

Axial Exhaust Steam Turbine and Low Level Type Direct Contact Condenser for Kamojang Geothermal Power Plant Unit5 in Indonesia

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Keywords

Geothermal steam turbine, condensing, axial exhaust, low level type, direct contact, dry steam, Kamojang, Indonesia

ABSTRACT

Kamojang Geothermal Power Plant Unit5 was put into commercial operation on July 15th, 2015. The plant applies the combination of the axial exhaust type turbine and the low level type direct contact condenser. Since a condenser is horizontally connected to a turbine when a axial exhaust turbine is used, additional protection consideration is mandatory to protect the turbine from water back flow from the condenser. Therefore, various protection logics and instrumentation (redundancy) are considered to minimize such risks. This paper introduces those logics and instrumentation for the turbine and the condenser at Kamojang Geothermal Power Plant Unit5.

1. Introduction

Kamojang Geothermal Power Plant Unit5 is located in Kamojang geothermal area in West Java, Indonesia. It takes approximately five hours by car from Jakarta or two hours from Bandung city, the capital city of West Java, to this power plant. Kamojang geothermal area is at the mountainside of Mt. Guntur, and it is famous for the vapor dominated geothermal field. Four power plants have been operating, and additionally Unit5 was put into commercial operation on July 15th, 2015. The plant owner and operator is PT. Pertamina Geothermal Energy (PGE) who is a subsidiary company for geothermal power generation of Indonesian national oil company, PT. Pertamina. PGE is strongly leading development of geothermal power plants in Indonesia according to a presidential order which encourages electrical power development and energy source diversification.

The project consists of Steamfield Above Ground System (SAGS) and power plant, and Fuji Electric Co., Ltd. supplied the major equipment in the power plant such as turbine, generator and condenser.

The geothermal steam is produced mainly from two production wells for Unit5. Kamojang has a vapor dominated geothermal reservoir and produces saturated steam, therefore a flash vessel / separator is not required for steam-brine separation. The steam is transferred directly from the

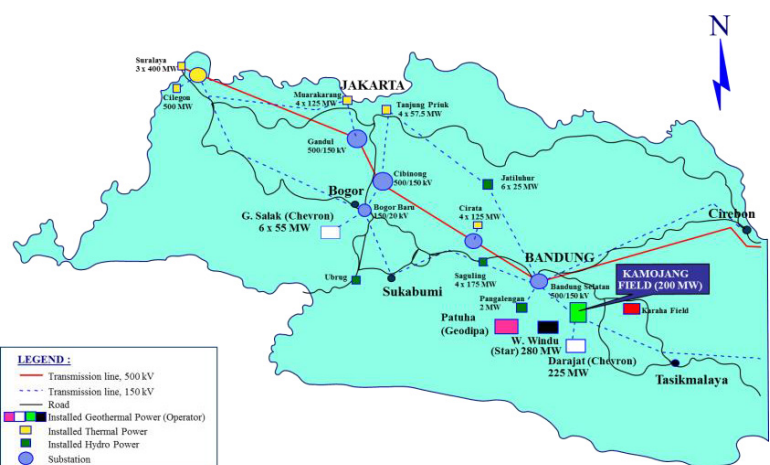


Figure 1. Kamojang and other West Java geothermal area map (PGE, 2015).

production wells to the power station via the pipe line approximately 3km long, and it is introduced to the steam turbine after the final moisture elimination by the cyclone type separator / scrubber.

In order to enable the turbine generator building cost and erection period to be reduced, the power plant utilizes the axial exhaust type geothermal steam turbine. In general, the axial exhaust turbine has advantages as shown in Table 1.

On the other hand, because the turbine is horizontally connected with the direct contact type condenser, a risk of water back flow from the condenser to the turbine shall be considered, and various protection logics and instrumentation (redundancy) shall be applied to minimize such risks. This paper introduces those logics and instrumentation for the turbine and the condenser at Kamojang Geothermal Power Plant Unit5.

Table 1. Characteristics for each types of turbine exhaust direction.

Exhaust direction	Down exhaust	Upper exhaust	Axial exhaust
Foundation height	Tall	Low	Low
Building height	Tall	Middle	Low
Pressure loss in exhaust part	deemed zero (if internal parts are negligible)	High	Recover

2. Technical Features of the Turbine and the Condenser

2.1 Axial Exhaust Type Geothermal Steam Turbine

The power plant utilizes the axial exhaust type geothermal steam turbine, which enables to reduce construction cost and period of the turbine foundation as well as the powerhouse. The turbine has 7 stages of reaction type blades and the last stage blade is 22" (555mm). Table 2 shows the specifications and Figure 2 shows the turbine installed in the power house.

Table 2. Design parameters of Turbine.

Rated output (Net)	35 MW
Rated speed	3,000 rpm
Inlet steam pressure	6.5 bar abs
Inlet steam flow	76.11 kg/s
NCG in steam	1.0%

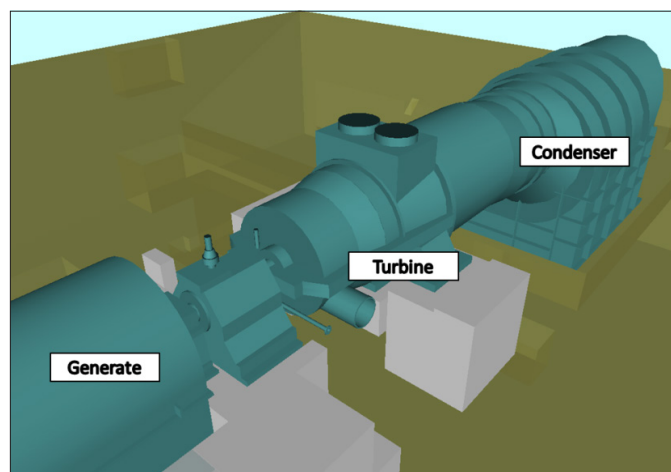


Figure 2. Brief 3D model of Generator-Turbine-Condenser arrangement.

2.2 Direct Contact Condenser – Low Level Type

The condenser is direct contact type and located to the axial direction of the turbine. At the condenser, the exhaust steam and the non-condensable gas (NCG) from the outlet of the steam turbine is condensed and cooled respectively by contacting with cooling water from the cooling tower. The cooling water for the condenser is supplied from the cooling tower basin by the pressure difference between cooling tower (atmospheric pressure) and the condenser (full vacuum during normal operation). The cooling water flow rate will be set by adjusting the condenser inlet valve positions. The cooling water line splits into two (2) paths and there are two (2) inlet valves for the better controllability.

The low level type is applied to the condenser of this plant. Compared to the barometric type, the low level type condenser does not require a deep hotwell pit and it gives an advantage on reducing construction period. Figure 3 shows a comparison of those types. In the case of the low level type condenser, hotwell capacity is smaller than the barometric type, and it has an effect on the possibility of water back flow to the turbine. Therefore technical considerations to block a back flow of cooling water into the turbine are required to be more reliable.

The condenser also receives the drain from the gas extraction system (GES) and the recirculation flow from the hotwell pump (HWP) outlet when

Table 3. Design parameters of Condenser.

Type	Jet spray direct contact
Inside pressure	0.1 bar abs
Circulating water flow	8,100 m ³ /h
Circulating water temperature	26 deg.C

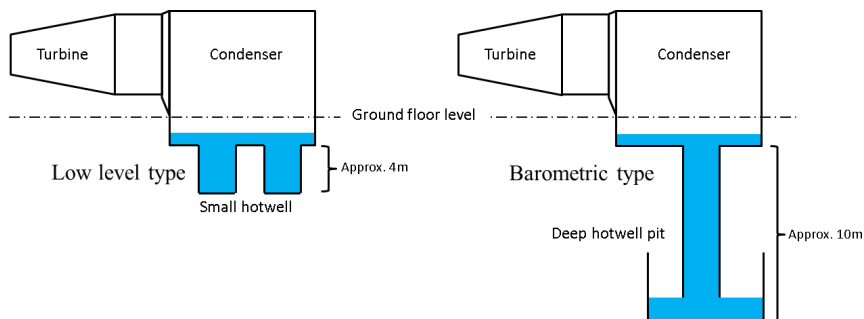


Figure 3. Comparison of low level type and barometric type.

the cooling water flow rate is low such as during plant start-up. The condenser level instruments consist of four (4) level transmitters; each hotwell of condenser has two level transmitters.

3. Combination of Axial Exhaust Turbine and Direct Contact Condenser

There is a concern of water back flow from the condenser to the turbine in case of the circulating water system failure due to emergency condition such as black out. In case of all HWP's stop by black out, pumping water out of the condenser will be stopped, however the water will continue to flow into the condenser by the pressure difference between the condenser vacuum and the atmospheric pressure, and then the water level will increase abnormally high. This kind of abnormal water level increasing is always associated with the direct contact type condenser.

In the case of water level increasing, subsequent water flow back to the turbine is a concerned. When the downward exhaust turbine or the upward exhaust turbine is applied, the possibility of water flow back to the turbine is negligible because water will flow back to the turbine after the condenser is fully filled with water. On the other hand, when the axial exhaust turbine is used, water will flow back to the turbine before the condenser is fully filled with water because they are connected horizontally. Therefore very careful considerations in the plant design are mandatory to apply a combination of an axial exhaust turbine and a direct contact condenser.

In general, the logics shown in Table 4 are considered to geothermal direct contact condensers to avoid back flow of cooling water into the turbines.

Standard arrangement of the cooling water from the cooling tower to the condenser is to let the water flow by the pressure difference between the condenser vacuum and the atmospheric pressure via a siphon. In case of events B and D in Table 4, cooling water flow to the condenser shall be immediately shut off to avoid excessively high water level in the condenser so that the water will never reach to the turbine. One of the means for shutting down the cooling water flow is to close the cooling water condenser inlet valves (①), and the other is to open the siphon breaker valve (②). Because of the standard arrangement, siphon breaking is the essential way to stop cooling water supply completely. Therefore the redundant siphon breaker valves were used to make sure its action.

In case of one HWP trip, the turbine and generator load will be decreased down to 50% by interlock (run-back operation) and one condenser cooling water inlet valve will be closed and another is throttled to reduce the main cooling water down to approximately 50% by interlock.

In addition to the cooling water from the cooling tower, the drain from the GES is also required to be shut off even if its amount is small. There are two intercoolers for condensing ejector motive steam in the GES, and cooling water is supplied from the cooling tower by a pump. The water supply to GES can be shut off by the motor operated valve on the common line for GES, and moreover an air-operated valve is used at each intercooler to stop cooling water immediately (these valves are shown as ③ in Figure 4).

Figure 4 shows the arrangements of the above logics. Applying the above logics reduces the risks of water flowing back to the turbine, and it can be minimized to similar level of those for downward exhaust type and upward exhaust type turbine.

Table 4. Protection logics to avoid water back flow to turbines.

Event	Action
A: High water level in the condenser	alarm
B: Very high water level in the condenser	turbine trip (2 out of 3 voting) all cooling water condenser inlet valves (①) emergency close siphon breaker valves (②) at cooling water inlet line open
C: One HWP stop	turbine and generator load decrease to 50% one cooling water condenser inlet valve (①) close one cooling water condenser inlet valve (①) throttle
D: Both HWP's stop	turbine trip (2 out of 3 voting) all cooling water condenser inlet valves (①) emergency close siphon breaker valves (②) at cooling water inlet line open

(The circled numbers are corresponding to the numbers in Figure 4.)

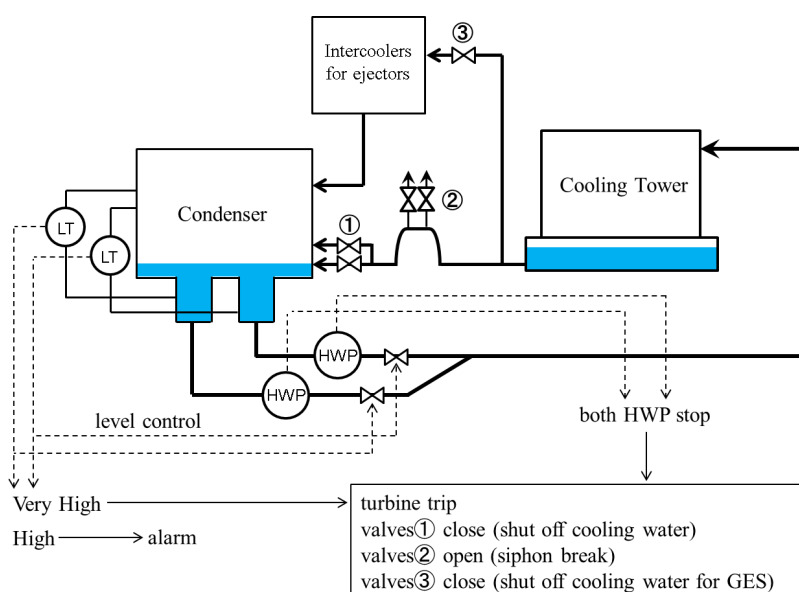


Figure 4. Configuration of Protection logics to avoid water back flow to turbines.

4. Conclusions

As is well known, the axial exhaust turbine has an advantage of reducing the construction cost and period. The combination of the axial exhaust turbine and the direct contact condenser brings this advantage to geothermal power plants, and all the more so with the low level type condenser. The well-considered protection logics realize the minimization of risks related to this arrangement and will encourage geothermal developments with limited project time and resources

5. References

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