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Prospect of Pumped Storage Hydroelectric Power Generation in Bangladesh through Sea Water Pumping

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Abstract: *Existence of pumped storage plant with its optimal operation can play an important role for financial savings and load management in any power system. The idea of power generation from Pumped Storage System (PSS) is apparently new in context of Bangladesh. In this paper the feasibility of pumped storage hydroelectric power generation in the coastal hilly area of Bangladesh is investigated. The result shows that materialization of pumped storage project can significantly contribute in reducing the fuel cost for power generation. The electrical load of Bangladesh Power System (BPS) varies with seasons. The runtime of PSS throughout the year in different climate condition is also discussed in this paper. Some proposals are also given for the better performance of this project which will make it more beneficial and feasible for BPS to reduce the subsidy of the government for power generation.*

Keywords: *Pumped Storage System, optimal pumping distribution, geographical potential, energy curve, energy subsidy.*

1. Introduction

Pumped Storage Hydroelectricity (PSH) is a type of hydroelectric power generation used by some power systems for load balancing and for financial benefit. In this process energy is stored in the form of water, pumped from a lower elevation reservoir to a higher elevation. Low-cost off-peak electric power is used to run the pumps. During periods of high electrical demand, the stored water is released through turbines to produce electric power. Although the losses of the pumping process make the plant a net consumer of energy overall, the system increases revenue by selling electricity during periods of peak demand, when electricity prices is very high. A new optimal operation scheduling method of the pumped storage station with the thermal power station is proposed in [1]. The transmission losses and characteristics of the pumped storage stations are also considered. Development of optimal bidding strategies for individual pumped-storage unit owners and optimization of the generation scheduling for other limited energy generation resources are discussed in [2].

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The profit due to participate in the energy and the ancillary service markets is maximized ignoring the power balance in the system referred as self-scheduling (SS), is discussed in [3]. A study on the feasibility of PSS in a power system with its capacity value considering the load and generating unit profile along with extensive financial analysis is carried out in [4]. The authors of [4] have not considered the actual physical existence of pumped storage potential.

This paper tried to evaluate the feasibility of PSS in Bangladesh and its contribution to reduce the fuel cost for power generation. Possible power generation from the plant, the important parameters of PSS, current fuel cost for generation is also discussed in this paper.

This paper is organized as follows; Section 1 presents general discussion on PSS and literature review. Section 2 is helpful to understand the scope of PSS in Bangladesh power system by discussing geographical potential and financial viability. Section 3 explains operation plan by analyzing the energy curve of BPS. Section 4 concludes the paper by representing overview of the possible impact of PSS on the economy of Bangladesh and followed by the reference.

2. Scope of PSS in BPS

To justify the feasibility of PSS in any power system two things must be analyzed critically; the first one is geographical potential, more specifically upper reservoir storage system and available water resource in lower reservoir and secondly profitability, considering electricity price in off peak and peak hours. The price of electricity in different part of a day can vary, that depends on load profile, types of fuel with it cost and generating unit characteristics.

2.1 *Geographical Potential in Bangladesh*

As two things are important to judge the physical viability of PSS, which are upper reservoir and lower reservoir with available water resource, there is an opportunity in Bangladesh to setup a PSS with sea water pumping. The potential spot is located at Teknaf ($20^0$54'14" N, $92^0$15'08" E) coastal belt hilly area in Cox's Bazar district that is shown in Fig. 1. A valley surrounded by mountain is at 30.5m elevation from Mean Sea Level (MSL) and the lateral distance from the sea is 1.6 km. To turn the valley into an upper reservoir a 76m long dam is needed that is also located in the figure. As the sea water would be pumped, therefore the sea is considered as lower reservoir.

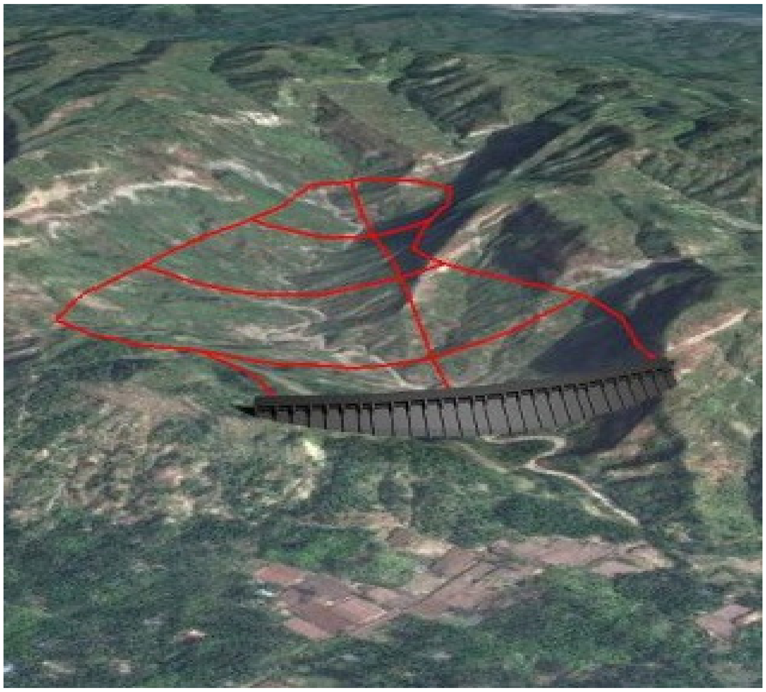

Fig. 1 PSS location with selected area

The usable head of water in the reservoir is about 77m which can capture a massive volume of water of 4634255m^3. The pumping and generating duration of the PSS is considered as 4 hrs. This results in requiring a turbine with the flow rate as below.

Flow rate, $Q = \frac{4634255.232}{4*3600} = 320 m^3/s$

Potential energy of water that can be stored by pumping on the upper reservoir is given by equation (1)

$$P = \rho Q g H \eta \quad (1)$$

Where,

ρ= density of sea water
Q= turbine flow rate
H= head
η= motoring efficiency
g= gravitational acceleration

Assuming 80% of pumping efficiency, it gives 784.6MWh of storage energy and assuming an overall efficiency of 70 % that gives 548 MWh of energy during generation.

To formulate a pumped storage system, three distinct steps are required. The first step is to establish the design and objectives, the second is the sizing of pipes and ducts, and the third is the calculation or determination of the pressure drop in the system. To estimate the price for pipes in the installation, calculation of the diameter is necessary. To calculate the diameter of the pipe, the Reynolds number R_e, the friction factor f and the pressure drop H_f are calculated with equations (2), (3) and (4). [6]

$$R_e = \frac{4\rho Q}{\pi \mu D} \tag{2}$$

$$f = 0.316\, R_e^{-\frac{1}{4}} \tag{3}$$

$$H_f = \frac{8 f L Q^2}{\pi^2 g D^5} \tag{4}$$

Diameter of the pipe is determined by comparing the value obtained from equation (4) with equation (5)

$$H_f = \frac{\eta P}{Q} \tag{5}$$

The velocity of the water in the pipe can be calculated with equation (6)

$$v = \frac{4Q}{\pi D^2} \tag{6}$$

From G.S Sarkaria's formula [7], the most economical diameter of the penstock is given by

$$D' = 0.62 \left(\frac{P^{0.43}}{H^{0.65}}\right) \tag{7}$$

Equation (6), (7) results in velocity of water through the pipe is 11ms^{-1} and economical diameter of the penstock as 7.2m respectively. This diameter is for single generating unit but for the convenience of PSS project the unit number can be increased and corresponding diameter would be decreased.

2.2 *Financial Viability*

For power generation, BPS is dependent on fossil fuel mainly on gas, oil and coal. The financial viability of a pumped storage plant depends on various factors such as higher cost peaking plant characteristics, mode of operation of peaking plants, scheduling plan for pumping and generation mode of PSS, load difference between peak and off peak periods, transition cost of the generating units etc.

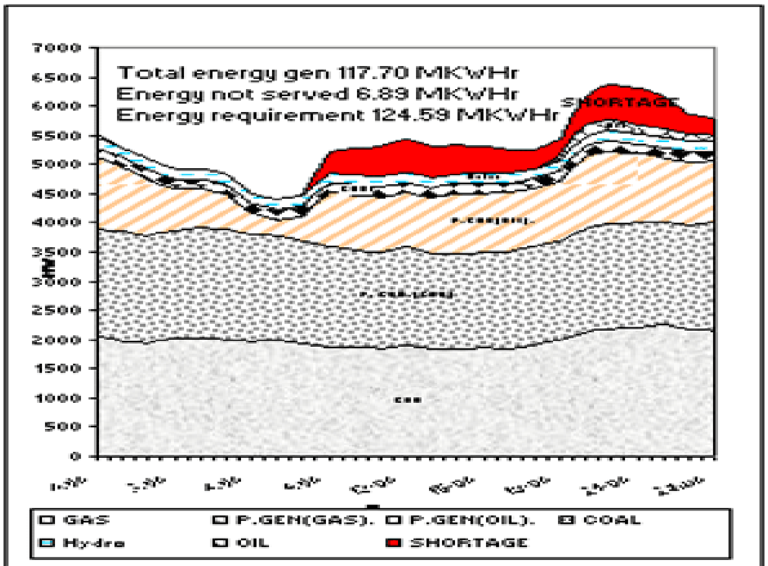

Fig. 2 Energy curve for 10th September 2012 according to BPDB

The load profile of BPS is presented in Fig. 2. The figure clearly reveals that there is a 2300 MW load difference between peak and off peak load in BPS but if the generation is considered there is 1200MW difference between peak and off peak generation. Considering the energy curve given for that day during the peak load, energy generated by gas, oil and coal are 20, 6.5 and 1 MkWhr respectively [10]. Summing the individual cost of these fuels, it results in BDT 110166334 i.e. BDT 3865485/ MkWhr or BDT 3.865/kWhr. During off peak load energy generated by gas, oil and coal are 19, 1.5 and 1 MkWh. These different fuels give a total cost of BDT 40552334 i.e. BDT 1802326 / MkWh or BDT 1.802/ kWh. It is also worth noting that the oil based peaking unit generation cost is BDT 13-15/kWh [9].

In this typical day, if a pumping load of 196.15MW is imposed for 4 hours(784.6MWh) during off peak period the cost of pumping would be BDT 1413849 (784.6*1000*1.802). Recalling section 2.1 possible generation from PSS is 137 MW for 4 hours (548MWh). The PSS operation in generation mode in the peak hour will cause the off loading of the higher cost peaking units those are run by liquid fuel (i.e. diesel, furnace oil, SKO, HSD etc.). If 137MW of power is generated for 4 hours during peak period by higher cost peaking unit instead of PSS the production cost of that energy would be

BDT 7542124 (548*1000*13.763). Therefore the operation of PSS will give a savings of BDT (7542124-1413849) = BDT 6128275 in each day.

3. Proposed operation plan of PSS

An Optimal Pumping Distribution Strategy is given in [4]. Though the cost of pumping can be reduced by the distribution of pumping load among the load stages that are adjacent to the off peak load, but in [4], it is simulated that the pumping load distribution on adjacent stages is not much more profitable for BPS.

From the energy curve provided by BPDB [8] throughout the year, it is seen that there is severe power crisis from the month of March to May. In most of the days of these months whole day is in power shortage that shown in Fig. 3. From the off peak to peak load hour, all day long there is acute power shortage. In this situation giving an additional pumping load of 196MW in the off peak period is not possible. As the period is already subjected to power crisis, PSS is not feasible in this period.

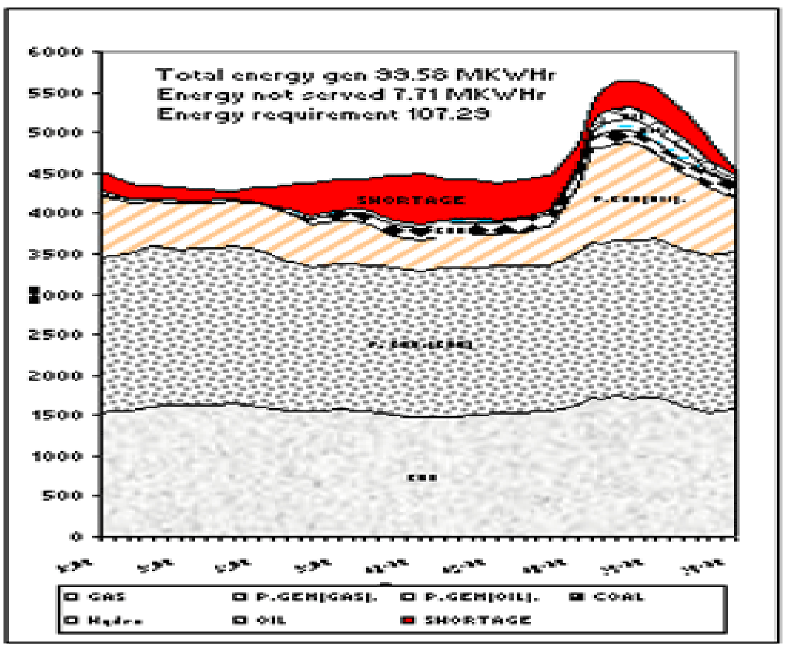

Fig. 3 Energy curve for 19th March 2012

From the month of November to February there is almost no power shortage. It is seen that the demand and power supply is equal in typical days of this period of time. Although there is no power shortage in the peak hours but the power demand is nearly 5000MW and some hundreds of MW of energy is coming from oil based peaking units in that peak hours, this is why in these months the idea of PSS is feasible and can significantly reduce the fuel cost of per unit power generation in the peak hours of BPS. From the month of June to October, the power crisis is moderate. Fig. 5 represents the energy curve for a typical day in this period. BPS faces power shortage in this period but not in a severe extent like period of March to May. As the power crisis is only in the peak hours so the PSS can be run and effectively reduce the fuel cost for BPS throughout the period. Due to round the clock power crisis in March to May the PSS can be run for the rest of the nine(09) months(272days) of a year. As the evaluated savings per day is BDT 6128275 the total savings of that operating period in a year is approximately BDT 1.67 billion (6128275*272) which is 0.59% of the financial subsidy in the energy sector in 2012 fiscal year. Note that the energy subsidy of Bangladesh in 2012 fiscal year was estimated BDT 282 billion [10].

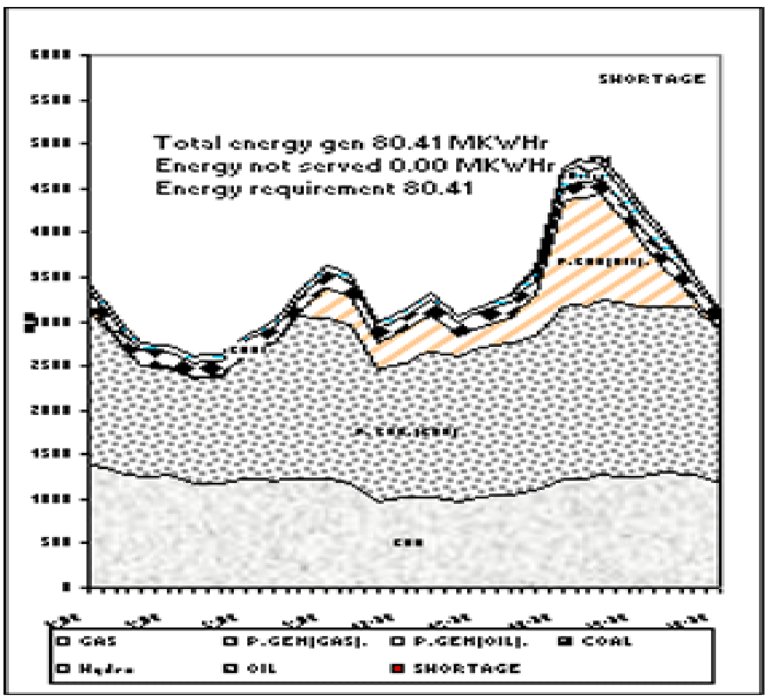

Fig. 4 Energy curve of a typical day from the month of November to February

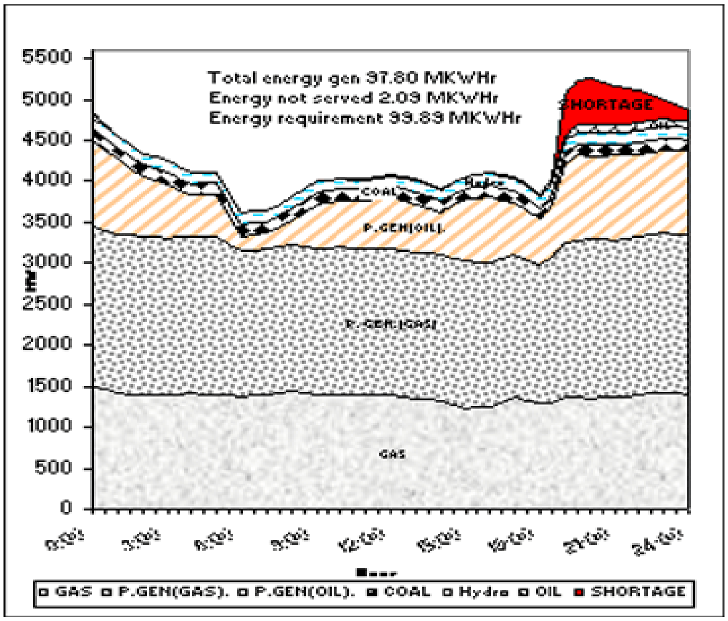

Fig. 5 Energy curve of a typical day from the month of June to October

From the Summary of Daily Electricity Generation presented by Power Grid Company of Bangladesh Ltd. (PGCB) [9] it is seen that many of the generating units are shut down in the month of March to May. If a better and timely planned maintenance is ensured then there might not be so many generating units in shut down condition. Moreover, power crisis during off peak period may be disappeared and in turn the PSS operation would be feasible during the period of March to May. So to get a running time of PSS throughout the year, BPS should take measures for better maintenance and over hauling action.

4. Conclusion

There are some certain losses in the motoring and the generating action of PSS but in terms of overall economy it is much more profitable. Total energy subsidies for the Fiscal Year (FY) 2012 are estimated at more than BDT 282 billion, almost 90% of the total amount spent on all subsidies. PSS can become a solution to reduce this subsidy. The possible savings by using PSS in a typical day is BDT 6128275. Considering the proposed operation plan in section 3, a savings of BDT 1.67 billion is possible by implementing PSS which is 0.59% of the total energy subsidy for FY 2012.

This paper presented the feasibility of the PSS for Bangladesh from both geographical and financial point of view. It also clearly revealed the fact that the contribution of PSS in BPS will certainly reduce fuel cost. BPS planners should take this project for economical and power sector development of Bangladesh.

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