

Implementation of induction motor speed control Using a pid controller

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ABSTRACT

The three-phase induction machine that is used has a constant speed in accordance with the factory capacity without being able to adjust the speed. The inverter is a motor speed control device by changing the frequency value that enters the motor. Setting the frequency value is intended to obtain the desired rotation speed or as needed. But the inverter itself needs to be added with a controller so that the control value of the motor can be adjusted according to the desired needs. PID controller is a controller that is most widely used in the field of control systems in the industrial world. Combining the three PID constants in parallel can cover every disadvantage and strength of each constant so that a good controller is obtained. Based on the results of the experiments that have been carried out, it can be concluded that the speed of the three-phase induction motor can work well. When tested by giving values of $K_p = 0.2$, $K_i = 0$ and $K_d = 3.7$, it was found that the motor speed response had a Time Constant = 1.5 seconds, Rise time = 2.2 seconds and Settling time = 2.7 seconds.

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1. INTRODUCTION

Induction motors are alternating current (AC) electric motors that are widely used in everyday life both in industry and in everyday life both in industry and in household. Induction motors that are commonly used are three-phase induction motors and one-phase induction motors. three-phase induction motors are widely used in various industrial fields with large capacity [1],[2].

The three-phase induction machine used has speed that is fixed according to the factory capacity without can be adjusted. In large capacity industries must have maximum engine performance with have a constant engine rotation speed. As controller of a 3-phase induction motor, an inverter is needed. inverter. An inverter is a tool for regulating motor speed by changing the frequency value that into the motor. Setting this frequency value intended to obtain the desired rotation speed or as needed. desired or as needed. But in the

inverter itself needs to be added a controller so that the the control value of the motor can be adjusted to the desired needs [3],[4].

Pulse Width Modulation (PWM) is one of the techniques to regulate transistor switching in inverters. This technique is basically comparing two signals to get the transistor's switching pattern [5],[6]. Proportional Integral Derivative (PID) controller is a controller that is most widely used in the field of control systems in the industrial world. This is because the PID controller has three control constants where the three constants have their respective advantages and disadvantages. But by combining the three constants in parallel can cover every shortcoming and advantage of each constant so that a good controller is obtained [5],[6]. From this review, in this final project, a frequency control device is designed in the speed regulation of a three-phase induction motor using PID control.

2. LITERATURE REVIEW

In research conducted by Wildan et al. [5] the research discusses analyzing the control system contained in the inverter, especially the PID controller using the Genetic Algorithm (GA) method. With the test results stating that the three-phase induction motor speed response after being given a GA-based PID controller can reach a reference of 120 rad/s with the actual speed when the load is 100 Nm of 120.1 rad/s so e_{ss} 0.083%. But this test was carried out only as a simulation using MATLAB software. In research conducted by Rachmadyanti et al. [7] the research discusses the application of the PID control system for DC motor speed regulation in the automatic baby swing prototype, this method uses tangent line taking by making a straight line and intersecting the response that has the most linear value and through the torque value, namely the time required by the response to reach 63.2% of the steady state response value. In this study, a three-phase induction motor speed control device will be made using a PID controller to control the pulse width to obtain the desired frequency so that the speed of the three-phase induction motor is obtained in accordance with the desired frequency or speed.

3. METHOD

3.1 Three Phase Induction Motor Parameters

The induction motor used in this final project research is a three-phase induction motor with the source connected to a star (Y). The following is a table of three-phase induction motor parameters used:

Tabel 1. Parameters of the three-phase induction motor used

| MOTOR SPECIFICATIONS | |
|----------------------|----------------------------|
| Motor Type | Three-Phase Induction (AC) |
| Type | EM-3330-3C |
| Number of Poles | 4 Poles |
| Rotating Field Speed | 1420/1670 RPM |
| Frequency | 50/60 Hz |
| Current | 1.4 Ampere |
| Power | 0.3 kW |

3.2 System Design

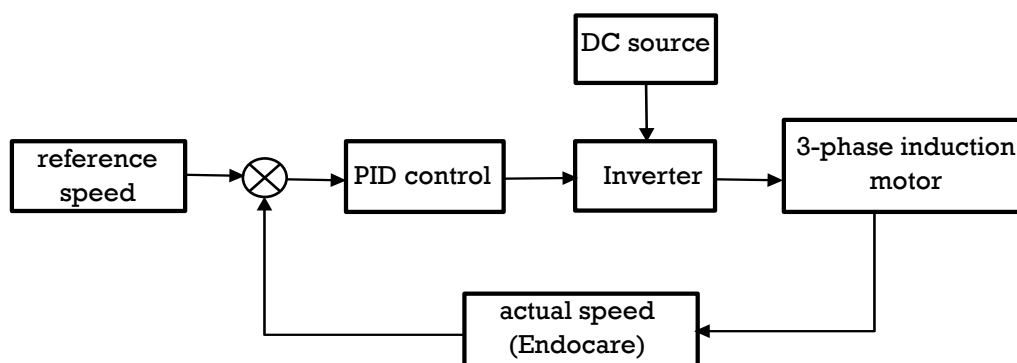


Figure 1. Tool Design Block Diagram

System design and modeling is carried out to show the condition of the three-phase induction motor speed control on the inverter to be controlled using a PID controller [8]. Modeling of a motor speed control system using an inverter with a PID controller as shown in Figure 1. From the DC voltage source used as input to the inverter so that it can be converted into AC voltage with frequency adjustments that can be adjusted to rotate the three-phase induction motor. The actual speed of the induction motor is then compared to the reference speed, the difference from the motor speed comparison is fed back to the PID controller [8]. Determination of the Parameter gain controller K_p , K_i and K_d in PID is done by trial & error until an approach with a small error value is obtained.

3.3 Three-Phase Inverter

Below is a three-phase inverter that has been successfully designed to convert direct voltage and current into three-phase alternating voltage and current. The following is a description of the three-phase inverter device used:



Figure 2. Three-Phase Inverter

In Figure 2, is a system design that system design that has been assembled and put together in a box.

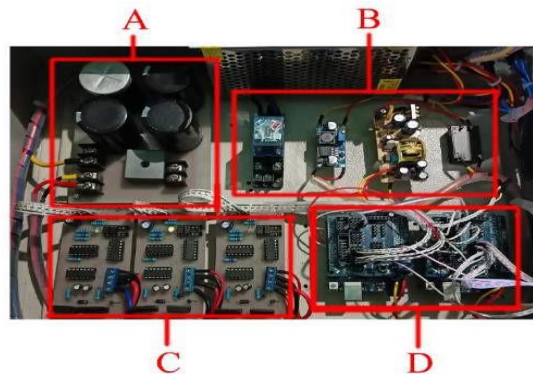


Figure 3. System Design View of a three-phase Inverter

Image description:

- A. Rectifier
- B. Power supply
- C. Three phase inverter driver
- D. Microcontroller

3.4 Mikrokontroler

The microcontroller used is 2 Arduino UNO units that are communicated with each other, each of which has a different task where one of them acts as the data sending side and the data receiving side. On the Transmitter side, it has two data inputs obtained from outside, namely set point data and data from motor rotation read by the encoder sensor. On the receiver side, it has a PWM (duty cycle) input. Three data are sent or communicated from the transmitter to the receiver, namely sensor (encoder) data, frequency and set point data. Then all data sent to the receiver will be displayed on the LCD screen. The three phase inverter driver has a Frequency input from Arduino 1 and a PWM input from Arduino 2.

3.1 Three-Phase Inverter Driver

Figure 4 is a three-phase inverter driver hardware that functions to convert DC voltage into three-phase AC voltage with phase R, phase S and phase T outputs. Where the PWM and frequency and phase difference angle shift have been set by the microcontroller.

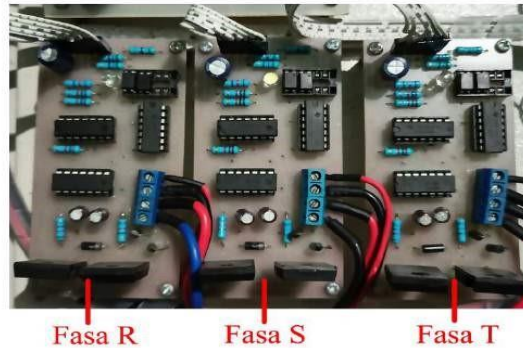


Figure 4. Three-phase inverter driver

3.6 National Instrument LabVIEW

This software is used to display the system response, using the help of Arduino UNO microcontroller to connect it to the software. into the software. Here is the picture diagram and display of LabVIEW.

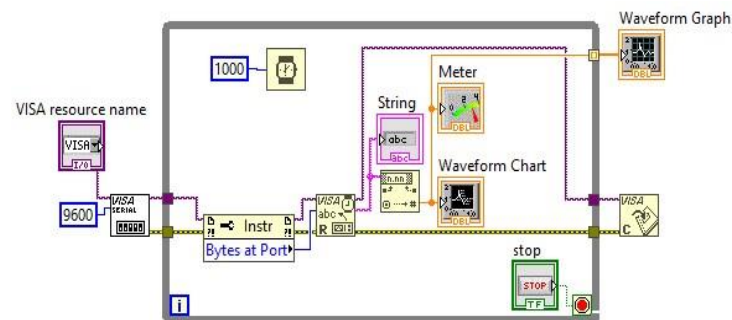


Figure 5. LabVIEW block diagrams

4. RESULTS AND DISCUSSION

4.1 Encoder Speed Sensor Calibration

Analog to Digital Converter (ADC) is a converter of analog input into digital codes. At the encoder sensor calibration stage by giving varying rpm to the sensor. The range used in this study is the speed of 1000 rpm - 2000 rpm with a fixed step per 1000 rpm. By looking at the ADC value the results obtained are as follows.

Tabel 2. Calibration of Encoder Sensor

| No | RPM | DC Value |
|----|------|----------|
| 1 | 1005 | 199 |
| 2 | 1104 | 219 |
| 3 | 1202 | 239 |
| 4 | 1300 | 259 |
| 5 | 1400 | 279 |
| 6 | 1501 | 299 |
| 7 | 1604 | 319 |
| 8 | 1702 | 339 |
| 9 | 1800 | 359 |
| 10 | 1903 | 379 |
| 11 | 2004 | 399 |

Based on the table, the voltage sensor linearity graph and the linearity equation of the sensor are obtained using Microsoft Excel. In testing the linearity of the variable being sought is the input speed against the output speed of the encoder sensor.

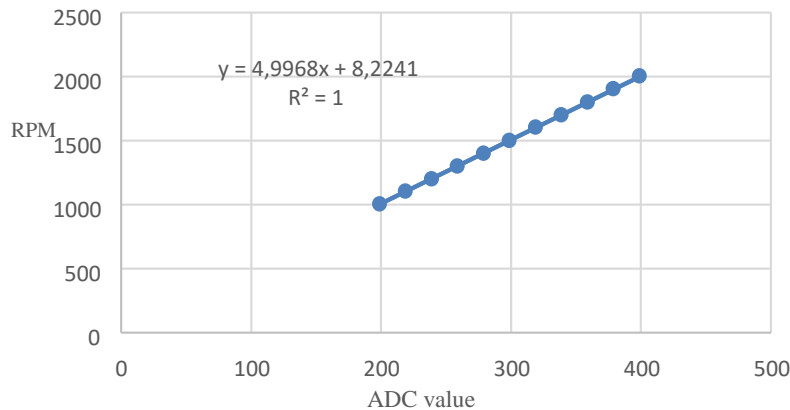


Figure 6. Encoder Sensor Linearity Graph

From Figure 6, it can be seen that the R^2 value or correlation value for the voltage sensor is 1, having a very high level of linearity relationship. It is said that the linearity value is very high because the relationship or correlation value between the two variables compared between the readings from the rpm sensor and the input rpm has a correlation value between 0.8 to 1. Based on the graph with the equation $y = 4.9968x + 8.2241$, it is used to access the sensor.

4.2 PWM Testing

At this stage, PWM testing will be carried out using an oscilloscope measuring instrument which aims to determine the frequency used has successfully worked as desired. As the following parameters are the calculation results of PWM testing with a frequency of 50Hz.

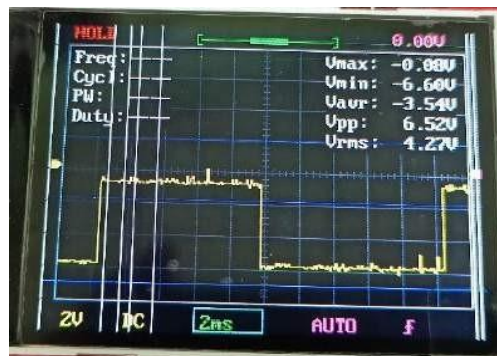


Figure 7. Wave frequency

Then PWM testing is continued at a frequency of 50-100Hz

Tabel 3. PWM Testing Results

| PWM Frequency (Hz) | T & Number of horizontal boxes |
|--------------------|---------------------------------------|
| 100 | Number of boxes = 5 T = 0,01 s |
| 90,9 | Number of boxes = 5,5 T = 0,011 s |
| 80,6 | Number of boxes = 6,2 T = 0,0124 s |
| 70,4 | Number of boxes = 7,1 T = 0,0142 s |
| 60,9 | Number of boxes = 8,2 T = 0,0164 s |
| 50 | Number of boxes = 10 T = 0.02 s |

Based on the readings in figure, the results show that the output of PWM output at the frequency can already work according to the desired. With the change of PWM at frequency, the motor rpm speed can be controlled.

4.3 Open Loop System Testing

At this stage, inverter testing will be carried out in an open loop to ensure that the driver or inverter is able to work as desired. From this test the results were obtained.



Figure 8. Input Voltage Open Loop Testing



Figure 9. RPM of motor in 50Hz

When the inverter is operated in an open loop the motor can work in accordance with the referenced motor range on the name plate listed in table 1. When given a 220Volt input source and under conditions of 50Hz frequency, the motor rotation given is 1482 rpm.

4.4 Determination of K_p , K_i and K_d values

At this stage after ensuring the system can work in open loop, the PID controller is implemented where the determination of the gain of each controller is done by trial & error until an approach with a small error value is obtained. Then testing on each additional constant value is carried out in the initial motor speed range of 1000 rpm which is then increased rapidly to 2000 rpm, after which the system response graph will be displayed through the LabVIEW software.

4.4.1 Parameter Test by Entering the Value Proportional (K_p)

System response with a given value of $K_p = 0.2$



Figure 10. System response graph of $K_p = 0.2$

From the system response graph at $K_p = 0.2$, the values of Time Constant = 1 second, Rise time = 1.5 seconds and Settling Time = 2 seconds are obtained. Giving the value of $K_p = 0.2$ shows the ideal system response with rise time, settling time and settling time the system becomes the ideal and fastest and without experiencing spikes, decreases or oscillations in motor rotation.

Tabel 4. System Response Data K_p

| Value Input K_p | Time Constan (second) | Rise Time (second) | Settling time (second) | Error steady state (%) |
|-------------------|--------------------------|-----------------------|---------------------------|------------------------|
| $K_p = 2$ | 3,2 | 3 | 3,2 | 36 |
| $K_p = 1$ | 1,6 | 2,3 | 2,8 | 34 |
| $K_p = 0,5$ | 1,5 | 2 | 2,5 | 24 |

| | | | | |
|-------------|---|-----|-----|---|
| $K_p = 0,1$ | 3 | 4,1 | 5,9 | 3 |
| $K_p = 0,2$ | 1 | 1,5 | 2 | 0 |

4.4.2 Test parameters by entering Proportional (K_p) and Derivative (K_d) values

System response with a given value of $K_p = 0.2$, $K_d = 3.7$.



Figure 11. Graph of system response $K_p = 0.2$ $K_d = 3.7$

From the system response graph at $K_p = 0.2$ $K_d = 3.7$, the values of Time Constant = 1.5 second, Rise time = 2.2 second and Settling time = 2.7 second are obtained. Giving the value of $K_p = 0.2$ $K_d = 3.7$ shows the ideal system response. Where it can be seen that the rise time, settling time and settling time of the system become faster than before. Without experiencing the slightest surge, decline and with oscillations at very small motor speeds.

Tabel 5. System Response Data K_p , and K_d

| Value Input K_p & K_d | Time Constan (second) | Rise Time (second) | Settling time (second) | Error steady state (%) |
|------------------------------|--------------------------|-----------------------|---------------------------|------------------------|
| $K_p = 0,2$ $K_d = 1$ | 1,7 | 2,1 | 2,8 | 3,5 |
| $K_p = 0,2$ $K_d = 1,8$ | 2,6 | 2,4 | 3,9 | 3 |
| $K_p = 0,2$ $K_d = 3$ | 1,8 | 2,4 | 2,9 | 7 |
| $K_p = 0,2$ $K_d = 3,7$ | 1,5 | 2,2 | 2,7 | 0 |

4.4.3 Test the parameters by entering the values of Proportional (K_p) and Integral (K_i) values

System response with given value of $K_p = 0.2$ $K_i = 1$

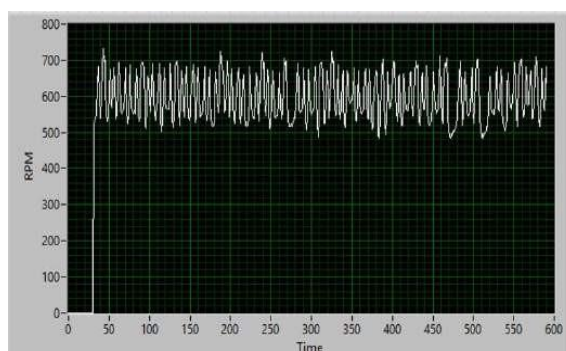


Figure 12. System response graph of $K_p = 0.2$ $K_i = 1$

At the time of applying the Integral constant, from each experiment, giving the value of K_i resulted in the system becoming very unstable. And from the system response graph when given the value of $K_i = 1$, the motor cannot work up to the predetermined setpoint. So in this motor control system it was decided to keep giving the value 0 to the K_i constant.

4.5 Overall System Testing

For the final stage in testing this control device after all the tools and components and systems work properly, and also after getting the K_p , K_i and K_d gain settings to get the desired response and setpoint. Then the last experiment was carried out by operating the motor from a speed of 1000 rpm for 30 seconds then to a speed of 1500 rpm for 30 seconds and to a speed of 2000 rpm for 30 seconds. After that the rpm is returned to the point of 1500 rpm for 60 seconds. Here is the final system response displayed.

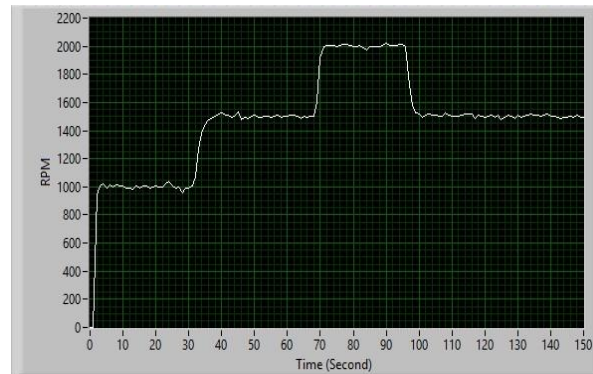


Figure 13. Test response graph of the whole system

By using the values $K_p = 0.1$, $K_i = 0$ and $K_d = 3.7$, the system response graph obtained that the system has worked with the specified setpoint with a fast response and without any spike or drop in motor speed and steady state error.

Tabel 6. Frequency Value Data Using PID

| RPM | Frequency (Hz) |
|------|----------------|
| 1000 | 37 |
| 1100 | 41 |
| 1200 | 45 |
| 1300 | 48 |
| 1400 | 52 |
| 1500 | 56 |
| 1600 | 60 |
| 1700 | 64 |
| 1800 | 68 |
| 1900 | 71 |
| 2000 | 76 |

Furthermore, in the last overall system test by operating the motor and giving a torque load of 0.04 kg-m then comparing the system response from without using PID control to using PID control. The following is a comparison picture of the system response displayed.

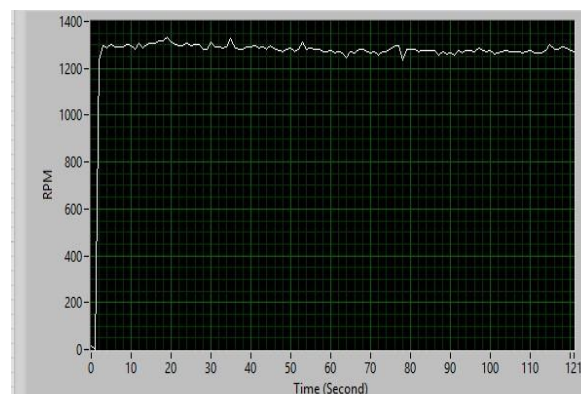


Figure 14 System response with torque load without PID control

It can be seen the response in Figure 14 when the system is given a torque load without using PID control, slowly resulting in a decrease in the rotation speed of the motor by 1300 rpm - 1250 rpm. Then with the same torque load and then given a PID control input with a value of $K_p = 0.2$, $K_i = 0$ and $K_d = 3.7$.

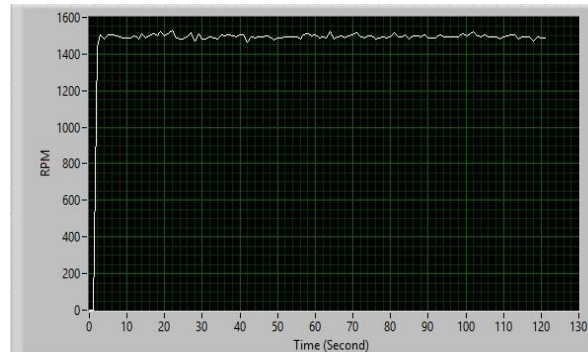


Figure 15. System response with torque load using PID control

It can be seen that the system response in Figure 15 when using PID control by setting a set point of 1500 rpm, can maintain a stable motor rotation speed at a predetermined set point.

5. CONCLUSION

From this research, several conclusions were found. First, PWM settings on frequency affect the speed of the induction motor the higher the frequency, the motor speed (RPM) will increase proportionally. Second, the application of PID control can correct the system response error, by providing appropriate K_p , K_i , and K_d values to achieve the desired setpoint response. Third, the test results of determining the gains of K_p , K_i , and K_d show that the values of $K_p=0.2$, $K_i=0$, and $K_d=3.7$ provide the most ideal system response. Fourth, in the inverter system created, giving the value of the Integral constant (K_i) causes the system to become unstable and cannot operate at the specified setpoint.

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