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Technical Features of Kawerau Geothermal Power Station, New Zealand

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ABSTRACT

The Kawerau Geothermal Power Station owned by Mighty River Power Limited (MRP), New Zealand was put into commercial operation in August 2008. The nominal net output is 100MW and this is the largest single geothermal development in NZ in more than 20 years. Fuji Electric Systems Co., Ltd. (FES) was the technical leader of the project to deliver the plant to MRP under Engineering, Procurement and Construction (EPC) contract.

The Kawerau Geothermal Power Station has unique technical features in its concept and system designs. This paper introduces and outlines key features of the steam separation and washing system, brine reinjection system, power generation facility and coordination control of steamfield and power station.

1. INTRODUCTION

The New Zealand government expressed their vision of a sustainable, low emissions energy system with the New Zealand Energy Strategy (NZES) in October 2007. In this strategy, the government is introducing a target for 90 percent of electricity being generated from renewable sources by 2025. This new Kawerau Geothermal Power Station greatly contributes to achieve this target.

Kawerau is placed at the northern end of the Taupo volcanic zone on the North Island of New Zealand. (Figure 1&2) It takes approximately four hours by car to the southeast from Auckland. Kawerau geothermal power station is located in the industrial area of Kawerau.

FES was responsible for the conceptual and detail engineering, overall project management, installation supervision and commissioning & start-up of the power station including both Steam Separation System and Power Generation Facility.

The project proceeded with the fast and smooth progress as below.

- August 2006: Resource consents received
- November 2006: EPC project commencement
- October 2007: Delivery of generation equipment (turbine, generator , condenser)
- April 2008: First steam delivery from wells to power station
- August 2008: Power station operational

The power station commenced commercial operational more than one month ahead of schedule in compliance with the contractual performance guarantees. This is the outcome of the high technical performances and great contributions from all related parties, i.e., the owner, civil partner, regulatory agencies, erection contractors, manufactures, designers and their staff.

Figure 1: Map of New Zealand Geothermal Fields, NZGA

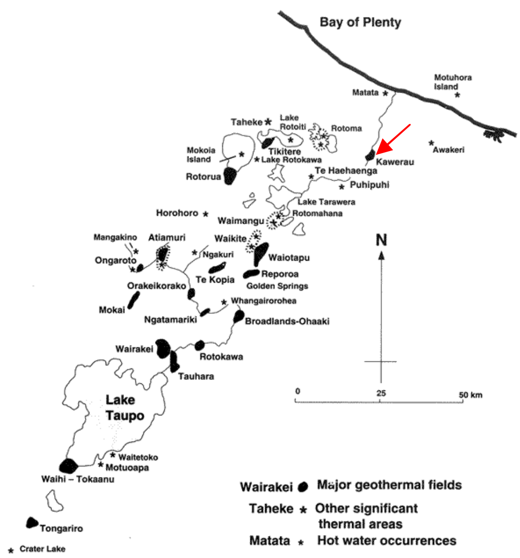

Figure 2: Map of Geothermal Fields in the Taupo Volcanic Zone, NZGA

2. POWER STATION

The site used to be an airstrip. The land is quite flat at 18m above sea level and 150m x 350m approximately rectangular shape. This site condition is rare for a geothermal power station, which is usually in a hilly or mountainous area. The Steam Separation System as well as the Power Generation Facility is sited within the power station boundary. The equipment, buildings and ponds are well arranged in the available space to provide good access for operation and maintenance, as shown in the Figure 3. Figure 4 shows the plant view.

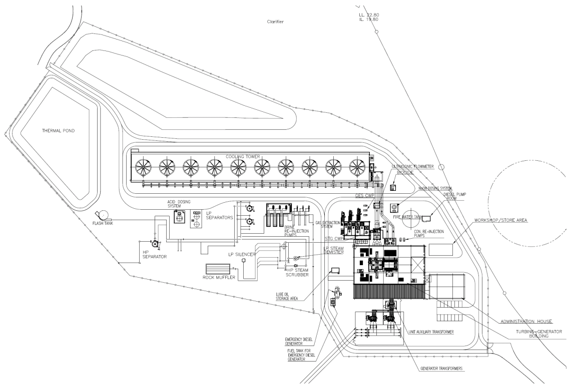

Figure 3: Plot Plan

Figure 4: Photograph of Entire Power Station

The process interface between the steamfield and the power station is incoming geothermal two-phase fluid and return of brine and condensate for reinjection, each at the power station perimeter fence. The plant is designed for a rated two-phase fluid flow of 45,000 tonnes per day and a maximum of 55,000 tonnes per day. Six production wells of 1,900 - 2,100 m depth, supply two-phase fluid with an enthalpy of approx. 1300kJ/kg. To provide flexibility to changing reservoir conditions the plant is designed to cover a range of enthalpy, NCG content and chemistry.

3. STEAM SEPARATION SYSTEM (SSS)

SSS receives the two phase fluid delivered from the production wells, separates the steam and brine, remove impurities in the steam, then delivers the purified steam to the steam turbine. Figure 5 shows the SSS system overview. The details are described in the following paragraphs.

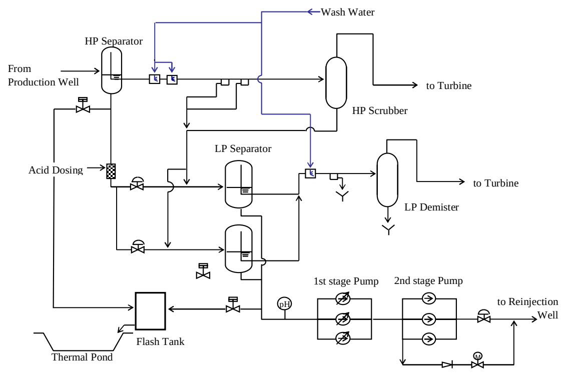

Figure 5: SSS System Overview

At first, a high pressure (HP) separator receives the geothermal fluid from the production wells and separates it at approx. 12 bara. The separator is a vertical, Webre type cyclone with a spiral two phase inlet, internal steam pipe with side outlet and a tangential brine outlet from the steam drum. Brine flows from the steam drum to the brine drum through a loop seal. The HP separator is approx. 20m high and has a diameter of approx. 3.3 / 4.0m for the steam zone/ brine drum respectively. (Fig.6) The delivery and installation of a large vessel such as this required significant coordination with other construction work in the area.

Figure 6: Photograph of HP separator

The separated steam may carry minor quantity of impurities such as brine and volatile silica. The operating regime envisages that the steam turbine will be able to achieve four years operation between major overhauls, when the turbine will be opened up for internal inspection and cleaning. This resulted in a strong focus to achieve high steam purity at the steam turbine inlet. Particular attention was paid to the design of three key elements, namely: separator, purifier and steam-line scrubbing system. The two-phase fluid gathering system results in relatively short steam piping compared with plant using well-head separators. That is where separators are located near productions wells some distance from the power station, and natural condensation can be used to facilitate steam scrubbing. Therefore, to capture impurities carried over from the separator, steam wash water is injected downstream of the HP separator. The wash water spray provides nucleation sites for condensation of steam and agglomeration of the droplets which have been carried over from the separator. Impurities fall down to the bottom of the pipe and are collected at the condensate pots. To enhance the scrubbing effect, the steam scrubbing piping is designed so as the length is at least 100m and the steam velocity is no more than 20 m/s. The remaining liquid in the steam is removed at the recycling type HP steam scrubber. The drains from the HP condensate pots and the scrubber are directed to the low pressure (LP) separators to utilize the available energy and minimize the discharge to the surface drains.

Post weld heat treatment was applied to the HP separator and HP steam scrubber to reduce residual stresses and mitigate the risk of hydrogen induced cracking.

The HP separator brine discharge line includes two parallel level control valves. The brine flashes at the level control valves and it becomes two phase LP fluid at approx 1.8 bara.

High purity LP steam is achieved in a similar manner to the HP steam, with Webre type cyclone separators, water washer steam-line scrubbing and a vane type LP steam demister.

Isokinetic probes and selective ion analyzers are provided at the outlet of the HP steam scrubber and LP steam demister for the on-line monitoring of the steam purity. The on-line monitoring provides trends for the steam purity and detects up-sets, which are checked against monthly chemical samples and laboratory analyses.

The LP separator levels are usually controlled by the variable speed brine reinjection pumps. The separated LP brine is pumped up by the pumps and returned to the steamfield for reinjection. The brine reinjection pumps are tandem configuration; the first stage utilizes the variable speed pump and the second stage pumps utilize the fixed speed pumps. The second stage pumps provide flexibility to address changes of the reinjectivity of the wells during start up and long-term operation. The second stage pumps also provide sufficient pressure to enable the plant to operate with one well out-of-service. In normal operation, with all reinjection wells in service, the first stage pumps are sufficient and the second stage are stand-by.

After removing the steam and reducing the temperature by flashing to approx 1.8 bara, the silica in the residual LP brine becomes supersaturated. To prevent the consequent polymerization and deposition of silica in brine system, the pH of the brine is controlled by dosing the HP brine with sulfuric acid. The acid injection rate is precisely adjusted by the variable speed dosing pump to target the LP brine to the reinjection system at pH 5.0 where the acid titration curve is quite steep. The pH control logic is designed with the acid dosing rate being proportional to HP brine flowrate. The set point for this control loop is trimmed with the measured LP brine pH. The acid dosing rate depends on the brine composition, which changes when the production well flows are adjusted.

Under normal operation the plant output is controlled by throttling the production well control valves. 3 x 50% vent valves on each of the HP and LP steam lines control pressure surges. The HP steam is vented using a rock muffler and LP steam is vented to a mechanical silencer. Rupture discs designed as 100% plus one spare, for the HP and LP steam systems provide over-pressure protection. The HP and LP brine systems have 2 x 100% emergency dump valves downstream of the separators. Excess brine is discharged to the thermal pond, which has a design capacity of 3 hours discharging brine.

4. POWER GENERATION FACILITY (PGF)

HP steam and LP steam from SSS, is brought to steam turbine to produces electricity at the generator.

The steam turbine is of dual pressure inlet, single casing, single shaft, single flow HP section and double flow LP section, bottom exhaust and its rated output is 95MW. It utilizes 31.4 inches long last stage blades, which are the largest in any geothermal application. This makes it feasible to build the largest single casing geothermal power station utilizing dual flash cycle technology.

The generator is totally enclosed water to air-cooled (TEWAC) type with brushless exciter. Design features to mitigate the risk of corrosion from H_2S gas include: global vacuum pressurized impregnated stator coil; tin-plated rotor coil and slot wedges; and catalytic filters for circulating and make-up air.

Table 1 shows the major design parameters of the steam turbine and generator and Figure 7 show a view of the steam turbine and the generator.

Steam Turbine

Type	Single cylinder, Double flow, Reaction, Condensing
Output	Rated 95.7MW, Max 113MW
Inlet steam pressure	HP 11.3/ LP 1.8 bara
Inlet steam temperature	HP 185/ LP 118 deg.C
Exhaust pressure	0.08 bara
Steam flow	HP 465 (including 2.3 wt% NCG) /LP 180 t/h
Rotation speed	3,000 rpm

Generator

Type	Totally Enclosed Water-to-Air Cooled (TEWAC)
Capacity	130 MVA
Voltage	11 kV
Rotation speed	3,000 rpm

Table 1: Design Parameters of Steam Turbine and Generator

Figure 7: Photograph of Steam Turbine and Generator

Turbine exhaust steam is condensed at approx. 0.08 bara in a direct-contact, spray type condenser with cooling water from the forced draft cooling tower. The non-condensable gases are removed from the condenser with a hybrid gas extraction system (GES). The steam turbine, generator and condenser are manufactured by FES. Figure 8 shows the PGF system overview.

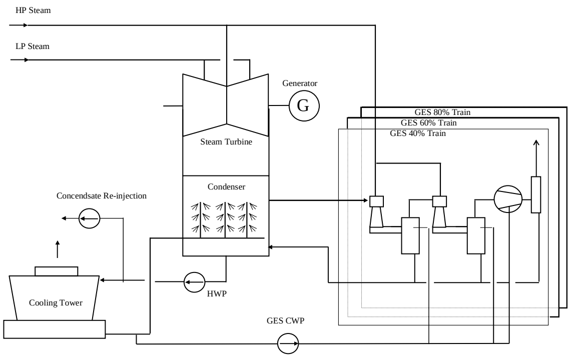

Figure 8: PGF System Overview

The GES comprises of three independent trains sized for 40%, 60% and 80% of the design NCG flow. Each train utilizes the hybrid system, with two (2) stages of ejectors followed by a liquid ring vacuum pump. (Fig.9)

This configuration produces the seven (7) combinations of the GES trains, which handle 40-180% of NCG flowrate. This configuration provides flexibility to allow for the uncertainty of NCG content. It should be noted that the GES is procured before all production wells are drilled and tested. During the commissioning period, all three trains were operated but after six months operation, only 40% and 80% trains are required in normal operation.

Figure 9: Photograph of Gas Extraction System

The cooling tower is a counterflow, mechanical draft type and made of FRP. It consists of ten (10) cells, arranged in a single line. Two (2) cells are equipped with dual speed fans. Switching fans on or off and selection of half/full speed provides flexibility to adjust the operating configuration to the atmospheric conditions and save the auxiliary power consumption.

The steam flow into the system exceeds the cooling tower evaporation loss, which results in an excess of condensate. Condensate is reinjected to the condensate reinjection well to maintain a constant level in the cooling tower basin.

5. PLANT CONTROL

The plant control system provides overall control and supervision not only for SSS and PGF, but also for steamfield and switchyard. The control system matches the steamfield supply to the power demand and maintains safe operation of the plant under transients or equipment faults. This is achieved as follows. The turbine governor controls the entire plant steam pressure and the production well control valves open or close in accordance with the required generator output. In the event of a fault or transient, when the steam vent valves open or rupture disc burst, the production well control valve position is automatically locked to prevent the further discharge. For a turbine trip the fluid supply from the steamfield is reduced and shut down automatically without operator intervention.

6. CONCLUSION

The construction of the Kawerau Geothermal Power Station has taken advantage of the latest technologies. The design has maximized the power output for a given geothermal energy input and minimized the parasitic loads, under consideration of economic factors. Appropriate design margins have been included for the plant and equipment to provide operation flexibility and ensure that the plant can respond to foreseeable changes in the geothermal reservoir. This plant is aligned with New Zealand government strategy and contributes to a reduction of New Zealand's carbon footprint from a global perspective.

Success of Kawerau project lead us, MRP and FES to continue working together on next project, 132MW Nga Awa Purua Geothermal Power Station on the Rotokawa geothermal field, New Zealand, of which construction is underway with commissioning scheduled for mid-2010.

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