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Hydropower Development in India for Energy Security

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ABSTRACT: India has a large hydropower potential and much of it is still unutilized. Presently, the country is facing a severe shortage of electric energy and this shortage is going to further increase with economic development and change in life style. Estimates show that only about 20% of the assessed hydropower potential of 150,000 MW has been utilized so far. Further, there are large regional variations in the utilization of the potential. Hydropower projects require large finances and there are infrastructure and other bottlenecks in construction of new projects. In view of serious shortage of electricity, the Govt. of India has launched many measures for accelerated development of hydropower including the involvement of private sector. Hydropower is clean energy whose generation is not linked to fuel supply and its price, transportation of fuel, and environmental pollution. This paper discusses the present status of hydropower development, the hindrances in utilizing the potential, and the ways to accelerate development of the remaining potential for long-term energy security in India.

INTRODUCTION

With the average growth rate of above 7%, India is one of the fastest growing economies of the world these days. But as the country is striving for still higher growth rates, many stumbling blocks are appearing. Shortage of electric energy is a major concern for our planners. Rough estimates show that the current condition of unreliable and inadequate power supply causes the Indian economy to lose up to 1.5% of GDP annually (The Times of India, dated June 3, 2004). It is pertinent to note that the GDP of India for 1998–99 was Rs. 11,10,000 crore and 1.5% of this amount equals Rs. 16,650 crore. In the same article, the cost of unserved power to the Indian economy is assessed to be Rs. 15–25 per kWh. Clearly, in the next few decades we will have to explore all possible means of generating electricity. Hydropower, due to several highly desirable properties, is among the top contenders in meeting the electricity demands.

Hydropower generation follows a simple concept: water falling under the force of gravity turns the blades of a turbine, which is connected to a generator. The rotating generator produces electricity. Hydropower is the cheapest source of generation of electricity in the long run since it has no fuel cost and it is almost free from increase in operating cost. Hydropower is a renewable source and no harmful gases or waste is produced in hydropower generation. Figure 1 shows a conceptual representation of hydropower generation through a storage project.

Although the head is usually related to the dam height, a low dam can yield a high head if the turbines and generators of powerhouse are located some distance downstream of the dam.

The amount of power generated is a function of discharge and the hydraulic head. It can be computed as,

$$P = 9.817QH\eta \qquad \ldots (1)$$

where P is the electric power in kW, Q is the discharge through power plant in m^3/s, H is the net head in m, and η is the overall efficiency of the power plant expressed as a ratio (usually about 0.85). The overall efficiency of the power plant is obtained by multiplying the turbine efficiency with the generator efficiency. The hydroelectric power generation depends on the volume of water passing through turbines and the effective head. Thus, the same amount of power can be produced by releasing more water at a low head or less water at a high head. Furthermore, it is better to construct these plants in hilly areas where steep slopes provide high heads.

Despite the obvious advantages, generation of hydropower has come under flak in the recent times due to a general opposition to the large dams, many of whom generate hydropower. Since the debates have been emotionally surcharged, logic usually takes back seat. Nevertheless, very few people would disagree with the fact that the environmental benefits of hydropower are far superior to fossil fuel-based energy generation. Hydropower does not lead to atmospheric

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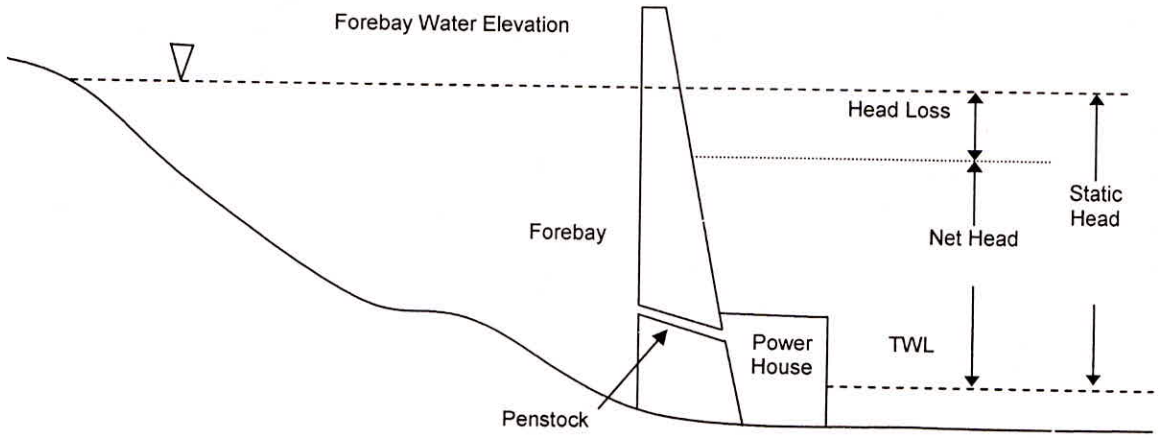

Fig. 1: Generation of hydropower through a storage project

pollution, no greenhouse gases are emitted and it does not adversely contribute to global climate change. Calculations show, for example, that in 1997, hydropower saved greenhouse gas emissions equivalent to all the cars on earth (in terms of avoided fossil fuel burning). Of course, it is inevitable that some small price is to be paid for any development activity and the same holds good for the hydropower too.

CHARACTERISTICS OF HYDROPOWER

Some noteworthy characteristics of hydropower are:

- Its inputs are widely, although not uniformly, spread around the country and indeed around the world.
- Hydropower is a proven (backed up by more than a 100 years of experience) and highly advanced technology and the modern power plants can generate energy at more than 90% efficiency.
- Flexibility of operation in terms of quick start and equally quick shutdown makes hydropower plants suitable to take up peak load, while base load can be picked by less flexible sources. Fast response time enables hydropower plants to meet sudden fluctuations in demand.
- Hydropower stations have the lowest operating costs and longest plant life compared to the other large electricity generating options. Since the *fuel* (water) is renewable, production is not subject to market fluctuations (recall oil prices hike recently and in early 2004).
- Hydropower plants are usually located in remote regions close to the source of energy. Unlike thermal power plants, fuel of hydropower plants is not transportable to places near the demand centers. This means that often long transmission lines are to be laid out.

Hydropower Benefits

After irrigation, hydropower is the source of the largest benefits from water resources development projects. In some projects, the hydropower benefits are so large that these exceed the project costs by a wide margin. For example, the cost of the Sardar Sarovar project was estimated at Rs. 14,266 million by the World Bank and Rs. 15,408 million by Sardar Patel Institute of Economics and Social Research (SPIESR) (Alagh *et al.*, 1995). The benefits, on the other hand were estimated at Rs. 149974 million by the World Bank and Rs. 260203 million by SPIESR. Note that in the SPIESR study, the price of power was fixed at Rs. 3.07 per kWhr for peak power and Rs. 1.83 per kWhr for non-peak power. Another reason behind the large difference in benefits and costs could be that the costs are under-estimated.

Various authors have tried to estimate the net economic benefit from one additional unit of hydropower and the figure of Rs. 0.50 per kWhr appears to be a reasonable indicative value. This value translates to large sums of money when the power generation from even a mid size hydropower plant is considered. This also implies that it is easy to justify hydropower plants on economic basis even if conservation estimates are adopted.

HYDROPOWER RESOURCES OF INDIA

The hydropower potential of India has been assessed as 84,000 MW at 60% load factor which implies 148,700 MW of installed capacity. In addition, small hydro schemes have a potential of nearly 10,000 MW. Furthermore, the Central Electricity Authority (CEA) has identified 56 sites which are suitable for pumped storage schemes with an aggregate installed hydropower

capacity of 94,000 MW. Jain *et al.* (2007) have described hydropower development in India and have listed major projects in operation.

The first hydropower plant in India was constructed in 1897 at Darjeeling. It was a small plant of 2 × 200 kW of installed capacity. The first hydropower project of significant capacity was completed in 1902 at Sivasamudram, an island located in the upper course of the Cauvery River in south India, in Karnataka having installed capacity of 4.5 MW. At the time of Independence, total installed capacity of hydropower plants was 508 MW. After Independence, generation of hydropower was taken up in a planned way and there was impressive growth in additional installed capacity. As a result, the installed hydropower capacity by 1998 was about 23,500 MW (and generation about 80 billion units per annum) out of total installed capacity of 89,000 MW. Even with this capacity, the country has serious shortage of electricity and the deficit of peaking power is estimated to be around 10% or to the tune of 10,000 MW.

Per capita consumption of electricity in the country is about 612 kWh per annum (MoP, 2008) which is quite low by world standards. Electricity demand in India is growing at a rate of 8 to 9% per annum. For the tenth plan, target capacity addition from hydropower is about 14,400 MW. Estimates show that by the year 2020, installed capacity required to meet the electricity demand will be of the order of 350,000 MW. The estimates of the International Energy Agency (IEA) quoted in The Times of India, dated June 3, 2004, indicate that India would require 308 lakh crore ($685 billion) as investments in the power sector during the period 2001–2030. Obviously, government alone cannot invest this much and help from private sector is needed. In fact, some private projects have been commissioned also but capacity addition has been far much smaller to make a significant contribution.

Share of Hydropower in Total Installed Capacity

In discussions related to hydropower development in India, frequently one comes across the question of ratio of installed hydropower capacity to the total installed capacity. In this context, it is important to note that Europe and North America have developed more than 60% of their hydropower. Canada is the world's biggest producer of hydropower, generating 350 TWh/year (nearly 62% of the country's total electricity production). Canada produces more than 13% of the global output of hydropower and is the world's second largest exporter of electricity after France. The largest hydroelectric complex in the world is on the Parana River, between Paraguay and Brazil. It is known as the Itaipu Dam and its 18 turbines produce 12,600 megawatts (MW) of electricity. This Itaipu dam supplies about 80% of the entire electricity demand in Paraguay and 25% of the demand in Brazil. Norway meets virtually entire (99.6%) electricity demand by hydropower. Twenty-five countries worldwide depend on hydropower for more than 90% of their electricity needs.

Due to several reasons, the pace of addition of hydropower has been tardy and a large potential still remains to be exploited. A study of potential of various river basins in the country shows that most large basins have very low level of hydropower exploitation. Basinwise and regionwise hydropower potential for India is given in Table 1. For Brahmaputra basin, the potential at 60% load factor is 34,920 MW while the potential utilization from the projects already constructed and those under construction stands at 1746 MW which is 5% of the potential. Likewise, for Indus basin, the potential is 11,988 MW while the utilization is nearly 4887 MW which is about 24.5%. The situation in central Indian rivers is better where nearly 80% of the 2740 MW potential has been either utilized or is under development.

Overall for the nation, nearly 70% of the identified capacity remains to be developed.

Figure 2 shows the installed electricity generation capacity in India and the share of hydropower up to the year 2003–04. As per the latest estimates (as on May 31, 2008), out of the total capacity of 144,565 MW hydropower contributes 36034 MW i.e. 24.7% of the total installed capacity. For an optimal and efficient management of a combined hydropower thermal power system, the hydrothermal mix has been estimated to 40:60. However as a result of slow down of hydropower utilization, the hydrothermal mix at present is about 25:75. If we consider the figures given earlier stating that by 2020, total installed capacity required will be of the order of 350,000 MW, the maximum percentage contribution of hydropower will be 24%, that too when full potential is tapped (neglecting small and pumped storages). Based on the current trends, it appears that the share of hydropower will be less because full potential will be quite difficult to exploit within the next 12 years. In view of these facts, the debate about the optimal hydro-thermal mix seems to be irrelevant. As mentioned above, many countries are meeting more than 90% of their requirements from hydropower. Therefore, the nation should focus on maximum

Table 1: Hydropower Potential of India and its Status of Development as on 1.1.2005

Basin/River/Region	*Potential at 60% Load Factor MW*	*Potential Developed up to 31.8.98 in MW*	*Potential Under Development from Ongoing Projects as on 31 .8.98 MW*
Basin-wise			
Brahmaputra	34920	661	1085
Gang	10715	1901	1367
Indus	19988	3731	1156
Central Indian Rivers	2740	1060	1147
East Flowing Rivers	9532	4168	144
West flowing Rivers	6149	3704	41
Total	**84044**	**15225**	**5339**

Region-wise (status as on 30.06.2008)				
Basin/River/Region	*Identified Capacity (MW)*	*Capacity Developed (MW)/%*	*Capacity Under Const. (MW)/%*	*Capacity Yet to be Developed (MW)/%*
North Eastern	58971	1202/2.04	2724/4.62	55044/93.34
Northern	53395	13305/24.92	7184/13.45	32905/61.63
Western	8928	5784/64.78	400/4.48	2744/30.74
Southern	16458	9101/55.3	1055/6.41	6302/38.29
Eastern	10949	3049/27.85	2211/20.19	5689/51.96
Total	**148701**	**32443/21.82**	**13574/9.13**	**102685/69.05**

Source: ADB (2007), Central Electricity Authority (www.cea.nic.in).

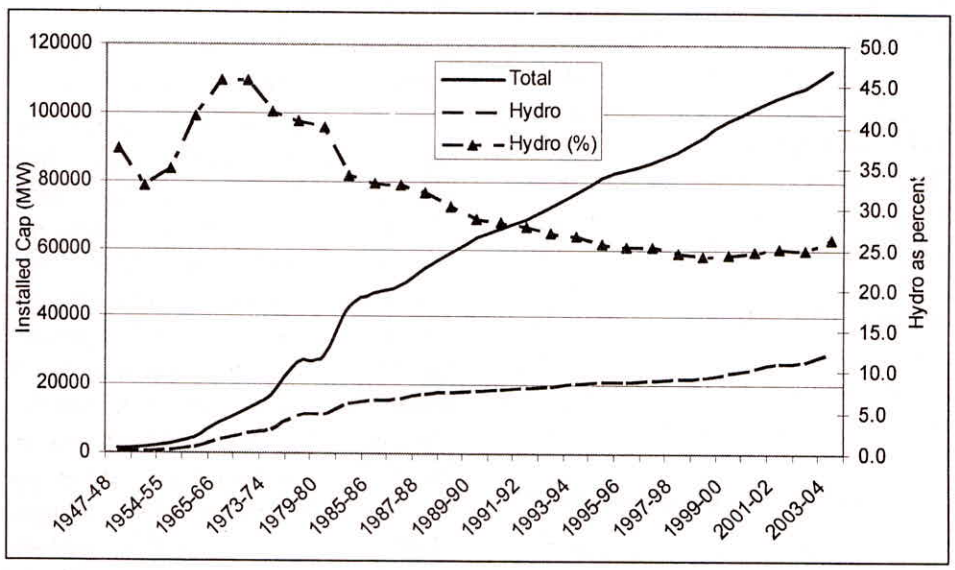

Fig. 2: Installed Electricity Generation Capacity and Share of Hydropower

utilization of the hydropower potential in a sustainable and environmentally sound manner.

Hydroelectric Policy of 1998

India is one of the few countries in the world that have a comprehensive policy for development of renewable energy sources. In 1998, Govt. of India adopted the policy on hydropower with the objective of developing hydropower potential of the country at an accelerated pace. The policy recognizes that hydropower is a renewable economic, environmental friendly and non polluting source. Hydropower plants can start generation at short notice, can be stopped quickly and help in reliability of power system. Such stations are

ideal for meeting the peak demand. The short term goal is to fulfill the minimum energy needs of the entire population and reach the remote and isolated corners of the country at the earliest.

Following objectives for accelerating the pace of hydropower development have been identified by the government:

1. To ensure targeted capacity addition during the 9th Plan,
2. To exploit vast hydro electric potential at a faster pace,
3. To promote small and mini hydropower projects,
4. To strengthen the role of PSUs/SEBs for taking up new hydropower projects, and
5. To increase private investment.

The policy also recognizes that the current hydro thermal mix is imbalanced for hydropower and even if the current share of hydropower is to be obtained, the capacity addition during the 9^{th} and 10^{th} Five Year Plans would be about 23,000 MW.

According to estimates, an additional 100,000 MW of installed capacity would be required to meet the demand for power by 2012. This implies that the power sector has to grow by approximately 10,000 MW every year. This will require huge quantum of investment which is estimated to be about Rs. 9000 billion. This estimate includes investments to be made for transmission and distribution systems. The private sector is likely to contribute about 40% of the generating capacity of 100,000 MW required to be added by 2012. An important aspect of the Electricity Laws Amendment Act, 1998, is to promote private sector investments in transmission. The Government has also issued guidelines for private sector participation in electricity generation in January, 2000.

Despite clear policies, the actual development has not been impressive due to several reasons. Development of water resources falls under the jurisdiction of several departments, usually with sub-optimal or no-coordination among them.

Reasons for Slow Development of Hydropower

Slow development of hydropower can be attributed to a number of reasons, chiefly environmental aspects, rehabilitation and resettlement problems, shortage of funds and geological problems. Indian Water Resources Society (2002) has identified the following reasons for slow development of hydropower:

1. Shortage of funds,
2. Resettlement and rehabilitation problems,
3. Dearth of good contractors,
4. Interstate aspects,
5. Delays in environmental and forest clearance,
6. Slow development in north-east region having largest hydropower potential,
7. Law and order problems,
8. Land acquisition problems, and
9. Geological surprises.

To overcome and minimize the above problems, Government of India has taken many steps like opening up of hydropower sector for private sector participation in year 1991; framing policy on hydropower development in 1998; ranking of potential hydro sites; Prime Minister's 50,000 MW hydroelectric initiative; and framing of Electricity Act 2003. Some initiatives are also being taken by state Governments.

Since, the hydropower resources are property of states, many of whom do not have adequate financial resources to exploit these, hydropower corporations have been set up in Central and joint sectors. The major corporations include National Hydropower Corporation, North Eastern Electric Power Corporation, Tehri Hydro Development Corporation and Satluj Beas Power Corporation. In addition, the National Thermal Power Corporation has also been authorized to undertake hydropower projects. To help overcoming funds constraints, Power Finance Corporation was created and to encourage trading of electricity, Power Trading Corporation has been created. The Government has approved a three stage clearance procedure for the projects to be executed by the Central Power Sector Units to cut down the construction time. There is a need for a national *R* and *R* policy in order to reduce the delays on account of this factor.

Obstacles in Hydropower Development

Major obstacles in hydropower development in India are enumerated below:

1. Preparation of DPR of hydropower projects takes much longer time than any other form of power projects because it requires detailed and reliable hydrological, geological, geographical, seismological and environmental studies. Coupled with capital intensive nature of these projects as well as longer gestation period of these projects is obstacles for hydropower development.
2. Investigation and construction of many hydropower projects have been delayed because of interstate issues. In some projects, dam to be constructed in one State would result in submergence in a different State and due to this disputes arise.

3. There is no clear cut environmental impact and rehabilitation policy of the Government of India, which causes delay.
4. Submergence of forest areas and sites of archeological, religious and historical importance, protection of wild life and disaster potential of the project are some reasons for which clearance is required from different agencies. Such clearances usually take considerable time.
5. The Centrally empowered committee has recommended the compensation value of forest land for non-forest use at Rs. 5,80,000 to 9,20,000 per hectare. The NPV has to be paid to the Ministry of Environment and Forests. There is a tendency that many State Government agencies charge NPV on higher side, which is disincentive for hydropower development.
6. Land and order is a problem in several areas where hydropower projects to be constructed and due to this reason, people are unwilling to work in these areas which result in delaying construction.
7. Land acquisition for hydropower projects is a prime issue for which no fixed solution exists. Non-availability of clear land may result in delay or suspension of the work.
8. Large number of hydropower projects are located in remote and inaccessible areas where adequate demand for electricity is not there. Hence, power is to be transmitted to long distances, which result in high initial investment cost to the project.
9. In the Himalayas, geology has substantial variation within short distance and due to this, many times there are unsuitable geological formations which are revealed only during construction stages. Such geological surprises may delay construction and increase the project cost.
10. Constructability is the capacity of the project being constructed. In developed countries, advanced techniques are used to optimize the constructability of projects which results in cost savings and timely completion. Such practices are not followed widely in India.
11. The present system of contract award and format of contract does not permit the Engineer in-charge to quickly solve problems that may arise during the construction. It is necessary to change the format of the contract to allow the Engineer in-charge to arrive at reasonable decisions during the course of construction.
12. There is shortage of good contractors which also cause delay in completion of projects in time.
13. It has been pointed out that many issues such as catchment area, etc. there is lack of coordination between State and Central Government agencies. To avoid these and related procedural delays, the rules and responsibilities of each concerned agencies should be clearly defined.
14. Sometime the contracting agency is to provide employment to the project affected people. Many times they may not have adequate means on this which leads to resistance from the project affected population and result in delay in construction.
15. Sometime requirement are placed on power utility companies to set aside certain amount of money for local area development, lease rent and other purposes and it is making the project financially unviable.

It will be necessary to overcome the above obstacles so that hydropower development can take place at an accelerated pace.

LONG-TERM ENERGY SECURITY BY ACCELERATING HYDROPOWER DEVELOPMENT

The gap between electricity generation and its demand is monotonically increasing in India. This is not a welcome sign. For the long-term energy security, it is essential to close this gap and thereafter, to plan energy generation in such a way that the available energy always exceeds the demand.

Table 2 lists world electricity generation by source in the year 1999. It shows that hydropower is the second major source of electric energy after coal. Clearly, hydropower has a crucial role to play in long-term energy security.

Table 2: World Electricity Generation by Source (1999)

Source	*Percentage*
Hydro-power	17.5%
Coal	38.1%
Nuclear	17.2%
Gas	17.1%
Oil	8.5%
Other	1.6%

Source: International Energy Agency (www.iea.org), 2001.

Some recommendations to accelerate utilization of still untapped hydropower potential are placed below:

- First important step for any nation is to develop energy policies which clearly set out rational long-term objectives regarding the development of all

power generation options, including hydropower and other renewable sources.

- The gestation period of hydropower projects is said to be quite long. However, a review of major ongoing and planned projects shows that for many projects, this period is smaller than the time taken in clearing the projects. It is, therefore, essential that the clearing period be accelerated and well-defined and time-bound procedures for obtaining clearances be put in place.
- Environment related issues are the major reason behind delay in clearing the projects. It is necessary that the country has a well-defined policy to settle these issues so that the impact of these on a proposed project is known in the planning stage itself and does not appear as an unexpected input.
- Rather than size (big dam or small dam) and nature (pumped scheme or not), the project approval mechanism should support projects on the basis of their merits.
- The nation can ill-afford to have frequent policy and direction changes in electricity generation, distribution, and pricing. It is in this context that the first item becomes still more important.
- Considerable hydropower potential exists in neighbouring countries such as Nepal and Bhutan and accelerated efforts are needed for its exploitation.
- A decision making process which is equitable and credible, coupled with an effective environmental assessment process which considers the interests of people and the environment will go a long way to remove many of the delays. To be effective, this process should focus on quick decisions making.
- Planners should apply environmental and social criteria when preparing master plans for development and should eliminate unacceptable alternatives early in the planning process so that these do not cause problems in later stages.
- Project benefits should be shared with local communities so that they benefit—both in the short term and in the long term. This will help in making them proponents of a project rather than its adversaries.
- Two neighbouring countries of India i.e. Nepal and Bhutan have rich hydropower potential. There is a need for further cooperation with Nepal and Bhutan for the development of hydro electricity in these countries.
- The large hydro power projects requires large amount of money. So there is need to raise the finances through private sector and international agencies.
- There is a need to plan and build the power transmission system joining hydropower project sites with the location where electricity is to be used or to the nearest grid stations.

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