance or burn up, that is the amount of heat obtained from a given weight of nuclear fuel before discharge from the reactor. The fuel burn up is limited by two factors, reactivity and integrity. The first arises from the necessity of having a sufficient amount of fissionable materials to maintain criticality for plant operation. The second is determined by the mechanical and chemical damage suffered by the fuel element as a result of radiation exposure. The estimated requirements for fuelling of reactors has been based on physics and other criteria.

For estimates of unit fuel cost, present-worth method has been adopted, since it permits transforming an irregular set of variable amounts of money separated by varying time intervals into equal amounts spread uniformally over the period considered.

On the basis of best estimates available, the unit energy fuel cost calculates to 2.05/ p/kWh including customs duty.

2. The average unit energy sale price for Tarapur Power has been agreed to be fixed at 5.61 p/kWh, which will form the basis of arriving at a suitable two part tariff.

RANAPRATAP SAGAR AND KALAPAKKAM POWER COSTS

	RAPP 1 & 2	MAPP 1 & 2
1. Installed capacity (two reactors) . . .	440 MWe	470 MWe
Net capacity. . .	400 MWe	430 MWe
2. Capital outlay exclusive of Heavy Water, Fuel and interest during construction . .	Rs. 125 crores	Rs. 144 crores
Cost per KWe installed . . .	Rs. 2850	Rs. 3080
3. Cost of First fuel load.	Rs. 5·2 crores	Rs. 5·6 crores
Customs duty . .	Rs. 0·3 crores	—
4. Interest during construction (National). .	Rs. 18·2 crores	Not yet calculated as the PERT has not been fully established.
5. Annual Operations and Maintenance costs .	Rs. 1·66 crores	Rs. 1·66 crores
6. Fuelling cost in paise/kWh		
Without rebates for Plutonium etc. . .	1·43 p/kWh	1·33 p/kWh
With rebates for Plutonium etc . .	0·83 p/kWh	0·83 p/kWh
7. Cost of Energy		
A. Basis		
Life . . .	25 years	25 yea s
Interest rate . .	6% per annum	6% per annum
Depreciation . .	1·82% (Sinking Fund)	1·82% (Sinking Fund)
Annual Plant Factor	75%	75%

B. Annual charges and Cost in paise/kWh	RAPP 1 & 2		MAPP 1 & 2	
	Annual charges Rs. crores	Cost p/kWh	Annual charges Rs. crores	Cost p/kWh
Interest on capital at 6% and lease charges of heavy water . .	8·7		10·1	
Depreciation . . .	2·3		2·6	
Operation & Maintenance	1·6		1·6	
	12·6		14·3	
Fuelling cost . . .		0·83		0·83
Cost of energy generation . .		5·21		5·46
Cost of energy sent out .		5·65		5·89

C. Details of Fuelling Cost Calculations.

1. Cost of fabricated fuel elements — 500 Rs. /kg of Uo2
2. Average net burn up. . . — 6700 MWD/TeU
3. Effective plant efficiency . . — 26·5%
4. Gross fuelling cost . . . — $\frac{500 \times 100}{6700 \times 24 \times 26 \cdot 5 \times 238} \times \frac{100 \times 270}{}$ $= 1 \cdot 33$ p/kWh
5. Rebates . . . . . — 0·50 p/kWh
6. Net fuelling cost . . . — 1·33—0·50 = 0·83 p/kWh

NOTE 1. Cost of heavy water has not been included in the capital outlay. It has been explained by the Atomic Energy Commission that heavy water would be leased out by the Heavy Water Board to the various Heavy Water Nuclear Stations proposed to be set up. At the end of the station life time, the entire heavy water inventory would remain intact and would be returned to the Heavy Water Board for use in subsequent nuclear stations. However, heavy water make up requirements are included in the annual operation and maintenance costs.

2. The rebate of 0.5 paise/kWh in the fuelling cost is on account of the credits for by-products like depleted uranium, plutonium, etc.

3. The generation costs have been worked out on the lines suggested by the Power Economy Committee. It has no bearing with the sale price.

BREAK-DOWN OF CAPITAL OUTLAYS FOR RAPP & MAPP

Values in crores of Rs.

Sl. No. (1)	Description (2)	Rapp 1 & 2 (3)	Mapp 1 & 2 (4)
1.	Site investigations and improvements, all buildings and structures	10	12
2.	Reactor equipment . . .	30	33
3.	Turbo-generator, condensing feed heating equipment .	16	26
4.	Electrical systems . . .	5	8
5.	Common services and systems	6	9
		67	88
6.	Construction facilities, housing field management and superintendence etc.		
6.1	Temporary construction buildings, equipment and facilities . . .	6·85	5·46
6.2	Field engineering (establishment designers' site representatives) . . .	2·60	0·35
6.3	Field management and superintendence (establishment, site construction forces)	2·82	3·02
6.4	Temporary & permanent housing	2·65	2·09
	Total Rs.	**14·92**	10·92
	Say Rs.	**15·00**	11·00
7.	Engineering, consultancy, inspection, purchasing, commissioning, etc.		
7.1	Engineering (Design efforts by DAE, consultancy, some training and development efforts, etc.) . . .	12·32	5·10
7.2	Inspection (quality Surveillance services in India and abroad including some training and development efforts)	2·47	1·35
7.3	Purchasing . . .	0·50	0·10
7.4	Foreign travel and giving some training and development efforts, deputations of engineers from public/private sector industries etc.	0·72	0·51
7.5	Commissioning (establishment, materials/equipment and heavy water losses).	5·04	2·50
	Total Rs.	**21·05**	9·56
	Say Rs.	**21·00**	10·00
8.	Freight, insurance, customs duty	14	9
9.	Contingency and escalation during construction . .	8	26
10.	Total capital outlay excluding fuel and interest during construction.	125	144

NOTE:

I. It may be pointed out that provision for temporary construction facilities include estimated expenditure on water and power required during the construction period. This expenditure is quite sizeable, and hence, probably the difference when compared to the provision for construction facilities for a thermal power stations. It may also be noted that the temporary construction facilities also include provisions for (a) special reactor component assembly shops required to be maintained under clean and controlled atmospheric conditions and (b) special fabrication and handling equipment/materials required for reactor components. The main reasons why the provision for RAPp are higher than MAPP are :—

1. Remoteness of RAPP site from any industrialised centre for supporting facilities.
2. Provision for zircoloy tube processing facilities which had to be set up at RAPP site, and which are now proposed to be moved to the Nuclear Fuel Complex at Hyderabad where such work for MAPP and other future stations will be undertaken.
3. A shorter construction period envisaged for MAPP as a result of RAPP experience, resulting in lower maintenance cost of construction facilities.
4. Canadian field engineering staff (AECL and MECO's site representatives) at RAPP.
5. The expenditure on temporary housing at MAPp is lower as the permanent housing and community facilities have been set up much earlier as compared to RAPP. Besides civil engineering costs are generally lower in Madras.

II. In case of RAPP, Atomic Energy of Canada Ltd. (AECL) and Montreal Engineering Company (MECO) are the consultants for the nuclear and conventional portions respectively. In case of MAPP, no foreign consultancy has been considered necessary. Consultancy for the nuclear portion is being provided by the Power Projects Engineering Division (PPED) of Department of Atomic Energy, and consultancy for the conventional portion has been divided between Messrs Kuljian Corporation and Messrs Tata Consulting Engineers. It may be noted that the main reasons for higher expenditure for RAPP are :—

1. Design and supervision of development work associated with progressive indigenisation.
2. Higher salaries of Canadian personnel for RAPP (excluding commissioning, expenditure on this account amounts to about 13% as compared to about 5% for MAPP).
3. Training of personnel including those from Public/Private sector industries.
4. Though actually major quantities will be recovered and reconcentrated for further use, some heavy water leakage which is irrecoverable has to be completely written off. It is also envisaged that as a result of RAPP experience heavy water leakage for MAPP would be reduced.

III. The provision for contingency made in the cost estimate is to cover for design changes considered necessary to be incorporated during the construction period as a result of Douglas Point and subsequently RAPP, variation in quantities and costs, unexpected difficulties during manufacture and construction, indigenisation, accidents to structures or equipment, extended deliveries of materials/equipment, etc.

IV. The provision for escalation during construction has been considered necessary as a result of past experience, particularly when the construction period is large. Whilst tenders call for firm price bids, from past experience it has been observed that most bidders quote prices subject to escalation. Some purchase orders placed for equipment/materials containing high content of nickel, copper etc. suppliers have not accepted any ceiling on escalation. Other purchase orders placed on public/private industries, where ceilings have been stipulated on escalation, experience has shown that these amount to between 10-15%.

It is to be noted that when the RAPP cost estimates were originally framed, the provision for contingency and escalation was about Rs. 21 crores. As the cost estimates have been revised and most of the payments actually committed, the provision has now been reduced to about Rs. 8 crores for balance payments. At the end of the project when the final accounting is done, the provision for contingency and escalation would, of course, be nil. In case of MAPP, as the project is still in the very initial stages, provisions for contingency and escalation are high and as project estimates are revised during the construction period, these provisons would be reduced and ultimately disappear when final costs are revised during the construc'ion period, these provisions entire provision for contingency may not be spent, and the unspent amount under this head would be excluded from the final as built station cost.

CHAPTER 12

RURAL ELECTRIFICATION

12.1. Introduction

12.1.1 Rural electrification is one of our most basic needs. It is an indispensable element in the transformation which has just started in the country's agriculture production. It is a key factor in the development of rural industries. It is one of the most important, nay, the most important tool in the hands of the farmers for bettering their lot. It brings with it social, civic and domestic amenities to rural communities. The use of electricity has a very good psychological effect on the rural people as they begin to feel themselves as members of the modern age. It helps to reduce the disadvantages of living conditions in villages and stops the consequent drift of villagers to the towns.

12.2.1 Electric power is one of the best means for increasing the productivity of human labour inside the farm, in the kitchen, stables, workshops and elsewhere. Agriculture accounts for about half of India's national income and also for half of foreign exchange earnings. The agricultural sector is not only the major source of foreign exchange to finance imports and capital investment, but also the largest potential market for the industry.

12.3.1 The expected foodgrains production by the end of 1975-76 to attain minimum daily requirements is estimated to be of the order of 130 million tonnes against the production of about 100 million tonnes in 1969-70. This could be achieved only through extensive irrigation, electrification of pumping sets and by adopting the improved agricultural practices including the use of improved seeds.

12.3.2 In U.S.A. less than 7% of the population engaged in farming not only produces enough food for the country but also a large surplus which is exported. In Germany a relatively small labour force in the agricultural sector produces so much food that they are nearly self-supported. On the other hand, in India about 80% of the population work, directly or indirectly in the agricultural sector but the output of farming is low. Generally, it does not rise above low level subsistence farming except a few areas like Punjab where green revolution has recently taken place. The reasons for this are many but one important factor as to why the productivity of farming is low is that *energy and motive power* on a large scale are not applied for farming as in the developed countries. In order to increase the food production and improve the lot of the villagers, electricity will have to be applied on a very large scale for agricultural production. Intensive irrigation can be increased by electrification of more and more of tube-wells and installation of pump sets for pumping of river waters etc. The average cost of water from tube-wells based on power rate of 15 paise per kWh is Rs. 3.5 per 100 cubic metres (16 paise per 1000 gallons).

12.3.3 It has to be remembered that animals and human beings are very ineffective convertors of energy. Much land is required to maintain the animals when this land could profitably be utilised for increasing food production in the growing population.

12.3.4 In India, upto the 3rd Plan, the emphasis in the rural electrification programme was on the number of villages electrified. After the meeting of the National Development Council in September, 1965, when it was decided to give the highest priority to agricultural production during the Fourth Plan, rural electrification schemes have been oriented to subserve agricultural needs primarily. The schemes for rural electrification from 1966-67 have been formulated with a bias towards providing connections for energisation of irrigation pump sets/tube-wells.

12.3.5 The total number of villages electrified till the end of March, 1970 was 90,258. The number of villages electrified till the end of October, because of the tempo created owing to Gandhiji's Birth Centenary, rose to about one lakh out of a total number of 5,66,878. As against 5.13 lakhs pump sets energised by the end of the 3rd Plan, the total number rose to 13.53 lakhs on 31st March, 1970. It would be observed that there has been a remarkable progress in the programme of providing irrigation facilities through rural electrification during the last few years. The average population served by the electrified villages is about 35% at present.

12.4.1 The terms of reference required that this Committee should review and examine the technical and economical aspects of rural electrification, particularly with a view to enabling the State Electricity Boards and Electricity Authorities to undertake a massive programme of rural electrification and making electricity available at an economical rate. This subject has been very comprehensively dealt with in the report of Study Group 4 of the Committee. Detailed information regarding costs, technical data, yardsticks employed for sanction of schemes etc. was received by the Committee from 10 State Electricity Boards and is incorporated as an Appendix to the Report of Study Group-4.

12.5. Socio-economic Benefits

12.5.1 The general yardstick that is applied for sanctioning of rural electrification schemes is the financial returns on investments involved. But in this manner numerous other advantages—social, economic and other are lost sight of. When these are considered, the schemes perhaps start paying handsome dividends much faster. In order to examine the socio-economic benefits referred to above, a study of the impact of rural electrification in Punjab was taken up by the National Council of Applied Economic Research and the results of this study are contained in their publication "Impact of Rural Electrification in Punjab", May, 1967. The findings of this study are very interesting and a few important ones are given below :

(i) After electrification, there is an increase on an average of 7.63 acres of gross irrigated area per user of pump set/tube-well, the additional income realised therefrom works out to Rs. 237 per cultivated acre. The benefit derived by the user of electricity for pump set/tube-well seems to increase as the size of the village decreases. Thus in a village with a population of less than 1000 this works out to Rs. 256 per cultivated acre per year compared with Rs. 120 in a village with a population of 5000.

(ii) On an average, a pump set/tube-well user saved 354 bullock labour days per crop year, the average saving of which worked out to Rs. 712.

(iii) A farmer using pump set/tube-well saved about 357 days of family or hired labour valued at Rs. 1017.

(iv) On an average, the net income of industrial unit increased by Rs. 1602 per annum after electrification. The industrial user of electricity saved of commercial fuel at Rs. 2417 per annum after switching over to electricity.

(v) On an average, the advent of electricity gained for the villager 1.72 additional working hours per day. The additional time gained for reading was estimated at 1.83 hours per day.

(vi) The villagers experienced a better sense of security after electrification and felt a decrease in the chances of fire.

(vii) Commercial establishments in rural areas benefitted, on an average, to the extent of Rs. 532 per annum as a result of electrification.

(viii) After electrification, there was an increased participation in the cooperative institutions such as Panchayat Ghars, Mahila Mandals, etc. Considerable reduction in the migration of educated youths from rural to urban areas was also reported.

12.5.2 A similar study to assess the impact of rural electrification in Kerala was carried out by the Council of Applied Economic Research in 1968 and the findings of these studies were also similar to those noticed in Punjab.

12.5.3 From the studies carried out by the National Council of Applied Economic Research, it is obvious that rural electrification bestows enormous advantages in agriculture, industry, socio-economic, general etc. The NCAER made out an exhaustive study after evaluating the indirect benefits referred to above and found that in the case of Punjab, the benefit-cost ratio of all the rural electrification schemes was well above unity which proves that the schemes undertaken are economically justifiable. It was also found that the benefit-cost ratio for the villages within the group (less than 1000 population) is much more than the benefit-cost ratio for the villages of bigger size. If this criterion rather than the basis of overall direct return on capital is accepted, the economic feasibility of electrification of villages would stand justified. The Committee would recommend that the benefit-cost ratio of different rural electrification schemes should be worked out and this should be taken into consideration while considering schemes for sanction and execution.

12.6. Balanced Regional Development—Preference to backward areas

12.6.1 Regional differences between better developed and less developed areas do not seem to be taken into account while preparing project reports in some States. The selection of rural areas for electrification is mainly done on the basis of financial yardsticks, nearness to electrical installations including H.T. and feeder lines, population, accessibility and such other factors. In some States, preference used to be given for electrification of backward areas. Some years back the composite State of Punjab laid down a policy to give preference to the hilly and backward districts in the matter of rural electrification. Separate funds were earmarked and a number of projects were sanctioned for extension of electricity to backward districts like Mohindergarh, Hissar, Kangra, Sangrur, etc. In Mysore, preference in rural electrification has been given to backward districts (Malnad areas) for which a lower level of gross revenue return was specified. In a few other States like Andhra Pradesh. Bihar, Maharashtra and Uttar Pradesh where although the financial policy and yardstick of returns show no differentiation between forward and backward regions for rural electrification, some preferential treatment is accorded to backward or hilly areas in the actual execution of the programme.

12.6.2 The order of priority followed in the selection of villages for rural electrification in different States does not seem to indicate that it has been spelt out fully. Broadly speaking, remunerativeness, nearness to main transmission lines, population, and accessibility have been the guiding criteria. Due consideration should be given for electrification programmes in backward areas. Also to the extent possible, rural electrification should be taken up in a concentrated form in compact blocks of area with considerable agricultural or other potential as such a programme will lead to an integrated area development and yield richer dividend in the future.

12.7. Financing

12.7.1 Earmarked Central assistance was provided by the Government of India for rural electrification schemes up to 1968-69 which amounted to Rs. 254

crores. Since the beginning of the Fourth Plan, no earmarked Central assistance is provided for rural electrification schemes and the expenditure on such schemes is incurred by State Governments from the State Plans inclusive of overall Central assistance provided to the State Governments. In the Fourth Five-Year Plan, outlays in the State Plans are expected to be of the order of Rs. 285 crores and the Plans of the Union Territories of the order of Rs. 9.5 crores. In addition to the above amount of Rs. 294 crores, Rs. 150 crores will be made available by the Rural Electrification Corporation as also has been discussed in detail in para 9. Various commercial institutions like L.I.C., Land Development Banks, Agricultural Refinance Corporation, Commercial Banks, Agricultural Finance Corporation etc. have been providing funds to the State Electricity Boards for rural electrification and the extent of the institutional finance expected to be available to the Electricity Boards during the Fourth Plan period has been broadly estimated at about Rs. 75 crores by the Working Group on Power. Detailed position and terms of various loans in this behalf have been discussed in Chapter-4 of the Report of Study Group No. 4.

12.7.2 Survey of the financial position and problems of the State Electricity Boards shows that inadequacy of funds has been hampering their efforts for rural electrification. There is a strong case for giving them financial assistance on specially liberal terms if a massive programme of rural electrification is to be promoted and intensified. So far not much assistance of this type has been actually made available. The desirability of working out a suitable pattern of financial assistance to the Boards for the rural electrification programme can hardly be overstressed. In this connection, it may be stated that in foreign countries, subsidy has been given for rural electrification in one form or the other. Arguing that rural electrification is not remunerative, at least in the initial stages, the State Electricity Boards which are the authorised agencies for the execution of this programme, have emphasised the need of financial assistance in one form or the other. The parallelism has been cited in the assistance for rural electrification provided in foreign countries such as Belgium, France, Italy, Switzerland and Canada where subsidy has been given at varying rates. These are indicated in para 4.3.1 of the Report of Study Group 4. In U.S.A., long-term loans at low interest (2% per annum) repayable in a maximum period of 35 years are given. Financial assistance to the State Electricity Boards in India can take various forms ranging from out-right grant-in-aid or subsidy to interest free loans or long-term loans at reduced rates of interest. Maharashtra Government charges interest on loans advanced for rural electrification at reduced rates of 1% for the first year, 2% for the second year, 3% for the third year, 4% for the fourth year, 5% for the fifth year and 6% thereafter. One of the recommendations of the Report of the Committee on the Working of the State Electricity Boards, headed by Shri R. Venkataraman (now Member of the Planning Commission) was :—

"to facilitate intensified rural electrification, Committee recommends that the possibility of getting loans interest free for the first 5 years may be explored.'

The Committee would recomend that in order to enable the State Electricity Boards to take up the programme of rural electrification in a massive manner which generally results in fiancial losses, especially in the first few years, financial assistance in one form or the other should be provided to them.

12.8. Prospective Planning for rural electrification in India and magnitude of the task.

12.8.1 There are about 5.66 lakh villages in India out of which only about one lakh have so far been provided with electricity. It is expected that the number of villages electrified by 1973-74 would be about 121000. The number of electrified pump sets by 1973-74 would be about 26 lakhs. The position regarding planning for the period 1974-81 has been discussed in detail in Chapter 2 of the Report of Study Group No. 4. It has been suggested therein that this plan should comprise electrification of additional 28.11 lakh pump sets and of 140,000 villages. In addition, financial provision has to be made for the normal load growth of villages already electrified. On these bases, the requirement of funds for the seven-year period 1974-81 has been worked out as Rs. 1850 crores (Table-1 of the Report of the Study Group). In other words, about Rs. 265 crores annually would be required for the above modest plan against about Rs. 104 crores proposed to be spent annually during the Fourth Plan. Immediate consideration should therefore be given by all the concerned Central and State authorities to ensure that it would be possible to provide about Rs. 265 crores on the average annually for the rural electrification programme during the period 1974-81.

12.9. Rural electrification corporation

12.9.1 In order to arrange for further funds for rural electrification, the Rural Electrification Corporation has been set up by the Government of India in the Public Sector with effect from 25th July, 1969.

12.9.2 During the Fourth Plan, the Central Govt. will contribute Rs. 45 crores to the Corporation and U.S. AID will contribute Rs. 105 crores from U.S.—Use Funds. The capital contributed to the Rural Electrification Corporation during the Fourth Plan will, therefore, amount to a total of Rs. 150 crores. It is expected that with the resources available from the Corporation, an additional number of 5 lakh pump sets would be energised during the Fourth Plan. After taking into account the outlays indicated in the Fourth Plan for State Governments, Union Territories and also the additional resources which can be mobilised by State Electricity Boards, the additional number of pump sets expected to be energised during the Fourth Plan would be about 15 lakhs, which would provide irrigation facilities to an area of about 8 million acres and attains not less than four million tonnes of food grain production

12.9.3 The terms and conditions of loans to be given by the Rural Electrification Corporation are given in the Report of Study Group No. 4. In economically backward areas with future agriculture potential, the requirement of a proper return on investments have been waived for a short initial period not exceeding 5 years.

12.10. **Rural cooperatives**

12.10.1 In order to spread the use of electricity in rural areas, 5 co-operatives have been set up on a pilot basis with the assistance of U.S. AID and the National Rural Electric Co-operative Association of U.S.A. These are, one each in the States of Andhra Pradesh, Gujarat, Maharashtra, Mysore and Uttar Pradesh. The Cooperative Societies have been already formed and registered. These 5 rural co-operatives will be financed by the Rural Electrification Corporation. The purpose of introducing pilot co-operatives is to achieve the following :

(i) Furnish electricity to the rural people at a reasonable cost in order to increase agricultural production; stimulate small agro-industry; and improve the standard of living for the rural population.

(ii) Increase responsible action of the people by giving them some degree of control of their electricity supply.

(iii) Establish local organisations for the financing, procurement, installation, repair and proper use of electrical appliances and equipment such as pumpsets.

(iv) Provide the basis for a rapid and standardised pattern of construction and operation for rural electric systems in all States of the Union.

(v) Provide meaningful training experience for Indian personnel involved in rural electric co-operative activities so that they can help other such co-operatives.

12.10.2 The co-operatives will enthuse the spirit of ownership in the villages and thus help to avoid damages to the electric installations and theft of energy. If co-operative use of pumping sets, electric machinery such as threshing machines, drying facilities for fruit, cold storage facilities, etc. is organised, it will result in many advantages. Purchase of such machinery by individual farmers may not be possible especially in areas within an unsatisfactory agricultural production. The appliances would be too expensive and their insufficient utilisation may not, because of the high cost, increase profitability of the farm. In the co-operative method the poor farmer can take full advantage of electricity for his work. Further, this would result in a better load factor for the power supply authorities because the use would be spread over a number of hours. It will go a long way if the co-operatives set up electrified farms which would set an example to the farmers as to how the power should be utilised to better their lot and to improve their revenues. These farms will also serve the purpose of supplying necessary data to the electric utilities as to how the consumption of farms can be used and as to how the load factor can be improved.

12.11. **Integration of rural electrification with rural Industries etc.**

12.11.1 In order to derive the optimum benefits it would be best to integrate the rural electrification programme with the programme for installation of tube-wells/pump sets and that of rural industries. This question also came up for consideration in a meeting held by the Planning Commission in July 1970. Two suggestions that emerged were : (a) setting up of a Co-ordination Committee at the level of the State Electricity Boards; and (b) similar committees at the district levels. The Committee at the Electricity Board level should help the Boards in formulating the new schemes of rural electrification with reference to the potential demand for power for agriculture as well as small industries, it could review the progress of implementation of approved schemes, suggest measures for better utilisation of the load and devise ways and means of encouraging the entrepreneurs to develop small industries by taking advantage of the avaliability of electricity in rural areas. Similarly, the committees at the district level could assist the Board in carrying out a field survey to assess the potential demand for power in the selected areas and in securing better utilisation of power by carrying out the implementation of sanctioned rural electrification schemes with the programme for growth of small industries and development of agriculture. The Committee would recommend that the above suggestions of the Planning Commission and the Rural Electrification Corporation should be implemented by the States.

12.12. **Survey of underground water resources**

12.12.1 After the meeting of the National Development Council in September, 1965, the emphasis in rural electrification has been shifted to electrification of agricultural pumping sets. It is envisaged that during the Fourth Plan, about 15 lakh pump sets will be electrified. The electrification of pump sets is linked with the availability of ground water in the area. All the wells draw upon sub-surface water, shallow or deep depending on the nature and formation of water bearing strata. In the alluvial plains of Punjab, Haryana and Uttar Pradesh, water bearing strata are easily available but in the peninsular plateau, such strata are limited because of rocky sub-surface formation. It is, therefore, necessary that before a scheme for electrification of tube-well is sanctioned, a check for the availability of under ground water should be made. This information can be obtained from the respective Regional Directorates of Geology, which are situated in almost all the Regions. Not only the quantity of groundwater available from an area is important but also its quality. The quality should, therefore be checked before the groundwater is used for irrigation to see that it meets the requirements of irrigation water. The electrification schemes should be considered for sanction only where water availability has been already established.

12.13. Methods for economies in electrification

12.13.1 There are about 5.66 lakh villages in India. Only about one lakh or about 15% have so far been electrified. There are at present about 6 million wells in India irrigating about 20 million acres of land, out of which only about 2.5 million are expected to be energised by the end of the Fourth Plan. In view of the enormous advantages that rural electrification bestows on the villagers, who form the bulk of the population of the country, rural electrification has to be extended to all the rural areas. Yet, it is necessary that in view of our relatively limited financial resources maximum economies should be affected in this work. The sub-transmission systems at 33 kV and above form a part of the transmission systems of the State Electricity Boards and the rural works chiefly comprise the construction of 11 kV lines, 11/0.4 kV sub-stations and low tension lines. An attempt has, therefore to be made towards maximum economies in these works. Study Group No. 4 of this Committee has examined these matters in detail and their recommendations are contained in their report. Briefly these are :

(i) Standardisation of specifications for materials and all construction practices would help in reduction of cost. No complex techniques are involved in erection of rural lines and sub-stations and there is little scope for the reduction of cost by further spohistication of technology. The work, though voluminous and involving considerable capital expenditure, is of repetitive nature. Great deal of economy would, therefore, be possible by streamlining and standardising administrative and construction methods and construction tools and equipment. Standardisation, variety reduction and lowering of cost of enabling mass production of all the equipment and fittings will yield substantial economies. Indian Standards Institution has worked out specimens of some of the basic construction materials required in rural electrification. The specifications however do not cover all items and views in those items for which specifications have been standardised; the practices adopted by different State Electricity Boards are not uniform. There is, therefore, a large scope for evolving standardised designs and specifications and ensuring the actual use of standardised design and materials in the work. The Rural Electrification Corporation has set up a Special Cell for this purpose and we are glad to note that the State Electricity Boards have welcomed this move and expressed their readiness to cooperate with the Corporation in this important task. Standardisation can lead to economy in cost and help the even flow of supplies by making it possible for manufacturers to keep in stock materials of standard specifications and designs instead of having to suit their manufacturing capacity every time to the varying requirements of different State Electricity Boards.

A few manuals on standardisation are brought out by the CW&PC years back. It is suggested that the Rural Electrification Corporation in consultation with CWPC and the State Electricity Boards should revise these manuals keeping in view the latest experiences gained in this country as well as in other countries.

(ii) from the information given in the Report of Study Group No. 4 it would be seen that the cost per kilometre of 11 kV lines varies from Rs. 6,300 to Rs. 13.000. The variation in the cost can be attribuited to the method of construction and type of materials used. For bringing about economy in the construction of 11 kV lines, it is necessary to adopt uniform and most economical procedures and specifications as explained in the preceding para.

(iii) In transmission and distribution lines various sizes of ACSR are being used. In a Seminar which was recently organised by the REC and attended by the senior representatives of the State Electricity Boards it was decided that 0.03 and 0.05 sq. inch copper equivalent ACSR should be used both for 11 kV and low tension lines. All aluminium conductors are not to be entirely given up in low tension lines but wherever ACSR is to be employed, the above sizes should be used.

(iv) The type of poles varies from State to State. PSC, RCC, Steel structural sections, second-hand rail poles and wood poles are being used according to availability. It is high time that one or two types which are most economical and easily available are adopted. RCC and PSC poles appear to be the best choice under the prevailing conditions. The use of fly ash for partial substitution of cement for the fabrication of such poles should also be used. The fabrication should be arranged at a number of suitable places in order to reduce transport charges.

(v) Labour and transport forms about 15 to 20% of the total cost of the lines. If the villagers can be enthused to supply labour and transport free of cost, enormous savings could be effected which would result in electrification of more villages with the same funds. It is understood that this experiment has been already tried in a couple of States. Another advantage of such a method is that the villagers will feel that these are the works created by them and are likely to ensure that no damage is caused. This method should be extended on as large a scale as possible. For this purpose, however, it is necessary that the concerned officers of the State Electricity Boards are suitably trained in human relations etc. so that they can enthuse and persuade the villagers to offer free labour and transport services in a tactful manner.

(vi) Some States have successfully adopted the use of multiple earth return in low voltage systems where only one wire is used to serve both as neutral and earth wire and it is earthed at frequent intervals. Other states may follow suit especially in rural areas.

(vii) In Australia a significant feature of rural electrification has been the extensive use made of single wire earth return (SWER) distribution. This system which uses the earth as a return both in conjunction with a single high voltage conductor, has a low initial capital cost (upto 30% less than conventional distribution system). This use has promoted the economical extension of electricity supply in Australia to many isolated rural consumers. Merits and demerits of this system have been discussed in detail in the Report of Study Group No. 4. Experimental lines have been already set up by Tamil Nadu, Mysore, West Bengal and Punjab State Electricity Boards. The research unit of the Ministry of Industrial Development and Internal Trade at Bhopal has developed a converter for transforming single-phase into 3-phase supply. Further research work should be carried on at a faster speed by all concerned so that this method can be applied on an ever increasing scale for electrification of villages especially the small ones with a population of 500 or less whose load demands can be catered by single-phase supply.

(viii) In rural areas the cradling below 11 kV lines and that between 11 kV and LT lines in the case of composite lines should be dispensed with except on strategic points such as crossings etc.

(ix) Anti-climbing devices and danger plates should be omitted in rural areas.

12.13.2 11/0.4 kV *Sub-stations* : The question of effecting economies in 11/0.4 kV sub-station was discussed in a Seminar recently organised by the Rural Electrification Corporation. The subject has been also dealt with in detail in the report of Study Group No. 4. The cost of 100 KVA transformer, 11/0.4 kV pole sub-stations varies from Rs. 8,300 to Rs. 15,600. Standardisation of equipment and construction practices can bring about considerable reduction in the cost of rural substations. The following suggestions are made in this regard :

(i) Some State Electricity Boards are using economical type of gang-operated switches. These switches are at present being made for a rating of 200 amperes. The full load current of 100 KVA transformer at 11 kV is about 5.5 amperes of course the fault current will be much higher. There is scope for considerable reduction in the current ratings of isolating switches. However, economies can be made by employing steel jaws and steel blades instead of copper. The State Electricity Boards may instal some percentage of the sub-stations with the simplified gang-operated switches, as above and gain experience. The method can then be further extended.

(ii) Omission of 11·kV lightning arresters from transformer substations upto 50 KVA in all the regions and upto 100 KVA in areas with low isoceraunic level. Instead, arresters may be installed only at strategic points.

(iii) Use of transformers with low iron loss and high copper loss. This will help in keeping the losses low as the load factor is very low in rural areas.

(iv) In the Seminar organised by the Rural Electrification Corporation referred to above, it was decided that the use of 25 KVA, 50 KVA and 100 KVA transformers should be standardised as this would help in considerable reduction of manufacturing costs. Decisions in the Seminar were also taken about omission of (i) off-load tap changing switches from 25 KVA and 50 KVA transformers, (ii) Conservators, (iii) Filter valves, (iv) Rollers etc. If transformers are standardised and manufactured on these bases, considerable economies in their cost would accrue. Installation of transformers of capacities to match with the anticipated loads in only the next 2 to 3 years and avoiding installation of large capacity transformers as far as possible. In the continuous process of electrification, the transformers can be replaced after some years as may become necessary. This would result in initial capital saving as well as reduction in distribution losses. The low tension switch should be installed on the sub-station structure itself to economise on the length of low tension cables.

12.14. Incentives for use of electricity in rural areas

12.14.1 The use of electricity in rural areas will result in revolutionising the agricultural and industrial economy of the villagers and also go a long way in modernising their habits and social activities. If the country has to progress, it is necessary that the economic lot of the villagers who constitute about 80% of the country's population is ameliorated considerably. The use of electricity has therefore to be spread out in rural areas as best as possible. At the same time it has to be remembered that at present the bulk of the villagers are poor and do not have necessary finances for purchase of pumpsets, electric driven appliances etc. Therefore suitable incentives are required to be provided to encourage them to go in for the use of electric power. The subject has been studied in detail by Study Group No. 4 of this Committee and their recommendations in this behalf are summarised below :

(i) The rate for supply of power should be as low as possible. Of course the rate at which energy is to be sold should be arrived at after making provision for all necessary expenses connected with generation, transmission and distribution including depreciation and interest charges so that the State Electricity Boards and the Electric Utilities do not incur any undue losses. It is, therefore, imperative that generation, transmission and distribution costs are reduced to the maximum extent. The question of reduction in these costs has been discussed at length in the report of Study Groups 2 & 3. The question of reduction in the cost of rural lines and sub-stations has been discussed in para 12.13.

(ii) In the case of the State Electricity Boards where the minimum consumption guarantees are high at present these should be reduced to a reasonable figure.

(iii) For rural industries also the minimum consumption guarantee should be reduced to a reasonable figure.

(iv) The revenues realised from electricity duty should be earmarked for works connected with the electrification of rural areas.

(v) For distances exceeding 100 ft. from the distributing main, the State Electricity Boards should provide free services connections if the cost does not exceed a certain figure per BHP of connected load. It may be stated that in Tamil Nadu this has been fixed at Rs. 60.

(vi) Whenever wells go dry or pumping is not possible on account of insufficiency of water, the minimum guarantee charges should be waived during such periods.

(vii) Agricultural services should be allowed installation of 3 light points upto a connected load of 100 watts for farm use and these should be charged at the agricultural tariff.

(viii) Co-operative use of agricultural machinery like threshers, chaff cutters, etc., should be arranged and encouraged. The pilot rural electric co-operatives which are being set up in 5 States should try this experiment.

(ix) The agricultural services should not be disconnected if there are standing crops.

(x) Loans for purchase of electric motors and pumps repayable in easy instalments should be made available to the farmers by the concerned Central and State Agencies.

(xi) Service stations with mobile squads which should take up work of internal wiring etc. on behalf of the farmers at reasonable charges need to be set up at different centres. These units should also take up the maintenance work etc. for the rural consumers on reasonable charges. It is suggested that the State Governments should organise suitable rural Technical Centres. These could utilize unemployed technical personnel. They should be given necessary incentives to offer their services to the farmers. The State Electricity Boards should also set up such centres or assist in their establishment. This has been examined in detail in para 7.2.1 of Report of Study Group No. 4.

(xii) The rural co-operative should try to set up experimental electrified farms. These farms will set an example to the farmers as to how the power could be utilised to better their lot and to improve their revenues. These farms will also serve the purpose of supplying necessary data to the electric utilities so as to how the consumption of farms can be increased and as to how the load factor can be improved.

(xiii) The standard of reliability of power supply to the rural consumers should be maintained at the same level as in the case of urban consumers so that, the farmers may be confident that the electric supply will not leave them at the time when needed the most.

(xiv) After the necessary formalities have been completed, the connections to the rural consumers should be given within a very reasonable time and there should be no undue delay in this.

(xv) With the growth in the consumption of electricity and dispersal of electrification to the rural areas, the demand for tehcnical personnel will increase considerably. A carefully worked out programme of expansion of short-term training facilities in technical schools, polytechnics and similar institutions would be helpful.

CHAPTER 13

RESEARCH AND DEVELOPMENT

13.1. One important factor retarding the growth and vitiating the functioning of power supply industry in an optimum manner is the gross inadequacy of the research and development activities. This is true mainly for the conventional modes of power generation as well as transmission and distribution. Fortunately nuclear power engineering which is just making a start in this country has some very good research and develop ment facilities and organisation available within the country. However, strangely, there has been little development in this respect for conventional power engineering. The research effort required for the power supply industry falls into two broad categories : (i) scientific and technological and (ii) commercial, economic and statistical. The present-day needs so far as the power supply industry is concerned may briefly be outlined as follows :—

13.2. **Technological Research**

13.2.1 *Generation Research* : The broad objectives of the research are to improve the reliability and economy of generation, with due consideration for the effect on the environment.

13.2.2 *Transmission Research* : The general objectives of the programme are to improve the efficiency and reliability of transmission and to achieve effective control and monitoring of the energy supply. As the system grows with the extension of the main transmission network and as generation is increasingly important to study system behaviour throughout the annual load cycle so as to prevent wide-spread dislocation of supply under disturbed conditions.

13.2.3 *Distribution Research* : The objectives of distribution research include development of cheaper cables and joints and improved methods of installing them; evaluation of certain new forms of overhead line conductor; and study of methods of improving system design.

13.2.4 *Utilisation Research* : The aim of utilisation research is to develop new uses for electricity or to improve existing applications.

13.3 **Commercial, Economic & Statistical Research**

13.3.1 Commercial and economic research aims to predict how much electricity will be required in the future, where and for what purposes; to assess load characteristics and the costs of supplying various kinds of load; and to provide information about the buying habits of customers.

13.3.2 The supply industry has to commit itself further in advance than most industries to orders for new plant and equipment. To ensure that capital investment programmes are as soundly based as possible, continuous research is carried out into methods of forecasting customers' demands for electricity up to six years ahead and also in the longer term. This research embraces such subjects as the effects of changes in incomes on customers' choice of fuels, and many of the load and market research projects are designed to obtain the information needed to improve the accuracy of the forecasts.

13.3.3 Load research analyses the pattern of electricity consumption at different times and different seasons under varying weather conditions (in particular, varying temperatures) and it uses both practical and theoretical techniques. Market research into electricity consumption is less concerned with time patterns; it aims rather to discover why customers increase their use of electricity and thus to make better predictions of customers' future behaviour.

13.4 In most of the advanced countries, it is recognized that appropriate research effort plays a vital role in technical and economic advancement of the industry and is largely instrumental in keeping the cost of electrical energy from rising in spite of large increases in the general price levels. Apart from keeping down the cost of electrical energy, the research effort, particularly in its statistical and economic aspects, is essential for providing data base for planning of future development.

13.5 In U.K., the Electricity Council, which is the apex organisation of the electricity supply industry has a statutory duty to settle in consultation with the Minister of Power a general programme of research into matters affecting the supply of electricity and other functions of the Council. A note on Research under the Electricity Council in U.K. is given as an Appendix 13-1. In the USA the Edison Electric Institute, which is a cooperative organisation of the public utilities in the field of electric power supply has been giving the lead in research activities both technological as well as economic.

13.6 In India, some efforts have been made but these have not been sufficiently effective. There is a need for an authoritative body of technical experts backed with necessary laboratory facilities capable of giving unbiased technical opinion or evaluating design and performance of electrical equipment. The CWPC comes closest to this but needs to be adequately equipped for the purpose. A reliable and continuing arrangement for watching the technological and scientific advances elsewhere in the world is required, keeping the Govt. and the power supply industry informed of the latest developments and devising the manner in which and assessing the extent to which, these can be utilised. A follow up study based on collection and analysis of statistical data of working experience with technical advances newly introduced in India is also necessary. The need for such activities is perhaps much

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more for a country like India. It must be remembered that the advanced countries are all in the temperate zone of the globe and most of the technological developments are taking place in those regions. India is easily the most advanced country in the tropics and cannot, therefore, have the benefit of the full experience of any other country in the region under conditions peculiar to the tropics. It is, therefore, necessary to develop our own research and development facilities for evaluation and adoption of new technological advances.

13.7 **Technological Research:** The Central Power Research Institute was set up in 1960 under the CWPC(PW) but this has not made adequate progress. Recently, the awareness of lacunna in this regard has grown and, through the initiative of the Ministry of Irrigation and Power and the Central Board of Irrigation and Power, research units have been formed in each of the State Electricity Boards and a few large electricity undertakings in the country. These have started some work for collection of experience data and analysis of the same for deriving valuable lessons from the performance of the installations in all areas of power engineering under the conditions obtaining in this country. The Government of India in the Ministry of Industrial Development have also set up a Research and Development Organisation for the Electrical Industry (RDOEI) for serving the needs of both the private as well as public sector manufacturing units. While these are welcome developments, these do not go far enough. The universities and higher technical institutes, some of which have highly qualified and competent staff and sophisticated equipment would also normally be expected to play an important role. However, this has not been so. What is required is some way of giving a lead in the field of power research. Some organisation that can identify the types of development and research work required from time to time and can act as a catalyst for new research and development work in different organisations, coordinating or guiding where necessary. It is felt that this, coupled with statistical analysis of performance of the power system components, will greatly help in operating the present generating plants and transmission and distribution systems in the best possible manner under the Indian conditions and, after analysis of current performance and problems, better methods and equipment can be evolved, leading to better efficiency, reliability and economy under the Indian conditions.

13.8 For this purpose, there is an immediate need for broadening the activities of the Central Power Research Institute and making it work in active collaboration with the Specialised Engineering Organisation of the CW&PC in the first instance and with other leading engineering organisations as well as research laboratories as the next step. The Central Power Research Institute should initiate pilot/trial installations of new devices or innovations in collaboration with Specialised Engineering Organisation and the Power System for making a proper study appraisal of their working under Indian conditions.

13.9 An arrangement is already being evolved through the Central Board of Irrigation & Power to bring together and co-ordinate the activities of the Research Units in the Electricity Undertakings on the one hand and Research Institutes like CPRI and RDOEI as well as those of the universities on the other. This promises to be a most rewarding area of activity and deserves to be pursued effectively. One of the main difficulties in achieving applied research work of adequate standard has been the lack of sufficient wide coverage in obtaining basic field data regarding operation under practical conditions. The Research Units of the Electricity Undertakings will play an important role of making such data and information available to the Research Institutes and providing means of giving field trials to the recommendations of the Research Institutes.

13.10 Another handicap in working the power installations efficiently is inadequate knowledge about the actual rating and capabilities of the different components in the power generating plant. Elaborate Acceptance Tests in the field provide the requisite data and information. It is well-known that thorough programmes of such testing proved to be an important factor in technological development both for equipment manufacturers as well as equipment users in countries like U.S.S.R. In order to derive such benefits in the full measure, it is necessary to have these activities carried out through a single organisation independent from both manufacturers and users of power equipment. In India, these tests have had to be waived in a very large number of cases (although required under the Purchase Contract Provisions) on account of various reasons such as non-availability of the requisite testing equipment and expert personnel, the exhorbitant cost (and foreign exchange) in importing these from abroad for any particular installation, the prospective delay in the commissioning of the plant on account of these tests. These troubles can be overcome by having an organisation like CPRI equipped for taking up these tasks. Already a nucleus for field as well as model tests on hydraulic turbines has come up in the Central Water and Power Research Station (CWPRS), Poona. Further work could utilise these CWPRS facilities very usefully. These field tests will enable the power plant authorities to institute (as already recommended by PEC elsewhere) a programme of Index testing and monitoring of the performance and efficiency of the plant. This, in turn, will enable better and efficient operation and checking of any deterioration at an incipient stage.

13.11 In the light of foregoing, there is an urgent need to accelerate the technological, research and development effort in power engineering very rapidly. It is necessary to co-ordinate the efforts of a number of different organisations in the field and to initiate work in new areas where necessary. It is, therefore, recommended that the Ministry of Irrigation and Power may consider the setting up of a high level National Power Research Council with a proper secretariat and with representatives of Central Water & Power Commission, Central Board of Irrigation & Power, Manufacturers, State Electricity Boards, important Undertakings, Institutes of Higher Education and other National Laboratories etc. on lines similar to those in U.K.

13.12 Statistical and Economic Research

13.12.1 At present practically the entire task of collection of statistical data for the power supply industry and processing of it is being done in the CWPC (PW). This has been organised mostly under one Directorate of the CWPC. Monthly data is collected in respect of energy generation and fuel consumption, maximum demand, sales etc. Further detailed data regarding revenue, collection, transmission lines consumers, connected loads, accidents etc. are collected annually. Data regarding the loads, industrial growth etc. required for the survey work is collected separately. A number of data are also collected on an ad hoc basis on topics like cost of generation, losses, extent of rural electrification etc. from time to time. This system of data collection has grown from that initiated during the World War II and some of the basic data are available right from 1939.

13.12.2 To establish planning for energy and electric power development in the country on rational and scientific lines, as well as to improve the working of the existing installation by introducing scientific methodology, it has become essential to organise the collection of statistics in a comprehensive manner on some scientific lines and in such manner as to require a minimum of effort on the part of the power systems. This has been discussed at length by the Study Group 1 of the PEC in their report in so far as performance of hydro and thermal power stations is concerned. Some *ad hoc* efforts have been made towards this objective by the Regional Electricy Boards compiling their own data books in respect of the power systems in the respective regions. Similarly, the Designs Directorates of the CWPC and other organisations are also often engaged in collection of data from the various power installations, in connection with the technical examination of certain types of problems of operation and maintenance, assessment of the requirement of spares, operating staff and so on. The Planning Commission as well as other Central Government Organisations like the Central Statistical Organisation, Ministry of Finance and Bureaus of Economics and Statistics of the various States in India and the furnishing of data to International Organisations such as United Nations (ECAFE), U.I.P.D.E.E. (International Union of Producers and Distributors of Electrical Energy, (Paris) etc. depend entirely on the data collected by the CWPC(PW).

13.12.3 A review of the working as organised at present shows that it is highly inadequate. The data do not flow fast enough and there is not adequate capability for statistical analysis for the same. The Committee set up by the Ministry of I&P to consider reorganisation of the Statistical Unit in the CWPC recognised these and other shortcomings but could not make detailed study and recommendations in respect of statistical work in the Power Wing. The shortcoming in this respect were also noted during the conference of the Irrigation and Power Ministers in May, 1969. At that time, it was agreed that in view of the importance of this work, the States will also streamline and strengthen the organisation for data collection in these respects.

The following recommendations are made in this regard :

(i) The scope of collection of statistical data and information and analysis thereof should be widened considerably. A number of new items of data collection will have to be included to meet the modern requirements.

(ii) The work can be rationalised. The proformae for data collection should be rationalised and simplified. These should further be recast so as to enable use of modern computer facilities for the analysis of the data. The data and information of lasting nature should be formed into a data bank wherein only supplementary data or corrections need be fed from time to time.

(iii) A time table should be prescribed for data processing and publication of periodical reviews so that the latest data can be made available with a minimum time lag.

(iv) All the State Electricity Boards and Electricity Undertakings should be made fully aware of the importance of furnishing timely, accurate and complete returns of data. If necessary, requisite legislation may be passed as recommended by Study Group 1 in their report for ensuring collection of statistical and other information.

(v) This work is rightly the charge of CWPC (PW)/CEA. It is felt that this arrangement is beneficial and although the Power Research Council suggested in para 13.11 above will also consider the needs in this respect from time to time, the work should be the responsibility of CEA. The Organisation in CWPC(PW)/CEA needs to be suitably strengthened and equipped in order to ensure speed and accuracy. Besides engineers, persons trained in statistical work should also be employed on this work and machine methods of data analysis and presentation should be introduced.

A NOTE ON RESEARCH UNDER THE ELECTRICITY COUNCIL IN U.K.

GENERAL

1. The Electricity Council have a statutory duty to settle, in consultation with the Minister of Power, a general programme of research into matters affecting the supply of electricity and other functions of the Council and the Electricity Boards in England and Wales. The reserach effort of the supply industry falls into two broad categories, technological on the one hand and commercial and economic on the other.

2. Technological research on generation and main transmission is undertaken primarily at the CEGB's laboratories. Research into Area Board problems, both technological and commercial and economic, is undertaken by the Boards and by the Council. Research undertaken within the supply industry is supported, as appropriate. by research contracts placed with universities and other outside organisations. For some years, collaborative research has also been under taken with certain large manufacturers in areas of work. A mutual interest in the results can be identified and the work shared.

3. In 1967-68, the council reviewed the Industry's research policy and concluded that the large increase of research effort during the past ten years had been justified. From the outset the policy of the industry's research establishments has been that research is an investment in the expectation of future commercial benefit. Total expenditure on research is now ten times greater than in 1967-68 and as a percentage of turnover at nearly 1 per cent is five times greater.

4. The two Scottish Boards have been closely associated with the research programme and together have been contributing 9 per cent of all revenue expenditure on distribution, utilisation and commercial and economic research.

5. **Research Council:** The Electricity Supply Research Council advises the Electricity Council on the industry's research programme and research activities. Its 14 members include representatives of the CEGB and the Scottish Boards as well as Commercial Adviser and Head of Engineering Branch of the Commercial Deptts. of Electricity Council, Chief Scientist of CEGB and a number of eminent scientists and technologists (some of them from Universities/industries or National laboratories. The Director of the Central Electricity Research Laboratories is the Secretary. The terms of reference are:

(a) To advise the Electricity Council and the Electricity Boards on specific problems relating to electricity supply;

(b) To keep under review matters affecting the supply and utilisation of electricity and to advise the Electricity Council and the Electricity Boards on programmes and planning of research carried out over the whole field;

(c) To make recommendations to the Electricity Council on research which the Research Council considers it desirable to initiate.

6. **Research Expenditure:** Total expenditure on research in 1968-69 amounted to £ 10·0 million, of which £ 1·8 million was charged to capital and £ 8·2 million to revenue account; of this total about £ 200,000 represented contracts placed at universities and colleges of technology.

Sd/- (K.L. VIJ)	Sd/- (K.M. CHINNAPPA)
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Sd/-
(S.N. VINZE)

CHAPTER 14

SUMMARY AND CONCLUSION AND RECOMMENDATIONS

Cost of Electric Power

1. During the last six years the cost of electric energy has, generally, been rising. If the element of increase in the cost of energy owing to unrealistically low older rates is discounted the increase in the cost of energy is substantially less than the general rise of price levels in the country.

2. In some countries like U.S.A. and Canada the cost of electricity has been decreasing due to economies secured by operation on increasingly larger scale and economies due to technological advances. In order to keep the cost of power supply as low as possible, India also has to plan, construct and operate the power systems in the most economic manner.

Plant availability and utilisation

3. There is an urgent need to improve power plant availability and utilisation. For this integrated operation of the power systems in every region as well as improvement in availability of thermal power plants are necessary.

4. Modern methods of scientific management, particularly operation analysis should be introduced immediately and utilised increasingly for improving the quality of preventive maintenance and reducing the plant outage time for maintenance.

5. Separate technical cells for quality control in operation and maintenance, improving fuel efficiency etc., should be set up in each organisation directly under the Chief Engineer and in the case of Electricity Boards directly under Technical Members.

6. Continuous monitoring of the plant availability (including partial availability) should be introduced immediately.

7, There should be a system of studying the plant availibility, causes of outages and statistical analysis of availability outages on a nationwide basis. This may be done through Central Board of Irrigation & Power. The system evolved by Edison Electric Institute of U.S.A. may be adopted for the purpose with certain modifications.

8. A system of voluntary reporting in respect of technical problems of equipment failures, loss of efficiency and operating difficulties should be instituted immediately. The systems already developed in India as well as in U.K. and U.S.A. should be studied and common modern system of reporting and analysis should be evolved, for All-India application. The data collection may be at the level of individual systems or regions, but the analysis of incident and sharing of this valuable technical experience should be on an all-India basis. This should be organised through the Central Water and Power Commission.

If the above system of voluntary reporting of problems does not work satisfactorily, statutory regulations making compilation and supply of such information obligatory should be made.

Hydro-electric Power Stations

9. Each Hydro-electric Project should be designed for flexibility of operation and the capability to assist optimisation of power system performance should be built into it.

10, All new projects should permit (i) substantial additions to installed capacity for enabling low load factor operation and (ii) addition of governing and excitation equipment for remote monitoring and control and better system performance.

11. Design capability for planning engineering and designing of hydro-electric projects need to be built up in a big way.

12. Each hydro-electric power station must be operated to utilise fully the energy potential available at the site from year to year and season to season.

13. Periodical expert inspection and preventive maintenance must be arranged for all the different components of hydro-electric projects.

14. Every effort must be made to maintain the instrumentation, control, protection and alarm devices in the hydro power stations fully operative at all times.

15. Communication facilities between different portions of hydro-electric project should be watched and improved wherever necessary from time to time.

16. In all power stations, special facilities as well as equipment and tools and tackles required for efficient and rapid mainteance operations should be kept available.

17. The maintenance and overhaul of hydro-electric plants should be carefully scheduled to ensure full plant availabilty and utilisation.

18. Projects older than about 20 years should be reviewed from time to time to see how the benefits from these could be improved by modernisation.

19. The performance of hydro-electric plant and the water conductor system etc. should be checked every 2—3 years by index methods. The necessary calibration for the index methods should be provided during the initial commissioning tests.

20. A service organisation for the safety of water storage structures should be set up immediately. If scope should preferably cover water conveyance structures as well, in the case of hydro-electric works.

STEAM POWER STATIONS

Efficiency of Energy Generation

21. The causes of decrease in efficiency with increase in energy generation where occurring should be investigated.

22. There is a need for improvement in efficiency of operation and maintenance of thermal power plants.

23. Studies should be undertaken to see if the power stations listed in Section 6, para 4.5 of the Report of Study Group No. 1 could not be backed down and the energy requirements supplied from higher efficiency plants in the region.

24. Concerted efforts should be made to improve the efficiencies of the plants listed in Section 6, para 4.4 of the Report of Study Group No. 1 or to reduce their energy generation in favour of generation at higher efficiency plants in the region.

Coal and Washery by-product prices

25. Pit head coal prices need to be rationalised on the basis of heat content of the coals.

26. Long-term coal contracts should be drawn up on the basis of standard form to be developed by the Regional Electricity Boards. These should cover the question of prices as well as the quality of the fuel.

27. The Energy Survey Committee of India which submitted its report in 1965 had considered the washery by-products as zero cost fuels for planning purposes. There is, therefore, a clear case for a lower price for these. This can be worked out taking into account the loss of efficiency, plant availability and plant capability in power stations using such fuels. For middlings having ash content less than 32%, it may be reasonable to fix the price at a rate equivalent to that for coal of the same heat value less Rs. 2.5 per tonne.

28. In order to improve the operation of the thermal generating units it is considered that the ash content of the fuel burnt in the boilers should not exceed 32%. For this purpose blending will be required to be done when either coal or washery by-products with ash content of more than 32% have to be utilised. When, therefore, washery by-products with ash content of more than 32% are supplied by the washeries, further necessary adjustments in price will need to be made to cover the expenses on account of blending arrangements.

29. It is also recommended that the cess on middlings/by-products should be waived.

Utilisation of by-products from Coal Washeries

30. The working of existing coal washeries should be modified to reduce the ash content to 32 per cent and also to ensure removal of stones and other abrasive material from the by-products supplied to the power stations as fuel. A practical time schedule should be drawn up for this immediately. Studies and designs for the additional equipment and any changes required in the process for the above purpose should be started immediately jointly by National Coal Development Corporation, Hindustan Steel Ltd., Central Fuel Research Institute etc.

31, The future coal washeries should be 3 stage ones and the ash content of the middlings should be restricted to 32 per cent, and adequate arrangements for removal of abrasive material should be made.

32. The factors responsible for erosion damage to the boiler plant and equipment should be identified by careful and intensive research through the Central Fuel Research Institute and other appropriate bodies. Apart from identification of these factors, this should lead to improved supply of fuels and also include design and construction of boiler plant and appurtenant equipment for minimising the maintenance outage costs.

33. Design, construction and materials in the boiler plant and its auxiliaries require considerable further work for devising ways and means of operating satisfactorily with washery by-products fuel. The existing installation should be utilised for making field trials of different new innovations or designs of equipment for this purpose.

The equipment requiring particular attention is the coal mills, I.D. fans, layout and arrangements of superheater and economiser tubes, design and arrangement of burners and ash handling and disposal systems. It is recommended that indigenous boiler plant manufacturers and manufacturers of appurtenant equipment should be asked to tackle this problem in collaboration with the organisations owning and operating the existing power stations.

Transportation of Coal to Thermal Stations

34. Considering the volume of coal traffic for individual large power stations, the time is now ripe for the introduction of new innovations such as unit trains in the matter of transport of coal by rail. A study in depth should be undertaken for this purpose immediately by the Railways jointly with the coal and power stations authorities.

Rationalisation of freight structure over short distances

35. The freight structure for transport of coal by rail over short distances under 50 km. should be reviewed and rationalised.

Petroleum Fuels

36. The pricing of by-product petroleum fuels should be based on the costs of Indian crudes instead of on the basis of import parity.

37. Wherever there is possibility of obtaining supplies of petroleum, firm long-term contracts should be made between the suppliers of petroleum fuels and the power station authorities.

38. In the years to come, the by-products of refineries will mostly be required as industrial raw material. No large power stations should, therefore, be based on

petroleum fuels alone. Unless the petroleum authorities assure supply of petroleum on long-term contract basis, the siting of the power stations should be decided primarily on the basis of these being coal burning power stations.

39. Commitments made regarding supply of petroleum fuels to power stations should be honoured fully in future also. In case of 100 per cent petroleum fuel based power stations if petroleum fuels are not likely to be available in future, these power stations should be given a warning sufficiently in advance to enable their making alternative arrangements. The power stations should be compensated for the additional costs involved on this account.

40. Oil is essential for supporting for all pulverised fuel fired installation and its availability in adequate quantities at economic price must be ensured for such installations.

Problems of Operation and Maintenance

41. The thermal power plant equipment should be matched closely to the type of fuel, cooling water temperature and other site conditions.

42. The working of each power plant installation should be continuously watched for removing any snag at the incipient stage and improving the operation and maintenance. Full use should be made of the experience on similar power plants in other parts of the country.

43. A number of common problems in operation of steam power stations discussed in the report of Study Group I should particularly be avoided by proper action in planning, design and operation of the plant.

Relaxation of Boiler Act provisions

44. The provisions of Boiler Act should be modified to permit biennial inspection of boilers instead of annual. In fact, it may be worthwhile to have a separate set of rules and regulations drawn up for large installations of modern steam power stations with unit sizes of say over 50 MW.

Ash Disposal

45. Representatives of the Electricity Supply Industry and Central Water & Power Commission should be invited to participate in formulation of regulations regarding pollution of air and water courses.

46. Intensive research and development work as well as promotional work should be undertaken for utilisation of the ash produced as by-product in the steam power stations. Organisation like Central Building Research Institute, Central Road Research Institute, National Building Organisation, Cement Research Institute, as well as Indian Standards Institution and Central Water and Power Commission should be brought together for devising ways and means for utilisation of the fly-ash and bottom ash.

47. Utilisation of ash should be entrusted to a non-profit corporation to be established co-operatively by the different power station authorities in each region. This corporation, financed mainly from the sale of ash, should organise the development and promotional work applied research work (in different appropriate institutes) and the work of marketing and disposal of ash from thermal power stations.

COMMON PROBLEMS

Staffing for power plants

48. The pattern of staffing of the large power stations (Hydro, Thermal or nuclear) and their appurtenant works such as storages (hydro plants) etc. should be standardized on the basis of parameters of the generating sets, their number, type of fuel etc. The standardized patterns should be got approved from the Government as well as representatives of both Management and Labour. The scope of work and the responsibility of each person should be laid down clearly in the standardized staffing patterns.

49. The exact requirement of staff for any installation in the context of the standardized pattern mentioned above, should be specified by the designers of the installation.

50. The staff required for operation and maintenance should be sanctioned with the finalisation of the design and start of construction and in any case at least 18 months before the expected date of commissioning of the first unit. The sanctioned strength should be fully recruited at the earliest, for purposes of training on similar installations during the year preceding the commissioning of the power plant. The full sanctioned strength of the technical personnel should be in position for gaining an understanding of the plant by assisting during the Acceptance and Commissioning Tests and installation of the major plant sub-assemblies.

51. A separate Generation Cadre should be instituted to ensure that adequately trained staff is available at generation stations. A system of incentives or special pay etc. should be introduced for the Generation Cadre to attract and keep suitable persons.

Training of Personnel

52. There should be a requirement preferably statutory that the o&m staff must be qualified by proper training and experience preferably through some recognized training institutes before being given the full and independent charge of the costly and intricate modern power station equipment. A system of certification of the o&m staff similar to that in vogue in the Civil Aviation Industry could be adopted.

53. Refresher Training Courses should be arranged for all the technical staff in a phased manner so that each person has to go through a course at the interval of 5-7 years. Even the o&m staff at the technical level should be routed through other similar systems.

54. Existing facilities for training of personnel for operation and maintenance of steam power stations are grossly inadequate.

55. Training of personnel for operation and maintenance of power stations should be the responsibility of the Regional Electricity Boards. They should assess

the requirements and organise adequate training facilities including in-plant training to suit the requirements peculiar to the respective regions.

56. For the purpose of certification of competency in operation and maintenance, the Central Electricity Authority should formulate the minimum requirements on a nation-wide basis.

Instrumentation of Power Plants

57. Special attention should be given to the adequacy of control, protection and instrumentation systems in every installation. Proper operation and maintenance of these systems is of the highest importance for minimising forced outages. Well-equipped instrument laboratories should be provided for each large installation or group of installations. Special Instrumentation Cells should be manned by highly competent trained personnel who should ensure proper functioning of the instrumentation system throughout.

Documentation

58. Detailed completion drawings and reports should be available at each project, so that all changes adopted during construction are properly recorded.

59. Comprehensive manuals and instructions complete with drawings, photographs, descriptions etc. must be available for each element of power plant installations. These must cover operation, maintenance and instructions for abnormal conditions. Sufficient number of copies must be available for all concerned and these must be reviewed and brought up-to-date every year.

Manufacturing and Design Capability of Indigenous Manufacturers

60. There is an urgent need to develop the design capability in the manufacturing units, so that the technology acquired for plant and equipment is fully utilised in a manner suiting the Indian conditions.

61. At the time of commissioning any hydro-electric project, detailed guidelines for water management, most appropriate for the project, should be laid down.

62. The high cost of plant and equipment from indigenous sources causes an undue burden on the power systems in the country. Equitable methods should be evolved for apportioning the heavy cost of acquiring new technology among the present and future projects. The cost of social benefits like new housing colonies, schooling, hospitals and other facilities need not be a charge on the cost of plant and equipment for new power stations but should be borne by respective States in which the factories are situated or by the Central Government.

Import of Spares

63. The following should be done to streamline the procedure for import of spares for operation and maintenance of power systems and to eliminate the procedural delays and difficulties.

63.1 The clearance of applications from indigenous angle should be done by Central Water and Power Commission itself. For this purpose, the Directorate General of Technical Development should equip the Central Water & Power Commission with all the information about indigenous availability of spare parts auxiliaries etc. The Electricity Boards/Project Authorities should adopt modern methods of inventory control for dealing with their replacement of spares. In any case, the position regarding spares should be reviewed by them at least every quarter and anticipatory action taken so that the time normally required for release of foreign exchange, issue of import licence etc., does not come in the way of proper operation of the power installations or execution of projects. A special Cell should be created in the Central Water and Power Commission and the concerned officer should be provided proper facilities for conveyance etc.

63.2 Where a number of identical power plants have been installed in the country, some additional emergency spares, such as a spare thrust bearing may be obtained and kept in common reserve. Such common pool of spares, financed co-operatively by the different power station authorities may go a long way in reducing the loss of energy generation due to forced outages.

63.3 The Chief Controller of Imports and Exports should give necessary facilities to the liaison Officer of the Central Water and Power Commission for expediting the cases of issue of import licence for spares. This can be done by placing an Officer of the Central Water and Power Commission in the Office of the Chief Controller of Imports and Exports for carrying out liaison work. After release of foreign exchange and indigenous clearance, Regional Joint Chief Controller of Imports and Exports should be authorised to issue import licences.

63.4 Revalidation of import licences in cases on which project authorities have entered into commitments after clearance of the Directorate General of Technical Development, should be done as a matter of routine by the Chief Controller of Imports and Exports within a week. Any back reference by the Chief Controller of Imports and Exports should be addressed to the Central Water and Power Commission and not to the project authorities.

64. Adequate attention should be paid to the selection, installation and operation of electrical equipment as discussed in Section 4 (Chapter 5) of the Report of Study Group No. 1.

Measures to promote integrated development and operation of power systems in India

65. Power shortage conditions prevail today in many parts of the country. This position is likely to continue in the next few years or so and the available generating capacity would not be able to meet the anticipated load demand. It is, therefore, important to derive optimum benefits from the generating capacity available. This can be done only through integrated operation of regional power systems. Substantial

economies in the cost of power generation can also be achieved by developing well-integrated regional power grids, leading to the evolution of National power grid. There is an urgent need to devise measures which would promote development of such grids. As a first step a phased perspective plan of development of power systems leading to the National grid should be formulated.

66. Greatest economies in the cost of power production can be achieved through planning which looks far beyond the needs and requirements of small individual systems. The planning should, therefore, be done on a regional basis and the power projects should be chosen on regional considerations and on the basis of minimum cost and the operation should be planned with a view to optimising the use of national wealth.

67. The review of existing and proposed inter-State and inter-regional transmission lines in the country has brought out that the transmission capacity has been utterly inadequate in the past to permit efficient use of resources. It has also revealed that the proposed additions up to 1973-74 would not remedy this situation to any large extent. There is need for a complete change in the strategy of planning of inter system tie lines and need for allocation of more investments for this purpose.

68. The transmission and distribution network has to be strengthened. There has been an imbalance in the investments in the electric power supply industry in favour of generation. The allocation of funds for transmission and distribution should be separately made and it should be ensured that these funds are not diverted for other purposes.

69. One of the main reasons for low availability and utilisation of power plants in India is lack of interconnections and integrated operation between the small power systems obtaining in our country.

70. The capacity of the inter-State/Regional ties should be about 10% of the size of the systems which are tied together so that they may take care of a load slip of at least one year which is inescapable in a developing economy like that of India.

71. A case study for the Southern Region indicates that Rs. 8.27 crores could have been saved in the fuel charges alone in 1968-69 if principles of economic generation scheduling were applied to all resources. Similar study for the anticipated operating conditions in 1973-74 also shows that savings of Rs. 8.33 crores can be achieved if coordinated generation scheduling is carried out. Integrated operation of power systems is, therefore, essential for effecting economies and securing optimum benefits

72. The large range planning strategy should be based on the fact that in the next 10 years or so, not only the State systems should completely integrate to form regional grids, but also that the regional grids should get adequately interconnected to form a National Grid.

73. In the next 5 years, it is easy to conceive power transfers between the regions of the order of 500/700 MW over distances up to 1000 km. in the interests of economic utilisation of resources. For this purpose, a higher voltage in the range of 400/500 kV would be necessary. A Study Group should be set up to evaluate the needs of the country over the next 10 to 15 years and recommend the suitable voltage level above 220 kV.

74. There are instances where integrated operation of power systems and economy exchange of power is not taking place though transmission capacities exist. One of the reasons for this is lack of a commercial agreement between the two systems. The tariff principles should provide the necessary incentives to both the seller and the buyer. In economy interchanges, the position of seller and the buyer is interchangeable and hence the tariff structure should be reversible.

75. It is desirable to spell out all the objectives of interconnected or integrated operation in unambiguous terms in the agreements between parties which should necessarily precede construction so that all issues subsequently can be judged with these criteria.

76. U.S.A. has shown that independent utilities voluntarily surrender their individual authorities to a common pool for economic advantages. Similar conditions should be created in India.

77. Central Electricity Authority should take a lead and help various systems in the country to evolve and conclude agreements based on sound operating and costing principles.

78. In order to achieve optimum utilisation of resources and at the same time ensure reliability and continuity of power supply, proper institutional and technical set-up has to be created. This function is known as system operation management.

79. In an efficient operation management, the flow of decisions and the information between the participating organisations should be free and unrestricted to evolve a final dynamic operation policy and its execution.

80. Philosophy of interconnected operation should be evolved for each region by their technical coordination committees to ensure safety, security of the regional power system and coordination. Digital computer studies should be made to evaluate future operating costs. Long range operation plans evolved should be cleared through the various policy making bodies in each region.

81. State and Regional Load Despatch Stations (Pool Centres) should be set up at a very early date to enable integrated operation.

82. In operational planning, efforts should be made to optimise and conserve fossil fuel resources in the larger interests of the country and increase the utilisation of available nuclear and hydro resources.

83. In operational planning, a number of major and far reaching policy decisions are required to be taken.

This function should be performed by the Regional Electricity Boards comprising of representatives of various constituents of the regions having major generating capacities at the level of Chairman. This Board should be assisted by a full time Member-Secretary and by a Technical Co-ordination Committee and a number of groups consisting of specialists in various fields.

84. Execution of the operational plans and targets laid down by the Operating Committee should be executed in day to day operations by multitier load despatch organisations.

85. Load Despatch Stations should be equipped with the required communication facilities, instrumentation, controls interconnection manuals, safety manuals, operational planning computer etc. There is need to provide effective inter-system coordination and to provide the various load despatch centres with adequate modern tools for monitoring and control of the power systems.

Reliability of Power Supply

86. The reliability of power supply can be improved by careful application of the well-known principles of power system planning, operation and maintenance. Due to rapid development in power supply facilities, the standards of operation and maintenance have tended to be lowered in many systems. This tendency must be reversed by vigorous administrative measures.

87. There should be sufficient generation reserve, adequate transmission capacity and protection of various equipment and transmission lines should be suitably coordinated.

88. A well-organised load despatch centre is necessary for ensuring high system reliability. Restoration of a system to normalcy after a disturbance requires centralised decision making mechanism.

89. There should be (a) written operating instructions for all elements in the system for the operating staff covering switching procedures and other precautions; (b) adequate number of recording instruments at all major nodal points; and (c) disturbance recorders which can record a sufficient number of quantities simultaneously etc.

90. On long transmission lines, on-line fault locating equipment which can indicate faulty sections within a few seconds and save patrolling time should be provided.

91. Frequency of trippings can be reduced by adopting the practice of periodic inspection of lines and inspection after every trip-out. Comprehensive preventive maintenance procedures should be drafted and issued for the guidance of the maintenance staff.

92. All disturbances on the distribution network should also be fully reported and properly analysed and classified. It is only by keeping good records and carrying out an analysis of the causes that steps to improve reliability can be devised continuously and economically.

93. Spares and special T&P and expert team for quick restoration of normalcy in each part of the power system, *i.e.*, different types of generating plant, sub-stations, transmission and distribution.

94. O&M procedures and difficulties should be reviewed by expert teams periodically.

Transmission and Distribution Losses

95. The losses in the transmission and distribution systems in India are on the high side and have shown a tendency to increase further. Optimum performance of the power system is necessary for achieving economy. The principal lines of action are indicated below :—

(i) Improvements in the transmission and distribution system designs by :

(a) Selection of transformers with reference to expected load cycle so as to obtain minimum total fixed and variable losses.

(b) Use of flow iron loss transformers, particularly for rural areas and areas of low load factor.

(c) Reduction in the number of power transformation stages.

(d) Improvement of power factor—installation of capacitors etc. at appropriate locations.

(e) Selection of appropriate sizes of low tension feeders keeping in view their lengths and load required to be carried.

(ii) Introduction of proper instrumentation and information collection system at all levels for monitoring of system performance.

(iii) Integrated operation of power systems including reactive scheduling.

(iv) Elimination of theft of energy.

(v) Elimination of miscellaneous losses by improved operation and maintenance.

(vi) Continuous monitoring of system performance and introduction of corrective action at the divisional level.

Factories in the choice of Power Generation Schemes

96. In 1967 the effective consumption of energy in India was nearly 600 kg. of coal equivalent per head against 9830 in U.S.A., 8090 in Canada, 3960 in U.S.S.R., 2270 in Japan and the total world average of 1640. The per capita energy consumption will have to be considerably increased to better the economic lot of the people. In view of the lack of adequate oil and gas resources, the country would have to rely on electricity more and more to reach a reasonable figure of energy consumption. In this context, the nuclear energy has an important role in our future energy economy.

97. Under the existing conditions in the country, the hydel schemes constitute the most economic sources of electricity production. The estimated cost of power from the Atomic Power Stations based on heavy water reactor technology under construction indicate that atomic power would be competitive with prevailing cost of power from thermal stations located remote from the collieries. Conventional thermal stations based on coal located away from the collieries (600 Kms) involve the highest cost of energy generation in the country. Apart from their intrinsic economy, hydro schemes designed for complementary peaking with thermal/nuclear stations enable better utilisation of available generating capacity and energy potential.

98. The fact that hydro electric resources constitute the most economic sources of power generation in the country was recognised as early as 1956. Both the perspective plan for power development prepared by the CW&PC in 1962 and the report of the Energy Survey of India Committee (1965) emphasised the need for greater reliance on hydro power for economic power supply. During the past decade, the country's hydel resources have not been developed at the pace recommended and large scale thermal generation, especially in areas within economic reach of hydel potential and remote from the collieries, has been resorted to resulting in higher energy generation cost. It is estimated that if the economic path of power development indicated earlier had been adhered to the power supply industry would be generating additional revenue surplus of the order of Rs. 180 crores at prevailing tariffs during the Fourth Plan.

99. The main reason for our inability to ensure choice of schemes for expansion of power generation and supply following the path of lowest cost of development in the past are :—

(a) delay in adopting the regional approach to power development;

(b) consistent lack in the final stages of planning, of a perspective approach designed to secure the lowest cost developments;

(c) expectations of large surplus of by-product fuels from coal washeries, which have subsequently been belied;

(d) a general prevailing impression about large and decisive differences in the "construction time" factor in favour of conventional thermal generation; and

(e) longer plant delivery periods for hydro due to inadequate manufacturing capacity.

Now that reasons for higher power supply costs are apparent and it is desired that they should be reduced, remedial measures must be taken and rational considerations allowed to prevail in the future in the choice of schemes for expension of power generation and supply.

100. To control and reduce the cost of energy generation and supply in the country, to enable full utilisation of generating facilities already built up and to ensure that the limited capital allocations to the power supply industry go the farthest in meeting the country's estimated deficits, the bulk of new generating capacity to be added during the 5th and 6th Plans should be derived from hydro sources, both of energy intensive and peaking categories. The balance of new generating capacity should be derived from super-steam power stations employing the largest possible unit sizes and located at the coal washeries/coal mines. Nuclear power generation would have to be resorted to preferentially in areas with limited hydro resources and which are remote from collieries. Regionwise optimal mix would, of course, need to be made. The above provides the broad guidelines for future power policy to ensure utmost economy in power generation and supply for the foreseeable future.

101. It is also essential that a perspective plan for power development covering a period of 15 to 20 years should be drawn up for the entire country on a regional basis purely on economic consideration, irrespective of location of the resources and this plan adhered to in actual implementation.

102. The main economic factors which must prevail in the choice of appropriate sources of power supply in the various regions have been discussed in the Report of Study Group No. III. Suggestions for new schemes regionwise for deriving benefits in the Fifth Plan and early Sixth Plan have been made in Chapter 2 in consultation with CW&PC after taking into consideration all relevant problems.

103. The programme for indigenous manufacture of heavy electrical equipment is at present based on considerations other than the needs of economic power development in the country. This should be altered and the manufacturing programme revised to suit the needs of the power supply industry.

104. The inability of the various States to provide adequate financial resources has been one of the main reasons for the low allocation to power in the 4th Plan, which cannot even sustain expansion of our power supply on the scale required to maintain past rates of growth during the 4th Plan. To avoid critical power supply position in the future, central involvement would have to be on a much larger scale. Such increased central participation should be decided upon on purely techno-economic considerations and judiciously oriented towards providing economic power supply on regional and national considerations. A set of principles for deciding on the scope of central assistance in the various regions should also be evolved.

Institutional Arrangements

105. Some changes in the institutional arrangements are considered necessary to enable power development in a rational and coordinated manner throughout the country and faster pace of hydroelectric development which involves considerably

greater efforts at the stages of investigation and planning. These are :

(a) The Central Electricity Authority, which has statutory recognition, should be set up on a full time basis and should be charged with the responsibility for preparing the national perspective plan for power development, carrying out necessary investigations of schemes and processing them up to the point of construction. In drawing up such a plan, it may seek the help of Regional and State Electricity Boards which are familiar with the conditions in their respective areas.

(b) As preparation of perspective plan for power development has to be coordinated with plans for development of the other sectors of the economy and take into account the availability of financial resources, it is essential that the Central Electricity Authority works in close coordination with the Planning Commission. It would, therefore, be desirable to associate a representative of the Planning Commission as a part time member of the Central Electricity Authority to ensure proper coordination between the two organisations.

(c) The agency for construction of power projects would have to be decided on the basis of the type of scheme, its location with respect to the areas where output is to be consumed, type of financing etc. The institution of Control Board, which is already being adopted for implementation of many of our projects, may be followed for projects taken up on regional considerations.

(d) The Regional Electricity Boards should continue to concern themselves primarily with ensuring maximum economy by integrated operation of constituent power systems in the respective regions. In view of their knowledge of the local conditions, the Central Electricity Authority may utilise their services for the purposes of drawing up perspective plans for power development in their respective regions. The position of Regional Electricity Boards with respect to the CEA is not clearly defined at present. This anomaly should be removed by giving the Regional Electricity Boards statutory recognition and clearly defining its relationship with other State and Central organisations. The Regional Boards should also be strengthened to discharge their responsibilities.

(e) While the above suggestions, if adopted, would by and large make it possible to deal with the problems of short-term and long-term power development, it is recognised that there would be certain areas such as the Indus Valley and the Godavari basin, where the magnitude of the schemes, geographic location etc. are such that the above institutional arrangements may not be adequate. In such cases, separate river valley authorities may be more conducive both for conducting of investigations and execution of the project. These are, however, special cases which would have to be dealt on their merits.

(f) A proper analysis of power supply industry is extremely difficult at present because of paucity of data regarding actual investment costs, operating performance of power stations and power system etc. The CEA should be organised to collect and publish this data regularly.

Rural Electrification

106. Electricity has now become a necessity rather than an amenity and must be recognized as an important factor in economic progress even in rural areas. The higher production of foodgrains required to meet the minimum demand of 1975-76 can be achieved economically only through extensive irrigation, electrification of pump sets and by using modern electric equipment on the farmsteads.

107. There is considerable scope for effecting economy in the equipment, construction practices, designs etc. for rural electrification.

108. The N.C.A.E.R. studies on Punjab and Kerala have conclusively established substantial economic benefits from rural electrification.

The N.C.A.E.R. study shows larger benefit/cost ratio for smaller villages. This indicates desirability of extension of rural electrification to cover smaller villages notwithstanding the lower percentage of return on the capital employed.

109. ESTIMATE OF PROGRESS

	As on 31-3-69	During 1969-74	During 1974-81
1	2	3	4
No. of villages . .	71,410	53,590	1,40,000
Pump sets . .	10,88,696	15,00,000	28,11,000
Investment . .		Rs. 520 crores	Rs. 1,850 crores

110. Availability of underground water and absence of salinity should be checked before any scheme for electrification of tube-wells is sanctioned. A survey of groundwater resources should be conducted in the potential scheme areas and data in this respect kept ready by the State Electricity Boards. This work, could, perhaps, be carried out by the Department of Agriculture or the Underground Water Organisation in the State. Assistance could also be obtained from the Geological Survey of India and Exploratory Tube-well Organisation of the Union Ministry of Agriculture.

111. Co-operative use of tube-wells should be encouraged. This would help in pooling up of the resources for taking tube-well connections. Co-operative use of tube-wells and selling of tube-well water would increase the load factor and improve the economics of rural electrification.

112. *Finances* : Investment up to 1968-69 provided by earmarked central assistance was Rs. 254.00 crores. An estimate of financial resources for the 4th Plan is as follows :

(In crores of rupees)

(i)	Fourth Plan outlay by the States/ Union Territories etc.	294.50
(ii)	Rural Electrification Corporation.	150.00
(iii)	Financial Institutions comprising :	75.00
	(a) Land Development Banks.	
	(b) Agriculture Renfiance Corporation.	
	(c) Commercial Banks.	
	(d) Agricultural Finance Corporation.	
	(e) Life Insurance Corporation.	

113. Backward areas should be given due consideration in rural electrification programme.

114. State Governments should give loans on easy terms to State Electricity Boards for Rural Electrification.

115. Rural Electrification in India can spread rapidly if it takes the shape of a people's movement. As pilot projects, the Government have set up five rural electric co-operatives—one in each of the States of Andhra Pradesh, Gujarat, Maharashtra, Mysore and U.P. The co-operatives will enthuse the spirit of ownership in the villages and would also facilitate co-operative use of pump sets, electric appliances such as threshing machines, drying facilities for fruit, cold storage facilities etc. This will not only help the poor farmer to use such costly appliances but would also result in the improvement of the load factor in he rural areas.

116. It is felt that, in order to accelerate the deveopment of rural areas, the easiest and quickest way would be to integrate rural electrification programme with the programme of agricultural and other rural industrial development schemes. It is recommended that Co-ordination Committee should be set up (1) at the level of the State Electricity Boards and (2) at the District level, as suggested in the meeting in Planning Commission in July, 1970.

117. The work of rural electrification though voluminous and involving considerable expenditure, is of repetitive nature. Therefore, there is a very large scope for achieving economy by standardised designs, manufacture and construction practices in the field of rural electrification. The specific suggestions concerning certain major aspects of designs for rural lines and sub-stations which could economise in the rural electrification schemes have been given in Chapters 5 and 6 of the Report of Study Group No. IV. It is recommended that the same may be followed.

118. A special Technical Standards Committee under the aegis of the Rural Electrification Corporation should be formed for simplifying and standardising materials, equipment and construction practices for rural electrification works. This Committee should have a permanent Secretariat and should work in coordination with the *CW&PC, ISI, REC, manufacturers and Research Organisations.*

119. Single phase power distribution is inherently cheaper than 3-phase power distribution and deserves consideration. Chapter 5 indicates the development work already done in India on this. This system is very effective for villages with small loads, especially those with a population of up to 500 (which number about 3.67 lakhs).

120. Break-downs in power supply are mostly on account of failures of distribution lines and sub-stations. Standardised plans for operation and maintenance of these should be evolved (*See* Chapter 6 of the Report of Study Group No. IV).

121. Minimum consumption guarantee for agricultural consumers should be reduced to a reasonable figure.

122. There is considerable scope for increasing the load factor in the rural areas.

123. Suitable incentives are required to be provided to encourage the farmers to go in for the use of electric power (Para 7.2 of Chapter 7 of the Main Report). In this connection special mention is to be made about the need to set up service stations with mobile squads which should take up work of internal wiring, maintenance, etc. for the rural consumers, on reasonable charges. The State Governments should organise suitable rural technical centres. These could utilise presently unemployed technical personnel. They should be given necessary incentives to offer their services to the farmers. The State Electricity Boards should also set up such centres or assist in their establishment.

124. Rural electrification could be viable and successful if the integrated development of the rural areas done on an intensive basis by Agriculture, Irrigation, Industries Department etc., of the State Government in conjunction with the State Electricity Board.

Expeditious Construction of Power Projoects

125. There are serious shortfalls in achieving the targets for installation of generating capacity and transmission system in the country, year after year. If this trend continues, there are grim prospects of widespread and serious shortages of electric power. Further, on account of inadequacy of advance planning and investigations, there is likelihood of serious power shortage in the 5th and 6th Plans also, leading to grave consequences in retardation of industrial and

agricultural activity and economic progress. Concerted action on a wide front is essential for correcting this position and making up the lost ground.

Causes of Delay

126. Causes of delay in the projects taken up for implementation have been identified and are listed in Section 5 of the Report of Study Group No. 5.

Planning

127. A fairly large programme of construction has to be in hand all the time in order to keep up with the normal load growth. This is in consonance with experience in other countries also.

128. The perspective plan for the next 15 years should be available at any point of time and, every year, such plan should be updated and extended to cover the future 15 years. Advance action in respect of preliminary investigations and designs and estimates should proceed in a continuous manner. The proposals for the next 10 years should indicate details of the specific projects to be undertaken and their time-table of the major stages. The plans for the first 5-7 years should be very definite at any time and should be already under implementation.

129. Planning for electric power should be organised on a nation-wide basis. The overall responsibility for planning including investigations are processing of schemes right up to the point of execution should be centralised with the Central Electricity Authority. The existing legislation is adequate for this.

129.1. Each State Electricity Board should have a Planning Cell which will be capable of taking into account the long-range needs for electric energy as well as utilisation of the resources in the best possible manner.

129.2. Similar long-range Planning Cells should also be created in the Regional Electricity Boards. These should be able to coordinate and correlate the plans prepared by the State Cells so as to make the best utilisation of the availability resources in the Region.

129.3. At the Centre, the Planning Commission and the C.W.& P.C. should keep in constant touch with the work and progress of these Planning Cells at the Regional and State levels and a long-term power plan should be evolved continuously.

130. There is an urgent need for strengthening the Civil Engineering Organisation in each Electricity Board in order to cope with the large programme of investigations, planning and construction required for hydro projects. An experienced Chief Engineer (Civil) should be appointed for each Board, especially to look after the work of hydro-electric projects. Among other things, he should be in overall charge of a whole time planning and investigation circle.

131. The indigenous manufacturers should plan the manufacture of further larger sizes of generation units so that these are available in time when the power system require these, shortly.

Investigations

132. A massive and continuous programme of field investigations is needed immediately in each Region of the country so that the needs of the Fifth and Sixth Plan periods for investigated projects can be fulfilled.

133. The C.W.P.C. should keep in close touch with these investigations to ensure that these proceed on fruitful lines technically throughout.

134. The finances for project investigations should be provided in the initial stages as "on account grants" in the nature of promotional expenses. These expenses can be reimbursed to the common fund from the project estimate when a project is taken up for execution.

135. Detailed investigations should be entrusted to well-organised Survey and Investigations Units (in each State) equipped for geological as well as other investigations, Services of the Research Stations such as C.W.P.R.S., CSMRS, etc. should be utilised for arriving at adequate scientific data. Keeping the design engineers associated with the investigation work also proves valuable in ensuring proper orientation of the investigations and avoiding fruitless efforts.

136. Where inter-State development of a resource is indicated, the Regional Electricity Boards should take up the work. Formation of River Valley Authority to take the responsibility for further detailed project investigations and subsequent execution of individual schemes in the certain River Valleys with very large power potentials (according to a time table prescribed by the perspective plan) may also be considered.

137. After the feasibility of a hydro-electric project is established, construction of the minimum access road facilities should be taken up immediately from the 'investigation funds'. This will enable expeditious detailed investigations.

138. When the project is sanctioned, the construction of the access roads should be undertaken and completed at the earliest. This will expedite the execution and completion of the project.

Project Preparation

139. The model proforma circulated by the Planning Commission in consultation with the Ministry of Irrigation and Power, should be followed strictly for the preparation of the project report. This will eliminate protracted correspondence and resultant delays in sanctioning of the projects.

Financing

140. In order that the Project Authorities can plan and execute the construction programme according to the plan schedule, the finances should be made available as per the phased requirements of the project.

141. Power projects sometimes suffer due to diversion of funds to other purposes by the State Government. This could be discouraged by the

Planning Commission by "earmarking" the funds for specific projects at the time of formulation of plan provisions.

142. In the past there has been a great deal of excess expenditure as well as slippages in achievements of targets in the case of both generation and transmission. This is on account of two reasons, *viz.*

(i) Under-estimation of the cost at the time of preparation and sanction of the project report; and

(ii) Rising costs of materials, labour and other services like transport, etc., in the course of project execution.

143. The under-estimation of the cost is mostly due to inadequate investigation and in some cases due to inadequate or incompetent design and engineering. It is, therefore, very essential to have thorough and detailed investigations and sufficient preliminary designs as the basis for the realistic estimates of the time and the cost of project execution.

144. The C.W.P.C. should be charged with the responsibility for the accuracy of the estimates of time and cost of the project execution. The C.W.P.C. should organise and equip itself for such work without any delay.

Procurement

145. Tender specifications should be as detailed as possible and should include listing of all the information such as technical data, requirements of firm deliveries, contractual and financial requirements etc., required of a tenderer.

146. M/S H.E. and M/S B.H.E. should make their quotations thorough and businesslike by furnishing detailed lists of all equipment and accessories they would supply and the supplementary equipment that the project is expected to procure from elsewhere to make the supply complete.

147. A good many items of plant, their ancillaries and other items have been standardised; the purchase specifications should be based on these as far as possible.

148. A model 'general conditions of contract' applicable to public sector and, if possible, to private sector manufacturers, binding on all the parties, would reduce the time between the receipt of the tenders and placing of the orders, and should be prepared and adopted.

149. The manufacturing capability of the two manufacturing units, *viz.*, M/s H.E. and M/s B.H.E. is not sufficient to meet the requirements of the country fully. There is, therefore, no need at present for competitive bidding between them.

150. The model technical specifications (prepared by CBI&P Working Group) for each type of hydro-electric turbo-generator set based on each of the technologies adopted by M/S H.E. and M/S B.H.E. should be adopted for ordering of the hydro-electric generating units. Considerable saving of time and effort can thus be effected.

151. It is possible to secure overall economic advantage by grouping the orders placed on the two manufacturing units for different project rationally, so as to obtain optimum benefits regarding development and designs. This matter is complex and requires a cautious and informed approach. The planning of the orders may, therefore, be done in consultation with the Ministry of Irrigation and Power and Central Water and Power Commission.

Manufacture of Equipment

152. The manufacturer should indicate his need of foreign exchange (source as well as the amount) at the time of tender. The concerned Ministries should ensure the release of adequate foreign exchange.

153. The manufacturer should indicate all factors and assumptions on which their promise of delivery period is based. It would be desirable as a contractual obligation for the manufacturers of major items to furnish the project authorities with their PERT network chart for items of their supply including exchange of drawings and data.

154. Manufacturers should attempt to reduce the erection work at site to a minimum by adopting shop assemblies in as large a measure as possible. For this purpose, special wagons/transporters may be devised, if necessary for transport to site.

155. The Ministry of Irrigation and Power should be responsible for assigning priorities and programmes for the manufacture of equipment for various projects in consultation with all concerned.

156. There is much scope for standardisation and rationalisation of manufacture of a number of sophisticated items like automatic voltage regulators, excitation equipment, governors for generating sets etc. The Manufacturing Units and CW&PC should work jointly to achieve this.

157. In view of the monopoly of M/s. H.E. and M/s. B.H.E. in respect of generating plant and equipment, it is imperative to devise a mechanism whereby it can be ensured that the Manufacturing Units will strive towards attaining better efficiencies and producing increasingly superior machines. A Standing Advisory Committee comprised of representatives of the two manufacturers, CWPC, users, consultant and an academician should be set up to decide the targets and coordinate the action in this regard.

Transport Facilities

158. The Design Organisation of CWPC should survey and catalogue the special transporters available with the various organisations so that the different projects can draw upon these when required.

159. In view of the increasingly large sizes of generating units and other equipment, special transport equipment presently available will not meet all future needs. M/s. HE and M/s. BHE should take up the matter with the Railways for design and construction of special wagons, mobile cranes etc.

Shortages & Breakages in Equipment

160. Whenever any shortages or breakages are revealed, the project manager should have these inspected on his own and should proceed with ordering of the replacement. The process for making insurance claim and necessary inspection etc., therefore, can proceed separately simultaneously. The procedure of ordering the replacement should be initiated immediately after damage or shortage comes to notice without waiting for acceptance of the claim by the Insurance Company.

Construction Equipment & Plant

161. The engineer in charge of the project should decide the extent of mechanisation at the design/planning stage after taking the various factors into consideration. The procurement of construction equipment and plant should be initiated well before the start of the execution of the project so that it is available in time.

Construction Contracts

162. For timely execution of the project it is necessary to draw the overall project schedule as well as the schedules for the construction jobs proposed to be handled on contract before inviting tenders, or in any case, before awarding the contract. Such schedules should define the required date for any significant point of communication of transfer of responsibility between the contractor and other participants on the project.

163. The availability to control a construction project, most elements of which are given on contract, depends largely on the soundness of the contract documents themselves. A loosely defined contract may create considerable dissensions between the contractors and the project management due to individual interpretations of the intent as well as contents of the contract.

164. During the course of execution of the contract, the Project Management should retain full authority under the terms of contract to request any measures that may be necessary for the proper and timely execution of the work. The project personnel should constantly watch the project and evaluate the effect of slippage on the part of any contractor on the rest of the project.

165. Most of the needs of generating plant are going to be met from the indigenous manufacturers M/s. H.E. and M/s. B.H.E. who are not yet sufficiently equipped to undertake erection work of their own equipment. The Electricity Boards should, therefore, build up suitable teams for undertaking the work of installation and commissioning of plant and equipment. Such teams will be of great value to the organisation in arranging overhaul and proper maintenance work also.

166. In the absence of free exchange of ideas between contractors and project officers, there are considerable difficulties regarding measurement or assessment of work done, contractual obligations and responsibility of different parties etc. These difficulties are increasing with the increasing complexity and volume of project construction work. Some organisations like the Institution of Engineers (India) should bring together the contractor firms and project execution people to evolve a common understanding of the problems and to work out possible solutions.

167. The accounting proformae and procedures prescribed for the project works of complexity, particularly the electrical works, do not suit the work involving complex technology. The Ministry of Irrigation and Power should appoint an Expert Committee to go into the methods, detailed rules and proformae and suggest changes for simplifying and rationalising the work in the projects including methods of recording measurements.

168. The consultancy organisations should build up the expertise and capacity for undertaking inspection during manufacture and witnessing of tests on behalf of the projects.

169. The CWPC should make a comprehensive survey of the facilities available in the country for undertaking quality control "type" and other proving tests and catalogue these for the use of the Project Authorities.

Miscellaneous Bottlenecks

170. The project authorities should be aware of the various possible serious bottlenecks such as land acquisition, rehabilitation, labour strikes, clearances of local/State Authorities etc. and timely action should be taken for tackling these matters at the appropriate level.

Project Organisation & Management

171. It is essential that every project should be organised from the beginning under a suitable qualified and experienced project manager who is vested with adequate financial and administrative powers including placement of orders.

172. Modern Management methods need to be adopted for efficient and timely execution of the projects. "Systems" approach to the question of project management and control should be adopted. Proper planning of the project work at all stages, marshalling of all the resources (material as well as human) in appropriate combinations at every stage, proper intermeshing of the vast number of different activities by different agencies and monitoring and control of the project by watching the progress of physical achievements as well as spending of funds in a rational manner are the main techniques by which an optimum efficiency and speed can be achieved.

173. PERT/CPM network techniques should be introduced from the earliest possible stages of the project and preferably even to cover the planning stages also. Establishment of PERT Cell to cover all projects of an organisation as well as individual PERT Cells for each project or even its major elements are very desirable.

174. These network techniques have to be integrated in a comprehensive management information and control system. The objectives of this management information system should be primarily achieving *on time* and *on cost* completion of each phase of the power project. A model management information system has been given in the Report.

175. Where the project organisation are not adequately equipped, it is advisable to retain the services of an experienced consulting engineer organisation such as the Specialised Engineering Organisation of CWPC or other Consulting Engineers available in each specialised field.

176. The system of "performance budgeting" should be adopted as an important management tool for monitoring and control of a project.

Marshalling of Resources

177. Nation-wide survey and planning is necessary to ensure adequate resources for construction projects in respect of construction materials, equipment manufacture, construction machinery and design and engineering capability.

178. There should be a panel of experts who may be available in the State Electricity Boards, Universities, and other Organisations in the country. Standing arrangements should be made so that the CWPC or the projects can avail of the expertise of these persons whenever required at short notice.

179. In view of the ever increasing scale of project execution in the field of power, there is an urgent need of expansion of the design units in the Electricity Boards/Undertakings, the Specialised Engineering Organisation of CW&PC an Consulting Engineer Firms.

180. The CWPC has the dual role of being Consulting Engineers to the power projects and Technical Advisers to the Central Government. There is an urgent necessity to undertake a deliberate programme for building up of the Specialised Engineering Organisation of CWPC in order to ensure that the design and engineering capability in specific areas of complexity is available.

181. There is an urgent need for developing technical manpower resources to remove scarcity of adequately trained and experienced personnel for manning technical jobs at all levels. This will also help reduce growing unemployment among persons passing through technical institutes.

182. Every effort should be made to accelerate the growth of the capability of M/s HE and M/s BHE and their feeder projects so that the future requirements of plant and equipment for power projects can mostly be met by these.

183. Where M/s HE and M/s BHE cannot cope up with the needs of the power supply industry for enabling it to meet the needs of growth of industry and agriculture, *import of plant and equipment to the extent necessary* for uninhibited growth of the power sector should be approved.

184. Close collaboration of the Design and Research Organisation in the country should be established for developing designs to get around problems of scarcities of certain materials arising from time to time.

185. Each State Electricity Board should form a pool of construction plant and machinery for all its construction projects. Each project should draw upon this pool in respect of equipment, spares as well as operation and maintenance personnel according to needs. The Regional Electricity Boards should assist by keeping consolidated inventories of the equipment and spares available at different places for with different Electricity Boards in the region facilitating better utilisation of the equipment and reduction of down time for want of spares. At the national level the CWPC should take a census of the plant and machinery and its current conditions periodically and make this information available to the Electricity Boards/Construction Projects.

Future Pattern of Project Execution

186. In view of the ever increasing tempo of project execution in the field of power, the Centre may have to play an increasingly active role. The Centre should take immediate steps to review and strengthen the Central Electricity Authority.

187. For a number of reasons discussed in the report, it would be desirable for the large or inter-State projects to be taken up for execution by the Regional Boards or by the Centre.

188. Presently, the State Electricity Boards are engaged in multifarious activities due to which adequate attention cannot be given to the problems of long-term planning etc. The top management should, therefore, be strengthened and organised by having the State Electricity Boards headed by an experienced Power Engineer as the Chairman and by putting all Members heading two Wings of the Board—one being in-charge of planning, construction of power stations and transmisson systems of 220 kV and above and other in-charge of construction of transmission and distribution systems upto 132 kV, operation and maintenance and rural electrification etc.

189. A uniform system of accounting needs to be prescribed for use by all Electricity Boards and undertakings so that confusion regarding real figures of cost both financial and economic is avoided.