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Analysis Of Comparison Between Direct Starting Method (Direct On Line) With Variable Speed Drive (VSD) In Three-Phase Induction Motors

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Abstract - Electric motors are essential tools in the industrial world, frequently used to drive various industrial processes. Induction motors come in different capacities based on needs, and large-capacity motors generate high starting currents, which can potentially damage the motor. To minimize the risk of damage, an appropriate starting method is required. The Direct On Line (DOL) method is a simple, commonly used method due to its easy maintenance and economical installation. The Variable Speed Drive (VSD) method shows better operational efficiency. This study compares these two methods by conducting direct measurements at the Transmission and Distribution Laboratory of the University of North Sumatra. The calculation results show that the motor efficiency using the DOL method is 93.2%, while with the VSD method, it is 95.6%. This comparison indicates that the performance of VSD is superior to the DOL method.

Keywords - Three-Phase Induction Motor, Starting Method, Variable Speed Drive, Direct On Line, Starting Current.

1. INTRODUCTION

Induction motors have varying capacity values that are adjusted based on the operational needs of the machinery. Therefore, depending on the motor's capacity value, the starting current value will also vary. The larger the capacity of the induction motor, the greater the starting current value. The starting current value of a motor is also influenced by the Full Load Ampere (FLA).

When an induction motor is started during its initial operation, the starting current value will exceed the motor's FLA value. High starting current can pose a problem during the starting process of an induction motor. The high starting current, which is four to seven times the nominal current, has the potential to damage the induction motor. Therefore, the starting process of an induction motor needs to be carefully considered to minimize the potential for machine damage [1].

In three-phase induction motors, there are various types of starting methods. These starting methods apply to squirrel-cage rotor three-phase induction motors and wound rotor three-phase induction motors. Several starting methods for three-phase induction motors involve adjusting the input voltage to the electric motor, such as wye-delta starting, autotransformer starting, direct on line starting, soft starter, and variable speed drive [2].

Previous research conducted by Febrian Nugroho in 2015 discussed the design of modules and comparison of starting methods and speed control of induction motors, concluding that the soft starter method is the best [3]. Furthermore, a study comparing direct on line (DOL) and variable speed drive (VSD) starting methods on fan motors for cooling towers at PT. RAPP stated that the starting performance based on efficiency shows that the VSD method is much more efficient compared to the DOL method on fan motors, and in terms of electrical energy consumption, the VSD method is much more economical than the DOL method on fan motors [4].

In this study, a comparative analysis of the direct starting method (direct start) and variable speed drive (VSD) on three-phase induction motors is conducted. This research aims to compare the performance of starting methods on three-phase induction motors. The direct starting method (direct start) and variable speed drive (VSD) were chosen by the authors to test their performance on three-phase induction motors.

2. LITERATURE REVIEW

2.1 Induction Motor

An induction motor is the most widely used type of alternating current (AC) electric motor. The term "induction" refers to the way the motor operates, based on the induction of a magnetic field from the stator to the rotor. The rotor current is not supplied by an external source but is induced by the relative difference between the rotor's rotation and the rotating magnetic field produced by the stator current.

Induction motors are AC motors whose rotor speed is not equal to the stator magnetic field's rotation speed. In other words, there is a difference in speed between the rotor and the stator magnetic field, known as slip. Induction motors are the most commonly used motors in various industrial applications due to their simple design, low cost, availability, and direct connection to AC power sources. Generally, there are two types of induction motors based on

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the number of phases: single-phase induction motors and three-phase induction motors. As the name implies, three-phase induction motors are designed to operate using a three-phase voltage supply.

2.2 Direct On Line (DOL) Method

Direct On Line (DOL) is a starting method where the motor is connected directly to the full voltage of the power supply. This means the motor receives the full current generated by the supply voltage at the start.

DOL is a very simple and economical starting method for induction motors, but it comes with the risk of high starting current and voltage drop. This method is suitable for applications where high starting current is not an issue and the motor is not frequently started and stopped.

2.3 Variable Speed Drive (VSD) Method

Variable Speed Drive (VSD) is a device that controls the speed of an electric motor by varying the frequency of the electrical power supplied to the motor. This allows for speed adjustment from zero to the designed maximum speed. VSD is also known as Adjustable Speed Drive (ASD) or Frequency Converter.

VSD is a highly efficient and flexible technology for controlling motor speed. With VSD, users can adjust the motor speed according to application requirements, which not only improves energy efficiency but also reduces mechanical stress on the motor. Although the initial cost of VSD is higher, its long-term benefits in terms of energy efficiency and extended motor lifespan make it a popular choice in many industrial applications.

2.4 Motor Efficiency

Motor efficiency is a measure of how effectively an electric motor converts the electrical energy it receives into mechanical energy. Motor efficiency is expressed as a percentage and is calculated by comparing the mechanical output power (power used to perform work) with the electrical input power (power supplied to the motor).

Motor efficiency (η) can be defined by the following formula:

$$\eta = \frac{\text{Pout}}{\text{Pin}} x\ 100\%$$

Output Power: The mechanical energy produced by the motor to perform work, usually measured in watts (W) or kilowatts (kW).
Input Power: The electrical energy supplied to the motor, also measured in watts (W) or kilowatts (kW).

2.5 Motor Torque

Motor torque is an important parameter that determines the motor's ability to drive a load. Sufficient torque is required to overcome initial inertia and maintain motion under a given load. Understanding and measuring torque helps in selecting the appropriate motor for specific applications, ensuring optimal performance, and avoiding damage to the motor or connected equipment.

Motor torque can be calculated using the output power and rotational speed. The basic formula for calculating torque is:

$$\tau = \frac{P}{\omega}$$

where:
τ = Torque (Nm)
P = Output power (W)
Ω = Angular speed (rad/s)

Angular speed ω\omegaω can be calculated from the rotational speed (n) in revolutions per minute (rpm) using the formula:

$$\omega = \frac{2\pi n}{60}$$

2.6. Rotational Kinetic Energy

Rotational kinetic energy is the energy possessed by the motor's rotor and the rotating load due to their rotational motion. Understanding rotational kinetic energy is important in motor performance analysis, especially in applications involving changes in speed or load. By knowing the moment of inertia and angular speed, we can calculate rotational kinetic energy and use it to enhance motor efficiency and operational stability.

Rotational kinetic energy (E_k) can be defined by the following formula:

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$$E_k = \frac{1}{2} I \omega^2$$

where:
Ek = Rotational kinetic energy (Joule)
I = Moment of inertia (kg·m²)
ω = Angular speed (rad/s)

3. RESULTS AND DISCUSSION

The specifications of the induction motor used are in accordance with the nameplate specifications:
Motor Power: 1.1 kW
Motor Current: 11 A
Motor Voltage: 110V
Rotational Speed: 1420 rpm
Power Factor: 0.53
Horsepower: 3
Frequency: 50 Hz

Further measurements were conducted on motor current, voltage, starting current, and rotational speed of the three-phase induction motor using Direct On Line (DOL) and Variable Speed Drive (VSD) methods. The measurement data obtained are as follows:

Table 1. Measurement Results Using DOL Method

Tgl Penelitian	I (A)			V (V)			Arus Start			Kecepatan Motor (Rpm)
	I_R	I_S	I_T	V_{RS}	V_{ST}	V_{RT}	I_R	I_S	I_T	
14 Juni 2024	8,81	7,71	7,89	110,6	110,2	109,8	34,29	34,22	34,5	1443,5

Table 2. Measurement Results Using VSD Method

Tgl Penelitian	I (A)			V (V)	Arus Start			Kecepatan Motor (Rpm)
	I_R	I_S	I_T		I_R	I_S	I_T	
14 Juni 2024	6,72	6,97	6,72	110	7,29	7,42	7,28	1042

There are several losses that are always considered constant from zero load to full load, whereas these losses actually vary slightly with the load. All losses, whether known or unknown, which are relatively small in value, contribute to Stray Load losses that increase as the load increases.

Table 3. Percentage of Stray Load Losses

Machine Rating (kW)	Percentage of Stray Load Losses
1-90	1.8%
91-375	1.5%
376-1850	1.2%
1851 or greater	0.9%

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Calculation to determine input power, output power, efficiency, torque, and rotational kinetic energy for motor frame/no. D90S R939380 based on direct location measurements can be seen in the following Table 4.

Table 4. Calculation Results Based on Nameplate and Measurements

Metode Starting	Name Plate motor			Pout (kW)	Pin (kW)	Efisiensi	Torsi (Nm)	Energi kinetik rotasi (Joule)
	Pout (kW)	Pin (kW)	Efisiensi					
DOL	1,1	1,1107	99,03%	0,7412	0,7952	93,2%	0,709	1309,5
VSD				1,0037	0,6785	95,6%	1,38	1236,17

The input power of the three-phase induction motor frame/no. D90S R939380 is influenced by the motor current and power factor. For the motor using the DOL method, based on calculations with a current of 7.89 A, voltage of 109.8 V, and power factor of 0.53, the output power is 0.7412 kW, input power is 0.7952 kW, efficiency is 93.2%, torque is 0.709 Nm, and rotational kinetic energy is 1309.5 Joules. Meanwhile, for the motor using the VSD method, with a current of 6.72 A, voltage of 110 V, and power factor of 0.53, the output power is 1.0037 kW, input power is 0.06785 kW, efficiency is 95.6%, torque is 1.38 Nm, and kinetic energy is 1235.17 Joules.

4. CONCLUSION

Based on the analysis conducted, the following conclusions were obtained:
1. The starting current with the DOL method is IR = 34.29 A, IS = 34.22 A, IT = 33.45 A, while the starting current with the VSD method is IR = 7.29 A, IS = 7.42 A, IT = 7.28 A.
2. The rotational speed of the motor using the DOL method is 1443.5 rpm, while the rotational speed of the motor using the VSD method is 1042 rpm.
3. The efficiency of the motor using the DOL method is 93.2%, while the efficiency of the motor using the VSD method is 95.6%.
4. The torque of the motor using the DOL method is 0.709 Nm, while the torque of the motor using the VSD method is 1.38 Nm.
5. The rotational kinetic energy of the motor using the DOL method is 1309.5 Joules, while the rotational kinetic energy of the motor using the VSD method is 1236.17 Joules.

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