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Optimal Peak Shaving Operation of Hydroelectric Power Station in Bangladesh and its Impact on the Reduction of Severe Load Shedding

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Abstract: *Bangladesh Power System (BPS) is facing an acute Power crisis round the clock, especially in the summer season. The crisis turned in to a sever condition during peak hours and results in intolerable load shedding. This paper investigates this load shedding problem in the peak load hours under the consideration of available generation capacity of BPS and presents an analysis to minimize the load shedding through the optimal operation of existing hydro power station in BPS. Moreover it exposed different mode of utilization of hydro resource with promising results. The investigation of this paper shows that the installed capacity of the existing Hydro power station can be increased as the available hydro potential becomes higher than the installed capacity for nearly 35% time of a year. The proposed different mode of operation of hydro power plant would create a feeling among the system planner for planned maintenance & overhauling of the hydro generating units.*

Keywords: *Peak hours, load shedding, hydro-electric energy, system reliability.*

1. Introduction

Hydro electric power Station converts the potential energy of water head that stored at a reservoir in to electrical energy. It is economical to utilize all the available hydro potential associated with a hydro electric power station because of virtually nonexistent generation cost. Owing to this advantage electric utility gives prime emphasis on the commitment of hydro unit. On the contrary, rainfall, reservoir size & the stream flow are the main limitations of hydroelectric power.

The idea of optimal use of hydro-electric energy is briefly discussed in [1]. The authors of the paper investigated the impacts of exhaustive use of hydro power station on the reliability and production cost in BPS. This paper considers the generalized forced outage rate of the hydro unit instead of actual shutdown of the units throughout the investigation period that may not bring the actual result. Q.Ahsan & MR. Bhuiya proposed a technique of simulating energy limited hydro unit utilizing all the convertible water head in [2].

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The probability density function of water head in kaptai reservoir and multi state model of that power station is developed in [3]. The detail information about hydro-electric power generation, power shortage, power demand and load-shedding in Bangladesh is presented in [4].

This paper presents the impacts of optimal peak shaving operation of hydro electric power station on the reduction of sever load shedding in peak load hours considering the actual shutdown condition of the hydro units throughout the year 2011. The paper also investigates the different modes of utilization of hydro potential and their impacts on load management system.

2. Power crisis scenario in Bangladesh

The daily electric load in BPS is not even throughout the day, it varies from time to time that shown in figure 01[5][6]. Figure 01 depicts that, at 6.00 pm load starts to increase and it reaches at the peak at 10.00 pm. It is seen that the demand of electricity is massive at peak hours which is around 5100MW causing load shedding of 1300 MW and this peak load varies from season to season of a year . As the demand is higher than the generation, the BPS is forced to curtail electric demand during the peak hours usually evening of the day throughout the year and all the hours of the day in summer.

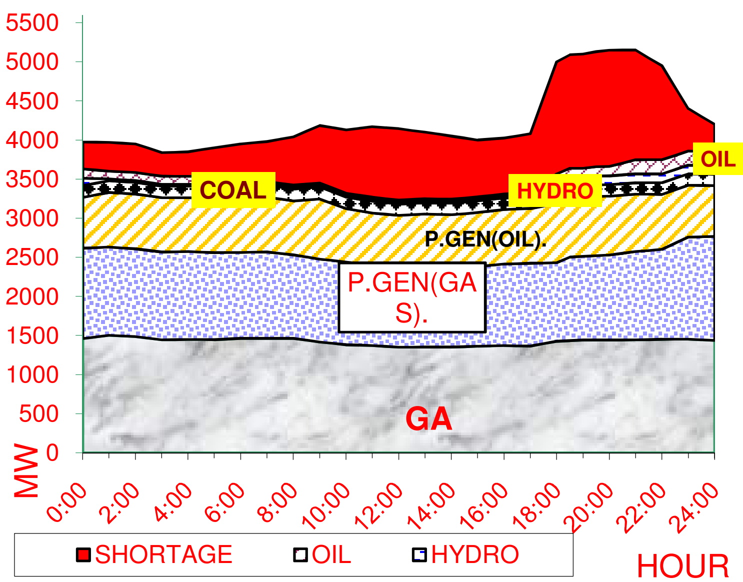

Fig 01: Load curve of BPS for a typical summer day in 2011

Although the installed capacity of the generating units of BPS is higher than the demand, however a big amount of installed capacity is always disappeared due to maintenance and overhauling of the units because of old aged. Moreover the hydro potential of kaptai reservoir is not being exploited properly because of unplanned maintenance and operation of the hydro units. If it could be ensured the proper planning in the operation of hydroelectric power station there would be an opportunity to increase the generation and the reduction of load shedding during peak load hours.

3. Hydro electric potential in Bangladesh

There is only one hydro-electric power generating station in Bangladesh, situated at Kaptai in Rangamati. It has five generating units with combined generation capacity of 230 MW. The rated capacity of the reservoir at Kaptai is 5.25 million acre-ft with a maximum water head of 109 ft (from mean sea level) [6]. The electricity generation of 230 MW can be obtained at a water level of 96 ft and the generation becomes zero at 66 ft water head.

Mathematical Model

A simple equation for the conversion of water head of Kaptai reservoir into electricity in Megawatt is presented in equation (1).

$$Y = 7.5X - 490 \tag{1}$$

Where, Y is station output in megawatt and X represents water head in feet.
The variation of water head is random and discrete in nature. To convert this potential head, a probability density function (PDF) of water head is essential. The PDF of water head in terms of delta function for all kinds of hydro unit is shown in equation (2).

$$f_H(h) = \sum_i f_H\,(h)\partial(H - h_i) \tag{2}$$

$$f_{C_e}\left(C_{e_j}\right) = f_H(h_i) \quad for\ h_{min} < H < h_{max} \tag{3}$$

Where the PDF of water head $f_H(h)$ is obtained from historical data. The electricity generation with convertible water head is presented in equation (3).
In reality the generating units are not 100% reliable. Some units may be out of service due to maintenance and overhauling or forced shutdown. Considering all the factor the actual output is given by equation (4)

$$C = min(C_g, C_e) \tag{4}$$

$$f_C(c) = f_{C_e}(C_e) * f_{C_g}(C_g) \tag{5}$$

Where, C_g and C_e are the available generation capacity of the units and electrical capacity of water head respectively. The equation (5) gives the exact PDF model of output capacity of any hydro generating unit. The output PDF model of kaptai hydro power station is developed in [3] which is shown in figure 02.

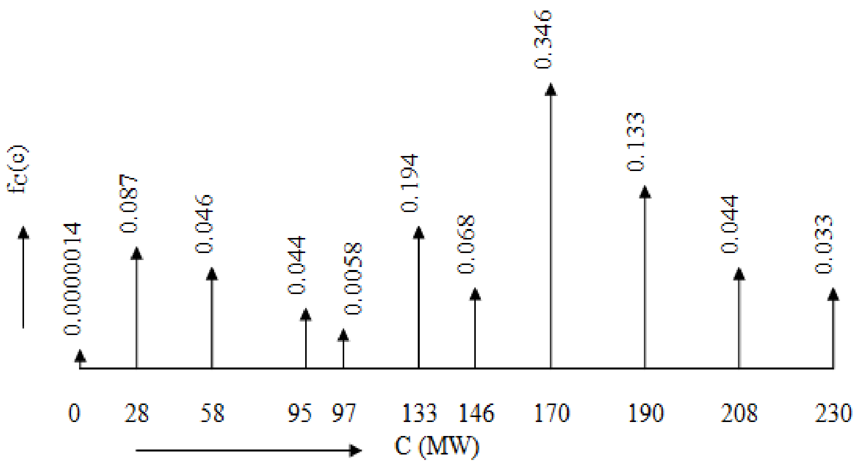

Fig 02: Probability Density Function with respect to Generation Capacity of Hydro Potential

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4. Hydro electric power generation in different modes of operation

To investigate the impacts of hydro generation through different mode on the peak hour load shedding the monthly PDB generation, possible hydro potential and hydro generation through different modes are given in table 01. The Possible Hydro Potential (PHP) indicates that there is enough provision to generate electrical energy from available water head. But the actual scenario is that there is no enough generating capacity of the power station to produce that amount of energy. By considering the existing highest generating capacity which is 230 MW, a modification has been done in the evaluation process that indicates 'Mode A'. This mode of operation shows that generation never exceeds 230 MW having a water head of higher potential. For different reasons like forced shut down, maintenance and overhauling etc, it is not possible to run all the generating unit at a time and that is why the actual generating capacity is considered in 'Mode B' instead of installed capacity of the power station. In all the above mentioned three cases of evaluation from column 3 to 5.

Table 01: Peak hour's hydro power generation in different modes of Operation in 2011

Months	Actual Generation by PDB (MWh)	Possible Hydro Potential (MWh)	Mode A (MWh)	Mode B (MWh)	Mode C (MWh)
Jan	18273	33136.75	33033.63	20150	20150
Feb	12527	22603.875	22603.88	14800	14800
Mar	15292	20333.875	20333.88	19349	20150
Apr	11812	14244.375	14244.38	14244.38	19500
May	8567	11647.875	11647.88	11647.88	21750
Jun	14880	17091.375	17091.38	17091.38	27000
Jul	20586	25957.75	25957.75	25957.75	27900
Aug	22997	36231.625	34187.13	27900	27900
Sep	23009	46265.625	34500	27000	27000
Oct	25021	45348.875	33350	26100	26100
Nov	20855	39366.25	32200	25200	25200
Dec	23851	38991.25	35650	27900	27900
Total	**217670**	**351219.5**	**314799.9**	**257340.4**	**285350**

The electricity generation is considered as same in all the hours in a particular day. To generate highest hydro power at peak hour's further modification has been done in the evaluation process that is shown in 'Mode C'. In this mode of operation highest amount of energy is generated in peak load hours considering water head and available generating capacity and rest of the hydro potential is utilized in other part of the day.

The table clearly reveals that the evaluated energy in all the four cases during peak load hours is higher than the actual generation of BPDP through conventional process of operation. To examine a clear view of increment in hydro energy generation through all the mode of evaluation in comparison with the actual generation a chart is presented in figure 03.

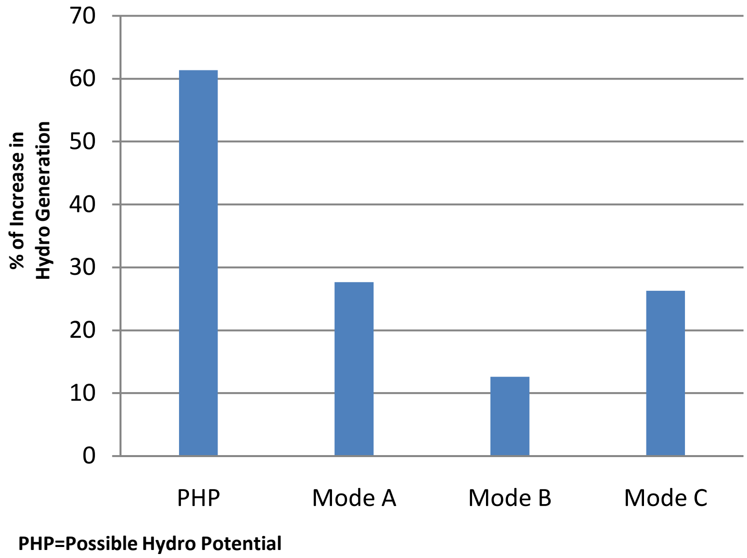

Fig 03: Annual Increase in Hydro Generation

The figure shows that if there was enough generating capacity to utilize the available hydro potential it would have been possible to increase the hydro generation by 61% over the actual generation of 2011. Although it is not possible at this moment but considering all the constraints the other operating mode like A, B & C show a significant increase in hydro energy generation. As 'Mode C' is the peak shaving mode of operation, it gives a 26% increment in energy generation over the conventional one which gives a promising result for the reduction of load shedding.

5. Impact of optimal hydroelectric power generation on peak load shedding

Under the consideration of hydro electric generation on load shedding, the different modes of operation mentioned above have different impact on peak load shedding. As the evaluated results of different modes of operation give increased hydro generation, there would be a reduction in load shedding in peak hours that has been presented in table 02. The table shows monthly remaining load shedding with annual total at different modes compared with the actual load shedding.

Table 02: Peak hours load shedding by applying different modes of modification

Months	Load Shedding in MWh				
	Actual Generation by PDB	Possible Hydro Potential	Mode A	Mode B	Mode C
Jan	46345.7	31481.95	31585.08	44468.7	44468.7
Feb	61577.4	51500.525	51500.53	59304.4	59304.4
Mar	124751.15	119709.275	119709.3	120694.2	119893.2
Apr	77041.175	74608.8	74608.8	74608.8	69353.18
May	67865.2	64784.325	64784.33	64784.33	54682.2
Jun	75376.375	73165	73165	73165	63256.38
Jul	62298.575	56926.825	56926.83	56926.83	54984.58
Aug	60991.8	47757.175	49801.68	56088.8	56088.8
Sep	58633.375	35376.75	47142.38	54642.38	54642.38
Oct	322934.9	302607.025	3146059	3218559	3218559
Nov	2354.5	-16156.75	-8990.5	-1990.5	-1990.5
Dec	4272.51	-10867.74	-7526.49	223.51	223.51
Total	**964442.66**	**830893.16**	**867312.8**	**924772.3**	**896762.7**

Load shedding with possible hydro resource generation gives lowest amount of unserved energy. A total of 830893 MWh load shedding would occur if the total Hydro potential of the reservoir could be used in order to produce power. It is also observed from the annual total the other mode of operation gives a good amount of reduction in load shedding. In the month of November and December negative numerical value indicates excessive hydro generation that caused the off loading of higher cost peaking units. To bring a clear perception on the reduction of load shedding a chart is presented in figure 04.The effect of introducing different mode of hydro generation on load shedding can be clearly understood by the chart.

According to the figure 04, if it was possible to use total hydro resource then the load shedding could be reduced by 13.84 percent and if 'Mode A' was applied then the load shedding would have been reduced by 11.69%. But these two techniques cannot be taken under consideration for some reason which is mentioned earlier.

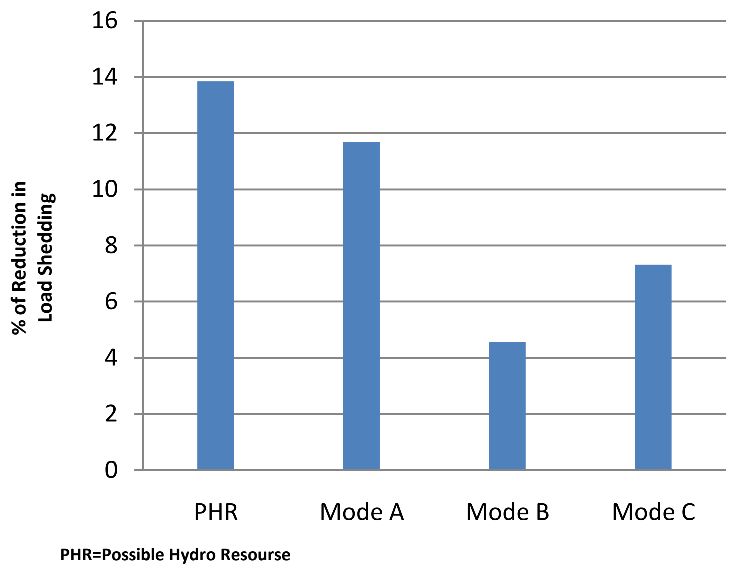

Fig 04: Percentage of reduction in Load shedding

By Appling 'Mode B' modification technique the load shedding could be reduced by 4.57%. 'Mode B' is a possible technique but its reduction of load shedding is lower than 'Mode C'. Moreover, Mode B does not ensure optimal utilization of hydro resource during peak hours. The targeted peak shedding 'Mode C' gives 7.32% reduction of load shedding during peak hours with a numerical value of 67679MWh in the year of 2011.

6. Conclusion

Load shedding is one of the major problems in BPS and it becomes more severe at the peak hours. In this case, Hydro potential can play a vital role to reduce peak hour load shedding as well as total load shedding. The evaluated result of different mode of operation of hydro station that investigated in this paper gives a promising result to reduce the magnitude of load shedding, especially in peak shaving 'Mode C' which could give 7.32% reduction of load shedding in peak hours in the year of 2011 with an amount of 67679 MWh energy. If the existing hydro power station is operated in planned way to reduce the load shedding, this will be very much helpful for the total power generation system to improve the reliability.

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