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Optimization of Steam Pipeline in Geothermal Power Located on Java Island

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Abstract

In geothermal power plant, pipeline is steam gathering system that transmitting steam from the well head to the turbine. Issue that occur is loss of energy during the transmission process in the form of heat loss, pressure drop, and decrement of flow rate. When major heat loss and pressure drop occur, the a low level of steam quality is an unavoidable consequence that leads to a higher risk of water hammer along the pipeline and water droplet that could cause corrosion in the turbine. On the other hand, decrement of flow rate means a lower amount of steam that transmitted to the turbines. All these phenomena would cause to a lower output power of the power plant.

In order to restore the output power to its initial condition, optimization of the pipeline must be conducted. This optimization will be conducted by analysing the pressure drop and calculating the heat loss and flow rate. These efforts will be followed by studying all possible scenarios that can be implemented to have a minimum pressure drop, heat loss, and a steady flow rate of the steam. A simulation using computerized fluid dynamic software will also be executed in order to have a clear view of the steam flow inside the pipeline. This simulation will also useful to obtain a best scenario that leads to minimum energy loss in the transmission process.

Background

Geothermal energy is a form thermal of energy contained underneath the rock and fluid below the surface of the earth. Geothermal energy which is used to generate electricity utilize two physical parameters, enthalpy and mass flow rate from its fluid known as steam, to spin blades of the turbine. Enthalpy and mass flow rate are the main parameters that determine the ammount of energy generated by geothermal power plant, which enthalpy itself is a pressure and temperature dependant parameter.

Steam from the production well is transmitted through pipeline toward the turbine. The problem that commonly occur during the transmission process is energy loss. Energy loss occur in the form of pressure drop, heat loss, and the decrement of flow rate. In order to minimize the energy loss, Pressure drop is caused by various factors, such as friction of the fluid on the inside pipe wall, elevation, elbow,and junction. When major heat loss and pressure drop occur, a low level of steam quality is an unavoidable consequence that leads to several disadvantages, such as a higher risk of water hammer along the pipeline and corrosion on the turbine due to water droplet. All these phenomena would cause to lower output power of the power plant.

Minimimum operating condition was established by PT PLN to ensure the power plant is operating well. In one of the geothermal power plant located on Java Island, it is found that one of its pipelines has an indication of no longer fulfilling the minimum criteria of operating condition, in this case minimum operating pressure and temperature are respectively, $P_{operation}$ > 6.5 kg/cm^2 and $T_{operation}$ >161^{o}C. It is necessary to conducted research related to pressure drop, heat loss, and decrement of steam quality. This research is intended to minimize energy loss by optimizing the pipeline. The output of this research is an engineering recommendation related to production facilities.

Methodology

The first step of conducting this research is to gather information and related data of the actual condition of pipeline. Pressure drop is calculate manualy using Panhandle A equation. This equation is used because in high temperature and superheated condition, the behaviour of steam is relatively simmilar to gas. As consequences, all thermodynamics and hydraulics of gas can be implemented. By calculating using this calculation, pressure as a function of length can be obtained.

Form of heat loss is calculated through conduction, convection, and radiation. Due its limitation, these manual calculations is supported by computer modeling using computational fluid dynamic software to study not only the pressure and temperature profile but also steam flow pattern.

Result and Disscussion

After gathering relevant information and data, the actual operating condition on well head connected to the pipeline is shown below

Table 1. Actual operating condition

Well Head	Diameter (inch)	Well Head Pressure (kg/cm^2)	Pipe Pressure (kg/cm^2)	Temperature (^{o}C)	Debit (ton/hour)
1	24	9,8	9,8	185	58,96
2	16	10,2	7,6	174	26,22
3	12	12,7	7,4	172	27,15
4	10	9,6	7,6	172	11,37
5	14	8,2	7	170	13,74
6	14	13	8	180	49,06
7	14	9,5	7,6	171	18,2
8	10	9,6	9,1	178	36,05
9	24	9,2	7,5	180	14,36
10	10	10,5	7,4	175	26,16

There are 10 well head that connected to the pipeline as production well, where each well has its own pressure and temperature. Steam from all of the production wells is transmitted to header. In order to know the pressure on the header, pressure is calculated by using Panhandle A. Based on the calculation using Panhandle A equation with the assumption of steam velocity is 30 m/s, pressure profile as a function of length is as below

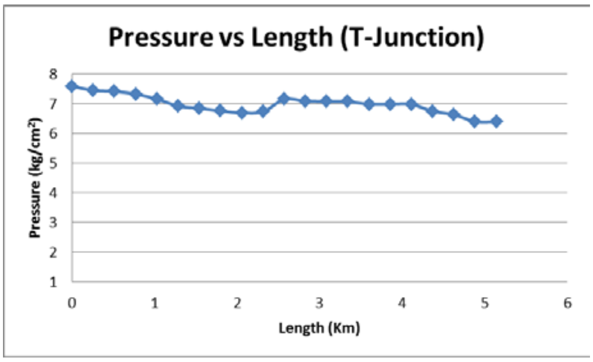

Figure 1. Pressure as a function of length (T-Junction is used on the pipeline).

This figure shows us that the pressure is dropping as the length increase. But in the length between 2 and 3 km, the pressure slightly increase to 7,1 kg/cm^2. The pressure increment occur because in this length, well 9 and 10 are located. It has significant pressure boost because well 9 and 10 have the biggest pressure compared to other wells. The other 8 wells which is located between 0 – 2 Km dont show a significant boost to the pressure profile because they only have small ammount of pressure difference between them. The most important value is the value at the downstream of pipe, refered as header. The pressure by the header is 6.39 kg/cm^2 , which is below the minimum operating condition requirement, 6.5 kg/cm^2. The result of pressure by the header using Panhandle A equation is relatively the same as direct measurement on geothermal field that show the value of 6.4 kg/cm^2.

One of the possible scenario to minimize the pressure drop is to replace T-Junction with Y-Junction. Pressure profile after replacing T-Junction with Y-Junction is as follow

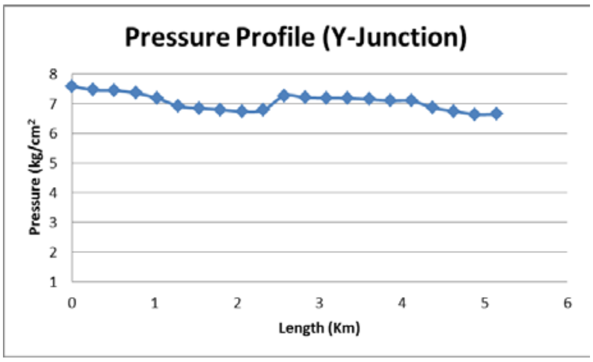

Figure 2. Pressure profile after replacing T-Junction with Y-Junction.

Based on the figure above, the pressure is relatively higher along the pipeline compared to pressure profile while still using T-Junction. The most important value after replacing the T-Junction is that the pressure by the header is 6,65 kg/cm^2. It means that the pressure by the header is above the meets the minimum operating pressure condition. Based on the scenario above, Y-Junction will give a higher pressure than J-Junction.

The terms of heat flux due to conduction, convection, and radiation is used to calculate the heat loss along the pipeline. It is assumed that the pressure is constant along the pipeline and the insulation along the pipeline is still good and has no physical defect. With T = 180^{o}C, mass flow = 281.27 ton/hour, and P = 0.75 Mpa, using thermodynamics tabel we have enthalpy h = 2780.1 kj/kg and total enthalpy of 217202 kj/s. The total heat flux due to convection, conduction, and radiation is 1684 kj/s. By reversing the equation, loss precentage is obtained with the value of 7.7 %.

Conclusion

Based on the calculation and the simulation that has been conduted, the replacement of T-Junction with Y-Junction will give a higher pressure by the header that meet the minimum operating condition. The result of manual calculation and simulation is relatively the same, although the simulation givea better result than manual calculation due to its limitation.

Heat loss along the pipeline is 1684 kj/s by manual calculation. Manual calculation could give a brief view of heat flux. But to its limitation, the temperature profile along the pipeline is hard to be obtained. Using the simulation, a more realistic temperature profile is obtained.

Reference

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