ENVIRONMENTAL EFFECTS OF GEOTIXERMAL POWER PLANT OPERATIONS IN INDONESIA

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ABSTRACT

The current operating geathermal capacity in Indonesia consists of 140 MW of conventionally-designed units and 0.25 MW of noncondensing units at Kamojang; 2.0 MW of noncondensing backpressure units at Dirng; and 2.5 MW of hinary cycle units at Lahendong,

The development of geothermal power plants can adversely affect the surrounding environment. The potential environmental effects of geothermal plants vary, depcnding on the characteristics of the geothermal fluid and the technology being used.

This paper provides an nvervicw of the geothermal resources, engineering, and environmental effects of the different geothcrmal power plant operations in Indonesia.

1. INTRODUCTION

A heightened awareness of the environmental effects of power plant operations has resulted in stricter conrrol on their environmental impacts. Any power plant development needs to deal with the significant impacts on the surrounding physical and biological environmenr, Some of these impacts are similar for all kinds of site development, regardless of the type of technology or steam used.

This paper discusses the environmental effects of geothermal projects that vary depending on the characteristics of the geothermal fluid and the type of technology used. It describes and compares the environmental effects of the discharge of separated hot water and the impacts on air quality for each geothermal technology.

2. KAMOJANG GEOTHERMAL FIELD

The Kamojang geothermal power plant is located about 40 km south of Bandung in West Java.

Detailed geological, geophysical, arid geochemical studies have delineated a geothermal field of about 14 km^2 in area. The feasibility studies concluded that, using conservative assumptions, the reservoir is capable of supporting between 100 and 200 MW of electrical power over a 25-year period. The Kamojang geothermal field is a vapor-dominated system, and the wells produce dry or superheated steam with a gas content of 0.5-1.0% by weight.

Production wells have been drilled to a 1,500-meter nominal depth. These wells have the potential to supply about 380 tonnes/hr steam to Unit I. Thirty deep production wells provide mostly superheated steam to Units 1, 2, and 3.

A steam collection pipeline links all the projection wells to the power station. The pipeline is supported above ground level and includes a number of loops to allow for thermal expansion. The piping is thermally insulated and enclosed in aluminum cladding.

2.1 Kamojang Geothermal Power Station

The power station at Kamojang consists of threc units, Unit 1 is 30 MW and Units 2 arid 3 are 55 MW each, bringing the total installed capacity to 140 MW.

The steam turbine for Kamojang Unit I is a single-cylinder double-flow 5-stage condensing type unit with a steam inlet pressure of 6.5 bar (abs) and an exhaust pressure of 0.113 bar (abs). Steam consumption at the rated load is 233 tonnesihr, producing 30 MW of electric power

The gas cnntcnt of the steam at Kamojang is 0.5-1.0% by weight. The cooling system includes a low-level direct contact condenser, a 2-stage steam ejector gas extraction system, two vertical can-type cooling water pumps, and a mechanically-induced draft 3-cell crossflow cooling tower. Circulating water flow is 5,690 tonnes/hr, and the cooling system is designed to reduce temperature from 49.6°C to 20°C.

Eactt steam turbine at Kamojang Units 2 and 3 is a single-cylinder double-flow condensing unit with a steam inlet pressure of 6.5 bar (abs) and an exhaust pressure of 0.113 bar labs). The gas ejectors consist of steam-driven, 2-stage steam jet ejectors incorporating direct-contact inter- and aftercondensers. Condensate arid cooling water returns to the main condensers via barometric legs, and noncandensahlc gases discharge to the atmosphere via a penstock at each cooling tower fan.

Mechanical draft cooling towers are used in a closed-loop system. The amount of circulating water produced by the condensed steam exceeds the loss of water by evaporation and atmospheric drift from the cooling tower. Excess water is disposed of by blowdown to a wastewater disposal sysrem. Circulating water flow is 14,040 tonnes/hr with a maximum drift loss of 0.05%.

2.2 Geothermai Wastewater at Kamojang

The Kamojang geothermal reservoir is vapor-dominated, so the liquid wastewater is predominately steam condensate that contains relatively few contaminants. Chemical analysis of the production steam indicates the presenca of only small quantities of chemical impurities in the steam condensate.

The amount of excess condensate generated by the station depends on the performance of the cooling towers, which is in turn dependent on the ambient wet bulb temperature. Under design operating conditions, the cooling towers at Units 2 and 3 will: produce an excess condensate flow rate of 234 tonnesihr. When the blowdown produced by Kamojang Unit 1 is added, the total reaches 288 tonnes/hr. Excess condensatc from the cooling tower basin is returned to the four injection wells and reinjected into the reservoir.

2.3 Geothermal Gaseous Wastes at Kamojang

The partitioning ratio of the noncondensable gases after the geothermal steam enters the condenser is somewhat dependent on condenser design. The amount of carbon dioxide (CO_2) and hydrogen sulfide (H_2S), extracted from the condenser and vented to the atmosphere depends on the size arid performance of the condenser. The remaining gases are absorbed in the circulating water and either chemically reacted or stripped out in the cooling tower.

The total gaseous discharge from the condenser and cooling towers vent of the Kamojang statian is 1.548 kg/s of CO, and 0.061 kg/s of H_2S. Indonesia has riot set a standard for the allowable level of H_2S in the atmosphere. In other areas common standards are based on the odor threshold for general public exposure and the onset of eye Irritation for occupational exposure

3. LAHENDONG GEOTHERMAL FIELD

Lahendong geothermal field is located approximately 30 km south of Manao, the capital city of North Sulawesi Province.

Exploration drilling at the Lahendung geothermal field started in 1983 and has demonstrated the existence of geothermai energy. An area of approximately 4.4 km^2 has been delineated by drilling The deep reservoir has an estimated area of 3.7 km^2 and an electric potential of 65 MW

The Lahendong geothermal power plant with installed capacity a 2.5 MW is currently under construction , and this capacity will be expanded by an additional 20 MW as additional geothermal resource and funds became available. The French government funded engineering design in 1992 and power plant construction in 1993. The power plant is schedule to be commissioned in late 1996 or early 1997.

3.1 Lahendong Geothermal Power Station

Binary technology was initially considered for the Lahendong geothermal field Due to the insufficient thermal capacity in the hot water, the unit must operate only on the steam phase.

The geothermal fluid used for the binary power plant is supplied from the LHD-5 well. The tluid from LHD-5 has a wellhead pressure of 11.6 bar jabs) and a temperature, of 180°C. This fluid is be flashed in a wellhead separatot at 5.26 bar labs) and 160°C, producing 41.65 tonnes/hr of wet steam and 180 tonnes/hr of hot water.

The binary unit operates on a conventional Rankine cycle. The steam heats an organic fluid (n-pentane) through heat exchangers or evaporarors, which vaporizes it. The organic vapor drives a normal axial flow turbine and is then cooled and condensed within a condenser. The hot water from the wellhead separator is discharged into a sump pit through the separator drain, then usually cooled in several cascading ponds and discharged to a nearby river.

3.2 Geothermal Wastewater at Lahendong

Since the hot water released from the separator drain will be discharged into a nearby river, chemical and thermal pollution will occur.

The temperature of the wastewater Is 130°C, significantly higher than the 28°C temperature of the river water. After mixing, the local river temperature will increase up to 90 °C, resulting in thermal pollution. Water quality criteria of PLN regulatory define the threshold of environmental effects as a 5°C increasc in temperature over ambient receiving water temperatures.

In addition , the separated hot watcr from the pump pit contains some potentially hazardous substanccs, such as boron. ,If this water is discharged into wafer used for irrigation, a problem may arise, as it is considered undesirable to allow the concentration of boron to rise above 0.5 - 1.0 mgkg.

3.3 Geothermal Gaseous Waste at Lahendong

The natural geothermal features at Lahendong have been discharging H_2S to the atmosphere for many years. This continual emission of gases has created a natural level of H_2S in the ambient atmosphere at Lahendong.

Small quantities of H_2S discharged from the binary cycle genthermal power plant at Lahendong will be added to the release of gases already present at Lahendung. The H_2S is extracted from the top of the condenser and vented to the atmosphere through the cooling tower. Venting through the cooling tower exhaust plumes reduces the ground level concentrations of H_2S in the vicinity of the station.

4. DIENG GEOTHERMAL FIELD

The Dieng geothermal field is lacated about 100 km south of Semarang in Centrat Java. Detailed geologic, geophysical, and geochem icat studies have delineated four gcothcrmal arcas in Dieng, namely, Sikidang-Sikumang (6 km^2), Sileri (4 km^2), Seroja (8 km^2), and Candradimuka (7 km^2). Exploratory drilling of the Dieng 1 and Dieng 2 wells indicate a geothermal field with an electric potential of 2,000 MW. The feasibility study performed by West Jec of Japan concluded that the first priority for Dieng Geothermal development,the Sikidang-Sikunang area was capable of supporting between 153 MW and 306 MW of electric pawer over a 30-year period. The Dieng geothermal field is a water-dominated system with high concentrations of noncondensable gases and boron. At prescnt, the Dieng Monoblok Geothermal Power Station in the Sikidang area has an installed capacity of 2.0 MW in operation.

4.1 Dieng Monoblok Geothermal Power Statian

The geothermal fluid used for the Monoblok Geothermal Power Station is supplied from the Dieng 2 well. This production well was drilled to 1,662 m and has the potential to supply about 35 tonnesihr of steam to the existing Monoblok powcr station. Tlie well discharges a mixture of sream (70%) and water (30%). The noncondensable gases in the steam are 2.2% by volume.

The steam turbine for the Dieng Monoblok is a backpressure type unit with a steam inlet pressure of 8.06 bar ab5 and a steam pressure of 1.01 bar ahs . Steam consumption of 122.76 tonnes/hr, producing 2.0 MW of eiectric power.

The Dieng Monoblok Geothermal Power Station is a pilot project that supplies electricity for Kejajar, Garung, Batam, and Pejawaran through a 20-kV distribution network

The Dieng Monoblok Geothermal Power Station has experienced some operational problems such as boron and sulfur deposition and scaling on the turbine blades.

4.2 Geothermal Wastewater at Dieng

The Dieng geothermal field produces a steam-water mixture (70% steam and 30% water). The liquid discharge is predominately separated hot water that contains relatively high concentrations of contaminants, Chemical analysis of the separated hot water indicates the presence of high concentrations of chemical impurities in the separated water.

The separator at Dieng 2 releases 13 tonnes/hr of hot water, This waste flows into a flash tank through the water collection tank and is then discharged into a river, resulting in chemical and thermal pollution. The separated hot water contains potentially hazardous concentrations of boron (480 mg/kg) and ammonia (15 mg/kg).

4.3 Geothermal Gaseous Wastes at Dieng Monoblok

Estimated impacts of the Dieng Monoblock geothermal power station is based on the damaged to potatoes hal already occurred during production testing. Fogging at Dieng is a common occurrence and the operation of the Dieng Monoblock geothermal power station will effect air quality and local climate due to heat discharge.
The high concentration of H_2S extracted from the back pressure Turbine released to the atmosphere rogether with high moisture content in the air will produce sulphur dioxide (SO,) due to the air oxidation of H_2S. Sulphure dioxide in *the* air can pose a hazard *to* the environment.

5. COMPARISON OF IMPACTS AND CONCLUSION

All geothermal power plant operations have the potential to produce both liquid (separated hot water and/or steam condensatc) and gaseous releases.

The Kamojang geothermal field is vapor-dominared and its liquid waste is predominantly steam condensate, which conrains small Concentrations of chemical impurities. Steam condensate together with excess condensate from the cooling tower basic is returned to an injection well for injection into the reservoir.

The H_2S from the Kamojang power plant is released by venting the gas into the coding tower plume, reducing the ground level concentrations. The Kamojang geothennal power plnr operations do *not* present a hazard to the environment.

In contrast, the Dieng geotherma! reservoir is liquid-dominated, and the liquid wastewater- is predominantly separated hat water that contains high concentrations of chemical impurities. About 13 tonnes/hr of separated hot water flows through surface drainage and is discharged to the river. High concentrations of boron (boric acid) present a hazard to the environment. Treatment is needed, or the separated brine should be returned to the reservoir.

The H_2S gases together with boron and the steam discharge from the backpressure turbine can be damaging tn plant crops. Treatment is needed if there is no regulatory mandate] to reduce H_2S levels and the deposition of boron

The Lahendong geothermal reservoir is also a liquid-dominated system, but it contains small concentrations of chemical impurities About 180 tonnes/hr of separated hot water is discharged to the nearby river, which can be damaging to aquatic life and crops. Cooling is needed if the separated water should he returned to the reservoir.

In conclusion, Lapor-dominated reservoirs with conventional type of power generating equipment have less adverse effects on the environment than the liquid-dominated reservoirs with backpressure turbines In liquid-dominated fields, reinjection of the separated hot water is necessary fur environmental protection.

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