ADDITIONAL WELLHEAD UNITS AT ULUMBU, INDONESIA

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ABSTRACT

Geothermal Development Associates (GDA) provided engineering, major equipment, and startup and commissioning services to PT Perusahaan Listrik Negara (Persero) (PLN) for a modular 2 x 2.5 MW geothermal wellhead plant located at Ulumbu, Flores Island, Indonesia. PT Rekadaya Elektrika (Rekadaya) constructed the plant under a separate contract with PLN. The plant was commissioned in August 2014. GDA also provided construction support and training for PLN personnel. The new units, supplied by GDA, are the 3rd and 4th units installed at Ulumbu, which are all served by the same dry steam production well, ULB-2, drilled in 1994.

1. BACKGROUND

1.1 Project History

In late 2012, GDA, based in Reno, Nevada, USA, entered into a contract with PLN for the engineering design, supply of major equipment, and commissioning of a modular 2 x 2.5 MW geothermal wellhead power plant at Ulumbu, Indonesia. GDA completed the plant design and began shipping equipment just seven months after contract signature. The plant was synchronized to the grid after seven months of construction. The general location of the site is shown in Figure 1. Under a separate contract with PLN, construction was awarded to Rekadaya, based in Jakarta, Indonesia. Rekadaya was responsible for the installation of GDA equipment, as well as providing the balance of plant equipment including fire suppression, civil works, transformers, and switchgear.

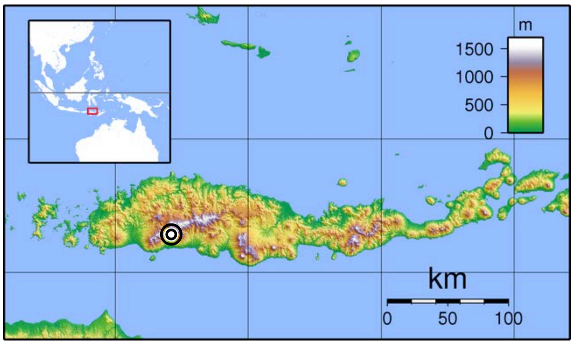

Figure 1: Map showing the approximate location of the Ulumbu geothermal field on Flores Island, East Nusa Tenggara, Indonesia

Figure 2: The Ulumbu geothermal site on Flores Island

1.2 Site Description

The Ulumbu geothermal site (Figure 2) is located in the Manggarai regency on the island of Flores, East Nusa Tenggara, Indonesia, approximately 13 km south southwest of the city of Ruteng. The site is located on the flanks of the Poco Leok stratovolcano at an elevation of approximately 650 m. Development began in 1992 as a partnership between the Indonesia and New Zealand governments. The Indonesian government was responsible for the organization, supervision and implementation of the site development, while New Zealand's Ministry of Foreign Affairs Development Assistance Division (then the Ministry of External Relations and Trade) provided financial and technical support to the project. In 1994 and 1995, three wells were drilled south of the fumarole field to an average depth of approximately 1200 m. Well monitoring and flow testing equipment were provided by the New Zealand government in addition to technical services. Over the next 10 years, the wells were flow tested several times. The acquired test data found that well ULB-2 was the most prolific, capable of producing at least 120 tons per hour of dry steam at 10 barg from a depth of 879 m. The bottom hole temperature of ULB-2 is approximately 240°C. It serves as the production well for this project and the adjacent 2 x 2.5 MW plant.

1.3 Indonesian Geothermal Power

As Indonesia's state owned electric company, PLN has a total installed capacity of 34,205 MW (≈80% of national capacity). Currently, there is approximately 1,300 MW of installed geothermal capacity in Indonesia, including 568 MW owned by PLN. The estimated geothermal potential within Indonesia approaches 27,000 MW. The Indonesian government intends to install 9,500 MW by 2025.

The use of geothermal resources in Indonesia has the potential to diminish reliance on fossil fuel power sources, reduce costs, and stabilize the electrical grid with modern power plant designs. For example, on Flores Island the primary source of base load power is diesel generators. Their contribution to the local power system is being minimized by the installation of geothermal power plants. Similar situations occur on many smaller islands in Indonesia. At locations such as these, rural electrification can frequently be supported by small-scale wellhead geothermal power plants supplementing or replacing diesel and other fossil fuel power sources.

2. GDA ENGINEERING AND PROCURMENT

2.1 Plant Design

Based on the characteristics of well ULB-2, the following conditions were used in the design of this plant:

Unit Steam Flow	35,800 kg/hr
Non-Condensable Gas	3%
Turbine Inlet Pressure	1000 kPa (abs)
Turbine Inlet Temperature	180 °C
Turbine Exhaust Pressure	98 kPa (abs)
Gross Unit Power Output	2500 kW

The process consists of two (2) typical steam backpressure units, each utilizing 35,800 kg/hr of steam to produce 2.5 MW of electrical power. Waste steam and entrained non-condensable gases are released to atmosphere south of the plant via exhaust piping. Steam condensate collected by the process is discharged to the existing power plant drainage system. A closed loop water-to-air heat exchange system is used to cool lube oil and the generator while reducing water consumption, maintenance demands, and parasitic loads. A simplified process overview is shown in Figure 3.

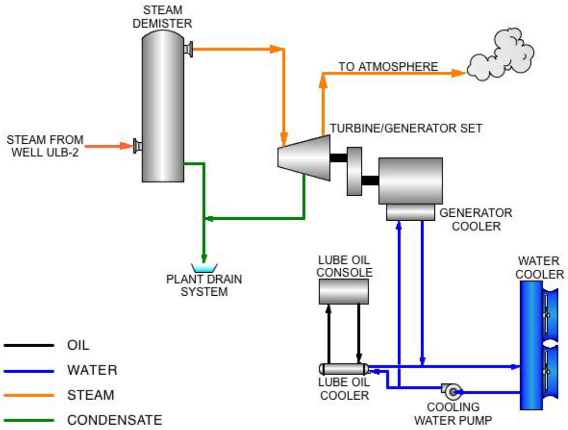

Figure 3: Simplified Ulumbu dry steam process diagram

GDA provided the process and detailed design at Ulumbu. The scope of work included foundation designs, electrical designs, pressure control system, and piping. Several recommendations and requirements were extended to project partners, including design constraints for switchgear, motor control centers, and compressed air systems. Bills of quantities were provided with all designs to aid procurement of materials purchased within Indonesia.

GDA was responsible for the supply of major equipment, including:

- Turbine generator sets and auxiliaries (see Figure 4)
  - GE 7-stage axial flow steam turbine enhanced for geothermal service by Elliott Group
  - Brushless, synchronous, totally enclosed water-to-air cooled generator manufactured by Kato Engineering
  - Parallel-shaft speed reduction gear manufactured by Lufkin Industries
  - Lube oil system designed and manufactured by GDA (see Figure 5)
  - Inlet steam control valve system designed and manufactured by GDA (see Figure 6)
- Vertical gas separators (demisters) manufactured by Peerless Manufacturing Company
- Water coolers designed and manufactured by Custom Air Coolers
- Cooling water circulation pumps manufactured by Goulds Xylem Inc.
- Remote control panels and work stations designed and manufactured by GDA

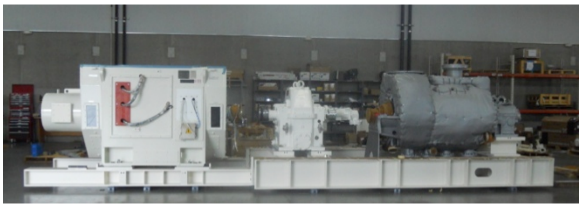

Figure 4: Turbine generator set prior to shipment

Figure 5: Lube oil consoles prior to shipment

Figure 6: Inlet steam lines prior to shipment

In addition to the major process equipment described above, GDA provided auxiliary systems and equipment including:

- Three vent station control valves
- Rupture disk station
- Turbine water wash systems, including reservoirs, pumps, instrumentation and nozzles
- Turbine exhaust piping
- Piping materials and valves for cooling water, lube oil and steam systems

2.1.2 Turbine Generator Set

In order to optimize the marine turbines for geothermal use the turbine rotors were re-rated. Modeling conducted by GDA and PerAero Turbine Designs determined that a 7-stage rotor would provide the best performance and turbine reliability. The bearings, instrumentation, and steam path were enhanced, resulting in a turbine ideally suited for harsh geothermal service. The Elliott Group's Fairfield, California service shop implemented these modifications, and the turbine was shipped to GDA in Reno, Nevada for final assembly. At GDA's facility, the turbine, gearbox, and generator were mounted to their skids, mated to each other, and shop-aligned. During this process the lube oil system was also fitted, resulting in a complete turbine generator package. After auxiliary piping and components were mounted, each TG set was prepared for shipment to Indonesia. This process assured that final assembly at Ulumbu would require a minimal amount of time and effort.

2.1.3 Lube Oil System

The lube oil system was custom designed by GDA to provide a stable, conditioned oil supply to the TG sets. An AC motor-driven pump is used to boost supply pressure until the gear-driven main oil pump reaches sufficient speed to lubricate all equipment. At approximately 75% of rated speed, lubrication demands are fully met by the main oil pump. In the event that the AC pump fails to start or is unavailable, an emergency DC motor-driven pump activates. This system minimize**s** the risk of bearing failure in the turbine and generator.

Lube oil cooling is provided for each unit by two oil-to-water heat exchangers, with each cooler rated at 100% duty. Cool oil is circulated back to the lube oil console, where a thermostatic control valve automatically adjusts the oil temperature discharged to the supply header. This temperature control system requires almost no maintenance, and operates without external power supplies.

2.1.4 Control System

The Ulumbu control system uses redundant controllers and remote I/O connected with an Ethernet ring backbone. Separate device level rings allow the extensive use of remote input/output (I/O) while still maintaining high reliability and reducing the number of terminations. Devices that do not have available network redundancy are connected to the network at one of three switches on the base ring. The network design also allows use of a single pair of redundant controllers to control the entire power plant as opposed to using an individual controller for each unit. This controller configuration increases the reliability of the control system by allowing the second controller to take control should the other controller fail. Analog instruments are connected to HART enabled I/O cards allowing reading of the process values without uncertainty from scaling. RTDs are used for temperature sensing via RTD I/O cards; thus no transmitters are required as intermediaries between the RTD and the PLC. These techniques help to eliminate computational errors while increasing reliability and simplifying maintenance.

2.2 Construction and Commissioning

GDA manufactured and packaged major equipment to simplify and expedite field construction. As shown in Figures 4, 5, and 6 the turbine generator sets, inlet steam control assemblies, and the lube oil consoles were built at GDA's facility in Nevada, USA, and then shipped to Indonesia.

Once Rekadaya was prepared to install GDA equipment, engineers began regular 30-day assignments in Indonesia. In an effort to ensure compliance with all plans and specifications, GDA engineers supervised construction, start-up, and commissioning of the plant. The commissioning team consisted of engineers from GDA and Rekadaya, supported by construction staff and PLN plant operators. From first roll of a unit to reaching rated speed took less than 24 hours. Figure 7 shows a complete unit installed on site.

Figure 7: Unit 1 turbine generator set, inlet steam line and lube oil console during plant commissioning; auxiliary water coolers are installed in the background.

2.3 Lessons Learned

During the construction period, it became evident how far remote islands in Indonesia can be from the "normal" industrial infrastructure. Procurement of additional materials was difficult for all parties involved with the project. Most basic industrial items (steel, wire, etc.) are only available in large cities on Java. Large equipment and bulk materials had to be delivered by ship; however there were no permanent ports near the site. A temporary jetty was built in a nearby coastal village to take delivery of large items, but delivery could extend past several weeks, depending on seas and weather. Air freight worked well for smaller items, but was quite expensive. Depending upon the nature of the goods, air freight may not be an option (large pipe or hazardous items), or modifications could be required (small pipe and bars, cut into 1 or 2 meter sections). Cutting down larger pieces of material frequently led to increased lead times and cost, while sometimes adding to the amount of work required on site. To further complicate matters, once deliveries were made to the island, a private courier was needed in order to deliver the items to the project site. Considering the poor nature of the roads and the arrival time, this could add days to material availability. These logistical problems require significant planning early in the design phase, as failure to account for them may add months to the project schedule.

It is recommended for projects at remote sites that any specialty items, or those with any significant lead-time, are ordered with several spares early in the procurement process and are shipped with the major equipment. Further, it is imperative to consider the industrialization of the island. Many islands do not possess items that are easily procured in places such as Java, Bali, or Sumatra.

2.4 Training Program

Training for this project occurred in several stages. In late September 2013, a team from PLN (Figure 8) traveled to the United States for a two-week training program covering the principles of the design and geothermal processes. GDA coordinated the training of PLN engineers at OEM factories of Kato Engineering for the generator, and turbine enhancements carried out at Elliot. In early July 2014, a group of plant operators and PLN representatives received additional onsite classroom training on the operational and maintenance theory of the plant and its components. Throughout the startup and commissioning process, GDA provided training to PLN engineers, operators, and maintenance personnel.

Figure 8: Classroom training of PLN engineers at the GDA offices in Reno, Nevada, USA

GDA's onsite training program focused on the operation and maintenance of the following:

- Turbine generator sets
- Lube oil system operation and maintenance
- Control valve and steam pressure control systems
- Remote control panels and work stations
- Process design and controls

3. WELLHEAD POWER GENERATION UNITS

GDA has deployed several wellhead units throughout the world. An example of a similar turbine generator set provided by GDA is the Eburru project for Kenya Electricity Generating Company. On the Eburru project, a single wellhead unit was designed in a condensing application that produced 2.4 MW. Plants of this design have a great advantage of simplicity and reduced cost, while remaining the most portable type of wellhead power generating unit.

Common characteristics of wellhead power generation units are:

- Standardized design and construction
- Simple installation
- Simple operation and maintenance
- High reliability
- Standard shipping containers used for transport of all equipment and materials.

Geothermal wellhead power generation units can provide several notable benefits, including:

- Utilization of wells unsuitable for large projects
- Long term testing of wells prior to investment on larger projects
- Power supporting the development of larger projects
- Power for remote locations
- Training of O&M personnel

4. CONCLUSION

The Ulumbu project provides an excellent example of how small wellhead generation units can be quickly deployed to even the most remote locations successfully. Ulumbu further demonstrates that small-scale non-condensing power plants can serve as an economical alternative over other viable technologies such as a binary process for medium to high enthalpy geothermal resources. Direct steam gains additional benefits in remote locations over technologies such as binary, as there is no need for large supplies of specialized chemicals (e.g. isopentane), which can be difficult to supply and transport within the region.

With only seven months to design the plant and ship major components, GDA has further demonstrated that the simple modular nature of wellhead generation units permit accelerated project development times. Additionally, the seven (7) month construction time in a rugged, remote, non-industrialized location serves as a shining example of how units of this type can be quickly constructed and brought on line. Ulumbu has, in the authors' opinion, reinforced the economical application of wellhead power stations in remote and developing parts of the world.

5. ACKNOWLEDGEMENTS

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