EFFICIENCY ANALYSIS OF MOTOR 2A CONDENSATE PUMP AT STG 2.0 TAMBAK LOROK STEAM POWER PLANT PT INDONESIA POWER SEMARANG

Denis Denis[1], Yosua Alvin Adi Soetrisno[2], Trinita Ro Ulina Bahari Sigiro[3]

[1] *Assistant Professor, Dept. of Electrical Engineering, Diponegoro University, Semarang, Indonesia*
[2] *Assistant Professor, Dept. of Electrical Engineering, Diponegoro University, Semarang, Indonesia*
[3] *Students, Dept. of Electrical Engineering, Diponegoro University, Semarang, Indonesia*

ABSTRACT

Gas and Steam Power Plant (PLTGU) is a power plant that utilizes gas and steam power as a turbine propulsion that will drive a generator to produce electricity. In the operation of generating electrical energy at the PLTGU, it is necessary to transfer a material in the form of liquid or gas. In the transfer using a pressure regulator such as a pump. A condensate pump or condensate pump is one of the pressure regulating equipment whose existence is very important in the water-steam cycle of gas and steam power plants. Because of the important role of pressure regulating equipment for a substance, it is necessary to analyze the power efficiency of the Condesate pump motor so that the water supply to the deaerator can be transferred optimally. The condensate pump functions to transfer condensate water from the condenser to the deaerator and feed water tank. Based on the results of the analysis, the efficiency of the Condesate pump motor is in the range of 85% to 95%. Because, in general, the efficiency of a motor never reaches 100% when working with an existing load due to various factors that cause power losses that are difficult to avoid in induction motors.

Keyword : *PLTGU , Condesate Pump, Efficiency, Power Losses, Vibration*

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1. INTRODUCTION

The need for electricity is gradually increasing due to the invention of electric-powered technology because of its efficiency and impact on a friendly environment, such as the emergence of electric car innovations to reduce air pollution and the use of fuel oil which is increasingly depleting in the bowels of the earthThe increase in electricity consumption in Indonesia is considered quite significant.

Components of PLTGU and PLTU consist of various components to support electricity production, one of which is a Condesate pump motor or commonly known as a condensate extraction pump. In general, the condensate pump serves to supply condensate water from the hotwell condenser to the next process, namely the deaerator to the HRSG to be converted back into steam. Based on this background, it is necessary to analyze the performance efficiency of the Motor Condesate pump in supplying and pumping water to the HRSG drum on the Steam Turbine Generator (STG 2.1) PLTGU PT Indonesia Power Semarang PGU to reduce the use of less effective electricity and to increase electricity production to meet optimal national electricity demand. The results of this study are expected to be useful for the parties concerned.

1.1 Purpose

The purpose of this study was to determine the performance and efficiency value of the motro condesate pump 2A in pumping condensate water which will be used as feed in the Heat Recovery Steam Generator (HRSG).

1.2 Scope of Problem

In this paper, the research is limited to discussing analysis only efficiency, power losses and vibration of the Condesate Pump 2A motor at STG 2.0

2. BASIC THEORY

Condensate pump (CP) motor is a 3-phase induction motor that functions as a pump to drain condensate water from the condenser to the preheater then to the deaerator which then becomes feed water for HRSG by the feed water pump. The PLTGU Add Lorok Block 2 has 2 Condesate pumps (CP), namely the CP 2A and CP 2B motors. Condesate pump motors 2A and 2B are a type of vertical motor. In general, the difference between vertical and horizontal type motors lies in the position of the shaft. Horizontal motors have a shaft with a horizontal side while a vertical motor has a shaft with an upright side. Vertical pumps can pump water with a large capacity but have a low head.

Fig -1 Motor Condesate Pump 2A (CP)

Condensate pump (CP) motor is a 3-phase induction motor that functions as a pump to drain condensate water from the condenser to the preheater then to the deaerator which then becomes feed water for HRSG by the feed water pump. The PLTGU Add Lorok Block 2 has 2 Condesate pumps (CP), namely the CP 2A and CP 2B motors. Condesate pump motors 2A and 2B are a type of vertical motor. In general, the difference between vertical and horizontal type motors lies in the position of the shaft. Horizontal motors have a shaft with a horizontal side while a vertical motor has a shaft with an upright side. Vertical pumps can pump water with a large capacity but have a low head.

2.1 Work principle Motor Condesate Pump (CP)

The working principle of the Condesate pump motor as a 3-phase induction motor is that if the stator coil is connected to a 3-phase voltage source, a rotating magnetic field will arise on the coil which is proportional to the synchronous rotation. The rotating magnetic field will cut the conductor rods on the rotor. As a result, the armature coil generates an asynchronous voltage (EMF) of E. Since the armature coil is a closed circuit, the emf (E) will produce a current I. The presence of current I in the magnetic field causes a force F on the rotor. If the initial coupling produced by the force f on the rotor is large enough to support the load coupling, the rotor will rotate in the direction of the stator rotating field. The rotational speed of the rotor will not reach the synchronous rotation, because if the rotor rotates at the same speed as the synchronous speed, the conductor rods on the rotor will not be cut into pieces by the magnetic field so that induction does not occur in the rotor.

2.2 Efficiency

The efficiency of an induction motor is defined as a measure of the effectiveness of an induction motor to convert electrical energy into mechanical energy which is expressed as a ratio / ratio of output power (output) to input power (input), or can also be formulated by:

$$\eta(\%) = \frac{P_{out}}{P_{in}} \times 100\% \tag{1}$$

Where :

η: Efficiency (%)

P_{input} :Input power (Watt)

P_{output} : Output power (Watts)

2.3 Power Flow and Power Losses

In an induction motor, there is no voltage source directly connected to the rotor, so the power through the air gap is equal to the power input to the rotor. Before power is transferred through the air gap, the induction motor suffers losses in the form of stator copper losses (Pts) and stator core losses (Pi). The power transferred through the air gap is equal to the sum of the rotor copper losses (Ptr) and the mechanical power (Pmek). The power transferred through this air gap is often referred to as the rotor input power. The following is a power flow diagram for a 3-phase induction motor.

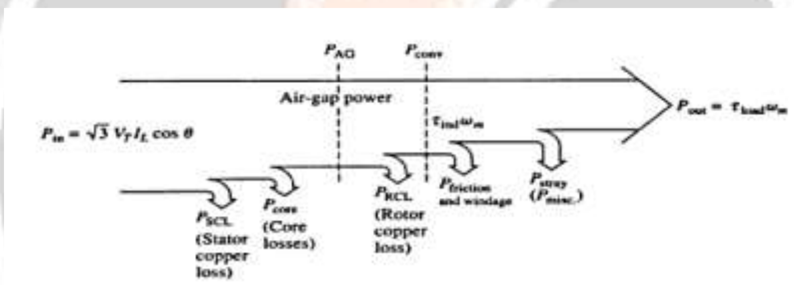

Fig -2 Power Flowchart

Based on the picture above, it can be seen that the induction motor experiences frictional and wind losses (Pa&g) so that the mechanical output power which is the driving force of the shaft (Ps) is the same as the mechanical power. In addition, the induction motor will also experience blind losses (Pb) or commonly known as stray load with a very small value.

3. DISCUSSION AND ANALYSIS

3.1 Specification Data Motor Condesate Pump 2A (CP) At STG 2.0 PLTGU PT. Indonesia Power Semarang PGU

At STG 2.0 PLTGU PT. Indonesia Power Semarang PGU, there are 2 Condesate pump motors that have the same function to drain condensate water from the condenser to the preheater then to the deaerator which then becomes feed water for HRSG by the feed water pump. Meanwhile, for the motor specifications for the Condesate pump STG 2.0 PLTGU PT. Indonesia Power Semarang PGU is shown in the following figure.

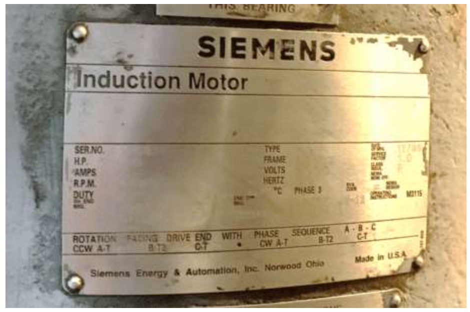

Fig 3 - Product Specification Motor Condesate Pump 2A STG 2.0

3.2 Breaker Motor Condesate Pump 2A (CP)

Circuit Breakers serves to protect the network, distribution system from high currents caused by equipment, in this case electric motors. The circuit breaker will disconnect or isolate the circuit from the power source in the event of an overcurrent. Furthermore, the protection relay is used to control the circuit with isolation between the control circuit and the controlled circuit and will separate electrical equipment that is disturbed by electrical disturbances. The protection relay works before the PMT trips.

If there is system instability, then the protection relay can automatically respond in the form of a signal to move the mechanical power breaker system so that the disturbed part can be separated.

Fig 4. Breaker ON

Fig 5. Breaker OFF

3.3 Condesate Pump Motor Operation Data 2A

Data were collected using 3 variations of operating patterns, namely 1-1-1 operating patterns, 2-2-1 operating patterns, and 3-3-1 operating patterns. Operation data can be seen in Table 1

Table 1 Motor Operation data Condesate Pump

Operation Pattern	Voltage)	Current (Amperes)	*Power Factor*
1-1-1	6000	44.7	0.9
2-2-1	6000	44.7	0.9
3-3-1	6000	48.4	0.9

3.4 Efficiency Calculation and Analysis

a. Motor Efficiency Calculation *Condensate Pump*2A Operation Pattern 1-1-1

- Stator Copper Losses

$P_{ts} = 3.I_1^2.R_1$

$P_{ts} = 3 \times 68^2 \times 1.6$

$P_{ts} = 22.195,2\ Watt$

$P_{ts} = 22,1952\ kW$

- Power on Air Gap

$P_{cu} = P_{in} - P_{ts}$

$P_{cu} = 596 - 22,1952$

$P_{cu} = 573,8048\ kW$

- Slip

$s = \frac{(Ns - Nr)}{Ns}$

$s = \frac{(1500 - 1482)}{1500}$

$s = 0.012$

So with a slip value of 0.012, the rotor copper losses are obtained using the following formula:

$P_{tr} = s.P_{cu}$

$P_{tr} = 0,012 \times 573,8048$

$P_{tr} = 6,8856\ kW$

Furthermore, to obtain mechanical losses, the following equation is used:

$P_{mek} = P_{cu} - P_{tr}$

$P_{mek} = 573,8048 - 6,8856$

$P_{mek} = 566,9192$

$P_{rot} = P_{innl} - P_{ts}$

$P_{rot} = 200,9 - 22,1952$

$P_{rot} = 178,70\ kW$

- Output power (P_{output})

$P_{out} = P_{mek} - P_{rot}$

$P_{out} = 564,9432 - 178,70$

$P_{out} = 386,24\ kW$

- input power (P_{input})

$P_{input} = \sqrt{3}.V.I.Cos\ \theta$

$P_{input} = \sqrt{3} \times 6000 \times 44,7 \times 0,9$

$P_{input} = 418.082,42$ Watt

$P_{input} = 418,082\ kW$

- Motor Efficiency

$$\eta(\%) = \frac{P_{out}}{P_{in}} \times 100\%$$
$$\eta(\%) = \frac{386,24}{418,082} \times 100\%$$
$$\eta(\%) = 0,923 \times 100\%$$
$$\eta(\%) = 92,3\ \%$$

b. Motor Efficiency Calculation *Condensate Pump*2A Operation Pattern 2-2-1

- Stator Copper Losses

$$P_{ts} = 3.I_1^2.R_1$$
$$P_{ts} = 3 \times 68^2 \times 1.6$$
$$P_{ts} = 22.195,2\ Watt$$
$$P_{ts} = 22,1952\ kW$$

- Power on Air Gap

$$P_{cu} = P_{in} - P_{ts}$$
$$P_{cu} = 596 - 22,1952$$
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$$P_{mek} = P_{cu} - P_{tr}$$
$$P_{mek} = 573,8048 - 6,8856$$
$$P_{mek} = 566,9192$$
$$P_{rot} = P_{innl} - P_{ts}$$
$$P_{rot} = 200,9 - 22,1952$$
$$P_{rot} = 178,70\ kW$$

- Output power (P_{output})

$$P_{out} = P_{mek} - P_{rot}$$
$$P_{out} = 564,9432 - 178,70$$
$$P_{out} = 386,24\ kW$$

- input power (P_{input})

$$P_{input} = \sqrt{3}.V.I.Cos\ \theta$$
$$P_{input} = \sqrt{3} \times 6000 \times 44,7 \times 0,9$$
$$P_{input} = 418.082,42\ \text{Watt}$$
$$P_{input} = 418,082\ kW$$

- Motor Efficiency

$\eta(\%) = \frac{P_{out}}{P_{in}} \times 100\%$

$\eta(\%) = \frac{386,24}{418,082} \times 100\%$

$\eta(\%) = 0,923 \times 100\%$

$\eta(\%) = 92,3\ \%$

c. Motor Efficiency Calculation *Condensate Pump*2A Operation Pattern 3-3-1

- Stator Copper Losses

$P_{ts} = 3.I_1^2.R_1$

$P_{ts} = 3 \times 68^2 \times 1.6$

$P_{ts} = 22.195,2\ Watt$

$P_{ts} = 22,1952\ kW$

- Power on Air Gap

$P_{cu} = P_{in} - P_{ts}$

$P_{cu} = 596 - 22,1952$

$P_{cu} = 573,8048\ kW$

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$P_{rot} = P_{innl} - P_{ts}$

$P_{rot} = 200,9 - 22,1952$

$P_{rot} = 178,70\ kW$

- Output power (P_{output})

$P_{out} = P_{mek} - P_{rot}$

$P_{out} = 564,9432 - 178,70$

$P_{out} = 386,24\ kW$

- input power (P_{input})

$P_{input} = \sqrt{3}.V.I.Cos\ \theta$

$P_{input} = \sqrt{3} \times 6000 \times 48,7 \times 0,9$

$P_{input} = 452.688,79$ Watt

$P_{input} = 452,688\ kW$

- Motor Efficiency

$$\eta(\%) = \frac{P_{out}}{P_{in}} \times 100\%$$
$$\eta(\%) = \frac{386,24}{452,688} \times 100\%$$
$$\eta(\%) = 0,8532 \times 100\%$$
$$\eta(\%) = 85,32\ \%$$

Based on the efficiency calculation above, the efficiency value in the 1-1-1 and 2-2-1 operating patterns is the same, namely 92.3%, while the 3-3-1 operating pattern gets an efficiency value of 85.32%.

3.5 Calculation of Vibration on the Motor Condesate Pump 2A

Vibration is an oscillatory motion (back and forth) that is repeated from an elastic part of a machine (an object) from its static equilibrium position (rest position) at certain intervals if the equilibrium is disturbed by the presence of a power moment of the machine body movement.

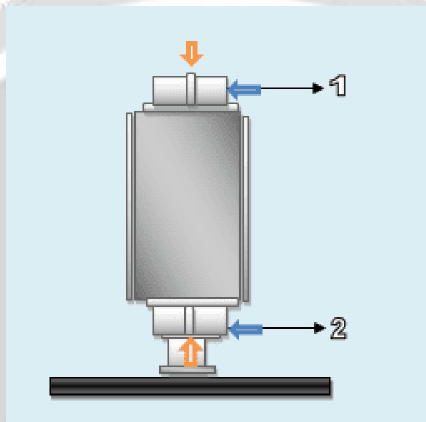

Fig 6 . Motor Condensate Pump Vibration Measurement Point 2A

The result of reading the vibration data of the Condesate pump shows that the horizontal position of the motor 1 has the highest value, namely 4.06 mm/s and 3.73 mm/s. Based on the data specifications, the Condesate pump is included in the class category above 15KW and the operating speed is between 120 and 15,000 RPM. So that it refers to the ISO 10816-3 standard which has 4 levels of vibration standards, namely:

(green)	: *New Machine Condition*	<1.4 mm/s
(blue)	:*Unlimited long-term operation allowable*	1.4 – 2.8 mm/s
(yellow)	: *Short-term operation allowable*	2.8 – 4.5 mm/s
(red)	: *Vibration Causes Damage*	>4.5

Fig 6 . Colour Condition of Measurement

Referring to the data above, the highest Condesate pump motor vibration is at the blue level (Unlimited long-term operation allowable) on the 1 side of the Horizontal bearing motor (1H) which is 4.06 mm/s and 3.73 mm/s. This level indicates that machinery with vibrations in this zone is normally allowed to operate for an indefinitely long period of time.

As for the motor vibration *Condensate pump* the lowest is in the yellow level (Short-term operation allowable) which is on side 2 Axial bearing motor (2A) which is 1.32 mm/s. This level indicates that it is allowed to operate in the short term. So from the results of the vibration data collection above, it can be recommended that it be necessary to check the motor (rotor bar condition, winding), check the bearing grase, and check the foundation and structural reinforcement.

4. CONCLUSIONS

Based on the results of measurements and calculations of the efficiency of the Condesate Pump 2A motor on January 1, 2022, it can be concluded as follows:

1) Condesate pump motor on STG 2.0 at PT Indonesia Power Semarang PGU is still good because its efficiency is in the range of 85% to 92%. Because, in general, the efficiency of a motor never reaches 100% when working with an existing load due to various factors that cause power losses that are difficult to avoid in induction motors.
1) Vibration conditions on the Condesate pump motor with measurements on the 1 Horizontal side were obtained at 4.06 mm/s and at 1 Vertical obtained 3.04 mm/s which means they are at the level of Short-term operation allowable so that it requires checking the condition of the motor.
2) Voltage imbalance on the Condesate pump motor is at a percentage of 3.6% which is in accordance with existing standards such as ANSI Std C84.1 – 1989 the unbalance voltage tolerance value is 3% which indicates that the condesate pump motor requires checking winding insulation and checking the motor cooling system.
3) Current imbalance in the Condesate pump motor is at a percentage of 0% which indicates that the condesate pump motor has good specifications in terms of current imbalance.

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