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# Close Loop Speed Control Design for 3Ø Induction Motor on Electric Railway with Embedded PID Controller

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***Abstract***— *An electric railway has its propulsion, which is AC or DC motors sourced from electric power. Motor speed control is necessary so that the motor speed consists of a setpoint. In the operation of the electric railway are many factors that can reduce the rate of it, for example, the load that occurs through the incline or turn tracks. The author uses a PID controller embedded in Arduino as the microcontroller in this design. This control system maintains the motor speed when there is a load according to the setpoint. To adjust the setpoint, a potentiometer, and the tachometer as feedback. The PID controller testing results are obtained at rising time 3 s, peek time 4.5 s, delay time 1.2 s, settling time 8.9 s, and overshoot 5%. The loading test results on the PID controller can maintain speed at a load of 4 kg, and it takes 5.8 s to return to the setpoint.*

***Keywords***— *Three phase induction motor, PID controller, Arduino.*

## I. INTRODUCTION

Electric railway has their propulsion using a three-phase AC motor or a DC motor sourced from electric power. The electric railway motor speed control system uses an inverter as a frequency regulator and the driving voltage.

The speed of the electric railway has decreased due to the load obtained when passing through inclines and turns. Therefore, an appropriate speed control system on the electric rail carriage is needed to restore the original speed.

Three-phase induction motors are widely used in various fields. This is because of its advantages, such as a lighter structure than DC motors for the same power, relatively lower prices, and more efficient maintenance. The use of PID controller to obtain stable motor speed and fast system response.

PID Controller consists of proportional, integral, and derivative controls. Determine the value of the PID parameter that can regulate the stable speed in this design using the Ziegler-Nichols method. PID controllers are easy to implement and low cost.

The PID controller is implemented in a microcontroller, namely Arduino. As feedback using a dynamo tachometer and as a comparison between the setpoint and the actual speed, the error value of the motor speed can be reduced by using the PID controller.

Based on the problem of designing the motor speed control system, the author implements a 3-phase induction motor, and the speed is adjusted according to the setpoint with varying loading.

## II. METHODOLOGY

### A. *System Diagram*

The diagram system of the 3-Phase Induction Motor Speed Control System on an Electric Train using an Embedded PID Controller is shown in Figure 1.

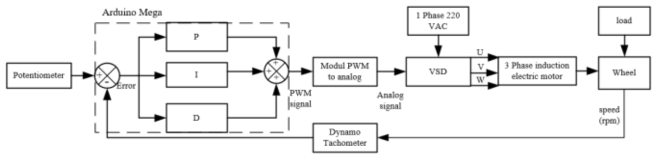


Figure 1. System Diagram

1. The potentiometer is a device used to set the setpoint.
2. The error is the difference between the actual value and the setpoint and is used as input from the PID controller.
3. PID controller maintains the motor speed when there is a load according to the setpoint.
4. PWM to Analog Module is a device to convert the PWM signal from the Arduino output to analog so it can be used on a VSD.
5. VSD is a device used to convert the 1-phase input voltage value of 220 VAC to an output voltage of 220 VAC 3-phase by assembling it using a star circuit for 3-phase induction motors. Analog input on VSD with 0-10 VDC voltage with PWM to the analog output module.
6. A 3-phase induction motor is a device used as a wheel drive that will be given a load.
7. The wheel is used as an object to read the motor speed (RPM) and as feedback using a dynamo tachometer.
8. Load is simulated as an electric railway when going through the incline and turning rails.
9. Dynamo Tachometer is a device for reading wheel rotational speed and as feedback.

### B. *Design Software*

This section explains the design of software as a system, as shown in the following flowchart.



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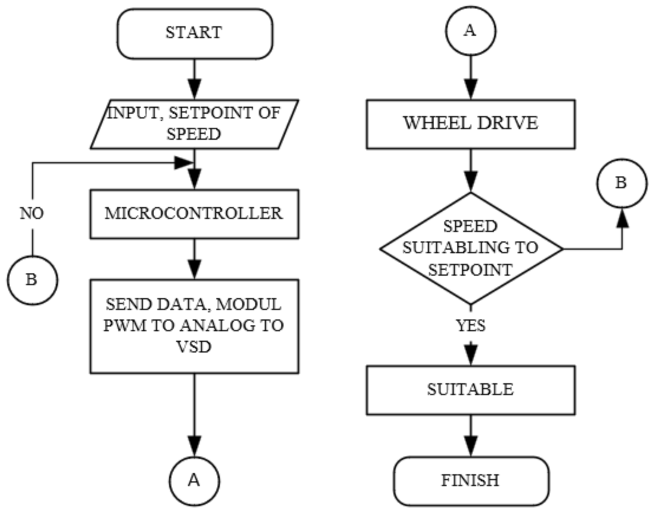


Figure 2. Software System Flowchart

Figure 2 is a flowchart that shows the hardware system on a 3-Phase Induction Motor Speed Control System on Electric Train using Embedded PID Controller. PID controller is embedded in the Arduino Mega 2560 microcontroller. The potentiometer is the input setpoint, and the dynamo tachometer is feedback to the Arduino Mega 2560. The output value of the PID is a PWM signal. The PWM signal issued by Arduino Mega 2560 will then be converted into an analog signal by the PWM module to an analog converter so that it can make the inverter as an analog input.

## C. *Design of 3-Phase Induction Motor Speed Control System on Electric Train using Embedded PID Controller*

Design of 3-Phase Induction Motor Speed Control System on Electric Train using Embedded PID is a tool consisting of a 3-phase induction motor, VSD, microcontroller, prony brake dynamometer, and frame. The microcontroller uses the PID controller system as a controller to maintain the speed according to the setpoint.

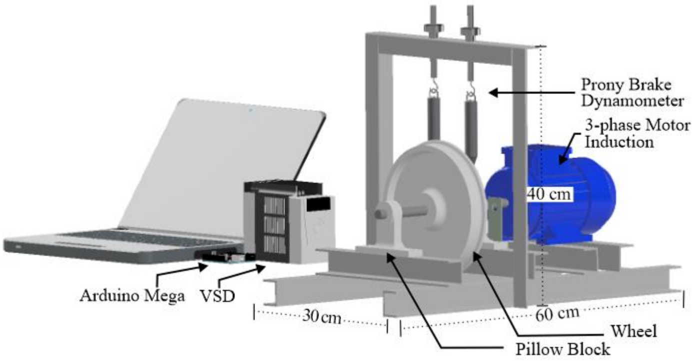


Figure 3. Design of 3-Phase Induction Motor Speed Control System on Electric Train using Embedded PID Controller

## D. *PID Controller*

Proportional, integral, and derivative (PID) control reduces errors, namely the difference between the setpoint and actual signals. The faster the controller response follows the output signal, and the smaller the error value obtained, the better the PID controller system. Suppose the difference between the setpoint and the output value is significant. In that case, the PID controller is expected to be able to quickly change the system output to reduce the error as small as possible.

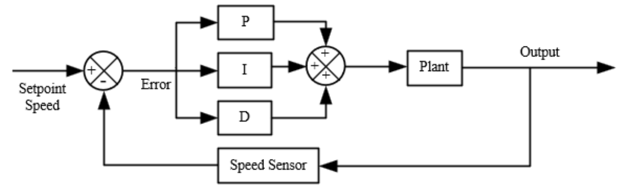


Figure 4. Design of PID Controller

## E. *PID Tuning*

The tuning method used for this system is using Ziegler-Nichol's tuning method. By reading the open loop response and Ziegler-Nichol's first table we can determine the Kp, Ti, and Td.

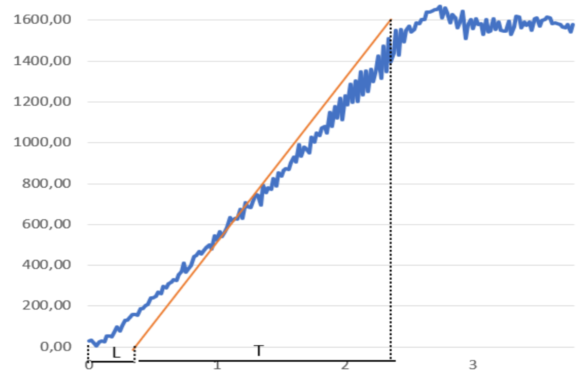


Figure 5. Open Loop System Response

From the data of the system response, the delay time value is 0.4 s and the time constant value is 2.4 s. From these values we can determine the values of Kp, Ti, and Td.

TABLE 1. Ziegler-Nichol's Tuning Parameter

| Controller | Kp | Ki | Kd |
|---|---|---|---|
| PID | 7.2 | 9 | 1.44 |

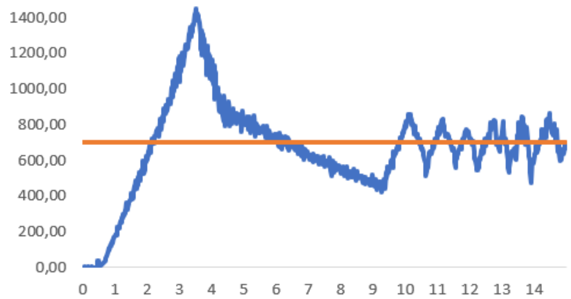


Figure 6. Ziegler-Nichol's System Response

From the results of tunning using the first Ziegler-Nichols method, it was found that the system is unstable, so it needs to be fine tuning, the result of fine tuning is displayed in Table 2.

TABLE 2. Fine Tuning Parameter

| Controller | Kp | Ki | Kd |
|---|---|---|---|
| PID | 0.4 | 0.008 | 9 |

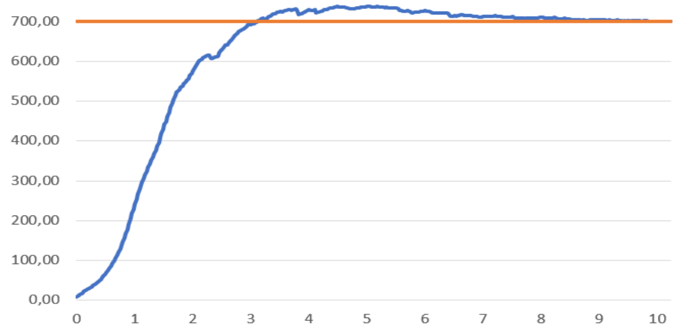


Figure 7. Fine Tuning System Response

## III. Result

The Test is carried out on the open loop and close loop systems. The available loop test describes the electric rail train starting from a speed of 0 rpm to 700 rpm. The tight loop test tells the electric train starting from 0 rpm to 700 rpm and stable speed conditions at 700 rpm. The load used on the prony brake dynamometer is a maximum of 4 kg.

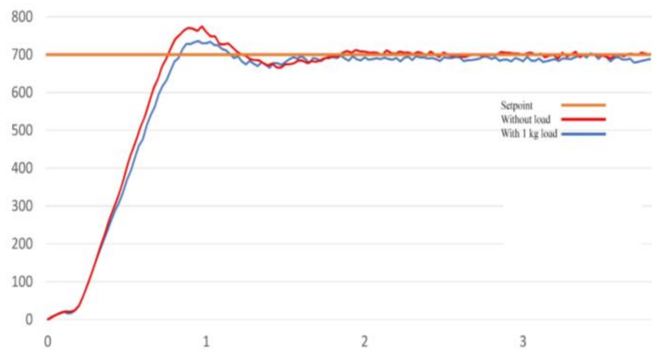


Figure 8. Output response open loop system

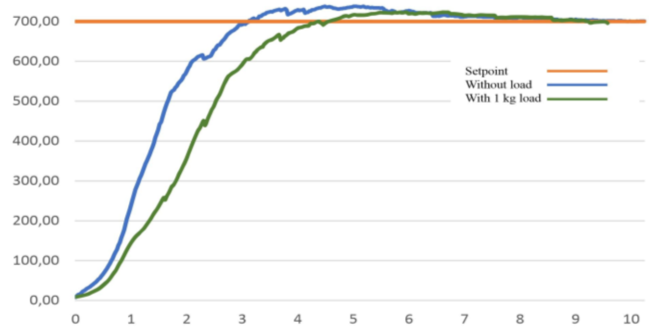


Figure 9. Output response close loop system

TABLE 3. Controller test results

| No | Type | Load (kg) | Overshoot (%) | Rise Time (s) | Settling Time (s) |
|---|---|---|---|---|---|
| 1 | No Controller | 0 | 10 | 0.7 | 1.8 |
| 2 | No Controller | 1 | 5 | 0.7 | 2 |
| 3 | PID Controller | 0 | 5 | 3 | 8.9 |
| 4 | PID Controller | 1 | 3 | 4.3 | 9.5 |

1. Testing when the speed is stable at 700 rpm with a load on the prony brake 1 kg.

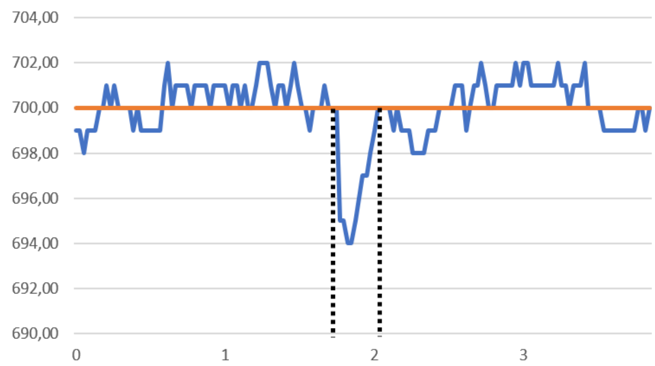


Figure 10. Output response with 1 kg load

2. Testing when the speed is stable at 700 rpm with a load on the prony brake 2 kg

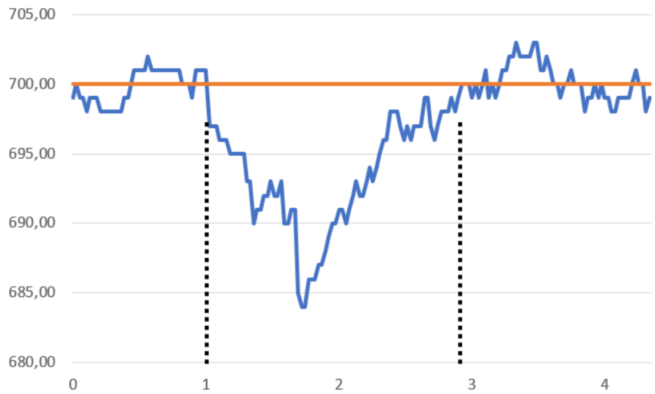


Figure 11. Output response with 2 kg load

3. Testing when the speed is stable at 700 rpm with a load on the prony brake 3 kg.

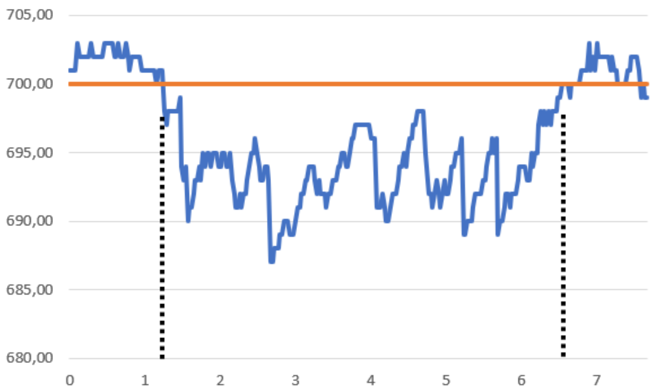


Figure 12. Output response with 3 kg load

4. Testing when the speed is stable at 700 rpm with a load on the prony brake 4 kg.

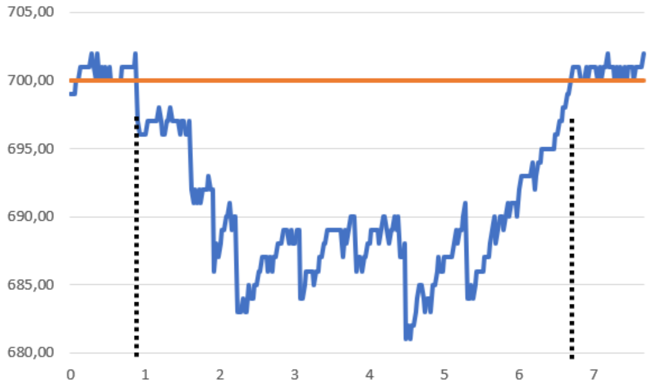


Figure 13. Output response with 1 kg load

## IV. CONCLUSION

Based on the results of the design, testing and analysis carried out on the "3-Phase Induction Motor Speed Control System on Electric Train using Embedded PID ", it can be concluded:

1. The design of a 3-phase induction motor speed control system using a PID controller is carried out after each microcontroller component has been programmed and functions appropriately during testing. The features can be integrated. The integration of components is intended for the PID controller to control the speed of a 3-phase induction motor according to a predetermined setpoint.
2. It is known that the PID controller can maintain speed by testing the PID controller system with a speed setpoint of 700 rpm and load variations. The response of the PID controller system to return to the setpoint, with a pack of 4 kg, is 5.8 s and with a load of 1 kg is 0.3 s.

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