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Research Original Article

Electrical Energy Audit of Operation Support Equipment at 200 MW Steam Power Plant

Heri Priagusno✉[1], Surya Hardi[2], Rohana[2], Arnawan Hasibuan[3], Muzamir Isa[4]
[1]Student Program in Postgraduate of Electrical Engineering, Universitas Muhammadiyah Sumatera Utara, Jl. Denai No. 217, 20226, Medan, Indonesia
[2]Electrical Engineering Department, Universitas Sumatera Utara, Jl. Dr. T. Mansur No.9, Padang Bulan, Sumatera Utara 20155, Indonesia
[3] Electrical Engineering Department, Faculty of Engineering, Universitas Malikussaleh, Bukit Indah, 24352, Lhokseumawe, Indonesia
[4]School of Electrical System Engineering, Universiti Malaysia Perlis, Perlis, Malaysia
✉Corresponding Author: priagusno@gmail.com | Phone: +6281362036238

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Abstract
Based on data from the Pangkalan Susu steam power plant, the total amount of electrical energy used for generating process is on average 10% by the total of electrical energy generated by the plant. Increasing of electrical energy used will reduce the electrical energy sales to the network system. This research was carried out with reference according to ISO 50006:2014. This research is studies to the sample equipment with the largest rating capacity (significant energy user), such as boiler and turbine operation support equipment with on voltage 6 kV. The data of electrical energy in equipment is taken from the last 3 years historical data, namely in 2020, 2021 and 2022, Furthermore, the lowest point of electrical energy usage data was selected, then analyzed with the Linear Regression method to obtain the baseline Energy equation. The equation is used to conduct an analysis by comparing against the new data of the electrical energy in equipment, namely on April 1, 2023, the analysis showed that there was a waste of electrical energy of 164.12 kW equivalent to a fuel purchase loss of IDR 2,343,960 in 1 day. Furthermore, the baseline equation is used to input formulas in the AVEVA application (PI VISION). The Changes of electrical energy used will be monitored directly, so that if there is a waste of electrical energy, the operating pattern can be regulated directly to avoid energy waste in the electrical equipment and earn the fuel cost reduction of the Steam Power Plant.
Keywords: energy; audit; Power; Plant; Aveva

Introduction
Energy audit program own base strong law especially with has its publication Law no. 30 of 2007 concerning energy specifically Article 25 concerning Conservation Energy and Regulations of Indonesia Government No. 70 of 2009 concerning Conservation Energy. In regulations no. 70/2009. One regulation from ministry environment life and forestry (KLHK) for evaluation ranking performance company or PROPER is evaluation efficiency energy (Junaidi, 2011), (PP, 2009), (KLHK, 2021).

Energy audit of the steam power plant system implemented at least every year. Energy audit carried out by the company that owns it competence as required by the Ministry of Energy and Mineral Resources where own standardization for conducting an energy audit of the company nor industry user sufficient large energy in Indonesia like Steam power plant. However, an energy audit was carried out as an energy audit comprehensive covers all part used energy. Started from use energy from fuel until use energy generated electricity (Muljono et al., 2022).

Based on operational data of the Steam power plant Pangkalan Susu generating unit, the electricity usage own is total amount Energy electricity used for the production process electricity at the generator, is an average of 10% of total amount of energy electricity gross generated by the generator. Because if the more large the electricity usage used that, will reduce electricity energy distributed to the grid system (*ProNIA 5.5*, 2023), (Yudiyana et al., 2019), (Mukarom et al., 2014), (Sulistyowati, 2012), (Sulistyowati, 2012), (SIHOMBING et al., 2014).

By on that reason so need an electricity energy audit is carried out in equipment supporter operation system generator electricity, so that can be known the most efficient use electricity energy and reliable saving use of fuel and more increase company profits (Biantoro & Permana, 2017), (Barus & Kasim, 2015), (Untoro, 2014), (Winardi, 2009).

Literature Review
1. Hadi Prasetio (2008)

Hadi Prasetio's research entitled "Conservation Electrical Energy in Automotive Industry" discusses about Conservation energy electricity at PT Astra Daihatsu Motor Press Plant (PT ADM PP) which was carried out with optimization capacity Power installed, repaired factor power, as well reduction distortion harmonics current in the

system PT ADM PP distribution.

Repair factor Power done with bank installation capacitor so that increase factor Power substation PK 87 from 0.69 to 0.95 and factor Power PK 79 substation from 0.74 to 0.95. Savings energy obtained is 2.4% per month with investment amounting to IDR 897,649,239 and time come back capital is 4 months. Conservation energy through reduction distortion harmonics current done using a harmonic filter so that lower distortion harmonics current from above 20% to 2.5%. Savings energy obtained is of 1.58% per month with investment IDR 100,000,000 and time come back the capital is 7 months.

Potency savings energy and reduction costs earned from activity conservation energy electricity is amounting to IDR 17,405,000 per month from decline capacity subscriber electricity Then savings energy of 2.40% per month from repair factor power and 1.58% per month from reduction distortion harmonics current. Consumption energy specifically PT.ADM PP fell 3.98% from mark beginning amounting to 62.12 kWh/unit to 59.65 kWh/unit.

2. Wawan Gunawan (2018)

Wawan Gunawan did research entitled "Reducing Consumption Energy with Audit and Management Energy in the Control Room (Case Study at PT PWI)". On research This discussed about consumption energy electricity in space control at PT PWI. Methods used in research This is with step main conduct initial audits of areas and equipment used energy electricity, data analysis, detailed audits, monitor and recommendations to next fix. Collected data used to calculation by Intensity Value Consumption Energy (IKE).

Implementation opportunity economical decent energy held is replace the air conditioning (AC) from Freon R22 material replaced with material hydrocarbon MC-22, with average AC operating for 7 hours per day. The size consumption energy electricity before done savings on the system conditioning air is amounting to 1,409,865.39 kWh/ year, after done savings with method change type of AC refrigerant, then big consumption energy to 501,694.55 kWh/ year, so There is subtraction amounting to 908,170.84 kWh/year (Gunawan, 2018).

3. Sunarto, Khusnul Khotimah and Sigit Santosa (2021)

Study This entitled "Implementation Conservation Energy in BATAN Via Application System Management Energy Based on ISO 50001" research This discuss regarding the energy audit carried out at BATAN for apply conservation energy in accordance with mandate Regulation Head (Perka) BATAN Number 177/KA/IX/2011 Concerning Guidelines Maintenance and Maintenance of Supporting Infrastructure (Sarpras), Installation Nuclear supporting.

This Study analyze awareness all of employee to apply culture economical energy according to ISO 50001. Research methods used is a qualitative method use data collection natural (natural setting) through interviews, observations nor from studies literature.

4. This moment researches.

This moment research entitled "Electrical Energy Audit of Operation Support Equipment At 200 Mw Steam Power Plant". This research will discuss regarding audits energy of electricity used in the generator steam power plant. This study aims to identify equipment electricity that becomes user energy significant (SEU) so obtained potency efficiency energy with consider aspect technical and economical. The approach method used in the research This is the approach method Simple Linear Regression as reference from previous data and becomes next data reference.

Materials & Methods

1. Approach Study

This study started from studies of literature, field observation, initial data collection until gets results analysis. Initial data used is historical data from production electricity and electricity consumption. Historical data analyzed and evaluated to obtaining the best reference for next study. Historical data that has been collected furthermore done approach with Linear Regression so that obtained coefficient determination to know how much the influence of data variables than other data (ASTUTI & others, 2021).

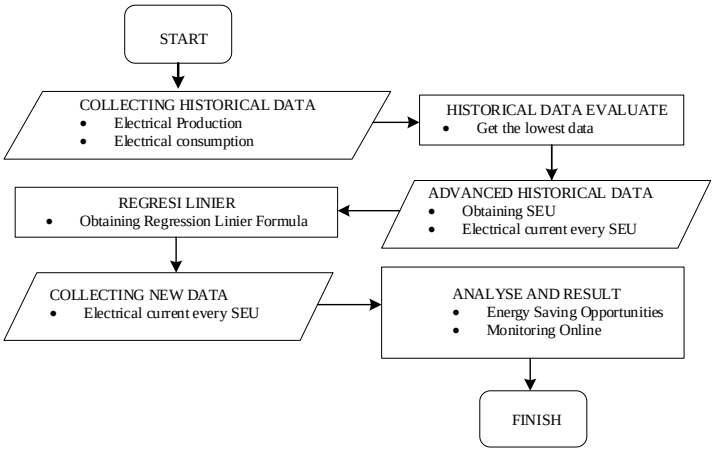

Figure 1. Energy Audit Flow chart

2. Initial Data Collection

Initial data is the historical data of electricity production and the data of electricity usage (PS) in 36 months last to get it obtained from application as shown in Figure 2. It can be seen the trending chart of the historical data to know the change of electricity usage against electricity production of generator power in 36 months last (*Matlab Mathworks, "MATLAB,"* n.d.), (Marsudi, 2006), (GPEC, 2004a), (GPEC, 2004b).

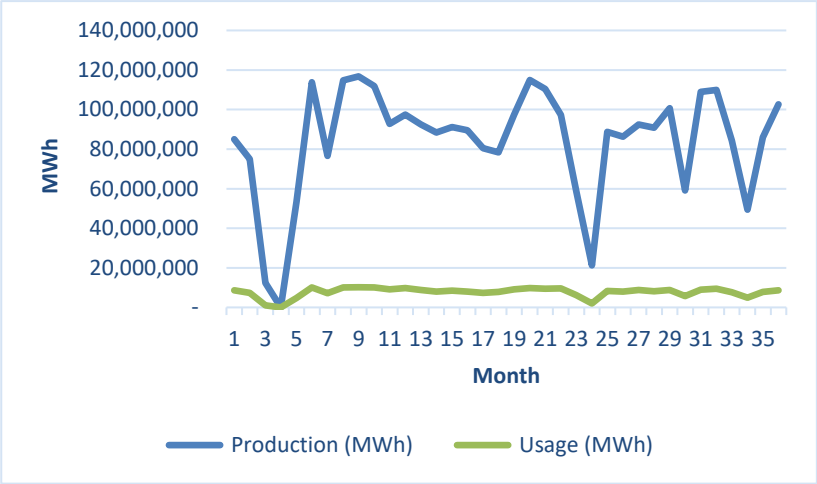

Figure 2. The 36 months data chart

In Figure 2. can seen that the lowest data is in the 24th month, namely data for July 2022. Meanwhile, the data in the 3rd and 4th months looks very low. due to the generating unit currently No operates normally, ie currently during maintenance.

3. Significant Energy User (SEU)

According to ISO 50006:2014 which is collection and identification data equipment based on the largest motor power capacity is set by SEU, there are 8 (eight) types of equipment supporter in Turbine and Boiler operations are shown in Table 1. Energy Performance Indicator (EnPI) is quantitative or proportion of the energy performance [28]. In electricity energy audits EnPI is energy electricity unit, which is Mega Watt hour (MWh). By choosing the electric motor with a 6 kV as a SEU then an audit is carried out on electricity energy usage on a 6 kV electric motor in electricity current monitoring (ampere) (TAMPUBOLON, 2019), (Dahlan, 2018).

Table 1. Significant Energy User

No	Equipment	Area	Qty	Power (kW)
1	Boiler Feed Pump (BFP)	TURBIN	2	5500
2	Condensate Extraction Pump (CEP)	TURBIN	2	630
3	Circulating Water Pump (CWP)	TURBIN	2	1500
4	Pulveriser (Mill)	BOILER	5	450
5	Primary Air Fan (PAF)	BOILER	2	1250
6	Force Draft Fan (FDF)	BOILER	2	450
7	Induced Draft Fan (IDF)	BOILER	2	1550
8	Seal Air Fan (SAF)	BOILER	2	250

4. Advanced Historical Data

Next, the collection is carried out advanced historical data samples namely the electricity current data of every equipment supporter operation which is 6 kV in July 2022 on HMI (Human Machine Interface) application i.e., operating system generator electricity based on DCS (Distributed Control System) as shown in Table 2. Current electricity data is taken for each 6kV motor equipment in various types of level magnitude power generator output as comparison usage current electricity 6 kV motor equipment.

Table 2. Current electricity 6 kV motor in July 2022

No	Data Point	Value						Unit
1	Real Power Generator	192,79	171,33	150,18	131,60	110,14	100,08	A
2	Boiler Feed Pump A	-	-	-	-	-	-	A
3	Boiler Feed Pump B	489,21	427,95	371,41	352,04	302,44	280,93	A
4	Condensate Extraction Pump A	58,67	58,57	58,07	58,16	58,34	57,12	A
5	Condensate Extraction Pump B	-	-	-	-	-	-	A
6	Induced Draft Fan A	110,51	109,62	90,73	106,32	91,60	82,10	A
7	Induced Draft Fan B	113,30	113,85	113,99	108,15	114,15	95,06	A
8	Primary Air Fan A	111,01	110,23	109,03	110,40	110,63	110,03	A

9	Primary Air Fan B	125,20	124,65	117,18	123,58	106,77	103,56	A
10	Force Draft Fan A	28,41	28,33	26,84	28,94	27,37	25,64	A
11	Force Draft Fan B	28,51	29,32	25,93	26,49	25,34	24,31	A
12	Seal Air Fan A	29,86	28,48	25,82	29,55	29,98	30,53	A
13	Seal Air Fan B	-	-	-	-	-	-	A
14	Pulveriser A	-	-	-	-	-	-	A
15	Pulveriser B	36,12	32,80	32,06	33,13	33,40	-	A
16	Pulveriser C	38,12	39,38	36,95	39,25	38,01	35,70	A
17	Pulveriser D	42,41	38,22	38,02	-	-	35,17	A
18	Pulveriser E	37,25	38,56	35,11	36,90	36,93	33,93	A
19	Circulating Water Pump A	-	-	-	-	-	-	A
20	Circulating Water Pump B	164,80	162,44	165,23	163,54	163,63	161,96	A

5. Energy Baseline (EnB)

Historical data consumption energy electricity that has already been collected furthermore made as achievements performance use the electricity energy, made, and used as base reference evaluation for standard determination of the advanced electricity management energy. Determining the baseline is using the Linear Regression method. To get the linear regression equality is using MatLab application. This method is intended to obtain equality as reference for subsequent audits and obtain mark influence magnitude mark usage electricity energy to mark production electricity.

For example: Boiler Feed Pump B, input historical data script in the command window Matlab to get Linear Regression equation:

```
x= [192.79 171.33 150.18 131.60 110.14 100.08];
y= [489.21 427.95 371.41 352.04 302.44 280.93];
P= polyfit (x,y,1);
 yfit= polyval (P,x);
 figure (1)
    h=plot (x,y,'-.k',x,yfit,'-*r')
    xlabel ('Output Generator')
    ylabel ('Current BFP')
     text (110,400,['y=' num2str(P(2)) '+' num2str(P(1)) 'x']);
```

After script is RUN so will get results equations and graphs of Linear Regression as shown in Figure 3.

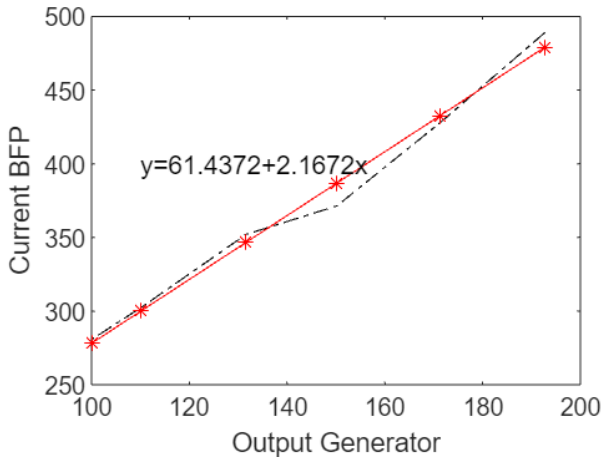

Figure 3. BFP Regression

Electricity current of each equipment in Table 2. then apply to linear regression test was carried out using MATLAB application to various generator Output levels to get equality as shown in Table 3.

Table 3. Linier Regression equality

No	Equipment	Regression
1	Boiler Feed Pump B	y = 61,437 + 2,1672x
2	Condensate Extraction Pump A	y = 56,477 + 0,0118x
3	Induced Draft Fan A	y = 60,517 + 0,2661x
4	Induced Draft Fan B	y = 91,256 + 0,1296x
5	Primary Air Fan A	y = 109,69 + 0,0037x
6	Primary Air Fan B	y = 84,105 + 0,2293x
7	Force Draft Fan A	y = 24,64 + 0,0207x

8	Force Draft Fan B	y = 19,758 + 0,0483x
9	Seal Air Fan A	y = 30,768 - 0,0063x
10	Pulveriser B	y = 27,77 + 0,0367x
11	Pulveriser C	y = 35,187 + 0,019x
12	Pulveriser D	y = 27,791 + 0,0694x
13	Pulveriser E	y = 32,486 + 0,00278x
14	Circulating Water Pump B	y = 161,17 + 0,017x

Results and Discussion

1. Calculation

After get equality of Linear Regression as reference base (EnB) for this research, then furthermore done retrieval of new electricity current data to every equipment (SEU) in April 2023. Reference base (Energy baseline, EnB) has determined previously with Linear Regression method and have obtained equality of electricity current equipment to the Generator output (Real Power).

Table 4. Current electricity 6 kV motor in April 2023

No	Point Data	Value Data					Unit
1	Real power Generator	197,26	169,48	149,98	130,05	115,91	MW
2	Boiler Feed Pump A						A
3	Boiler Feed Pump B	489,14	415,97	363,94	357,45	327,09	A
4	Condensate Extraction Pump A	57.93	58.21	57.85	57.34	57.49	A
5	Condensate Extraction Pump B						A
6	Induced Draft Fan A	107.88	105.75	105.45	105.24	106.05	A
7	Induced Draft Fan B	110.42	111.58	108.27	104.60	106.94	A
8	Primary Air Fan A	111.19	111.65	111.25	111.91	110.90	A
9	Primary Air Fan B	115.62	123.98	123.81	123.81	122.21	A
10	Force Draft Fan A	29.22	26.33	26.25	26.44	27.75	A
11	Force Draft Fan B	28.09	27.03	27.23	25.62	26.95	A
12	Seal Air Fan A						A
13	Seal Air Fan A	31.02	30.89	30.72	30.89	31.13	A
14	Pulveriser A	36.87	32.26	32.04	31.28	33.58	A
15	Pulveriser B	39.23	36.43	35.35	35.81	34.28	A
16	Pulveriser C						A
17	Pulveriser D	43.40	38.61	37.35	35.26	36.30	A
18	Pulveriser E	39.91	36.70	35.64	31.86	34.97	A
19	Circulating Water Pump, A	127.65	127.03	129.78	128.43	127.72	A
20	Circulating Water Pump B	165.28	166.88	163.49	163.27	163.47	A

As shown in Table 3, as example testing on every equipment:

1. Boiler Feed pump B is obtained equality linear regression as following:

$$y = 61.437 + 2.1672x \quad (1)$$

Where:
y = Equipment Electric Current (A)
x = Real Power Generator (MW)

So that EnB current electricity equipment Boiler Feed Pump can follow the following equation:

$$y = 61.437 + 2.1672\ x\ Real\ Power\ Generator\ (MW) \quad (2)$$

In Table 4, namely data on April 2023, the generator output was 197.26 MW measured current electricity equipment Boiler feed pump B amounting to 489.14 A. If apply calculation with the baseline equation:

y = 61,437 + 2,1672 x Real Power Generator (MW)
= (2,1672 x 197,26) + 61,437
= 488,94 A

From the calculations on obtained mark current electricity equipment Boiler feed pump B in accordance base reference (baseline) at real generator power of 197.26 MW is amounted to 488.94 A, whereas current electricity actual measurable amounting to 489.14 A. There are deviations between baseline calculation data and actual data of -0.2 A, so can called Boiler Feed Pump B experienced **waste** of -0.2A on April 1, 2023.

2. Induced Draft Fan A earned equality linear regression as following:

$$y = 60.517 + 0.2661x \quad (3)$$

Where:
y = Equipment Electric Current (A)
x = Real Power Generator (MW)

So that EnB current electricity equipment Induced Draft Fan A may follow suit the following equation:

$$y = 60.517 + 0.2661 \; x \; Real\ Power\ Generator\ (MW) \quad (4)$$

In Table 4, namely data on April 1, 2023, the generator output was 197.26 MW measured current electricity equipment Induced Draft Fan A amounting to 107.88 A. If apply calculation with baseline equation:

y = 60,517 + 0,2661 x Real Power Generator (MW)
= (0,2661 x 197,26) + 60,517
= 113 A

From the calculations on obtained mark current electricity equipment Induced Draft Fan A in accordance base reference (baseline) at real generator power of 197.26 MW is of 113 A, meanwhile current electricity actual measurable amounting to 107.88 A. There is deviation between baseline calculation data and actual data of 5.1 A, so can called Induced Draft Fan A experience **savings** of 5.1 A on April 1, 2023.

3. Primary Air Fan A is obtained equality linear regression as following:

$$y = 109.69 + 0.0037\ x \quad (5)$$

Where:
y = Equipment Electric Current (A)
x = Real Power Generator (MW)

So that EnB current electricity equipment Primary Air Fan A can follow the following equation:

$$y = 109.69 + 0.0037\ x\ Real\ Power\ Generator\ (MW) \quad (6)$$

In Table 4, namely data on April 1, 2023, the generator output was 197.26 MW measured current electricity equipment Primary Air Fan A is 111.19 A. If apply calculation with baseline equation:

y = 109.69 + 0.0037 x Real Power Generator (MW)
= (0,0037 x 197,26) + 109,69
= 110,42 A

From the calculations on obtained mark current electricity equipment Primary Air Fan A is appropriate base reference (baseline) at real generator power of 197.26 MW is of 110.42 A, meanwhile current electricity actual measurable amounting to 111.19 A. There is deviation between baseline calculation data and actual data of -0.77 A, so can called Primary Air Fan A experienced **waste** of -0.77 A on April 1, 2023.

Table 5. Audit result on April 1, 2023

No	Point Data	Baseline	actual value	Calc Value	Saving/ Losses
1	Real power Generator		**197,26**		
2	Boiler Feed Pump A		OFF		
3	Boiler Feed Pump B	y = 61,437 + 2,1672x	489,14	488,94	-0,20
4	Condensate Extraction Pump A	y = 56,477 + 0,0118x	57,93	58,80	0,87
5	Condensate Extraction Pump B		OFF		
6	Induced Draft Fan A	y = 60,517 + 0,2661x	107,88	113,01	5,13
7	Induced Draft Fan B	y = 91,256 + 0,1296x	110,42	116,82	6,40
8	Primary Air Fan A	y = 109,69 + 0,0037x	111,19	110,42	-0,77
9	Primary Air Fan B	y = 84,105 + 0,2293x	115,62	129,34	13,72
10	Force Draft Fan A	y = 24,64 + 0,0207x	29,22	28,72	-0,50
11	Force Draft Fan B	y = 19,758 + 0,0483x	28,09	29,23	1,14
12	Seal Air Fan A		OFF		
13	Seal Air Fan B	y = 30,768 - 0,0063x	31,02	29,53	-1,49
14	Pulveriser A	y = 27,77 + 0,0367x	36,87	35,01	-1,86

15	Pulveriser B	y = 27,77 + 0,0367x	39,23	35,01	-4,22
16	Pulveriser C	y = 35,187 + 0,019x	OFF		
17	Pulveriser D	y = 27,791 + 0,0694x	43,40	41,48	-1,92
18	Pulveriser E	y = 32,486 + 0,00278x	39,91	33,03	-6,88
19	Circulating Water Pump, A	y = 161,17 + 0,017x	127,65	134,52	6,87
20	Circulating Water Pump B	y = 161,17 + 0,017x	165,28	164,52	-0,76

Table 5. shows an audit results calculation is carried out in accordance with the baseline of each equipment against data on April 1, 2023, from audit results obtained several equipment work with good below the baseline current limit (EnB), however Still seen several experienced equipment waste works above the baseline current limit and if accumulates all current experienced equipment waste to -18.6 A. Next calculated to in energy electricity in accordance becomes:

$$P = \sqrt{3}. V. I . Cos \phi = \sqrt{3} \times 6000 \times 18,6 \times 0,85$$
$$= \mathbf{164.12\ kW}$$

Known that on April 1, 2023, equipment Electric Motor 6kV experienced waste energy electricity as **164.12 kW.** When reviewed return from ratio specific fuel consumption (SFC) Pangkalan Susu steam power plant, then can is known loss usage coal fuel amount:

Loss Coal usage = 164.12 x 0.7 kg/kWh x 24 hours= **2,757.22 kg/ day**

When reviewed from price Purchasing Coal Fuel then can is known loss amount:
Loss BB Purchase = 2,757.22 kg x IDR 850 = **IDR 2,343,960** in 1 day

When reviewed from cost principal production so can is known loss amount:
Cost loss = 164.12 kW x 1100 IDR/kWh x 24 hours = **IDR 4,332,768** in 1 day

2. Energy Saving Monitoring

For makes it easier in know is 6 kV motor equipment experienced savings or waste (Losing), arrange it an ONLINE monitoring media with an actual database electricity current 6 kV motor equipment and actual generator power data. Namely with create the monitoring display in the "AVEVA, PI VISION" application is as shown in Figure 4.

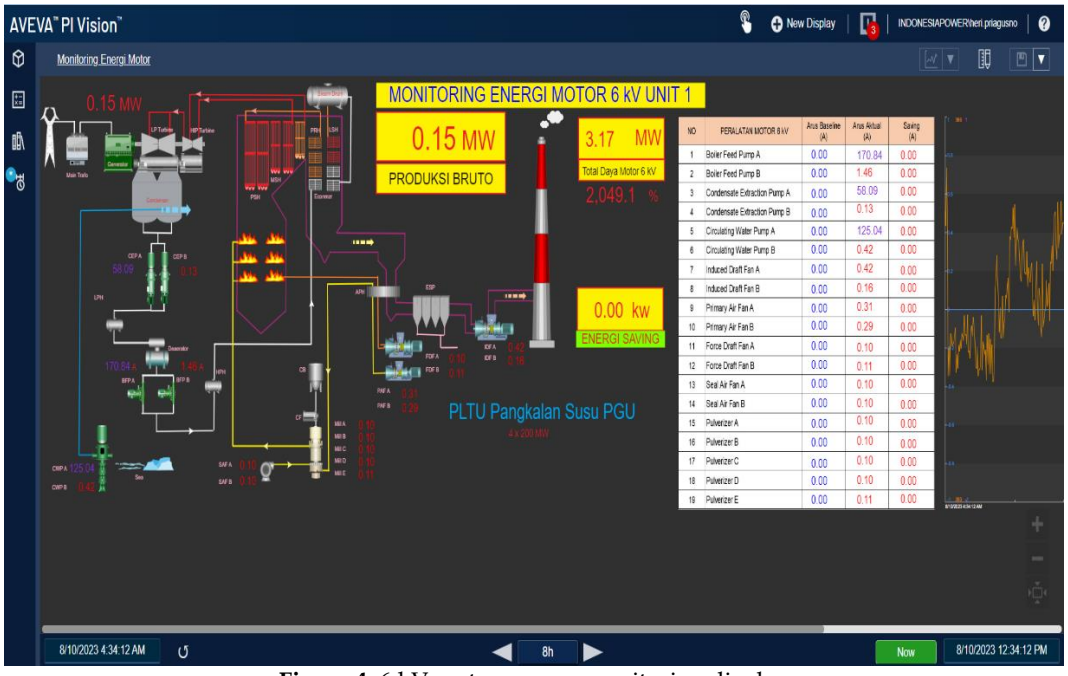

Figure 4. 6 kV motor energy monitoring display

The PI VISION application is application used for ONLINE monitoring generator parameter conditions whole Indonesia power plant. This application can be utilized for monitoring the electricity current 6 kV motor equipment actual and real time, so can used to monitoring electricity energy consumption from equipment the with add equations in configuration. In applications that have been arranged and carried out equality configuration like that appearance so that can monitor parameters equipment in a way directly (Sabubu, 2020).

With this application the plant operator can in a way directly know the condition of current Motor 6 kV usage. If

operation waste (loss) occurs on electric motors, then the generator operator can in a way directly arrange pattern operation electric motor equipment so that savings energy electricity can always awake.

Conclusions

The lowest point of electrical energy used in 36 months final in July 2022, amounting to 8.2 % of the electrical generated. Apply the Linear Regression analysis on the data so that obtained the Energy baseline (EnB) equation of each equipment as shown in Table 3.

An electrical energy audit was carried out on April 1, 2023, applying the Energy baseline (EnB) equation on 8 types of equipment. The result was obtained the waste electrical energy amount to **164.12 kW**. If reviewed from fuel cost is known experience loss as **IDR 2,343,960** in single day. And if reviewed from principal production cost is known experience loss as **IDR 4,332,768** in single day.

Input the Energy baseline (EnB) equation in the PI Vision monitoring application formula, the Changes of electrical energy used will be monitored directly, so that if there is a waste of electrical energy, the operating pattern can be regulated directly to avoid energy waste in the electrical equipment.

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