IMPROVING SEDIMENT HANDLING IN THE HIMALAYAS

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Abstract: The Himalayan Rivers provide a great potential for hydroelectricity generation due to its steep gradient. Steep topography, fragile geology and intense rainfall have led to large flow volume and exceedingly high sediment transport in these rivers during rainy seasons. This has posed a challenge to many hydropower plants with respect to sediment handling at headworks, leading to severe sand erosion of turbines and causing loss in energy generation.

A research on sediment handling is initiated to understand the sediment problems in Himalayan Rivers in a better way and facilitates in handling sediment problems optimally in run-of-the-river power plants.

This paper presents the results from measurements taken to improve sediment handling from a project in Nepal.

1. INTRODUCTION

The Himalayan Rivers provide a great potential for hydroelectricity generation due to its steep gradient. Steep topography, fragile geology and intense rainfall have led to large flow volume and exceedingly high sediment transport in these rivers during rainy seasons. This has posed a challenge to many hydropower plants with respect to complete sediment exclusion at headworks and severe sand erosion of turbines leading to loss in energy generation.

The 12 MW capacity Jhimruk Hydropower Plant (JHP) developed in Nepal in 1994 has been facing considerable sediment erosion resulting in the need of repairs on an annual basis. Due to limited knowledge regarding the damages caused by the sediments, and to have a better understanding of the problems caused by sediments in run of river hydropower plants, a research on optimum sediment handling in run of river power plants was initiated in 2003.

The objective of the sediment handling research is to try to find out what is the optimum for investment with regard to sediment handling in steep sediment loaded rivers. The methodology adopted is to measure the sediment load passing through the turbine unit, its grain size distribution and mineral composition, and its effect on the turbine with regard to loss in efficiency. JHP was taken as a first case for gathering knowledge related to sediment handling in steep sediment loaded rivers.

2. SEDIMENT IN THE HIMALAYAS

The sediment supply and transport in the Himalayas is quite significant and is considered to be highest in the world. Geologically, the Himalayas (formed about 10 million years ago) are considered to be fairly young in the mountain building process and are still active as they rise 10 mm per year. This has led to many rock and slope instabilities that are the primary source of sediment for the river system. Topographically, the Himalayas are characterized by a steep and rugged terrain that plays significant role in spatial distribution of rainfall. A heavy rain in the catchment area results in an unusual stream flow event creating widespread slope instabilities, sediment transport and flooding. Hydrologically, the Himalayas are characterized by four months of rainy season termed as ‘monsoon’ or the wet period. About 70-80% annual precipitation occurs over the four months monsoon season that extends from June to September. The peak flow and sediment transport in most rivers in the Himalayas occurs during July and August which is the time for highest monsoon rain period.

Having such characteristics, the Himalayan rivers pose an immense challenge with regard to sediment management, as the basic theories of sediment transport mechanics developed for sand bed and silt bed rivers are not following the sediment transport in steep mountain rivers. The sediment transport in such rivers is normally much higher than the actual sediment transport in other rivers.

3. THE SEDIMENT HANDLING RESEARCH

The presence of sediment in water flowing through the turbine causes wear on them by its abrasive impact. The higher the sediment content and the harder the minerals, greater is the wear. The wearing of the vanes and runner results in poor performance of the plant than its optimum. This results in loss of energy production during operation and ultimately the loss becomes so high that the plant has to be shut down to allow for the turbine to be repaired to its original condition. In such conditions there is cost due to loss of efficiency in energy generation, repair and shut down. In order to reduce the sediment-induced wear, measures are taken to reduce the sediment exposure of the turbines through settling basins and improved plant operation strategies as well as measures to increase the resistance of the turbines to sediment-induced wear.

It has been observed in run of river power plants in steep sediment loaded rivers that the conventional design criteria to trap 0.2 mm size sediment particles do not seem to function satisfactorily. In general, projects are having damages to runners due to severe erosion caused by silt. In case of Jhimruk Project, the wear on runner is so high that it requires repair after every monsoon. There is limited knowledge as to what is the optimum with regard to investment in sediment handling structures such that there is benefit from operation and maintenance of the power plant. Hence an initiation was taken to do research on optimum sediment handling in run of river power plants.

The hypothesis for optimum sediment handling research is that an optimized sediment handling at run-of-river hydropower plants are obtained through minimization of the total investment and operation costs throughout the lifetime of the project. This is planned to be achieved by i) reducing sediment exposure to turbines through improved exclusion of sediments in the abstracted water through the settling basins and through sediment guided operation regime based on real time sediment monitoring and ii) increasing capacity to resist sediment-induced wear through an efficient overhaul and maintenance programme for the turbines and through improved turbine technology, so called “silt-friendly” turbines.

As sediment transport in Nepalese Himalayan Rivers is much larger than most other places, sediment handling research initiative has been initiated in Nepal in order to have results quickly. The findings from the data and analysis from several power plants are expected to contribute in sediment management of steep sediment loaded rivers. The research on optimum sediment handling is initiated by the Hydro Lab Pvt. Ltd. Nepal in joint cooperation with Norwegian University of Science and Technology (NTNU)-Water Power Laboratory, NTNU-Hydraulics Laboratory, Butwal Power Company, GE Energy Norway and Sediment Systems, Norway.

The main objective of the first research case is to study how the turbine efficiency decreases as a result of the sediment load passing through a turbine over time.

As JHP has experienced severe sediment-induced wear of the turbines in the past, this hydropower project is well suited for "accelerated" research on sediment transport and sediment-induced wear of the turbines. Therefore, JHP has been taken as the first case for studying sediment handling in run of river projects.

4. CASE FROM JHIMRUK RIVER IN NEPAL

The Jhimruk Hydropower Project has been taken as a first case due to sediment handling problems it has been facing resulting in severe erosion of its turbines.

4.1 Jhimruk Hydropower Project

The Jhimruk Hydropower Plant (JHP) abstracts water from Jhimruk River located in Pyuthan district of Mid-Western region of Nepal. JHP is a 12 MW run-of-river type project built and commissioned in 1994. The owner of JHP is Butwal Power Company (BPC) who is operating the plant. The Jhimruk River has a catchment area of 645 km^2 at the headworks. The average annual runoff of Jhimruk River based on flow data for the years 1972-1990 is 27 m^3/s. The annual rainfall at the catchment is about 1,610 mm and 83% of it appears during monsoon.

4.2 Design basis for sediment handling

There were no sediment data available for the Jhimruk River during the planning and design stage of the JHP. Due to the lack of sediment data, the design was based on the general design criteria and on the experience of design of similar projects in Nepal at that time, and on general references to sediment transport in the Himalayan Rivers. As a result, the Jhimruk settling basins have been designed to trap 90 % of 0.2 mm size particles.

4.3 Previous sediment monitoring

Lack of sediment data in Jhimruk River and cases of severe sediment induced wear on turbines in the Himalayan Rivers has initiated the power plant owner to carry out the sediment monitoring programme from the very beginning of its operation.

The summary of four years (1994-97) of sediment data recorded in monsoon is presented in Table 1.

Table 1 Measured concentrations in Jhimruk River (1998, Biswakarma)

Year	1994			1995			1996			1997		
Month	C_{min}	C_{mean}	C_{max}	C_{min}	C_{mean}	C_{max}	C_{min}	C_{mean}	C_{max}	C_{min}	C_{mean}	C_{max}
June	-	-	-	8	1,797	12,875	4	4,301	20,075	-	-	-
July	91	3,685	23,760	44	2,077	42,970	28	5,908	57,094	196	6,675	47,602
August	102	2,316	18,170	39	2,536	31,130	164	2,904	16,074	56	2,882	27,693
September	18	423	5,220	17	1,064	31,124	36	2,739	28,950	19	280	3,139
October	-	-	-	5	14	26	52	1,646	9,080	9	37	323

The sediment data revealed that:

- The average values for suspended sediment concentration in Jhimruk river during the peak monsoon ranges from about 2,000 to 6,000 ppm (parts per million) with upper values ranging from about 20,000 to as high as 60,000 ppm. This indicated that sediment transport in Jhimruk River during the monsoon is quite significant.

- The runners were significantly worn out after every monsoon. From the damages observed in the runners it revealed that the runners in the power plant were exposed to much higher sediment load than expected during the planning and design stage.
- It also revealed that the settling basins structure designed as per conventional design criteria was unable to trap sediment that was causing erosion on the runners. The high concentration of sediment particles finer than 0.2 mm that is not being trapped in the basins is causing the abrasive effect on the turbine. Hence, the power plant has been normally operated at lower capacity than installed.

Though various discussions have taken place during the operation of JHP for increasing the sediment exclusion from the withdrawn water into the system, any relations had not been established between the sediment and wear in runner. The objective of this measurement was to estimate the sediment load to which the turbine was being exposed to and corresponding decrease in efficiency of the turbine over a time period. The wear on the runner leads to the loss of efficiency in the turbine or generation loss. So one of the key questions in the first research activity was to study how the turbine efficiency decreases as a result of the sediment load passing through a turbine over time.

4.4 Methodology

The methodology adopted to find the ddecrease in turbine efficiency due to sediment load passing through it, was done by measuring the efficiency of a new turbine, then measuring the sediment load passing through it for a period and then measuring its efficiency again at the end. The sediment passing through the turbine was measured by taking samples every one hour and analysing it.

4.5 Preliminary Findings

The result from this research is expected to contribute to remedial solutions for handling sediment induced problems in Jhimruk. This would reveal how the sediment has been affecting the turbine. The details of measurements are not elaborated in this paper.

The result from sediment measurement is given in Figure 1. Higher concentrations are found in September and lower ones are in October.

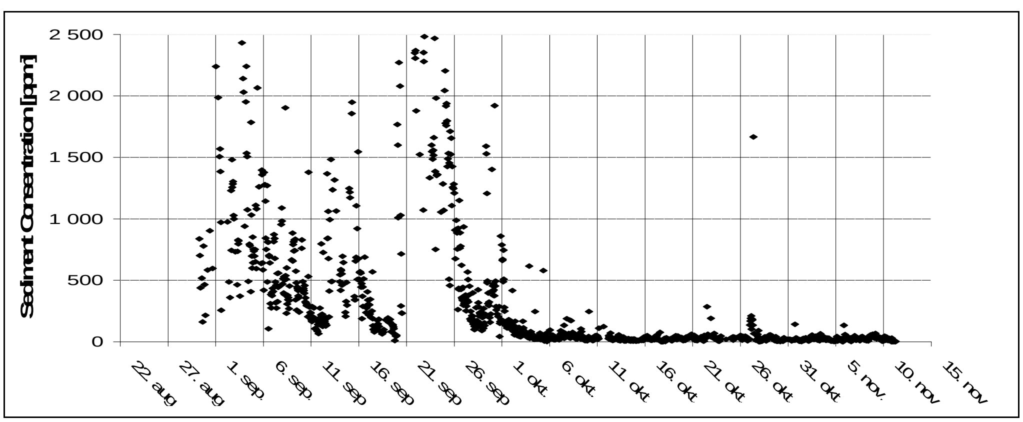

Figure 1 Concentration analysis result of sediment through turbine unit no. 3

Calculations show that turbine unit no.3 was exposed to a sediment load of 6,900 tons during the period 1 September to 11 November 2003 (Pradhan et al 2003). The mineral contents in the sediment passing through the turbine unit no. 3 are 61% of quartz, 22% of feldspar, 16% of mica and other 1% is rock fragment and tourmaline. It indicates that about

80% of the sediment is composed of hard minerals (quartz and feldspar) that abrade the runners.

The results from the thermodynamic efficiency measurements are shown in Figure 2. The efficiency loss is 4% at best efficiency point and 8% at 25% load (Pradhan et al 2003). These losses have occurred in the period 1 September to 11 November 2003

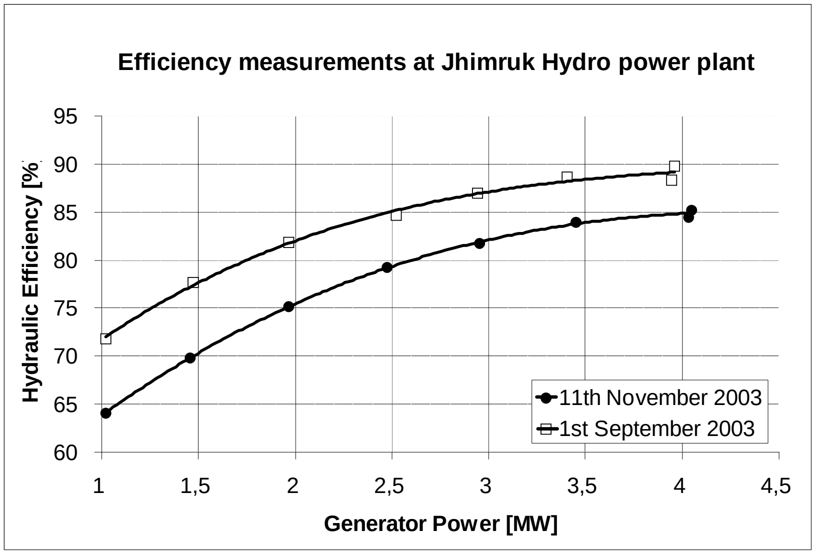

Figure 2. Results from the thermodynamic efficiency measurements

The shifting of the curve in Figure 2 from upper to lower indicates loss of the turbine efficiency. The loss in efficiency of the turbine unit no.3 in JHP is attributed to the abrasive erosion of various parts of the turbines. The erosion was found on guide vanes, runner blades, sealing rings and face plates. This is due to the abrasive action of mainly hard minerals present in the sediment passing through the turbine. The presence of more than 80% of hard minerals (quartz + feldspar) in the sediment is considered responsible for this erosion.

5. CONCLUSION

The result of sediment measurement in one unit shows that the turbine was exposed to a total sediment load of 6,900 tons in the period 1 September to 11 November, 2003. The efficiency loss was found to be 4% at best efficiency point and 8% at 25% load in that period.

It is noted here that the measurement was made in the month of September and November 2003, which covers only a part of monsoon i.e. the falling limb of the monsoon flows. For Nepal, the second week of June is considered to be the start of monsoon and July/August is regarded as the peak period in normal cases. Therefore this measurement does not cover the peak of the monsoon period. The peak period of the monsoon is expected to have much higher sediment concentration. Given this condition, the turbine wear is expected to be much more severe for the whole monsoon season. Hence loss in efficiency is likely to be more than what was shown from this measurement if the entire period of the monsoon is included in future measurement.

The measurement has given a set of data but it is not possible at this stage to establish any correlation between the losses of efficiency versus sediment load. In order to secure broader knowledge with respect to efficiency loss due to sand erosion, additional thermodynamic efficiency measurements need to be performed covering the whole monsoon period. Such measurements can provide valuable guidelines for operation strategy of the power plant during the monsoon seasons that will generate additional income for the plant owner and is likely to reduce operation and maintenance cost of the turbine. In addition to this, it will facilitate in understanding loss in efficiency of turbine over a time period caused by sediment load passing through a turbine.

Sediment induced wear in turbines is a serious problem for run-of-the-river power plants in Himalayan Rivers. Thermodynamic efficiency measurements carried out for a turbine in JHP, Nepal showed decrease in efficiency substantially due to sand erosion. It is recommended to collect and analyze data from several hydropower projects with respect to sediment measurements and erosion on turbines so that it can provide guidelines to understand the sediment problems in Himalayan Rivers in a much more informed manner and will facilitate handling the sediment problem optimally in run-of-the-river power plants.

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