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HEAT RATE SYSTEM ANALYSIS IN THE STEAM POWER PLANT IN NIITANASA USING ENVIRONMENTALLY FRIENDLY LOW-CALORIE FUELS (REVISI)

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Abstract

The heat rate in a steam power plant is very important to know because it involves the amount of energy supply needed to produce electricity. This is done to determine the heat energy input from fuel needed in an electric energy. The purpose of this research is to analyze the heat rate needed in a steam power plant. The method used is the direct method, the required input is Gross kWh, Net kWh, coal fuel use, calorific value of the fuel. The type of fuel used is low calorie type of lignite. The results of the Gross Heat rate in January were seen 4,323.98 kcal / kWh while the Net Heat rate was 5,010.97 kcal / kWh. In December the Gross Heat rate was 4,141.72 kcal / kWh while the Net Heat rate was 4,992.96 kcal / kWh. This value is relatively high at a capacity of MW 100 MW.

Keywords

Heat Rate, Coal, Steam, Electric, Fuel

1. Introduction

1.1. Background

Steam power plants are a solution to meet energy consumption, especially in coastal areas where sea water can be converted into steam and also the use of coal which is thermally converted into steam. Sea water is distilled into fresh water and then converted to steam through a thermal process. These changes require a boiler as a heater and pump to flow the fluid, so that it is processed through a thermal system that can produce high heat and then it is converted into steam. The function of the steam here is to turn the turbine and then the turbine can turn the generator.

Energy can be used both for electricity needs and for other needs such as heating or cooling. This can be applied to industrial or household electricity transmission or distribution systems. The energy can be changed from one form to another to make it more useful. In general, energy changes the perspective of utilization that is more effective, efficient and can consider the effects or costs of energy supply to meet electricity needs.

The NiiTanasa steam power plant is a steam power plant with a capacity of 3 * 10 MW using coal fuel. The location of the plant is located in Soropia sub-district, Konawe, Southeast Sulawesi Province. In operation, one of the turbines does not work, so the turbine used is only 2 * 10 MW.

Development of electricity using steam power must consider environmental factors, where the use of fuel does not contain harmful toxins that will damage the surrounding environment. The use of coal in various types of course there are also those that contain toxic levels that are harmful to health, so the need for environmentally friendly coal selection, where the levels of toxins used are safe for health and the environment.

Analysis of the Heat rate is very important. In the generator is very related to load fluctuations in the form of daily, monthly or annual, as well as relating to the heat rate to analyze the heat generated from coal combustion, the amount of fuel used, the power generated by the generator, so based on this, researchers are interested in researching.

1.2. Research Purposes

This study aims to determine the heat rate of a steam power plant in NiiTanasaKonawe Regency, Southeast Sulawesi.

1.3. Literature Review

Energy cannot be created or cannot be destroyed but can change shape to another form or experience energy transfer, for example: mechanical energy, thermal energy, electrical energy, radiation energy, etc. The energy contained in a thermodynamic system is called internal energy or simply system energy. In all processes, reversible or irreversible, changes in internal energy must comply with the first law of thermodynamics (Stølen, 2004)

Once a system has been selected for analysis, it can be further described in terms of its properties. A property is a characteristic of a system and its value is independent of the history of the system. Some thermodynamic properties are directly or indirectly measurable, such as pressure, temperature, volume, specific heat at constant pressure, and specific heat at constant volume. (Wiu, 2007)

Thermodynamics is the science of energy transfor-mations. The first law of Law of thermodynamics tells us that energy cannot be created or destroyed, but it can be Entropy transformed. The second law of thermodynamics tells us what happens in those transformations (Fleisher, 2002).

Coal is a fossil fuel. The general understanding is that combustible sedimentary rocks, which are formed from organic deposits, are derived from plant remains and formed through a very long process. The main elements consist of carbon, hydrogen and oxygen. In principle, coal can be obtained from a relatively shallow layer by removing the soil above it, or the cover layer. Overburden is then methodically removed and stored for soil restoration to the original contour after coal removal. Dragline is usually used to expose coal seams, this is seen in (Figure 1). Stripping ratio is defined as the number of overburden units that must be removed to access the number of coal units. Strict environmental regulations limit the amount of land surface area that can be exposed at one time, control runoff, and establish land reclamation procedures (Stulzt, 2005)

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Figure 1: *Large Coal Dragline in Operation (Courtesy of National Coal Association)*

The process of cleaning coal includes garbage disposal, destruction of coal specimens, coal refining or filtering which serves to separate sizes from coal. Picture 2 shows the general layout of the operation of the coal cleaning unit. Specific gravity concentration and also subsequent coal separation into several products are the most common ways of mechanical coal cleaning. Coal and impurities can be separated by inherent differences in specific gravity, as shown in Table 1.

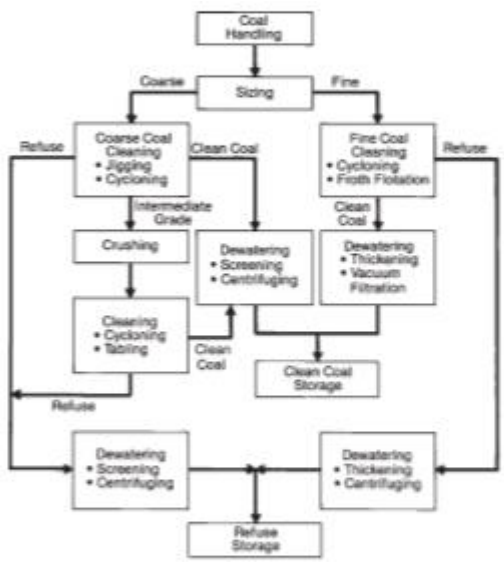

Figure 2: *General Layout of Coal Cleaning Operations*

Table 1: *Typical Specific Gravities of Coal and Related Impurities*

Material	**Specific Gravity**
Bitumious Coal	1,10 to 1,35
Booc Coal	1,35 to 1,70
Carbonaccous Shale	1,60 to 2,20
Shale	2,00 to 2,60
Clay	1,80 to 2,20
Pyrate	1,80 to 5,20

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A boiler is a closed vessel in which heat is flowed through the fluid through the conduit to the pipe to produce or form steam. The surface of the boiler is defined as a tube and drum skin which is part of the water-vapor circulation system, and which is in contact with hot gas (exhaust gas). Water tube construction allows greater boiler capacity and higher pressure than shell or fire tube designs. The boiler system consists of feed water sub system, steam sub system and fuel sub system. Water tube boilers are more flexibility; this allows more efficient use of furnaces, super heaters, reheaters, and other heat recovery components. Higher heat absorption results in higher vapor temperatures leaving the superheater and higher boiler output. (See Figure 3.)

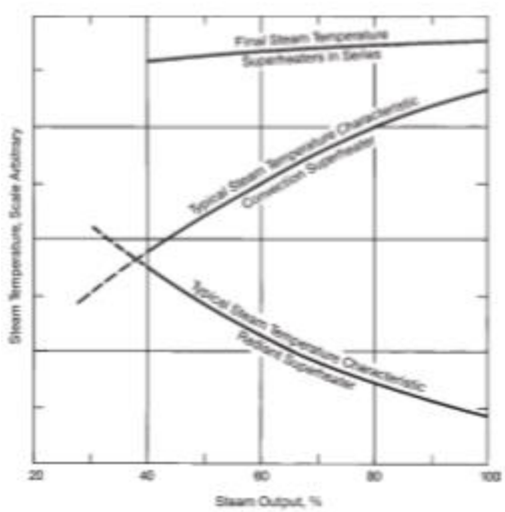

Figure 3: *A Substantially Uniform Steam Temperature over a Range of Output can be attained by a Series Arrangement or Radiant and Convection Super Heater Components*

Figure 4 shows a generic steam system. Water obtained from the sea needs to be filtered and processed through a tube. The treated water is then thermally conditioned and the temperature is increased using either condensate return or primed steam injection. The increase in temperature also serves to reduce thermal shock to the boiler which is a significant cause from local cracking in pressure vessels. The water is then treated with various kinds chemicals to provide optimal properties, such as the correct pH or required level oxygen scavenger.(Roberts, 2017)

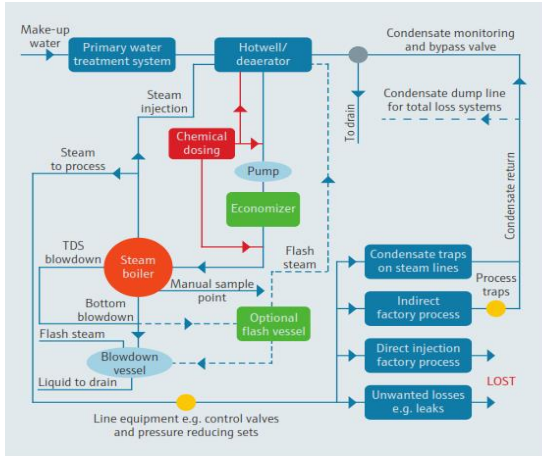

Figure 4: *Scheme of a Generic Steam System*

In the step control system, where one or more control approaches have been adopted to control an emission in a steam power plant:

a) Emission standards This limits the mass of SO2, NOx, or other pollutants emitted by volume, either from heat input, or electrical energy output, or by time units (hours, daily, yearly)

b) Percent removal requirements this determines the portion of uncontrolled emissions that must be removed from the flue gas.

c) Fuel requirements mainly intended for SO2 control, this limits the type of fuel that can be burned or the sulfur content of the fuel.

d) Technology requirements usually indicate the type of control technology that is specifically required or indicate the use of the best available control technology. (Stulzt, 2005)

Table 2: *The Exergy Destruction and Exergy Efficiency Equations for Plant Components*

Indentified	Exergy destruction rate	Exergy Efficiency
Boiler	$i_{Boiler}=\dot{X}_{fuel}+\dot{X}_{in}-\dot{X}_{out}$	$\eta_{Boiler}=\frac{\dot{X}_{out}-\dot{X}_{in}}{\dot{X}_{out}}$
Pumps	$i_{Pump}=\dot{X}_{in}-\dot{X}_{out}-\dot{X}_{Pump}$	$\eta_{Pump}=1-\frac{i_{pump}}{\dot{W}_{pump}}$
Heaters	$i_{heaters}=\dot{X}_{in}-\dot{X}_{out}$	$\eta_{heater}=1-\frac{i_{heater}}{\dot{X}_{in}}$
Turbine	$i_{Turbine}=\dot{X}_{in}-\dot{X}_{out}-\dot{W}_{el}$	$\eta_{Turbine}=1-\frac{i_{turbine}}{\dot{x}_{in}-\dot{x}_{out}}$
Condenser	$i_{Condenser}=\dot{X}_{in}-\dot{X}_{out}+\dot{W}_{f}$	$\eta_{Condenser}=\frac{\dot{x}_{out}}{\dot{x}_{in}+\dot{W}_{f}}$
Cycle	$i_{Cycle}=\sum all\ Components\ i_{i}$	$\eta_{Cycle}=\frac{W_{cycle}}{\dot{x}_{out}}$

Source: (H.Aljundi, 2007)

Mass, energy, and exergy balances for any control volume at steady state with negligible potential and kinetic energy changes can be expressed, respectively, by

$$\sum \dot{m}_i - \sum \dot{m}_e (1)$$

$$\dot{Q} - \dot{W} - \sum \dot{m}_e h_e - \sum \dot{m}_i h_i (2)$$

$$\dot{X}_{beat} - \dot{W} - \sum \dot{m}_e \psi_e - \sum \dot{m}_i \psi_i + i (3)$$

Where the net exergy transfer by heat ($\dot{X}_{beat}$) at temperature T is given by:

$$\dot{X}_{beat} - \sum(1 - T_o/T)\dot{Q} (4)$$

$$\Psi - h - h_o (s - s_o) (5)$$

Then the total exergy rate associated with a fluid stream becomes

$$\dot{X} - \dot{m}\Psi - \dot{m}[h - h_o - T_o(s - s_o] (6)$$

Under steady state operating conditions, the choice of each component of the volume control is seen, as shown in Figure 5. The level of exergy damage and exergy efficiency is defined as shown in Table 2. The exergy efficiency of the power cycle can be defined in several ways, but the definition used not only cannot heat transfer be returned to the steam in the boiler, but also the destruction of exergy associated with burning fuel and the exergy lost by exhaust gas from the furnace. (M. Kanoglu, 2007)

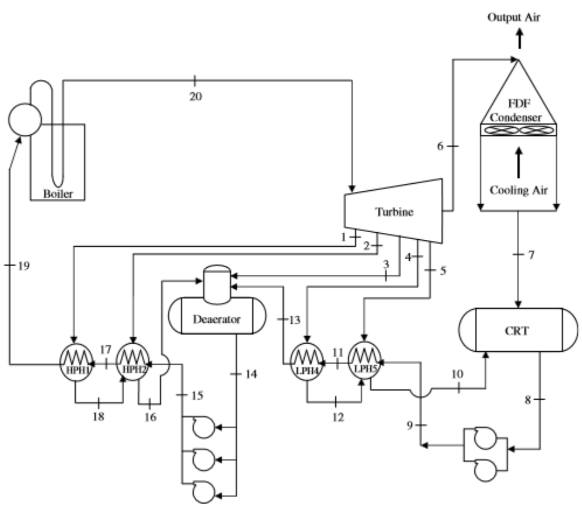

Figure 5: *Schematic Diagram of the Power Plant*
(Source: (H.Aljundi, 2007)

Calculation of heat race uses a formula based on SPLN number 80 in 1989 with the following equation:

$$HR_{Brutto} = \frac{q_f * LHV}{kWh_{Brutto}} (7)$$

$$HR_{Netto} = \frac{q_f * LHV}{kWh_{Netto}} (8)$$

Where

q_f = The amount of fuel used (kg)

LHV = calorie value of fuel (kcal/kg)

kWh_N = Data generated by the generator after being reduced by the generator's own usage (MW)

kWh_B = Data generate dimpor by the generator (MW)

The heat rate in a steam power plant is the amount of energy supply needed to produce electricity by 1 kWh. This is done to determine the heat energy input from fuel needed to produce energy of 1 kWh.(PLTU, 2018)

NiiTanasa steam power plant uses low-calorie type of lignite coal, with a calorific value of 3500 kcal / kg - 4611 kcal / kg, its water content is around 60%, this affects the heat rate value.

2. Research Methods

2.1. Time and Place

When this research was conducted in July 2019 at the Halu Oleo University Faculty of Engineering

2.2. The Method Used

The method used in this study is: using the Direct method, which is the fuel used in the generator, will be compared directly with the output energy produced by the generator. Where the data used is sourced from secondary data Steam power plants in NiiTanasa with a capacity of 2 * 10 MW.

2.3. Research Procedure

The work procedures in this study can be illustrated through the following flow diagram:

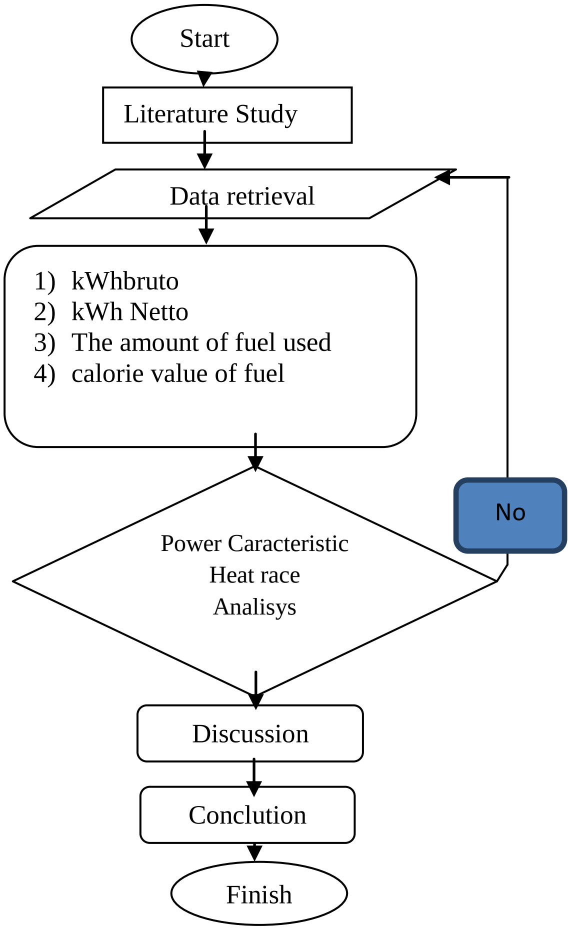

Figure 6: *Flow Chart Research*

3. Results and Discussion

The value of heat rate on steam power plants based on semester one and semester two data taken at the beginning of the month and end of the month can be calculated as follows:

a) January 2018 (semester 1)

$HR_{Brutto} = \frac{Qf.LHV}{kWh_{Bruto}}$

$= \frac{402,13*4000}{372} =$ 4.323,98 kcal/kWh

$HR_{Netto} = \frac{Qf.LHV}{kWh_{Netto}}$

$= \frac{402,13*4000}{321} =$ 5.010,97 kcal/kWh

b) December 2018 (semeter 2)

$HR_{Brutto} = \frac{Qf.LHV}{kWh_{Bruto}}$

$= \frac{134,81*4000}{130}$ = 4.148,00 kcal/kWh

$HR_{Netto} = \frac{Qf.LHV}{kWh_{Nettto}}$

$= \frac{134,81*4000}{108} =$ 4.992,96 kcal/kWh

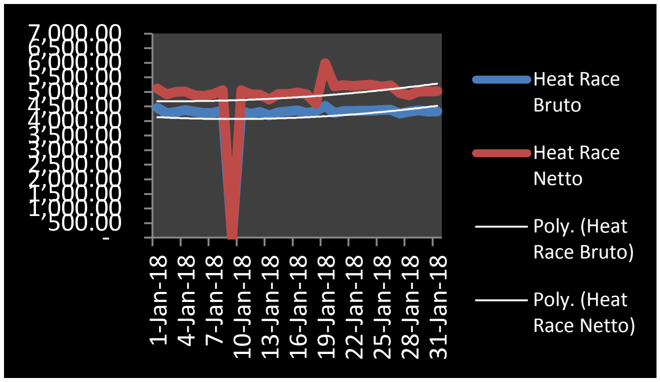

Figure 7: *Heat Race (kcal / kWh) Value in January 2018*

In the analysis of Gross Heat race Value data when the generator produces the highest value obtained on January 19 is 4,514.62 kcal / kWh, while the lowest value on January 9 is 0 kcal / kWh. The average value is 4,323.98 kcal / kWh. For January 9, 0 kcal / kWh is caused because there is no data collection on that day. In the analysis of the value of the Net Heat race the analysis when the generator produces the load obtained the highest value on January 19 at 5,984.50 kcal / kWh, while the lowest value on January 9 at 0 kcal / kWh. The average value of 5010.97 kcal / kWh. For January 9, 0 kcal / kWh is caused because there is no data collection on that day. If you see Polynominal trends tend to experience a slight increase but remain stable, this is due to data collection in January for Gross kWh, Net kWh, Fuel Usage, Calorie value of coal fuel, tend to be stable. Based on the proposed PLTU heat race limit in Indonesia in the category ≤100 MW with a maximum allowable heat race limit of 3,632 kcal / kWh.NiiTanasa'sTenga Steam Power Plant with a capacity of 2 * 10 MW, "based on the proposed maximum heat rate limit is outside the maximum heat rate range proposed by the State Power Plant (PLN)".

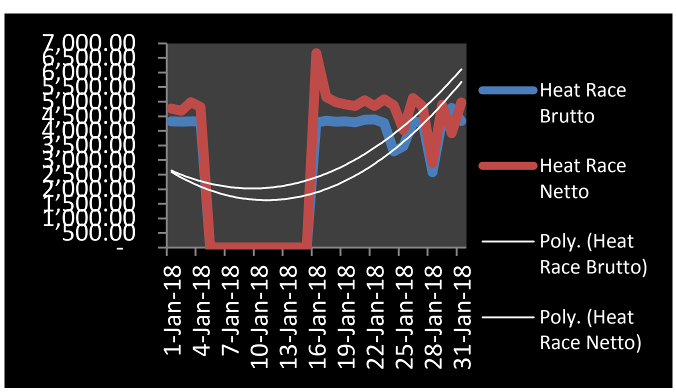

Figure 8: *Heat Race (kcal / kWh) Value in December 2018*

In the analysis of Gross Heat race Value data when the generator produces the highest value obtained on December 30 is 4,788.46 kcal / kWh, while the lowest value on December 5-15 is 0 kcal / kWh. The average value is 4,141.72 kcal / kWh. For December 5-15 0 kcal / kWh is caused because there is no data collection on that day. In the analysis of the value of the Net Heat race in an analysis when the generator produces the load obtained the highest value on December 16 at 6666.67 kcal / kWh, while the lowest value on December 9 at 0 kcal / kWh. The average value is 4,992.96 kcal / kWh. For December 5-15 0 kcal / kWh is caused because there is no data collection on that day. If you see Polynominal trends tend to increase, this is due to data collection in December for Gross kWh, Net kWh, Fuel Usage, coal fuel Calorie values, tend to be unstable or a lot of empty data, especially December 5-15. But if it is seen from the aspect of the heat the race has shown the average value based on the analysis of the above calculation. Based on the proposed PLTU heat race limit in Indonesia in the category ≤100 MW with a maximum allowable heat race limit of 3,632 kcal / kWh.NiiTanasa'sTenga Steam Power Plant with a capacity of 2 * 10 MW, "based on the proposed maximum heat rate limit is outside the maximum heat rate range proposed by the State Power Plant (PLN)".

The heat race value is one of the thermal generator performance indexes. The higher the value of the heat race, the higher the efficiency of a generator, so that the accuracy of a parameter will affect a heat race calculation, both the input put-out method and head loss.

4. Conclusion

Based on the above analysis, it can be concluded as follows:

1) In the analysis of Gross Heat race value data when the generator produces the highest value on January 19 is 4,514.62 kcal / kWh, while the lowest value on January 9 is 0 kcal / kWh. The average value is 4,323.98 kcal / kWh. In the analysis of the value of the Net Heat race the analysis when the generator produces the load obtained the highest value on January 19 at 5,984.50 kcal / kWh, while the lowest value on January 9 at 0 kcal / kWh. The average value of 5010.97 kcal / kWh

2) In the analysis of the Gross Heat race Value analysis data when the generator produces the highest value obtained on December 30 was 4,788.46 kcal / kWh, while the lowest value on December 5-15 was 0 kcal / kWh. The average value is 4,141.72 kcal / kWh. In the analysis of the value of the Net Heat race in an analysis when the generator produces the load obtained the highest value on December 16 at 6666.67 kcal / kWh, while the lowest value on December 9 at 0 kcal / kWh. The average value is 4,992.96 kcal / kWh

3) Based on the proposed PLTU heat race limit in Indonesia in the category ≤ 100 MW with a maximum allowable heat race limit of 3,632 kcal / kWh. NiiTanasa'sTenga Steam Power Plant with a capacity of 2 * 10 MW, "based on the proposed maximum heat rate limit is outside the maximum heat rate range proposed by the State Power Plant (PLN)".

5. Future Research

Researching more about thermal efficiency indirectly with the influence of the high heat race, and also connecting the coal moisture content parameters used.

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