

# Hydro Power Technology in India: A Review Paper

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*Abstract-- Encouraged by a maintained monetary process and ascend in economic advantage levels, Asian nation is ready to confront an essential increment in vitality request inside the following couple of decades that conjointly translates into higher interest for power. The hole inside the power request supply situation is featured by the everyday reality that the nation old a pinnacle deficiency of 5.2% and a vitality shortfall of 4.2% in FY 13-14, with the abundance western unfit to offer reparations for the extremely shortage northern, southern and north-eastern areas. Considering partner vitality snap of 0.82, Asian nation is anticipated to need around seven-membered yearly development in power offered to manage an esteem development of around 8.5% p.a. over after a couple of years. This requires stable every potential source to deal with the shortage and take care of the demand development for quick monetary improvement though thinking about worries of long-run property, ecological and social perspectives. Global environmental change and distinctive negative impacts of exploitation of petroleum products for control age together with developing contemplations over vitality security are driving the augmentation of hydropower around the globe. Even though supply based for the most part hydropower returns have come underneath feedback on account of ozone-harming substance and alkane arrangement discharges on the far side good breaking points, most hydro-rich nations have taken after partner coordinated full life-cycle approach for the appraisal of the preferences and effects to ensure property. The examination is a preliminary to bring out strikingly the past, blessing, and way forward for hydro vitality in India; some significant parts of the overall circumstance are specified. Meaningful strategies of the local government are contacted upon ace re data while talking about the bottlenecks experienced in rapid hydropower division advancement.*

**Keywords:** *Hydropower, Indian Strength in Hydro Engineering, Hydro Development, Modeling and Simulation, Comparison, Economic Analysis, Financial aspects, Policies*

## 1. HVDC History :

Hydropower has been used since old conditions to pulverise flour and perform distinctive endeavours. In the mid-1770s, the French fashioner Bernard Forest de Bélidor appropriated Architecture Hydraulique, which depicts weight driven machines with vertical and even tomahawks. Around the complete of the nineteenth century, the electric generator was created and would now have the capacity to be joined with control through weight. The creating enthusiasm for the cutting edge surprise would in like manner engage headway. In 1878, William Armstrong developed the first hydroelectric planet Cragside in Northumberland, England. It was used to control a single roundabout section light in his speciality show. The past Schoelkopf control station n. 1, close Niagara Falls, on the American side. UU., Started making power in 1881. The essential Edison hydroelectric plant began, the Vulcan Street plant, working September 30, 1882, in Appleton, Wisconsin, conveying around 12.5 kilowatts. In 1886, there were 45 hydroelectric plants in the United States and Canada. In 1889, there were 200 in the United States alone. [1-4]

Already, hydropower occupations came back to Mesopotamia and antiquated Egypt, notwithstanding territory India and Sri Lanka. Due to the diverse techniques to change imperativeness, the water framework has remained an arrangement for the 6th thousand years BC. Water timekeepers have been utilised since the start of the second thousand years BC. Other outstanding instances of "weight driven power" are the Qanat system in antiquated Persia and the Turpan watershed in old China. Hydropower was additionally utilised from past conditions to smash the flour and offer other practically identical lenient gestures. Regardless, an expansive piece of the fast water or utilisation of the imperativeness based change, specifically the streams streaming with weight driven wheels, are usually the gross nature with little thought for effectiveness, creation, and so on. Since the mid-nineteenth century, the diagrams of the driving wheels by the water have been refined and envisioned that the start gauges of liquid mechanics by the French and Americans. Sooner or later, certain sorts of water turbines have been envisioned, for instance, Fourneyron, Francis, Kaplan and Pelton. The utilisation of these turbines, situated in or close water goals, significantly expanded the productivity of the immediate use of water in the national organisations of the time and was likewise to a high degree essential and it was a phenomenal achievement. Activity for the likelihood of making hydroelectricity, it was conceivable uncommon for the world in 1879. It was in the late nineteenth century when the electric generator was formed and joined the turbines are crashed into the water. In 1886, there were around 45 hydroelectric plants in the United States and Canada. In 1889, there were 200 plants in the United States. In the mid-twentieth century, many hydropower plants were abused by business associations in the mountains that secured the metropolitan regions. In 1920, 40% of the imperativeness conveyed to the United States. UU It was hydroelectric. Hydropower plants kept on creating all through the twentieth century. After the initial 1345 MW hydroelectric plant at the Hoover Dam turned into the biggest hydroelectric office on the planet in 1936, it was overwhelmed for quite a while by the Grand Coulee Dam of 6809 MW in 1942. Itaipu Dam in Brazil and Paraguay II opened in 1984 as the biggest, making 14,000 MW, however, was surpassed in 2008 by the Three Gorges Dam in China with an age utmost of 22,500 MW.[35]

India did not much longer behind. The initiation of the Hydropower plant in India started in 1897 with a power producing station of 130 kW limit, named Sidrapong. Utilizing the capability of Teesta waterway at the site, this office was built and put into a benefit by the Municipality of slope station of Darjeeling in (the present day) State of West Bengal. India is honoured to have all

the essential wellsprings of essentialness, for instance, coal, hydropower, uranium/metal, et cetera. Regardless, among them, hydropower is the principal wellspring of the consistent power source and has been seen as a commercial and celebrated source. Because of its various purposes of intrigue. The progression of hydroelectric resources is necessary for the country's essentialness security.

Hydropower can be an unlimited, traditionalist and non-dirtying wellspring of imperativeness. Hydropower plants have as far as possible concerning fast start-up, shutdown and load assortments that give operational flexibility and encourage the resolute nature of the workplace. The hydro station an area unit is the slightest complex another choice to deal with the stature request. Not only is the estimation of age not free of swelling, but instead it is diminished after some time. Power has a long future that crosses more than fifty years and energises the preservation of phenomenal non-sustainable power sources. Additionally, they support the gap of streets for development in remote and in turn around locales. The essential effective and disclosed focus to assess the power control capacity of the country was endeavoured all through 1953-59 by the govt of India Central Water and Power Commission (CW&PC) based on the all-encompassing development, out there geography and hydrological information. The examination doles out by CW&PC (Power Wing) put the country's ability and yearly essentialness potential, severally as forty-two,100 MW at hr extent looking like annual age imperativeness of 221 billion units. The going with re-evaluation seems at dole out by the Central Electricity Authority (CEA), Ministry of Power, all through 1978-87 have put the hydropower potential at eighty-four,044 MW at hr extent and along these lines the fiscally exploitable hydro-potential as one,48,701 MW. The re-assessment analyses grasped by CEA were to supply A revive of intensity capacity of the country with a specific end goal to empower a fast improvement and endeavour the event of the country's exploitable hydropower capacity. A sum of 845 plans was known to yield 442 billion units of power. Besides, 56 goals were conjointly known in contrasted zones of the country for the event of pumped-up limit designs with AN assessed blend put in the capacity of concerning 94000 MW. The most basic potential calculable was 37.91% inside the northern Japanese territory took after by 35.88% inside the north of the area. The lion's offer of potential inside the incline states of Jammu and land locale, Himachal Pradesh, Uttarakhand, Arunachal Pradesh and geographic region were by than at any rate to be made. 35-36]

## 2. Executive Summary:

Hydropower contributes around 16 per cent of general power, an offer that is relied on to make. Hydro's particular potential is five times the present usage rate, and the massive possibility exists in making nations. As indicated by U.S. Centrality Information Administration (EIA) projections, hydro can contribute up to 16,400 TWh/yr, and by 2050 aggregate introduced hydropower most extreme will twofold (1,947 GW), making a yearly 7,100 TWh [EIA 2010]. Most immediate estimated and substantial hydro assets in influenced nations to have been abused at any rate open passages for further perceiving the use of little hydropower plants exist in all countries, mainly really taking shape scene. Sub-Saharan Africa, where the vitality gets the chance to need is most noteworthy, has more than 400 GW of undeveloped hydro—sufficiently potential to fourfold the landscape's present exhibited purpose of imprisonment of 80 GW. It is run of the mill that the bit of hydropower will keep developing, particularly in making nations. IFC dispatched this manual for collect learning and gather limit of those had with the entire hydro meander progress cycle from meander beginning to develop. This guide covers masterminded composes and sizes of hydropower meanders—run-of-course, aggregating and pumped hoarding—and little, medium and liberal hydropower plants. The manual talks about each development of a hydropower meander—site affirmation, plant setup, allowing/permitting, financing, contracting and endorsing, and lights up key issues and typical reactions. The guide means to help all players in hydropower movement associated with meander organising, assessment (examination), execution and checking.

Hydropower plants (HPPs) are uncommon wandered from other power supply choices, for example, warm. HPPs are persistently handmade site-particular activities. HPP require liberal capital meander, yet they offer to an exceptional degree low working expenses and long working fates of 40– 50 years that would much be able to of the time be stretched out to 100 years with some recovery. The outcome is to a mind-boggling degree mighty creation costs for control. Regardless, building up a hydro meander is routinely a test. There are liberal vulnerabilities related to hydrology (which impacts control age and wages) and topography (which may radically expand headway costs). Site licenses and allows could be hard to get a relative number of associates are fused, consistently with clashing rights and commitments. Change in remote spaces is hard to plan and measure the expenses. Natural or possibly social dangers can be whimsical to comprehend and regulate and may present reputational risks for the authority and administrators. At long last, pay (affected by both the measure of noteworthiness conveyed and the commitment the power broadcast can pay) is flawed. Like this, HPP meander engineering and execution must be broad and all around produced using beginning to affirming. Figure 1. demonstrates a normal progress process from the points of view of the undertaking planner and credit master. Essential choices, for example, site affirmation, HPP plant setup, allowing/endorsing and financing must think about significant segments, for example, hydrology, topography, geology, social and natural effects, and future potential vocations of the water, for water structure or upstream HPPs for instance. Extra ask for to be seen as uniting the running with: What part would the proposed HPP meander play in the power plug? Does the power show off require extra most elevated or hugeness and when? What level of commitment can be standard? What measure of pay will the HPP make? Who are the key associates and how will they be influenced? How will open social affair and theory be done all through planning and execution stages to keep up critical assistant help and incorporate to time meander climax?

Site confirmation is the hidden progress. In making nations, data on potential HPP locales, particularly for little HPPs, might be far off or tricky and out of date, in no way like made nations where most potential objectives for medium and full hydropower plants are beginning at now unmistakably appreciated. Conditions encompassing HPPs are in danger to changes, not just the power charges or the power advance structure, yet also the social and organic properties, all of which can affect the appeal of potential objectives. Everything considered goals that were horrifying in the past might wind up connecting later on and then an alternate way. Unprecedented hydrological information is significant to pick an HPP site and build up the ideal plant format. Routinely, hydrological information for no under 15 a long time is required and should join the measure of water (stream rate) and also yearly arrangement. Pre-likelihood (pre-FS) and sound judgment (FS) considers are coordinated to demand site progress, build up a unique plant course of action, study meander necessities, set up the going with stages for meander execution (counting meander design) and set up the undertaking for financing. Similarly, pre-FS and FS perceive potential meander dangers and chances to help them by important refreshing errand parameters, including plant outline and yield. Task particular highlights are overseen by site-particular conditions: [22-28]

- a) How much storing should the HPP have? Limit restrict is managed by the whole entirety of water open, water consistency, control promote necessities and specific geological and topographic conditions that allow store advancement. If the limit isn't achievable or not required, HPPs can be arranged as run-of-stream plants.
- b) What is the appropriate and perfect head? This is basic in light of the way that head choice chooses the plant to constrain (MW) and impacts turbine decision.

Permitting and approving is as often as possible a jumbled strategy requiring various supports from various central and adjacent government associations. Water rights arrive getting, and the site gets to be among the key segments that must be checked from both authentic and helpful viewpoints. Wander accomplishment depends upon buy-in and support from close-by areas, which requires accomplice guidance and two-way correspondence all through the entire HPP change process, beginning with the organising stage. Close-by concerns should be assessed, and control frameworks should be delivered and set up. In parallel and comparatively necessary, natural and social examinations must be finished in light of the way that impacts can be critical.

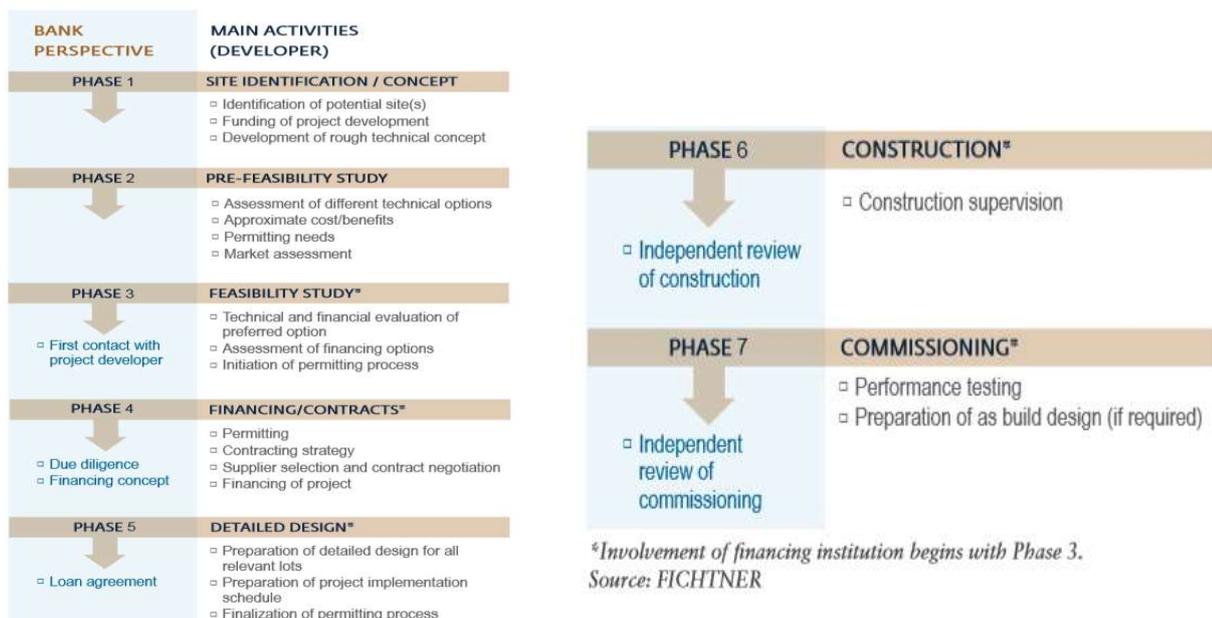


Fig.1. Project Development Process of HPP. [34]

Precisely when HPP meanders join liberal dams. Help procedures ought to be conveyed and executed. All around perceived overall benchmarks that have been sent for wicked proper regular and social examination of private zone meanders join, among others, the IFC Performance Standards, which are talked about later in this guide. The Performance Standards thus plot the beginning of the Equator Principles, a thinking way to deal with overseeing typical and social threat association got by different budgetary affiliations. The best approach to manage contracting can vary anyway conventionally a wander is parcelled into three to four contracts in the going with characterisations:

*Civil works, Electrical and mechanical (E&M) equip, Grid affiliation, Penstock (often fused into regular jobs)*

For every last one of above, generally too delicate and sign a plotting, acquiring and change (EPC) contract. Under an EPC get, the little authority outlines the HPP, procures materials and builds up the undertaking, either primarily or through subcontracts. Generally, the legitimately restricting worker passes on meander timetable and spending dangers because of a settled regard lone total, for which 10-30 per cent ahead of time divide is required; 10-20 per cent is needed withholding, which is to be paid upon profitable plant peak and assertion. If all else fails, the proprietor's creator coordinates and screens the task, every so often adjacent an expert used by the administrator (besides if the authority can manage/ test the undertaking). The fundamental course things for

hydropower meanders are: get to avenues, penstock headway, burrowing, E&M gear get-together, and matrix connection. Table 1 gives a hostile thought of average HPP costs, despite the way that HPP costs are site-particular and can move generally. Most large greenfield meanders extend from US\$1000/kW to US\$3500/kW. Little HPPs have higher hypothesis costs—US\$1300/kW to US\$8000/kW.[28-34]

| Technology            | Installed costs (US\$/kW) | Operations and maintenance costs (%/year of installed costs) | Capacity factor (%) | Levelized cost of electricity (LCOE) (2010 US\$/kWh) |
|-----------------------|---------------------------|--|---------------------|--|
| Large hydro           | 1,050–7,650               | 2–2.5  | 25 to 90            | 0.02–0.19  |
| Small hydro           | 1,300–8,000               | 1–4  | 20 to 95            | 0.02–0.27  |
| Refurbishment/upgrade | 500–1,000                 | 1–6  |                     | 0.01–0.05  |

Table 1. Typical HPP costs[34]

| Phase                | Check by bank   | Data/study requirements   |
|----------------------|---|---|
| 1. Initial screening | Check plausibility of main project parameters; check developer financial standing/ integrity  | Project data sheet or pre-feasibility study (PFS)<br>Financial statements<br>Basic information about developer  |
| 2. Screening         | Check technical/ economic project feasibility<br>Check status of permits and licenses<br>Check for completeness of required documentation for Phase 3 | Minimum pre-feasibility study<br>Information about permits and licenses obtained/outstanding<br>Other studies, in case of PFS gaps                                      |
| 3. Due diligence     | Detailed technical, environmental and social, financial, legal due diligence of project   | Minimum feasibility study (FS)<br>Information about permits and licenses obtained/outstanding<br>Other design documents in case of FS gaps<br>Supplier price quotations |

Source: FICHTNER

Table 2. HPP requirements during the project cycle [34]

Yearly O&M costs extend from 1.0– 4.0 per cent of meander costs. The IEA recognise 2.2 per cent for tremendous HPP and 2.2– 3 per cent for little HPP. In any case, these figures do dismiss significant electro-mechanical hardware substitution, which would be required two or three times amidst the HPP future and would raise standard O&M expenses to US\$45/kW/year for gigantic HPP; US\$52/kW/year for little HPP. Considering past usages and the constraining part (influenced by hydrology), the vitality expenses of PPH continue running from 0.02 USD/kWh to 0.085 USD/kWh; the base expenses are to repair/re-outline existing HPP. HPPs can be attempting since all the meander is required early and most central focuses are perceived over the errand's long working life expectancy. Natural for each HPP wind are vulnerabilities that add weights to financing challenges. For example, hydrology picks water stream sums, which pulls the measure of essentialness passed on. Be that as it may, hydrology relies on yearly climate conditions, which can move entirely. Similarly, medium and gigantic HPPs can join high change chances, a drawn-out meander usage plan (e.g., ten years) and timetable concede in perspective of working in remote areas, admits given allowing and affirming, neighbourhood assurance from the task, or debilitating environment conditions. Accordingly, analysts must survey all dangers and confirmation that they are tied down. These merge hydrology and sedimentation, allowing and permitting, political risks, parcel default, near to money degrading, neighbourhood close-by commitment moderateness, cost assaults, and effect advertise changes. For instance, a responsibility advantage scope degree (DSCR) more important that one must be guaranteed under the most negative circumstance hydrology condition, for example, dry years.

Private corporate substances (asset report financing) or task back can fund PPS. Besides standard is open private-affiliation (PPP) outlines in light of the way that HPP benefits are multipurpose and meld externalities that private inspectors discover hard to get. In spite of the source, financing must be long-tenor and must be moored with long-term off-take control buy understandings. Hydro meander progress design During the errand coordinating procedure, a few things must be checked for diverse conditions with developing an admiration for better reasons for the excitement of each perspective while experiencing each stage. This guide expects that the engineering methodology has three steps—starting screening, screening, and due inventiveness. Table 2 underneath demonstrates the critical area of examination and information necessities for each level. Regardless of the way that only a solitary out of each unique financing process takes after this structure, due consistency is a precondition for each financing choice.

### 3. Hydro Electric Power Potential and Development in India:

Central Electricity Authority did reassessment investigations of Hydro Electric Power Potential in different stream bowls of the nation amid the period 1978-87. As indicated by these examinations, low Hydro Electric Power potential in the country was assessed as 84044 MW (at 60% load factor) from a total of 845 number of recognised H.E. Plans which when made would achieve a presented farthest point of around 148701 MW in light of conceivable typical load factor. The aggregate vitality potential is surveyed as 600 billion units for each year. The unique capability of H.E. plots over 25 MW introduced limit works out to be 145320 MW from a sum of 592 H.E. plans. [5] As on 31.03.2015, H.E. Plans to have an absolute proposed threshold of 36481.80 MW (25.10%) barring pumped capacity stations of the threshold of 4785.60 MW have just been produced and the plans being worked on represent the limit of 12738 MW (blocking PSS of 1080 MW) (8.77%). It would be watched that around 66.13% as far as Installed Capacity is yet to be undertaken.

Electric Potential development in the country is indicated in Tables 3, and four respectively as well as shown in Fig. 2 & 3.

Table 3: [6]

REGIONWISE/STATEWISE STATUS OF HYDRO ELECTRIC CAPACITY  
 (In terms of Installed Capacity-above 25 MW as on 31.03.2015)

| Region/ State        | Identified Capacity as per reassessment study (MW) |              | Capacity Developed |              | Capacity Under construction |              | Capacity yet to be developed |              |
|----------------------|--|--------------|--------------------|--------------|-----------------------------|--------------|------------------------------|--------------|
|                      | Total (MW)   | Above 25 MW  | (MW)               | (%)          | (MW)                        | (%)          | (MW)                         | (%)          |
| <b>NORTHERN</b>      |  |              |                    |              |                             |              |                              |              |
| Jammu & Kashmir      | 14146  | 13543        | 2669.0             | 19.71        | 1630.0                      | 12.04        | 9244.00                      | 68.26        |
| Himachal Pradesh     | 18820  | 18540        | 8908.0             | 48.05        | 2616.0                      | 14.11        | 7015.99                      | 37.84        |
| Punjab               | 971  | 971          | 1206.3             | 100          | 206.0                       | 21.22        | 0.00                         | 0.00         |
| Haryana              | 64   | 64           | 0.00               | 0.00         | 0.00                        | 0.00         | 64.00                        | 100.00       |
| Rajasthan            | 496  | 483          | 411.0              | 85.09        | 0.00                        | 0.00         | 72.00                        | 14.91        |
| Uttarakhand          | 18175  | 17998        | 3426.4             | 19.04        | 1640.0                      | 9.11         | 12931.65                     | 71.85        |
| Uttar Pradesh        | 723  | 664          | 501.6              | 75.54        | 0.0                         | 0.00         | 162.40                       | 24.46        |
| <b>Sub Total(NR)</b> | <b>53395</b>                                       | <b>52263</b> | <b>17122.3</b>     | <b>32.76</b> | <b>6092.0</b>               | <b>11.66</b> | <b>29048.74</b>              | <b>55.58</b> |
| <b>WESTERN</b>       |  |              |                    |              |                             |              |                              |              |
| Madhya Pradesh       | 2243   | 1970         | 2395.00            | 100          | 400.00                      | 20.30        | 0.00                         | 0.00         |
| Chhattisgarh         | 2242   | 2202         | 120.00             | 5.45         | 0.00                        | 0.00         | 2082.00                      | 94.55        |
| Gujarat              | 619  | 590          | 550.00             | 93.22        | 0.00                        | 0.00         | 40.00                        | 6.78         |
| Maharashtra          | 3769   | 3314         | 2487.00            | 75.05        | 0.00                        | 0.00         | 827.00                       | 24.95        |
| Goa                  | 55   | 55           | 0.00               | 0.00         | 0.00                        | 0.00         | 55.00                        | 100          |
| <b>Sub Total(WR)</b> | <b>8928</b>  | <b>8131</b>  | <b>5552.00</b>     | <b>68.28</b> | <b>400.00</b>               | <b>4.92</b>  | <b>2179.00</b>               | <b>26.80</b> |
| <b>SOUTHERN</b>      |  |              |                    |              |                             |              |                              |              |
| Andhra Pradesh       | 2366   | 2341         | 1746.80            | 74.62        | 50                          | 2.14         | 544.30                       | 23.25        |
| Telangana            | 2058   | 2019         | 431                | 21.35        | 360                         | 17.83        | 1228.00                      | 60.82        |

|                        |               |               |                 |              |                 |              |                 |              |
|------------------------|---------------|---------------|-----------------|--------------|-----------------|--------------|-----------------|--------------|
| Karnataka              | 6602          | 6459          | 3585.40         | 55.51        | 0.00            | 0.00         | 2873.60         | 44.49        |
| Kerala                 | 3514          | 3378          | 1881.50         | 55.70        | 100.00          | 2.96         | 1396.50         | 41.34        |
| Tamil Nadu             | 1918          | 1693          | 1782.20         | 100          | 0.00            | 0.00         | 0.00            | 0.00         |
| <b>Sub Total (SR)</b>  | <b>16458</b>  | <b>15890</b>  | <b>9426.85</b>  | <b>59.33</b> | <b>510.00</b>   | <b>3.21</b>  | <b>5953.15</b>  | <b>37.46</b> |
| <b>EASTERN</b>         |               |               |                 |              |                 |              |                 |              |
| Jharkhand              | 753           | 582           | 170.00          | 29.21        | 0.00            | 0.00         | 412.00          | 70.79        |
| Bihar                  | 70            | 40            | 0.00            | 0.00         | 0.00            | 0.00         | 0.00            | 0.00         |
| Odisha                 | 2999          | 2981          | 2027.50         | 68.01        | 0.00            | 0.00         | 953.50          | 31.99        |
| West Bengal            | 2841          | 2829          | 272.20          | 9.62         | 160.0           | 5.66         | 2396.80         | 84.72        |
| Sikkim                 | 4286          | 4248          | 669.00          | 15.75        | 2622.0          | 61.72        | 957.00          | 22.53        |
| <b>Sub Total (ER)</b>  | <b>10949</b>  | <b>10680</b>  | <b>3138.70</b>  | <b>29.39</b> | <b>2782.0</b>   | <b>26.05</b> | <b>4759.30</b>  | <b>44.56</b> |
| <b>NORTH EASTERN</b>   |               |               |                 |              |                 |              |                 |              |
| Meghalaya              | 2394          | 2298          | 282.00          | 12.27        | 40.0            | 1.74         | 1976.00         | 85.99        |
| Tripura                | 15            | 0             | 0.00            | 0.00         | 0.00            | 0.00         | 0.00            | 0.00         |
| Manipur                | 1784          | 1761          | 105.00          | 5.96         | 0.00            | 0.00         | 1656.00         | 94.04        |
| Assam                  | 680           | 65            | 375.00          | 57.69        | 0.00            | 0.00         | 275.00          | 42.31        |
| Nagaland               | 1574          | 1452          | 75.00           | 5.17         | 0.00            | 0.00         | 1377.00         | 94.83        |
| Arunachal Pradesh      | 50328         | 50064         | 405.00          | 0.81         | 2854.00         | 5.70         | 46805.00        | 93.49        |
| Mizoram                | 2196          | 2131          | 0.00            | 0.00         | 60.00           | 2.82         | 2071.00         | 97.18        |
| <b>Sub Total (NER)</b> | <b>58971</b>  | <b>58356</b>  | <b>1242.00</b>  | <b>2.13</b>  | <b>2954.00</b>  | <b>5.06</b>  | <b>54160.00</b> | <b>92.81</b> |
| <b>ALL INDIA</b>       | <b>148701</b> | <b>145320</b> | <b>36481.80</b> | <b>25.10</b> | <b>12738.00</b> | <b>8.77</b>  | <b>96100.20</b> | <b>66.13</b> |

Note:- 1. In addition to above 4785.60 MW PSS are under operation and 1080 MW PSS under construction.  
 2. In some states the total capacity developed and balance capacity is different from the potential assessed.  
 This is due to change in capacity of the schemes, addition/ deletion of the schemes and merger of two schemes into one etc.

Table 4: [7]

BASINWISE STATUS OF H.E. POTENTIAL DEVELOPMENT-BASINWISE  
 (In terms of Installed Capacity-above 25 MW as on 31.03.2015)

| River Basin                 | Identified Capacity as per Reassessment Study (MW) |               | Capacity Developed |              | Capacity Under Construction |             | Capacity Yet to be Developed |              |
|-----------------------------|--|---------------|--------------------|--------------|-----------------------------|-------------|------------------------------|--------------|
|                             | Total  | Above 25      | (MW)               | (%)          | (MW)                        | (%)         | (MW)                         | (%)          |
| Indus                       | 33832  | 33028         | 12723.3            | 38.52        | 4341.0                      | 13.14       | 15963.69                     | 48.33        |
| Ganga                       | 20711  | 20252         | 4987.2             | 24.63        | 1751.0                      | 8.65        | 13513.60                     | 66.73        |
| Central Indian River System | 4152   | 3868          | 3147.5             | 81.37        | 400.0                       | 10.34       | 320.50                       | 8.29         |
| West Flowing Rivers System  | 9430   | 8997          | 5660.7             | 62.92        | 100.0                       | 1.11        | 3236.30                      | 35.97        |
| East Flowing Rivers System  | 14511  | 13775         | 7843.2             | 56.94        | 410.0                       | 2.98        | 5521.85                      | 40.09        |
| Brahmaputra                 | 66065  | 65400         | 2120.0             | 3.24         | 5736.0                      | 8.77        | 57544.0                      | 87.99        |
| <b>Total</b>                | <b>148701</b>                                      | <b>145320</b> | <b>36481.8</b>     | <b>25.10</b> | <b>12738.0</b>              | <b>8.77</b> | <b>96100.2</b>               | <b>66.13</b> |

Note:- 1. In addition to above 4785.60 MW PSS are under operation and 1080 MW PSS under construction.

Figure 2. [7]

REGION-WISE STATUS OF HYDRO ELECTRIC CAPACITY AS ON 31.03.2015

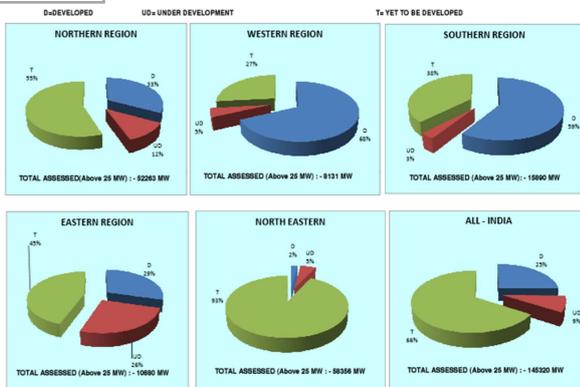
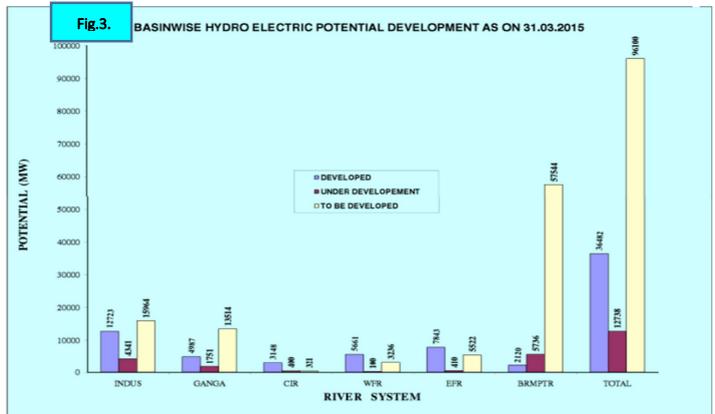


Fig.3.

BASINWISE HYDRO ELECTRIC POTENTIAL DEVELOPMENT AS ON 31.03.2015



#### 4. Hydro Generating Units: Indigenous and imported:

As on 31.03.2015, there were 659 hydro producing units in activity including indigenous and imported units at 189 stations according to subtle elements given in Table 5 underneath. Among the transported in Turbines, it is watched that Japan, UK and Canada have provided the most significant number of turbines, however, limit shrewd, Japan, Canada and USSR are the most prominent providers. Notwithstanding, if there should be an occurrence of generators, Switzerland, France and the UK have

provided the most significant number of generators, however, limit shrewd, Switzerland, UK and USA are the most prominent providers. [14]

Table 5: [6]

HYDRO GENERATING UNITS INDIGENOUS/IMPORTED FROM VARIOUS COUNTRIES AS ON 31-03-2015

| Name of Country     | Turbines supplied |                 | Generators supplied |                 |
|---------------------|-------------------|-----------------|---------------------|-----------------|
|                     | Numbers           | Capacity (MW)   | Numbers             | Capacity (MW)   |
| <b>A-Indigenous</b> |                   |                 |                     |                 |
| BHEL                | 282               | 17713.02        | 279                 | 17436.02        |
| OTHERS              | 18                | 831.00          | 20                  | 949.50          |
| <b>Sub Total</b>    | <b>300</b>        | <b>18544.02</b> | <b>299</b>          | <b>18385.52</b> |
| <b>B-Imported</b>   |                   |                 |                     |                 |
| U.K.                | 64                | 1257.10         | 44                  | 3132.00         |
| CANADA              | 44                | 3132.00         | 17                  | 1726.00         |
| SWITZERLAND         | 22                | 815.20          | 75                  | 6029.40         |
| JAPAN               | 76                | 6362.20         | 11                  | 219.00          |
| FRANCE              | 33                | 2186.40         | 59                  | 1637.90         |
| USSR                | 26                | 2804.00         | 26                  | 543.15          |
| USA                 | 9                 | 351.00          | 26                  | 2804.00         |
| Other               | 85                | 5815.50         | 102                 | 6790.45         |
| <b>SUB-TOTAL</b>    | <b>359</b>        | <b>22723.40</b> | <b>360</b>          | <b>22881.90</b> |
| <b>TOTAL</b>        | <b>659</b>        | <b>41267.42</b> | <b>659</b>          | <b>41267.42</b> |

### 5. Generation Performance:

2014-15 was 129243.68 MU against the target of 124297 MU Generation from hydroelectric power stations (above 25 MW Installed Capacity) which was 3.98% more than the destination.

Region-wise generation performance of hydroelectric stations during 2014-15 is indicated in Table 6.

Table 6. [6]

GENERATION PERFORMANCE – REGIONWISE (2014-15)

| S. No. | Region                  | Installed Capacity as on 31.03.2015 (MW) | Generation During 2014-15 |                  |   |
|--------|-------------------------|--|---------------------------|------------------|---|
|        |                         |  | Target (MU)               | Actual (MU)      | Shortfall(-)/ Surplus (+) Over Target (%) |
| 1      | Northern                | 17122.27                                 | 61804                     | 65993.25         | 6.78                                      |
| 2      | Western                 | 7392.00                                  | 15918                     | 15657.40         | (-) 1.64                                  |
| 3      | Southern                | 11432.45                                 | 31603                     | 31855.11         | 0.80                                      |
| 4      | Eastern                 | 4078.70                                  | 10884                     | 12195.82         | 12.05                                     |
| 5      | North-eastern           | 1242.00                                  | 4088                      | 3542.11          | (-)13.35                                  |
|        | <b>Total(All India)</b> | <b>41267.42</b>                          | <b>124297</b>             | <b>129243.68</b> | <b>3.98</b>                               |

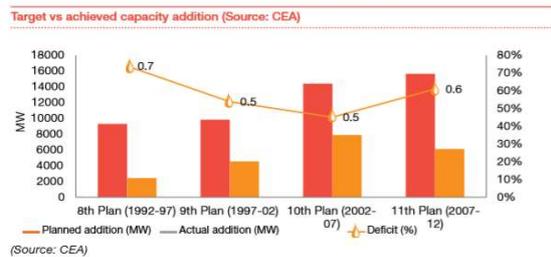
Power generation during 2014-15 has exceeded the objective in Northern, Southern and Eastern Region while it was not as much as the objective in Western and North-Eastern Region of the nation. Hydel age amid 2014-15 was 129243.68 MU against the aim of 124297 MU viz more in era 4946.68.MU (3.98%). The real period of 129243.68 MU was not as much as earlier year age of 134847.52 MU by 4.16%. Hydel generation was more than the age focus in Northern, Southern and Eastern by 6.78%, 0.80% and 12.05% separately, while Hydel generation was not as much as a focus in Western and North Eastern Region by 1.64% and 13.35% individually..[6][16-20]

### 6. Recent trends:

The administration of India has extended financial assignment, nearby other non-cash related help, to sort out hydropower change and augmentation restrict development. Similarly, in the Eleventh Five Year Plan, the target for hydropower confine development was put at 16.5 GW, which was half of the total presented restrict by then. Regardless, the achievement, at around 5400 MW, was well short of the goal. A comparative example of success coming up short concerning centre by far can be found in the past course of action time spans too. Distinctive variables, for instance, biological concerns, R&R issues, arrive getting issues, high flexibility and underwriting frameworks, the capacity of designers, et cetera have added to the right pace of hydropower progression already. These issues have been bothered as hydropower change has, for the most part, remained under the ambit of state governments (water being a state-specific subject) with contrasting systems (e.g. straightforward premium, sway control, arrive getting methodology, et cetera.) grasped by the states.

To animate advancement in the hydropower division and to navigate any obstruction between the certified and orchestrated full development, the private part is being seen as a fundamental accomplice. The hydropower part was opened up for own territory enthusiasm for 1991. Along these lines completed the years, to empower stretches out through PPP/JV mode, a couple of states have assigned a state nodal association with an option of significant worth hypothesis by the state government Fig.4. Nevertheless, from 1991 to 2012, the private portion has added to around 11.5% of as far as possible choice. So far just around 2700 MW has been approved through the private course, which constitutes under 7% of the total presented hydropower restrain. Despite the way that own enthusiasm for the hydropower section has gotten a drive in the continuous past, in any case, it faces deterrents in the execution of errands transversely finished distinctive periods of the wander utilisation cycle. The central and state governments need

to make a pleasant theory climate for extending private collaboration by tending to issues related to shields, arrive obtainment, clearing, legitimacy issues, particular challenges and non-vitality about the risks related with wander improvement. Fig.5 [6,7,14] [5]



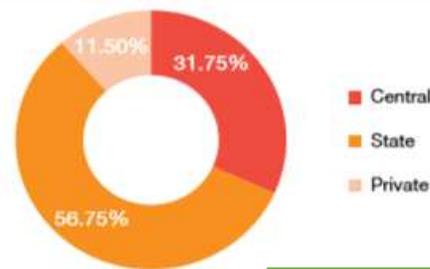
Major slippage reasons for 10th Plan projects

| Major reasons for slippage   | Hydro capacity slipped (MW) |
|--|-----------------------------|
| Geological surprises   | 510                         |
| Natural calamity   | 450                         |
| Delay in award of works  | 823                         |
| Delay in MoEF clearance  | 400                         |
| Delay in clearance/investment decision/funds tie-up constraints/delay in financial closure | 1400                        |
| Delay in preparation of DPR and sign of MoU between HP & SJVNL                             | 400                         |
| CR & R issues  | 400                         |
| Court cases  | 675                         |
| <b>Total</b>   | <b>5058*</b>                |

\* This does not include 3009 MW dropped from 10th Plan  
 Source: Working Committee on Power for 11th Plan

Fig.4. (a) Target vs achieved capacity addition (Source: CEA), 10th Plan projects [5] [34]

Percentage contribution in hydro capacity addition from 1992-2012



(Source: CEA)

Fig.5. Percentage contribution in hydro capacity addition from 1992-2012 [34]

## 7. Current Issues and Challenges:

### Hydropower planning:

Predicting hydropower movement in India has for the most part been arranged toward singular undertakings. Regardless, this approach has a few confinements for the proficient change of a whole stream bowl. Between state, the question is another point which envisions melded stream bowl movement for hydropower meanders. A vast number of hydropower meanders with necessary stream frameworks between flanking countries are held up because of a nonappearance of between state assertions and clear thought on water-sharing. The Sutlej-Beas question among Punjab and Haryana and the Mullaperiyar dam battle among Kerala and Tamil Nadu especially point by point cases of water-sharing clear thinking between states. The contentions in Assam and Arunachal Pradesh on division and utilise instances of the Brahmaputra are also making. Figure 6 demonstrates the entire strategy of Hydro control sorting out.[5]

### 7.1 Land attainment:

Land accessibility and securing are among the centre assistant issues that affect all structure regions. Problems ascending in the acquisition of land for hydropower meanders are causing suspension and delay being produced exercises. Till beginning late, under the 120-year-old winning Act, arrive procurement for clear reason had been assaulted by a few issues encompassing strategy, systems and pay, as the term 'open arrangement' was never obviously portrayed. The new law, which wound up great from January 2014, endeavours to address the social aberrations in the present course of action of land obtaining. Regardless, there are so far huge issues which should be coordinated to discharge targets in foundation change. The get together had formally seen the running with issues and is working towards finding an ideal arrangement between watching out for the land-washout's burdens and the organiser's points of view:

- a) Consent of half landowners in PPP extends regardless of whether the possession vests with the legislature
- b) Compensation sum for procurement in rustic zones and urban districts
- c) The Social Impact Assessment (SIA) forms which, rather than tending to issues identified with dependable advancement and advantage sharing, cause delays
- d) Legal definitions which increment many-sided quality and cost for engineers without enough profiting the influenced populace.

Fig.6. Hydropower Planning [34]



Developing numerous activities on a similar waterway regularly bargains the limit of an undertaking to take care of pinnacle demand because of other pinnacle stack extends in this manner created. Effects of social and ecological appraisal may rise in more serious shape when advancement of different undertakings in a bowl is considered.[5]

### 7.2 Safeguard issues:

Improvement and errand of hydropower dams would altogether be able to impact typical stream systems and furthermore angle and untamed life peoples. Also, hydropower wanders incorporate submergence causing the expulsion of undertaking an area people. The recuperation of undertaking impacted people is moreover a critical issue which is more enunciated by limit based hydropower wanders, as was evident in the midst of the progression of the Tehri dam. The endeavour addressed with mass difficulties and open uproar on the issue of security, condition and reclamation, achieving extraordinary deferrals (e.g. the Tehri dam was dispatched more than 25 years after R&R was started). Hydropower broadens routinely require timberland zones for their execution and compensatory afforestation on non-forest terrains. The progress in various endeavours has been impacted due to delay and non-breathing space on condition and boondocks perspectives. These segments have achieved negative open acknowledgement about hydropower.

### 7.3 Market Development:

The power pitch change in India is still at a starting period. Regardless of the way that bit 63 of the Electricity Act makes focused offering mandatory for all power acquiring, hydropower meanders are exempted under a dusk stipulation which sneaks past end 2015 (according to the June 2011 change to the Tariff Policy 2006). The deferral for hydro control depends upon the recommendation of a Power Ministry taskforce, which referred to high dangers and vulnerabilities characteristic to these activities as among the reasons why it is troublesome for hydro tries to fight with warm age on entire arrangement introduce. Besides, the present market structure does not permit hydropower fashioners to understand the potential favoured point of view of managing peak ask for as the costs for both zenith stack and off-top load are undifferentiated. Notwithstanding the way that the Enquiry Committee constituted after the two primary system thwarted expectations in the nation on 30 and 31 July 2012 opined that "an investigation of UI fragment ought to be done in the setting of its effect on consistent cross segment upsetting effects. Rehash control through UI might be discarded in a timebound way and age recuperations and right-hand associations might be utilised for rehash control", a real definitive portion for use is yet to be set up.

### 7.4 Financing:

There is in like manner a need to off-stack unusual cost fragments on the hydro wander. Various hydro wanders are arranged in plague domains attacked by militancy and dread monger works out. There is a critical need to adjust the present approach of the lawmaking body as for charging the entire security use from thought and to the point that approving on the errand cost. In any case, the rehashing utilisation achieved on security, once an assignment is started, could be charged on the endeavour build.

The cost of access lanes should not be joined into the assignment cost as a change of hydro wanders triggers budgetary and business practices around the endeavour site and results in money related preferred standpoint to the state. Joining of R&R, surge control costs, close by the course of action of 12% free ability to the country in the capital cost of the errand required reconsideration as the game plan did not make a difference to warm power wanders.

In spite of the way that the organization expected to achieve 50,000 MW of additional power before the completion of the Eleventh Plan, and obtained private players, it is fought that driving forces, for instance, benefits/concession in custom commitments and adjacent requests/charges on wander parts are being denied for wanders even up to 250 MW realizing low interests in new power designs. A premium and lease rent @10% is charged where woods arrive is diverted for a hydro control wander. This is similarly a condition of trade between the state governments and specialists, as land is a state subject as indicated by the Constitution.

### 7.5 Technical Challenge:

Particular troubles Techno financial common sense of hydropower wanders depends upon the topography, geography, hydrology and receptiveness of the endeavour site. Notwithstanding whether comprehensive examinations using state-of-the-craftsmanship examination and improvement procedures are getting, a part of weakness remains in the sub-surface geology.

Land stuns in the midst of genuine advancement can't be blocked. This unpredictable geography is more verbalised in the young wrinkle Himalayas where most of the Indian hydropower potential stays. Such specific troubles add to advancement risks.

#### 7.6 Infrastructure:

Distinctive hydropower meanders are masterminded in remote objectives in states which don't have pleasant excitement for control. This makes the requirement for making connecting with the framework for control clearing. The 'chicken neck' presents topographical limitations in making fundamental transmission foundation for hydropower departure from the northeast. There are certain different inconveniences for the dealt with the progress of the transmission arrange, e.g. perceiving recipients well early, influencing overabundance departure to oblige recalling the future development of undertakings (particularly where there are Right of Way (RoW) issues). Also, the Plant Load Factor (PLF) for hydropower meanders is generally under half, under which basic transmission limit is under-used. All these outcomes in higher transmission costs. Hydropower grows likewise require the movement of the related structure, for example, roads and expansions in the zone. The thought of the price of the progress of such related foundation broadens the value of intensity appeared well and good and supportability. Nonappearance of the foundation, for example, schools, retouching workplaces and troublesome access to areas from time to time progress toward getting the opportunity to be squared to moving talented work to troublesome meander goals.[5]

#### 8. Conclusion:

Hydroelectricity is starting at now the greatest endless hotspot for control age on the planet, meeting 16% of the overall power needs in 2010 (IEA, 2012). Entirely, completed the latest decade, the advancement in control age from additional hydro limits has been similar to the combined improvement of all extraordinary renewables. It has moreover been seen the world over that hydropower when related with water accumulating in archives, can store essentialness over weeks, months, seasons or even years. As turning turbines can be increment more rapidly than some other age source, hydropower and pumped limit add to the roundness of the electrical structure by giving versatility and cross-section organisations; like this, giving the full extent of helper organisations required for the high passage of variable maintainable power sources, for instance, wind and sun-based.

India needs to get up to speed with its hydropower age with whatever is left of the world. There has been continuously a desire that the offer of hydropower would extend around 40% for which abundant augmentation exists in India. In any case, the continuing abatement in hydropower share and the moving toward additionally rot from its 19% of lattice offer should be pivoted for the general welfare of imperativeness mix. The share cost of hydropower age in a multipurpose store plot is far not as much as the one foreseen; and, it will continue being the scarcest cost, supportable headway course of action in essentialness age. In the routinely changing dynamism that the globe faces with natural change, financial swings and downturns with fuel techniques and overall driving forces to add to ozone hurting substances, at any rate, hydropower would continuously remain the best reasonable imperativeness decision.

It is assumed that with the general undertakings and creative degrees of progress, the most puzzling Himalayan errands could in like manner consider nearby investment and quality. India ought to show the best way to deal with lead the South Asian power security by utilising the massive unfamiliar hydropower potential in the Himalayas in the decades to come. The building system would be set up to address any troubles, having shown their tremendous limits in accomplishing to a high degree troublesome exercises, for instance, the high dam in Tehri in an exceedingly seismic condition, the most extended section and underground works in NathpaJhakhri, incredible Tala Project in Bhutan et cetera., to refer to several continuous planning ponders.

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