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Combination of Axial Exhaust Turbine and Direct Contact Condenser Maibarara Geothermal Power Plant

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ABSTRACT

Maibarara Geothermal Power Plant commenced commercial operations on February 8, 2014. A combination of the axial exhaust type turbine and the direct contact type condenser is applied in the plant. When using the direct contact condenser, water level in the condenser must be monitored and the design of protection logics is critical to protect the turbine last stage blades from water back flow from the condenser to the turbine. Therefore, various protection logics and arrangements are considered in order to minimize such risks. Since the condenser is horizontally connected to the turbine when the axial exhaust turbine is used, additional protections are mandatory. This paper introduces logics and arrangements for the turbine and condenser at Maibarara Geothermal Power Plant which can reduce the risk.

1. INTRODUCTION

Maibarara Geothermal Power Plant is located in Sto. Tomas, Batangas, the Philippines, and is at the foot of Mt. Makiling. The plant commenced commercial operation on February 8, 2014. It is the newest geothermal power plant in the Philippines and the first one under administration of President Benigno S. Aquino. This is also the first geothermal power plant which applies the Renewable Energy Law (2008). The owner and operator of the plant is Maibarara Geothermal Inc. (MGI) which is a joint-venture company owned by PetroGreen Energy Corp., TransAsia Oil & Energy Development Corp. and PNOC Renewables Corp. The project is an integrated power facility comprising of steamfield, power station and transmission line. The steamfield was designed and constructed by MGI and the power plant was built by EEI Corp. under the EPC contract. The main types of equipment in the power plant such as turbine, generator and condenser were designed and manufactured by Fuji Electric Co., Ltd.

Figure 1: Overview of Maibarara Geothermal Power Plant.

Figure 2: Location of Maibarara Geothermal Power Plant.

The geothermal fluid is produced from two production wells at the steamfield. The steam separated from the separator is piped to the turbine by way of the steam scrubber at the power plant. The power plant is located just next to the steamfield.

The power plant utilizes the axial exhaust type geothermal steam turbine coupled with the direct contact type condenser. This configuration saves building cost of the turbine generator. The condenser is of the barometric type.

This paper describes the technical features of the installed geothermal steam turbine and condenser, as well as various technical considerations for the combination of the axial exhaust type geothermal steam turbine and the direct contact type condenser.

2. TECHNICAL FEATURES OF THE TURBINE AND THE CONDENSER

2.1 Axial Exhaust type Geothermal Steam Turbine

Employing the axial exhaust type geothermal steam turbine in the power plant allows the construction cost of turbine foundation and powerhouse to be reduced. The turbine has seven stages of reaction type blades and the blade of last stage is 20” (510mm). Table 1 shows some specifications of the turbine and Figure 2 shows the turbine installed in the power house.

Table 1: Design parameters of the turbine.

Rated output	20 MW
Rated speed	3,600 rpm
Inlet steam pressure	6.6 bar abs (96 psia)
Inlet steam flow	42 kg/s (68.6 kpph)
NCG in steam	2.5 %

Figure 3: An overview of 20MW Geothermal Steam Turbine

2.2 Direct Contact Condenser – Barometric type

The condenser is of the direct contact type. The cooling water supplied from the cooling tower is sprayed onto the turbine exhaust steam to cool it off. Figure 4 shows the outline of the condenser.

Figure 4: Outline of the condenser.

Since a large amount of cooling water will flow into the condensing zone to cool the turbine exhaust steam, one concern is the back flow of such large amount of cooling water to the turbine. Various technical considerations are integrated in the plant design to eliminate the concern, which are detailed in the next section, and one of the solutions is to adopt a barometric type condenser. The barometric type condenser is used at some geothermal power plants; however, the majority of the geothermal power plants are still using the low level type condenser. Figure 5 shows a comparison of those two types of condensers.

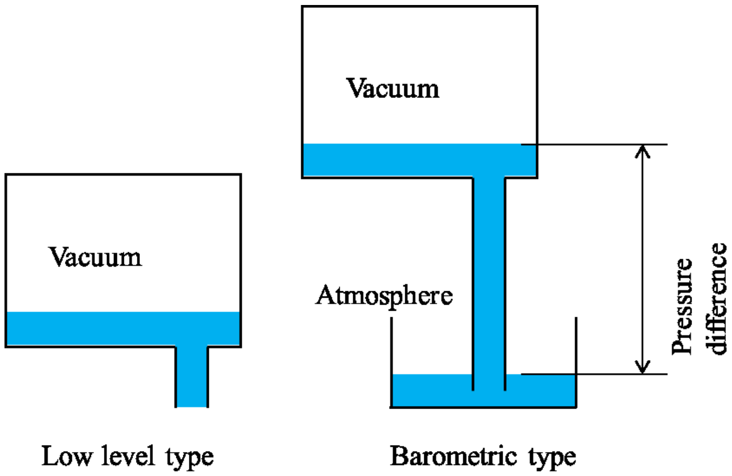

Figure 5: Comparison of low level type and barometric type condenser.

The barometric type condenser is originally used to raise the condenser installation level, which creates a static head between the condenser vacuum and the atmospheric pressure. The mixture of the cooling water and the condensate flow out of the condenser and goes into the hotwell pit. The condenser can be installed on the ground level by making deep hotwell pit below the condenser. The commonly used low level type condenser requires barrel type hotwell pumps to extract the mixture of the cooling water and the condensate. The low level type condenser imposes limits on the capacity of the hotwell because of its dimensions. On the other hand, the hotwell pit can be designed with a larger capacity for the barometric type condenser as the pit is constructed outside of the condenser.

3. COMBINATION OF AXIAL EXHAUST TURBINE AND DIRECT CONTACT CONDENSER

As explained above, there is a concern about the back flow of water from the condenser to the turbine in case of emergency. Back flow water to the turbine would result in heavy damages of the turbine blades, which is always an issue associated with the direct contact type condenser. When the downward exhaust turbine or the upward exhaust turbine is applied, water will flow back to the turbine, in case of emergency, but only after the condenser is fully filled with water. However, when the axial exhaust turbine is applied, water will flow back to the turbine before the condenser is filled with water due to its special arrangement. Therefore extra careful considerations in the plant design must be taken into account when applying a combination of axial exhaust turbine and a direct contact condenser. The barometric type condenser is one of the solutions to avoid such risk, because it can have a large capacity hotwell positioned below the condenser.

In general, the following logics are considered for geothermal direct contact condensers to avoid back flow of cooling water to turbines.

1) High water level in the condenser - alarm

2) Very high water level in the condenser – turbine trip
– condenser cooling water valves closed emergently
– siphon breaker at cooling water inlet line open

3) Both hotwell pumps stop – turbine trip
– condenser cooling water valves closed emergently
– siphon breaker at cooling water inlet line open

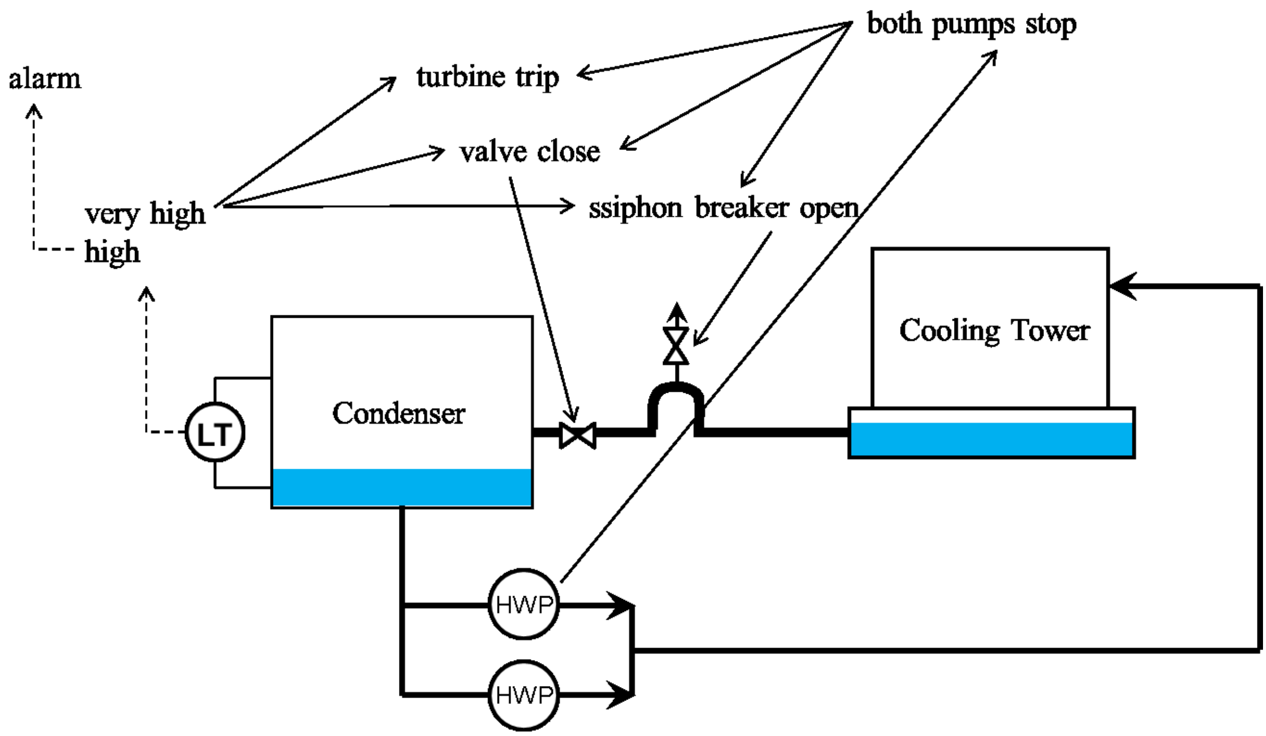

Figure 6: Standard logic around condenser.

Figure 6 shows the arrangement of the above logics. Cooling water will flow from the cooling tower to the condenser with an arrangement that provides a pressure difference and the condenser vacuum, a level difference between the cooling water cold water basin and the condenser is also required. In case of emergency as illustrated in 2) and 3) above, the flow of cooling water to the condenser should be stopped immediately to avoid excessive water accumulation in the condenser so that water will not reach the turbine. In the condition of standard arrangement, opening the siphon breaker is quite effective to stop the water flow in addition to closing the condenser inlet valves. In the standard arrangement, the vacuum breaker is manually opened and controlled by operation engineers, because breaking vacuum will result in higher turbine exhaust pressure which is not good to the turbine last stage blades in general.

In addition to the above arrangement for the standard direct contact type condenser, the following designs should also be considered to increase safety in case of emergency as a result of internal HAZOP discussions.

4) Both hotwell pumps stop or very high water level in the condenser – vacuum breaker open

5) Redundant siphon breakers, pneumatic and motor operated

After applying the above two logics, the risk of water back flow to turbine can be minimized to a similar level as those for downward exhaust type and upward exhaust type turbine.

4. CONCLUSIONS

During the commissioning period, the units were tested such that the designed protection logics are properly actuated to securely protect the turbine. After the units commenced into commercial operation, Maibarara Geothermal Power Plant has continuously operated with high stability. As the axial exhaust turbine has become increasingly common for thermal power plants, it will also become a part of standard arrangement for geothermal power plants.