Effect of ambient temperature organic Rankine cycle geothermal power plant with Aspen plus

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Abstract. This study concerns a thermodynamic analysis of the Organic Rankine Cycle for energy conversion from geothermal resources. Some thermodynamic variable was simulated by using Aspen plus. The equation of state is expressed by the Peng-Robinson formulation. Analysis carried out considering the variance of ambient temperature (27°C, 30°C, 33°C, 35°C, and 40°C) on air-cooled in the condenser. Result is obtained for several set operating parameters, such as the evaporation and condensation pressure for the variance of ambient temperature, the mass flow rate of the geothermal fluid. From results, the ambient temperature has affected for power generated of ORC. The lower ambient temperature then will increase the power generate of the system.

1. The first section in your paper

Today’s base on increase of people widely in the world has impact for electricity. Until today much of the world’s energy is produced by burning fossil fuel such as oil, coal, and gas. The production of energy in the word comes, approximately 86 % of fossil fuel. Burning fossil fuel emit into atmosphere carbon dioxide gas. They are the main cause of global warming which is causing serious damage to the environment [1]. Once fossil fuel is gone it cannot be replacing, so people need find the alternative energy like renewable energy source. The energy must safe, sustainable, and environmental-friendly source of power production. Proper utilization of renewable energy like wind, solar, geothermal, and biomass are capable to decreasing the rate consumption of fossil fuel and help to reduce the global warming and ozone depletion [2].

The organic Rankine cycle (ORC) is a promising process for the conversion of low and medium temperature heat to electricity. Unlike the conventional steam Rankine cycle, the organic Rankine cycle (ORC) uses an organic, and high molecular mass organic fluid. It allows heat recovery from low-temperature sources such as industrial-like waste heat, to converted into useful work or could be converted into electricity [3].

Some the literature studies concerning this research. Himsar and Hendrik [4] analyzed the performance of organic Rankine cycle (ORC) based on some of working fluids for cycle. There are three variances of working fluid, R245fa, R11, and R123. Han LV et al [5] simulated organic Rankine cycle based on Aspen plus. It showed the increasing the evaporation temperature and pressure could reduce steam consumption rate. Giuliano C et al. [6] studied the thermodynamics analysis of organic Rankine
cycle with compare the working fluid. There are two working fluid was simulated, isopentane and isobutane. Talieh Rajabloo studied the organic Rankine cycle base on different of working and peripheral conditions.

In this present work, this paper reports a thermodynamics analysis of ORC application for generating energy by exploiting geothermal resources. Results are carried out for variance of ambient temperature on power generating of organic Rankine cycle.

2. Modelling

Numerical models are built-up by some parameters approach. Modelling workflow is based on the following steps. Firstly, flowsheet is created, this organic Rankine cycle plant should consist of a pump, an evaporator, a turbine, and a condenser. The working fluids and their physical properties are implemented. Based on Aspen Plus software to simulate the process of the system, using the formulation of the equation of state as proposed by Peng-Robinson property calculation method [8].

\[
p = \frac{RT}{\bar{V} - b} - \frac{\alpha \alpha(T)}{\bar{V}^2 + 2b\bar{V} - b^2}
\]

Where \(\bar{V}\) is molar volume and coefficients are expressed as reported below:

\[
\alpha = \frac{0.45724R^2T^2}{P_c}
\]

\[
b = \frac{0.07780RT_c}{P_c}
\]

\[
\alpha(T) = \left(1 + \left(0.37464 + 1.54226\alpha_0 - 0.26992\alpha_2\right)\left(1 - T_r^{0.5}\right)^2\right)
\]

\[
T_r = \frac{T}{T_c}
\]

A workspace can then be produced, where the plant elements are introduced. Links joining the different symbolic object are then defined in respect of the mass and energy balances during the process. Boundary conditions and environmental parameters for the systems are set also. A schematic representation of the studied in the workspace is illustrated in figure 1.

![Figure 1. Aspen plus schematic for ORC plant](image-url)
Figure 2. Thermodynamic cycle in T-s chart for ORC

Figure 2 shows a representation of the thermodynamic cycle of the system under investigation in the temperature-entropy chart. The working fluid leaves the condenser as saturated liquid (state point 4) at condenser pressure. Then it is compressed by pump itself as subcooled liquid make increase the pressure but low temperature. Then the pentane enters evaporator, hot steam from geothermal heating the pentane to increase the temperature of the pentane and cold steam through back to underground, then the steam with high temperature and pressure enter to the turbine and generate the generator to get the electricity. The low pressure and temperature of Pentane will enter the condenser before being pump back into the evaporator. The main operational conditions and assumption for plant calculation as described in table 1.

| Parameter                                      | Value                                                                 |
|------------------------------------------------|----------------------------------------------------------------------|
| Working fluid                                  | R245fa (1,1,1,3,3-Pentafluoropropane)                                |
| Mass flow rate of working fluid (kg/hr)        | 360                                                                  |
| Phase fraction of working fluid (outlet of pump)| 0                                                                  |
| Phase fraction of working fluid (outlet of heat | 1                                                                  |
| exchanger, outlet expander)                    |                                                                      |
| Outlet pressure of expander (bar)              | 5                                                                   |
| Geothermal fluid mass flow rate (kg/hr)        | 2000                                                                |
| Geothermal fluid temperature (°C)              | 100                                                                  |
| Cooling water mass flow rate (kg/hr)           | 30000                                                               |
| Cooling water source temperature (°C)          | 27, 30, 33, 35, and 40                                               |
| Efficiency turbine (%)                         | 80                                                                  |
| Efficiency pump (%)                            | 80                                                                  |

3. Results
There are five the temperature was simulated, 27 °C, 30 °C, 33 °C, 35 °C, and 40 °C as ambient temperature to obtain the highest electricity output, and obtain the effect of variance of ambient temperature an operating condition on $\eta_{th}$ are analyzed. On figure 3 showed during the simulation, pressure inlet pump (Pp) of the organic Rankine cycle (ORC) is set to 2 bar, the temperature and pressure
steam geothermal resources were constant 100°C as temperature and temperature of air ambient in condenser was variance (27 °C, 30 °C, 33 °C, 35 °C, and 40 °C). The mass flow rate of the system was constant at 360 kg/hr.

Figure 3. Simulation ORC plant base on Aspen plus
From simulation showed that temperature environment as ambient temperature has effect for performance of organic Rankine cycle. An operating condition on $\eta_{th}$ are analyzed. During the simulation, pressure outlet turbine (P_out) of the ORC is set to 2 bar and the pressure inlet turbine (P_in) 5 bar. From simulation showed that pressure inlet turbine and working fluids variance has effect for performance of organic Rankine cycle.

Figure 4. Outlet power of ORC turbine for variance working fluids
Figure 4 shows changes in the power generated under different ambient temperature condenser ORC. The pressure working fluid of the heat source has a nominal value and equals to 2 bar. For each pressure, the system was optimized for the maximum system efficiency. With the increase of temperature in the range from 27 °C, 30 °C, 33 °C, 35 °C, and 40 °C, the power output ORC of the system decreases from -0.9573 kW to -0.9578 kW. From figure 3 shows outlet power of ORC turbine for variance ambient temperature, the highest outlet power was obtained for 27 °C as ambient temperature, and the lowest was the highest temperature 40 °C. Average power decrease 0.06% from 27 °C to 40 °C as ambient temperature. The figure showed that increase the temperature ambient for cooling on condensate has decrease the outlet power turbine ORC.

4. Conclusions
The ORC to generate the electricity was simulated and analysed in this study. Aspen plus V10 software simulation was used to calculate the thermodynamic characteristics of the design. On this study simulated the variance of ambient temperature 27°C, 30°C, 33°C, 35°C, and 40°C. The system obtained for R245fa (Pentafluoropropane) as working fluid. Form this research showed that the ambient temperature has affected for power generate of ORC. The lower ambient temperature then will increase the power generate of the system.

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