EXERGY ANALYSIS OF POWER PLANT AND EVALUATION OF SILICA SCALING POTENTIAL FOR OPTIMUM UTILIZATION OF HIGH TEMPERATURE GEOTHERMAL FLUID

Agung Pambudi, Nugroho

https://doi.org/10.15017/1470556

出版情報：九州大学, 2014, 博士（工学）, 課程博士
バージョン：

（様式２）

氏　　名　：ヌグロホ　アグン　パンブディ

論文題名　：EXERGY ANALYSIS OF POWER PLANT AND EVALUATION OF SILICA SCALING POTENTIAL FOR OPTIMUM UTILIZATION OF HIGH TEMPERATURE GEOTHERMAL FLUID
（高温地熱流体の最適な利用のための発電所のエクセルギー解析とシリカスケーリングポテンシャルの評価）

区　　分　：甲

論　文　内　容　の　要　旨

In the last few decades, consumption of energy has been drastically increasing globally, particularly in developing countries. In order to meet the ever increasing demand for energy, various energy resources need to be developed not only fossil fuel resources but also renewable energy resources. At the same time, energy utilization efficiency is also needed to be improved for suppressing consumption of primary energy resources. Geothermal energy is one of the renewable and natural energy resources, and can be used for various purposes depending on its temperature from power generation to hot spring. Most of the geothermal reservoirs which are developed for producing steam for power generation belong to the water dominated type. Geothermal wells in water-dominated reservoir produce steam-water two-phase mixture, and then separated steam is transported to power plant for electricity generation whereas water is sent back to reservoir via reinjection wells. This separated water still contains a large amount of energy which can be further used for power generation.

The Dieng geothermal field located in central Java, Indonesia, has adopted a single flash system for power generation using a steam produced from water-dominated reservoir with temperature higher than 300ºC. The objective of this research is to investigate an optimum utilization of high temperature geothermal fluid at Dieng by conducting exergy analysis for various development scenarios in terms of power generation system. This process can be started by evaluating a working performance of the existing power plant that comprises many components where losses of both energy and exergy occur. Brine utilization always accompanies silica scaling problem, and thus present mitigation methods for avoiding silica scaling at Dieng was examined and scaling potential was evaluated.

The dissertation consists of six chapters starting from Chapter 1 that describes the background of study, literature review, and objectives of study.

Chapter 2 discusses the performance of the present single flash geothermal power plant in Dieng using a thermodynamic method. Energy and exergy streams of the plant were analyzed by solving a set of mathematical equations with Engineering Equation Solver(EES). This performance evaluation extracts important parameters at major stage in the plant, which is used to calculate the losses of energy and exergy at each component of the plant such as separator, turbine, pump, condenser and cooling water.

The results from the performance evaluation indicate that the total available exergy in the produced fluid from wells is 66,204 kW. From this total exergy, 24,300 kW is converted to electricity and 16,140 kW is lost in the brine that flows into canal and pond before injected back to the reservoir. The Grassmann diagram illustrates an exergy stream in detail in the power plant. Waste brine accounts for 19.04% of the total available exergy. Optimization analysis by controlling the separator pressure from 10 bar to 8.6 bar resulted in a slight increase of power output by 109 kW. Thus, the present operation scheme of the plant is close to the optimum operational condition.

Chapter 3 covers the performance improvement scenario of the single-flash geothermal power plant. The plant is expanded into a double flash system that consists of the present single flash system and a low pressure steam generation system. The plant receives the same amount of geothermal fluid from production wells as indicated in Chapter 2. Thus, the total available exergy contained in the produced fluid is 66,204 kW. The low pressure steam is generated by flashing the separated water from the single flash plant, and sent to a low pressure turbine. A key parameter for an optimization is a pressure of low pressure separator(LPS). With the LPS pressure of 1.77 bar, the maximum power output is increased from 24,300 kW to 29,155 kW. Overall efficiencies of the first and second laws for this system then are calculated to be 14.09 % and 44.04 %, respectively

Chapter 4 discusses two scenarios of improving performance by adding a binary system to the present single flash system and to the designed double flash system in Chapter 3. In the first scenario, separated water at the single flash plant is directly supplied to a binary system. Working fluids used in binary systems have a wide range of evaporation temperature, thus this system has more flexibility for optimization compared with the double flash system in Chapter 3. Exergy contained in the waste brine from the separator of the single flash system is calculated to be 16,140 kW. Simulated result for optimum operational conditions of pump pressure in the binary system gives 7.4 bar with evaporation temperature of the working fluid, pentane, at 110.3˚C, then the maximum net power ouput by the binary system is calculated to be 3,646 kW. The amount of working fluid employed is 61.18 kg/s. In the second scenario, a binary system combined with the double flash system, available exergy contained in the brine discharged from the LPS is calculated to be 5,535 kW at 116.4˚C. For this scenario, pump pressure of the binary system is found to be 3 bar, yielding 1,310 kW output.

Chapter 5 discusses the behavior of silica in geothermal brine at the Dieng facilities. Silica concentrations along the canals are analyzed for the total silica and monomeric silica. Both concentrations decrease with a distance from the flasher where the brine is disposed into the canal. The decrease in the total silica concentration implies deposition of silica along the canal. Acidified brine to pH 3.3 successfully suppresses silica deposition along the canal as the total silica concentration remains constant. A batch experiment of silica polymerization is conducted under constant temperature of 80 ˚C using plastic container that immersed in the canal. The total silica concentration of 1,400 ppm at initial quickly decreases to 500 ppm within an hour, implying deposition of polymerized silica. Silica scaling potential for Dieng brine by referring solubility of amorphous silica would be lower for the double flash system compared to the binary system.

Finally Chapter 6 gives summary of the dissertation and recommendations.