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Perspectives of Hydro Power Plant and Pumped Storage System in Tamil Nadu

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Abstract : The increase in power demand causes more challenges in power sector of developing countries. In India, the increase in peak power demand necessitates energy storage schemes over and above the conventional power plants to ensure power system stability. In utility energy storage schemes, the Pumped Storage System (PSS) attract more attention even in the developed countries due to its unique operational flexibility over other energy storage systems. PSS is the most reliable and commonly used option for large scale energy storage purposes worldwide. As the contribution of renewable energy is increasing rapidly in the total energy, it becomes more relevant to construct PSS plants to store the energy trapped considering its intermittent nature which may otherwise hamper the stability and security of the power system. This paper presents an overview of the distribution of PSS available in India and highlights the need to develop PSS in different regions to meet the demand.
Keywords : Power Demand **,** Renewable Energy, Pumped storage system , Hydropower plant.

1. Introduction

Energy is one of the major inputs for the economic development of any country. The major sources of energy in the world are oil, coal, natural gas, hydro energy, nuclear energy, renewable combustible wastes and other energy sources. The contribution of different energy sources to the total supply of energy in the world are: Oil-35.1%, Coal-23.5%, Natural gas-20.7%, Renewable combustible wastes-11.1%, Nuclear-6.8%, Hydro-2.3% and Other sources-0.5%. World electricity demand is expected to continue more strongly than any other form of Energy [1].

As the most reliable renewable energy, hydropower energy is widely used throughout the world. Hydroelectric power captures the energy released from falling water. In the most simplistic terms, waterfalls due to gravity, this causes kinetic energy to be converted into mechanical energy which in turn can be converted into a useable form of electrical energy by the water turbine and generator. Hydroelectric power plants are categorized according to size. They fit into one of four different size ranges: Micro, Mini, Small, and Large. A Micro sized plant is one that generates less than 100 KW of electricity and would typically be used to power 1-2 houses. A Mini facility can serve an isolated community or a small factory by generating 100KW-1MW of electricity. A Small plant generates 1MW-30MW and can serve an area

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while supplying electricity to the regional grid. Lastly, alarge facility generates more than 30MW of power[2].

A small Hydro-Electric Plant (130 kW) established near Darjeeling in 1897 ushered the beginning of hydro-electric power development in the country. Since then, development of hydro-electric power in the country has made rapid strides. The Hydel installed capacity which was only 508 MW in 1947 with 12 Hydro Electric (H.E) stations, 51 units and the maximum unit size of 22 MW at Bihar H.E. Project under TATA's, has risen to 41267.42 MW (as on 31.03.2015) from H.E. station above 25 MW capacity. Conventional Hydro Electric Stations of run-off-river type, single purpose hydro electric stations with storage, multipurpose projects as well as pumped storage projects have been executed through-out the country[3].

Some of the hydro electric schemes are provided with storage reservoirs. Water during monsoon and/or snowmelt period, is collected in these reservoirs. The regulated discharges from reservoirs are utilized for power generation, irrigation and other purposes[4]. Reservoir based schemes are of two types i.e. single purpose and multipurpose. Single purpose schemes are operated only for power generation. Multipurpose storage schemes are operated for more than one purpose such as flood control, irrigation, water supply, pisciculture, navigation, tourist attraction and other recreational facilities besides power generation[5].

Pumped storage hydropower is "a special type of hydropower development, in which pumped water rather than natural stream flow provides the source of energy" [6]. In general terms, pumped storage hydropower is a technology that stores low-cost off-peak energy or excess or unusable energy (perhaps generated from renewable energy sources) for later use[7,8]. While pumped storage hydropower projects are a net consumer of electricity, they provide many useful power system operational benefits, including system storage capacity and power grid ancillary services, which allow other types of electrical plants in the system to operate more efficiently. From the late 1980s pumped storage hydropower projects became popular in India[9,10]. Tamil Nadu power system's Renewable energy penetration with various percentage levels along with the inclusion of Pumped Storage System was discussed [11].

This paper presents the current status of PSS and utilization of PSS potential in Tamil Nadu. The development of PSS is proposed based on the assumption that these targets would be achieved as per the plan to sustain the energy needs of the country. Wind and solar power have grown significantly in last few years and the future growth rate is also expected to be very high due to economic and fiscal reasons.

2. Pumped Storage Plant Technology

The design of PSS is similar to conventional hydropower with some functional differences. The main difference is that PSS requires two reservoirs at different levels (upper and lower) to store water and the stored water is moved to and fro via a pump-turbine arrangement. In simpler terms, PSS technology can be described as having two reservoirs, natural or artificial, situated at sufficient head difference, connected through a penstock of minimum possible length through which water can be moved as per the requirement with the help of a pump-turbine arrangement. Water can be pumped to the higher reservoir when excess or cheaper energy is available and the same water is passed through the hydraulic turbine to generate power in peak demand period when price of the electricity is high.

The schematic diagram of pumped storage plant is shown in figure 1.Pumped storage is a method of keeping water in reserve for peak period power demands. Pumped storage is water pumped to a storage pool above the power plant at a time when customer demand for energy is low, such as during the middle of the night. The water is then allowed to flow back through the turbine-generators at times when demand is high and a heavy load is place on the system.

The reservoir acts much like a battery, storing power in the form of water when demands are low and producing maximum power during daily and seasonal peak periods. An advantage of pumped storage is that hydroelectric generating units are able to start up quickly and make rapid adjustments in output. They operate efficiently when used for one hour or several hours.

Because pumped storage reservoirs are relatively small, construction costs are generally low compared with conventional hydropower facilities.

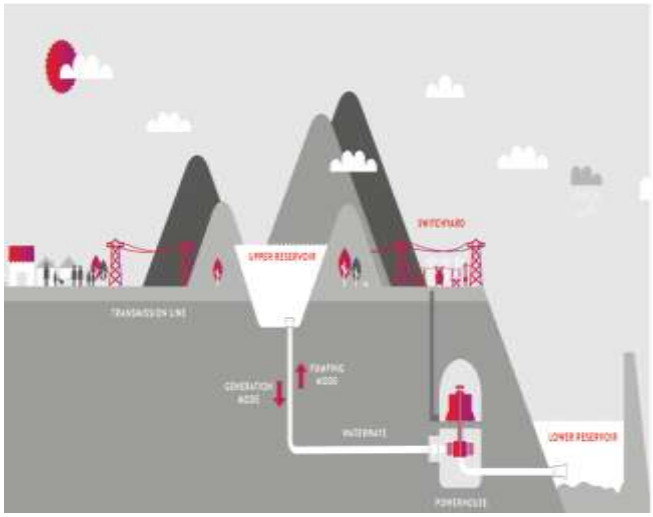

Figure 1. Schematic of Pumped Storage plant

Advantages of a PSS

- Provides Large Grid Storage and Long Discharge time
- High Ramp rate
- Balancing the Grid for Demand -Driven variations
- Balancing Generation -Driven Variations
- Voltage Support Grid Stability Black start facility
- Improves overall economy of power system operation and increases capacity utilization of thermal, solar and wind stations.

3. Contribution of Tamil Nadu in Hydro power generation in India

Tamil Nadu's higher percentage of renewable energy comes from the fact that State has geographic conditions that are suitable for harnessing such sources of energy. In Tamil Nadu, small hydro has an estimated potential of 659.51 MW through197 sites. As of November 2011, 94.05MW was installed. Many small micro hydroprojects are being set up in remote and isolated areas. The figure 2 shows status of hydropower potential in India and figure 3 shows the Capacity of Hydropower potential in India.

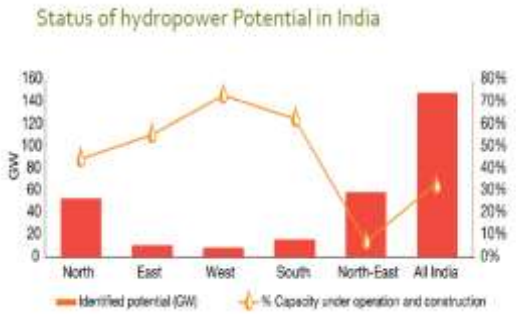

Figure 2 Status of Hydropower potential in India

Figure 3Capacity of Hydropower potential in India

4 Development in Tamil Nadu

Tamil Nadu has been a pioneer State in the field of hydro power development in India. It is the only State in India where all of its economically exploitable hydro power potential has been harnessed. The State has the highest head hydro power plant in India and has developed every type of hydro power schemes: run off river & storage based schemes, surface & underground power houses, high head & low head plants, base load & peak load stations, single & multi-purpose schemes, conventional & pumped storage schemes, schemes in cascade development, inter-basin transfer of water for power generation etc. The development activities of hydro electric generating circles in Tamil Nadu are tabulated in Table 1.

Table 1 Hydro Electric generating circles in Tamil Nadu

Sl. No.	Kundah hydro – electric generating circles	Capacity in MW	Kadamparaihydro – electric generating circles	Capacity in MW	Erode hydro – electric generating circles	Capacity in MW	Tirunelvelihydro – electric generating circles	Capacity in MW
1	Kundah Power House 1	60	Sholayar Power House – I	70	Mettur Dam Power House	50	Kodayar Power House – I	60
2	Kundah Power House 2	175	Sholayar Power House – Ii	25	Mettur Tunnel Power House	200	Kodayar Power House – II	40
3	Kundah Power House 3	180	Aliyar Power House	60	Lower Mettur Barrage Power House – 1 / Chekkanur	30	Servalar Power House	20
4	Kundah Power House 4	100	Aliyar Mini Power House	2.5	Lower Mettur Barrage Power House -2 / Nerinjipettai	30	Papanasam Power House	32
5	Kundah Power House 5	40	Sarkarpathy Power House	30	Lower Mettur Barrage Power House-3 Kuthiraikkalmedu (Konerpatti)	30	Suruliyar Power House	35
6	Kundah Power House 6	30	Kadamparai Power House (Pumped Storage Scheme)	400	Lower Mettur Barrage Power House -4 /Uratchikottai	30	Periyar Power House	154
7	Pykara Power House /Singara	59.2	Thirumurthy Mini Power House.	1.95	BhavaniKattalaiBarrgae - I	30	Vaigai Power House	6
8	Pykara Micro Power House	2	Poonachi Mini Power House	2	Sathanur	7.5	Perunchani	1.3
9	Moyar Power house	36	Amaravathi	4	Lower Bhavani -1 / Micro HydelPh / BhavaniSagar	8	PeriyarVagai Mini I	4
10	Maravakandy Power House	0.75	-	-	Lower Bhavani RBC	30	PeriyarVagai Mini Ii	2.5
11	Mukurthy Micro Power House	0.75	-	-	BhavaniKattalaiBarrgae - II	30	-	-
12	Pykara Ultimate Stage Hydro-electric Power Plant (PUSHEP)	150	-	-	-	-	-	-

In terms of installed capacity, the total hydro power potential identified for Tamil Nadu as per reassessment studies is 19.18 MW including station capacity up to 2.5 MW and is 16.93 MW excluding station installed capacity of 2.5 MW. All the conventional hydro power potential in Tamil Nadu has been harnessed.

4.1Pre-Independence Power Scenario

Tamil Nadu has been one of the earliest States in Indian Union, where water was utilized for power generation. Until about 1908, hydro electricity generation in Madras State was confined to a few tiny hydro plants in tea estates utilising waters of mountain streams and to small hydroelectric installation of Kattery in Nilgiris. The first river tapped for power development by Government of Madras was Pykara in Nilgiri Hills (first 3 units of 6.65 MW each) in 1932 and 1933. Fourth and fifth units of 11 MW each of this plant were commissioned in 1939. Thus, pre-Independence hydro power capacity in Nilgiri Hills and hence in Madara State was 41.95 MW.

4.2 Post-Independence Power Scenarios

After Independence of India, hydro power capacities were added during various Five Year and Annual Plans in Tamil Nadu. At present total hydro installed capacity of Tamil Nadu is 2,191 MW, 2,120 MW from stations having individual station capacity over 25 MW and 71.35 MW from stations having individual station capacity up to 25 MW.

Tamil Nadu has developed almost all type of hydro power schemes: run off river & storage based schemes, surface and underground power houses, high head and low head plants, base load and peak load station, single and multi-purpose schemes, conventional and pumped storage schemes, cascade development, inter-basin transfer of water etc.

4.3 Major/ Medium Stations (Station Capacity over 25 MW)

There are 29 hydro power schemes having individual station capacity over 25 MW aggregating to an installed capacity of 2,191 MW in operation in Tamil Nadu. These schemes include 28 conventional hydro power schemes aggregating to an installed capacity of 1,812.2 MW and one pumped storage scheme, namely Kadamparai PSS of 400 MW.

All hydro power stations in Tamil Nadu are conventional except, one station, viz. Kadamparai, which is pumped storage scheme having reversible generating units. This station adds valuable peaking power capacity to the grid and enables better utilization of thermal/ nuclear energy generation capacities in the State. In addition, it affords conventional energy generation of 77 MUs per annum on an average.

In Generation Mode, machines of Kadamparai PSS operate to cater peak hour power demand for full load depending on level of Kadamparai reservoir and level of Upper Aliyar dam. In Pump Mode, machines of this station operate as pump mode to pump the water from upper Aliyar dam to Kadamparai reservoir during night hours on grid frequency above 49.4 Hz utilizing off peak energy.

Also in the south, the 400MW Kadamparai pumped storage plant came up in Tamil Nadu state during the years 1987-89. It is located on a river of the same name and utilises the base created for the earlier 60MW Aliyar project. An upper reservoir had to be created by construction of a masonry-earthen dam. Its underground power house has four vertical Francis reversible units rated at 102MW, with generators of 100MW. The first unit was supplied by Boving and GE of the UK, while the latter collaborated with India's BHEL to supply the other three units, all of mixed type. The Kadamparai Pumped Storage Hydro Electric station (4 x100 MW) in Coimbatore District was commissioned in the year 1986 and is the first of its kind in the country to operate both in operation and pumping mode since 1987. In this Power House the off peak energy is utilized to pump water to the upper reservoir and during peak hours the Power House is put in generation mode.

One of the most significant pumped hydro storage projects currently underway is Sillahalla, a 6,914 crore- Indian rupees, 2000MW plant in the Nilgiris District of Tamil Nadu [12,13].The plant is being developed by the Tamil Nadu Generation and Distribution Corporation and involves construction of a dam across the Sillahalla River and a 2.75-kilometer tunnel connecting it to the existing Avalanche-Emerald reservoir. This pumped storage Hydro Electric Project envisages construction of an upper reservoir across Sillahalla river with a capacity of 2250 Mcft and keeping the existing Pillur reservoir as lower reservoir.

It is proposed to establish a water conducting system, comprising of 3800 m Head Race Tunnel, Head Race surge shaft, 2 nos. pressure shafts of length 3900m and Tail race Tunnel of 8980 m with Tail Race Surge Shaft. It is also proposed to construct an underground Power House along with a 5750 m long Access tunnel to the Power House. A control cumventilation tunnel and a switch yard are also proposed. Pre-feasibility report has been prepared. GOTN's in principle approval has to be obtained. The project will be implemented in two phases. Detailed Project Report for Phase I, namely, formation of upper reservoir (Sillahalla reservoir) and the interconnecting tunnel with the TANGEDCO's existing Emerald reservoir will be taken up toavail the benefits forthwith. The Phase I execution will be taken up in 2012-15 after obtaining techno-economic clearance, environmental clearance, etc.

The dam is scheduled for completion in 2018 or 2019, while the rest of the project is due to start operation in 2022, according to news reports last year. A tender is currently open for laboratory tests on borehole core and bedrock samples at the site.

Other pumped hydro projects known to be under consideration include the 1-gigawatt Turga project in West Bengal, the 600MW Upper Indravati plant in Odisha, and a 500MW development based around the existing Kundah hydro stations in Tamil Nadu.

The Kundah hydro power project is located in the Nilgiris with the budget of 1500 crore- Indian rupees. TANGEDCO proposes to commission a pumped storage project with a capacity of 500 MW (4X 125). All the statutory clearances except techno - economic clearance from Central Electricity Authority have been obtained. Considering the difficulties in obtaining interstate clearance from Central Water Commission for executing the Kundah pumped storage HEP (500 MW) as a whole and the immediate need for the project to meet the peak power demand, TANGEDCO's Board has decided to take up the project in three phases. The present status of the project is as follows:

- Taking over of 30 hectares of forest land required for the project is underway (as per the Forest
- Conservation Act, 1980)
- MOEF has been approached for renewal of environmental clearance (clearance expired on 7/05/2012)
- Project pre-development works and residual studies have been undertaken
- Tender for consulting services have been called
- Steps for obtaining Government of Tamil Nadu approval for Phase II are being undertaken.

Velimalai Pumped Storage Hydro Electric Project, this projects proposes to construct a dam at the originating point of Valliyar river (i.e.) at Maruattarkannu in Kanya Kumari District, which would act as a Forebay dam for the proposed project, costs with the budget of Rs 1200 crore- Indian rupees. TANGEDCO proposes to commission a pumped storage project with a capacity of 500 MW Another dam is proposed to be constructed which will also act as a Fore bay dam at the origin point of the main tributary of Tamiraparani river (i.e.) at Velimalai. These two reservoirs will be connected by an interconnecting tunnel to enhance the storage capacity of the Forebay. The lower reservoir (viz) Kumarakoil reservoir is proposed in the Mambazhathuraiar basin on the south eastern slope of Velimalai. Preliminary steps involve measurement of inflows in the upper and lower reservoir locations to establish hydrological feasibility which would take at least 3 years. Thereafter, the work on pre-feasibility report would be started. In 2017-18, the preparation of Detailed Project Report and statutory clearances would be taken up.

5. Conclusion

Tamil Nadu has been a pioneer State in the field of hydro power development in India. It has harnessed of all its economically exploitable conventional hydro power potential. To meet their power requirements, hydro potential at the existing irrigation dams is being exploited. To meet long term peaking requirements, provision of additional peaking capacity at the existing projects (operating at a very high load factor) is being given consideration. It is a fact that hydro energy is an alternate source of green power. Though the cost of generation from small hydro generator is slightly higher than the coal based generation, it is felt that the small hydro power should be promoted at preferential tariff since it is a green and sustainable power. This also helps to exploit the balance hydro potential in the State. Besides the positive effects on climate mitigation, stand-alone renewal energy technologies also presents other considerable advantages: it promotes price stability because, unlike fuel and natural gas, it is not subject to market fluctuations; it reduces environment vulnerability

to floods; it contributes to fresh water storage for drinking and irrigation exploitations; it makes a significant contribution to development by bringing electricity, roads, industry and commerce to communities which can benefit future generations as hydro power projects are long-term investments.

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