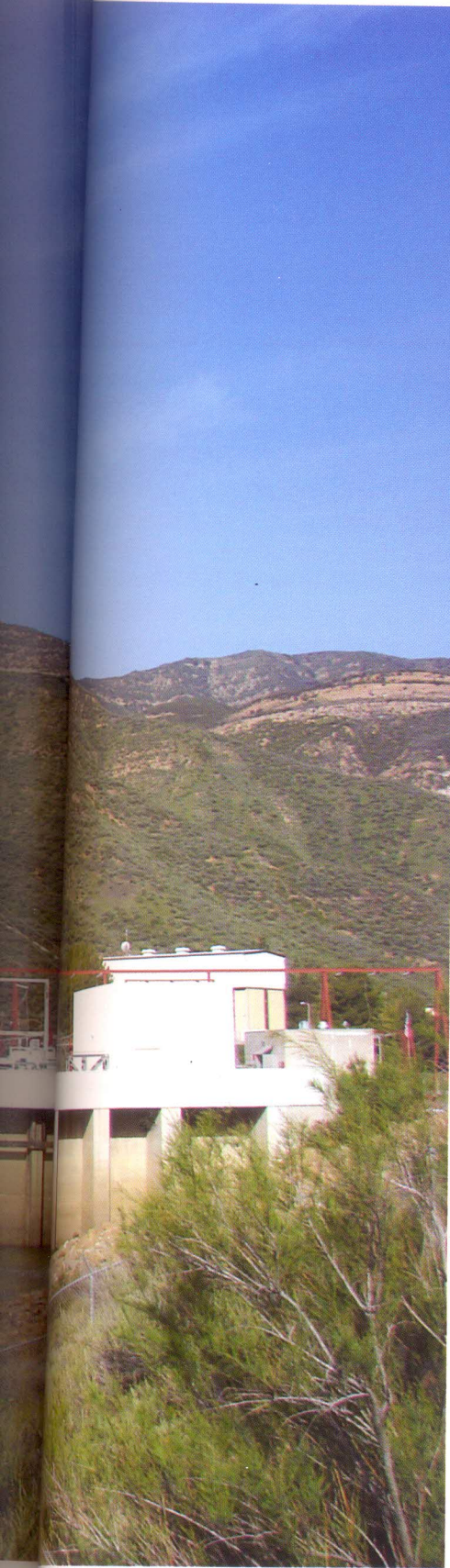


Pumped Storage Hydro Power Plant

Pumped storage hydro power plant is a type of hydroelectric generation plant that stores energy in the form of water, pumped from a lower elevation reservoir to a higher elevation reservoir. It pumps water from lower reservoir to upper reservoir during off-peak period and generates electricity during peak periods. This is currently one of the most effective means of storing large amount of electrical energy. It helps in power generation load levelling.

- Mayadhar Swain



Electricity is one of the essential infrastructures for the country. Our gross domestic product depends on the availability of adequate amount of electricity. Statistics shows that in our country, almost every year the demand of electricity is more than its production as a result there is regular load shedding and disruption in industrial output. For example, for the year 2012-13, the total energy demand in the country was 998114 MU and production was 911209 MU, the short fall being 86905 MU (8.7%). Similarly against a peak demand of 135453 MW, availability was 123294 MW, shortfall being 12159 MW (9%). As per generation load balance for

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the year 2013-14 prepared by Central Electricity Authority (CEA), the energy shortage for the year will be 6.7% while peak megawatt shortage will be 2.3 %.

Every year new power plants are being installed. But simultaneously energy demand is also increasing every year. Another problem is the greater variation in the energy used between day and night, week days and holidays. Daily and weekly maximum loads pose serious problem to the electricity supply companies to deal with. If sufficient generating capacity is to be provided to meet the maximum peak load, it will require a heavy expenditure on the generating company with little earning of revenue from it.

But electricity companies have to do something to supply the peak load and simultaneously not recurring losses due to this. One way is to leveling-up of their load curves. But it is not in their hand. They can only persuade the consumers by offering concessional rate in off-peak period. It is seen that it is not possible as desired by the electricity distribution companies.

Technically, this problem can be tackled by storing energy generated by the base-load power plants during off-peak hours or by installing

special peak-load power plants having low fixed charges. Since electrical energy as such cannot be stored in large quantities, there is a method to store it in form of potential energy. This method is the pumped storage scheme.

Pumped Storage Scheme (PSS)

The basic principle of PSS is to store energy by pumping water from a low level reservoir downstream to power house (lower reservoir) into a high level storage reservoir (upper reservoir) at times when the demand for power is low and then by utilizing the stored water of upper reservoir to generate hydroelectric power during the peak load periods.

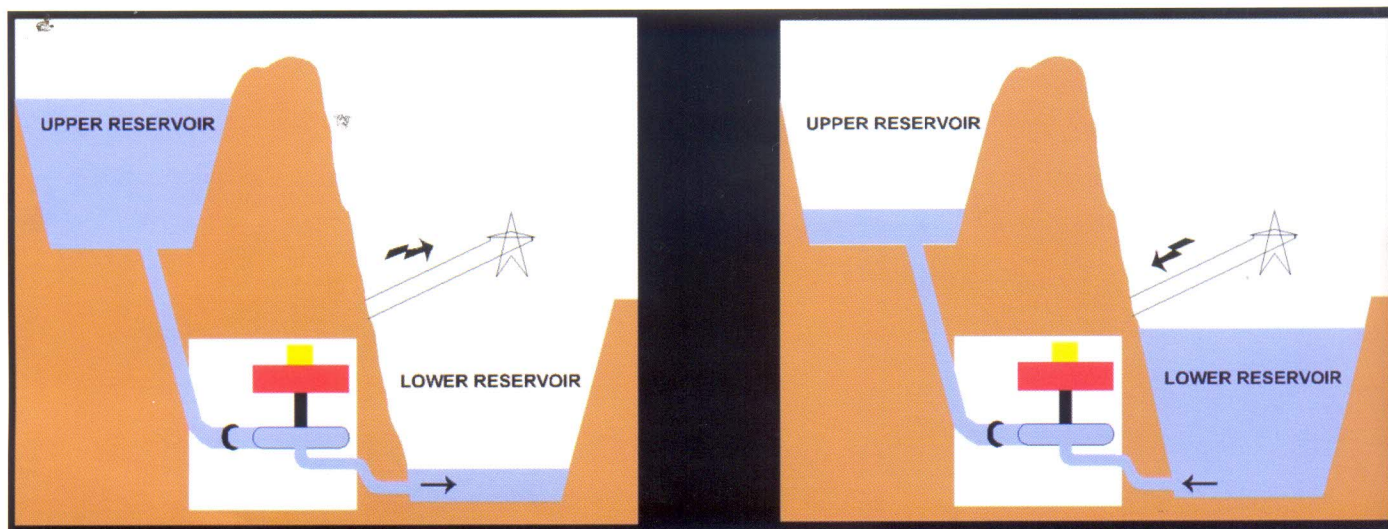
The reservoir-based hydro power plant generally utilizes the water of the reservoir in a controlled manner to generate electricity and the water discharged from the turbine is passed to the tail trace from where it joins to the river. In a pumped storage scheme the water from the tail-trace is stored in a lower reservoir. During off-peak period, this water is pumped to the upper reservoir and during peak load hour this water is again used for power generation. Power for pumping is supplied either by an onsite conventional steam power plant or

from remote generating plant through electric grid.

A separate pump can be installed to pump the water from the lower reservoir. Alternately, the turbine-generator set can be designed to operate as pump also so that during peak load hour it will function as power generating unit and during pumping it will act as a pump. Generally, the later method is utilized in most of the pumped storage schemes.

In other words, the same machine which is reversible is used to generate power (in generation mode) utilizing the potential energy of water stored in the upper reservoir during peak hours of demand and for pumping back water from the lower reservoir into the upper reservoir (in pumping mode) during off-peak hours utilizing surplus power from the grid. The water conductor path is same in both generating and pumping mode of operation.

When a reversible unit is rotated in one direction, it functions in the usual manner as turbine and generator. In the reverse direction, it operates as pump and motor. One crucial condition for installing pumped storage scheme is the availability of cheap off-peak power.



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Classification of Pumped Storage Schemes

Pumped storage schemes can be broadly classified into the following categories:

Pure Pumped Storage Scheme (Recirculation Type): In this type of PSS, electricity is generated by re-circulating water between lower and upper reservoirs. The same quantity of water is used for generation and also for pumping operation. The water loss due to evaporation, seepage etc. are met by some small inflows into the upper or lower reservoir. There is no conventional power generation at their power house. Power is generated only at peak load period. The sizes of these two reservoirs are almost equal. This scheme is found more feasible in the region where hydroelectric potential has already been developed.

case, the unit may be operated in generator mode for some time during off-peak period. Therefore, the water used for power generation is more than the water used for pumping. In some plants, sufficient water is available during monsoon and the run-off is drastically reduced during lean months of the year. So when sufficient water is available, power is generated in conventional method and during dry period, pumped storage method is adopted.

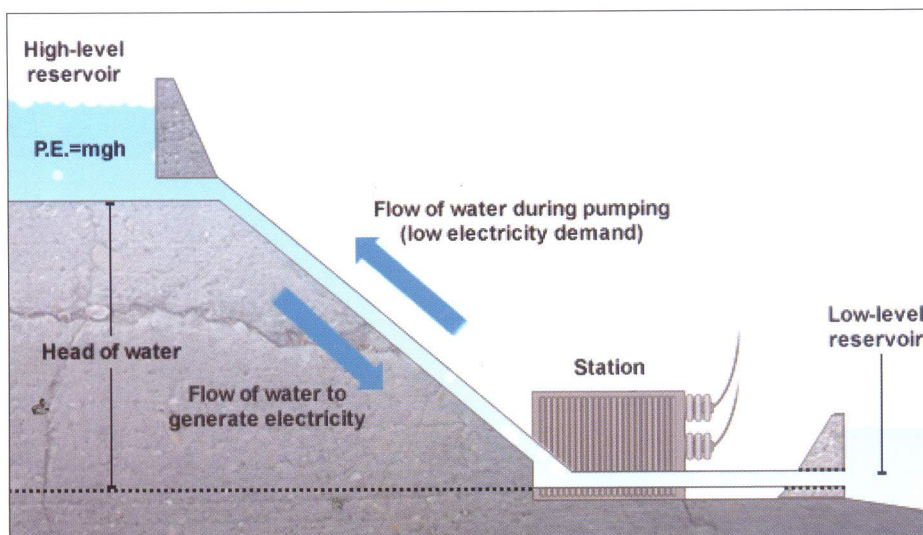
Pumped storage scheme to supplement the storage capacity of conventional Hydro Power Plants: There are some locations which are very attractive for hydro power plants from the consideration of available head, but availability of water is not sufficiently large so that capacity of power plant is less. But simultaneously large availability of

Underground Pumped Storage Scheme: Most pumped storage power plants have underground power houses, because it is more economical to link the upper and lower reservoirs via the shortest route. In this case, the necessary high head can be created by excavating the lower reservoir underground.

Advantages of Pumped Storage Scheme

The advantages of PSS are given below.

- The net gain in energy for pumped storage scheme is negative depending on the efficiency of generator, turbine & pump due to the fact that some energy is lost while pumping & again during generation. But cost wise the company is not looser as peak-load energy is costlier than off-peak load. Hence the pumped storage schemes are economically advantageous because they convert low-value, low-cost, off-peak energy into high-value, high-cost, on-peak energy.
- PSSs help in power generation load levelling. There are severe fluctuations in the daily power consumption patterns and it has become increasingly necessary to optimize the various types of power generation in order to achieve the most cost efficient supply of electricity. PSSs can make this possible by utilizing power from thermal and nuclear plants during off-peak hours to pump water from lower reservoir to upper reservoir and generate power during peak demand hours.
- Although there are many methods of storing excess energy, it is the most attractive method of storing large amount of energy.
- It meets the peak demand of the system and improves system reliability. The availability of a



Mixed Pumped Storage Scheme: When a conventional hydroelectric power plant and pure pumped storage plant are combined, it is called as mixed pumped storage scheme. In this scheme, sufficient amount of inflow are available to this upper reservoir throughout the year or upper reservoir is too large and stores sufficient water to generate power most of the times of the year. In this

water is there in the nearby stream or river from where water can be pumped at relatively low head to the reservoir of the power plant. In this case, the scheme for pumping the water at lower head to the planned storage scheme is to utilize the available higher head for generating power through a conventional hydro electric scheme. Pumping is done in off-peak periods.

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pumped storage plant is much higher than that of a thermal or nuclear plant.

- Due to this, efficiency and economy of thermal power stations are improved. Thermal power plants cannot run at low loads efficiently. Pumped storage scheme consumes the off-peak power of thermal power plants making their operation economical.
- Hydel Power Plants can be started and connected to the grid within 5 minutes where as thermal plant takes four to six hours. So to meet the peak load, pumped storage scheme is best suitable.
- Voltage and power factor corrections are additional operating benefits of pumped storage schemes, as the units can operate in voltage regulation mode like a synchronous condenser and can reduce losses as well as maintain the quality of service to customers.
- Pumped storage hydro electric schemes are environmentally friendly. These schemes generate electricity by regulating water between upper and lower reservoirs. Once the water has been stored, it can be used repeatedly without change in water levels downstream, except during the initial filling of the reservoirs.

Pumped Storage Scheme Development in India

The first pumped storage hydro power plant in India was commissioned in sixth five-year plan at Nagarjunsagar, Andhra Pradesh. Till now total capacity of pumped storage schemes installed in the country is 4804 MW. These are given in Table 1.

The Tehri Hydro Development Corporation is constructing country's largest pumped storage scheme of 1000 MW (4X250 MW) in Uttarakhand. It is scheduled to be completed by 2016.

Sl. No.	Location	State	Capacity (MW)	Year of commissioning
1.	Nagarjunsagar	Andhra Pradesh	7x100	1980-1985
2.	Paithan	Maharashtra	1x12	1984
3.	Kadamparai	Tamilnadu	400	1987-1989
4.	Kadana	Gujarat	4x60	1990-1996, 1998
5.	Panchet (DVC)	Jharkhand	1x40	1990-91
6.	Ujjain	Madhya Pradesh	1x12	1990
7.	Bhira	Maharashtra	1x150	1995
8.	Srisaillam	Andhra Pradesh	6x150	2001-2003
9.	Sarda Sarobar	Gujarat	6x200	2006
10	Purulia	West Bengal	4x225	2007-2008
11	Ghatghar	Maharashtra	2x125	2008
	Total		4804	

Table 1: Pumped Storage hydro power plants in India

Plan	Installed capacity of PSS (MW)	Cumulative capacity of PSS at the end of plan (MW)
Up to fifth plan (31-03-1980)	Nil	Nil
Sixth plan (1980-1985)	612 (Nagarjunsagar, Paithan)	612
Seventh plan (1985-1990)	500 (Kadamparai, Nagarjunsagar)	1112
Two annual plans (1990-1992)	160 (Kadana Units: 1 and 2, Panchet)	1272
Eighth plan (1992-1997)	222 (Kadana Unit 3:, Bhira, Ujjain)	1494
Ninth plan (1998-2002)	960 (Srisaillam, Kadana Unit:4)	2454
Tenth plan (2002-2007)	2100 (Sardar Sarovar, Purulia)	4554
Eleventh plan (2007-2012)	250 (Ghatghar)	4804
Twelfth plan (from 2012)	1000 (Tehri)	5804

Table 2: Pumped storage growth based on 5-year plans in India

As seen in Table 1, at present, 11 PSSs are located in various states in India. Out of which, nine pumped storage stations are mixed type and 2 are pure pumped storage type (Purulia and Ghatghar). Most of the pumped storage stations are operating in pumping mode for fewer hours than that contemplated in the project report due to the

unavailability of surplus energy in the power system for more hours. It is the prime reason for less overall output from these stations. In India, in normal days surplus power is available only during off-peak hours i.e. midnight to 5 am with limited capacity or less than the requirement of pumping capacity of the plant. During national holidays and

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Region	No. of identified schemes	Probable installed capacity (MW)
Northern	7	13065
Western	25	38220
Southern	8	16650
Eastern	6	9085
North-eastern	10	16900

Table 3: Region wise distributions of identified PSSs

weekends the machines are operated as pump for more hours since there is low energy consumption by the industrial sector. More surplus power is available during widespread rain in a region when energy for agricultural pumping is not required. However, daily assigned pumping and generating hours which have been designed as per Detail Project report (DPR) e.g. 6 h generation, 8 h pumping for a day for a typical PSS has not been achieved so far. Hence most of the PSS stations achieved 40 - 50% of the projected design energy as mentioned in DPRs of the corresponding pumped storage plants.

Nagarjunasagar, Panchet (DVC) and Sardar Sarovar PSSs are working as conventional hydro generators due to more inflow and commitment to irrigation needs. The tail race reservoir is under construction in respect of Nagarjunasagar and Panchet hill stations. Although these power stations have been constructed as pumped storage plants, these are being used for generation only mode since more inflow is available to the

respective reservoirs. However, due to upstream developments taking place at present, the corresponding reservoirs are receiving less inflow. Hence the tail race dam is under construction to develop the lower reservoir, so that these stations can also operate in pumping mode. In the case of Sardar Sarovar Project, priority is given for irrigation for the period of 5 years and pumping operation from the station will be carried out at a later stage after stabilization of the irrigation lands in desert area.

Future Prospects of PSS in India

CEA has identified 56 potential sites suitable for the development of pumped storage schemes. Table 3 indicates the region wise capacity

available for PSS development. Only two PSSs have gone through all the processes laid down by CEA and the remaining proposals are in the planning stage. The two projects are 1000 MW Terhri-II in Uttarakhand and the 1000 MW Koyna pumped storage scheme in Maharashtra.

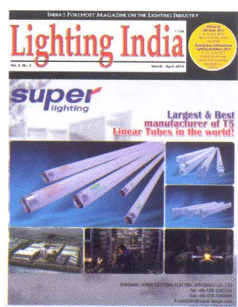
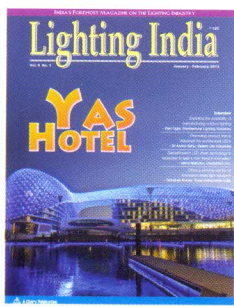
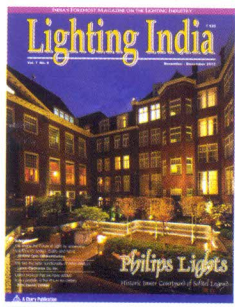
Conclusion

For grid stability, reliable supply and providing quality power (in terms of voltage and frequency), peak load plant to base load plant mix ratio should be 60:40. This can be achieved by installing pumped storage schemes.

Study reports suggest the optimum installed capacity of PSS in a predominant thermal / nuclear would be in the order of 4 - 5% of the total installed capacity. Before planning a pumped storage scheme, availability of surplus energy (off-peak power) should be ensured. It is seen that pumped storage plants so far installed in our country are not able to function fully due to non-availability surplus energy in the power system to meet the pumping power needs. ■



Mayadhar Swain is BSc Engg. (Elect.) from University College of Engineering, Burla, Odisha and ME in Water Resources Development from IIT Roorkee. After serving in NTPC, Talcher Thermal Power Station and Orissa Hydro Power Corporation in different capacities, he is now working as Deputy General Manager in MECON Limited, Ranchi. Throughout his service he has worked in Design, Erection, Commissioning, Operation and Maintenance of Thermal and Hydro Power Plants. At present he is working in consultancy jobs for Thermal and Hydro Power Plants. He has published 40 papers in different journals.



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