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Review Article

Hydro Energy Sector in India: The Past, Present and Future Challenges

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During the last century, hydropower has made an important and significant contribution to meeting the energy needs of countries. In developed countries, most hydropower potential has been harnessed. However, the situation is not similar in developing countries such as India. It is seen that nearly 3/4 of exploitable hydro energy potential in India is yet to be harnessed for the betterment of growth and welfare of population of the region and boost industrial growth. The estimated economically exploitable hydro potential in India is assessed at 84,000 MW (@ 60% load factor) with a suggested installed capacity of 1,48,700 MW. About 26% of this has been exploited with the existing hydro power plants.

The study is an effort to bring out vividly the past, present and future of hydro energy in India; some relevant aspects of the global situation are also discussed. Relevant policies of the central government have been touched upon as required while discussing the bottlenecks encountered in accelerating hydropower sector development.

India has the capacity to play a lead role in energy security if it were able to harness all the exploitable hydro energy in the region, including Himalayas in collaboration with its neighbouring countries.

With the completion a few world class hydro projects of challenging nature such as the Tehri Dam and power plants, Naptha Jhakri Hydro Project, etc. in recent decades, the engineering community in India is well-poised to focus on the development of hydro energy in challenging sites, mostly in the Himalayas, and accomplish the realization of the balance available energy potential that is sizeable.

Keywords: **Hydropower; Historic Scenario in Hydro Development; Water Resources Sector and Hydropower Generation; Government Policies in Energy and Water Sectors; Resettlement Issues; Indian Strength in Hydro Engineering**

Historical Glimpse of Hydropower – The Global Scenario

The world's first electrical power generation on a commercial scale is just 130 years old. The first hydropower station was constructed in England in 1881 by utilizing the water potential of river Wey at Godalming Surrey, and put into operation to supply electricity. The world's first electrical power generation for a specific customer however was started in 1879 in Switzerland when a hydropower generating set was installed for supply of electrical power to a hotel in St. Moritz for its lighting. The old Schoelkopf Power Station No.1 near Niagara Falls in the U.S. side began to produce electricity in 1881. The first Edison hydroelectric power plant – the Vulcan Street Plant – began operating in September 1882, in Appleton, Wisconsin, with an output of about 12.5 kilowatts. Switzerland's first power station on commercial scale started in 1882 at Laussane. Soon other countries of Europe such as Italy in 1884 and Germany in 1891, also commissioned power

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generating stations using water potential. In USA, the first hydropower station was commissioned at Niagara Falls in 1885, having two units of 5500 kW each.

The earlier uses of waterpower could be traced back to Mesopotamia and ancient Egypt, besides peninsular India and Sri Lanka. Through different means of energy conversions, irrigation stood as a practice since the 6th millennium BC. The water clocks had been used since the early 2nd millennium BC. Other notable earlier examples of ''water power'' include the Qanat system in ancient Persia and the Turpan water system in ancient China. Hydropower had also been in common use since the ancient times for grinding the flour and to perform other similar tasks. However, most of the direct uses or conversion of water power especially from flowing streams using water wheels were mostly of crude nature with little regard to efficiency, output, etc. From the early 19th century, the water wheel designs were being refined and engineered on the basis of principles of fluid mechanics by the French and Americans. In course of time, various types of hydraulic turbines were invented such as Fourneyron, Francis, Kaplan and Pelton. The use of these turbines, located at or close to the water sites, considerably improved efficiency of direct water power use in domestic industries of the day and also proved very handy and was a boon when the possibility of electricity generation from hydropower became feasible for the first time in the world in 1879. It was in the late 19th century, when the electrical generator was developed and coupled with hydraulic turbines.

By 1886, there were about 45 hydroelectric power plants in the USA and Canada. By 1889, there were 200 plants in USA. At the beginning of the 20th century, a large number of small hydroelectric power plants were constructed by commercial companies in the mountains that surrounded metropolitan areas. By 1920, 40% of the power produced in USA was hydroelectric. Hydroelectric power plants continued to become larger throughout the 20th century. After Hoover Dam's initial 1345 MW power plant became the world's largest hydroelectric power plant in 1936, it was soon eclipsed by the 6809 MW Grand Coulee Dam in 1942. Brazil's and Paraguay's Itaipu Dam opened in 1984 as the largest, producing 14,000 MW but was surpassed in 2008 by the Three Gorges Dam in China with a production capacity of 22,500 MW.

India did not lag much behind: the commencement of the maiden hydropower generation plant in India began in 1897 with an electricity generating station of 130 kW capacity, named Sidrapong. Using the potential of Teesta river at the site, this facility was constructed and put into service by the Municipality of hill station of Darjeeling in (the present day) State of West Bengal.

Hydropower plants all over the world produce about 24% of the world's electricity and supply more than 1 billion people with power. According to National Renewable Energy Laboratory, the combined output of the world's hydropower plants is about 675,000 MW, the energy equivalent of 3.6 billion barrels of oil. More than 150 countries around the world generate hydropower now. About 44% of the world's hydropower was generated in four countries in 2002, mostly large- and mid-scale plants. Asia accounted for 24% of the world's hydropower generation, with 618 GWh, followed by North America with 23% (595 GWh) and Europe with 20% (537 GWh). Currently, 808,000 megawatts of hydropower generation capacity are in operation or under construction around the world.

Central and South America generate nearly 70% of their electricity from hydropower, and many countries, including several large countries such as Canada and Brazil, rely on hydropower for more than half of their electricity. Brazil, Canada, Norway, Paraguay, Switzerland, and Venezuela are the only countries in the world where majority of the internal electric energy production is from hydroelectric power. Paraguay produces 100% of its electricity from hydroelectric dams, and exports 90% of its production to Brazil and Argentina. Hydropower makes up 85% of Brazil's electricity generation with 69 GW of installed capacity. The capacity under construction or planning is more than 25 GW. One of the hydropower plants under construction is the giant 11.18 GW Belo Monte power plant. Hydropower accounts for 57% of the electricity generated in Canada, 7% in USA (USA uses hydropower for peaking and not as base load) and 12% in Mexico. Canada's economical hydropower potential is second only to that of Brazil in the Western Hemisphere. Canada still has several projects either under construction or planning, amounting to 6.6 GW. In Western Europe and USA, the scope for additional hydropower is limited, as most economic sites have already been developed.

An incredible 99% of all electricity in Norway is produced from hydropower with an average annual production capacity of about 125 TWh (2005). This is achieved through 620 power plants spread along the whole country and utilization of approximately 60% of Norway's accessible hydropower potential.

Norway is the world's sixth largest producer of hydropower and the largest producer in Europe. While the developed countries have harnessed their respective hydro potential, other countries such as Brazil, China and India embarked upon development of their hydropower a little later. Brazil and China had done it in a big way. India is progressing to develop its hydropower potential but due to wide ranging issues such as resettlement of affected people and other environmental concerns is lagging behind some of these developing nations. Smaller countries such as Nepal and Bhutan having huge untapped hydropower potential are also pursuing ambitious plans for development of hydropower. In particular, the importance of hydropower is well-recognized in Bhutan and seeing the immense contribution of hydropower projects developed in the last few decades with Indian co-operation such as Chukha, Tala, etc. to their economy, envisaged in 2011, a target of adding yet another 10,000 MW hydropower in Bhutan by 2020. Many of these would be joint venture operations with several leading Indian public sector power utilities.

China obtained about 17% of its electricity from hydropower during 1990 to 2006. Chinese hydropower generation grew at a compounded annual growth rate of 8% (compared to 1.5% for the rest of the world), thus increase in Chinese hydropower generation over this period accounting for 36% of the global increase in hydropower generation.

Historical Glimpse of the Indian Hydropower Scenario[1]

India is fortunate to be endowed with all the primary energy sources such as coal, hydropower, uranium/ thorium, etc. However, among these, hydropower is the only renewable source of energy and has been recognized as economical and a preferred source of electricity due to its various benefits. Development of hydropower resources is important for energy security of the country. Hydropower is a renewable, economic and non-polluting source of energy. Hydropower stations have inherent ability of quick starting, stopping and load variations offering operational flexibility and help in improving reliability of power system. Hydro stations are the best choice for meeting the peak demand. The generation cost is not only inflation-free but reduces with time. Hydroelectric projects have long useful life extending over 50 years and help in conserving scarce fossil fuels. They also help in opening of avenues for development in remote and backward areas.

Although hydropower was generated at Darjeeling in 1897, the first major landmark hydropower station, designed to promote industrial development, was set up at Sivasamudrum on the river Cauvery with an initial capacity of 7.92 MW in 1902 and in due course of time, this was increased in stages. The final installed capacity of this powerhouse became 47 MW by 1938. Initially, power was supplied to Kolar Gold Fields for mining development and operations and later to Bangalore and Mysore cities too. Mysore Darbar's second development was in 1940: the Shimsapura hydro power station (2 × 8.6 MW), also on the river Cauvery.

In the north, in 1905, a 4 MW Mohora hydro station on river Jhelum was the first major hydropower development in the then princely state of Jammu and Kashmir. The maximum contribution to hydro development was made later in the west by the renowned private industrial house of the Tata's who set up three major hydro stations in the Western Ghats in the then Bombay Presidency, namely 40 MW Khopoli (5×8 MW) in 1915, 48 MW Bhivpuri (4×12

[1]Please see reference 1

MW) during 1922-25 and 90 MW Bhira (5×18 MW) in 1927.

In 1932, two major hydro development projects, namely 48 MW Jogindernagar (Uhl) hydro station (now in Himachal Pradesh), and 14 MW (initial capacity) Pykara hydro station were taken up and completed by the then provincial governments of Punjab and Madras, respectively. Further notable developments in the then Madras Presidency were Mettur dam hydro station (40 MW) in 1937 and Papanasam (14 MW initial) in 1944. The then Travancore-Cochin princely state (now in Kerala) and the State of United Provinces (now Uttarakhand and Uttar Pradesh) also carried out some significant hydro developments namely the Pallivassal hydro station (with 15 MW initial capacity), and a series of hydro stations on Ganga canal, respectively. A total installed hydro capacity at the time of independence increased to 508 MW in a span of about 50 years since the first development project that surfaced in the British period.

A few notable major projects were undertaken since independence that made significant strides in the subsequent few decades after the 1950s. Prime Minister Pandit Nehru was quite proud to proclaim some of the impressive dams and hydro as ''the modern temples of India''. Inter-alia, one can view a few from among a larger list[2] viz:

- Bhakra Dam multipurpose project complex comprising Bhakra Dam and dam toe powerhouse – 450 MW, and two canal powerhouses – total 154 MW, in the then larger Punjab state (later divided into smaller states, Punjab, Haryana and Himachal Pradesh)
- Rihand Dam multipurpose project – 300 MW in the then United Province, now Uttar Pradesh
- Gandhi Sagar multipurpose project in the then Madhya Bharat, now Madhya Pradesh
- Koyna Dam multipurpose complex project (with first major underground powerhouse) – 540 MW in the then larger Bombay state, now Maharashtra
- Sharavati project – 891 MW in the then Mysore State, now Karnataka
- Periyar project – 140 MW
- Kundah complex project PHs I-60 MW and II-175 MW in the then larger Madras state, now Tamil Nadu
- Machkund – 120 MW, and the famous Hirakud dam multipurpose projects 308 MW in Orissa.

A host of other smaller capacity projects ranging from the minimum of a few MW to 50-60 MW were also undertaken in J&K, UP (now in Uttarakhand), Mysore State, Madras State, Travancore-Cochin now Kerala, Bihar now in Jharkhand, West Bengal and the then Assam State (now in Meghalaya) and in various other states. By 1960, these developments resulted in increasing the hydro capacity to about 1920 MW from 508 MW at the time of independence.

The first systematic and detailed study to assess the hydroelectric power potential of the country was undertaken during 1953-59 by the Government of India in the then Central Water & Power Commission (CW&PC). This was on the basis of the then prevailing technology, available topographical and hydrological data. The study carried out by CW&PC (Power Wing) placed the country's power and annual energy potential, respectively as 42,100 MW at 60% load factor corresponding to annual energy generation of 221 billion units. The subsequent re-assessment studies carried out by the Central Electricity Authority (CEA), Ministry of Power, during 1978-87 have placed the hydropower potential at 84,044 MW at 60% load factor and the economically exploitable hydro potential as 1,48,701 MW. The re-assessment studies undertaken by CEA were to provide an update of hydroelectric potential of the country in order to facilitate a quick follow-up and undertake the development of the country's exploitable hydropower capacity. A total of 845 schemes were identified to yield 442 billion units of electricity. In addition, 56 sites were also identified in various regions of the country for the development of pumped storage schemes with an assessed aggregate installed capacity of about 94,000 MW. The largest potential estimated was

[2]Central Board of Irrigation and Power Hydropower in India Publication (2012)

37.91% in the north eastern region followed by 35.88% in the northern region. The bulk of potential in the hill states of Jammu & Kashmir, Himachal Pradesh, Uttarakhand, Arunachal Pradesh and Sikkim were then yet to be developed.

Though the country ranks fifth in terms of available hydropower potential globally, much remains to be achieved despite their timely identification. This is a challenge while one takes pride in what could be achieved in a developing country with financial resource limitations soon after gaining its independence. Some 177 hydro power stations with a station capacity above 25 MW (having 617 generating units) provide a total installed capacity of about 38,748 MW that are operational; and, about 50 projects with an installed capacity of 15,065 MW are under execution as of December 2011.

The latest assessment reveals the hydro share percentage to the grid in India as just 19%. The potential harnessed within India remains at about 15%, with yet another 7% in various stages of development. The balance potential of about 78% remains unharnessed due to many issues and barriers, with more and more new challenges creeping in before their development.

Future Prospects – Indian Hydropower

Large Hydropower Potential

The estimated economically exploitable hydropower potential in India is about 84,000 MW at 60% load factor with a suggested installed capacity of 148,700 MW[3]. The Indus, the Ganga and the Brahmaputra, basins together in the administrative boundary of India could contribute about 80% of the hydropower. The majority of India's hydropower development potential lies in the key basins of Brahmaputra Basin (66 GW), Indus Basin (34 GW), Ganga Basin (21 GW), and the rivers of South India (24 GW). From a total hydropower potential of 149 GW, India can currently develop only 40 GW of the assessed potential.

Small Hydropower Potential

India's small (capacity less than 25 MW), mini (3-25 MW) and micro hydropower schemes (with capacity less than 3 MW) have been assessed at 6781.81 MW of installed capacity. Despite such an amazing opportunity, due to varying reasons, even the small and mini hydropower plants could not make an impressive progress.

Should the development of the regional resources that can be pooled together with cooperation from India's neighbouring countries such as Bhutan and Nepal, the hydropower potential figures (149 GW) could increase further by over 50 GW; this can make South Asia's energy position quite enviable. The share of hydro energy will then really boost the desired grid security of the entire region as a whole even under extreme variations in the load pattern in summer and winter. Efforts by India in this direction under international cooperation mechanism can ensure the overall welfare of the region, which lags behind many others such as South East Asia.

The hydropower sector in India today is considered to be at crossroads as the decline in its share is impacting the energy grid and its stability. The hydropower's share was at a high of 40% in the 1970s and one wonders if the same could ever be reached again in the future. In hindsight, even in 2006, hydropower shared about 26% of the installed capacity of the then total energy generation that stood at 124 GW. The balance is tilting adversely with the passage of time. A mid-course correction in our energy policy for an enhanced focus on hydro energy option with all encouraging policies, as rapidly as possible, is a requisite now and this has to consider several new factors that surfaced after the announcement of liberal policies two decades earlier to bring in the private sector with some encomiums.

What is crucial is that the energy segment too is given an impetus and hydropower potential unique to regional development obtains the requisite support, not only from the national budgets but also from international funding agencies. The role of India is of importance. The challenges that the sector faces are numerous and all pervasive to social, political,

[3]Central Electricity Authority official website http://www.cea.nic.in/hydro_wing.html; see the report annex, listing region-wise development in hydropower (above 25 MW)

environmental, economic and engineering dimensions with the geological and geotechnical risks that are inherent in Himalayan river valley projects.

India's Power Grid

India's power system is divided into five major regions namely, the northern region, western region, southern region, eastern region and north-eastern region. It is well-known that each of the regions faces distinct issues. While the eastern and north-eastern (NE) regions are power abundant, the northern and western regions are power deficit essentially due to greater power demands. The hydropower potential is largest in the NE region and lies in Brahmaputra and Barak basins but it is a fact that not much could be accomplished in the last seven decades: nearly 98% of the available resources remain to be harnessed in this region. A similar comparison indicates that the northern, eastern, western and southern regions have 79%, 77%, 23% and 33% untapped hydropower potential, respectively.

The CEA and Ministry of Power (MoP) are the nodal agencies involved in power sector planning and development in the Centre for accomplishing the Government of India's ''Power Vision''. Being a concurrent subject under the Indian Constitution, electricity is generated, transmitted, maintained and the hydro projects are developed by the Central and State authorities. Since liberalization, independent power producers (IPPs, under private sector participation) were encouraged to participate in the power sector and this segment had also contributed, since the last two decades impressively though not to the expected levels. The primary role continues to be that of the states besides a number of central projects undertaken by the public sector undertakings such as National Hydro Power Corporation (NHPC), Sutlej Jal Vidyut Nigam (SJVNL), Tehri Hydro Project Ltd. (THDC), North Eastern Electric Power Corporation Ltd. (NEEPCO) and National Thermal Power Corporation (NTPC) who were also enthused to take up hydro projects. With the central policy providing the overall direction for development, the states decide their needs for power generation, distribution and management systems.

Table 1: Station-wise installed capacity of H.E. stations (above 25 MW) in the country[4]

Region	No. of Utility/ Stations	No. of Units X size MW	Capacity in MW
Northern	67	228	17487.27
Western	28	101	7392.00
Southern	68	243	11432.45
Eastern	17	61	4078.70
North Eastern	10	29	1242.00
All India Total	190	761	32182.25

[4]Central Electricity Authority official web site http://www.cea.nic.in/hydro_wing.html; see the report annex, listing region-wise (station-wise) installed capacity in the country (above 25 MW)

Energy Development and India's Water Resources Sector – Mutual Issues

The development of water resources and its management is equally important when dealing with all forms of energy sector, and particularly hydro power. The subject ''water'' lies with the states as per the Constitution and the role of the Centre in an effective manner in water issues have been rather persuasive than directive, so far, despite certain available provisions as per River Boards Act 1956. The establishment of the River Boards was left purely as a voluntary measure for the states concerned in a shared river basin and despite differences in water sharing of the basin in several cases, none of the states invoked the provisions to request the Centre to constitute a River Board for the basin issues. The Centre felt that it could only propose a River Board when there is a solicitation to that effect from Basin States which was never the case since 1956.

The funding support for the state-sponsored Water Resources Development (and management) Projects could of course play as a catalyst to the Centre's intervention and this has been used to encourage the project planning and development in a manner that helps avoid conflicts between basin states. Besides, several centrally sponsored schemes are declared as ''National Projects''; and, these are so articulated and shaped to take on board multi-state interests as well as national objectives, at large.

Since hydropower development involves water resources, the responsibility of hydro-project development stayed (*and remains so even now*), primarily with the state agencies; however, in respect of inter-state rivers, the Centre's role in ensuring fairness and acceptability for all parties continues to remain a primary factor for projects to get initiated and this task takes considerable time. This adversely impacts the speedy implementation of several large projects including the long distance water transfer projects that has a hydro component of over 34,000 MW (popularly known as interlinking of rivers or ILR) among other benefits such as irrigated agriculture, flood and drought mitigation, navigation and ensuring reasonable environmental flows.

While the private sector was enthusiastic to step in when private participation in energy generation opened up in 1990s, there were other hurdles that had lessened the initial spirit and enthusiasm of the private sector which looked forward to certain new policy supports from time to time after experimenting with the effects of several liberalization measures announced for their entry, ever since 1992.

The energy sector in India remains largely public with a share of nearly 89% in the total installed capacity, even now.

Risks and Benefits – Hydropower

While the hydropower stands out as a class of its own right, the sector faces several inevitable competition from among other energy options and this is exasperating. Owing to the large quantities of water required to be stored in large dam-based storage projects, hydrologic uncertainties creep in. This is also the case with the 'run-off' type of developments. The other major risks that surface even during the project planning, design and construction are the *geological and geotechnical risks*. The Himalayan projects are particularly complex.

The meeting of ever-growing energy demand cannot be dealt with isolatedly, without also addressing durable and acceptable trade-offs between ''water and energy'' and ''water, energy and climate change mitigation''.

In terms of electrical power generation, the intermittency of most renewable energy options such as solar and wind, had an inherent problem (i) how could a ''*well-secured load balance*'' on grids be maintained against the backdrop of ever-increasing demand and (ii) energy storage. Two options are currently more feasible and cost-effective than others – hydropower and natural gas – both having their advantages and disadvantages from water resource and climate change perspectives, as well as broader social, environmental and economic considerations. Hydropower has a well-deserving recognition as the best option in terms of energy storage (with large dam-backed storage option) and quick dispatch power in India's energy development programmes given that the resource itself is renewable. However, the tendencies tilt in favour of opting for quick-fix solutions. These, among others, include (imported) natural gas. This can pose a threat, counterbalancing aspirations for self-reliant sustainable energy security in the light of global economic upswings and downturns and climate change associated threats with regard to bioenergy.

Implementation Challenges in the Hydropower Sector, after Selection of Projects

Hydropower has the following benefits and challenges:

- Abundantly available potential for hydropower development, particularly in the Himalayan river basins
- Hydropower involves no extra foreign exchange outgo year after year and insulates the nation with the relative independence in its price. Unlike gas power that is prone to international market such as oil prices, and energy costs, it is self-reliant energy when developed to a sufficient extent in the country.
- Hydropower is subject to no inflationary trends once construction phase is over as the ''raw material'' for power generation is free from such effects.

- Hydropower is green energy and hence stakes better claim as an environment-friendly energy option.
- Hydropower development can take onboard a few of the concerns such as submergence-induced involuntary displacement of people through proper "mitigation" measures to ensure that the adverse effects are minimized to affected families and sustainable solutions that provide welfare to their families and successive generations.
- Hydropower projects support socio-economic development of remote areas as the project site is developed and it is a development option that helps to reach areas that remain neglected, otherwise.
- Hydropower is not only cost-effective and a renewable form of energy but also multi objective multi-purpose development option as it extends additional benefits such as irrigated agriculture, secure food production and hence food security on a self-reliant basis, flood control, tourism, etc.

The hydropower development stands retarded in India, especially in recent times. The challenges are many apart from a few mentioned elsewhere, earlier. Hydropower development is unable to face competition from other energy options despite its attractiveness.

National Policy (1998) on Hydropower[5]

With an aim to accelerate the development of hydropower, Ministry of Power (MoP), Government of India, introduced the National Policy on Hydropower Development in 1998. The policy document has identified and responded to the major issues and barriers. The objectives of the National Policy document on Hydro Power Development, 1998 are as follows (*as stated in the document*):

"*To ensure targeted capacity addition during 9th Five Year Plan (and subsequent plans) with central, state and private hydropower projects contributing 3455, 5810 and 550 MW respectively, the government at the centre pushed forward all-round efforts. The 11th Five Year Plan aimed subsequently at a capacity addition of 18,781 MW in the hydropower sector with the same vigour. Accordingly, an assurance to speed up steps such as execution of all CEA-cleared projects, update and clear pending detailed project reports of all identified schemes, etc., ensued. Small and mini hydro projects are especially viable for remote and hilly areas where extension of grid system is comparatively uneconomical*".

In 2001, the CEA introduced a ranking study which prioritized and ranked the future executable projects. As per the study, 399 hydro schemes with an aggregate installed capacity of 106910 MW were ranked in A, B & C categories depending upon their *inter se* attractiveness. This was followed by a 50,000 MW hydro initiative in which preparation of Pre-Feasibility Reports (PFRs) of 162 projects was taken up by CEA through various agencies. The PFRs for all these projects (with the first year tariff less than INR 2.50/kWh) were identified for preparation of Detailed Project Report (DPR). The governments in the centre and states aimed to realize 100% hydropower potential of the country by 2025-26 with the new liberal measures spelt out in the policy.

The objectives were to be able to surmount some of the identified engineering, geological, geotechnical, hydrological, economical as well as financial and other social/environmental constraints.

Despite the above, hydro-development is lagging behind and investments, both public and private sectors, could not provide the desired impetus. A review of difficulties of the private sector needs better appreciation.

A few reasons for hesitation by independent power producers and planners to participate in hydro-development were the following:

(a) Long gestation period

- Time-consuming process for project clearances
- Until recently, the national focus has been on thermal generation.

[5]Please see reference 4

- Highly capital intensive and absence of committed funds
- Technical, including difficult investigation, inadequacies in tunnelling methods

(b) Inaccessibility of the area

(c) Geological surprises (especially in the Himalayan region where underground tunnelling is required)

(d) Technical constraints due to complex geological nature of the projects

(e) Managerial weakness (poor contract management)

(f) Problems due to delay in land acquisition and resettlement of project affected families

(g) Law and order problem in militant-infested areas

(h) Financial (deficiencies in providing long-term finance)

(i) Tariff-related issues

- Absence of long tenure loans makes it difficult for private investors
- Advance against depreciation is disallowed

(j) Return on equity (ROE) (around 14%) is not attractive enough for investors

(k) Dearth of competent contracting agencies to construct the project in the remaining dams and hydro plant sites that are increasingly quite challenging where infrastructure such as roads, etc. are unavailable, in totality. In a few cases, security issues and internal disturbances are not uncommon.

(l) Inter-state disputes as water is a state subject has however remained a bottleneck.

(m) The poor financial health of State Electricity Boards (SEBs).

(n) Environmental interests bringing additional new issues such as the hydro reservoirs impact ‘‘greenhouse gases’’, etc.

(o) The civil society’s activism, especially on other sociocultural issues got triggered, in addition.

(p) There were sacred shrines and temples along the rivers and at the confluence of rivers sites and though in all such cases, plans are dovetailed to relocate them in a socially best possible manner, these were questioned and status quo was demanded. They are roadblocks in a few cases.

- **E Flows**

Environmentalists urging rivers to be left as such, activists arguing for a higher stake for eco-flows for protecting aquatic ecosystem such as riverine fish, dolphins, etc., issues connected with species, flora and fauna and protection of archeological monuments and places of worship commonly found in the development sites results in extended dialogue and judicial interventions. In a recent case, projects that were being developed were halted due to such perceptions and litigation even after sizeable investment (Lohari Nagpala HEP of NTPC). The project is in an abandoned status now, with new threats for decommissioning the head race tunnel that was halfway through, after surmounting tunnelling problems with a tunnel boring machine (TBM), with certain unique site-specific solutions while problem shooting.

Thus, the old as well as new issues are, oftentimes, affecting the smooth progress of hydro projects, even after the policy announcements.

The bottlenecks that retard the progress in hydro could also be traced to the multiplicity of agencies involved in the hydro sector such as Ministry of Environment & Forests (for forest clearance and ecological flow assessments and provisions), the issues of affected families due to projects in the submergence areas and other affected ancillary structures.

The issue of resettlement and rehabilitation has been always by and large in the fore as a social problem and despite many efforts such as the national policy supplemented by state-level policies that are further liberalized substantially in many projects, the delays due to agitation from project affected people with some support from NGOs and civil societies continue to impede the development of hydropower projects to the extent envisaged.

National Resettlement and Rehabilitation (R&R) Policy[6]

The National R&R Policy-2007 provides the basic minimum requirements, and all projects leading to involuntary displacement of people must address the rehabilitation and resettlement issues comprehensively. The state governments, public sector undertakings or agencies, and other required bodies are given in the policy further liberty to put in place liberalized benefit levels than those prescribed in the NRRP-2007. These have enabled several successful attempts to address the issues of concern so that the development could proceed as planned for the overall betterment of the nation and assure the targetted GDP.

The NRRP 2007 took on board the need to provide succor to the asset-less rural poor, support the rehabilitation efforts of the resource poor sections, namely small and marginal farmers, SCs/STs and women who have been displaced. Besides, it sought to provide a broad canvas for an effective dialogue between the project-affected families and the administration for resettlement & rehabilitation to enable timely completion of project with a sense of definiteness as regards costs and adequate attention to the needs of the displaced persons. The objectives of the policy are to minimize displacement, plan the R&R of PAFs including special needs of tribals and vulnerable sections to provide better standard of living to PAFs and to facilitate harmonious relationship between the Requiring Body and PAFs through mutual cooperation.

National Water Policy 2002 (and the Draft Revision in Consultation of NWP 2012)[7]

The National Water Policy 2002 explicitly brings out national-level preferences in water use. Hydropower ranks next to drinking water and irrigation in the water allocation priorities in the relevant Section 5. Other energies that consume water are apparently to be considered under ‘‘other industrial use’’ ranked subsequently after ‘‘ecology’’ but prior to ‘‘navigation’’. In the recent draft revision of National Water Policy, the need for storage finds a place in the increasing water scarcity scenario. Apart from other measures for water harvesting, large dams also have been explicitly mentioned; the importance of prudential water use and management on a basin level is an interesting addition. Setting up of basin level authorities with the cooperation of the basin states, new institutional mechanism etc., are welcome features as they can pave way for the holistic planning and operation of a system of basin water storage for multiple uses including hydro plants, for optimal basin water resources management. The earlier NWP 2002 had been explicit on issues concerning storage, R&R, etc. and in the light of other parallel national policies brought out by line ministries, the focus in the revised draft (2012) has been on efficiency and water savings.

Renovation, Modernization and Up-rating (RM&U)

In order to augment the hydropower generation and improve the availability of existing hydropower projects, the Government of India has laid emphasis on renovation, modernization and up-rating of various existing hydroelectric power projects in the country. RM&U of the existing/old hydroelectric power projects was considered the best option, being a cost-effective and quicker solution option to achieve than setting up of green field power projects. The cost per MW of a new hydropower project hovered around INR 4 to 5 Crores (2006-07); whereas the cost per MW of capacity addition through up-rating and life extension of old hydro power project worked out to just about 20%. It was opined that the RM&U of a hydro project can be completed in 1 to 3 years depending upon scope of works as compared to gestation period of 5 to 6 years for new hydro projects.

Under the hydro RM&U programme, 33 hydroelectric projects (13 up to the 8th Five Plan & 20 in the 9th Five Plan Plan) with an installed capacity of 6174.10 MW were completed by the end of the 9th Plan. During the 10th Plan (2002-07), 47 hydro power projects with an installed capacity of 7449.20 MW were selected. For the 11th Plan (2007-12), a

[6]Please see reference 8.
[7]Please see reference 10.

total of 59 hydroelectric power projects having an installed capacity of 10325.40 MW, were programmed for completion of RM&U works to yield a benefit of 5461.18 MW.

Capacity Addition Scenario 11th Five Year Plan (2007-12)[8]

The plans of the government to wipe out all energy shortage by the end of 2011-12, i.e. by end of 11th Plan and also to provide spinning reserve and ensure uninterrupted quality power at affordable cost did make some impact. With coal-based power plant as the backbone of the Indian power sector, during the 11th Five Year Plan, there was a capacity addition of about 47,000 MW coal-based plant with the introduction of super critical technology.

Table 2: Sector-wise plan of capacity addition in the 11th plan

Prime Movers	Hydro (MW)	Thermal (MW)	Nuclear (MW)	Total (MW)
State Sector	3957	15538	—	19495
Central Sector	11080	19880	3160	34120
Private Sector	3744	11145	—	14889
Total	18781	46563	3160	68504

Steps taken from time to time to accelerate hydropower projects in India

- Clearances of projects with a ''Three-stage clearance system''[9]

A three-stage clearance system has been set up to enable relatively faster and hindrance-free clearance of suitable projects and includes survey, investigation and pre-construction activities. The three-stage clearance system works as follows:

Stage I: Survey and preparation of pre-feasibility reports

Stage II: Detailed investigation, preparation of Detailed Project Report (DPR) and pre-construction activity including land acquisition

Stage III: Execution of the project after investment decision through PIB/CCEA

(Small hydropower projects up to 25 MW can be set up in private sector without central government's involvement. Techno-economic clearance needs to be obtained from CEA if the estimated cost of the project exceeds INR 2500 million and/or there are inter-state issues involved).

To expedite early execution of hydro projects, bankable DPR based on detailed survey should be prepared to avoid geological uncertainties. Survey & investigation and analysis of geological, geo-morphological, hydrological data, etc. should be done at the time of preparation of a DPR itself in order to minimize the impact of risks. The survey and investigations should be expedited with the latest state-of-the-art technology. It is necessary to prepare a shelf of projects for execution. The quality of DPRs should be of high standard which should infuse confidence in the national/international developers to take up the execution of projects without losing time in rechecks, etc. at the same time, contract monitoring as distinct from project monitoring should be emphasized and land acquisition and infrastructure development be settled and completed before the start of the project.

Pumped Storage Hydropower

The pump storage potential was a new type of hydropower identified to be harnessed as it was considered quite helpful in optimizing energy generation from base load thermal stations and in meeting peak load and system contingencies. Only 2.45% of the total identified potential of 94,000 MW pump storage schemes was assessed to have been harnessed while another 2.5% were under construction stages. A new exclusive programme/action plan for pumped storage schemes was therefore encouraged to tap the vast potential.

[8]Central Board of Irrigation & Power 2012: a Publication on Hydropower
[9]Internal circulars

Standardization in Hydropower and the Status of Engineering of Indian Hydro Projects in Regard to the Global Hydro Projects Including Innovations

Hydropower development has a unique character that demands site-specific solution not only in articulating the layout of headworks (diversion or storage dam with other objectives embedded), but also in every bit of its several components such as desilting chambers for desanding to draw as much as possible, silt-free water to prolong turbine life, water conductor systems in long tunnels or surface channels, penstocks with surge chambers where needed, machine hall/ transformer hall in case of underground structures with geological and geotechnical challenges, etc. Tail race arrangements for letting water back to the stream can be included in this list.

There is no universally accepted standard in hydropower. The International Congress on Large Dams (ICOLD) and recently the International Hydro Power Association are bringing out general bulletins (ICOLD bulletins are over 180 in number). Each aspect of hydropower project design is attempted to be influenced by Indian standards (leaning upon international bulletins or earlier CWC manuals), but each large or medium hydro project, being unique adopts its own distinct design as per compelling circumstances encountered at each site.

Hydro projects are site-specific. Tremendously sizeable hydro development in recent times has been witnessed globally. Examples such as the Chinese Three Gorges Project or Brazil's Itaipu Project display as to how hydro power could strengthen the nation's power potential in a big way; but as one could easily appreciate the geo, political, social and other environment matter a good deal in planning boldly very large structures in Indian settings, given the complex decision-making processes in democratic India involving many states and disciplines that cut across and spill beyond pure engineering sciences. India has experienced enough hiccups with respect to Sardar Sarovar Project or Tehri Hydro Development Project with the highest rock fill dam in the Himalayas. The resistance to hydro project development in any form, storage-based or the run-off plants continues unceasingly notwithstanding the proximity to green power development that hydropower offers. Thus, a comparison of Indian hydro sector with that of global hydro development and their particular features is difficult.

The National Electricity Policy 1998 adequately attempts to address the aspirations of hydro sector as well as the challenges that one confronts in hydro development. Elsewhere in the article, this aspect has been elaborated. The elaboration of each one of these challenges, particularly when it transcends the engineering disciplinary features (social, socio economic, political, geographic/administrative state boundaries and water sharing issues, legal and others of similar nature) is beyond the scope of this chapter.

Infrastructural Issues, Viewed from Private Participation in Hydro Sector

The independent power producers (IPPs) feel a strong a need to set up a single window clearance for hydro projects. Various authorities such as CEA, the Ministry of Finance, Ministry of Environment and Forests, etc. who are involved in the appraisal of a hydro power project before it is certified for development. It is being increasingly felt should get their actions together by a time-bound manner. A single window dispensation/authority is advocated so that a project can be cleared without many hassles. Any hydro project submitted for clearance should receive, as per their demand, all the statutory/non-statutory clearances/approvals within six months of submission of the proposal. The certification of commercial viability should be given within 15 days, especially to private developers. The Techno-Economic Clearance (TEC), MoEF and CCEA clearances should be given within 1, 2 and 2 months respectively, as voiced by these groups. The Ministry of Power should have a set of hydro projects cleared from all the angles to avoid hold-up after project commencement by private sector players.

Also unidentified are the long delays on account of land acquisition for the project. The process of land (both private and government) acquisition for a project differs from state to state as per the Land Acquisition Act. The government should amend the Land Acquisition Act and include hydropower projects in the priority list and state governments should be persuaded to provide land to the project authority in the agreed time frame to facilitate shifting of project-affected persons (PAPs).

Hydro projects which involve lesser risk element and entail lesser capital investment can be considered for development in the private sector. Public sector entities could preferably take up all.

(a) Multipurpose projects

(b) Projects involving inter-state issues and in inter-state river systems

(c) Projects involving cooperation with neighbouring countries

(d) Projects for complementary peaking with regional benefits

(e) Projects in the north-eastern region, etc.

Financial Issues Generic to the Hydro Sector

There is also a need to off-load indirect cost components on the hydro project. Many hydro projects are located in troubled areas infested by militancy and terrorist activities. There is an urgent need to amend the present policy of the government with regard to charging the entire security expenditure from concept and until commissioning on the project cost. However, the recurring expenditure incurred on security, once a project is started, could to be charged on the project developer.

The cost of access roads should not be included in the project cost as development of hydro projects triggers economic and commercial activities around the project site and results in economic benefit to the state. Inclusion of R&R, flood moderation costs, along with the provision of 12% free power to the state in the capital cost of the project needed reconsideration as the provision did not apply to thermal power projects.

Although the government planned to achieve 50,000 MW of additional power by the end of the 11th Plan, and brought in private players, it is argued that incentives such as benefits/concession in custom duties and local levies/taxes on project components are being denied for projects even up to 250 MW resulting in low investments in new power schemes.

A premium as well as lease rent @10% is charged where forest land is diverted for a hydro power project. This is also a point of dialogue between the state governments and developers, as land is a state subject matter as per the Constitution.

The Way Forward

Notwithstanding the apparent efforts of the Government of India by enabling provisions for promoting large-scale development of hydropower in India including a few that brought in a new set of greater private entrepreneurs, problems persist unfortunately due to certain inherent conflicting policies and issues. There is no doubt that several major issues plaguing the hydropower sector have been identified but mending the barriers requires working together at various levels of the ministries in the Centre, and states with the Centre.

Some of these issues have been discussed earlier in this chapter. A few aspects may merit greater attention in the days ahead and the way forward is as follows:

- Rrecommendations by the Standing Committee for hydropower development are crucial and should be enforced for maximum benefit to the Indian hydropower sector.
- Consistent policies and regulations should be made through the states. Any variation in policies and benefits offered by different states will cause problems in development of many project sites in different states.
- Large-scale hydro projects which involve greater risks due to geological uncertainties, etc. should be implemented by the state agencies, while the relatively safer projects with reduced risks and smaller capital investments should be offered to private entrepreneurs.
- A single window clearance set up for hydro projects will solve most problems related to clearances, etc.

- The hydro sector needs to develop a set of competent civil engineers/contracting agencies that have the technical and management expertise to conceptualize and develop a project of the required scale.
- Contract management practices with a transparent system of selection of contractors could resolve any disputes that may arise in the course of execution of various works of complexities in underground works such as long tunnels that can pose several risks such as geological and geotechnical besides being hydrogeological in nature. This also applies to underground power houses as well surface power houses with many hill slope instability problems and surge shafts and other cavities such as de-silting chambers underground and other chambers for locating valves and expansion chambers.
- Development of each of the hydro projects is unique and may require special provision that could help obviate difficulties, be it of technical, social or environmental nature. Once the project stands launched, revisiting the very scope of the project such as those happening in Ganga Valley or elsewhere, are detrimental to the country's larger interest in protecting the energy needs by diversifying the generation to assure a stable grid in a sustainable manner.
- More and more of the pumped storage schemes, involving unique solutions depending on site possibilities shall add more capacity to hydropower generation.

Conclusion

Hydroelectricity is currently the largest renewable source for power generation in the world, meeting 16% of the global electricity needs in 2010 (IEA, 2012). Globally, over the last decade, the growth in electricity generation from additional hydro capacities has been similar to the combined growth of all other renewables. It has also been recognized the world over that hydropower when associated with water storage in reservoirs, can store energy over weeks, months, seasons or even years. As spinning turbines can be ramped up more rapidly than any other generation source, hydropower and pumped storage contribute to the stability of the electrical system by providing flexibility and grid services; therefore, providing the full range of ancillary services required for the high penetration of variable renewable energy sources such as wind and solar.

India needs to catch up on its hydropower generation with the rest of the world. There has always been an anticipation that the share of hydropower would reach around 40% for which ample scope exists in India. However, the steady decline in hydropower share and the looming further decline from its 19% of grid share should be reversed for the overall welfare of energy mix.

The share cost of hydropower generation in a multipurpose reservoir scheme is far less than the one projected; and, it will continue to be the least cost, sustainable development solution in energy generation. In the ever changing dynamism that the globe faces with climate change, economic swings and downturns with fuel policies and global compulsions to contribute to greenhouse gases, at the least, hydropower would always remain the best sustainable energy option.

It is hoped that with the all-round efforts and technological advancements, the most intricate Himalayan projects could also come up with regional cooperation and strength. India should show the way to lead the South Asian power stability by utilizing the enormous untapped hydropower potential in the Himalayas in the decades to come.

The engineering community would be ready to meet any challenges, having demonstrated their immense capabilities in accomplishing very challenging projects such as the high dam in Tehri in a highly seismic environment, the longest tunnel and underground works in Nathpa Jhakhri, impressive Tala Project in Bhutan etc., to quote a few recent engineering marvels.

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