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Construction and Operation of Kamojang Unit 4, the First Commercial Geothermal Power Plant Built, Owned and Operated by PT Pertamina Geothermal Energy

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ABSTRACT

PT Pertamina Geothermal Energy (PGE) is established in December 19, 2006 to deal with geothermal business in Indonesia. It carried on the role of PT Pertamina, a state-owned oil and gas company, in developing the geothermal energy in this country, starting in 1976, then succeeded in supplying steam to the first commercial geothermal power plant (30 MW.) namely Kamojang Unit 1 in 1983. It was followed by Unit 2 and Unit 3, 55 MW capacities each, commissioned in 1987. These 140 MW total capacity power plants are owned and operated by Indonesia Power, a subsidiary company of PT PLN the state-owned electricity company. Since then, PT Pertamina is recognized as an upstream player in geothermal energy development, to be precise: a steam seller geothermal company. It was ended in early 2008 when PGE successfully commissioned a Geothermal Power Plant (GPP) namely Kamojang Unit 4. This 63 MW installed capacity geothermal power plant is the first large-scale geothermal power plant built, owned and operated by PGE, and will be a starting point to install and operate a total of 500 MW geothermal power plants in the next 3 years.

The geothermal power plant had a starting commercial operation date (COD) on January 26, 2008, following a successful commissioning conducted at the end of the 2 year construction period. The basis of design is to acquire a lowest cost for every kW (net) installed capacity by conducting an optimization study of the circulating water system. The zero venting principle is applied to eliminate the steam loss through the rock muffler during normal operation. The geothermal power plant consumes about 423 ton/hr of steam which originated from 8 production wells to produce 60.5 MW (net) of electrical power. Initially, only 7 wells are used to supply steam to the geothermal power plant, however due to decline in steam production, one additional well was put in on June 2008. On the other hand, Non Condensable Gas (NCG) content in steam declined from 1.9% to 0.85% wt which allows operating only one Vacuum Pump. Despite problems that occurred during the first year operation, the geothermal power plant was able to dispatch 471 GWh of electricity to the National Grid, equivalent to a capacity factor of 95.78%.

1. INTRODUCTION

Kamojang Geothermal Field is located in 40 km South East of Bandung and about 24 km North West of Garut at an elevation of about 1500 m above sea level. The ambient temperature is around 15°C - 20°C with an average rainfall of 2,885 mm annually.

Early exploration in Kamojang was carried out by Dutch Colonials in 1926–1928 by drilling five shallow wells at about 120 m depth. Until now, one of the wells namely Kmj-3 is still discharging superheated steam to the atmosphere.

In 1971–1972, a prefeasibility study was conducted by Geothermal Survey of Indonesia (GSI) collaborating with the New Zealand Government. It was followed by geology, geophysics and geochemistry surveys which were conducted together by Pertamina and ENEX-GSI.

In 1974, Government of Indonesia granted Pertamina, a state-owned company, the right to develop geothermal energy in Indonesia. Therefore, again under New Zealand government aid, Pertamina drilled the first exploration well on September 22, 1974 and by 1979 five exploration wells and ten production wells had been drilled (Suryadarma et al., 2005). On November 27, 1978, a 250 kW Monoblok was inaugurated by the Ministry of Mines and Energy to be the first geothermal power plant installed in Indonesia.

On January 29, 1983, Kamojang was inaugurated as the first Geothermal Production Field in Indonesia following operation of a 30 MW commercial geothermal power plant which is operated by PT PLN, a state-owned electricity company.

Further production well drilling was aimed at supplying sufficient steam to two 55 MW capacity geothermal power plants, namely Unit 2 and Unit 3, which commenced operation in 1987. Nowadays, these geothermal power plants are operated by Indonesia Power, a subsidiary company of PT PLN.

To increase the capacity of Kamojang Geotherma Field from 140 MW to 200 MW, Pertamina drilled 11 wells in the east block during 1989–1996 and two more in 2001–2002 to secure a total steam potential of about 74 MW at the wellheads. Figure 1 shows location map of Kamojang Unit 4 geothermal power plant, and other geothermal power plants in West Java.

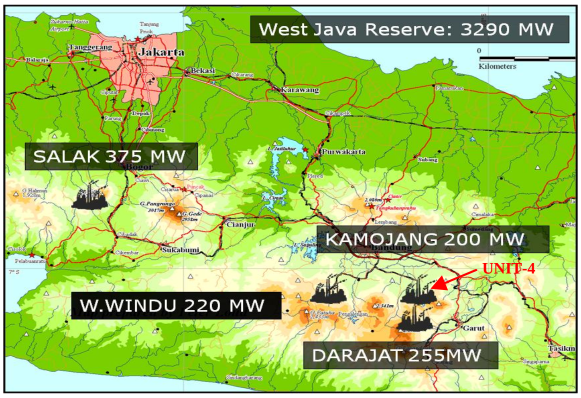

Figure 1: Location map of Kamojang geothermal power plant.

Following the monetary crisis which hit Indonesia in 1998, Pertamina acquired a privilege to develop a new geothermal power plant in a total project scheme. After about a 2 year construction period, the geothermal power plant, namely Kamojang Unit 4, commenced commercial operation on January 26, 2008.

This paper gives a general overview of PGE geothermal business development and transformation from a steam field operator to a power plant operator as well as features and lessons learned from the first year operation of Kamojang Unit 4 geothermal power plant.

2. PERTAMINA ROLE IN GEOTHERMAL ENERGY DEVELOPMENT

Pertamina was established in December 10, 1957 as the first national oil company. After several acquisitions and merging, Law No. 8 of 1971 was enacted and confirmed Pertamina to be the only national oil and gas company to hold the concession of oil and gas fields in Indonesia and manage them for the prosperity of the Nation.

Pertamina Geothermal business started with the Presidential Decrees No.16 / 1974, No.22 / 1981 and No. 45 / 1991. Pertamina, the state oil and gas company was granted the authority to undertake exploration and exploitation of geothermal resources in Indonesia as well as to generate electricity from these resources. The energy or electricity can be sold to either PT PLN (Persero) the State Electricity Company, Government Private Companies (Industries) or Cooperative Bodies.

Later on, Government Regulation No. 31 / 2003 and The Law No.22 / 2001 were released. These are the basis of Pertamina's transformation, as a state enterprise, into a Limited Liability company (PT) whose geothermal business will be controlled by its subsidiary company. The subsidiary, called **PT Pertamina Geothermal Energy (PGE)** was established on December 12, 2006.

PGE owns the authorities of 15 geothermal concessions throughout Indonesia as shown in Figure 2. Totally it yields the potential of 8,480 MW, equal to 4,390 MMBOE, consisting of resource 1,990 MW and reserve 6,490 MW. The utilization in such activities comprises both own operation and partnership. Currently, seven geothermal areas located in six geothermal concessions are already operating at installed capacity of 1,182 MW where 272 MW among them are PGE own operation.

3. PGE BUSINESS SCHEME

Regarding Presidential Decree No. 45/1991, there are two business schemes that can be decided on in developing geothermal resources, as is shown in Figure 3.

The first option is to develop the steam field (upstream) and then sell the steam to PT PLN who constructs and operates the power plant (downstream) under a Steam Sales Contract (SSC).

The second option is to develop both upstream and downstream in a total project scheme and sells the electricity to PT PLN under an Electricity Sales Contract (ESC).

Among 272 MW PGE own operation, 210 MW were managed under SSC where PGE supplies steam to PT PLN or its subsidiary as the power plant operator. They are comprised of Kamojang Units 1, 2 and 3 (140 MW), Lahendong Units 1, 2 and 3 (60 MW) and Sibayak 2 x 5 MW.

The remaining 62 MW were managed under ESC where PGE operates the power plant and delivers electricity to PT PLN. They are comprised of a 2 MW back pressure Monoblok in Sibayak and a newly commissioned large scale geothermal power plant namely Kamojang Unit 4 (60 MW net). The Kamojang Unit 4 geothermal power plant is the first large scale geothermal power plant built, owned and operated by PGE.

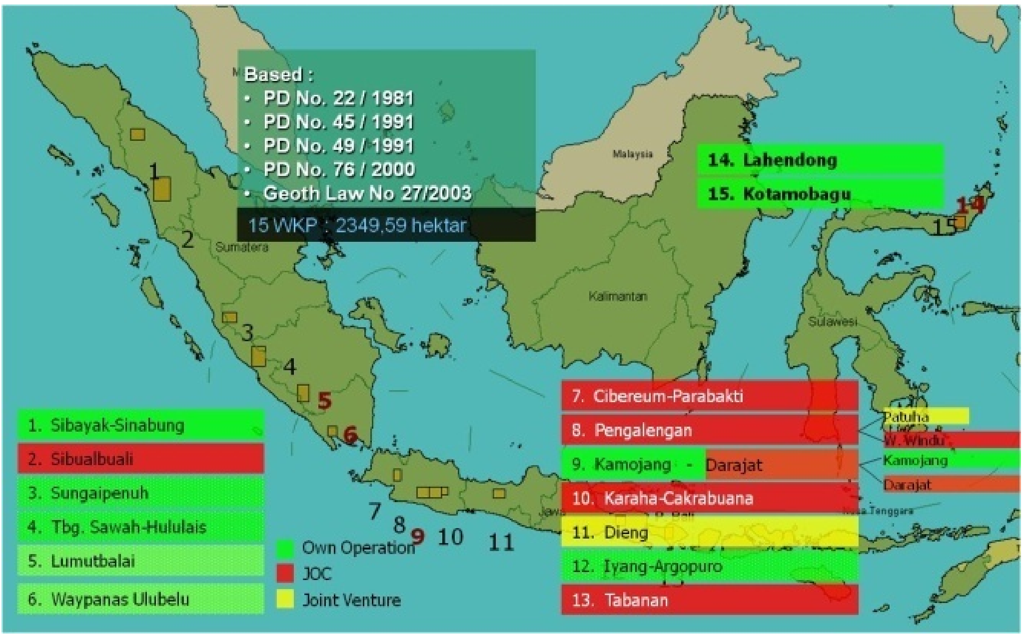

Figure 2: PGE geothermal concessions.

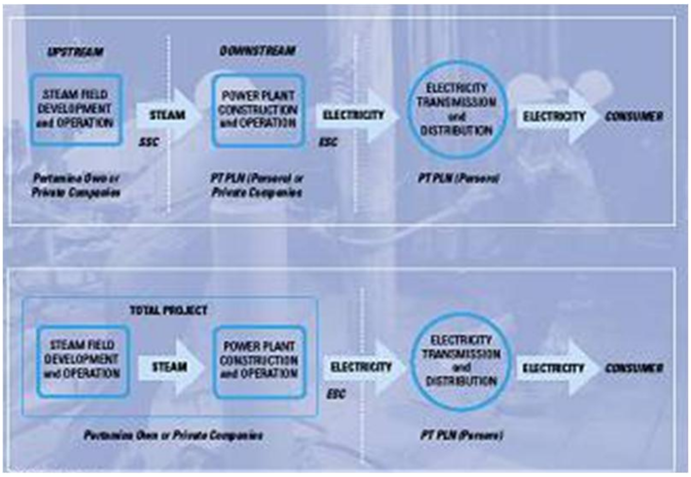

Figure 3: Geothermal business schemes.

4. KAMOJANG STEAM FIELD

Since 1974, not less than 75 geothermal wells have been drilled in Kamojang to support a total of 200 MW geothermal power plant. They comprise 43 production wells, 9 injection wells, 20 monitoring wells and 3 abandoned wells excluding 5 earlier Dutch Colonial wells.

For the first three geothermal power plant units (140 MW), the steam transmission pipe lines are divided into four supported pipe line (PL) namely PL-401 (Ø 32”); PL-402 (Ø 24”); PL-403 (Ø 40”) and PL-404 (Ø-40”). The pipeline operation pressure is 10-15 bar abs corresponding to the turbine inlet pressure of 6.5 bar abs. Steam flow in each PL is controlled manually and maintained at 2.5% greater than the power plant demand. During normal operation, the excess steam is vented automatically through a butterfly controlled valve into a vent structure (Suryadarma et al., 2005).

Kamojang geothermal field has been supplying steam since 1983 at optimum wellhead pressure of about 15 barg. Since 1987, not less than 1100 ton/hr of dry steam has been fed to generate 140 MW of electrical power continuously. Nowaday, 28 production wells at average wellhead pressure 12 barg supply steam of about 1100 ton/hr to the geothermal power plant. The continuous operation from 1983 to 2009 is characterized by a decline in reservoir pressure by 1 to 2 bar with corresponding temperature decline of 2°C to 4°C. The annual well productivity decline is about 3% after 27 years of commercial operation. Figure 4 shows the location of wells, pipelines and geothermal power plants at Kamojang Geothermal Field.

For Kamojang Unit 4 geothermal power plant, at least 423 ton/hr of steam is required to generate 60 MW (net) of electrical power. The steam is extracted from 8 of 11 production wells at wellhead pressures of about 17-20 barg and maximum shut-in pressure of 32 barg. The higher pressure at the wellheads compared to that of wells drilled earlier for the 140 MW geothermal power plants made it possible to design higher turbine inlet pressure for Unit 4 geothermal power plant, in order to obtain a better thermal efficiency.

These wells are located in f clusters on the east part of Kamojang Geothermal Field. Each well of the same cluster is connected together by cluster pipelines and then combined with pipelines from other clusters to enter a main transmission pipe line of 36” diameter namely PL-405. The upstream pipe line from each cluster to the Steam Receiving Station (SRS) located at the power plant is designed at 35 barg maximum working pressure while the downstream pipe line to the turbine is design at 15 bar maximum working pressure.

Unlike pipelines for the 140 MW geothermal power plants, PL-405 is designed to employ Zero Venting Criteria where no steam is discharged to the vent structure during normal operation. This is accomplished by installing a pressure control valve (PCV) at the SRS which splits the main pipeline into higher upstream pressure and lower downstream pressure. Steam flow to the geothermal power plant is controlled by throttling action of the PCV to admit just enough steam to generate 60 MW (net) of electrical power. The higher designed pressure of upstream pipeline is used to accommodate the fluctuation of pressure in the pipeline due to throttling action of the PCV. Figure 5 shows the steam gathering system diagram for Unit 4 geothermal power plant.

Figure 4: Location of wells, pipelines and geothermal power plants.

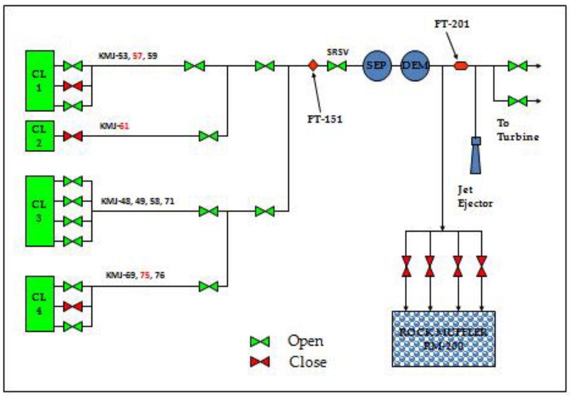

Figure 5: Steam gathering system diagram Unit 4 geothermal power plant.

In case pressure in the main pipeline exceeds 34 barg, rupture disks and pressure relief valves (PRVs) which are installed along the pipeline will burst and discharge steam to normalize the pressure. On downstream pipeline, PCVs are installed near the vent structure. Therefore, if the pressure exceeds 10.15 barg, the PCVs automatically release steam into the vent structure.

5. KAMOJANG UNIT 4 POWER PLANT

The Kamojang Unit 4 geothermal power plant has an installed capacity of 63 MW and generates 60 MW (net) of electrical power. It consists of steam turbine and generator, gas extraction system, condensing, and cooling water systems. Supporting utility systems are also included consisting of the water treatment system, plant service and instrument air system, fire fighting system, chemical injection units, lube oil system, diesel generator with its fuel system; together with the necessary electrical and control system. An overview of the geothermal power plant is shown in Figure 6.

Figure 6: Kamojang Unit 4 geothermal power plant overview.

5.1 Process Design

Dry, slightly superheated steam from steam field is received at a normal operating pressure of 11 bar abs. Condensate in the steam will be separated in the separator and transferred to the reinjection sump via the power house drain pit. Steam from the separator will then pass through a demister for further moisture and solid removal. The condensate level in separator and demister will be controlled with a level transmitter controlling a level control valve. A venturi flow meter located downstream of the demister will measure steam flow to the turbine and auxiliaries such as the steam jet ejectors, and the gland steam system. Figure 7 shows the process flow diagram of Kamojang Unit 4 geothermal power plant.

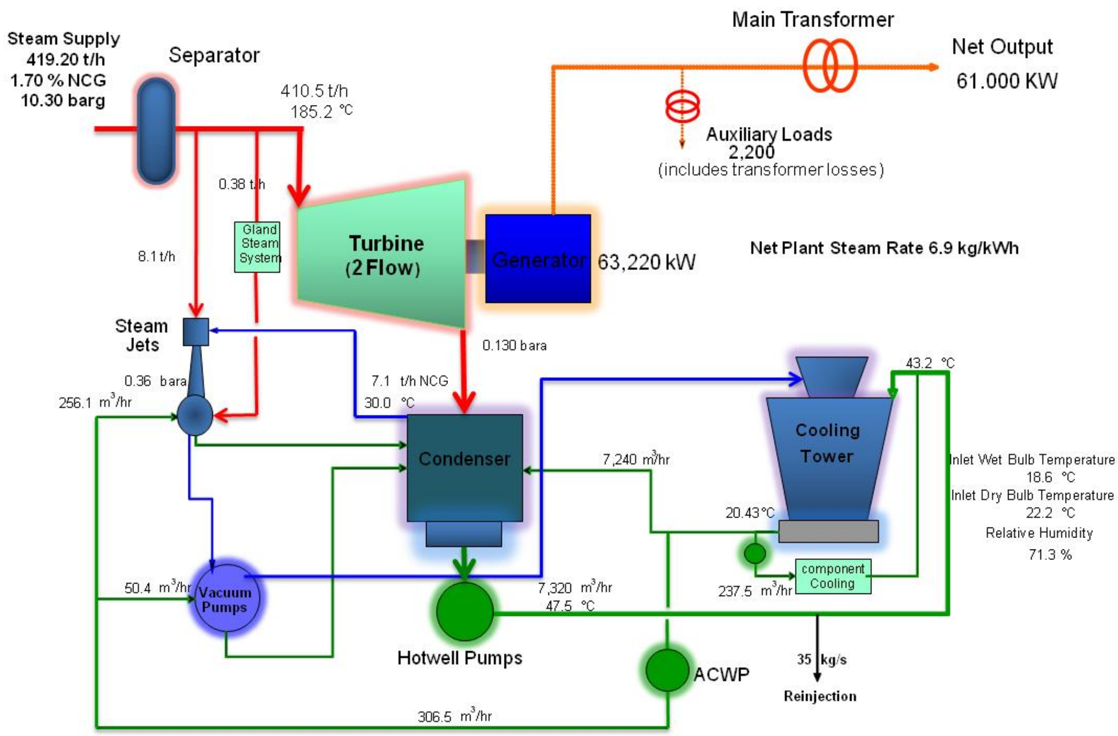

Figure 7: Process flow diagram Unit 4 geothermal power plant.

The main steam at 11 bar abs and 423 ton/hr pass through strainers, stop valves and control valves, before being admitted to the steam turbine. The steam turbine is a double flow unit which has two steam inlet lines. It is directly coupled to the generator and the exciter and has self-contained lubrication and hydraulic systems. The turbine generator has a maximum continuous rating (MCR) that is equal 60 MW (net) plus transformer losses and auxiliary power consumption, or about 63 MW (gross).

A special feature of the plant design is a turbine control system which allows the turbine generator to generate only the auxiliary power requirements in the event of transmission system failure (island operation). If there is an interruption in the power transmission system, the electrical breaker at the switchyard will open, while the turbine control valves will throttle the turbine generator in order to allow it to continue running and provide station service power (house load). In this condition, excess steam will need to be vented through a vent structure/rock muffler in order to prevent an overpressure steam condition. Once the transmission system becomes operational again, the running plant can be synchronized with the grid and power export can resume.

Exhaust steam from the outlet of the steam turbine at 0.16 bar abs pressure goes to a direct-contact condenser, located below the turbine. Cooling water at 26.2°C is distributed within the condenser to condense the turbine exhaust steam and leaves the condenser at 51.7°C.

Hot water from the condenser is delivered to the cooling tower by two 50% capacity hotwell pumps. The hot water will be cooled in the cooling tower and the cooled water returned to the condenser by the suction created by the condenser vacuum. Water level in the condenser is controlled automatically by level controllers which operate butterfly valves on the discharge of each hot well pump.

Noncondensable gas (NCG) and some water vapor from the condenser will be removed using three first-stage ejectors with 25%, 35% and 65% capacity, which are driven by main steam. Normally, the ejectors with 35% and 63% capacity will be operated if the NCG content is 1.7 % by weight. Mixed NCG, carry-over vapor and motive steam, flow from the ejector at a pressure of 0.474 bar abs to the intercondenser, where they are cooled by cooling water. Condensed steam and cooling water are drained from the intercondenser through a loop seal and then flow back to the condenser. The NCG is extracted from the intercondenser by two 50% capacity liquid ring vacuum pumps. The vacuum pumps are supplied with cooling water to form the liquid ring seal and then the liquid and NCG are separated in the NCG separators. Condensate drains from the bottom of the separators and is returned to the condenser through loop seals. The NCG, consisting mainly of CO_2 and H_2S, leave the separators or second stage after condenser and then are vented to atmosphere through the cooling tower fan stacks in the rising vapor plumes. The gas release valves are electrically interlocked with the cooling tower fan motors.

The cooling tower is an induced draft counterflow type, designed to cool hot water from the condenser and achieving an outlet water temperature dependent upon the actual wet bulb temperature. For the design condition the temperature of the outlet cooling water will be around 26.2°C. Cooling water is distributed to each operating cell of the cooling tower and contacts the incoming air, which is induced by the fans operating at the top of the tower.

5.2 Operating Philosophy

During normal operation, the turbine inlet pressure is maintained by placing the vent valves to the rock muffler (vent structure) into AUTO mode. The setting pressure of this valve is set to meet the required turbine inlet pressure of 10.15 barg (11.0 bar abs). The Pressure Control Valve (PCV) on the steam receiving station (SRS) is operated manually from DCS to get the vent valves to rock muffler closed as far as possible. The PCV is adjusted gradually from DCS with maximum 2% increment from its last position to keep the turbine inlet pressure stable.

In case of transmission failure, the turbine generator will run into house load operation, the vent valves to rock muffler will stay in AUTO. The vent valves will release excess steam to the rock muffler in order to keep the steam pressure to the turbine and pipelines in normal condition.

In case of turbine trip, the vent valves to rock muffler will automatically open to 100% in order to maintain steam pressure in the power plant and pipelines in normal condition.

In case of Hot Well Pump trip, generator output will be automatically reduced to 50% load and cooling water to condenser automatically closes to 50% from last position by mean of a MOV. Condensing pressure shall be observed and maintained at 0.16 bar abs by reducing the generator load. In a case if both hot well pumps trip, the turbine generator will trip automatically and the MOV will be fully closed.

In case of one vacuum pump trip, the generator output shall be reduced to maintain condensing pressure in stable normal condition. Next, the backup ejector and after condenser can be put on line and the second vacuum pump shall be tripped manually. Online changeover from backup ejector to vacuum pumps in operation or vice versa is possible.

In case of black out (emergency condition), the emergency diesel generator will start automatically in 10 seconds and supplies essential load such as UPS, auxiliary cooling pumps, lube oil pump, jacking oil pump, turning gear device, compressor, space heater, emergency lamps, etc. If the emergency diesel generator fails to start, the UPS will handle the essential load for about 2 hours.

5.3 Testing and Commissioning Results

The Kamojang Unit 4 geothermal power plant project commenced construction on February 24, 2006 and was scheduled to be finished within 23 months. The pre-commissioning stage started on August 15, 2007 which was indicated by energizing the low voltage switchgears. Following completion of the precommissioning stage, the Mechanical Completion Certificate (MCC) was issued on December 21, 2007 that allowed the EPC Contractor to begin the commissioning phase. The commissioning phase was indicated by admitting steam to turbine generator for the very first time on December 22, 2007. First synchronization to the grid was conducted on December 25, 2007 followed by load and load rejection tests. An accident happened on January 2, 2008 when a current transformer (CT) at the auxiliary transformer exploded. It caused a delay to project completion for about 3 weeks. While repairing the auxiliary transformer, the commissioning was continued by using external step down unit which tapped electrical power from PT PLN medium voltage switchgear. Reliability test 15 days non-stop, unit rated capacity (URC) test and performance test were conducted by using this external step down unit. URC test was conducted for 3 x 24 hours non-stop from January 22 to 25 and witnessed by PT PLN as energy buyer.

The next day after the completion of URC test that is January 26, 2008 was declared as the Commercial Operation Date (COD) for the Kamojang Unit 4 geothermal power plant. After fixing the auxiliary transformer, two last tests i.e. 50% and 100% house load test were conducted on February 14, and 15, 2008. On February 16, 2008, Commissioning Completion Certificate together with Take-Over Certificate were issued by PGE. It was a historical moment when PGE operated its own large scale geothermal power plant for the first time.

The performance test results showed that the guaranteed value could be exceeded. There are two guaranteed values i.e. Power Output of 60 MW (net) and Specific Steam Consumption (SSC) of 7.47 kg/kWh. The result was 62.4 MW (net) and 7.05 kg/kWh respectively. Table 1 shows summary of commissioning and operation results.

Table 1: Summary of commissioning and operation results.

DESCRIPTION	DESIGN	COMMISSIONING	OPERATION
Output net (MW)	60.0	62.4	61.0
SSC (kg/kWh)	7.47	7.05	6.98
Gen. Power Factor	0.80	0.98	0.98
Inlet Pressure (bara)	11.0	11.0	11.0
Exhaust Press. (bara)	0.16	0.146	0.13
Wet Bulb Temp. (°C)	21.0	16.0	13 - 20
NCG (% wt)	1.70	1.5	0.85
Atm. Pressure (bara)	0.85	0.9	0.85

5.4 First Year Operation

Commercial operation started on January 26, 2008 at 10:00 hour, following a successful Unit Rated Capacity (URC) test conducted for 3 x 24 hours without interruption. The test result confirmed the URC of 60.236 MW (net). This kind of test was conducted to comply with the contractual agreement requirement, where the URC will be the base for commercial energy transaction between PGE and PT PLN. It is related to Take or Pay (TOP) and Delivery or Pay (DOP) clauses of the contract agreement. PT PLN as electricity buyer is obliged to purchase 90% of the URC x period hours. Moreover, if PGE dispatch is more than 90% of the URC in such a period, the surplus energy selling price will be 50% of normal price.

In the first year of operation, the geothermal power plant was able to generate 471,508 MWh (net) of electricity which corresponds to 95.78 % Capacity Factor (Figure 8). The geothermal power plant operated for 7,500 hours of 8,174 available hours and outage of 674 hours consisted of 91 hours for planned outage and 587 hours for unscheduled outage. The unscheduled outages were caused mainly by CT explosion of auxiliary transformer during commissioning and flash over occurred in the main transfomer. The availability hours which is sum of operational hours and planned outage hours was 7591 hours which corresponds to Availability Factor of 92.87 %.

Initially, 7 production wells were used to supply about 423 ton/hr steam to the geothermal power plant. However, due to decline in well productivity, the eighth well was introduced in June 2008. In 2008, average decline rate of production wells reached about 15% which is common for newly discharged wells. After several years of operation, the decline rate usually will subside to about 3% annually, like other wells that supply the 140 MW geothermal power plants.

NCG content in the steam declined from 1.9% during commissioning to about 0.85% by July 2008. This reduction made it possible to use only one 50% capacity vacuum pump which saved about 200 kW of house load.

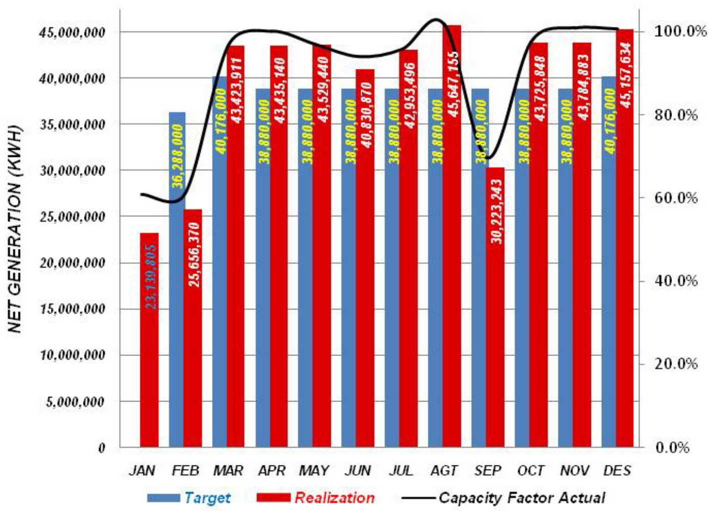

Figure 8: Kamojang Unit 4 generation and Capacity Factor CF in 2008.

6. KAMOJANG AND PGE FUTURE DEVELOPMENT

Kamojang potential resources calculated by using volumetric analysis suggest a power potential of 150–250 MWe within a reservoir area of 7.62 km^2 – 12.5 km^2. Individual calculation made by Fauzi (1999) suggested a power potential of 140 MWe to 260 MWe for 25 years of utilization from reservoir area of 8.5 km^2 – 15 km^2. Sanyal at al. (2000) estimated that proven reserves ranged from 210 MWe to 280 MWe for 30 years. The most likely power potential lies between 180 MWe to 250 MWe for 25 years operation. This has been proven by drilling wells and operation of the Kamojang Unit 4 geothermal power plant to make a total install capacity of 200 MWe. Recent reservoir modeling suggests that the Kamojang reserves are able to support another 30 to 60 MWe geothermal power plant for 25 years operation.

Despite Indonesia’s geothermal potential of 27,000 MWe, currently, only 4.5% (1,182 MW) is utilized to produce electricity. Moreover, geothermal energy contributes only about 5% of National Energy Mix. To cope with electricity demand growth of 6.8% annually (2002–2007), the government has launched a 10,000 MW two-phase crash program to accelerate construction of power plants. Approximately 4,733 MW (48%) of the program will be derived from the geothermal sector (MKI, 2009).

With 8,480 MWe potential from 15 geothermal concessions, PGE will play a very important role in future geothermal energy development in Indonesia. PGE has set up an aggressive target to develop a total capacity of 1,070 MW power plants in the next 5 years, to secure a total own operation capacity of 1,342 MW in 2014 (Figure 9).

Nowadays two geothermal fields i.e. Ulubelu and Lumut Balai in Sumatra are already in the drilling stage while four other geothermal fields i.e. Karaha (Java), Sungai Penuh and Hulu Lais (Sumatra) and Kotamobago (Sulawesi) are in exploration stage. All geothermal fields will be developed in a Total Project Scheme, except Lahendong Unit 4 (20MW) and Ulubelu Units 1 and 2 (2 x 55 MW). For the last two projects, PGE will supply steam to geothermal power plants that are owned and operated by PT PLN (Media, 2009).

7. CONCLUSIONS

PT Pertamina Geothermal Energy (PGE) with 15 Geothermal Concessions will play a very important role in Indonesia's geothermal energy development.

Successful construction and operation of the first commercial large scale Kamojang Unit 4 geothermal power plant will provide knowledge and expertise for PGE to develop new projects in a total project scheme.

Applying Zero Venting Criteria by putting a PCV upstream of the separator will reduce steam consumption to the geothermal power plant.

Commissioning and operation results show that the geothermal power plant performance exceeds its design and guaranteed value.

In the first year of operation, steam supply from production wells to Kamojang Unit 4 geothermal power plant declined at about 15% rate. Other production wells which supply steam for 140 MW geothermal power plants decline at about 3% rate.

Noncondensable gases declined from 1.9% during commissioning to about 0.85% in mid 2008, which allowed only one vacuum pump in operation.

Despite problems that occurred during commissioning and operation, Kamojang Unit 4 geothermal power plant was able to obtain 95.78% Capacity Factor and 92.87% Availability Factor in its first year operation.

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PERTAMINA OWN OPERATION	2007		2008		2009		2010		2011		2012		2013		2014	
RESERVES / GPP	590	162	695	252	970	272	1520	272	1560	347	1560	752	1970	917	1970	1342
KAMOJANG	300	140	300	200	300	200	300	200	300	200	300	260	300	260	300	260
LAHENDONG	80	20	100	40	100	60	200	60	200	80	200	127,5	200	127,5	200	127.5
SIBAYAK	40	12	40	12	40	12	40	12	40	12	40	19,5	40	19,5	40	19.5
ULUBELU	140	-	150	-	250	-	300	-	300	55	300	110	300	165	300	220
LUMUTBALAI			75	-	250	-	300	-	300	-	300	55	300	110	300	220
HULULAIS					-	-	150	-	150	-	150	55	250	110	250	110
KOTAMOBAGU							100	-	100	-	100	40	150	40	150	80
SUNGAI PENUH							100	-	100	-	100	55	150	55	150	110
KARAHA	30	-	30	-	30	-	30	-	70	-	70	30	180	30	180	140
IYANG ARGOPURO*)							Subject to Evaluate (Business Portfolio)						100	-	100	55

Figure 9: PGE geothermal business portfolio.