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Design of Wayang Windu Unit 2 Geothermal Power Station

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ABSTRACT

Wayang Windu geothermal power station, owned and operated by Star Energy Geothermal (Wayang Windu) Limited, has been operating its first unit (Unit 1) from 1999. Although construction of the second unit (Unit 2) was also scheduled at the same time as Unit 1, it was suspended due to the economy crisis. At that moment, the civil and architectural works including all equipment foundations were completed.

After a decade, the Unit 2 construction was resumed. It was not just a recommencement of the suspended works; it also involved some design improvements on the performance and operability under the restrictions of the existing constructs and materials. This paper introduces representative items of those improvements.

The construction of Unit 2 was completed ahead of the original schedule and the commercial operation started from February 2009 with producing more than the target gross output of 117MW.

1. INTRODUCTION

Indonesia is a leading country in terms of geothermal power generation, and is expected to have the world largest potential of the geothermal resources. In recent years, the Indonesian government has been strongly promoting extensions of the geothermal power generation aimed at a substitution of a certain part of the consumption of oil and other fossil fuels.

West Java, where the Wayang Windu geothermal power station is located, is one of the major regions abundant in geothermal resources in Indonesia. Development of geothermal power stations in this area has been most progressed due to its geographic advantages such that the central cities, Jakarta and Bandung, are located nearby.

Figure 1: Location of Wayang Windu

Wayang Windu geothermal power station has been owned and operated by Star Energy Geothermal (Wayang Windu) Limited, SEG (former Magma Nusantara Limited). The power station is named after two mountains Gunung Wayang and Gunung Windu. ("Gunung" means a mountain in Indonesian.)

Construction of Wayang Windu geothermal power station started in 1997. Originally, scope of the construction was two identical generating units ("Unit 1" and "Unit 2") with gross output of 110MW for each, scheduled to start operation around the same time. However, due to the Indonesian economic crisis which coincidentally grew with the progress of the Wayang Windu construction project, continuation of Unit 2 construction fell into difficulties. In the result, only the civil and architectural works were continued toward completion as they had already commenced for both units, and all other works associated with Unit 2 were suspended.

Just after a decade, in 2007, the construction of Unit 2 was resumed. In this new project, it was aimed to make improvements to the existing design; SEG had accumulated knowledge of the actual operating conditions through their experience of plant operation and maintenance, and established a concept of design improvements. The implementations of the concept which made by Fuji Electric Systems (FES) are introduced in Clause 3 of this paper.

2. OVERVIEW OF POWER STATION

Wayang Windu geothermal power station is located in Pangalengan, approximately 40km south of Bandung, West Java, Indonesia. A tea plantation surrounds the power station and its altitude is about 1700m above sea level. The ambient conditions are typical for highland climate in the tropical regions; the atmospheric pressure is around 830mbar, most of the time the ambient temperature is below 20deg.C, and the relative humidity is close to 100%.

Figure 2: Photo of the power station viewing from the tea plantation

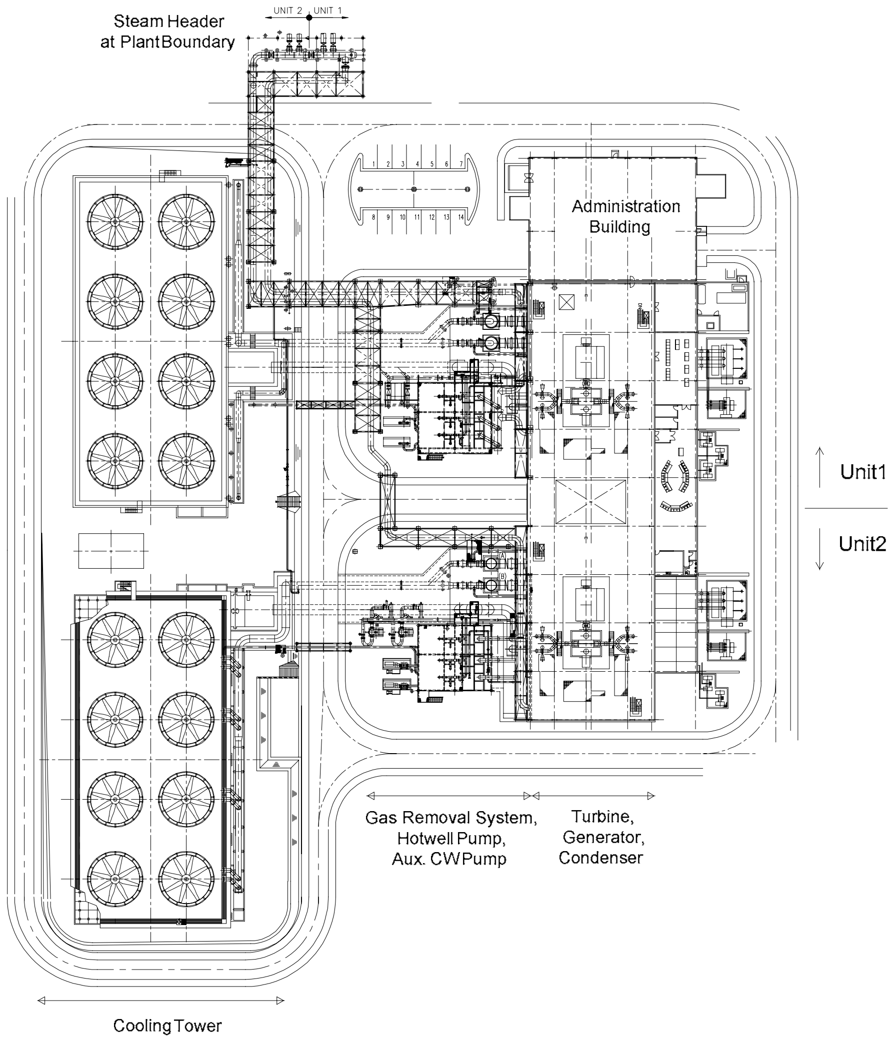

Figure 3: Layout of power station

This power station adopts a single-flash, condensing system for power generation. Unit 1 and 2 are arranged in parallel as shown in Figure 3. The geothermal steam delivered from SAGS (Steamfield Above Ground System) is received by the steam header at the power station boundary. Inside the power station, Unit 1 and 2 have separate systems for the main processes such as steam supplies and cooling water circulations. Also the electricity generated by the Unit 1 and 2 turbine-generators is dispatched to the substation individually. Each unit has a single-cylinder double-flow steam turbine with 697mm (27") long last row blades, associated with a 137.5MVA / 13.8kV TEWAC generator.

3. DESIGN IMPROVEMENT IN UNIT 2

This clause outlines the improvements implemented in the Unit 2 design from the original design employed for Unit 1.

3.1 Plant Performance

The first priority of the SEG improvement concept was increase of the power output. However, as described above, the construction works and material procurement for Unit 2 was partially completed. Especially, the all foundations had been made according to the original equipment designs, change of the equipment dimensions and weights was limited. In addition, it was decided to make the turbine, generator and condenser to be identical to Unit 1 in order to utilize the existing resources as much as possible.

Consequently, restrictions for each equipment were as listed below, which let our study turn to focusing on lowering the condenser pressure rather than increasing the steam pressure or flow.

- Steam turbine: To be identical to Unit 1
- Condenser: To be identical to Unit 1 (Only nozzle size and numbers could be changed)
- Hotwell Pump: Dimensions to be almost same as Unit 1 due to the pit size
- Cooling Tower: Length and width to be almost same as Unit 1 due to the cold water basin size

To lower the condenser pressure, increase of the cooling water flow and decrease of the cooling water temperature are required.

Increase of the cooling water flow affects the capacity of hotwell pumps and cooling tower. For the hotwell pumps, the only way to increase capacity was modification of impellers since shifting to a larger model was not possible due to the dimension restriction. Also the increase of cooling tower capacity was limited as the basin size was unchangeable. As a result of detail studies, the rated cooling water flow was increased about 7%.

Decrease of the cooling water temperature requires better cooling tower performance, i.e. the approach was to be made smaller by increasing the heat exchange surface area. For this purpose, higher cooling tower was adopted; the new height was set to be 18m whereas the original height was 12.5m from the basin curb to the top of fan stack. The rated approach of cooling tower decreased from 8deg.C to 5.5deg.C.

According to these design changes, the condenser pressure was lowered from 0.12bar to 0.11bar. Comparison of parameters between Unit 1 and 2 is shown in Table 4.

Table 4: Comparison of process values between Unit 1 and 2

	Unit 1	Unit 2
Condenser Pressure	0.12 bar(a)	0.11 bar(a)
Cooling water flow	4.64 m^3/s	4.97 m^3/s
Approach of cooling tower	8 deg.C	5.5 deg.C
Cooling water temperature (*)	23.5 deg.C	22.5 deg.C

* Note:
Since the design wet bulb temperature was changed from 15.5deg.C to 17deg.C based on the present site condition, the apparent difference of rated cooling water temperature between Unit 1 and 2 is smaller than the actual operation.

The overall plant cycle of Unit 2 is shown in Figure 5.

3.2 Integrated Control System

SAGS and the power station, whose process flow is indicated in Figure 6, have an integrated control system. Integration is implemented by the following control functions.

Primary Pressure Control (PPC)

Pressure control of the separators in SAGS and steam header at the boundary of power station, by manipulating the turbine governor and SAGS vent valves "PPC-G" is a sub-module of PPC, it controls the pressure by modulating the opening of turbine governor valves through Automatic Power Control (APC), one of the functions equipped in the turbine governor. "PPC-V" is another sub-module of PPC. It controls the pressure by modulating the vent valves in SAGS.

Secondary Pressure Control (SPC)

Pressure control of the steam header by manipulating the wellhead control valves

Secondary Load Control (SLC)

Turbine-generator output control by manipulating the wellhead control valves

The main feature of the original control concept was the optimized steam pressure control by coordinated action of PPC-G and PPC-V, which was intended to maintain the steam pressure stable and minimize steam venting to the atmosphere. However, in the actual operation of Unit 1, higher priority was given to a fine tuning of the turbine-generator load in order to generate maximum output obtainable by the operating condition at every moment. For this purpose, PPC-G was usually disabled and the operators were directly manipulating the APC of turbine governor; as there is a limitation on the turbine internal steam flow rate, the maximum obtainable output varies depending on the ambient condition, especially the wet bulb temperature. Therefore, the operators increased the target of APC during the night time, and vice versa in the day time. Based on this situation, reconstruction of the control concept was done during the Unit 2 engineering. The main subjects were,

a) Automate the operators' APC manipulation

b) Optimize the role of each control function

c) Add necessary interlocks for the combined operation of Unit 1 and 2

(a) Automation of APC Manipulation

In order to automate the operators' APC manipulation, a function to maintain the turbine internal flow rate was required. As the internal flow rate is represented by the turbine wheel chamber pressure, a control function to adjust the set value of APC by monitoring the wheel chamber pressure was added. This function was named "WCPC" (Wheel Chamber Pressure Control).

(b) Optimization of Control Function Roles

The fact that the turbine-generator output had been adjusted by using APC rather than SLC is considered to have suggested that positional relation between a control device and its corresponding controlled object should be as close as possible. As a result of many discussions in the design review and operation checks during the commissioning, roles of the control functions in the normal operation was configured as follows.

- Turbine-generator output: controlled by WCPC

- Separator and header pressure: controlled by PPC-V

- Production of wellhead: controlled by SPC

In this configuration, some steam venting to the atmosphere is expected due to the difference of the response time between PPC-V and SPC, but it is still within the acceptable level. In case the venting must be more strictly limited, WCPC will be switched to PPC-G.

(c) Addition of Interlocks for Unit 1 & 2 Combined Operation

Normally, Unit 1 and 2 SAGS operates with all crossover valves opened as shown in Figure 6, which is called "Combined Operation". In this operation mode, some behaviors of the controllers have to be different from the independent operation of each unit to avoid interferences between Unit 1 and 2. The required behaviors are listed below. Interlock logic circuits were added to establish (or check if established) these conditions when Unit 1 and 2 is going to shift to Combined Operation mode.

- PPC-V operates the all vent valves of Unit 1 and 2 sequentially

- PPC-G has to be disabled in both Unit 1 and 2

- SPC can be enabled in either Unit 1 or 2

- The vent valves rapidly open when a turbine-generator of either Unit 1 or 2 trips.

3.3 Cleaning Facility of Cooling Tower Intake Screen

Cleaning of the intake screens installed in a corner of the cooling tower basin is one of the touch works in the power station operation. Typically, screen cleaning is done with the following procedure: Insert a spare screen → Withdraw the screen to be cleaned→ Clean the screen by water jet→

Store the cleaned screen as a spare As the screens are large and heavy (dimension is 6.2m height x 2.7m width), the operators have to insert and withdraw screens by using a hoist every time. In Unit 2, a new cleaning system was designed which enables cleaning without withdrawal of the screens. As shown in Figure 7, a vertical guide which moves horizontally by hand is provided for each screen.

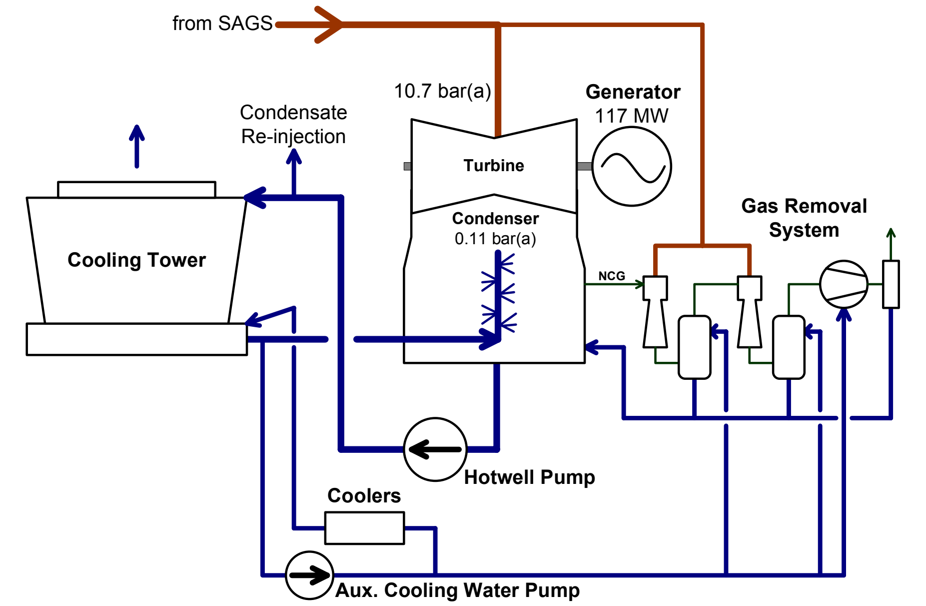

Figure 5: Unit 2 plant cycle

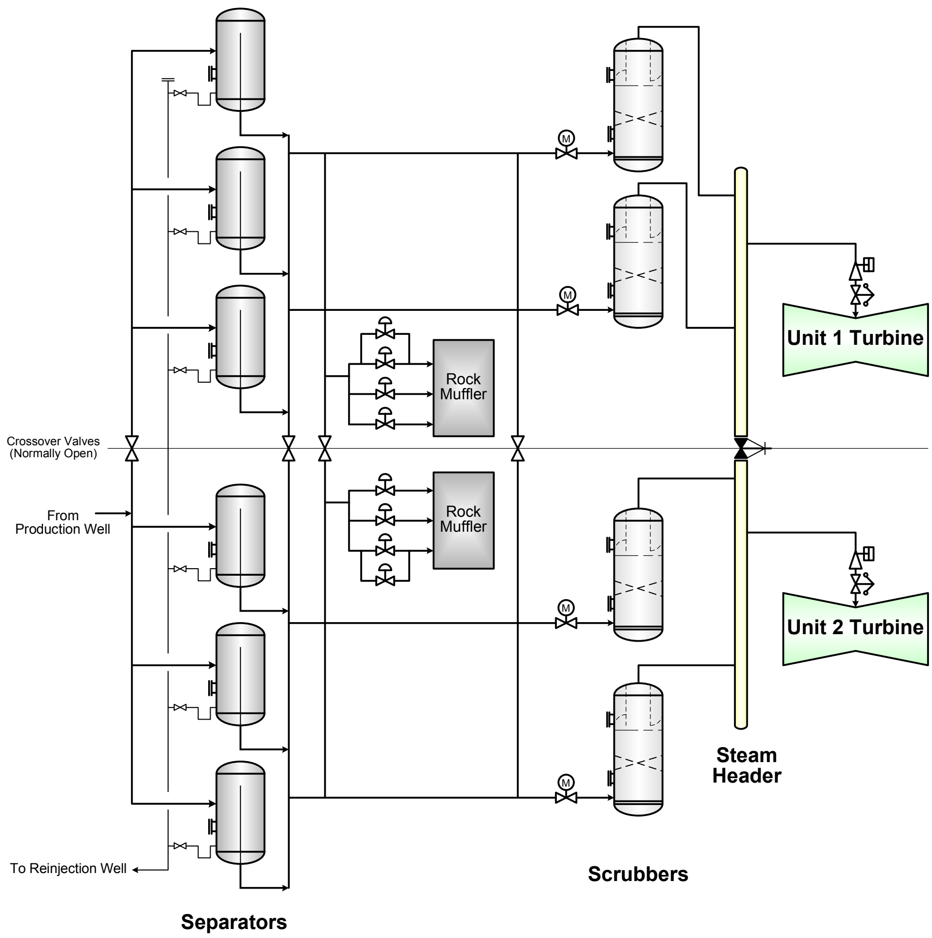

Figure 6: Process flow of SAGS and power station

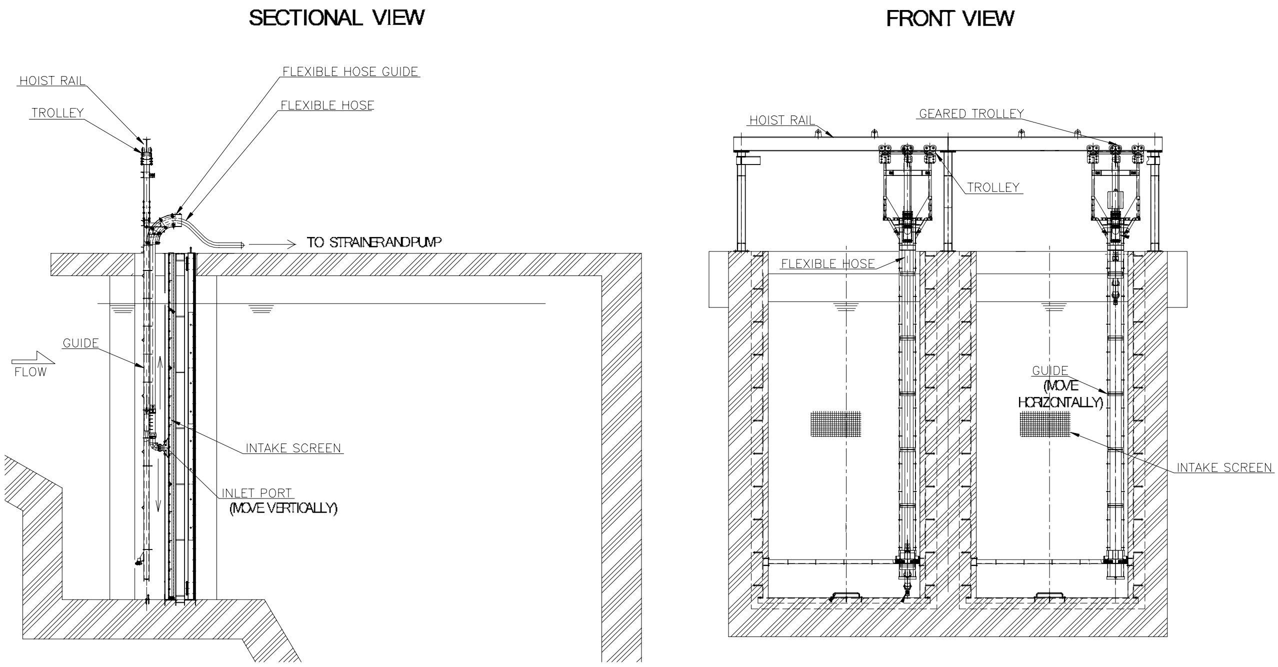

Figure 7: Intake screen cleaning system

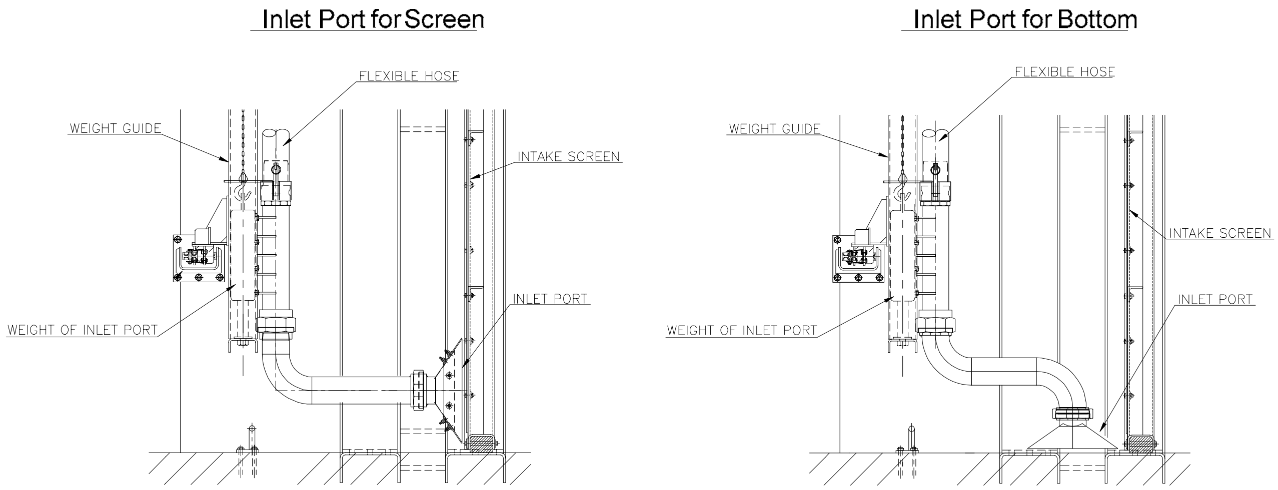

Figure 8: Samples of inlet ports for intake screen cleaning system

By lifting up and down an inlet port through this guide, trashes on any part of the screen can be drawn by the screen cleaning pump. The inlet port is changeable and the trashes accumulated on the bottom of the pit can be also removed as shown in Figure 8.

This new cleaning system enabled every regular cleaning with only 2 or 3 operators, and the time for preparation was significantly reduced.

4 CONCLUSION

Construction of the Wayang Windu Unit 2 geothermal power project has been successfully completed at the end of February 2009, about 2 weeks ahead of the contract schedule, and immediately the commercial operation followed.

Thanks to the SEG's solid experiences and knowledge on the actual plant operation, FES was able to make the new designs for Unit 2 with well-balanced flexibilities and simplicities. As a result, Unit 2 has been operating with superior performance on both the power output and steam consumption rate. Wayang Windu Unit 2 could be a good reference of large single-flash geothermal power plant in the world.

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