Injects International Journal of Economic, Technology and Social Sciences
e-ISSN 2775-2976

International Journal of Economic, Technology and Social Sciences
url: https://jurnal.ceredindonesia.or.id/index.php/injects
Volume 6 Number 1 page 56-68

Analysis of the Effect Rotation Speed Control on Three Phase Induction Motor Using VFD Powtech

Tri Safrizal[1], Adi Sastra P. Tarigan [2], Siti Annisah[3]

Email: trisafrizal21@gmail.com
Universitas Pembangunan Panca Budi

ABSTRACT

Technological advances in electric motor control systems have encouraged the adoption of more efficient and adaptive control devices. One of the commonly used devices is the Variable Frequency Drive (VFD), which plays a role in regulating the speed and torque of a three-phase induction motor. This study aims to analyze the effect of a three-phase induction motor rotational speed control system using a Powtech brand VFD. The main focus of this study is to evaluate motor performance in terms of rotational speed, torque, energy efficiency, and system response to frequency variations provided by the VFD. The research method used is an experimental approach, where a three-phase induction motor is connected to a Powtech VFD and tested under various load conditions and operating speeds. The test results show that the use of a Powtech VFD is able to provide more accurate speed and torque control, and contributes to increasing the efficiency of induction motor operation. In addition, smoother and more responsive rotation control can be achieved through flexible frequency adjustment, resulting in reduced power consumption and increased overall system performance. This study contributes to the development of VFD technology in three-phase induction motor drive systems, especially in efforts to improve energy efficiency in industrial applications.

Keywords: **Speed Control, Variable Frequency Drive (VFD), and Induction Motor**

INTRODUCTION

Three-phase induction motors are one of the most widely applied types of electric motors in the industrial sector, such as in pump systems, compressors, and various other drive systems. The popularity of this motor is supported by a number of advantages, including operational stability, resistance to heavy workloads, and relatively low maintenance costs. However, induction motors generally have limitations in terms of speed control, which under standard conditions is fixed and less flexible in adjusting to specific application needs. In some operational conditions, a more adaptive speed control system is required to improve energy efficiency and overall system performance.

In response to these problems, the use of Variable Frequency Drive (VFD) has become one of the technical solutions that is widely adopted. VFD allows efficient motor speed control by changing the frequency of the electric current supplied to the motor, resulting in more accurate and responsive rotation control. One of the VFD products widely used in the industry is the Powtech brand, which is known to have control features that can be adapted to various types of three-phase induction motors.

The implementation of Powtech VFD in a three-phase induction motor system has the potential to provide a number of performance improvements, such as reducing energy consumption, minimizing torque spikes, and increasing system reliability in general. However, there are still limited studies that examine in detail the effect of using Powtech VFD on controlling the rotation of a three-phase induction motor, especially in the context of evaluating

International Journal of Economic, Technology and Social Sciences
e-ISSN 2775-2976
International Journal of Economic, Technology and Social Sciences
url: https://jurnal.ceredindonesia.or.id/index.php/injects
Volume 6 Number 1 page 56-68

motor performance at various frequency variations. Therefore, this study aims to analyze the effect of controlling the rotational speed of a three-phase induction motor using Powtech VFD, focusing on the parameters of rotational speed, torque, and energy efficiency.

LITERATURE REVIEW

Past Research.

Research has been conducted by Muhammad Ridwan Amrullah and Lukman Aditya from Krisnadwipayana University in 2015 with the title "Analysis of inverter drive as a regulator of AC motor rotation speed". In this study, it was found that the electric current flowing to the AC motor through the Variable Speed Drive (VSD) differs depending on its output frequency. At a frequency of 10 Hz, the current flowing is 0.5 A; at 30 Hz it is 0.6 A; and at 50 Hz it is 0.7 A. This shows that the higher the frequency, the greater the current required by the motor. Kemas Nur Fuadi from Sriwijaya State Polytechnic also conducted a study entitled "Analysis of speed control of three-phase induction motor using variable speed drive in 2D bagging of PT. Pupuk Sriwidjaja". In his report, it was explained that the speed of the induction motor can be controlled through several methods, such as changing the number of motor poles, adjusting external resistance, and changing the frequency of the electricity supply.

One of the tools used to regulate this frequency is the Variable Speed Drive (VSD). This study also discusses the impact of frequency changes on motor speed both in no-load conditions and when loaded with 250 kg of urea fertilizer (equivalent to five bags). Furthermore, Muhammad Nahar from the University of Indonesia conducted a study entitled "Water level control based on LG inverter drive - SV008iC5". From a series of tests carried out, the results showed that the inverter device functioned well in regulating the speed of a three-phase AC motor, adjusting to variations in water surface height.

Three Phase Induction Motor Construction

Structurally, an induction motor consists of two main parts, namely the stator and the rotor. The stator is a stationary component and consists of a motor frame, stator core, stator windings, bearings, and a terminal box. On the other hand, the rotor is a moving part and generally consists of a rotor cage and a rotor shaft. These two parts are separated by an air gap and do not touch directly. Compared to DC motors, induction motors have a simpler construction because they do not require components such as carbon brushes and commutators. Therefore, maintenance of induction motors generally only involves mechanical parts. This motor is also known to be reliable and rarely experiences electrical damage (Siswoyo, 2008).

The rotor of a squirrel cage induction motor has a core equipped with conductors arranged parallel to the axis and encircling the outside of the rotor core. These conductors are directly connected to the core without insulation, because the rotor current will naturally flow to the path of least resistance, namely to the rotor conductors. At both ends of the rotor, the conductors are connected by end rings, forming a configuration resembling a rotating squirrel cage. Because of this structure, this motor is called a squirrel cage rotor induction motor. This type of motor is in great demand because of its simple construction, easy maintenance, and relatively low production cost.

International Journal of Economic, Technology and Social Sciences
url: https://jurnal.ceredindonesia.or.id/index.php/injects
Volume 6 Number 1 page 56-68

Air Gap (*Air Gap*)

In a three-phase induction motor, there is an empty space between the stator and rotor called the air gap. This gap acts as a medium for energy propagation from the stator to the rotor. In this area, the magnetomotive force originating from the stator works to rotate the rotor according to the direction of the magnetic field polarity. The size of the air gap must be made as small as possible to maximize the effectiveness of the magnetomotive force in moving the rotor, while being sufficient to maintain the physical distance between the stator and the rotor. In addition, the shape of the air gap must also be uniform, because irregularities in its shape can cause increased vibration and noise (Baharudin, 2016).

Induction motors operate on the principle of a rotating magnetic field, which is formed in the air gap of the motor due to the flow of electric current through the windings in the stator. The stator windings, consisting of three phases, are arranged with an electrical angle of 120°. When three-phase voltage is applied, current flows through the windings and produces a magnetic field. This magnetic field creates flux in each phase, which then combines to form a rotating vector flux around the inside of the stator at a constant speed. This rotating flux is called a rotating magnetic field, and this field induces motion in the rotor so that it rotates in the direction of the flux rotation.

Three Phase Induction Motor Power

In a three-phase induction motor, the rotor is not directly connected to the power source. Therefore, the power across the air gap is assumed to be the same as the power received by the rotor. The electrical energy entering the stator terminal is converted into mechanical energy on the rotor shaft, which then produces torque. This torque reflects the motor's ability to rotate the load. An inverter is a power electronic device that functions to change DC voltage (direct current) into AC voltage (alternating current) with adjustable values and frequencies. A three-phase inverter is a type of inverter that produces three-phase AC voltage. In general, a three-phase inverter circuit consists of six transistor switches.

Each transistor operates for 180°, with three transistors active simultaneously at any one time. When transistor Q1 is on, the a-phase terminal is connected to the positive side of the DC voltage source, while when Q4 is on, the a-phase terminal is connected to its negative side. In one complete cycle (360°), there are six modes of operation, each lasting 60°. To produce three-phase voltage, the trigger signal—as shown in Figure 2.8—is shifted by 60°. In a pair of inverter legs (for example, S1 and S4, S3 and S6, or S5 and S2), both switches should not be turned on or off simultaneously because this could cause a short circuit in the DC source.

METHODS

This paper writing is carried out at the workplace at CV. Kaya Karya Elektrindo Medan Helvetia. Thesis is carried out after the proposal is approved. And material equipment:

1. 3 Phase Induction Motor Type: cage rotor

Injects International Journal of Economic, Technology and Social Sciences
e-ISSN 2775-2976
International Journal of Economic, Technology and Social Sciences
url: https://jurnal.ceredindonesia.or.id/index.php/injects
Volume 6 Number 1 page 56-68

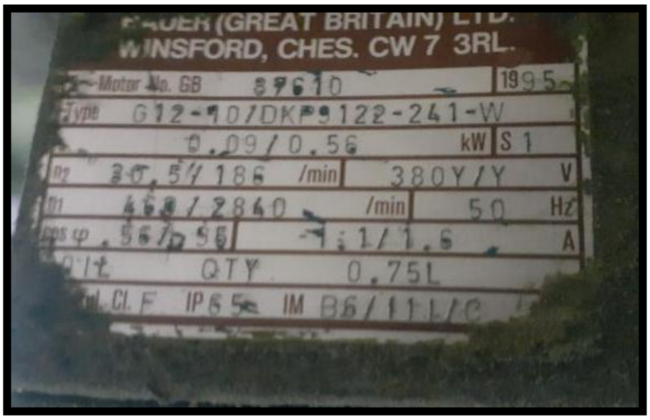

Figure 9. Nameplate of 3-phase induction motor

Specifications:

a. Nominal voltage (VL-L) = 380 V
b. Nominal current = 1.6 A
c. Power = 0.56 kW
d. Cos phi = 0.56
e. Frequency = 50 Hz
f. Number of poles = 4 Pole
g. Isolation class = F
h. Connection = Star (Y)

2. Ampere meter (Ampere Clamp)
3. Voltmeter
4. Variable Speed Drive (VSD)

In the implementation of the thesis, the required data is collected first, then analyzed and calculated using relevant formulas. The results obtained are then presented in the form of tables and curves. The variables observed in this thesis include:

a. Frequency
b. Load Torque
c. Voltage
d. Current
e. Motor Speed

Based on the flowchart*flow chart*, calculation and processing techniques can be seen in Figure 1 below:

International Journal of Economic, Technology and Social Sciences
e-ISSN 2775-2976

International Journal of Economic, Technology and Social Sciences
url: https://jurnal.ceredindonesia.or.id/index.php/injects
Volume 6 Number 1 page 56-68

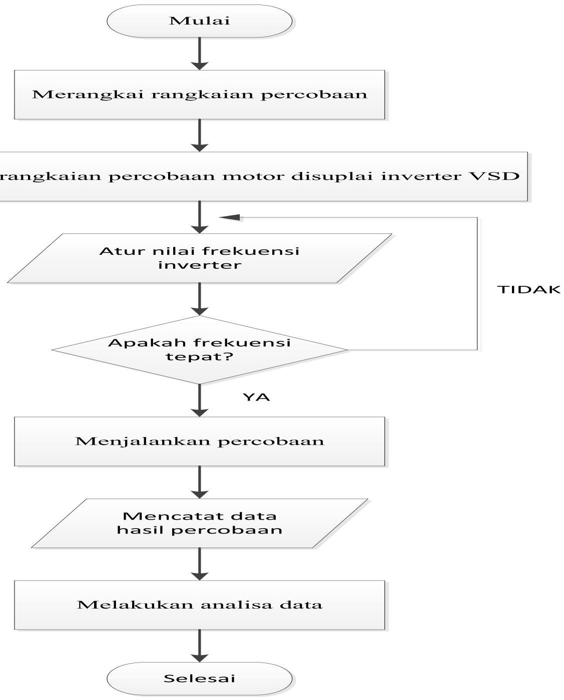

Figure 1. Flowchart System

Information :

1. Assemble the experimental circuit with supply from the mains.
2. Assemble the experimental circuit with supply from the InverterVariableSpeed Drive (VSD).
3. Run the three-phase induction motor by pressing the start button according to the nominal voltage of the motor in a state of balanced voltage with the supply from the Inverter.VariableSpeed Drive (VSD).
4. Set the frequency value on the InverterVariableSpeed Drive (VSD) from the range 0-50 Hz.
5. Measure the voltage, current and rotation speed of a three-phase induction motor at a frequency of 0-50 Hz.
6. Press the stop button until the motor stops rotating.
7. Experiment completed.

RESULTS AND DISCUSSION

Three Phase Induction Motor Experiment Supplied.

To see the effect of frequency reduction on the performance of a three-phase induction motor, a loading experiment was conducted on an induction motor with variable frequency. This experiment aims to compare the differences in motor performance in each condition. The effect of frequency changes will be analyzed on a three-phase induction motor with a cage rotor type.

International Journal of Economic, Technology and Social Sciences
e-ISSN 2775-2976
International Journal of Economic, Technology and Social Sciences
url: https://jurnal.ceredindonesia.or.id/index.php/injects
Volume 6 Number 1 page 56-68

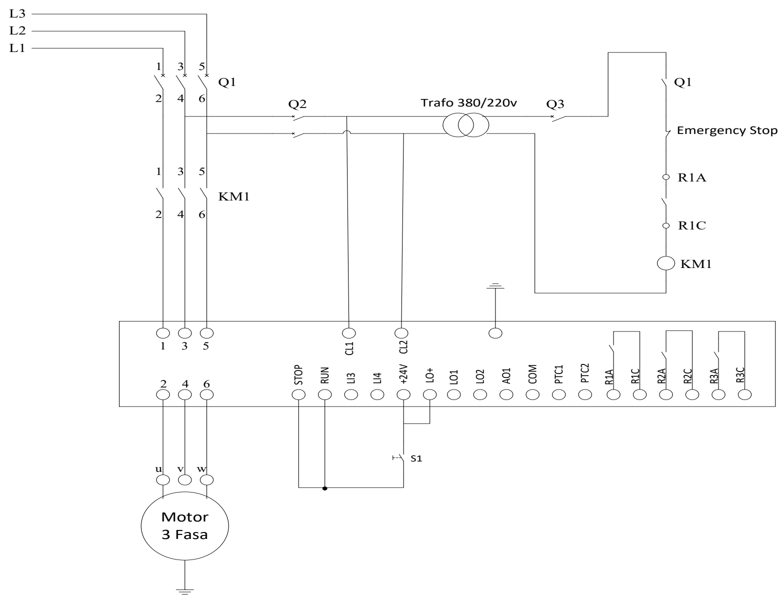

Figure 2. Experimental Circuit of 3-phase Induction Motor Supplied From a Variable Speed Drive Inverter

Experimental Procedure

1. Set up the experiment as shown in Figure 11.
2. Increase the three-phase voltage to 380 volts to be supplied to the induction motor.
3. Press the start button (S1) to run the motor and inverter.
4. Set the output frequency of the variable speed drive inverter by rotating the selector on the variable speed drive inverter. In this experiment, the selected frequency is from the range of 5 to 50 Hz.
5. Record current (I), input voltage (V), and motor speed (rpm).
6. Press the stop button to stop the motor and inverter.
7. Experiment completed.

The test results data for 3 phase induction motors are supplied from *Variable Inverter Speed Drive (VSD)* for frequencies 5 to 50 Hz.

Table 1. Test result data at frequencies of 5 to 50 Hz

No	Frequency (Hz)	Voltage (Vac)	Current (A)	Number (Rpm)
1	5	57.2	1.29	149
2	10	86.9	1.26	300
3	15	135	1.35	450
4	20	170	1.44	599
5	25	215	1.45	748
6	30	247	1.51	897
7	35	296	1.54	1048
8	40	330	1.66	1198
9	45	372	1.69	1347
10	50	405	1.62	1496

International Journal of Economic, Technology and Social Sciences
e-ISSN 2775-2976
International Journal of Economic, Technology and Social Sciences
url: https://jurnal.ceredindonesia.or.id/index.php/injects
Volume 6 Number 1 page 56-68

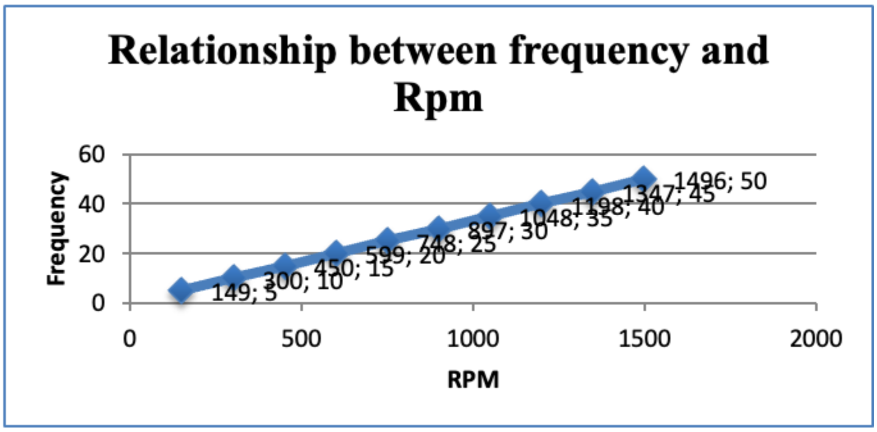

Figure 3. Frequency (5-50 Hz) vs speed graph of induction motor

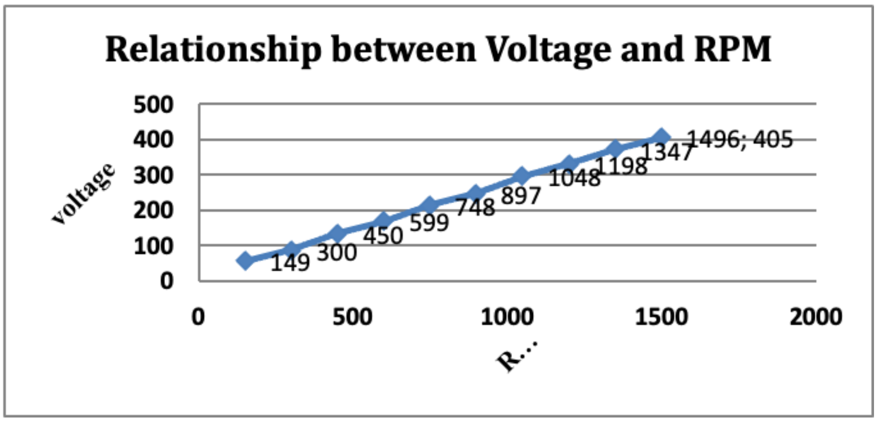

Figure 4. Graph of voltage (volts) vs speed of induction motor

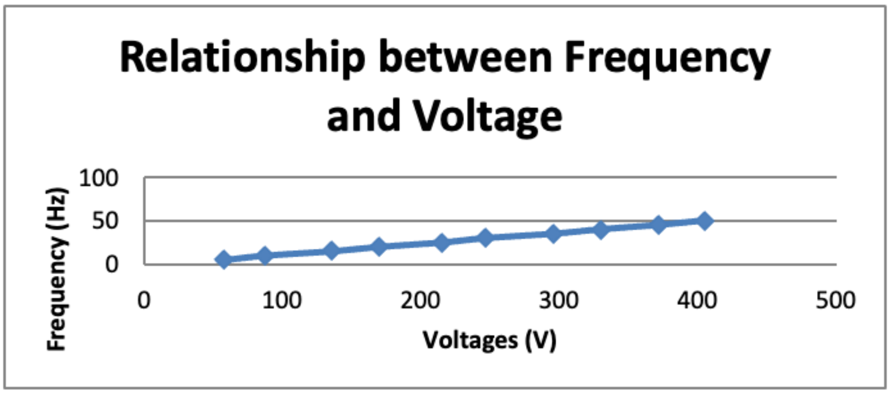

Figure 5. Frequency (Hz) vs Voltage (V) Graph

Analysis of Experimental Data Results

1. Frequency 10 Hz

International Journal of Economic, Technology and Social Sciences
e-ISSN 2775-2976
International Journal of Economic, Technology and Social Sciences
url: https://jurnal.ceredindonesia.or.id/index.php/injects
Volume 6 Number 1 page 56-68

From the experiment, when the motor is supplied from a variable speed drive inverter with a frequency of 10 Hz and given a load of 0.5 Nm, the following data is obtained:

V	: 86.9 volts	Cos θ	: 0.56
ILoad	: 1.26 ampere	R stator	: 21.28 Ω
IUnLoad	: 0.9 ampere	Pole	: 4
Nr	: 300 rpm		

Figure 6. Motor testing with 10 Hz frequency setting

Stator rotating field speed (ns)

$$ns = \frac{120 \times f}{p}$$
$$= \frac{120 \times 10}{4}$$
$$= 300 \text{ rpm}$$

a. Slip

$$S = \frac{ns - nr}{ns}$$
$$= \frac{300 - 300}{300}$$
$$= 0$$

b. Input power to the motor (PIn)

$$\text{Pin} = \sqrt{3} \times V \times I \times cos\,\theta$$
$$= \sqrt{3} \times 86{,}9 \times 1{,}26 \times 0{,}56$$
$$= 106.20 \text{ watts}$$

c. Core power loss at no load (P0)

$$\text{Pnl} = \sqrt{3} \times V \times I \times cos\,\theta$$
$$= \sqrt{3} \times 86{,}9 \times 0{,}9 \times 0{,}56$$
$$= 75.86 \text{ watts}$$

$$\text{PoSCL} = I^2 Rs = (0.9)^2 = 17.24 \text{ watts} \times 21{,}28$$

$$\text{P0} = P_{nl} - \text{P0SCL}$$
$$= 75.86 \text{ watts} - 17.24 \text{ watts}$$
$$= 58.62 \text{ watts}$$

International Journal of Economic, Technology and Social Sciences
e-ISSN 2775-2976
International Journal of Economic, Technology and Social Sciences
url: https://jurnal.ceredindonesia.or.id/index.php/injects
Volume 6 Number 1 page 56-68

Where:
Pnl = input power at zero load
P0SCL = power loss in the stator winding when the load is zero

d. Stator winding power loss (PrCu 1)
PrCu 1 = I2R× = $(1.26)^2$ = 33.78 watts× 21,28

e. Stator output power (P0S) = Power input to rotor (Pin R)
P0S = Pin R = Pin – (P0 + PrCu 1)
= 106.20 – (58.62 + 33.78)
= 13.8 watts

f. Motor output power (POut)
P_{Out} = (1-slip) x Pin R
= (1- 0) x 13.8
= 13.8 watts

g. Losses caused by friction and wind
P_t = 2% x P_{in}
= 2% x 106.20
= 2.124 watts

h. Output power (net)
$P_{Out\ B}$ = POut - Pt
= 13.8 – 2.124
= 11,676 watt

i. Induction motor efficiency (EFF)
$$EFF = \frac{Pout}{Pin} x\ 100\%$$
$$= \frac{13,8}{106,20} x\ 100\%$$
= 12.99%

2. Frequency 20 Hz

From the experiment, when the motor is supplied from a variable speed drive inverter with a frequency of 20 Hz and given a load of 0.5 Nm, the following data is obtained:

V : 170 volt   Cos θ : 0.56
ILoad : 1.44 ampere   R stator : 21.28 Ω
IUnLoad : 0.9 ampere   Pole : 4
Nr : 599 rpm

Stator rotating field speed (ns)
$$Ns = \frac{120 \times f}{p}$$
$$= \frac{120 \times 20}{4}$$
= 600 rpm

a. Slip
$$S = \frac{ns - nr}{ns}$$
$$= \frac{600 - 599}{600}$$
= 0.001

b. Input power to the motor (PIn)

Pin $=\sqrt{3} \times V \times I \times cos\ \theta$
$=\sqrt{3} \times 170 \times 1{,}44 \times 0{,}56$
= 237.44 watts

c. Core power loss at no load (P0)

Pnl $=\sqrt{3} \times V \times I \times cos\ \theta$
$=\sqrt{3} \times 170 \times 0{,}9 \times 0{,}56$
= 148.40 watts

PoSCL = I^2Rs = $(0.9)^2$ = 17.24 watts$\times$ 21,28

P0 = P_{nl}– P0SCL
= 148.40 watts - 17.24 watts
= 131.16 watts

Where:
Pnl = input power at zero load
P0SCL = power loss in the stator winding when the load is zero

d. Stator winding power loss (PrCu 1)

PrCu 1 = I2R×= $(1.44)^2$ = 44.13 watts$\times$ 21,28

e. Stator output power (P0S) = Power input to rotor (Pin R)

P0S = Pin R = Pin – (P0 + PrCu 1)
= 237.44 – (131.16 + 44.13)
= 62.15 watts

f. Motor output power (POut)

P_{Out} = (1-slip) x Pin R
= (1- 0.001) x 62.15
= 62.08 watts

g. Losses caused by friction and wind

P_t = 2% x P_{in}
= 2% x 237.44
= 4,748 watt

h. Output power (net)

$P_{Out\ B}$ = POut - Pt
= 62.08 – 4.748
= 57,332 watt

i. Induction motor efficiency (EFF)

EFF $=\frac{Pout}{Pin}$x 100%
$=\frac{62{,}08}{237{,}44}$x 100%
= 0.26%

3. Frequency 30 Hz

From the experiment, when the motor is supplied from a variable speed drive inverter with a frequency of 30 Hz and given a load of 0.5 Nm, the following data is obtained:

V : 247 volt Cos θ : 0.56
ILoad : 1.51 ampere R stator : 21.28 Ω
IUnLoad : 0.9 ampere Pole : 4

International Journal of Economic, Technology and Social Sciences
e-ISSN 2775-2976
International Journal of Economic, Technology and Social Sciences
url: https://jurnal.ceredindonesia.or.id/index.php/injects
Volume 6 Number 1 page 56-68

Nr : 897 rpm

Stator rotating field speed (ns)

ns $= \frac{120 \times f}{p}$

$= \frac{120 \times 30}{4}$

= 900 rpm

a. Slip

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

$= \frac{900 - 897}{900}$

= 0.003

b. Input power to the motor (PIn)

Pin $= \sqrt{3} \times v \times i \times cos\ \varphi$

$= \sqrt{3} \times 247 \times 1{,}51 \times 0{,}56$

= 361.76 watts

c. Core power loss at no load (P0)

Pnl $= \sqrt{3} \times V \times I \times cos\ \theta$

$= \sqrt{3} \times 247 \times 0{,}9 \times 0{,}56$

= 215.62 watts

PoSCL= $I^2 Rs$ = $(0.9)^2$ = 17.24 watts$\times$ 21,28

P0 = P_{nl}– P0SCL

= 215.62 watts - 17.24 watts

= 198.38 watts

Where:

Pnl = input power at zero load

P0SCL= power loss in the stator winding when the load is zero

d. Stator winding power loss (PrCu 1)

PrCu 1 = I2R$\times$ = $(1.51)^2$ = 48.52 watts$\times$ 21,28

e. Stator output power (P0S) = Power input to rotor (Pin R)

P0S = Pin R = Pin – (P0 + PrCu 1)

= 361.76 – (198.38 + 48.52)

= 114.86 watts

f. Motor output power (POut)

P_{Out} = (1-slip) x Pin R

= (1- 0.003) x 114.86

= 114.52 watts

g. Losses caused by friction and wind

P_t = 2% x P_{in}

= 2% x 361.76

= 7,235 watt

h. Output power (net)

$P_{Out\ B}$ = POut - Pt

= 114.52 – 7.235

= 107.28 watts

i. Induction motor efficiency (EFF)

$$EFF = \frac{Pout}{Pin} x\ 100\%$$

$$= \frac{114{,}52}{361{,}76} x\ 100\%$$

$$= 0.32\%$$

CONCLUSION

Based on the results of the thesis and analysis of the effect of three-phase induction motor rotation control using VFD Powtech, the author will conclude the contents of the thesis to obtain the essence and answer the research objectives. Some conclusions that can be drawn are:

1. Based on the testing and analysis that the author has done, the greater the frequency value, the faster the motor rotation speed will be. This can be seen when the frequency setting is 50Hz, then the motor rotation is 1496 Rpm. When the frequency value is 5 Hz, the motor rotation will be smaller, namely 149 Rpm.
2. Frequency control on a three-phase induction motor using an inverter variable speed drive will affect motor performance. Current will increase as frequency decreases, while voltage, power factor, and motor rotation speed will decrease as frequency decreases. In addition, the use of the inverter variable speed drive itself affects the amount of load that can be borne by the induction motor.

REFERENCES

Anisah, S., Fitri, R., Taro, Z., & Wijaya, R. F. (2022). Comparison of Lighting Efficiency (Led-CFL) based on Environmentally Friendly Technology. *Journal of Applied Engineering and Technological Science (JAETS)*, *4*(1), 568-577.

Aryza. S. et al (2024)). A ROBUST OPTIMIZATION TO DYNAMIC SUPPLIER DECISIONS AND SUPPLY ALLOCATION PROBLEMS IN THE MULTI-RETAIL INDUSTRY. *Eastern-European Journal of Enterprise Technologies*, (3).

B. Satria et al (2019) Penerapan metode Electre sebagai sistem pendukung keputusan dalam penerimaan beasiswa. *Jurnal Universitas Islam Sumatera Utara*, *14*(3).

Daut, I., “Parameters Calculation of 5 HP AC Induction Motor”, Malaysia, 2009

Hamdani, H., Tharo, Z., Anisah, S., & Lubis, S. A. (2020). Rancang Bangun Inverter Gelombang Sinus Termodifikasi Pada Pembangkit Listrik Tenaga Surya Untuk Rumah Tinggal. In *Prosiding Seminar Nasional Teknik UISU (SEMNASTEK)* (Vol. 3, No. 1, pp. 156-162).

Hamdani, H., Tharo, Z., & Anisah, S. (2019). Perbandingan performansi pembangkit listrik tenaga surya antara daerah pegunungan dengan daerah pesisir. In *Seminar Nasional Teknik (Semnastek) Uisu* (Vol. 2, No. 1, pp. 190-195).

IEEE Guides: Test Procedures for Synchronous Machines, IEEE Std 115-1995 (R2002)

Rao, KP Prasad, “Five-Leg Inverter for Five –Phase Supply”, India, 2012

Theraja, BL & Theraja, AK, “A Textbook of Electrical Technology”, New Delhi, S.Chand and Company Ltd., 2001

Tharo, Z., Tarigan, A., Anisah, S., Yuda, K. T., & LabuhanBilik, P. T. P. L. N. P. U. L. (2020). Penggunaan Kapasitor Bank Sebagai Solusi Drop Tegangan Pada Jaringan 20 Kv.

International Journal of Economic, Technology and Social Sciences
url: https://jurnal.ceredindonesia.or.id/index.php/injects
Volume 6 Number 1 page 56-68

In *Prosiding Seminar Nasional Teknik UISU (SEMNASTEK)* (Vol. 3, No. 1, pp. 82-86).

Wibowo P.S. Tarigan et al (2022) Comparisonal analysis study of power loss at the connection point of pierching connector with line tap connector on 220 V Low voltage network at PT. PLN (Persero) ULP Stabat. *INFOKUM*, *10*(03), 398-404.

Zuhal, "Basic Electrical Power Engineering and Power Electronics", ITB Publisher, Bandung, 1988