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Efficiency analysis of electric energy use in palm oil processing (case study Bandar Pulau)

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Abstract. One way to determine the energy processing planning policy for energy optimization is achieved by energy analysis. In this study, the analysis was done by the calculated energy value used in each stage in a system as a whole to get a picture of how much the energy usage. This study contains the description of the extent to which the use of electrical energy to run the production process in the palm oil mill with a capacity of 45 tons by calculating the consumption of electrical energy in each station. The result of this research showed that the total electricity usage for production process at palm oil mill with the capacity of 45 Ton is 502,4 kW, with an efficiency level of electrical energy usage in production process equal to 73,05%.

1. Introduction

Oil palm is one of the main plantation products for non-oil export commodities developed in Indonesia. The area of oil palm area increased from 1,126,667 hectares in 1990 to 11,444,808 hectares in 2015. Its production also increased from 2,412,612 tons in 1990 to 30,948,932 Ton in 2015 [1].

One way to determine energy planning policy so as to achieve achieved energy optimization is energy analysis. In the energy, the analysis is calculated energy value used in each stage in a system as a whole to get an idea of the extent to which the energy usage per kg of output [2].

In the process of processing oil palm, there are several stages of the process that require energy input. The more modern a tool then the need for energy will increase. Likewise, this energy demand increases with increasing palm oil production. General parameters of power consumption in palm oil mills are 17-19 kWh / ton FFB.

2. Material and Methods

2.1 Gas Turbine

Gas Turbine Generator (*Pembangkit Listrik Tenaga Uap* – PLTU) is a type of thermal power plant that is widely used because of its high efficiency so as to produce electrical energy that is economical. Chemical energy in the fuel is converted into electrical energy in the steam power plant [3].

The boiler serves to convert water into a high-pressure, high-temperature superheat vapor. The boiler can be said to be a sealed vessel that is efficiently capable of converting water to steam with the aid of heat from the fuel combustion process. If operated properly, the boiler can efficiently convert water in large volumes into very hot steam in larger volumes that will be used to rotate turbines.



The steam turbine serves to convert the heat energy that the vapor contains into rotating energy (mechanical energy). The turbine shaft is coupled with the generator shaft so that when the turbine spins the generator also spins.

A generator is a synchronous machine that serves to generate the voltage back and forth (ac), that is by changing the mechanical energy into electrical energy. The generator coupled directly with the turbine will generate an electric voltage when the turbine spins. Then the electricity generated channeled through the panel and distributed to the load in the form of electric motors. Almost all electrical energy is generated using a generator.

The induction motor is an alternating current electric motor (ac) whose rotation of the rotor is not the same as the rotation of the rotating field on the stator, in other words, the rotation of the rotor with the rotation of the field on the stator is the difference in rotation called slip [4].

The difference between the speed of the rotor and the synchronous speed is called slip (s). The slip may be expressed in a per minute split, but more commonly expressed as the percent of synchronous speed indicated by in Equation 1.

$$\text{Slip} = \frac{N_s - N_r}{N_s} \times 100 \% \quad (1)$$

In induction motors, no power source is directly connected to the rotor, so the power passing through the air gap is equal to the power inputted to the rotor. The total power introduced into the stator coil (P_{in}) is shown in equation 2.

$$P_{in} = 3V_1 I_1 \cos \phi \quad (2)$$

Where: V =Voltage (Volt) , I =Current (Ampere), $\cos \phi$ =Differences in phase angle between pseudo power with active power.

The efficiency of an induction motor is a measure of the effectiveness of the induction motor to convert electrical energy into mechanical energy expressed as the ratio between input and output or in the form of electrical energy in the ratio of the output wattage and the input watt shown in equation 3.

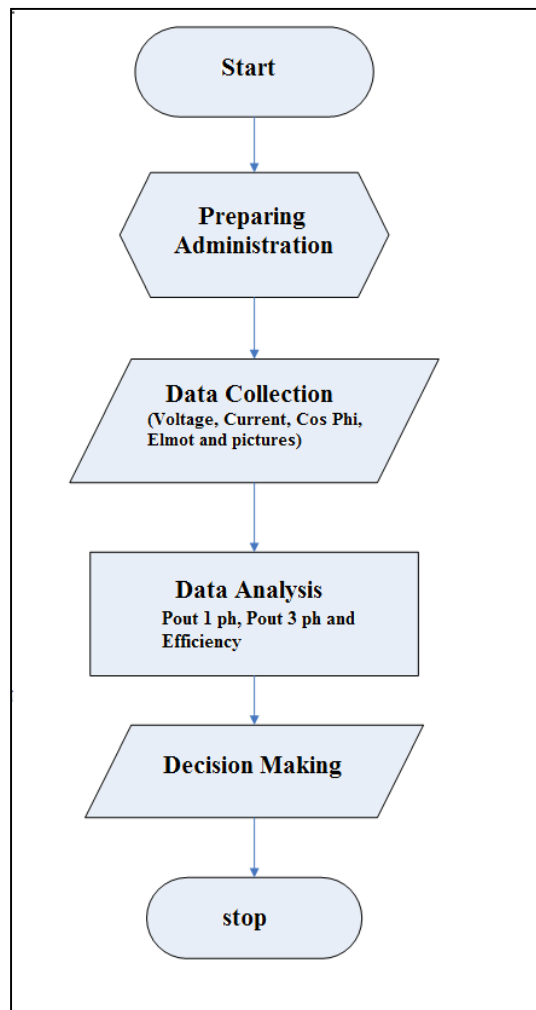
$$\eta = \frac{P_{out}}{P_{in}} = \frac{P_{in} - P_{loss}}{P_{in}} = \frac{P_{out}}{P_{out} + P_{loss}} \quad (3)$$

From the equation, it can be seen that motor efficiency depends on the amount of the loss. The losses of the equation are the sum of the overall loss components. The losses in question are the core loss, loss of copper and etc.

The steps of the research method of analysis of the efficiency of the use of electrical energy in the processing of oil palm are as follows:

- a) Determining the parameters to be measured (current, voltage, $\cos \phi$).
- b) Recording the specifications of the electric motors used.
- c) Perform measurements of currents, voltages and $\cos \phi$ made on the control panel at each processing station.
- d) Calculate P_{in} based on the corresponding formula.
- e) Displays tables and graphs of calculations.
- f) Drawing conclusions from the results of research.

Stages performed in this study can also be seen in the flow diagram in figure 1.

**Figure 1.** Research Flow

3. Results and Discussion

Considering research results at the palm oil mill PT. Djaja Putra Indonesia, a steam power plant generates 600 kW of electricity. The power plant itself consists of two units of steam power plants with a capacity of 1250 KVA and 3 units of diesel power plants with a total capacity of 1250 KVA. The observations on the control panel show the value of the current of 1150 A, the voltage 400 V, $\cos \phi$ 0.9, the frequency of 50 Hz. Analysis of the use of electrical energy in the sterilizer station. The results of measurements on the sterilizer station can be seen in table 1.

Table 1. The use of electrical energy at Sterilizer station

No.	Unit	Number of Tools	Input Power (kW)	Output Power (kW)	Electric Motors Efficiency (%)
1	Hidrolik Loading ramp	1	4	1,4	35
2	Scraper FFB	2	22	17,7	81
3	Scraper FFB Distribution	1	11	8,9	81
4	Hydrolic Sterilizer	3	4	3,5	89
TOTAL			41	31,6	71,2

The efficiency value at the sterilizer station is

$$\eta = \frac{31,6}{41} \times 100\% = 77,07\%$$

Analyze the use of electrical energy at the thresher station, the result of the measurement and calculation on thresher station can be seen in table 2.

Table 2. The use of electrical energy at thresher station

No	Unit	Number of Tools	Input Power(kW)	Output Power (kW)	Electric Motor Efficiency (%)
1	SFB Scraper bunch to hopper	1	15	7,7	51
2	Thresher drum	2	18,5	17,7	96
3	Under Thresher Conveyor	2	7,5	7,1	95
4	Horizontal Empty Bunch Conveyor	1	4,1	4,1	75
5	Inclined Empty Bunch Conveyor	1	4,1	4,1	75
	TOTAL		52	40,8	78,50

The efficiency rating at the thresher station is

$$\eta = \frac{40,8}{52} \times 100\% = 78,46\%$$

Analyze the use of electrical energy at the pressing station, the measurement results and calculations on the pressing station can be seen in table 3.

Table 3. The use of electrical energy at thresher station

No	Unit	Number of Tools	Input Power (kW)	Output Power (kW)	Electric Motors Efficiency (%)
1	Bottom Cross Conveyor	1	7,5	6,5	87
2	Fruit Elevator	2	7,5	6,5	87
3	Fruit Distribution Conveyor	1	7,5	5,9	79
4	Digester	3	37	26,6	72
5	Screw Press	3	30	23,7	79
6	Hydrolic Press	3	1,5	1,2	79
	TOTAL		91	70,4	80,4

The efficiency rating on the pressing station is

$$\eta = \frac{70,4}{91} \times 100\% = 77,36\%$$

Analysis of the use of electrical energy at the clarification station, the result of the measurement and calculation on thresher station can be seen in table 4.

Table 4. The use of electrical energy at the clarification station

No.	Unit	Number of Tools	Input Power (kW)	Output Power (kW)	Electric Motors Efficiency (%)
1	Vibro sieve	2	4	3	74
2	Continuous strirer	1	2,2	1,8	83
3	Sludge centrifuge	4	22	17,7	81
4	Sludge tank pump	2	11	7,1	65
5	Crude oil tank	2	11	7,1	65
6	Hot well tank	2	3	2,4	79
7	Fat pit pump	2	18,5	11,8	64
8	Sludge tank	3	15	8,9	59
9	Vibrating press	2	4	3	74
10	Vibrating sludge	2	2	1,8	89
11	Vacuum dryer pump	1	7,5	5,9	79
12	Pure oil transfer pump	1	7,5	5,9	79
	TOTAL		107,7	76,4	74,1

The value of Efficiency at a clarification station is

$$\eta = \frac{76,4}{107,7} \times 100\% = 70,93\%$$

Analysis of the use of electrical energy at seed stations and crusher, the results of the measurement and calculation on seed and the quenched station can be seen in table 5.

Table 5. The use of electrical energy at seed stations and pulp

No.	Unit	Number of Tools	Input Power (kW)	Output Power (kW)	Electric Motors Efficiency (%)
1	Cake breaker Conveyor	2	22	16,6	75
2	Nut polishing drum	1	11	5,9	54
3	Fibre cyclone airlock	1	7,5	5,3	71
4	Pneumatic nut transport fan	1	37	33,7	91
5	Super cracker	3	11	7,7	70
6	Dry kernel conveyor	1	5,5	4,7	86
7	Separating column airlock (LTDS)	1	3	2,1	69
8	Pneumatic fan LTDS	2	30	11,8	39
9	Dust cyclone airlock	2	3	1,8	59
10	Claybath pump	1	15	7,7	51
11	Claybath Vibrating	1	4	2,4	59
12	Wet shell fan	1	30	17,7	59
13	Ripple mill	3	11	7,7	70
14	Kernel silo fan	2	22	11,8	54
15	Nut grading drum	1	5,5	4,7	86
16	Nut grading conveyor	1	5,5	3,5	65
17	Cracked mix conveyor	1	4	2,4	61
18	Wet kernel transport fan	1	22	17,7	81
19	Kernel silo dryer fan	2	22	11,8	54
20	Kernel conveyor	1	5,5	3,4	61
21	Nut conveyor	1	5,5	3,3	60
22	Cracked mix elevator	1	5,5	3,3	60
TOTAL			287,5	187,3	65,3

The value of efficiency at the seed station and the felt pulp is

$$\eta = \frac{187,3}{287,5} \times 100\% = 65,14\%$$

Analysis of the use of electrical energy at the boiler station, the measurement results and calculations on the boiler station can be seen in table 6.

Table 6. Use of electrical energy at the boiler station

No.	Unit	Number of Tools	Input Power (kW)	Output Power (kW)	Electric Motors Efficiency (%)
1	Pendulum feeder	1	1,5	1,2	80
2	Fuel modulator	1	0,37	0,2	54
3	SA Fan	1	11	7,7	70
4	FD Fan	1	11	7,7	70
5	ID Fan	1	55	35,5	65
6	Air lock dust collector	1	1,5	1,1	75
7	Dust collector conveyor	2	5,5	4,1	75
8	Feed water pump	2	45	32,5	72
9	Conveyor boiler	1	7,5	5,9	79
TOTAL			138,37	96	71

The efficiency rating at the clarification station is

$$\eta = \frac{96}{138,37} \times 100\% = 69,37\%$$

Based on the calculation of the electrical energy requirement at the oil palm factory that has been described above, total demand for electrical energy in all processing stations can be seen in table 7.

Table 7. Recapitulation of energy usage Electricity

Processing station	Electrical energy needs (kW)
Sterilizer	31,6
Thresher	40,8
Pressing	70,4
Clarification	76,4
Seeds and pulp	187,3
Boiler	96
TOTAL	502,4

The total electrical energy usage for production process is 502,4 kW. When compared with power generated by the side of the power of 600 kW then the total level of electrical energy needs reached 83.7% of the total electrical energy generated.

Loss of power can be caused by many factors including, machines that work beyond capacity, lack of maintenance, damage to machinery and equipment driven, machines working under the proper capacity, etc.

The use of electrical energy is not entirely used to run the production process, but there are also used as street lighting, office electricity, maintenance workshop, mess employees, weighbridge and lighting inside the factory itself.

The percentage of electric energy sharing is shown in figure 2.

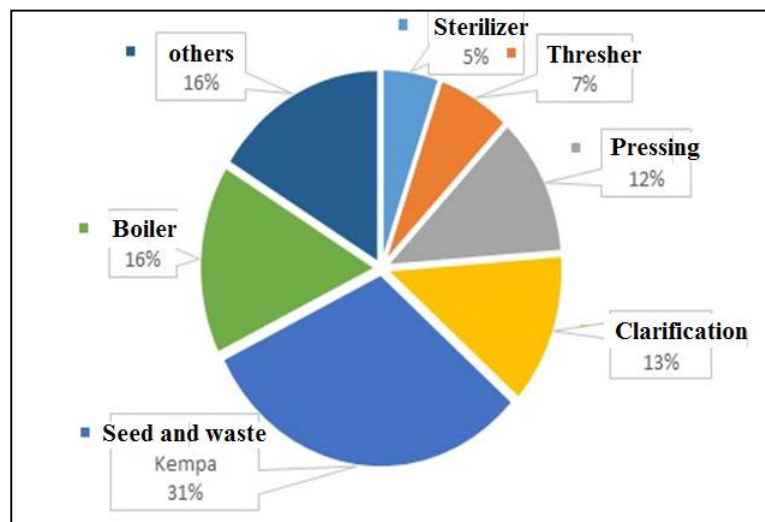


Figure 2. Percentage of energy sharing electricity

4. Conclusion

The overall use of electrical energy in the process of producing palm oil reached 502.4 kW. When compared to the power generated by the side of the plant that is equal to 600 kW then in total, the level of electrical energy demand in the palm oil mill PT. Djaja Putra Indonesia to produce crude palm oil (CPO) starting from the process of receiving the fruit to the tank is approximately 83.7% of the total energy raised.

The efficiency of electrical energy use in the palm oil production process at PT. Djaja Putra Indonesia amounted to 73.05%. This efficiency can be increased again by considering the workload of the motor so that the motor works in accordance with its production capacity. The highest efficiency is at thresher station with an efficiency level of 78,5%. The lowest efficiency is found in seeding and fermentation stations with an efficiency level of 65.1%. Substitution of an electric motor for Hydraulic Loading Ramp needs to be done because of its very low efficiency.

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