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CALCULATION NEEDS OF FUEL BOILER BIOMASS POWER PLANT OIL SEI MANGKEI CAPACITY 2X3,5 MW

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ABSTRACT

Palm Biomass power plant Sei Mangkei is an alternative electrical power source by converting energy of EFB (empty fruit bunches) and shell are used as fuel in steam generator. Common steam generators are called boilers produce pressure steam used to rotate of corners turbine. The amount of empty fruit bunches to be produce in Palm oil plantations based on the capacity. The capacity of palm oil plantation Sei Mangkei is 75 tons/hour. Material balance = 21.96% empty fruit bunches is 22%, the combustion process is well if the fuel composition EFB: shell = 70: 30. The needs fuel of shell is 5.8 tons per day and the need fuel EFB is 5.4 tons per day. After having research the need of boiler fuel in Normal Operation steam is 17.29 tons/hour or more excess of 8.40 tons of steam/hour. The needs of fuel boilers in abnormal operation steam required 17.29 tons of steam/hour or more 13.35 tons of steam/hour. In fact, during the factory operates, it doesn't need an electricity supply from outside like PLN. EFB and shell as fuel Biomass power plant oil Sei Mangkei generating produces energy 2 x 3.5 MW, the use can be economized so that shell is still left.

Key words: Calculation need of fuel, boiler, power plant Sei Mangkei, Capacity 2x3.5 MW

1. INTRODUCTION

Based on statistical data of State Electrical Company (PLN) on 31 March 2007 distributed fuel to generating until 34% of the total installed in generating capacity. The expensive fuel requires to PLN to review all thermal power plants that use oil as the main fuel steam generators. Beside that the amount of government subsidies to PLN in supplying electricity every year mainly oil power plants. The subsidies are mostly used to reduce loss operating PLTU. The cause of loss is the difference of the fuel cost in kWh and selling price (electricity tariff) to the consumer. Therefore, it is useful to change fuel so that the cost of electrical energy can be more economical.

Palm Biomass plants Sei Mangkei is an alternative power which the power is required for operating of factory and society is obtained by converting the energy of additional product itself into electrical energy. Additional products are EFB and shell which is used as fuel in steam generator. Steam generator or commonly called a boiler produces steam that will be used to rotate the blades of the turbine. Turbine produces electricity for the operational needs of factory and outside such as streetlighting, housing, etc. So as long as the factory is operating, it doesn't need electricity supply from outside like PLN or diesel generators.

EFB and shell as fuel for boiler is enough to produce steam to the pressure required by the turbine. Even the use can be saved. Boiler is a closed vessel in which the combustion heat transfers to water until steam form like energy. Water is useful and easy to flow heat to a process, then steam and a certain temperature have a value of energy which is used to flow heat in the form of heat energy to a process.

2 THEORETICAL FRAMEWORK ELECTRICAL STEAM POWER PLANT

Electrical steam power plant is a plant from kinetic energy from steam to electric energy. The main form of this type of power plant is a generator which is connected to turbine where to turn turbines required kinetic energy of steam. Electrical steam power plants use a variety of fuels, especially coal and fuel oil.

2.2. Steam power comes from nuclear Power Process

Nuclear power plant is thermal power station where the heat is from one or more nuclear reactors in it (www.wikipedia.org)

There are one or more nuclear reactors in PLN. In nuclear reactors, nuclear reactions take place. The nuclear reaction produces high heat. This heat is used to produce electricity.

2.3 Geothermal Energy comes from Solar

Geothermal energy is thermal energy stored in the rocks under the earth's surface and the fluid. Geothermal energy has been used for power plant in Italy since 1913 and in New Zealand since 1958. The utilization of geothermal energy for non-electric sector (direct use) takes place in Iceland around 70 years. The increasing needs for energy and rising oil prices, particularly in 1973 and 1979 has spurred other countries including the United States to reduce their dependence on oil by utilizing of geothermal energy. Nowadays geothermal energy has been used for power plants in 24 countries including Indonesia. Besides that the geothermal fluid is also used for non-power sector in 72 countries for space heating, water heating, greenhouse heating, drying of agricultural products, soil heating, drying wood, paper and so on.

2.3 Thermal Energy from Gas Combustion Process

PLTG (gas power plant) is a generator of electric energy using equipments/ gas turbine engine as a generator drive. Gas turbine is designed and made with a simple working principle where the thermal energy from the fuel combustion process is converted into mechanical energy and then converted into electrical energy or other energy according to the needs. The weakness of gas turbine is corrosive to material used for turbines components because it must work at high temperatures and there is chemical elements corrosive fuel (sulfur, vanadium, etc.), but in the development of knowledge evolving materials can be reduced although it can not be removed all. With a low level of efficiency this is also one of the weakness from gas turbine as well and the development to increase efficiency can be set at working temperature turbine cycle using the material that is able to work at high temperatures and also increase efficiency by combining the power turbine gas with steam turbine generator and it is commonly called by combined cycle.

2.4 Ocean Thermal Energy Conversion (OTEC)

Ocean Thermal Energy Conversion (OTEC) is a method to produce electrical energy using the difference temperature that lies between deep sea and near surface waters to run a heat engine. Commonly the heat engine and the largest energy are generated by the difference of large temperature. The difference temperature between deep sea and surface waters are generally greater if they are closer to the equator. At first, OTEC design challenge is to produce maximum energy with the smallest different temperature.

2.5 Heat (steam) comes from the process of Biomass Process Oil

Basically PLTBS is a PLTU which uses biomass palm oil. From PLTBS's scheme as shown in Figure 2.3 we can see that the EFB is passed to the shredder, in shredder TKS is shredded to obtain a piece of fiber with a maximum length about 100 mm. Then TKS is supplied by conveyor to oil presser. In oil presser water content is reduced to produce oil and fiber wadding. In dryer the moisture of EFB is reduced until 40%. Then TKS is collected in the silo before being fed into the combustion for heating

boilers. Steam produced by boiler will be used to turn turbines which steps directly with a generator and generator will rotate to produce electricity. After passing through the turbine, the steam pressure and high temperature comes into the condenser. The steam is condensed by the condenser into the water from the cooling becomes water which is pumped back to deaerator and then feeding to the boiler.

2.6. Rankine cycle

Rankine cycle (Figure 2.2) is the ideal cycle for steam power cycle. In the simple form of a Rankine cycle consists of four components, namely pumps, boilers, turbines and condensers.

Figure 2.6 Rankine cycle and graphs T (temperature) vs s (entropy)

Rankine cycle doesn't consist of four stages of the process:

- 1-2 is an isentropic compression process with pump.
- 2-3 Addition of heat in boiler at $P = \text{constant}$.
- 3-4 isentropic expansion into the turbine.
- 4-1 dismissing of heat in the condenser at $P = \text{constant}$

Water enters the pump on the condition 1 as a saturated liquid and compressed to the operating pressure of boiler. Water temperatures will rise during this isentropic compression through a simple reduction of water specific volume.

The water enters boiler as a compressed liquid in conditions 2 and will become superheated steam on condition 3. The Heat supplies boiler to water at T (temperature) permanently. Boilers and all parts are called by steam generators.

Superheated steam in conditions 3 will be entered turbine to be expanded and generate working to rotate shafts and it will be connected to the electric power generator so that it will produce electricity. P (pressure) and T (temperature) of steam will be down during this process towards condition 4 where the steam will enter condenser and usually in the form of saturated steam. This steam will be melted to P constant in the condenser and it will leave the condenser as saturated liquid to enter the pump to complete this cycle.

Data under the process of curve on the diagram $T - s$ (entropy) shows that transferring heat to the internal reversible process. An area under the curve of the process 2-3 shows transferring heat to boiler, and the area under the curve 4-1 shows the heat releases in the condenser. Differences between these flows are netto working produced during the cycle.

2.7 Energy Cycle of Power Engine

In PLTU, energy is a thermal energy produced from the burning of fossil fuels/conventional. The thermal energy is used to heat boiler and generate steam pressure and high temperature. Thermal

energy converted into mechanical energy which drive/rotate a generator, changing thermal energy into mechanical and electrical energy through an energy conversion cycle which depends on the amount of heat, the temperature pattern and environment temperature or the temperature of heat source (boiler). A heat cycle receives a number of thermal energy in a certain temperature, and convert part of thermal energy into working, discard or forwards the rest to the environment or heat receiver as "loss energy" at a lower temperature (in this case it can be seen in the function of condenser). Figure 2.1 shows a general heat cycle on temperature and entropy coordinates. Large 1-2-3-4 is the amount of thermal energy at a temperature T_1 which is accepted by the working medium at temperature T_2 . Large 1-2-3-4 is useful energy. This cycle is known as the Carnot cycle which is ideal cycle where the condition can't find thermal efficiency of the engine

According to Carnot cycle

$$\frac{Q_2}{Q_1} = 1 - \frac{T_2}{T_1}$$

Where:

T_1 = Temperature of Energy source, (K) and

T_2 = Temperature of receiver energy (K).

Figure 2.4. (a) Ideal heat Carnot cycle

Realistic energy cycle is shown in Figure 3.1 (b). T_1 temperature is not constant like Figure 3.1 (a), but T_1 is uneven curve. And T_2 temperature rises of 3-4 into 3'-4', and the amount of wasting energy is shown on the large 3'-4'-ab, which is larger than the 3-4-ab.

Figure 2.5. (b) Heat realistic Carnot cycle

In order to be high efficiency, the ratio T_2 / T_1 should be as small as possible. Temperature T_2 is the temperature of 303 K. The temperature of the environment eg T_1 is the temperature of the

steam, for example 600 °C or 873 K. The efficiency of the engine thus becomes $1 - 303/873 = 0.6529$ or 65.39%. It is difficult to improve efficiency, because the temperature of environment is a fact, while raising the temperature of the steam will knock on the durability of the material. In the energy cycle is very important to look at types of energy sources used to generate heat, steam cycle, the use of machine such as steam boilers, and meedium heat receiver with the lowest temperature (condenser).

3. RESEARCH METHODOLOGY

Palm oil factory produces three types of solid wastes such as fiber, shell and EFB (empty fruit bunches), other products from solid wastes are the result of fuel combustion. Utilization of biomass waste at this time is to fulfill the palm oil processing energy through direct combustion of fiber and shells. Meanwhile EFB and the rest of combustions are used as fertilizer in the farm to reduce the consumption of chemical fertilizers and maintain climatic conditions of palm tree.

Shells and fibers contain the value of calory relatively high as shown in Table 3.2 that can be used as fuel PLTBS.

Tabel 3.1 Composition of palm oil calory

Parts of Palm oil	Heating Value
Shell	4,105 – 4.802 kcal/kg
Fiber	2.637 – 4.554 kcal/kg
EFB	4.492 kcal/kg
Stem	4.176 kcal/kg
POME*	4.695 – 8.569 kcal/m ³

Note : 1 kcal = 4187 Joule = 1,163 Wh

Note : POME = Palm Oil Mill Effluent

(TabelSource : PT. PalsihokUtama Team, *An intermediate report biomass& biogas power plant at Blankahan palm oil mill*)

Figure3.1Schematic of Biomassa Power Plant Oil (PLTBS)

At this time the biggest user of fuel oil is for power generation purposes. The biggest PTPN in Kalimantan, Sulawesi and Sumatra are sources of potential biomass generate electrical energy which hasn't been managed effectively.

Table 3.2The potential energy produced by PTPN I–PTPN VII

PTPN	Total Installed Capacity(Ton/Hour)	Potential (MW)
PTPN I	135.0	12.0
PTPN II	240.0	32.0
PTPN III	510.0	60.0
PTPN IV	570.0	68.3
PTPN V	550.0	57.3
PTPN VI	220.0	25.3
PTPN VII	261.0	302.8
Sub-Total	2,486.0	302.8
NEW PKS	2,126.0	168.0

Note : Not all potentials MCC are used to PLTBS, because parts of compost are composted

Source : - BBN BUMN tim (2007) bioenergy development BUMN program, Jakarta.
- Muluk at al (2007), Workshop on Dissemination of Biofuel BUMN, Jakarta

Table 3.3 Potential Biomass PTPN III

Source	TBS (Kg)
Own Farm	1.695.927.000
Plasma farm and party III	686.135.000
Total	2.382.062.000

Table 3.4 Potential Biomass becomes electrical energy PTPN III

Source	EFB (Kg), 22%	Kolor value Kcal/Kg	Steam (ton)	MW	MW/h
Own Farm	373.103.940	2.021	912.263.82	182.452.76	21.12
Plasma farm P-III	150.949.700	2.021	369.082.00	73.816.40	8.54
Sub-Total	524.053.640		1.281.345.82	256.269.16	29.66
Source	Shell (Kg), 6%	Kolor Value Kcal/Kg	Steam (ton)	MW	MW/h
Own Farm	101.755.620	4.058	499.506.60	99.901.32	11.56
Plasma Farm and P-III	41.168.100	4.058	202.089.46	40.417.89	4.68
Sub-Total	142.923.720		701.596.06	140.319.21	16.24
Source	Fiber (Kg), 14%	Kolor Value Kcal/Kg	Steam (ton)	MW	MW/h
Own Farm	237.429.780	2.710	778.446.52	155.689.30	18.02
Plasma Farm and P-III	96.058.900	2.710	314.942.45	62.988.49	7.29
Sub-Total	333.488.680		1.093.388.97	218.677.79	25.31
Total					71.21 MW/h

Figure 3.2 Biomass Power plant Cycle

4. RESULTS AND DISCUSSION

Fiber EFB of palm oil plantation (PKS) 1 and 2 are sent by using the conveyor to PLTBS area. It reminds that unequally supply of EFB between PKS 1 and 2, EFB is placed temporary in hopper (accumulator) in order to supply EFB to the next constant process and adjustable speed. Accumulator has a capacity of 60 m3.

The following diagram is material balance of TBS:

From the diagram of TBS material balance can be known amount EFB to be produced in PKS based on capacity. For the capacity of PKS SeiMangkei capacity installed is 75 tons/hour. Material balance is known EFB $\approx 22\%$, it can be calculated the number of EFB is as follows:

$$\begin{aligned} \text{Number of EFB} &= 22\% \times 75 \text{ ton/hour} \\ &= 16,5 \text{ ton/hour} \end{aligned}$$

Tabel 4.1 The compotion of EFB and shell feed boiler

No	Source	Compositon (%)	Moisture (%)	Density (Kg /M ³)	Total (Ton/hour)
1	EFB	70	50	320	5,8
	Shell	30	20	574,71	2,5
2	Shell	100	20	574,71	5,4

- Moisture is the value of moisture content
- Density is the value of density

From the data above data, it can be calculated fuel supply without EFB or 100% shell is as follows:

- Capacity of shell silo = 250 m³
- Density shell (ρ) = 574,71 Kg/m³
- Shells need = 5,4 ton/hour

The amount of weight of shell silo
= 250 m³ x 574,71 Kg/m³
= 143677,5 Kg $\approx$ 143,7 ton

The need of shell in 1 day
= 5,4 ton/hour x 24 hours
= 129,6 ton/days

The amount of shell silo 2 unit
= 2 x 143,7 ton
= 287,4 ton

Shell supply
= $\frac{287,4 \text{ ton}}{129,6 \text{ ton/day}}$
= 2,2 days or 2 days 5 hours

Tabel 4.1. the need of Shell fuel

Fuel	Need/hour	Need/day	Need/month
Shell	5,4	129,6	3888
(cangkang)	ton/hour	ton/day	ton/month

The amount use of EFB in 1 day is:

- The need of EFB = 5,8 ton/hour
- Density (ρ) = 320 Kg/m³

- Capacity of accumulator = 60 m³

The need of EFB in 1 aday
 = 5,8 ton/hour x 24 hours
 = 139,2 ton/day

The amount of weight accumulator :
 = 60 m³ x 320 Kg/m³
 = 19700 kg or 19,7 ton

The supply of EFB in accumulator : $= \frac{19,7 \text{ ton}}{5,8 \text{ ton / hour}}$
 = 3 hours 24 minutes

Tabel 4.2. The need of EFB fuel

Fuel	Need/hour	Need/day	Need/month
EFB	5,8 ton/hour	139,2 ton/day	4176 ton/month

Comparison need of shell and EFB fuel can be shown in figure 4.2.

(a)

(b)

Figure 4.2.the comparison of fuel need shell (a) and EFB (b)

From description above Figure 4.2. (a) and (b) can be concluded that EFB has the biggest need for fuel supply compared with shell. EFB fuel requires a supply of 4176 tons/ month, while shell fuel requires a supply of 3888 tons/month.

To maintain a supply of good fuel boiler and shells keep going in time to maintenance or repair of equipment when processing does not exceed from the maximum of over calculation.

Calculation need of Fuel Boilers

a. The Needs Fuel Boilers In Normal Operation

Biomass Power Plant Oil (PLTBS) 2 X 3.5 MW in each unit requires a steam boiler as much as 4.94 kg per 1 kW per 1 hour generated.

Total steam required for 1 boiler:
 $= 3.500 \text{ Kw} \times 4,94 \text{ Kg/Kw/hour}$
 $= 17.290 \text{ Kg uap/hour}$
 $= 17,290 \text{ ton uap/hour}$

The fuel used is EFB70% dan shell 30% :

EFB = 5,8 ton/hour
 $= 5800 \text{ kg/hour}$
 Shell = 2,5 ton/hour
 $= 2500 \text{ kg/hour}$

Weight fuel:
 $= 5800 \text{ kg/hour} + 2500 \text{ kg/hour}$
 $= 8300 \text{ kg/hour}$

Heating value fuel boiler can be explained as follow:

- a. Shell
 $\text{Heating Value Shell} = 4120 \text{ Kcal/kg}$
- b. EFB
 $\text{Heating value EFB} = 1440 \text{ Kcal/kg}$

Heating value above used for boiler in certain condition :

Pressure $= 43 \text{ kg/cm}^2$
 Temperatur $= 400^\circ\text{C}$
 Kettle Efficiency $= 90 \%$
 Water vapor Temperature $= 110^\circ\text{C}$
 Water Pressure $= 48 \text{ Kg/cm}^2$
 Weight fuel $= 8300 \text{ Kg/hour}$

Entalphy in pressure. 43 kg/cm^2 , temp. 400°C

$= 764,09 \text{ Kcal/Kg}$

Entalphy in water pressure. 48 kg/cm^2 , temp. 110°C

$= 110,69 \text{ Kcal/Kg}$

$\Delta\text{Entalphy} = 764,09 \text{ Kcal/Kg} - 110,69 \text{ Kcal/Kg}$
 $= 653,40 \text{ Kcal/Kg}$

$$\eta_{\text{Ketet}} = \frac{Q(\Delta\text{Entalpi})}{GbbxN.O}$$

$$Q = \frac{\eta x GbbxN.O}{\Delta\text{Entalpi}}$$

$$Q = \frac{\{(90\% \times 2500 \times 4120) + (90\% \times 5800 \times 1440)\}}{653,4}$$

$$Q = \frac{(9270000 + 7516800)}{653,4}$$

$$= 25691,46 \text{ Kg steam/hour}$$

$$= 25,69 \text{ ton steam/hour}$$

While the steam needed is 17,29 ton steam/hour or it takes place of 8,40 ton steam/hour. Combustion process is happening well if fuel composition EFB : shell = 70 : 30.

b. The Needs Fuel Boilers In Abnormal Operation

If the need for EFB can not be supplied by PKS Sei Mangkei, the fuel Shell (Shells) is used entirely. The fuel used is shell of 100%:

$$\begin{aligned} \text{Shell} &= 5,4 \text{ ton/hour} \\ &= 5400 \text{ kg/hour} \\ \text{Weight fuel} &= 5400 \text{ kg/hour} \end{aligned}$$

Heating value of fuel boiler (shell 100%) can be explained as follow:

Heating Value Shell	= 4120 Kcal/kg
Pressure	= 43 kg/cm ²
Temperature	= 400°C
Kettle Efficiency	= 90 %
Water Temperature	= 110°C
Water Pressure	= 48 Kg/cm ²
Heating value (N.O)	= 4120 Kcal/Kg
Weight fuel	= 5400 Kg/hour

$$\begin{aligned} \text{Enthalpy in pressure. 43 Kg/cm}^2, \text{ temp. 400}^\circ\text{C} &= 764,09 \text{ Kcal/Kg} \\ \text{Enthalpy in water pressure. 48 Kg/cm}^2, \text{ temp. 110}^\circ\text{C} &= 110,69 \text{ Kcal/Kg} \\ \Delta \text{Enthalpy} = 764,09 \text{ Kcal/Kg} - 110,69 \text{ Kcal/Kg} \\ = 653,40 \text{ Kcal/Kg} \end{aligned}$$

$$\eta_{\text{Kettle}} = \frac{Q(\Delta \text{Enthalpy})}{G_{bb} \times N.O}$$

$$Q = \frac{\eta \times G_{bb} \times N.O}{\Delta \text{Enthalpy}}$$

$$Q = \frac{(90\% \times 5400 \times 4120)}{653,4}$$

$$\begin{aligned} Q &= 30644,62 \text{ Kg steam/hour} \\ &= 30,64 \text{ ton steam/hour} \end{aligned}$$

The steam required is 17.29 tons of steam/hour or an excess of 13.35 tons of steam/hour.

5. CONCLUSIONS

- 1) The amount of EFB which will be produced in PKS based on the capacity. For PKS Sei Mangkei, the capacity installed is 75 tons/hour. Material balance is 21.96% EFB $\approx$ 22%,

- 2) The combustion process takes place well if the fuel composition is EFB: shell = 70: 30.
- 3) The needs of Fuel Shell is 5.8 tons /day while demand Fuel EFB (tankos) 5.4 tons per day
- 4) The needs of fuel boilers in normal operation, the steam required is 17.29 tons of steam/hour or an excess of 8.40 tons of steam/hour
- 5) The needs of fuel boilers in abnormal operation, steam required is 17.29 tons of steam / hour or an excess of 13.35 tons of steam / hour.

team/hour.

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