Design Modification of Cooling Water System for Hydropower Plants [A Case Study of Middle Marsyangdi Hydropower Plant in Nepal]

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Received: 3 February 2015 Accepted: 5 March 2015 Published: 15 March 2015

Abstract

Middle Marsyangdi Hydropower Plant (MMHPP) in Nepal, has been currently facing a severe problem with the existing Cooling Water System (CWS) due to excessive silt which is coming with the flowing water in the open loop of CWS. Due to this, the existing system has been experiencing unexpected unit breakdown as well as frequent maintenance that ultimately cause a severe impact on the power generation. This problem could be overcome by introducing a close loop circuit along with an open loop circuit of cooling water supply which passes through a Tubular Heat Exchanger directly submerged into Draft Tube water where heat transfer could takes place. Based on the suitable design parameters, existing site conditions of the plant and ensuring its technical feasibility, a detailed design of proposed Tubular Heat Exchanger has been carried out.

Index terms— middle marsyangdi hydropower plant (mmhpp) in nepal, cooling water system (cws).

Frequent replacement of these damaged parts is not only expensive but also time consuming process when the unit cannot generate power. Cleaning of Heat Exchangers, Automatic Water Strainers and Pipings requires considerable time and the maintenance crews have to be engaged from time to time in carrying out such maintenance during monsoon affecting the other scheduled maintenances.

There is no doubt that the existing CWS of MMHPP is based on the latest and recent design and is better than the older system which exists at other large power plants such as Kaligandaki HPP, Marsyangdi HPP etc in Nepal. The older design incorporates only one loop i.e. open loop of Cooling Water Supply which either taps water directly from the Penstock (by gravity flow) or draws water from the Draft Tube by means of a water pump and supplies water to various consumers and sent back to the Draft Tube after cooling. Since MMHPP water from both sources is very dirty (full of silt) especially during monsoon, apart from damaging the associated components of CWS, it also damages the components associated with the various consumers at Year 2015 F different locations where such dirty water is being supplied.

The existing compact Plate Heat Exchanger provides highly effective cooling and is very useful with clean water, however in context of Nepal, where most of the rivers are originated from Himalayas and have excessive quartzite sand, it is getting damaged quickly with sandy water as in the open loop of MMHPP.

Hence the existing system is not serving the desired purposes effectively and necessitates some design modification for improved and reliable cooling system which could have better performance even with sandy water. The concept is to design a Heat Exchanger in the form of a cooling coil or a Shell and Tube type of Heat Exchanger (without Shell) and the entire unit shall be placed directly inside the Draft Tube or Tailrace chamber at appropriate location where optimum cooling effect for the close loop circulating water with minimum erosion of the unit can be achieved with the flowing water coming out of the runner exit via Draft Tube.

Proper sizing and selection of material of the cooling coil, its configuration, connection to the existing system, appropriate location for easy installation shall be determined during the design phase of the entire unit is performed in detail installation work. Hence the main objective of this paper is to modify the design of existing Cooling Water Supply System of MMHPP in order to achieve improved plant reliability with reduced plant breakdown and maintenance costs.

1 II.

2 Research Methodology

Review of existing design of CWS system of MMHPP was performed. All necessary design calculations associated with the modified system and proper analysis to ensure its technical and financial feasibility, were carried out. Middle Marsyangdi CWS is designed to be in function fully automatic. No manual interference is required. Cooling system is divided in two main cooling circuits and two water entrance supplies. In the first entrance for open circuit, water is taken from Penstock before turbine inlet valve and directed to one of two "Automatic self-cleaning Filter". From this filter, water circulates through one of two "Heat Exchangers" and then discharges back to Draft Tube. In the second entrance for open circuit, water is pumped by two of two 50% capacity pumps, from Draft Tube and directed to one of two "Automatic self-cleaning Filter". From this filter, water circulates through one of two "Heat Exchangers" and then discharges back to Draft Tube. Sediments and dirt are automatically directed to the Pump sump of the powerhouse from self-cleaning filters.

In the closed circuit, water is circulated by one of two 100% capacity circulation pumps to following five consumers:

? Governor Oil Cooler:

1.3 m^3/h ? Turbine Guide Bearing:

1.5 m^3/h ? Combined Bearing:

14.1 m^3/h ? Generator Guide Bearing:

3.9 m^3/h ? Generator Air Cooler :

119.2 m^3/h All cooling water pressure, flow and temperature in both open and close circuits are controlled by governor and in case of malfunction, stand by unit is automatically activated to cover and keep turbine in function.

For each closed circuit two circulation pumps with adjustable speed are provided, each one with 100% discharge capacity of the flow required under full load of the generator for the given temperature difference (35 0 C to 28 0 C).The discharge of one pump shall be not less than 40 lit/sec. The required head of the pump depends on the hydraulic resistance of all components within the closed circuit it uses motor capacity of 30 kW.

For each open circuit two centrifugal pumps with constant speed are provided, each one with 50% discharge capacity of the flow required under full load of the generator for the given temperature difference open circuit it uses motor capacity of 55 kW. Water flow velocity for each circuit shall not be higher than 2 m/s. Valves, Backwash Flushing System, Pipings etc.) had been found to be considerably higher than their usual levels. All the above graphs show that most of the tripping has occurred during monsoon and longer hours are spent on maintenance during monsoon in the cooling system.

The above graphs reveal that the problem occurring in the Cooling Water System has lead to Unit/Plant breakdown resulting in significant outage time. These yearly outage hours as calculated are much above than the normal outage hours. The total annual energy loss by the Plant and monitory loss of NEA due to frequent problems occurring in the CWS of MMHPP is very high. Significant amount of energy has been lost every year due to problems occurring in the existing CWS of MMHPP resulting in a huge amount of monitory loss to the organization. The loss of energy and associated energy costs due to Unit/Plant breakdown has been found to be significantly high.

3 IV. Design of Submersed Tubular Heat Exchanger

Referring to the Operation and Maintenance manual of CWS, MMHPP, following major Design Parameters have been identified to be considered for designing the Proposed Tubular Heat Exchanger and installed in Draft Tube of the power plant. Case being as forced convection, we should analytically consider the problem of heat transfer in fully developed laminar or turbulent tube flow as the case may be. The cases of underdeveloped laminar flow, flow systems where the fluid properties vary widely with temperature, and turbulent-flow systems are considerably more complicated but are of very important practical interest in the design of heat exchangers and associated heat-transfer equipment. These more complicated problems may sometimes be solved analytically, but the solutions, when possible, are very tedious. For the design and engineering purposes, empirical correlations are usually of greatest practical utility. In some differential length dx the heat lost dq can be expressed either in terms of a bulk -temperature difference or in terms of the heat -transfer coefficient:

4 b) Flow Inside Tubes

dQ= m ×Cp×dT h = h (2??) dx (T w -T h)

Where T w and T h are the wall and bulk temperatures at the particular x location. The total heat trans fer can also be expressed as - Calculation were performed for various sizes and best suitable is found for following parameters: Hence, if 1" diameter and 1.5 m long tubes are selected, 33 pieces will be required. Increased number of tubes leads to bulky heat exchanger with bigger flanges. Since the objective is to design optimum size Heat Exchanger, 1.5” mild steel tube is considered to reduce the overall size of the Heat Exchanger in Case Flow over Cylinders”, equation 7.169, Nusselt number is given by:Q = h × A × (T w -T h) av = h × A × (?T)Nu d = C × (Re) n × (Pr) 1/3 U o = 10,561 W/m 2 0 C

Where C and n are constants and its value corresponding to Re = 73,867, the values for C and n

The overall heat transfer coefficient is also related as:?? ?? = ?? ð ?”ð ?” ?? × (?ð ?”ð ?”) ?? = ???????? × ???? ?? ????ð ??”ð ??”???? × ????. ?? = ð ??”ð ??”. ??ð ??”ð ??”?? ?? ??

5 e) Turbulent Flow Over Cylinders

To calculate now h2, let’s first verify whether the flow over cylinders is Laminar or Turbulent. size but enough to transfer the desired quantity of heat from the hot water coming from the various consumers. Based on the existing CWS configuration, location, arrangements, space limitations and reviewing the relevant Mechanical as well as Civil As-Built drawings of MMHPP, the following figures are identified for the proposed modification works. Thus, total surface area required to transfer the desired amount of heat with 1” mild steel tube comes to be 5.453 m 2 . Because of space limitation inside the Draft Tube, 1.5 m long tube was assumed. Hence, number of 1.5 m long mild steel tubes; N required can be calculated as: In this case with 1.5” diameter and 1.5 m long tube, we have found that only 24 pieces are enough to transfer the desired heat from the flowing water through tubes for the desired inlet and outlet temperatures. Such a reduced number of tubes leads to comparatively smaller size and compact Heat Exchanger and hence cheaper in price. Hence second option i. e. 1.5”?× 1.5 m × 24 pieces mild steel tubes for making the required Heat Exchanger was considered. [1]

Figure 1: Introduction

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Figure 2: Fig. 1 :

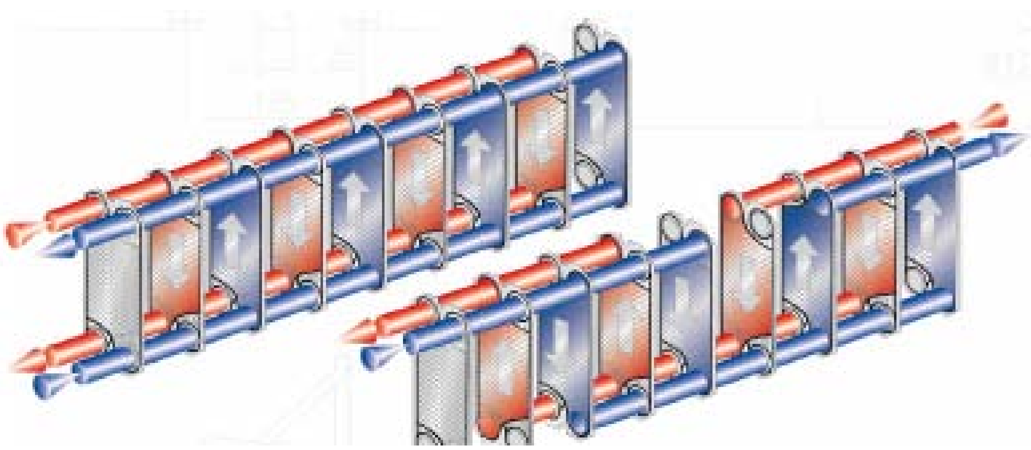

Figure 3:

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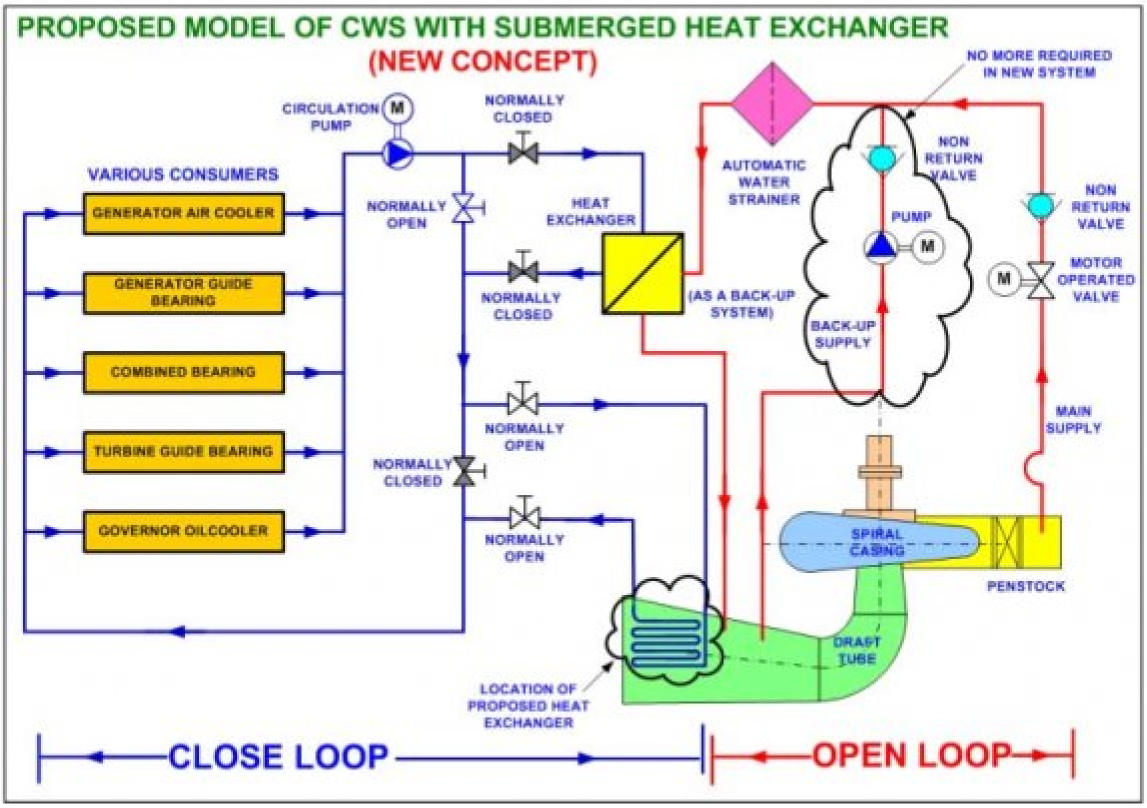

Figure 4: Figure 2 . 1 :

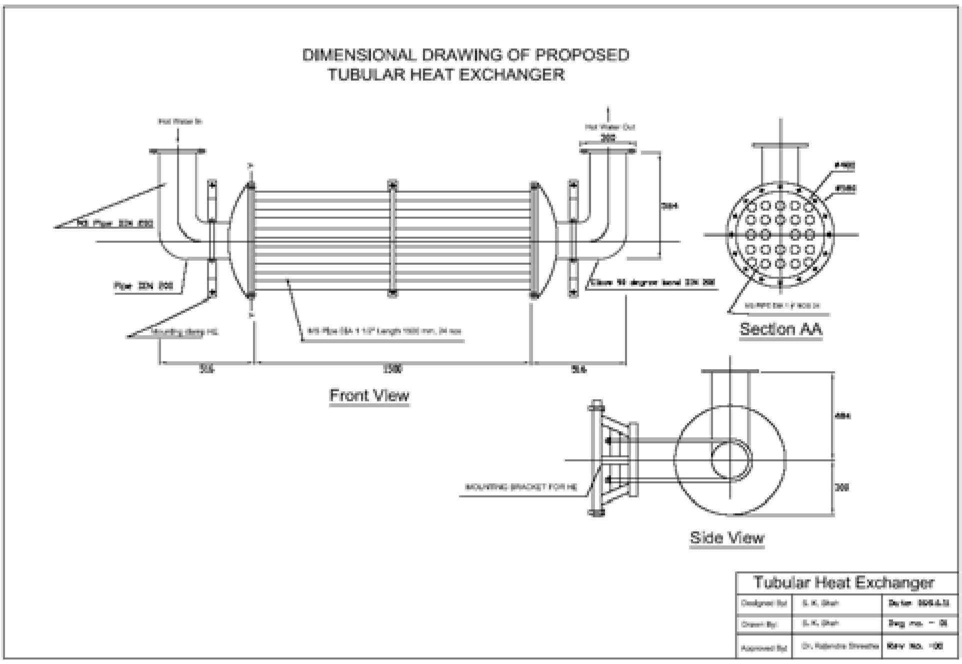

Figure 5:

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h = Heat transfer coefficient

A = Heat transfer surface area

Figure 6:

.1 j) Financial Analysis

Based on the Price Schedule received from Om Shakti Engineering Pvt. Ltd., Gothatar-9, Kathmandu and the Costs associated to entire modification works as determined, financial analysis for implementing the proposed modification has been presented below to confirm the economical viability of the system. Thus, the Payback Period comes to be just two months if we consider the benefits that are achieved with new system which otherwise is being lost due to problems occurring in the existing CWS as well as the potential savings that can be achieved from saving on Penstock water.

V.

.2 Conclusions

Based on detailed study, analysis and design, the proposed design modification of the CWS, MMHPP sounds technically feasible. The purpose of this research study is not just limited for the betterment of NEA in Nepal but also it is highly recommended to implement this proposed new system in the hydropower utilities around the globe.

[Holman ()] , J P Holman . 1997. McGraw-Hill, Inc. New York. (Heat Transfer Eighth edition)