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Co-operational Optimization of Two Cascade Hydropower Plants

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Abstract

In this research, the co-operational optimization of two cascaded hydropower plants in Lao PDR, Xeset1 and Xeset2, was investigated. For Xeset1, there are 5 units which are 2 units of 3.1 MW and 3 units of 13.1 MW. In case of Xeset2 hydro power plant, there are 2 units of 38 MW each, Xeset1 is located downstream from Xeset2 along the Xeset River. The main constraints of the optimization were the inflow of water into the dam and the vibration of each turbine unit. Since, Xeset 1-2 hydro power plants are the run-of-river power plant, therefore, the inflow of water equals to the outflow with no water storage in the reservoir. For the vibration, the main source of vibration of turbine comes from the cavitations. Therefore, the vibration of each turbine was measured at various water flow rate and power output while the head of water was kept constant. A computer programming was developed to find the optimum operation of each turbine unit to meet the requirement of the highest power and efficiency at various inflows of water while the vibration does not exceed the limit. The output of this research could be applied to find out the most suitable operating condition of Xeset1 and Xeset2 hydro power plant.

Keywords*:* Optimization, Hydraulic turbine, Turbine vibration, Turbine efficiency.

1. Introduction

At present, the electric demand of southern region of Lao PDR trends to increase approximately 13% annually. This result comes from the rapid economic growth of the southern part. Therefore, the stability of power plant located in this region is very important. To meet this requirement, the preventive maintenance has been adapted to eliminate the fault outage and also prolong the life time of power plant.

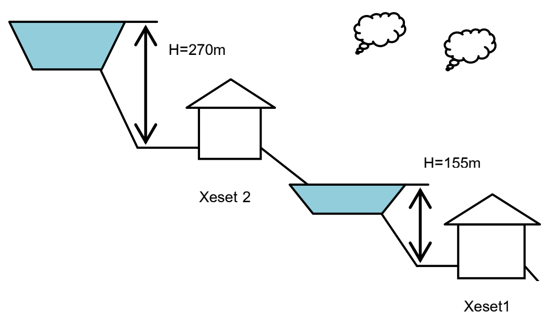

Fig.1 the cascade of Xeset1 & 2 along Xeset River.

The main power stations in southern part of Lao PDR are Xeset1 and Xeset2 hydro power plant. For Xeset1, there are 5 units, 2 units of 3.1 MW and 3 units of 13.1 MW. In case of Xeset2, there are 2 units of 38 MW. It should be note that Xeset1 is located downstream from Xeset2 along the Xeset River and both power plants are run-off river power plant. The power plants cascade is shown in fig. 1.

Since, all of the power station in Lao PDR is the hydropower plant. To operate the hydraulic turbine efficiently, the cavitation should be avoided. The cavitation leads to the destruction of turbine surface and also reduces the efficiency [1]. Normally the cavitation of hydraulic turbine can be observed by its vibration and noise. Therefore, the vibration monitoring system is selected as a tool for preventive maintenance of turbine [2]. This tool has been used for measuring the frequency and the amplitude of vibration harmonic and the results could be indicated the damage developed by cavitation [3].

Actually, the vibration of turbine is the limit of power plant operation. Therefore, the optimization of power plant operation under vibration constraint should be studied. In case of the optimization of hydro power plant, there are many researchers investigated. For example, Rauschenbusch [4] optimized the operation of 4 hydro power plants located along Dunav River. Divac et al [5] proposed the management of hydro power resources in Serbia. Cook and Walsh [6] studied the optimization and performance of run-off river power plant.

In this research, the co-operational optimization of two cascade hydropower plants (Xeset1 and Xeset2) was investigated. To avoid the damage from cavitation, the vibration of all turbines was measured to find out the suitable operation range. The computer programming was developed for evaluating the possible maximum operating power of these two power plants at various water inflows.

2. Research Methodology

This research work can be divided into two parts, vibration analysis and operating optimization. For the vibration analysis, the vibration of each turbine unit were measured at various powers by mounting 4 points of vibration transducers at turbine guide bearing (PC1 and PC2), head cover (PC3) and draft tube (PD1) which shown in figs. 2-3. The vibration data was collected by using vibration analyzer type CSI model 2120 and velocity transducer CSI model 341B Serial 01M35026Dv having frequency response between 2.0 Hz to 2000 Hz. The vibration result from monitoring apparatus was converted to RMS value by soft ware CSI Master Trend v270f. It should be notice that the specifications of turbine are shown in table 1

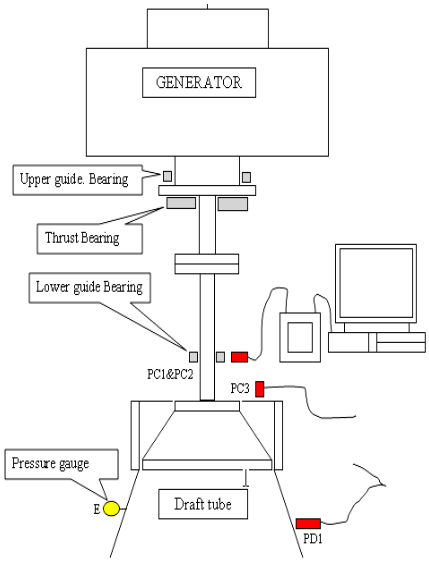

Fig 2 Positions for measuring vertical shaft turbine vibration

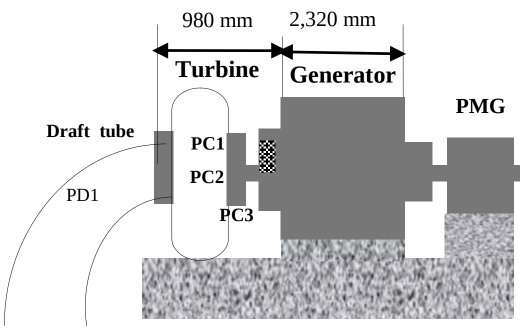

Fig 3 Positions for measuring horizontal shaft turbine vibration

Table 1 Prototype characteristics of turbine of XESET1&2

Power plant	XESET 1		XESET2
Type of Turbine	Horizontal	Vertical	Vertical
Orientation of shaft	Francis	Francis	Francis
Nominal power	3.1x2(MW)	13.1x3(MW)	38x2(MW)
Nominal Head	155m	155m	270m
Rated Flow	2.25 m^3/s	9.6m^3/s	16.71m^3/s
Rotating speed	750 rpm	600rpm	500rpm
Maximum vibration	2.1mm/s	4.5mm/s	4.5mm/s
Runner outlet diameter	589mm	1090mm	1930mm
Full supply level	el.482.00m	el.482.00m	el.813.00m
Minimum Operation	el.478.00m	el.478.00m	el.811.00m
Water level at tailrace	el.325.40m	el.325.40m	el.542.00m
Installation Year	1991	199	2009

The vibration monitoring results were used as an operation limit of each turbine. Therefore, the allowable operation range of each turbine could be developed. The search method was adapted to find out the maximum power generation of each turbine unit when the inflow of water was known. Moreover, the power plant efficiency was also calculated. It should be note that in case of Run-off River, the maximum efficiency is occurred when turbine is operated at maximum power. In this part, the computer programming was developed by using Pascal language.

Since the hydro power plants that form a cascade have their special characteristics. The Co-operational optimization of two cascade hydro power plants, XESET1&2, shall normally keep the reservoir level close to high level el. 482m (meters from sea level) for XESET1 and el. 813m for XESET2 at any time.

3. Results and Discussion

3.1 Vibration Analysis

The effects of turbine load on vibration of turbine are shown in figs. 3-5. It was found that the vibration at draft tube was higher than the turbine guide bearing. This undoubtedly result comes from the well support of bearing. However four measuring points had the same result that the vibration of the turbine was very high at minimum load and decreased with the increasing of load till the turbine load reached 2.43 MW for units 1, 2 and 12.23 MW for units 3, 4, 5 (in case of Xeset1). If the turbine load was higher than 3.1 MW for units 1,2 and 13.1 MW for units 3,4,5 the vibration was increased again.

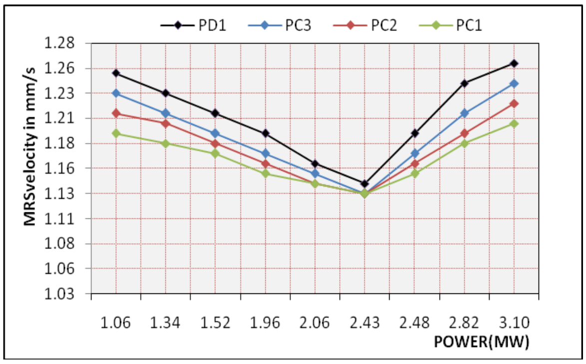

Fig. 3 Vibration characteristic curve of turbine unit 1,2 (XESET1)

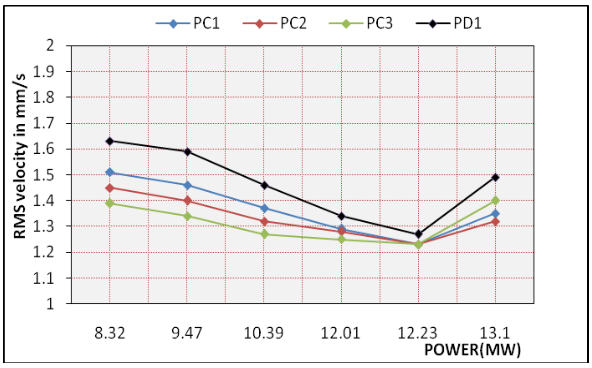

Fig. 4 Vibration characteristic curve of turbine units 3,4,5 (XESET1)

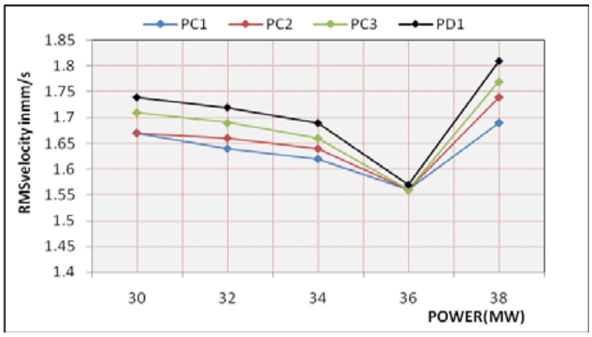

Fig. 5 Vibration characteristic curve of turbine Unit 1,2 (Xeset2)

In case of Xeset2 hydro power plant, it was found that the vibration result trended to be the same as that of Xeset1. However, the vibration changeover was at 36 MW. Not only the vibration monitoring of turbine at various loads, was the noise from cavitation effect also observed. These data was used for indicating the allowable operation range of each turbine and it is shown in table 2.

Table 2 Allowable range of turbine

Power plant	Unit	Allowable operation range (MW)
Xeset 1	1,2	1.06 to 3.1
Xeset 1	3,4,5	8.32 to 13.1
Xeset 2	1,2	30 to 38

3.2 Operational Optimization

From the allowable range of turbine shown in table 2, the search method was adapted to find out the suitable power of turbine at various inflow of water. Table 3 shows the calculation results from the computer programming. It should be noticed that Turbo Pascal Language was selected for developing the simulation program.

Table 3 the suitable power of turbine at various inflow of water

$Q(m^3/s)$	XESET1 HPP					XESET2 HPP		η	Total
	T1 (MW)	T2 (MW)	T3 (MW)	T4 (MW)	T5 (MW)	T1 (MW)	T2 (MW)	(%)	(MW)
4.5	3.1	3.1						92	6.2
5	3.1	3.1						92	6.2
10			13.1					88	13.1
15	3.1	3.1	13.1			36		89	55.3
20			13.1	13.1		38		87	64.2
25	3.1	3.1	13.1	13.1		38		86	70.4
30	2.1		13.1	13.1	13.1	38	34.63	91	79.4
32	3.1	1.7	13.1	13.1	13.1	38	38	91	120.1
33	3.2	3.2	13.5	13.5	13.5	38.5	38.5	89	123.95

From table 3, it was found that the total power of power plant depends on the inflow of water. If the amount inflow is not suitable for run turbine, it will be drained into spillway.

4. Conclusion

The vibration of turbines of Xesets 1&2 were measured in this work and the results were applied to find out the suitable range for turbine operation. The computer programming was developed for calculating the suitable power and efficiency of turbine for avoiding the damage from cavitation.

5. Acknowledgement

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6. References

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