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Analysis of Coal Feeder Motor Performance Under the Influence of Frequency Fluctuations at PLTU Pangkalan Susu

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ABSTRACT

The coal feeder motor is a three-phase induction motor whose speed is regulated by the Variable Speed Drive (VSD). The coal feeder motor functions as a medium for distributing coal fuel to the combustion chamber in the boiler which aims for the combustion process in heating water on the pipe wall (wall tube) which will be used as steam to drive the turbine. Before supplying coal, first pay attention to the amount of coal entering the coal feeder, because it will affect the coal flow and motor performance. The more coal that enters the coal feeder, the greater the coal flow, just as the high speed of the motor will increase the flow of coal entering the furnace. From the research results, the calculation of the change in motor speed to the torque of the coal feeder motor at a speed of 115.2 rpm obtained a torque of 7.88 Nm, at a speed of 144 rpm obtained a torque of 6.68 Nm, at a speed of 230.4 rpm obtained a torque of 5.33 Nm and at a speed of 288 rpm obtained a torque of 4.48 Nm%. at a speed of 115.2 rpm an efficiency of 31.05% was obtained, at a speed of 144 rpm an efficiency of 29.55% was obtained.

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INTRODUCTION

Currently, electric motors are widely used in various needs and requirements, especially in the industrial world. The alternating current (AC) electric motor used is a three-phase induction motor. Because this motor has a simple, sturdy construction, easy maintenance and a relatively cheaper price. Especially in the Pangkalan Susu Batubara PLTU, this is something that must be considered. Because coal is a natural resource used for fuel. In other words, the quality of coal, type, size and flow rate of coal entering the furnace greatly affect the production process.

At the Pangkalan Susu PLTU, there are many types of belt conveyors to distribute coal, from barges to furnaces. However, one of the belt conveyors that can be adjusted in speed using a Variable Speed Drive (VSD) in distributing coal is the coal feeder. The amount of coal flow distributed to the combustion chamber is regulated by the coal feeder, so motor speed regulation is required. Coal-fired power plants (PLTU) play a vital role in meeting the base load electricity demand in Indonesia. One of the critical components in the operation of a PLTU is the coal feeder system, which ensures the continuous and controlled delivery of coal from the storage area to the boiler. The coal feeder motor drives this process and its performance directly impacts the stability and efficiency of boiler operation.

At PLTU Pangkalan Susu, the coal feeder motor operates in synchronization with the plant's electrical system, which is designed to function at a standard frequency of50 Hz. Ho wever, due to various operational factors such as load changes, generator disturbances, or g rid instability, frequency fluctuations may occur. These fluctuations, although sometimes sm all, can significantly affect the speed, torque, and overall performance of the coal feeder mot or.

Frequency instability can lead to nonuniform coal feed rates, causing combustion ineffi ciencies, increased emissions, and even boiler protection system trips. This makes it essentia l to understand how frequency variations affect the motor performance and to develop strat egies for mitigation or adaptive control.

This research aims to analyze the performance behavior of the coal feeder motor unde r the influence of frequency fluctuations at PLTU Pangkalan Susu. The study uses data colle ction, motor performance evaluation, and simulation to assess how frequency deviations im pact motor parameters such as speed, current, torque, and power consumption. The finding s are expected to provide recommendations for improving system reliability and efficiency, p articularly in environments where frequency stability cannot always be guaranteed.

Before supplying coal, it is important to first pay attention to the amount of coal entering the coal feeder, because it will affect the coal flow and motor performance. The more coal that enters the coal feeder, the greater the coal flow will be, as well as the higher the motor speed will increase the coal flow entering the furnace. The coal flow capacity in the boiler is 80 t / h. In its operation, this coal feeder motor is operated at a frequency of 4 Hz, 5 Hz, 8 Hz and 10 Hz. This frequency is adjusted to the needs of the boiler which has a coal flow capacity of 80 t / h with 4 coal feeder motors per generating unit. If the coal flow exceeds and is less than the coal flow capacity in the boiler, it will affect the performance of the motor and the production process.

Literature Review

Induction Motor

An induction motor is an alternating current (AC) electric motor whose rotation of the rotating field on the rotor is not the same as the rotation of the rotating field on the stator, in other words, the rotation of the rotor and the rotation of the field on the stator have a rotation difference called slip. Induction motors are the most widely applied alternating current motors in the industrial world. This is because this motor has a strong, simple construction and requires little maintenance. In addition, the motor also provides good efficiency and constant rotation for each change in load.

Three Phase Induction Motor Working Principle.

If a 3-phase voltage source is installed on the stator coil, a rotating field will appear with speed

$$n_S = \frac{120.f}{p} \text{ rpm}$$

The stator rotating field will cut the conductor rod on the rotor so that an induced voltage (EMF Induction) arises in the rotor coil. Because the rotor coil is a closed circuit, a current (I) will flow. The conductor wire (rotor coil) that is flowing with current in the magnetic field will cause a force (F) on the rotor. If the initial couple produced by the force (F) on the rotor is large enough to carry the load couple, the rotor will rotate in the same direction as the stator rotating field. As has been explained, the induced voltage will arise because the conductor rod (rotor) is cut by the stator rotating field. This means that in order for the induced voltage to occur, a relative difference is required between the speed of the stator rotating field (ns) and the speed of the rotor rotating field (nr). The rotation of the stator magnetic field will be followed by the rotation of the induction motor rotor. The heavier the motor load, the rotor speed will also decrease so that slip occurs. The difference in speed between nr and ns is called slip (s) expressed by

$$S = \frac{ns - nr}{ns} x100\%$$

The equation above can also be written:

$$n_r = n_S(1 - s)$$

Similarly, the mechanical angular velocity ωm can be expressed in terms of the synchronous angular velocity ωs and the slip as
ωm = (1 – s) ωs...........
In radians per second that is:

$$\omega_r = \frac{2\pi \text{nr}}{60} = \frac{2\pi\{ns(1-s)\}}{60}$$

Changes in the source frequency in a three-phase induction motor will affect the magnitude of the motor coil impedance because the induction motor coil contains inductive reactance. If nr = ns the voltage will not be induced and the current will not flow in the rotor armature coil, thus no coupling is produced. Motor coupling is generated when nr is smaller than ns. It can also be seen from how it works, an induction motor is also called an asynchronous motor.

To calculate the power of an induction motor, you can use the equation below:

$$(P_{\text{In}})_{3\text{Ph}} = \sqrt{3}\text{xV}_1\ x\ I_1\ x\ \text{Cos}\ \phi$$

Stator copper losses

$$P_{\text{SCL}} = 3I_{1}{}_{2}R_1$$

Core losses

$$P_{\text{Core}} = 3E_{1}{}_{2}G_C$$

Meanwhile, the Gap Power can also be determined using the equation:

$$P_{\text{AG}} = P_{\text{In}} - P_{\text{SCL}} - P_{\text{Core}}$$

Rotor copper loss

$$P_{\text{RCL}} = s.P_{\text{AG}}$$

Power converted from electrical to mechanical form:

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$$P_{Conv} = P_{AG} - P_{RCL} = P_{AG} - s.P_{AG} = (1-s)P_{AG}$$

If the friction and windage losses and stray losses are known, the output power can be determined by the following equation:

$$P_{Out} = P_{Conv} - P_{FAW} - P_{Misc}$$

The induced torque can also be calculated using the following equation:

$$T_{Ind} = \frac{(1-s)P_{AG}}{(1-s)\omega_{sync}} \quad T_{Ind} = \frac{P_{AG}}{\omega_{sync}}$$

In addition, there is also a load torque which can be determined using the following equation:

$$T_{Load} = \frac{P_{Out}}{\omega r}$$

Working Principle of Variable Speed Drive (VSD)

The working principle of *Variable Speed Drive*(VSD) which is simple, namely the incoming voltage from the 220/380 volt network and a frequency of 50 Hz is an alternating current (AC) voltage with a constant voltage and frequency value. Then it is distributed to the DC rectifier/rectifier board. So from AC it is made into DC. If the rectifier used is a controlled rectifier, then the DC voltage can be regulated by (VSD). To level the DC voltage, the voltage is fed into the DC link. The components found in the DC link are capacitors or inductors. The DC voltage is then fed to the inverter circuit to be converted back into AC with the frequency as needed. So that the DC voltage is converted back to three-phase AC voltage. The switching components are active semiconductors such as IGBT or MOSFET. The output voltage from the VSD is in the form of voltage and frequency that can be adjusted so it is called Variable Voltage Variable Frequency (VVVF). The following is the equation for calculating the efficiency of an induction motor

$$\eta = \frac{P_{Out}}{P_{In}} x100\%$$

METHOD

At PLTU Pangkalan Susu, the coal fuel supply system is very important, because coal is something that is very important in the process of producing electricity. The Block Diagram can be seen in the image below:

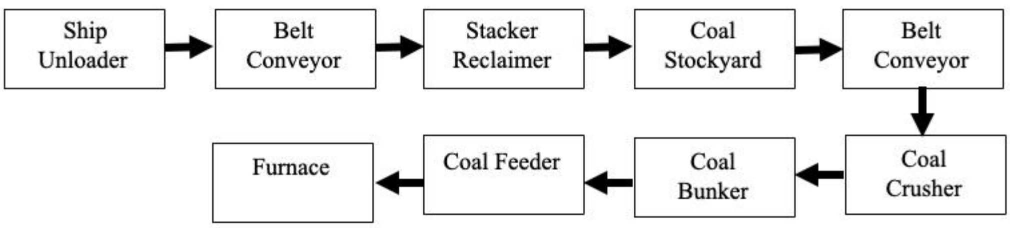

Figure 1. Block Diagram of Coal Cycle in Pangkalan Susu Steam Power Plant

The picture above shows a coal cycle from the ship to the combustion chamber (furnace). Coal is a very important thing to note, because coal is a source of fuel in the process of producing electricity. If the coal system is good, it will produce maximum production. Therefore, the role of the motor coal feeder is very influential in regulating the flow of coal that will enter the furnace.

RESULT

Testing With 4 Hz Frequency

The test starts from the lowest operating frequency of 4 Hz, with an inverter output voltage of 37 V, a current of 13.07 A and a power factor of 0.363, then it can be analyzed using the following equation:

$$f_s = 4\text{Hz}$$
$$V_{\text{In}} = 37 \text{ Volt}$$
$$I_{\text{In}} = 13{,}07$$
$$P_{\text{In}} = \sqrt{3} x 37 v \ x \ 13{,}17 \ x \ 0{,}363$$
$$= 306.37 \text{ Watt}$$

The stator and rotor speeds can be calculated using the following equations:

$$n_s = \frac{120 \ x \ 4}{4}$$
$$n_s = 120 \text{ rpm}$$
$$n_r = n_s(1 - s)$$
$$= 120(1 - 0{,}04)$$
$$= 115{,}2 \text{ rpm}$$

The angular velocity of the rotor and the angular velocity of the stator use the following equations:

$$\omega_r = (155{,}2 r/\text{min}) \ x \ (2\pi \text{ rad}/r) \ x \ (1\text{min}/60s)$$
$$= 12{,}06 \text{ rad}/s$$
$$\omega_s = \frac{\omega_r}{(1 - s)} = \frac{12{,}06}{0{,}96} = \frac{12{,}56}{\text{rad}/s}$$

Calculation of air gap power on a motor using the following equation:

$$T_{\text{ind}} = \frac{P_{\text{ag}}}{\omega_s}$$
$$P_{\text{ag}} = T_{\text{ind}} \ x \ \omega_s$$
$$= 7{,}89 \ x \ 12{,}56$$
$$= 99{,}1 \text{ Watt}$$

The motor conversion power uses the following equation

$$P_{\text{Conv}} = (1 - s) \ P_{\text{ag}}$$
$$= (1 - 0{,}04) \ x \ 99{,}1 \text{ Watt}$$
$$= 95.13 \text{ Watt}$$

The motor output power ignoring power losses uses the following equation:

$$P_{\text{Out}} = P_{\text{Conv}} - P_{\text{Loss}}$$
$$P_{\text{Out}} = P_{\text{Conv}}$$
$$= 95.13 \text{ Watt}$$

The load torque on the motor uses the following equation:

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$$T_{\text{Load}} = \frac{P_{\text{Out}}}{\omega_r} = \frac{95{,}13}{12{,}06} = 7{,}88 \text{ Nm}$$

The efficiency of an induction motor can be calculated using the following equation:

$$\eta = \frac{P_{\text{Out}}}{P_{\text{In}}} x100\%$$
$$\eta = \frac{95{,}13}{306{,}37} x100\% = 31.05\%$$

Testing With 5 Hz Frequency

The test starts from the lowest operating frequency of 5 Hz, with an inverter output voltage of 46 V, a current of 14.25 A and a power factor of 0.3, then it can be analyzed using the following equation:

$$f_s = 5\text{Hz}$$
$$V_{\text{In}} = 46 \text{ Volt}$$
$$I_{\text{In}} = 14{,}25$$
$$P_{\text{In}} = \sqrt{3} x 46v \; x \; 14{,}25 \; x \; 0{,}3 = 340.60 \text{ Watt}$$

The stator and rotor speeds can be calculated using the following equations:

$$n_s = \frac{120 \; x \; 5}{5}$$
$$n_s = 150 \text{ rpm}$$
$$n_r = n_s(1 - s) = 150(1 - 0{,}04) = 144 \text{ rpm}$$

The angular speed of the rotor and the angular speed of the stator in a motor use the following equations:

$$\omega_r = (144r/\text{min}) \; x \; (2\pi \text{ rad}/r) \; x \; (1\text{min}/60s) = 15{,}08 \text{ rad}/s$$
$$\omega_s = \frac{\omega_r}{(1 - s)} = \frac{15{,}08}{0{,}96} = \frac{15{,}7}{\text{rad}/s}$$

The air gap power in a motor uses the following equation:

$$T_{\text{ind}} = \frac{P_{\text{ag}}}{\omega_s}$$
$$P_{\text{ag}} = T_{\text{ind}} \; x \; \omega_s = 6{,}68 \; x \; 15{,}7 = 104{,}87 \text{ Watt}$$

The motor conversion power uses the following equation:

$$P_{\text{Conv}} = (1 - s) \; P_{\text{ag}} = (1 - 0{,}04) \; x \; 104{,}87 \text{ Watt} = 100.67 \text{ Watt}$$

The motor output power ignoring power losses uses the following equation:

$$P_{\text{Out}} = P_{\text{Conv}} - P_{\text{Loss}}$$
$$P_{\text{Out}} = P_{\text{Conv}}$$
$$= 100.67 \text{ Watt}$$

The load torque on the motor uses the following equation:

$$T_{\text{Load}} = \frac{P_{\text{Out}}}{\omega_r}$$
$$= \frac{100{,}67}{15{,}08}$$
$$= 6{,}67 \text{ Nm}$$

The efficiency of an induction motor can be calculated using the following equation:

$$\eta = \frac{P_{\text{Out}}}{P_{\text{In}}} x100\%$$
$$\eta = \frac{100{,}67}{340{,}60} x100\%$$
$$= 29.55\%$$

CONCLUSION

Based on the research results of the coal feeder motor at the Pangkalan Susu PLTU, the following conclusions can be drawn: The results of measurements and calculations of changes in motor speed against the torque of the coal feeder motor at a speed of 115.2 rpm obtained a torque of 7.88 Nm, at a speed of 144 rpm obtained a torque of 6.68 Nm, at a speed of 230.4 rpm obtained a torque of 5.33 Nm and at a speed of 288 rpm obtained a torque of 4.48 Nm. The results of measurements and calculations of changes in speed on the efficiency of the coal feeder motor, at a speed of 115.2 rpm, an efficiency of 31.05% was obtained, at a speed of 144 rpm, an efficiency of 29.55% was obtained. The results of the efficiency calculations show that as the frequency increases, the efficiency will also increase, this is because the motor speed increases as the frequency increases on the variable speed drive.

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