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Simulation of 25 MWe Steam Power Plants Using Gate Cycle

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Abstract: ***Power plants using steam are a very popular system today. To develop a construction of power plant system requires an accurate analysis in determining operating parameters as expected. Designing with manual calculations certainly requires a very long time. One of faster method use a thermodynamic simulation system such as a Gate Cycle. The goal of this research was to simulate a steam power plant to produce 25 MW net electric power and to investigate the effect of an increasing of main steam temperature, main steam pressure and condenser pressure on electrical power and thermal efficiency. The simulation was done using the main input data of simulation were tempe rature of 535 ^{0}C, pressure of 89 bar, condenser pressure of 0.084 bar and heating value of low rank coal of 3800 kcal/kg. The main steam temperature was varied of 515; 535; 555 and 575 ^{0}C. The main steam pressure was varied of 79; 89; 99 and 120 bar, The condenser pressure was varied at 0.064; 0.074; 0.084 and 0.094 bar. The simulation results showed the net electric power produced of 25.8 MW on the main input data. An increasing of the main steam temperature and the main steam pressure would increase the net electrical power and the thermal efficiency but an increasing of condenser pressure would decrease the net electrical power and the thermal efficiency***

Keywords: ***Steam Power Plant, Simulation, Gate Cycle, Electric Power, Thermal Efficiency.***

I. INTRODUCTION

Fossil fuel power plant have dominant to produce world electricity with about 68% of total world electricity [1]. Indonesia is a country that is rich in natural resources especially from fossil fuel such as natural gas, petroleum and coal. This condition illustrates the magnitude of the potential of energy that can be used to produce electricity. One of converting method is the steam power system or Rankine cycle. The Rankine cycle have range thermal efficiency of 33% to 45% but it still depended on main steam pressure, main steam temperature and fuel used [1][2]. The range of operation pressure and temperature of steam power plant of 10 kg/cm^2 to critical pressure and 250^{0}C to 650^{0}C respectively [3]. Circulating fluidized bed boiler is most popular to integrate on the steam turbine caused by lower emission produced (low temperature operation) and higher efficiency [4][5][6]. The thermal efficiency of Rankine cycle could be improved by the stage of regeneration (stage of steam extraction from the turbine) [7]. According the PLN reports, the steam power plant installed in Indonesia increase from 16,180 MW to 25,104 MW on period of 2011 to 2014, it was about 47% from total power plant installed [8].

In the process of developing steam power plant, a simulation process is needed to estimate the value of operating parameters that will be used to produce the targeted power. Several simulations of steam power plant systems using Gate Cycle have been carried out. Osmik et al conducted simulations on steam boilers using Gate Cycle. The simulation results showed that the boiler furnace geometry was strongly influenced by the flue gas temperature and the amount of coal mass flow rate [9]. Marcin et al performed a simulation on the gas turbine to see the effect of an air heat recovery turbine unit (ARHTU) on the turbine power and efficiency. The simulation results showed that ARHTU used will increase power to 32% and efficiency to 9% [10]. Ary et al did simulation steam power savings by varying pressure extraction of the system. The simulation results showed an increase in extraction pressure would increase in thermal efficiency [11]. Tie et al conducted a simulation using Gate Cycle to investigate the effect of operating parameters on the performance of the combination cycle. The simulation results showed ambient temperature, pressure ratio and turbine inlet temperature were important parameters in influencing of turbine efficiency [12]. Emmanuel et al conducted a simulation on the gas turbine system using Gate Cycle to investigate the effect of syngas combustion on gas turbines. The simulation results showed the concentration of hydrogen in syngas and the amount of moisture in the combustion product greatly affected the occurrence of the hot spots on the turbine [13].

In this study a simulation of the steam power plants was carried out to produce 25 MW of net electric power using Gate Cycle.

II. METHODOLOGY

The first step, in this simulation was the determination of the configuration of steam power plant. The system configuration chosen were one stage of turbine with three stage of steam extractions (regeneration) as shown in Figure 1.

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The type of boiler used was circulating fluidized bed (CFB). The configuration was created at Gate Cycle using the system blocks that have been provided as shown in Figure 2.

The simulation input data was obtained based on conditions that exist in the field and the data required as shown Table 1. The main pressure and temperature base on general used by industrial boiler. The auxiliary power used was base on requirement of industrial. The combustion process needed the proximate and ultimate of coal.

The first simulation was done using the main of input data as shown in table 1, then simulation was done using variation of main steam pressure of 79; 89; 99 and 120 bar, variation of main steam temperature of 515; 535; 555 and 575 ^{0}C, variation of condenser pressure of 0.064; 0.074; 0.084 and 0.094 bar.

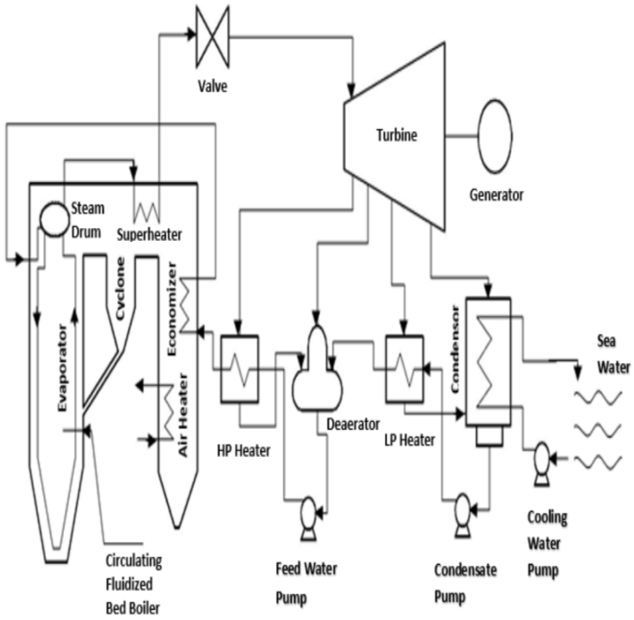

Figure 1. The Configuration Of A Steam Power Plant

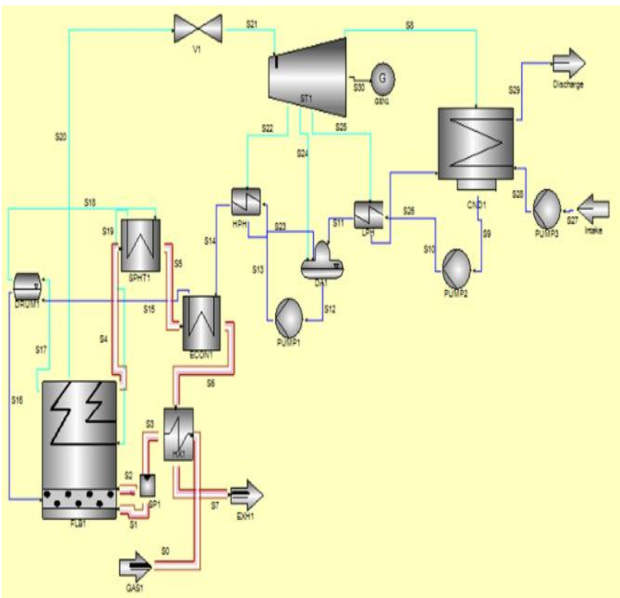

Figure 2, The configuration of a steam power plant on Gate Cycle

Table 1. The Main Input Data of The Simulation

Parameters	Unit	Value
Main Steam Temperature	535	^{0}C
Main Steam Pressure	89	bar
Condenser Pressure	0.084	bar
Calorific Value of Low Rank Coal	3800	kcal/kg
Low Rank Coal Mass Flow Rate	23.2	Ton/h
Water mass flow rate	29.299	kg/s
Steam extraction pressure 1	12	Bar
Steam extraction pressure 2	4,9	bar
Steam extraction pressure 3	0,38	bar
Auxiliary power	2086.7	kW

III. RESULTS AND DISCUSSIONS

From the simulation results show that the input data for each component of steam power plant as shown in table 1 can be obtained about 25 MWe of net electricity power. The other parameters obtained from the simulation results are shown in table 2. The result of simulation on variation of parameters as shown in Table 3.

Table 2. The Main Output Simulation Of Performance Steam Power Plant

Parameters	Unit	Value
Net Electrical Power Output	MWe	25.8008
Power Output of Turbine	kW	28701.41
Power Output of Generator	kW	28270.89
Thermal Efficiency	%	30.966

Table 3. The main output simulation on variation of Parameters

Parameters	Net Electrical Power (MW)	Thermal Efficiency (%)
Main Steam Pressure (bar)		
79	25.48	30.58
89	25.8	30.97
99	26.08	31.3
120	26.56	31.9
Main Steam Temperature (^{0}C)		
515	25.62	30.75
535	25.8	30.97
555	25.98	31.19
575	26.17	31.42
Condenser Pressure (bar)		
0.064	26.35	31.62
0.074	26.05	31.27
0.084	25.8	30.97
0.094	25.56	30.68

Figure 3 shows the effect of an increasing main steam pressure on the net electric power. An increased pressure tended to increase net electrical power. The increase in main steam pressure from 79 bar to 120 bar would increase net electricity power from 25.48 MW to 26.56 MW. This was caused by an increase in pressure results in an increase in steam temperature. The high of steam temperature identified the high of steam thermal energy which would increase net electrical power that can be produced.

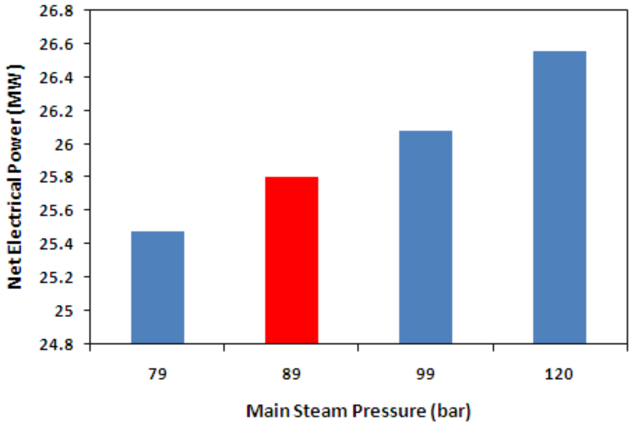

Figure 3. The influence of the main steam pressure on net electric power.

Figure 4 shows an increase in steam pressure tended to increase the thermal efficiency of a steam power plant from 30.58 % to 31.9%. This was caused by the increase in turbine power output was more significant than the increase in the input of power to the system that was identified in the net electric power as illustrated in Figure 3.

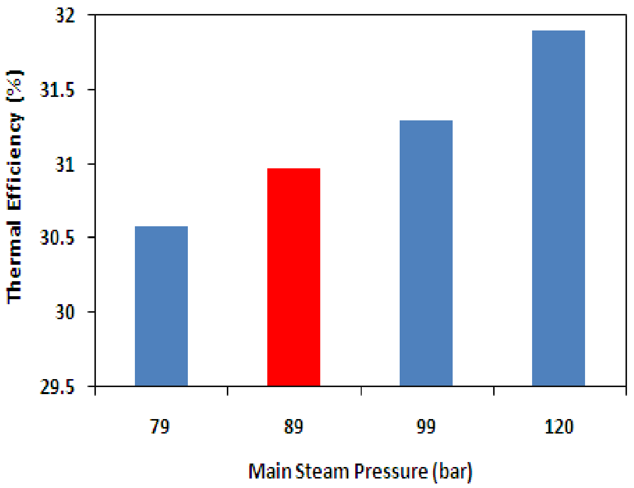

Figure 4. The Influence Of Main Steam Pressure On Thermal Efficiency

Figure 5 shows the effect of increasing the main steam temperature on the net electrical power produced. An increase in main steam temperature from 515 ^{0}C to 575 ^{0}C would increase the net electrical power from 25.62 MW to 26.17 MW. This was caused by the increase in the main steam temperature resulted in increasing the energy transferred to the steam that caused an increase in the turbine power produced. On the other hand, the pressure of steam was constant so there is no additional energy from the outside. As a result of these conditions was an increase in the net electrical power produced. The use of operation temperature would depend on the material of boiler used.

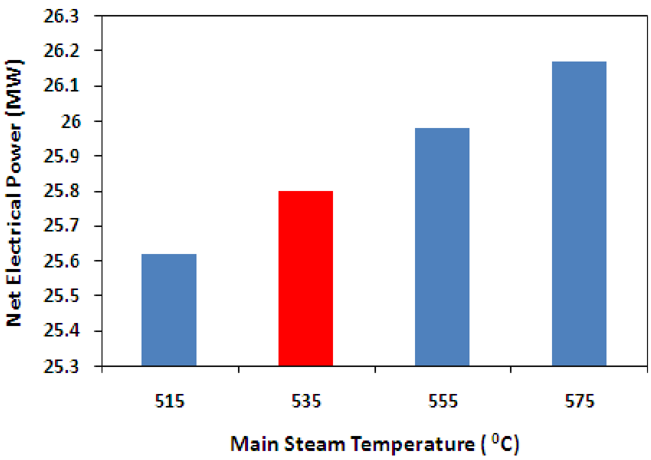

Figure 5. The Influence Of Main Steam Temperature On Net Electric Power

Figure 6 shows the increase in the main steam temperature tended to increase the thermal efficiency of a steam power plant from 30.75% to 31.42%. This was caused by an increase in the main steam temperature was not dominant to increase the input power of the all system, this was identified in the net electric power produced as shown in Figure 5.

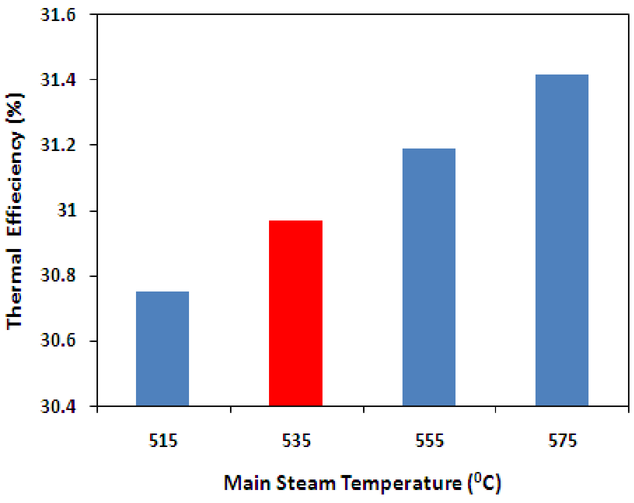

Figure 6. The influence of main stream temperature on thermal efficiency.

Figure 7 shows the effect of increasing pressure of the condenser on electric power. An increasing the pressure of the condenser 0.064 bar to 0.094 bar would reduce net electric power from 26.35 MW to 25.56 MW. This was caused by the increase in pressure of the condenser caused the expansion of the turbine to be reduced, thereby reducing turbine work which resulted in a decrease in the net electrical power produced.

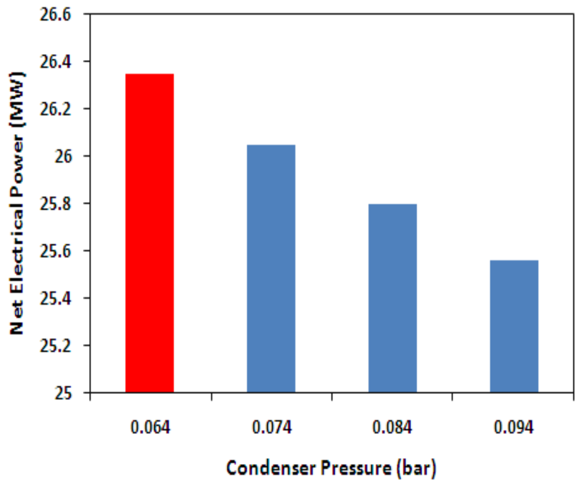

Figure 7. The Influence Of Condenser Pressure On Electrical Power

Figure 8 shows an increase in condenser pressure tended to decrease the thermal efficiency of a steam power plant from 31.62% to 30.68%. This was caused by the increase in condenser pressure was more significant in reducing on net electric power output as shown in Figure 7.

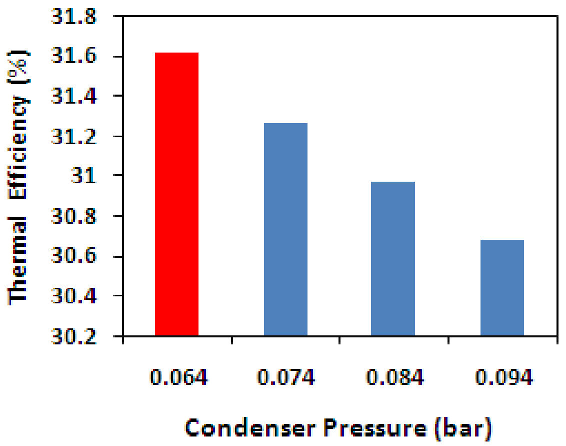

Figure 8. The influence of condenser pressure on thermal efficiency

IV. CONCLUSION

From the simulation results using Gate Cycle predicted a steam power plant with the net electric output power of 25 MW can be generated using coal with a heating value of 3800 kcal/kg, the main steam pressure of 89 bar, the condenser pressure of 0.084 bar and the main steam temperature of 535 ^{0}C. An increasing on pressure and temperature of the main steam would increase the net electrical output power and thermal efficiency while an increasing on the pressure of the condenser would reduce the net electric output power and thermal efficiency. The net electric power range was produced between 25.48 MW to 26.56 MW and thermal efficiency between 30.58% to 31.9%.

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AUTHORS PROFILE

Fajri Vidian, working as a lecturer at Mechanical Engineering of Universitas Sriwijaya. Master and Doctoral Research Projects were biomass gasification at Mechanical Engineering of Universitas Indonesia. Research area interest is gasification including: experimental of gasification and its application for producing heat and power, CFD of gasification and combustion, thermodynamic model of gasification, thermodynamic model of gas turbine power plant and thermodynamic model of steam power plant.

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