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PUMPSTORAGE PLANTS IN HIMALAYAN AND NON-HIMALAYAN REGIONS OF INDIA - PROSPECTS AND CHALLANGES

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1.0 INTRODUCTION

A significant grid transition is underway in India, as it gears up to meet its pledge of taking up the share of non-fossil energy capacity to 500 GW by 2030. This large-scale RE capacity addition, known for intermittency /variability in generation, may have large scale implications on the reliability and stability of the Indian power system. This in turn, requires sufficient availability of balancing power and storage solutions to smoothen the integration of renewable into the grid.

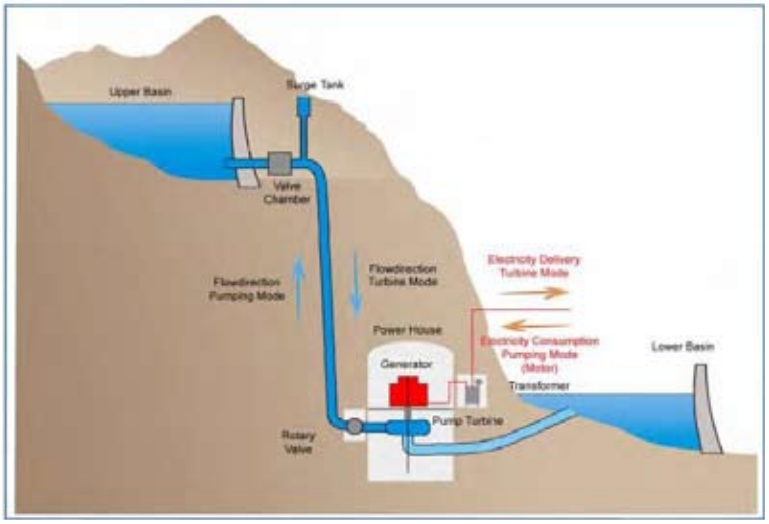
There is no easy and effective way to store energy that can be used during peak demand. While battery technologies are progressing, it's not yet possible for the quantum of energy that hydro-energy plants are producing to be stored in batteries.

That's where Pumped-Storage Projects (PSP) comes in. In the mix of different energy storage techniques, Hydropower and PSP is gaining ground as a reliable, time-tested technology, particularly suited for load management.

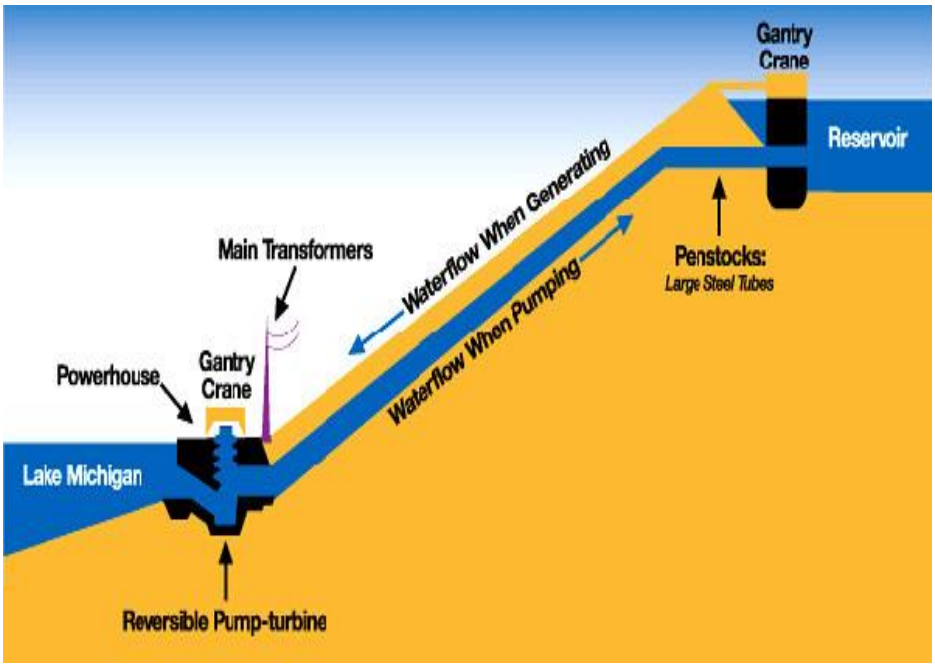
This water is pumped from a lower elevation reservoir to a higher elevation reservoir. The PSP schemes act as a giant battery (also called Water Battery) as it can store energy as per availability of cheap power and then use it for producing energy when it needs during peak hours.

In view of above, Ministry of Power, Govt. of India has emphasized time and again that all Hydro PSUs should study and identify the exploitable Pumped Storage schemes.

General Layout of the PSP plants



Underground Pump Storage Plant (Typical)



Surface Pump Storage Plant (Typical)

2.0 PSP POTENTIAL IN INDIA –CEA STUDY

As per the study carried out by CEA during 1978 to 1987, 63 potential Pumped Storage sites were identified with an aggregate capacity of about 96,524 MW all over india.

Subsequently, a screening of Pumped Storage Projects in India was carried out by Japan International Corporation Agency (JICA).The Report of JICA published in January 2017 which suggests that many of the 63 sites identified by CEA not found suitable to be taken up for development by the respective State Governments, primarily on account of environmental, social or viability concerns and/or refusal of clearance for Survey & Investigation by statutory authorities.

3.0 PUMPED STORAGE PROJECTS IN INDIA – LATEST STATUS

Completed PSPs in India-Operational/Technical Issues

As per CEA's status report dated 31.12.2021; there are eight (8nos.) of commissioned/installed Pump Storage plants above 25MW in India with cumulative capacity of 4745.6 MW, viz.

- Nagarjuna Sagar, Telangana 705.60MW
- Srisailam LBPH, Telangana 900MW
- Kadamparai, Tamilnadu 400MW
- Bhira, Maharashtra 150MW
- Ghatgar, Maharashtra 250MW
- Purulia, WestBengal 900MW
- Kadana Gujarat 240MW
- Sardar Sarovar Project Gujarat 1200MW

Out of the above 8 PSPs; Kadana and Sardar Sarovar PSP are not working in pumping mode at present on account of various technical &non-technical reasons.

About 2000 MW PSP Schemes are under Construction and schemes of about 27825 MW are under DPR Concurred/ under Examination in CEA/under S&I and PFR Preparation etc.

4.0 IMPORTANT PARAMETERS CONSIDERED FOR SETTING UP OF PUMPED STORAGE PLANTS

To explore the suitability of Pumped Storage Plant (PSP) schemes certain important following parameters have been examined;

- Length/Head(L/H) Ratio, Head and Energy stored
- Topography to create Reservoirs
- Location of the project & its accessibility
- Geological Aspects
- Reservoir Sedimentation and flood Management
- Environmental Aspects
- Proximity to RE power centers
- Proximity to Water source
- Cascade development constraints

5.0 FAVORABLE SITE REQUIREMENT CRITERIA FOR PSP

- Large head with relatively shorter water ways between upper and lower reservoirs preferably sites with Length/Head(L/H) Ratio < 10.
- Higher head requires lesser pondage thus results in smaller reservoirs, less civil works like smaller size dams, smaller size of water conductor system.
- Higher head results in smaller electro-mechanical components like smaller size of turbine, smaller size of stator and other associated E&M components resulting in smaller power house complex.
- Higher head reduces overall requirement of land for various components of project like size of HRT, TRT etc. together with reduction in quarry/borrow and dumping land requirements.
- The minimum practical head for an off-stream pumped storage project is generally around 100 m, with higher heads being preferred. However, very little technical know-how is available in the world for handling a project having head more than 800m. Therefore, range of head between 150m to less than 800m is preferable.
- PSP schemes with surface components are favorable as construction of underground pump storage plant generally require large size underground powerhouse caverns, transformer cavern, underground water conductor system which requires extensive geological and geotechnical investigations such as drilling, drifting, geophysical studies which is expensive difficult & time consuming.
- Other favorable site requirements of PSP are better accessibility, Suitable topography for creating reservoirs, better Geology, sites with less environmental concerns, proximity to RE power centers and proximity to water source.

6.0 OFF RIVER PSP: ADVANTAGES

- As no reservoir is located in any river, the project shall not require flood mitigation arrangements, Silt management arrangements and Diversion arrangement during construction and hence project cost shall be optimized.
- The construction of off-river PSP can be much faster than on river PSP because of no diversion arrangement, no gates for flood & silt management, desilting & silt flushing components etc.
- The construction cost &time of off -river PSP schemes are more predictable as there is less uncertainty such as flash floods etc.
- Environmental costs required in river system for the provision of Fish ladder, longitudinal connectivity, E-flows shall be avoided off-river PSPs.
- The location of off river PSP may be selected near to Renewable Energy Centers & Transmission lines.

It is generally easier to select an alternative nearby site if problems arise relating to geology, hydrology, road access, power line easements, land ownership, indigenous rights, environmental impacts or social opposition.

7.0 PSPS IN HIMALAYAN REGION – PROSPECTS & CHALLENGES

Large number of Hydroelectric projects (HEPs) are located in Himalayan region and many others are being planned & constructed. However the layout and many other technical requirements of On-river/Off-river PSPs are different from HEPs.

Some of the constraints for developing PSP in Himalayan region are described here.

7.1 Reservoir Capacity & Type of Scheme

- Many Himalayan region projects are pure ROR schemes with Fixed Reservoir Level and as such no pondage capacity is available for providing any additional storage for using the same as upper or lower reservoir for PSP.
- The available storage in ROR schemes with pondage is required for the peaking of that project only, so it cannot be used for new PSPs as the peaking capacity of existing HEPs will be affected.
- Some of the projects in Himalayan region are ROR schemes with diurnal pondage of about 3 hours only. However for managing flood and silt during the four months of monsoon the reservoirs of these projects are kept at MDDL, so no storage is available during this period for PSP.
- At some of the locations the reservoir capacity is allotted to flood mitigation. It has its own reservoir operation rule curve, so cannot be used for new PSPs.
- Some of the reservoirs have very large capacity (in BCM) with multi-purpose usage such as Power generation, Irrigation, Water supply and Flood mitigation. These projects are planned in such a way that all the silt also get settled in the reservoir and provide silt free water to the downstream. The PSPs can be planned in these reservoirs on the basis of topographical and geological suitability. Tehri dam is an example of such multi-purpose project.

For establishing new PSPs there will be requirement to locate sites for lower and upper reservoirs. In Himalayan region these reservoirs will also have lot of silt in flow during the monsoon season and have issues related to reduction in storage capacity.

7.2 Cascade Hydro power project Development in Himalayan Rivers

Many projects in Himalayan region have been located/proposed in the cascade pattern on the rivers for exploiting maximum head available. Hence, any additional storage for using it as lower and upper reservoir for PSP may affect the performance of upstream and downstream projects.

7.3 Sedimentation and Flood Management

- Most of the Himalayan region projects are located in heavily sediment prone areas. It is estimated that more than 80% of average annual sediment comes during the monsoon season i.e. from June to September along with high flood discharge.
- Reservoir operation rules of Himalayan region projects are framed for the silt and flood management suitable to intended purpose of the project. The sediment management in most of the Himalayan region projects are being done by keeping reservoir level near MDDL during Monsoon Season (Sluicing) so that a large quantum of the incoming sediment / deposited sediment can be passed through the spillway so it maintain the useful life of reservoir. Also Drawdown flushing is carried out during monsoon period. Even after adopting these international practices, live storage of Himalayan region projects are decreasing affecting diurnal peaking. If these practices will not be adopted then reservoir will be filled up with sediment in very short time, and will not serve the intended purpose. In view of these fluctuations in the reservoirs, there are limitations regarding their use as PSPs.
- All on-river reservoirs need to have proper silt and flood management arrangements and the cost of these arrangements is very significant as the spillways, sluices, energy dissipation arrangements, silt exclusion systems and desilting basins are planned from safety and operation aspects.

The upper and lower reservoirs of new on-river/off-river PSPs of Himalayan region will also need to be operated for silt and flood management due to which low level sluices, spillways, energy dissipation arrangements will be required in the diversion structure/dam of the scheme. These structures will affect the financial viability of the project.

7.4 Natural disasters &Accessibility

Himalayan ranges are vulnerable to heavy rains, landslides, cloud burst and other natural disasters. Many potential PSP sites are situated in inaccessible region so construction of new roads & bridges to various components of PSP including upper &lower reservoirs, penstocks & other water conductor system and power house would require large investments. These expenditures will make the scheme unviable in many cases.

7.5 Geological Aspects

- Himalayas are the youngest folded mountains having complex tectonic and geological setup, prone to land slide hazards and cloud bursts. Most of the projects in Himalayan terrain are dotted with various geological weaknesses, shear zones, folds, faults and lineaments.

- Lithology encountered in Himalayas is varied and complex. Himalayas are mainly divided into three divisions i.e. Shivaliks, Lesser Himalayas and Higher Himalayas. Rocks of Shivaliks are generally weak, have lesser strength and traversed by numerous faults and shear zones. Rocks of Lesser Himalayas and higher Himalayas are better in strength than Shivaliks however the lithological variation is more and rocks are complexly folded, faulted and sheared.
- Pump Storage Plants involve creation of two reservoirs, water conductor system and Powerhouse structures. In Himalayas, topography is generally rugged and steep and flat terraces/areas are scarce and generally of small dimensions. Wherever flat areas exist they are generally inhabited and cultivated. Moreover, flat terraces /areas in Himalayas are generally associated with faults/ thrusts/ buried channels or other geological anomalies. Due to steep topographies at many locations laying of surface penstocks, surface powerhouse for Pumped Storage plant is practically very difficult. Further, construction of large size underground powerhouse caverns, transformer cavern, and underground water conductor system may require detailed investigation and large investments.

This aspect will affect the feasibility of all the PSPs including On-river, Off-river and conversion of existing HEPs.

7.6 Proximity to RE power centers

Only a few solar & wind projects are being developed in Himalayan region. So, cheap RE will not be readily available for PSPs during pumping mode. It would be preferable that PSPs be developed in proximity to Solar & wind power centers for short transmission lines resulting in economical operation of PSP. In view of this it will be preferable to have PSPs near to the flat topographies where wind power and solar power can be established.

8.0 PSPS IN NON-HIMALAYAN REGION - PROSPECTS & CHALLENGES

The development of Pump storage plants in plain or non-Himalayan regions in India seems to be better option Considering the various important aspects such as geology, silt free water, accessibility, proximity to availability of large RE power from solar/wind etc. in peninsular India specially in states of Madhya Pradesh, Maharashtra, Andhra Pradesh, Karnataka, Kerala etc. huge potential for construction of pump storage plants are available. Some of the issues / challenges in construction of pump storage plants in non-Himalayan region are as under;

8.1 Land Submergence

Generally in peninsular India the land terrain is flatter and hence there will be large land submergence even for less reservoir capacity. Also chances of submergence of Agriculture land and Residential land are comparatively more. In Madhya Pradesh and Maharashtra various off river good PSP sites are available but terrain and topography of the site are such that large land submergence shall occur. Large agricultural land and residential land area submergence make the project construction difficult due to local resistance.

8.2 Rehabilitation and Resettlement issues

In non-Himalayan region, the settlement of habitats in plain area are sparse but in many dense clusters. As such construction of lower and upper reservoir will require more rehabilitation and resettlement.

8.3 Water rights of the area

The water rights of the stream and pond is the important factor required to be looked into before finalizing the PSP scheme in the area. Generally rain water during monsoon is used to be stored by check dams to be used for agriculture and domestic purpose for the rest of the year. The catchment area of upper and lower reservoir may be common with the existing ponds and the same may be point of concern.

8.4 Rainfall Dependency & Proximity to Water Source

The peninsular India, which is favorable for development of PSP plants have experienced heavy rainfall in the monsoon season. However less monsoon rainfall in any year will create paucity of water in the reservoir thus effecting the PSP operation. Major rivers of the region are monsoon fed and its discharge decreases substantially in non-monsoon period. The water is collected in the river by construction of small check dam and earthen dams. The paucity of water in this region also discourages construction of PSP plants. The availability of water source in the nearby area is one of the important aspects for development of off river PSP scheme. The nearby water source should have sufficient and perennial discharge to feed the lower/upper reservoir, in order to make up the loss of water due to seepage, evaporation etc.

9.0 OFF-RIVER PUMP STORAGE PLANTS–(AUSTRALIAN NATIONAL UNIVERSITY ATLAS)

Off-River (Closed Loop) PHES scheme is a relatively new approach for developing pumped storage projects, wherein the reservoirs are located in areas physically separated from existing river systems. Development of a off-River system requires

identification of a water source to provide the initial charge and after the initial filling of reservoirs, the only additional water requirement is the minimal operational make-up water required to offset evaporation or seepage losses. Off-river closed loop PHES can be an efficient & cost-effective option.

The Australian National University (ANU) has found 16,000 off-river sites in India with various storage capacities with many of them located in Himalayan region.

In view of above, MOP has directed all CPSUs to explore the possibility of new PSP in the vicinity of all their existing projects (completed & ongoing) based on the data provided by Australian National University (ANU).

Brief Summary of NHPC Study on Off-River Potential:

The 33 nos. off river PSP schemes in the vicinity of NHPC projects in Himalayan region has been studied. Himalayas, being the youngest folded mountains, have complex tectonic and geological setup, various geological weaknesses, shear zones, folds, faults and lineaments, prone to land slide hazards and cloud bursts and sediments inflow during monsoon. Further, topography is generally rugged and steep and flat terraces/areas are scarce and generally inhabited and cultivated. As such laying of various components at surface for Pumped Storage plant is practically very difficult and the option left is only to create underground structures.

Considering the various important aspects such as Geology, silt free water, accessibility, proximity to availability of large RE power from solar / wind, it is opined that locations for PSP near Narmada river region in Madhya Pradesh shall be better option.

For head nearly 300 m or more, separation upto 3 km, height & length of the dam required for creating upper & lower reservoir etc. 6 nos PSP sites were initially screened for detailed study.

These initially screened 6 nos PSP sites have been further examined and compared taking into account the various factors viz., Construction Issues, Height & Length of Dam etc.

Based on the above studies, 01 no. of location in Narmada river Region in Madhya Pradesh may be selected to be taken up for pre-feasibility studies.

10.0 CLEARANCES REQUIRED

The guidelines of MoEF & CC applicable for River Valley & Hydropower Projects are applicable for Environment, Forest and Wildlife clearances are same for Pumped Storage Projects in Himalayan or non-Himalayan region and on river or off river schemes.

The important clearances required are Environment clearance, Forest clearance, Wild life Clearance, clearance with respect to Private Land Acquisition, Consent to establish (by public hearing), longitudinal connectivity and E-flow.

Construction of Pumped Storage Projects are subject to due concurrence by CEA, CWC, CSMRS & GSI.

11.0 STUDY BY NHPC FOR CONVERSION OF ITS EXISTING HYDROPOWER PLANTS/PROJECTS TO PSP

A study for conversion of existing NHPC hydro projects to PSP was carried out by NHPC. The key- takeaways of this study are below;

- As most of the projects in NHPC are ROR with limited pondage, the sufficient reservoir capacity is not available round the year to support the Pump Storage Plant (PSP).
- Projects are generally developed in cascade pattern. Hence any additional storage for using it as a lower reservoir or upper reservoir may affect the performance of upstream and downstream projects.
- Most of the NHPC projects in Himalayan region have long underground water conductor systems making L/H ratio unfavorable for pumped storage. Some of the projects have quite low head and not suitable for PSP.
- If the machines of the existing power plants are replaced as PSP there will be requirement to modify/replace many electro-mechanical components and also complicated civil works.
- Considering availability of upper reservoir of Indira Sagar Power station and lower reservoir of Omkareshwar Power station in close vicinity, availability of silt free water, favorable geological conditions a probable PSP scheme near Indira sagar PS is taken up for making PFR.

12.0 CONCLUSION

In view of factors discussed, regarding reservoir operation, silt & flood management, geological complexities, accessibility, natural calamities and proximity to RE center Himalayan region appears to be less favorable to establish Pumped Storage Schemes. The PSP in Himalayan region may be planned, if the reservoir is very large like Tehri Dam Reservoir which absorb flood as well as and provide silt free regulated water to the downstream. However there are many issues /constraints with such large reservoirs in Himalayas.

Due to various limitations existing power stations / projects in Himalayan region cannot be converted into PSP schemes.

On comparing the merits and demerits of the PSP schemes in Himalayan and non-Himalayan region, part of peninsular India with desired topography and geological conditions comprising of Deccan trap Basalts seems a better suited area for locating pumped storage projects. In this area rock is strong, more or less uniform and with lesser structural and tectonic disturbances.

However favorable topographical conditions for locating upper and lower reservoir, availability of water source and other issues need detailed investigation.

Even in non-Himalayan region on-river reservoirs need to have proper silt and flood management arrangements. These arrangements like spillways, energy dissipation arrangements, silt exclusion arrangements etc. have significant financial implications which are not required for Off-river reservoirs.

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