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PUMPED STORAGE DEVELOPMENT EMERGING CHALLENGES AND AVAILABLE OPTIONS – CASE STUDIES

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ABSTRACT

Rapid depletion of fossil fuels together with associated adverse impacts on climate will result in large scale induction of renewable energy into the system in near future . These energies are abundant in nature but are intermittent and varying in nature. The output from these sources may not be in sync with the requirement in real time. Hence there is an urgent need for the large energy storage to ensure system reliability. However, The concept of Pumped Storage Projects is relatively new in India. Given its nature, almost all the Pumped Storage Projects have inherent challenges in planning, design and thus, require specialized expertise, knowhow and manpower from its concept to commissioning. There are only few pumped storage projects in India which have been designed, commissioned and running successfully in India. In this scenario well planned Pumped storage projects could play a vital role in mitigating above emerging issues.

In Indian context, there is an ambitious plan of 175 GW renewables generation as per various projections. But at the same time we are also looking at retiring many old Thermal plants while Hydro Sector passing through tough times and not looking promising in near future.

Development of projects with large submergence and associated land acquisition has become increasingly difficult proposition. Moreover many good sites identified earlier have now become unavailable over a passage of time due to various reasons such as new notification of National parks, Wild Life sanctuary etc. All these factors indicate that there are multiple challenges in development of land intensive projects having reservoirs. Hence Identifying sites for Pumped storage projects which essentially have two reservoirs become even more challenging.

In this context , this paper underlines the importance of exploring all the attractive available sites. It is also equally important to exhaust all possibilities for installation of large Pumped storage projects within existing projects having reservoirs to the extent possible. Since installing Pumped storage project within existing operational projects is a complex proposition and requires in-depth study to integrate both existing and new projects in such a manner that over all project benefit can be maximised. In such cases all possible technical combinations need to be studied and necessary trade offs amongst the priorities of existing and new project needs to be made in judicious manner. Three case studies with different possible options for installation of Pumped Storage project are also presented.

Keyword : Hydropower Storage, Pumped Storage, renewable integration, Energy Storage

1.0 PUMPED STORAGE PROJECTS :

1.1 Technology description

The basic arrangement of the Pumped storage scheme involves two storage reservoirs with adequate storage capacity , upper and lower separated at vertical difference called head H with reversible turbine /pump in the power house located in between the two reservoirs.

The technology is a mechanical storage of the energy. Water is lifted to the upper reservoir by pumping mechanism through extra electricity during off-peak time. The stored potential energy in the upper reservoir is used to generate electricity by turbines when they are needed. Pumping is similar to charging the batteries for future use.

Lower Reservoir (Purulia PSP)

Upper Reservoir (Purulia PSP)

1.2 Key Advantages and disadvantages of the Technology

A. Advantages

1. Quick on/off response of turbine
2. Quick Response to generation variability to stabilise grid
3. Best mechanism to help integrate the intermittent energy resources with system
4. Help improve grid efficiency.
5. Low O&M Cost
6. Environment friendly as helps reducing Green house gas emission from energy generation by fossil fuels
7. Can be used to provide Black start facility.

B. Disadvantages

1. Loss of energy while pumping.
2. At times Attracts adverse impact on environment due to large submergence in two reservoirs.
3. Large land acquisition.
4. Initial cost is very high and cost economics is a challenge.
5. Long gestation period
8. Requires highly meticulous and judicious planning and design.
9. Very difficult to find suitable site and the ideal site is rare to find.

1.3 Key Parameters in Pumped Storage Planning

1.3.1 *Desirable characteristics*

1. The geological setup should be conducive to create water tight reservoir to prevent the loss of water which is in turn loss of storage energy.
2. The excavation involved in the creation of reservoir should be minimum.

3. The site selected should be such that it provides higher head for the scheme. As higher the head will result in lower the storage requirement as well as smaller size water conductor system.
4. The length of the water conductor system should be minimum. The efficiency and economics of the scheme depends on the ratio of total length of the WCS to the head available i.e L/H ratio.
5. The entire water conductor system should be straight to the extent possible. However, many times Geology makes it difficult due to requirement of underground Power house orientation.
6. The general guideline in practice for L/H is as under:

   L/H between 10-12 for high head scheme>360m

   L/H between 4-5 for low head scheme between 150m -180m head.
7. The Power house should be located either in the middle of the both reservoir , preferably close to lower reservoir.

2.0 CASE STUDIES

2.1 Background

Given the paucity of new sites, it is difficult to find new sites for installation of Pumped Storage Projects. In addition, in the present context the large submergence together with the land acquisition has become a major constraint for constructing land intensive projects. All Pumped storage projects essentially require two reservoirs (Upper and Lower), and this fact entails that various innovative combinations are also considered for installing Pumped Storage Project. Efforts should be made to utilise existing H.E. projects with adequate reservoir storage.

In view of above, following combinations are possible:

1. **New Pumped Storage Projects** (Both new reservoirs to be made)
2. **Within the Existing Projects** (One Reservoir exists and One new reservoir is to be made)
3. **Within the Existing projects** (Both reservoirs exists)

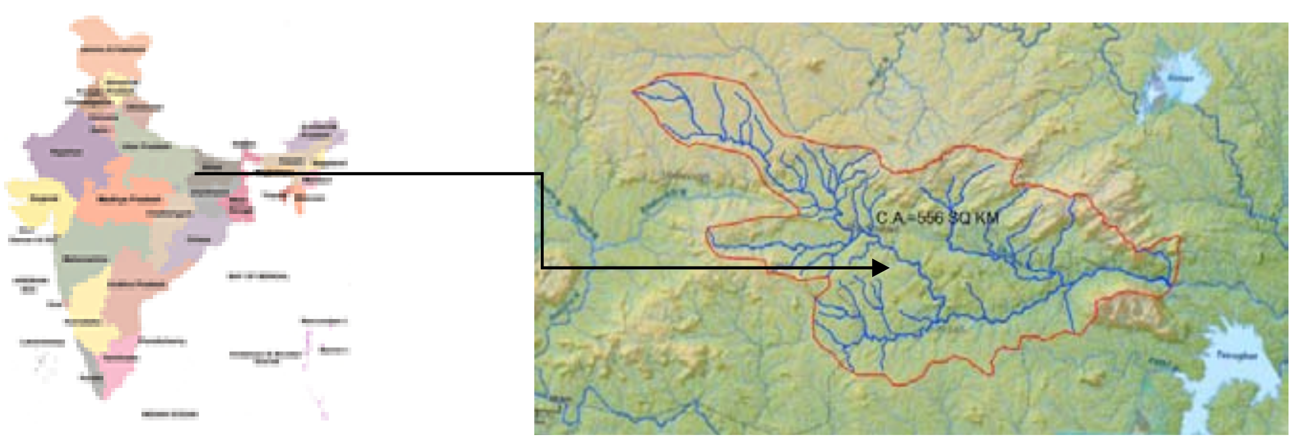
The planning and design of each of the above three types are distinctly different from each other and require meticulous planning at each stage of development. Three case studies are presented for each of the above option.

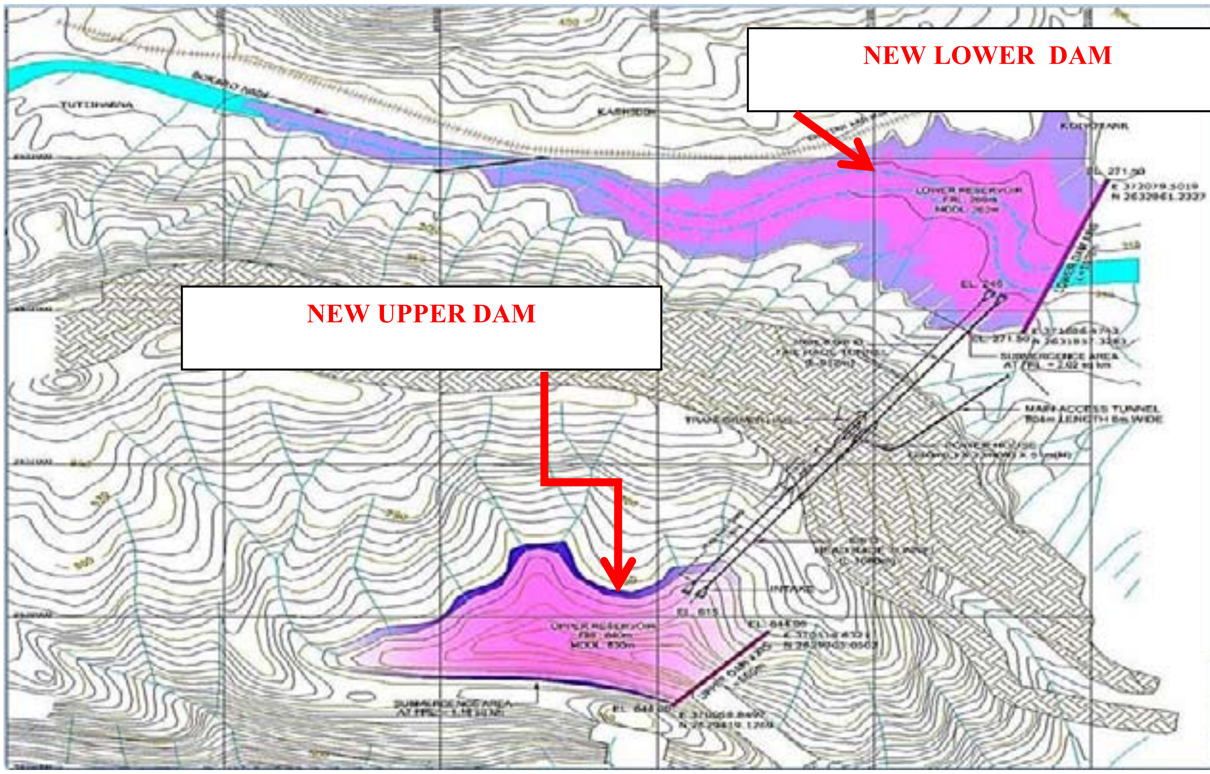
2.2 Option-1

New Pumped Storage Projects (Both new reservoirs to be made) - **Lugu Pahar Pumped Storage Project, 6×250MW, Jharkhand**

The proposed Lugu Pahar Pumped Storage Project is located near Lugu village in Gumia tehsil, Bokaro district, Jharkhand, India as shown in Figure 1. It is situated at 15 km away from sub-district headquarter Gumia and 70km away from district headquarter Bokaro. Gumia is nearest town to Lugu Pahar. The Nearest Airport is Ranchi which is about 90 km (approx) from the project site. The proposed lower dam site is approachable by fair weather

motorable road via. village Hosir,Tulbul and Pindra. The upper dam site is in Lugu Pahar on Kairo Jharna Nala and the basin is characteristic by hilly topography. The Lower dam site is on Bokaro River near Tulbul village and faces a vast plain at EL 240 m to 270m.





PROJECT LAYOUT

Key Project Features

The Lugu pahar Pumped Storage project envisages construction of:

- A 104.50 m high Rockfill New upper dam with central impervious clay core.
- Live storage of **10.10 M cum** with FRL at 640.0 m and MDDL at 630.00 m;
- A 31.50 m high Rockfill New lower dam with central impervious clay core.
- Live storage of 10.10 M cum with FRL at 269.00 m and MDDL at 262.00 m;
- 2 (two) No. 740 m long, 8.0 m diameter headrace tunnel
- 2 (two) No. 544 m long, 7.0 m diameter pressure shaft
- 2 (two) No. 950 m long, 8.0 m diameter headrace tunnel
- An underground power house having an installation of 6 Francis type reversible pump-turbine driven generating units of 250MW capacity each

An installed capacity of 1500 MW has been adopted based on the simulation studies carried out for different FRLs and installed capacities to provide peaking benefits for 6 hours.

2.3 Option-2

Within the Existing Projects (One Reservoir exists and One new reservoir to be made)- **Turga Pumped Storage Project, 4×250 MW), West Bengal**

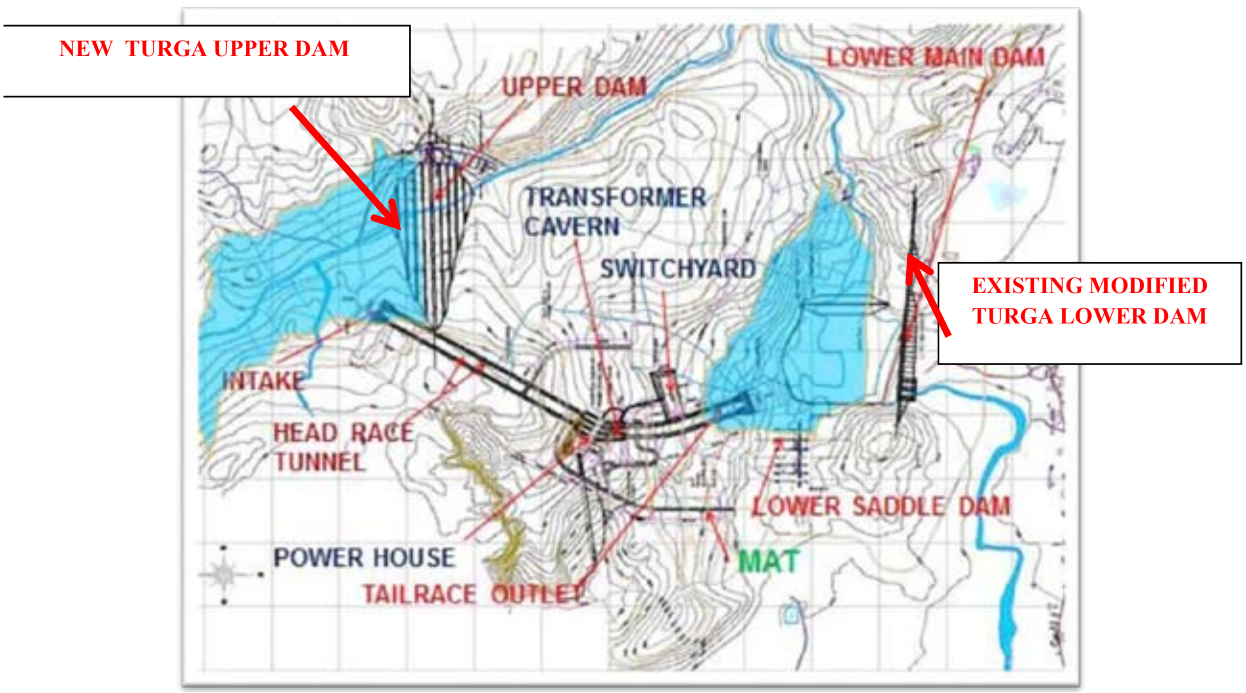
The Turga Pumped Storage Project located in Purulia district of West Bengal is one of the four Pumped Storage Schemes in Ayodhya hills in Purulia district of West Bengal. These hills present ideal sites for the construction of Pumped storage schemes . The scheme has almost all the desirable parameters required for a suitable pumped storage development.

Ayodhya hills form a part of Chhota Nagpur plateau. The plateau top is almost plain to slightly undulating and maximum elevation is about 610m. the bottom of these hills are at average elevation from 250m to 260m .The horizontal distance from hill top to plains is about 5-6 km.

Following characteristics inter-alia make these hills ideal for pumped storage schemes.

1. The entire Ayodhya hills constitute gneissic group of rocks belonging to Chhota Nagpur complex which is equivalent to chibasa stage or singbhum granite of Archean age.
2. The rock type and condition are very competent and suitable for water tight reservoir with no possibility of water path to adjacent valleys.
3. The topography allows large storage with medium height dams.
4. The average bed slope in the streams are from **1 in 20m to 1 in 40m. This is a highly favourable parameter as maximum head is available at minimum length.**
5. The foundation rocks are available at shallow depths presenting good foundation for storage structure.
6. The rock type of good quality present a conducive option of locating underground power house without any problem.
7. Availability of construction material like aggregates, plastic earthen core material , filter material present a good option of constructing rockfill dam with earthen core .

The Turga project with a proposed installed capacity of 1000 MW (4×250 MW) is an example of a good pumped storage scheme.



PROJECT LAYOUT

Key Project Features

The Turga Pumped Storage project envisages construction of:

- A 63.50 m high Rockfill New upper dam with central impervious clay core.
- Live storage of **14.20 M** cum with FRL at 464.0 m and MDDL at 444.40 m;
- A 64 m high concrete dam modified at existing lower dam location.
- live storage of 14.20 M cum with FRL at 316.50 m and MDDL at 280.40 m;
- 2 (two) No. 932 m long, 9.0 m diameter circular steel lined headrace tunnel
- An underground power house having an installation of 4 Francis type reversible pump-turbine driven generating units of 250MW capacity each
- 2 (two) No. 10m dia 605 m long tail race tunnels to carry the power house releases to lower reservoir.

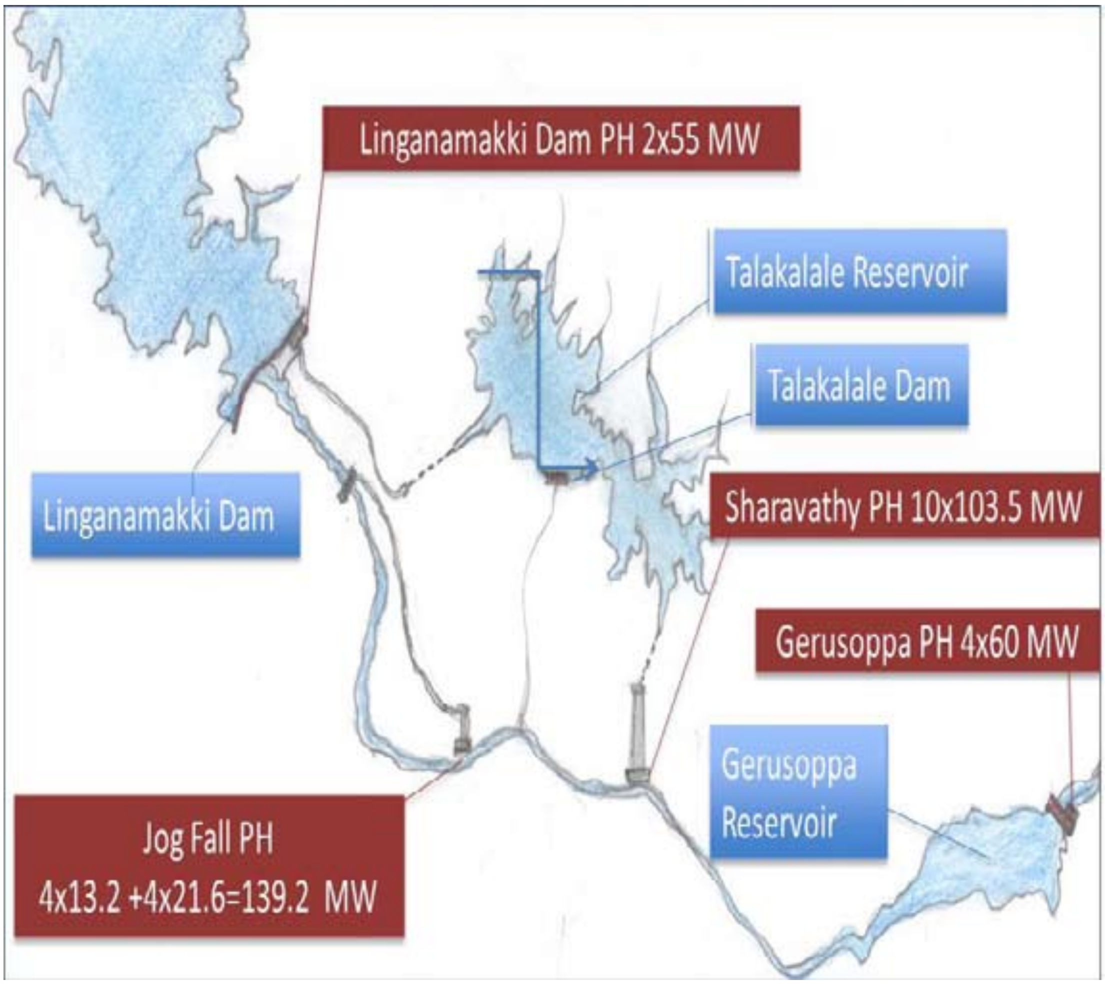
An installed capacity of 1000 MW has been adopted based on the simulation studies carried out for different FRLs and installed capacities to provide peaking benefits for 5 hours.

2.4 Option-3

Within the Existing projects (Both reservoirs exists)- **Sharavathy Pumped Storage Project, 8X250 MW, Karnataka**

The proposed Sharavathy Pumped Storage Project on Sharavathy river would perhaps be one of the biggest Pumped storage Schemes in the range of 2000 MW in India. The Sharavathy pumped Storage H.E Project with installed capacity of 2000 MW is planned between existing Talakalale and Gerusoppa reservoir which are situated at downstream of Linganamakki reservoir on Sharavathy River. The reservoir formed by the Linganamakki dam across the River Sharavathy is the key to the optimum development of water resources of the River comprising regulating dams, diversion structures and associated 4 power stations having an aggregate installation of 1469 MW.

The proposed pumped storage project is planned as an additional installation utilising the existing Sharavathy system consisting of Liganamakhi, Talakalale Dam and Gerusoppa Dam. Five (5) reservoirs regulate monsoon surplus waters of the Sharavathy and adjacent streams. KPCL has three major hydroelectric stations in the basin with a total installed capacity of 1330 MW.



EXISTING SHARAVATHY SYSTEM

The significant storage capacity at Talakalale and Gerusoppa reservoirs as given in the Table below together with their large elevation difference of about 450 m between the two reservoirs, renders this site as one of most attractive possibilities for Pumped Storage Development in the country.

Avaialable Storages in Sharavathy Reservoirs

Sr. No.	Reservoir	FRL (m)	MDDL (m)	Live Storage (MCM)
1	Talakalale	522.12	520.59	13.6
2	Gerusoppa	55.00	43.50	58.21

Storage Requirement (MCM) for Different Installed Capacity for 6 hours peaking Operation

Installed Capacity (MW)	Total Storage Requirement (MCM)	Storage Required for existing Sharavathy HEP (MCM)*	Storage Required for Sharavathy PSS (MCM)
1000	6.81	1.63	5.18
1250	8.11	1.63	6.48
1500	9.41	1.63	7.78
1750	10.7	1.63	9.07
2000	12.0	1.63	10.37

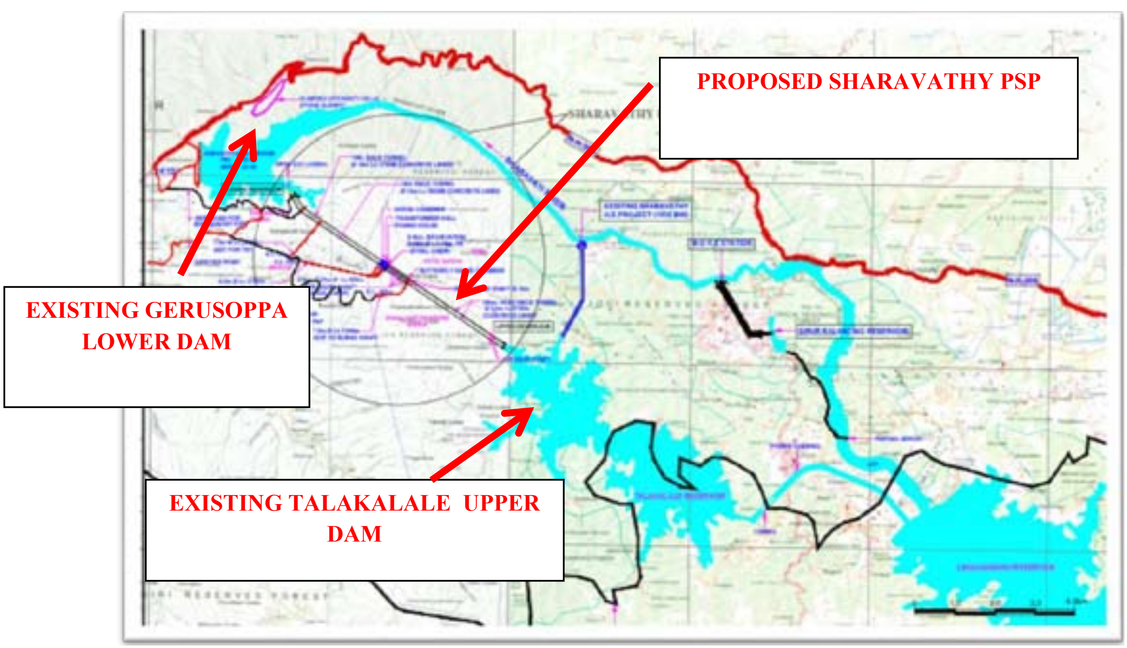
* During 6 hours of peaking operation

It would be seen from above that sufficient storage is available at upper reservoir for Sharavathy Pumped Storage scheme for installation of 2000 MW. The lower reservoir at Gerusoppa with live storage of 58.21 MCM would not pose any constraint in the selection of installed capacity. The energy generation/pumping energy requirement and determine the various parameters of the scheme such as operating levels of the two reservoirs, pondage requirement and the installed capacity. An average efficiency of reversible units has been considered as 92% in generating mode and 90% in the pumping mode. The cycle efficiency has been worked out as 80.9%.

With installed capacity of 2000 MW, daily generation for 6 hours peaking would be 12000 MWH. Daily pumping energy requirement would be 14834 MWH.

Key Project Features

- 2 (two) No. intake with trash racks having mechanical raking arrangement.
- 2 (two) No. 2.726 Km long, 9 m diameter circular concrete lined headrace tunnels including cut & cover.
- 2 (two) No. 0.828 Km long, 5.25m diameter inclined circular steel lined (including horizontal) pressure shafts
- 2(two) no. 16m dia circular Surge Shafts 52m high.
- An underground power house having an installation of 8 Francis type reversible pump-turbine driven generating units of 250MW capacity each
- 2 (two) no. 3.780 Km & 3.830 Km long concrete lined tail race tunnels to carry the power house releases to lower reservoir.



PROJECT LAYOUT

3.0 CONCLUSION

Based on the above following conclusion can be drawn:

1. In view of large scale induction of Renewables in near future development of Pumped Storage projects needs focused attention and support.
2. Pumped Storage project planning is distinctly different from conventional Hydro Planning.
3. There are inherent complexities and site specific constraints in planning and design of Pumped Storage Projects.
4. Hence, meticulous planning with judicious decision making is essential while making trade offs between priorities which are at times competing with each other.
5. There are only few good Pumped Storage sites, which meet the requirement of a good pumped storage development in India.
6. Many identified sites have now become unavailable due to stringent Environmental, and Social stipulations together with difficulties in land acquisition.
7. Many sites may be unavailable due to proximities to the national Parks etc.
8. In view of above, it is of utmost importance that all the possible new sites are explored in totality.
9. Efforts should be made to study all the existing projects having one reservoir or two reservoir in proximity and explore the possibility of installation of Pumped Storage projects within the existing system.
10. This will minimize many adverse impacts and address developmental challenges.
11. The PSP development within existing projects will greatly reduce the cost and help making Pumped storage project economically viable.

REFERENCE

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2. DPR of Turga Pumped Storage Project of WBSEDCL
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