1 Introduction

1.1 IMPORTANCE OF ELECTRICAL ENERGY & POWER SECTOR DEVELOPMENT

Energy, in its simplest form, is known as ability to do work. The energy, when converted into electricity, is called 'power'. Energy is required for doing any type of work in life. It is required for cooking, heating, cooling, lighting etc. in our homes; to run our machines and other mechanical equipment in industries; to run our locomotives for transportation. Since almost all our developmental activities are directly or indirectly dependent upon the energy consumption, the amount of consumption of energy by a nation is usually considered as an index of its development.

Power development is one of the key infrastructure elements for the economic growth of the country. Power projects are indispensable as they are inexorably linked to the Indian economy, besides their need for the welfare of the growing masses. The development of the power sector in the country since independence has been predominantly through thermal, hydropower, nuclear and non-conventional source.

Since energy plays a fundamental role in the economic development of any country, we have to ensure availability of energy that is affordable, reliable and secure in order to sustain modern ways of living. Giant strides have been made in the Indian electricity sector in past five decades. The generating capacity, which was a meagre 1362 MW at the time of independence, has presently increased to 1,40,302 MW (as on 31.12.2007).

The annual generation has grown from about 5 billion units to about 811 billion units for the year 2010-11. During this period of times, per capita consumption has increased from a mere 15 Kwh to 632 Kwh.

The demand for electricity has overtaken the supply and the gap has been increasing. The rapid economic growth for which the country is poised in the wake of economic reforms and globalization, would lead to further increased demand growth. To meet the increasing power requirement, it is necessary to speedily develop and utilize all types of energy resources at our command. Since 1990s India's Gross Domestic Product (GDP) has been growing quite fast and it is forecast that it will continue to do so in the future.

To satisfy our energy needs, India will have to find its own optimal energy mix ensuring the best compromise between energy requirements, environmental and social impacts. Despite the fact that India is the sixth largest country in terms of power generation, yet the overall electricity shortage continue to be a major concern. The peaking shortages are about 10.5% as on December 2010 on an all India basis.

The total installed capacity in the country at the end of 10th plan (as on 31.03.2007) stood at 1,32,330 MW comprising of 34,654 MW hydro, 86015 MW of thermal (including gas and diesel), 3900 MW of nuclear and 7,761 MW from other renewable energy sources (RES) including wind. The sector-wise details of installed capacity are given below:

Sector	*Hydro (MW)*	*Thermal (MW)*	*Nuclear (MW)*	*RES (MW)*	*Total (MW)*
Central	7562	33659	3900	0	45,121
State	25786	43334	0	976	70,096
Private	1306	9022	0	6785	17,113
Total	**34,654**	**86,015**	**3,900**	**7,761**	**132,330**

As on 31.7.2011, the installed capacity is 1,80,358 MW comprising of 38,106 MW hydro, 1,17,309 MW thermal, 4,780 MW nuclear and 20,162 MW from RES. Sector wise position is central sector 56,573 MW, state sector 82,813 MW and private sector 40,971 MW. In addition captive generating capacity connected to grid is 19,509 MW.

As discussed above electrical energy has become synonymous with progress. The lack of it can hamper the entire economic activity and well being of the country. Therefore, energy is considered a basic input for any country for keeping the wheels of its economy moving. Next to the food, the fuel and power are the most important items on which national standard of life depends. Therefore, every effort has been made to increase the power potential of the nation once the requirement of food is fulfilled. The production of food also increases with the increase in power. Thus, the increase in power potential of a nation is considered most important.

The electrical energy is easy to transport, easy to control, clean in its surroundings and can be easily converted in heat or any form of work as per requirements. The history of power development in India dates back to 1897 when 200 kW hydro-station first commissioned at Darjeeling. The majority of earlier power stations comprised diesel generating sets. The first steam station was commissioned in Calcutta in 1899 with a total installed capacity of 1000 kW.

During the first two decades of the twentieth century, steam power stations at Kanpur, Madras and Calcutta of 2,170 kW, 9,000 kW and 15,000 kW capacity respectively were commissioned. Similarly, hydro plants of 4,500 kW at Sivasamud in Karnataka in 1902, 3,000 KW at Mohora in J & K in 19,07,500 kW at Simla in Himachal Pradesh in 1911 and 40,000 KW (40 MW) at Tata Hydro (Bombay) in 1915 were installed.

Growth pattern of installed capacity of power is shown in the table given below:

S.*N.*	*Year*	*Installed Capacity in MW*		
		Total	*Hydro*	*Hydro power Share*
1.	1920	130	74	
2.	1940	1208	N.A	
3.	1951	1710	560	

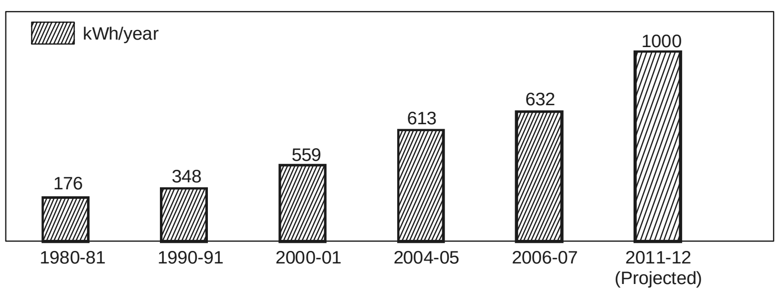
(*Contd...*)

4.	1956 (end of I plan)	2886	1061	36.78%
5.	1961 (end of II plan)	4653	1916	41.19%
6.	1966 (end of III plan)	9027	4124	45.68%
7.	1969 (end of 3 annual plans)	12957	5906	45.58%
8.	1974 (end of IV plan)	16664	6965	41.80%
9.	1979 (end of V plan)	26680	10833	40.60%
10.	1980 (end of annual plan)	28448	11384	40.01%
11.	1985 (end of VI plan)	42585	14460	33.96%
12.	1990 (end of VII plan)	63636	18308	28.77%
13.	1992 (end of 2 annual plans)	69065	19195	27.79%
14.	1997 (end of VIII plan)	85019	21644	25.46%
15.	2002 (end of IX plan)	103410	26261	25.40%
16	2007 (end of X plan)	132,329	34653	26.19%

**Includes 1168 MW of small hydro capacity which is now being considered as Renewable Energy Sources (RES) since 2007-08.*

A graphical representation of the growth profile in respect of per capita electric consumption is given below:

Table: Per capita consumption of electricity in India



Need based capacity addition targets for 10th plan (2002-2007) were fixed for 41,110 MW including 14393 MW for hydro capacity addition. Against this, a total capacity of 21,180 MW including 7,886 MW of hydro could be achieved.

To meet the energy requirements of 1038 billion units and a peak load of 1,52,746 MW with a 5% spinning reserve, a capacity addition of about 82,500 MW was required during 11th plan. However, a capacity addition of 78,577 MW comprising of 39,865 MW (50.7%) in Central sector, 27,958 MW (35.6%) in state sector and 10,760 MW (13.7%) in private sector was proposed during 11th plan. The proposed hydro capacity addition during 11th plan was 16, 553 MW.

As per the studies carried out by Central Electricity Authority (CEA) to assess the requirement of additional capacity during the 12th plan (2012-17), the requirement of installed capacity to meet the all India peak demand and energy requirement at the end of 12th plan would require a capacity addition of 82,200 MW, out of which 30,000 MW is proposed to be added through hydro projects. The exercise for this began well in advance by identifying the projects, taking up / completing their survey and investigation / DPR preparation and other pre-construction activities.

To boost the power generation government has taken many steps to take up the power projects in central, state and private sector. It has created, besides National Thermal Power Corporation (NTPC) and National Hydro-electric Power Corporation (NHPC), following corporations in the central and joint sector (central and state):

(*i*) North-Eastern Electric Power Corporation (NEEPCO)
(*ii*) Satlaj Jal Vidyut Nigam Ltd. (SJVNL-earlier NJPC)
(*iii*) THDC India Ltd. (Earlier Tehri Hydro Development Corporation Ltd.)
(*iv*) Narmada Hydro Development Corporation (NHDC).

Beside, NTPC has also taken up a number of hydro projects.

The acceleration of the process of industrialisation and urbanisation following the determined effort of the developing countries like India to improve their economic well-being has inevitably lead to larger and larger demands for energy. The central problem, therefore, is how a country like India can ensure adequate supplies of energy of fuel, its economic growth into global environment of scarcity of desired fuels and high costs.

In our country the main sources of energy are fossil fuels, hydel, and nuclear power even though solar energy, wind power and tidal power offer hopeful technological opportunities.

Coal will remain as main source of energy for several decades to come. While discovery of more oil and gas is not ruled out, the question is what production level can be reached and for how long can it be sustained. A large untapped hydro-potential exists in our country. It is found that total hydro-potential could be equivalent to 75,400 MW at 60% load factor of which about 10% to 12% has been exploited so far. Hydro power being a renewable source of energy must receive a high priority in our energy development programme.

The use of bio-gas for lighting and irrigation opens up new possibilities for self-contained rural communities. In the long run our energy economy would have to be built around land-based biomass fuels and the plentiful sunshine which we receive virtually throughout the year.

World over the trend has been towards utilising the existing resources like hydel and coal and at the same time developing nuclear power generation capabilities. Developed countries have taken a long term view of their power needs and have gone in for a jundicious mix of these source.

The various sources of power generation should be used to match particular circumstances and needs. Nuclear power is a clean source of energy and hazards can be minimised. Dams have longer life than thermal power plants. While the demand for electrical power is on the rise, the overall known resources of petroleum are on the decline. It is therefore imperative that the consumption of petroleum products in the field of power generation, transmission and distribution is conserved to the maximum extent.

In India, the present petroleum may not last long. Alternative sources of energy must therefore be found out so far the known sources of unconventional energy are nuclear fusion, solar energy, geo-thermal energy, wind power, tidal wave energy and biogas. In a tropical country with abundant solar energy, If we succeed in tapping solar energy on a massive scale for lift irrigation purposes, we may indeed achieve a break-through in our rural economy by successfully utilising under-ground water resources. All efforts should be made to conserve conventional sources and to develop non-conventional sources of energy.

1.2 CLASSIFICATION OF POWER PLANTS

As we know that a power plant is an assembly of equipment that produces and delivers mechanical and electrical energy. Power plant may be classified as under:

1. On the basis of service rendered:
   (*i*) Stationary (*ii*) Mobile.
2. On the basis of source of energy
   (*i*) Steam power plants:
      (*a*) condensing
      (*b*) non-condensing.
   (*ii*) Diesel power plants
   (*iii*) Hydro-electric power plants
   (*iv*) Nuclear power plants
   (*v*) Gas turbine power plants
   (*vi*) Tidal power plants
   (*vii*) Solar power plants
   (*viii*) Wind power plants
   (*ix*) Geo-thermal power plants
   (*x*) MHD power plants.
3. On the basis of location:
   (*i*) Central power station (*ii*) Isolated power station.
4. On the basis of nature of load:
   (*i*) Peak load plant (*ii*) Base load plant
   (*iii*) Stand-by plant
5. On the basis of conventional or non-conventional sources:
   (*i*) Conventional sources
      (*a*) Thermal power plants (Steam, Diesel, and Gas)
      (*b*) Hydro power plants
      (*c*) Nuclear power plants
   (*ii*) Non-conventional sources
      (*a*) Tidal (*b*) Solar
      (*c*) Wind (*d*) Geo-thermal
      (*e*) M.H.D.
6. On the basis of Renewable or Non-renewable energy resources
   (*i*) Renewable energy resources
      (*a*) Hydro (*b*) Solar
      (*c*) Wind (*d*) Tidal
      (*e*) Ocean thermal (*f*) Geothermal
   (*ii*) Non-Renewable energy resources
      (*a*) Coal (*b*) Oil
      (*c*) Gas (*d*) Nuclear

Steam Power Plants use solid fuel, *i.e.,* coal in pulverised form in burners or furnace oil in oil burners. Steam is produced in the boiler and is expanded in steam turbines which are coupled to electric generators, generating electricity. The plant may contain several other mountings, accessories and heat reclaiming devices such as economisers, air preheaters, feed water heaters etc.

Hydro-electric Power Plants have water stored behind a dam at an elevation. The potential energy of water is converted to mechanical energy allowing the water to flow through water turbines. Generators are coupled with water turbines to generate electric power.

Diesel Power Plants use diesel engines as the prime movers to drive the electric generators for producing electric power. The main equipments of these plants are diesel engines, engine starting and engine super-charging equipment, oil handling, oil cooling system and water cooling system.

Gas Turbine Power Plants use gas turbine as prime mover, where working medium is a gas. The air compressed in a compressor is then supplied in combustion chamber, where hot gas are generated, which are expanded in gas turbine to produce mechanical power. Gas turbine is connected to alternator to generate electric power. The main equipment in these power plants are: gas turbine, the starting device, fuel control system, compressor, reheater, regenerator, oil cooler etc. The heat from the gas turbine exhaust may be used for providing the heat for generating steam in a waste heat boiler.

Nuclear Power Plants employ nuclear reactor for generation of heat energy. These power plants are similar to steam power plants, in which boiler is replaced by nuclear reactor.

Solar Energy comes to the earth from the sun. Solar energy is converted to electricity by photovoltaic **solar** cells.

Wind energy may be used in remote areas where laying of transmission lines may be expensive. The wind energy is converted into electrical energy by the use of wind turbines. This is used in places where wind velocity is considerably high.

Geothermal energy. Approximately 94% of the earth is in molten state, and only the thin outer shell is a solidified rock ranging in thickness from 75 to 150 km. The temperature at the centre of the earth is around 3000°C, while temperature at the juncture between the magma body and the crust approaches 1200°C. Geothermal energy is the energy which lies embedded within the earth. The fact that volcanic action take place in many places on the earth supports these theories. The steam and hot water comes naturally to the surface of the earth in some locations of the earth. For large scale use bore holes are normally sunk with depths upto 1000 M, releasing steam and water at temperature upto 200 or 300°C, and pressures upto 30 kg f/cm^2. The steam coming out of the ground is used to generate electricity.

Magneto-hydro-dynamic (MHD) power generation. Faraday's law of electromagnetic induction states that when a conductor and magnetic field move relative to each other, an electric voltage is induced in the conductor. The conductor may be a solid, liquid or gas. In an MHD generator, the hot ionised gas replaces the copper windings of an alternator. The hot partially ionised and compressed gas is expanded in a duct, and forced through a strong magnetic field, electrical potential is generated in the gas. Electrodes placed on the side of the duct pick up potential generated in the gas. In this manner, direct current is obtained which can be converted to AC with the help of an inverter.

Tidal power. The tides in the sea and oceans of earth are the result of the universal gravitational forces of sun and moon on the earth. This results a periodic rise and fall in levels of sea water, which is in rhythm with the daily cycle of rising and setting of sun and moon. In a period of 24 hrs and 50 min, there are two high tides and two low tides. The water at the time of high tide is at a high level and can be let into a basin for storing there at a high level. This water is then allowed to come back into the sea during the low tide through the turbine, thus producing the power. The difference of head between high level in the basin and low level in the sea is utilised for running the turbine. In India following three sites for possible generation of power through tides have been selected. These are:

(*i*) Gulf of Cambay,
(*ii*) Gulf of Kutch, and
(*iii*) Sunderban area in the West Bengal.

Ocean Thermal Energy Conversion (OTEC). This is an indirect method of utilizing solar energy. A large amount of solar energy is collected and stored in tropical oceans. The surface of water acts as the collector of solar heat, while the upper layer of the sea constitutes infinite heat storage reservoir. Thus the heat contained in the oceans could be converted into electricity by utilizing the fact that temperature difference between the warm surface waters of the tropical oceans and the colder water in the depths is 20-25 K. The surface water which is at higher temperature could be used to some low boiling organic fluid, the vapours of which would run a heat engine. The exit vapour would be condensed by pumping cold water from the deeper regions.

OTEC systems work on a closed Rankine cycle and use low boiling organic fluids like ammonia, propane etc. The warm surface water is used for supplying the heat input in boiler while the cold water brought up from the depths is used for extracting the heat in the condenser.

1.3 POWER GENERATION IN INDIA

A. **Major Thermal Power Stations** (coal base) :

State	*Location*	*Capacity*
1. Andhra Pradesh	1. Ramgundam	2600 MW
	2. Manguru	3000 MW
	3. Kothagudum	240 MW
	4. Simhadri (Vishakha patnam)	1000 MW
2. Bihar	1. Kahalgaon I	840 MW
	2. Kahalgaon II	2800 MW
	3. Pathratu	310 MW
	4. North Karanpara	2000 MW
	5. Barh	2000 MW
	6. Jamshedpur	120 MW
	7. DVC	957 MW
3. Chhattisgarh	1. Seepat (Bilaspur)	2000 MW
	2. Korba	2100 MW
4. Delhi	1. Badarpur	720 MW

(*Contd...*)

(*Contd...*)

5. Gujarat	1. Ahmedabad	217 MW
	2. Dhuvaran	254 MW
6. Haryana	1. Faridabad	800 MW
	2. Yamuna Nagar	840 MW
7. Karnataka	1. Manglore	320 MW
	2. Chhamraj Nagar	500 MW
	3. Hasan	200 MW
8. Kerala	1. Kayamkulum I	420 MW
	2. Kayamkulum II	400 MW
9. Madhya Pradesh	1. Vindhyachal	2260 MW
	2. Waiden	3000 MW
	3. Pench	840 MW
	4. Satpura	312 MW
	5. Bhilai	500 MW
10. Maharashtra	1. Trombay	337 MW
	2. Nasik	280 MW
	3. Chola	136 MW
	4. Khaperkheda	120 MW
11. Orisa	1. Talchar	4000 MW
	2. Rourkela	125 MW
12. Punjab	1. Bhatinda	640 MW
13. Rajasthan	1. Kota	400 MW
14. Tamil Nadu	1. Nayveli	240 MW
	2. Chennai	2000 MW
	3. Ennore	120 MW
15. Uttar Pradesh	1. Singrauli-I	2000 MW
	2. Singrauli-II	3000 MW
	3. Rihand	3000 MW
	4. Dadri	840 MW
	5. Unchahar	840 MW
	6. Hardua Ganj	210 MW
	7. Obra	200 MW
	8. Kanpur	155 MW
	9. Renukoot	125 MW
16. West Bengal	1. Farakka	3800 MW
	2. Durgapur	406 MW
	3. Kolkata	507 MW
	4. Bandel	330 MW
B. Major Gas Operated Thermal Power Stations		

(*Contd...*)

(*Contd...*)

1. Andhra Pradesh	1. Hyderabad	650 MW
2. Delhi	1. Delhi	180 MW
3. Gujarat	1. Kawas-I	600 MW
	2. Kawas-II	1300 MW
	3. Gandhar (Bhadoch)-I	650 MW
	4. Gandhar-II	1300 MW
	5. Ukar	160 MW
4. Haryana	1. Faridabad	800 MW
5. Kerala	1. Kayamkulam	1300 MW
	2. Pambki	300 MW
6. Karnataka	1. Godawari	800 MW
7. Rajasthan	1. Anta-I	430 MW
	2. Anta-II	1300 MW
8. Uttar Pradesh	1. Aurayya-I	600 MW
	2. Aurayya-II	1300 MW
	3. Deoli	600 MW
	4. Dadri	1200 MW
	5. Yamuna	444 MW
9. Tripura	1. Tripura	500 MW

C. Nuclear Power Plants in India

Location	*Capacity*
1. Tarapore (Maharashtra)	2 × 210 + 2 × 500 = 1420 MW
2. Rawatbhata (Rajasthan) near Rana Pratab Sagar	2 × 220 + 2 × 235 + 4 × 500 = 2910 MW
3. Kalpakkam (Tamil Nadu) near Chinnai	2 × 235 + 1 × 500 = 970 MW
4. Narora (U.P.)	2 × 235 = 470 MW
5. Kakrapar (Gujarat) near Surat	2 × 235 = 470 MW
6. Kaiga (Karnataka)	6 × 235 = 1410 MW
7. Koodumkulam (Tamil Nadu)	2 × 1000 = 2000 MW

D. Major Hydro Power Station in India

NORTHERN REGION

Himachal Pradesh	1.Baira Siul	198 MW
	2. Chamera	840 MW
	3. Nathpa Jhakri	1500 MW
	4. Sanjay	120 MW
	5. Larji	126 MW
	6. Baspa	300 MW

(*Contd...*)

(*Contd...*)

	7. Allain Duhangan	192 MW
Jammu & Kashmir	1. Salal	690 MW
	2. Uri	480 MW
	3. Dul Hasti	390 MW
	4. Lower Jhelam	105 MW
	5. Upper Sindh	127 MW
	6. Baglihar	450 MW
Punjab	1. Bhakra	1325 MW
	2. Dehar	990 MW
	3. Pong	396 MW
	4. Shanan	110 MW
	5. Mukerian	207 MW
	6. AP Shahib	134 MW
	7. Ranjit Sagar (Thein Dam)	600 MW
Rajasthan	1. Rana Pratap Sagar	172 MW
	2. Jawahar Sagar	99 MW
	3. Mahi Bajaj	140 MW
Uttar Pradesh	1. Rahand	300 MW
	2. Obra	99 MW
Uttarakhand	1. Tehri	1000 MW
	2. Tanakpur	94 MW
	3. Dhauli Ganga	280 MW
	4. Yamuna St.I to IV	475 MW
	5. Ramganga	198 MW
	6. Chilla	144 MW
	7. Maneribhali	394 MW
	8. Vishnu Prayag	400 MW
WESTERN REGION		
Gujarat	1. Ukai	300 MW
	2. Kadana	240 MW
	3. Sardar Sarovar	1450 MW
Madhya Pradesh	1. Indra Sagar	1000 MW
	2. Omkareshwar	520 MW
	3. Gandhi Sagar	115 MW
	4. Bargi	90 MW
	5. Pench	160 MW
	6. Bansagar	425 MW
Chhattisgarh	1. Hasdeo Bango	120 MW

(*Contd...*)

(*Contd...*)

Maharashtra	1. Koyna	1956 MW
	2. Bhira	150 MW
	3. Bhira PSS	150 MW
	4. Ghatghar	250 MW
Southern region		
Andhra Pradesh	1. Machkund	115 MW
	2. Sileru	700 MW
	3. Nagarjun Sagar	966 MW
	4. Srisailam	1670 MW
	5. Priyadarshini Jurala	234 MW
Karnataka	1. Sharavathy	1246 MW
	2. Kalinadi	1125 MW
	3. Varahi	230 MW
	4. Supa	100 MW
	5. Almati	290 MW
	6. Jog	139 MW
	7. Tungbhadra	100 MW
	8. Tattochalla	810 MW
	9. Talakale	891 MW
Kerala	1. Idukki	780 MW
	2. Sabaragiri	300 MW
	3. Lower Periyar	180 MW
	4. Kuttiyadi	100 MW
	5. Kakki Dam	410 MW
Tamil Nadu	1. Kundah	555 MW
	2. Mettur	360 MW
	3. Periyar	140 MW
	4. Sholayar	95 MW
	5. Kadanparai	400 MW
	6. Pykara Ulimate	150 MW
	7. Kodayar	100 MW
Eastern region		
Jharkhand	1. Subern Rekha	130 MW
	2. DVC	147 MW
Orissa	1. Hirakud	332 MW
	2. Balimela	360 MW
	3. Rengali	250 MW

(*Contd...*)

(*Contd...*)

	4. Upper Kolab	320 MW
	5. Upper Indravati	600 MW
	6. Balimela Extn.	150 MW
Sikkim	1. Rangit	60 MW
	2. Teesta	510 MW
West Bengal	1. Purlia	900 MW
North-Eastern Region		
Arunachal Pradesh	1. Ranganadi	405 MW
Meghalaya	1. Kyrdemkulai	60 MW
	2. Umiam-Umtru	125 MW
Nagaland	1. Doyang	75 MW
Assam	1. Khandong	75 MW
	2. Kopili	200 MW
	3. Karbi Langpi	100 MW
Manipur	1. Loktak `	150 MW

1.4 RATIO OF DIFFERENT TYPES OF POWER GENERATION IN MAJOR COUNTRIES

(*In percentage of generation*)

Name of country	*Type of Power*			
	Thermal	*Hydro*	*Nuclear*	*Others*
Brazil	8	83	4	4
Canada	27	60	12	1
China	81	17	2	—
France	9	11	78	1
Germany	62	4	29	5
India	85	11	3	1
Japan	62	8	27	3
Russia	63	21	16	—
U.K	74	1	23	2
US	71	7	20	—

1.5 THERMAL-HYDRO GENERATION MIX

A power grid system is fed by number of power houses, may be thermal, hydro or nuclear. In a grid system, the general planning is such that some power houses run as base load stations while others as peak load stations. Generation-mix means how much load is shared by which type of power. Load sharing by hydro-power ought to be maximum when the natural flow is maximum *i.e.*, during monsoon months. This is necessary to take advantage of natural flow. Therefore, as a corollary load on the hydro power is as less as possible during dry season.

Thermal power is used as base load demands, whereas hydro-power is suitable for peak load demands. The Pumped storage hydro-plants provide the peaking power for limited hours of the day.

Today major part of the energy demands are being met by oil and coal. These sources will not last longer than a few decades. These also create pollution hazard.

As per the system studies conducted by CEA (Central Electricity Authority), India as a whole should have an ideal thermal-hydro mix of 60:40. A country like India which is endowed with coal as well as hydel resources has to envolve an optimum power mix from the viewpoint of healthy power system operation on one hand and environmentally sustainable development on the other. One of the important aims of optimization of thermal-hydro mix is that the system should have mix of plant characteristics of meeting the load demand fluctuations economically.

We should remember that thermal as well as nuclear power plants perform best when they are fully loaded and act as base load station. Whereas hydro, including pumped storage capable of storing off peak energy for its reuse during the peak demand, as complementary peak characteristics. These can be started and stopped quickly to meet the non-continuous type of load. Hydro-plants designed as low load factor and peaking operation can thus make a major contribution to the overall economy of generation.

As 40% of the total demand in India occurs as peak demand and since hydro-plants are best suited to meet this requirement, the ideal thermal-hydro mix should be 60:40.

At the time of independence in 1947, the total hydel installed capacity was only 508 MW with 12 hydro-electric stations against total installed capacity of 1362 MW from all sources i.e. 37.30%. This ratio was 45.68% in 1966 i.e., in the end of III plan. Later on it is continuously declining and was only 26.19% in 2007 i.e., in the end of 10th plan. The share of hydro-electric installed capacity was highest in 1962-63 as 50.61%.

1.5.1 Reasons for Adverse Thermal-Hydro Ratio

Main reasons for averse thermal-hydro ratio in the country are:

1. Long gestation period. Therefore, lack of emphasis while allocating financial resources.
2. Large surplus staff on completion of construction.
3. Virtual absence of private sector in hydropower development.
4. Dependence on neighboring countries in implementing hydro-schemes on international rivers.
5. Interstate river water disputes.
6. Emergence of environmental/ecological awareness/apprechensions
7. Geological surprise, particularly in Himalayan belt causing hazards and at times calling for design changes at construction stage, resulting in time and cost over-runs.
8. Location of hydro-power project sites in sensitive border areas.
9. Problems in acquisition of land and in rehabilitation and resettlement.

1.6 COMBINED WORKING OF DIFFERENT TYPES OF POWER PLANTS

There is always a trend to investigate the economics of the combined working of electric power plants. Hydropower plants can be developed only at sites where a large quantity of water is available at sufficient head. In considering the economy of power development the transmission liability of hydro-electric projects should be taken into account. Steam power plants can be located at or near the load centre and can be used as base load plant. When a number of power plants are worked in combination to supply an electric power system they are all connected together and the system is called inter-connected system. Before using inter-connected system it is necessary to draw the annual load duration curve of the area to which power is to be supplied and then to fit the various types of power plants into the area under the curve. Base load plants which run at a high load factor should be used to supply the load on the base portion of load curve and peak load plants which work at a low load factor should be used to supply rest of load on the top portion of load curve. Steam power plants can be used with advantage in combination with hydro-electric power plant to obtain economy from the mixed system. Steam power plants can be used on any portion of the load curve although it is not economical to use them as peak load plants.

In combined working of hydropower plant and nuclear power plant the nuclear power plant should be used as base load plant and hydropower plant can supply the variable load. Gas turbine plants are the cheaper type in some situations when they are used as peak load plants in combinations with base load plant.

During combined working of hydropower plant and steam power plant the hydropower plant with ample water storage should be used as base load plant and steam power plant should be used as peak load power plant. If the amount of water available is less at hydro-plant then the steam power plant should supply the base load and hydro-plant should act as peak load again. Diesel power plant are generally used as peak load plants.

When pumped storage plant is used in combination with steam power plant then pumped storage plant is used to supply sudden peak loads of short duration. The advantages of pump storage plant in an inter connected system are as follows:

(*i*) It stores the energy using off peak energy of thermal plant and the same is supplied during demand.

(*ii*) It minimises wastage of off-peak energy of steam power plant.

(*iii*) Use of pumped storage plant helps in loading economically the steam power plant. During coordination of hydropower plant and gas turbine power plant the gas turbine power plant is used peak load plant. The high working cost of gas turbine plant is compensated by lower fixed cost and lower operating and maintenance cost.

Inter connected power system can provide large savings both in capacity and fuel cost at the same time ensuring reliability and continuity of power supply. The main purpose of interconnection is to distribute the load among the interconnected power plants system in order to achieve the overall economy.

The various advantages of combined working of different types of power plants are as follows:

(*i*) There is a reliability of power supply to consumers because in the event of power failure at one of the power plants the system can be fed from other power plants to avoid complete shut down.

(*ii*) The spinning reserve required in a power system is reduced.

(*iii*) Combined working of different types of power plants reduces the amount of generating capacity required to be installed as compared to that which would be required without interconnection.

(*iv*) The interconnection of various power plants helps in reducing the amount of generating capacity to be installed.

(*v*) In an inter-connected system the overall cost of energy is less.

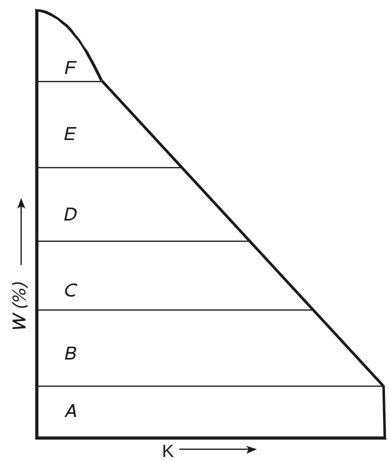


Fig. 1.1

Fig. 1.1 shows a typical annual duration curve between percentage of year *(K)* and load *(W)*. The various loads which should be supplied by different power plants are indicated in Table 1.1.

Table 1.1

Load	*Power plant*
A	Run off river plant
B	Nuclear power plant
C	Hydropower plant with sufficient storage
D	Steam power plant
E	Hydropower plant with limited storage
F	Diesel or gas turbine power plant or pump storage plant

Following factors should be considered while deciding the load to be shared among different types of power plants:

(*i*) Capacity of power plant

(*ii*) Degree of reliability

(*iii*) Probable load factor

(*iv*) Cost of fuel and transport facilities

(*v*) Initial cost and operating cost

(*vi*) Load between different power plants should be so decided that overall economy is achieved

(*vii*) Time required to start the plant from cold condition.

1.6.1 Economy of Operation

The factors directly affecting the economy of operation of various power plants are as follows:

(*i*) Cost of generating units
(*ii*) Normal and emergency equipment ratings
(*iii*) Fuel cost
(*iv*) Labour cost
(*v*) Reserve requirements
(*vi*) Voltage limitations
(*vii*) Characteristics of prime movers
(*viii*) Transmission losses.

1.6.2 Efficiency of Power Plants

The efficiency of a power plant depends on load and time period. Fig 1.2 shows the efficiency of various power plants with respect to load. The increase in efficiency of hydro power plants is higher as compared to other power plants at high load.

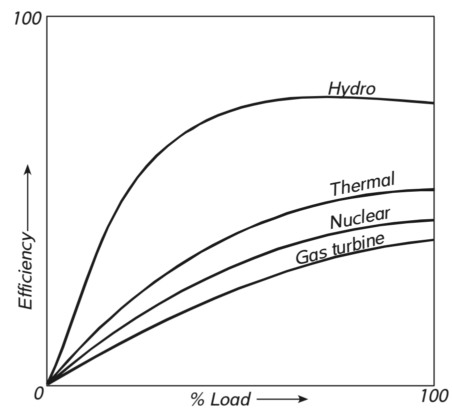


Fig. 1.2

1.7 CHOICE (LOCATION) OF POWER PLANTS

The type of power plant to be installed depends upon the source of energy. A *hydroelectric power plants* should be installed where sufficient water with sufficient head is available.

For conventional base load *thermal power plants*, following are the major factors which need be considered:

(*i*) Availability of fuel and cost of its transportation
(*ii*) Distance from the centre of gravity of load demand.
(*iii*) Availability of land with a provision for expansion at economical rates
(*iv*) Availability of cooling water
(*v*) Ecological considerations including air and water pollution
(*vi*) Disposal of ash
(*vii*) Rail and road connectivity

For *nuclear power plants*, in addition to the above, following factors are also considered:

(*a*) Density of population in the vicinity

(*b*) Danger of earthquake.

Diesel power plants are preferred for smaller loads at isolated place.

1.8 RECENT DEVELOPMENTS/STRATEGIES FOR FUTURE

The energy is still being produced primarily by burning of fossil fuels. Since the fossil fuels are available in a fixed limited quantity, and constitute a non-renewable resource, we can not look into them for fulfilling future increasing demand of energy. It is, therefore, necessary to develop hydropower and solar power, besides finding new technologies to harness the geothermal energy, contained in the form of excessive heat present under the earth's crust.

The intensity of use of electrical energy in the Indian economy has shown a steady increase. This trend necessitated substantial increase in the share of the investments. Help of private sector is also being taken in the power development for better utilization of funds, manpower, construction equipment and other resources.

It is also essential to keep transmission and distribution losses to minimum. Energy conservation is also required to be given maximum attention.

As hydro-electric power generation is most economical and it has vast unutilized potential, accelerating its development will help in achieving the twin objectives of optimising the generation and conserving energy resources.

The location of thermal power plants is being gradually shifted closer to the coal mines to reduce the energy costs required for transmission of coal. Solar and wind power offer the greatest scope for the development of new energy sources. A number of prototype devices have been developed for use of solar energy in areas like grain drying, water and space heating and power generation. Application of wind power for agriculture pumping with certain prototype models are undergoing field trials and evaluation.

1.8.1 Integrated Operation of Power Plants

Since power sector is highly capital intensive, it is desirable to utilize it in optimum manner. Once the generating facilities through different power plants are made available, it is important to have integrated operation of power systems so that maximum energy generation takes place and maximum energy and capacity are utilized. Power Grid Corporation of India is already doing the work of interconnection between the power systems to improve the continuity, security and reliability of power supply by providing sound mechanism for monitoring and control through proper administration and creating technical set-up.

When the number of different types of power stations (thermal, hydro, nuclear, gas etc.) work in combination with each other or supply the power to the consumers, these can be operated with great reliability and economy. The advantages of combined system over a single power plant are:

(*i*) The reliability of supply to the consumer is more.

(*ii*) It reduces the amount of generating capacity required to be installed, as the peak load of the combined system is less than the sum of the individual peaks, because there is certain diversity in time between peak demands of peak systems.

(*iii*) In the event of power failure at one of the stations, the consumers can be fed from the other station.

(*iv*) Overall cost of energy per unit of an interconnected system is less.

(*v*) It facilitate more effective use of transmission line facilities at higher voltages.

(*vi*) Peaking capacities can be planned on a joint basis, so that the peak loads of combined system can be carried out at a much lower cost.

1.8.2 Pump Storage Plants

Pump storage power plants are now a days acceptable for peak load operation in interconnected system. In these plants, the water from the tail (lower) water pond is pumped with the help of a pump using extra energy available during the off-peak period. Thus the surplus available energy during off-peak period is stored in the form of hydraulic potential energy by lifting the water from lower level to higher level. The same hydraulic energy is used during peak load period by supplying the water from the upper pond to the water turbine through the penstocks. The present trend to establish large capacity thermal or nuclear plants at high capital outlay has emphasized more and more importance and growing popularity of interconnected pump storage plants.

1.8.3 Entry of Private Sector

As the NTPC, NHPC and other public sector undertakings and also the State Electricity Boards etc., are unable to keep the pace with increased demand of power in future and as such a huge capital is not available with the government, the Government of India has decided to allow the private sector to enter in power generation industry. With the new policy of the government, many private companies from India and abroad have entered in power sector, as there is great scope in the power production.

1.8.4 Importance to Non-conventional Energy Sources

Realising the importance of Non-conventional energy sources, Government of India, has formed a separate Ministry of Non-conventional Energy Source (MNES) and has constituted Indian Renewable Energy Development Agency Ltd. (IREDA), a government of India Enterprise.

(*a*) *Wind power development.* Potential for wind power generation in India has been estimated 20,000 MW. Over the last two decades, the progress in wind power has been truly phenomenal. The cost of energy generation from wind is dropping and further cost reductions are possible. This, added to the growth of energy demand, environmental concerns, the rising cost of fossil fuel generation makes wind a competitive energy option in areas having a good wind resource base. Power generation from wind in the country was taken as a thrust area since the 8th plan (1992-97). The India is now the third largest wind energy generator in the world after the USA and Germany. We are now fully confident to progress rapidly in the exploitation of this eco-friendly natural resource abundantly available in our country, thereby contributing to energy sufficiency, stability and sustainability.

As per projections made by the MNES, 10% of the total installed capacity will now come from renewable sources. It is also envisaged that 50 % of this capacity may come from wind power. India has now gained sufficient technical and operational experience, and is now on the threshold of "taking off" in wind power. To sustain wind energy development, MNES has been planning and developing the basic infrastructure, institutions and resources for carrying out research and development.

Central and State Governments and IREDA is providing various assistance and incentives to the wind energy developers.

India is rated quite high in the world atlas of wind resource availability. The long-term meteorological data available indicate a large geographical area having an annual average wind speed higher that 18 kmph (minimum mean wind speed requirement for economic harnessing of wind power). Generally, large areas having annual average wind speed in excess of 20 kmph are available in four southern states and the coastal areas of Gujarat and Maharashtra, and certain areas of Rajasthan. A good progress have been observed in wind power installed capacity in Tamil Nadu, Maharashtra, Gujarat, Karnataka, Andhra Pradesh and Rajasthan.

Since the wind is neither consistent nor steady in India, the windmill power can be economically and beneficially used to irrigate the crops during September to March as there is almost no rain during the period and simultaneously large wind velocity is also available.

Integration of wind turbines into the powergrid systems does not pose serious technical problem as long as the wind capacity does not greatly exceed the minimum demand. In India, the demand almost always outstrips supply, and the additional energy from the wind turbines gets immediately abrsorbed. A spread out wind capacity of less than 20% of grid capacity is normally recommended.

(*b*) *Use of solar energy.* Among all the non-conventional energy sources, solar energy seems to hold out the greatest promise for the mankind. It is free, inexhaustible, non-polluting and devoid of political control. On the other hand, the practical applications of solar energy are not free from problems. Solar energy is not available at night or during periods when local weather conditions obscure the sun. Consequently, if solar energy is to be economically competitive, it must be converted to a usable form of energy with maximum effectivenes to reduce the capital costs.

Solar heaters, solar cookers, solar power fencing (to protect human life and agriculture land/crops from the wild animals), solar domestic lights, solar lanterns in rural households, solar water pumps and solar street lights are already on the market. Solar photo-voltaic cells,solar refrigerators and solar thermal plants, are expected to be technically and economically viable in a short time. Enough strides have been made during last two decades to develop the direct energy conversion systems to increase the conversion efficiency.

1.8.5. Mini and Micro Hydel Plants

More emphasis is now being given on'Mini' and 'Micro' Hydel plants. Though the idea of generating energy from the falls of small rivulets has been known since long and this has been utilised for operating flour mills etc., in hilly regions. Concerted efforts towards utilising the numberous falls have not earlier been made in planned way and we are now on the threshold of launching small (including micro and mini) hydro-electric projects. There are three conditions under which small hydro-electric generation possibilities exist, namely, hill areas (water falls), perennial river system, and drops along irrigation canals.

Government is giving priority for harnessing the hydro-potential available in various canals or springs etc., wherever the low heads are available and the small power houses could be set up. This will benefit the backward areas as rapidly as possible. Such plants have negligible adverse effect on ecology. The mini-plants operate with 5 m–20 m head producing about 1 MW to 3 MW of power, while micro-plants are still smaller and work under a head of less than 5 m and generate electricity between 100 KW–1 MW. The potential energy source in India in this category is around 20,000 MW. These are ideal for providing power supply in rural and remote locations. The main advantage of these plants is that they can be developed in a short time. Till recently, only a very small part was developed and there was a vast scope for further development.

1.8.6. Government Initiatives for Hydro Development

Government has taken following initiatives/measures for increasing the hydro capacity:

1. Government of India come up with, (*a*) Hydro policy, (*b*) National Tariff Policy 2006, (*c*) Electricity Act 2003, (*d*) National Water Policy 2005, (*e*) National Electricity Policy, (*f*) National Rehabilitation and Resettlement Policy 2007 for accelerated development of hydro projects in the country.

2. Announcement of Mega Power Projects Policy wherein hydro projects with capacity of 500 MW and above are given special preference like custom duty exemption, deemed export benefit, income tax holiday regime for a period of 10 years etc. The minimum qualifying capacity has been reduced from 500 MW to 350 MW for projects located in J & K, Sikkim and North Eastern States.

3. A policy to encourage greater participation by private entrepreneurs in India and abroad in electric power generation has been announced.

4. The Government has also approved a 'Three Stage Clearance Procedure' for hydel projects to be execulted by central PSUs. This will help in expeditious execution of projects.

5. With an objective of expediting hydropower development in a systematic manner, CEA (Central Electricity Authority) completed ranking study of the balance hydro potential sites for all the basins in the country (total of 399 sites with 106,910 MW potential) during 2001-02. These schemes have been graded in A,B and C categories in order of their priority for development.

Government of India, through CEA as a nodal agency has taken up with central PSUs/ state agencies, the survey and investigation of hydro projects in a big way so that bankable DPRs can be formulated for speedy development of hydro projects. In first phase 162 hydro-projects were taken up for preparation of Preliminary Feasibility Reports (PFRs). These PFRs were completed in 2004-05 with an aggregating capacity of 47,930 MW, thereafter preparation of DPRs for commercially viable schemes selected from the shelf of projects for execution was started. The work relating to survey and investigation in respect of other identified hydel schemes, in second phase, is also in progress.

6. A vigorous monitoring of all the projects under execution is being done at all levels including at the level of Ministry of Power and CEA, at regular intervals.

QUESTIONS

1. What are the conventional and non-conventional energy sources ? Discuss the potentialities of each.

2. Write short notes on generation of power by following sources:

(*a*) Solar energy (*b*) Wind power

(*c*) Magneto hydrodynamic (MHD) (*d*) Tide power

3. Describe in brief the following methods of energy generation:

(*a*) Bio-gas

(*b*) Ocean thermal energy conversion (OTEC)

(*c*) Mini and Micro-hydel projects

4. Enumerate the main applications of solar energy.

5. Why is electricity the most convenient form of energy ?

6. How will you classify different types of power plants ?

7. Explain in brief different types of power plants producing electricity in bulk quantities.

8. How is the demand for electricity related to the GNP of acountry ?

9. How is the total installed capacity of a power plant depend ?

10. Explain what do you understand by base load and peaking load. What are base load plants loaded heavily ?

11. Explain the advantages of having a common grid for all the power stations in a region.

12. Write short notes on:

(*a*) Peak load and off-peak load

(*b*) Peak load period and off-peak load period

(*c*) Peak load and base load

(*d*) Types of power plants

13. Discuss the combined working of different types of power plants. State their advantages.

14. What are the basic resources for power generation in India ?

15. Describe the hydel power development in India.

16. Describe the importance of thermal power development in the country.

17. Why the development of nuclear power is slow in India ?

18. What is the present position of power in India ?

19. What is the future planning of power in India ?

20. What do you understand by non-conventional sources of power generation ? What is their scope in India ?

21. Which of the non-conventional sources of power generation are considered as more prominent as future major power resources ?

22. What are the basic requirements for locating a wind power plant ?

23. What methods are used to overcome the fluctuating power generation of a wind mill?

24. What is the importance of solar power in the present energy crisis in the world ?

25. Give advantages and disadvantages of hydro electric plants over other electric plants.

26. What are the pumped storage plants ? Why they are installed in conjunction with an extensive distribution system ?

27. Mention the advantages and disadvantages of hydro electric power plants compared with thermal power plants ?

28. Enumerate the sources of energy used for power plants ? Also explain the difference between the renewable and non-renewable sources of energy.

29. What is solar energy ? Enumerate different devices and appliances through which the solar energy is used indicating their limitation.

30. What is wind energy ? Discuss the merits and limitations of using wind energy.

31. Discuss the present status of hydropower development in India ?

32. "Hydropower is the most viable and permanent source of electricity generation of our future ages", discuss critically the above statement.

33. Write an essay on "power sector development".

34. Explain the importance of electrical energy for the development of the country.

35. "Consumption of electrical energy is an index of development for the nation". Justify the statement.

36. "To boost the power generation, government has taken many steps to take up the power projects in central, state and private sector". Justify this statement by listing out the steps taken by the government.

37. What is thermal hydro generation mix ? What should by an ideal ratio ? Explain the efforts being made to rectify this ratio.

38. Explain the following:

(*a*) Reasons for adverse Thermal-Hydro ratio.

(*b*) Combined working of different types of power plants.

39. Explain in detail, the recent developments taken place in the power sector.

40. Explain the developments taken place in the following fields in the power sector:

(*a*) Integrated operation of power plants. (*b*) Pump storage plants

(*c*) Entry of private sector

41. Explain the efforts made by the government in the development of non-conventional energy source.

42. Explain various initiatives taken by the government for hydropower development.