Pumped Hydro Storage Technology as Energy Storage and Grid Management Element for Renewable Energy Integration in Karnataka

Y. Nagarjun

Abstract The increased penetration of wind and solar into existing grid poses more challenges, which brings the need for energy storage schemes and grid management assets to ensure power system stability. For which Pumped storage plants can be used as both energy storage and grid management element instead of energy generation source alone. Before this pumped storage power generation was not of in much interest to many states although its contribution towards grid frequency stabilization and load control was well proven. A recent trend of power consumption pattern in Karnataka predicts the need for 'Pumped Storage Technology'. With availability of about 5GW of wind and solar power, Karnataka almost meets its 60% needs. So, taking into consideration the growth of renewable energy in the state, Government of Karnataka intends to set up pumped storage plants for grid management and energy storage. The idea of pump storage is to use the excess energy and balance the grid. A pre-feasibility study carried out on the construction of 2000 MW pumped storage plant in Sharavathi valley project, Shivamogga district has been detailed in this paper. This will be a first-of-its-kind project in Karnataka and would perhaps be one of the biggest Pumped storage Schemes in the range of 2000 MW in India. The study shows that the proposed project is techno economically viable and is planned as an additional structure utilizing the existing Sharavathi hydro project consisting of Liganamakhi, Talakalale and Gerusoppa Dam.

Keywords Pumped hydro · Energy storage · Grid management · Renewable integration · Smart grid

1 Development Need of Pumped Storage Plants

In order to fulfill the electricity demand during peak hours and for managing the imbalance in thermal: hydel mix, pumped storage schemes were developed in the country during 1960s, Now in recent times the increasing imbalance of thermal: renewable mix (mainly wind and solar) is again bringing need for developing pumped

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storage schemes. Figure 1 shows the Karnataka state demand-wind-solar profile on a particular day. During a day wind generation does not take place during peak hours. Solar generation also occurs partly during off peak hours and partly during peak hours. Wind and solar plants are greatly subject to natural variations [1]. They fail to meet the electricity demand at required amount and at required time. So, excess renewable energy has to be stored so has to make it available when needed.

Integrating a large amount of MW scale wind and solar facilities into the electric grid system requires grid balancing and storage techniques. Though different forms of energy storage techniques have been tried and proven globally, pumped hydro storage plants are still playing an important role in meeting peak demand and helping maintain grid stability in many of the developed countries. Pumped hydro technologies can be thought of the only long term solution which can be technically effective, economical, more efficient and operationally flexible in large scale for energy storage use at a short notice. It is only pumped storage hydropower that can meet many of the grid-scale energy storage needs as no other storage system currently available can meet all grid demands. Pumped storage plants (PSP) has added benefits to reduce the effects of greenhouse gases on the environment. Developing pumped hydro plants particularly near sites with large scale wind and solar power generation, can improve grid reliability. The additional benefits of pumped storage schemes is the availability of spinning reserve to regulate the system frequency during sudden load changes and providing power factor and voltage correction when acting as synchronous condenser with no additional investment costs.

The first pumped hydro storage scheme was built in India at Nagarjunasagar Dam in 1970 with 700 MW installed capacity. Since then, several such pumped storage schemes were successfully built in India, which includes Bhira (150 MW), Kadana

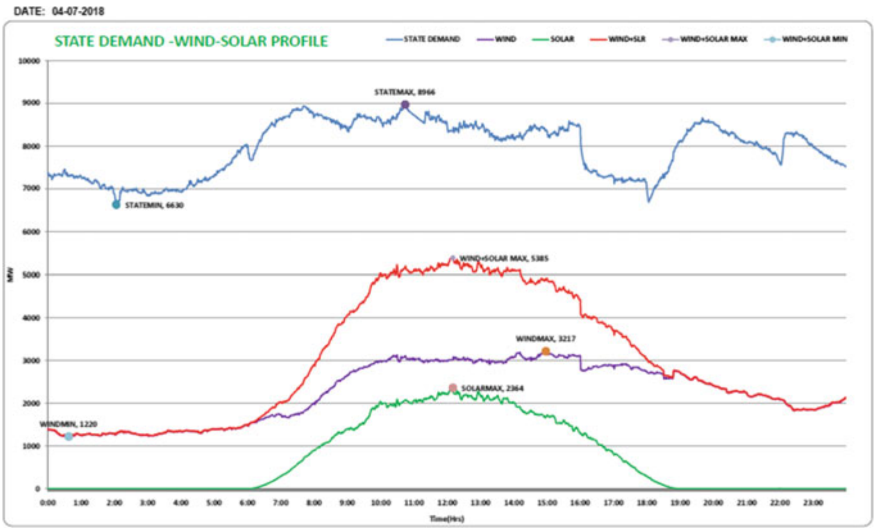

Fig. 1 State demand -wind-solar profile

(240 MW), Ghatghar (250 MW), Kadampari (400 MW), Srisailam (900 MW), Purulia (900 MW) storage projects [2, 3]. Currently nine such schemes are in operational with a total installed capacity of 4785.6 MW. Off these, only five schemes of total 2600 MW are being operated in pumping mode due to various techno-economic reasons. Now the support to develop grid scale energy storage for effective integration of new generation is bringing the need for development of pumped storage hydro power. Therefore Sardar-Sarovar Pumped Storage Scheme at 1200 MW and Tehri Pumped Storage Scheme at 1000 MW capacities are already under construction and 63 other such schemes identified across different parts of the country with an total installed capacity of 96,524 MW are planned for future.

2 Feasibility of Pumped Storage Schemes in the State of Karnataka

It is well known information that Government has devised an ambitious program for developing 175 GW of renewable energy generation by year 2022, comprising majorly Solar (100 GW) and Wind (60 GW). Whereas the total installed renewables in India reached around 75 GW at the end of 2018, representing 21% of the total installed capacity and making a record high of 11.9% of the total electricity generated in the September 2018 quarter. This clearly shows that solar and wind power generation has increased during past few years and contributes for a significant proportion of the total generation in the grid. This significant portion of renewable generation is mainly concentrated in few states of Tamil Nadu, Karnataka, Andhra Pradesh, Telangana, Gujarat, Maharashtra and Rajasthan. These states contribute more than 80% of total renewable generation.

Karnataka is one of the state which is blessed abundantly with all forms of renewable energy resources consisting of Biomass, Small Hydro, Solar, Wind, Cogeneration, Waste-to-Energy, and Tidal. As on November 2018 Karnataka has a renewable energy installed capacity of 12,662.67 MW of which wind (4736.76 MW) and solar (5265.26 MW) playing the major role. Considering the significance of this, Karnataka has long been a pioneer in the area of developing renewable energy projects in the country. As a part of its role to fulfill nation's renewable energy obligations and to reduce the increasing imbalance of thermal (7680 MW): renewable mix (12662 MW), the state is planning for developing pumped storage schemes. Karnataka has a good opportunity for adopting a sustainable model for development of Pumped Storage Schemes for integration of large renewable energy projects and to be a model for other states of the country. In the case of Karnataka state, it is observed from previous years data that most of hydropower projects were able to run at their full potential only during monsoon months. For remaining period, due to low reservoir levels the power generation varies accordingly and are not able to cater for peak hour demands. To overcome these challenges, the state's topography provides an opportunity for developing Pumped Storage Schemes. Compared to conventional hydro projects Pumped

Storage Schemes doesn't require large dams to be built and potential sites can be identified where a reasonably small reservoir can be built at different altitude to serve the purpose. As Pumped Storage Schemes require small storage to generate electricity for duration of up to 6–8 h during peak hours the water used can be pumped back to upper reservoir during off peak hours. Also, these projects will not have much of rehabilitation and resettlement issues, which is a big and problematic issue in conventional hydropower projects. Considering the tariff competition trend in recent times, the Pumped Storage Schemes are proven to be techno-economically feasible during peak hours. Having realized the above advantages the state utility has identified two such potential sites for developing pumped storage schemes on existing projects namely Sharavathy valley (2000 MW) and Varahi valley (700 MW). Karnataka Power Corporation Limited (KPCL) has submitted a draft pre-feasibility report (PFR) to Ministry of Environment and Forests (MoEF) for clearance. Topographical survey in Varahi Valley is done on the downstream of tailrace and PFR is under preparation for Varahi Pumped Project. A PFR study [4] submitted on the benefits of developing of Pumped Storage Scheme in Sharavathy valley has been detailed in this paper. The study shows that the Project is techno-economically viable.

3 Sharavathy Pumped Storage Project

The proposed Sharavathy pumped storage installation is planned within the existing Sharavathy Valley Hydro project. Figure 2 shows the flowchart of Sharavathy Valley Hydro project.

The Sharavathy Pumped Storage Scheme with an installed capacity of 2000 MW is proposed on the existing Talakalale and Gerusoppa reservoir which are situated at downstream of Liganamakhi reservoir on Sharavathy river. The reservoir formed by the Liganamakhi 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 Water resources of the Sharavathy River and adjacent streams have been optimally utilized for power generation in Sharavathy Basin. Five reservoirs plays a major role in regulating surplus waters of the Sharavathy river and adjacent streams during monsoon. The present scheme is a very attractive scheme both in terms of technical feasibility and from economical consideration. The proposed scheme contemplate for the utilization of the potential of the Sharavathy River released from Liganamakhi dam through dam toe Power house by a hydel channel in to Talakalale reservoir, which is a balancing reservoir for existing Sharavathy H.E. Project of 1035 MW. The proposed pumped scheme envisages for power generation during hours on a Pumped storage type model, utilizing a head of about 460+ m between Talakalale as upper reservoir and Gerusoppa as Lower reservoir. Since the Upper and Lower reservoirs of Sharavathy Pumped Storage Project (Sharavathy PSP) has effective storage capacity equivalent to four to five hours of generation daily at full rated output, it is not possible for Sharavathy PSP to operate on weekly or seasonal basis. Therefore,

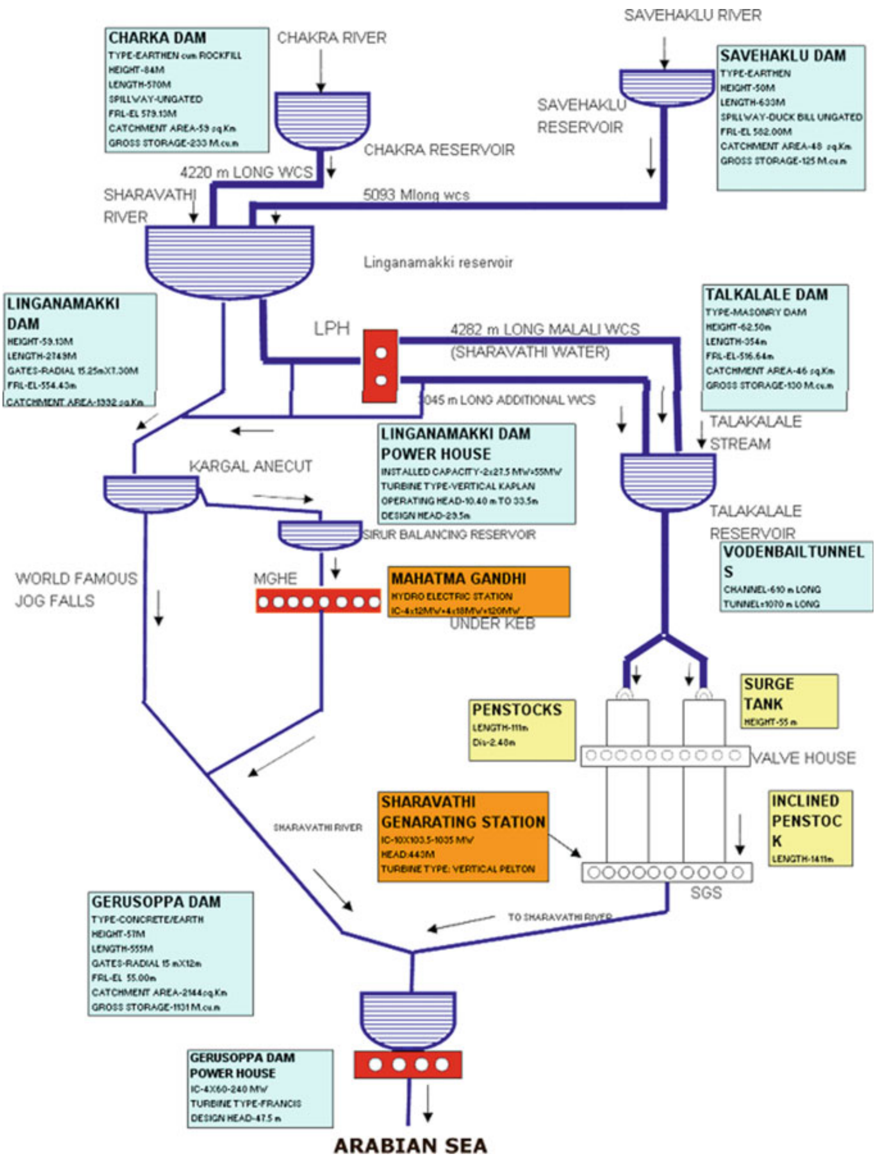

Fig. 2 Flowchart of Sharavathy valley hydro project

the Project is deemed to be operational on Daily basis. Figure 3 shows the proposed Integrated Sharavathy Basin Development Plan.

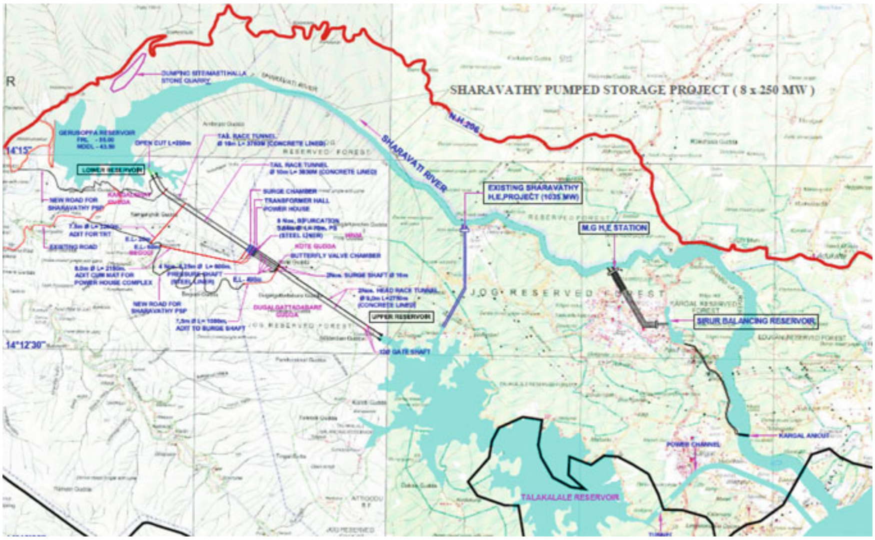

Fig. 3 Integrated Sharavathy basin development plan

The Sharavathy Pumped Storage project envisages to utilize the existing Talakalale dam as upper dam and Gerusoppa as lower dam without any modification in these structures. The present operating levels are also remain unchanged. The proposed scheme contemplates for the construction of:

- Two numbers of intake structure having necessary trash rack arrangement with mechanical raking system.
- Two numbers of 2.72 km long 9 m dia, concrete lined headrace tunnels.
- Two number of 0.82 km long 5.25 m dia, inclined steel lined pressure shafts.
- Two number of 52 m high 16 m dia Surge Shafts.
- A state of art underground power house with eight numbers of Francis type reversible pump-turbine driven generators of 250 MW capacity each.
- Two number of 3.78 and 3.83 km long concrete lined tail race tunnels to carry the releases to lower Gerusoppa reservoir.

3.1 Installed Capacity and Power Generation

For any given pumped storage scheme main influencing factor for installed capacity at a site are the requirement of daily operational peaking hours; operating head, live pondage in the dams and their capacity characteristics with regard to area. The technical details are summarized below in Table 1.

Table 1 Capacity and generation data

Installed capacity (MW)	2000
No of units	8
Unit size (MW)	250
Head (max)—generating	478 m
Head (Min)—generating	476 m
Hours of daily peaking operation	6
Energy generation (MWh)	12,000
Pumping energy (MWh)	14,833
Cycle efficiency	80.90%

3.2 Power Evacuation Arrangement

The power generated from the proposed scheme will be at 18 kV which is further stepped up to 400 kV. This power shall be further evacuated from Pothead yard area by following two 400 kV D/C transmission lines from Sharavathy PSP to 400 kV Sub-station at Talaguppa which is about 60 km.

3.3 Environmental Aspects

Based on the preliminary assessment of environmental issues considered in the present study, it can be concluded that the project is in proximity to ecologically sensitive area Sharavathy Wildlife Sanctuary (about 3 km). It is proposed to conduct, a detailed Comprehensive Environmental Impact Assessment (EIA) study with an objective to assess various impacts likely to arise as a result of construction and operation of the proposed project on various aspects of Environment. Appropriate management measures too shall be delineated as a part of Environmental Management Plan (EMP), which will be covered as a part of the Comprehensive EIA study. The water conductor system from Talakalale Reservoir is about 3.4 km from Sharavathy wildlife sanctuary. Hence, the project would require clearance from National Board of Wildlife.

3.4 Project Cost Estimates

At 2017 price levels the proposed project is estimated to cost about 5000 Crores. The guidelines of CEA/CWC was referred to prepare the preliminary cost estimate of the project. The cost estimate break-down is given in Table 2.

Table 2 Project estimate

Item estimated cost	(Rs. Lacs)
Civil works	273,980.38
Electro-mechanical works	227,764.24
Total	501,744.62

3.5 Financial Aspects

As indicated above, the Sharavathy Pumped Storage extension project, with an estimated cost (Generation only) of INR 5017.44 Crores and design peak energy generation of 4380 GWh is devised to be completed in a short period of five years. The generation tariff has been worked out considering a debt-equity ratio of 70:30, and annual rate of interest on loan at 12.50%. The tariff for initial year and levellised tariff has been worked out at INR 5.73/unit and INR 5.33/unit respectively in a 90% dependable year.

4 Conclusion and Recommendation

The project case detailed here has stressed for the need of utilizing existing hydropower projects to develop pumped storage schemes with an example of Sharavathy Hydro Project in Karnataka to cater for peak hours demands using pump storage technology. The proposed scheme has been planned such that it does not affect the original purpose of the existing dams for generating electricity. Based on the data reported following conclusion can be drawn.

The project is outside of the Sharavathy Wildlife Sanctuary. However, due to in proximity to the Wildlife Sanctuary the project layout has been prepared in such a way that it is completely underground. Dams are existing and the powerhouse complex is underground. Sharavathy Pumped Storage scheme requires minimum civil works and can be completed in 5 years. The project will be capable of generating a design energy generation of 4380 GWh in a 90% dependable year. The installation cost per MW works out at INR 2.50 Crores. The PFR encourages the scheme merits and for taking up for further detailed survey and investigation and preparation of DPR. The levellised tariff for the proposed 2000 MW scheme is of about INR 5.33/per unit which appears to be bit high. But per-capita energy consumption becoming bigger day by day, the construction of 8×250 MW will bring more benefits, as peak hours tariff can be very high.

A 2013 study report prepared for KPCL, involved load forecasting study, generation planning and prospective generation plan for the period from 2012–13 to 2021–22, it also had forecasted peak demands, demand met, deficiencies as well wind capacity credit (MW) for the years between 2014 and 2017. As per this study, the maximum monthly peak demand has progressively increased from 10,695, 11,468 and 12,302 MW in these three years. The report has concluded that improving wind capacity credit will depend on the flexibility of operation of future conventional generations like storage based hydro/pumped storage power plants and short term wind forecasting tools. Subsequent to this report, the Power System Operation Corporation Limited (POSOCO) and National Institute of Advance Studies (NIAS) have conducted study in March 2015 on "Wind and Solar Energy for meeting Karnataka's future electricity demand". The association developed a method of estimating hourly unrestricted demand and the likelihood of meeting bulk of it from conventional sources available then and the remaining from renewable sources to reduce the extent of deficit in Karnataka, which is substantial leading to economic losses and inconveniences. Analysis for 2017 and 2022 scenarios was done. The analysis for 2022 was based on the assumption of having a 1000 MW, 10 h pumped storage scheme. The report recommended a total of 4800 MW of wind power, 2500 MW of solar power and addition with energy storage facility (for 2022). It has concluded that combined, these are expected to reduce defict by 69% with no deficit for 7 months of the year and generate about 22% excess as expressed with defects as a base. Thus, 2000 MW Sharavathy Pumped Storage Scheme will go a long way in meeting Karnataka's future electricity demand.

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