Speed control of DC Motor using four-quadrant Rectifier based on Internet of Things

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ABSTRACT

DC motor is one of the important components in various industrial and automation applications due to its ability to provide precise speed control. This research aims to design and implement a DC motor speed control system using a four-quadrant rectifier based on the Internet of Things (IoT). This system allows the DC motor to operate in four quadrants, namely forward motor, reverse motor, forward regenerative, and reverse regenerative, thus providing flexibility and efficiency in controlling speed and rotation direction. By utilizing IoT technology, motor control can be done wirelessly through web-based applications or mobile devices, enabling real-time remote monitoring and control. The test results show that the system is able to accurately control the speed of a DC motor according to a given reference value, and can adapt to changes in load. The use of this IoT-based four-quadrant rectifier is expected to improve energy efficiency, operational flexibility, and ease of integration in modern automation systems.

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1. INTRODUCTION

As industry develops, drive devices such as electric motors have become crucial for mechanical production processes that produce industrial products [1]. A direct current motor is a machine that converts direct current electrical energy into mechanical energy [2]. Using a DC voltage source, the direction of motor rotation is determined by the forward or reverse current, or positive or negative voltage in a DC motor, while the speed of the DC motor is determined by changes or increases in the coil voltage. DC motors with field coils and DC motors with permanent magnets are two types of DC motors available. Because DC motors have high speed torque compared to other motors, speed control is very important for DC motors, so it is necessary to add on and off switches in their application. However, this is not recommended because it will cause very large starting currents in the motor, which will cause overload. Therefore, it is necessary to use an appropriate control system to handle this [3]-[5]. There are many DC motors, one of which is the 4-quadrant DC motor [6]-[8]. In this study, a PLC will be used as the controller type [9]-[11].

A microprocessor-based PLC is specifically designed to use programmable memory [12]. PLC is usually used to monitor and control a large number of sensors and actuators, and therefore differs from other computer systems in its extensive input/output (I/O) settings [13] to monitor the dc motor, HMI is used as its monitoring [14] And also in this study the internet of things is used for remote control and also connects the Siemens S7-1200 PLC to the internet via Node-RED. Node-RED is a browser-based tool for creating Internet of things (IoT) applications where the visual programming environment makes it easy for users to create applications as flows. To connect node-red and PLC S7-1200 to an external network, additional software is required, one of which is Ngrok. Comments function as a bridge between the local host node RED to a wider network [15].

2. METHOD

DC motor speed control using IoT-based four-quadrant phase controller has been carried out through a series of experiments in the laboratory. The experimental process begins with the design stage, hardware assembly, PLC programming, HMI program creation, and IoT program development, followed by testing and analysis. The DC motor speed control system proposed in this study can be seen in the block diagram shown in Figure 1 below. This control system consists of a DC motor amplifier as a controlled object, a 4-phase rectifier operated by the quadrant as a DC motor speed controller, a Siemens S7 1200 1215C DC/DC/Relay PLC as a control center, a TP700 Comfort HMI as a controller display interface, a current-to-voltage signal converter that functions to convert the control signal from the PLC analog output in the form of a 0-20 mA current signal into a 0-10 Volt voltage signal to control the rectifier, and a PC used for programming the PLC, HMI, and IoT. The PLC and HMI are operated using TIA Portal software, with a 24 Volt DC power supply for the PLC and HMI, and a 220 Volt phase 1 AC supply for the controlled rectifier.

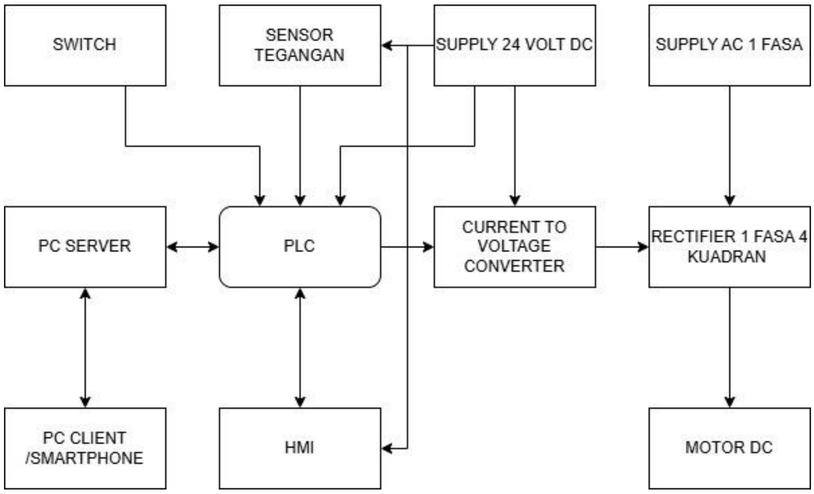

Figure 1. Block diagram of proposed DC motor control using rectifier.

Figure 1 shows that the PLC acts as a control center that regulates the DC motor based on a reference speed through an analog output terminal. This control signal will be used as a reference in setting the firing angle of the SCR in the controlled rectifier. The reference speed value entered into the HMI in rpm units will be converted into a 0-20 mA current signal, which corresponds to the analog output signal from the PLC. The current signal is then converted into a 0-10 Volt DC voltage value using a converter that matches the external input signal specifications on the four-quadrant phase controller found in the training system. Figure 2 shows the hardware circuit for a DC motor speed control system using an IoT-based four-quadrant phase controller.

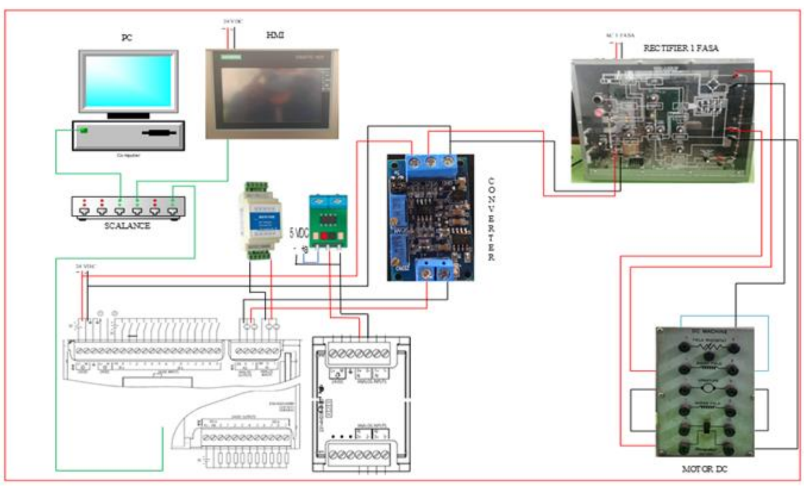

Figure 2. Circuit schematic of IoT-based 4-quadrant rectifier DC motor speed control

After the hardware assembly stage is complete, the next process is software development. This stage includes writing program code, testing to find and fix errors, and integrating the program with the hardware so that the system works as a whole. Software design in the form of a flowchart is defined as a diagram with graphic symbols that shows the flow of a process that displays several symbolized steps or as a graphical depiction of the steps or sequence of a program procedure that performs a certain function as shown in Figure 3 below.

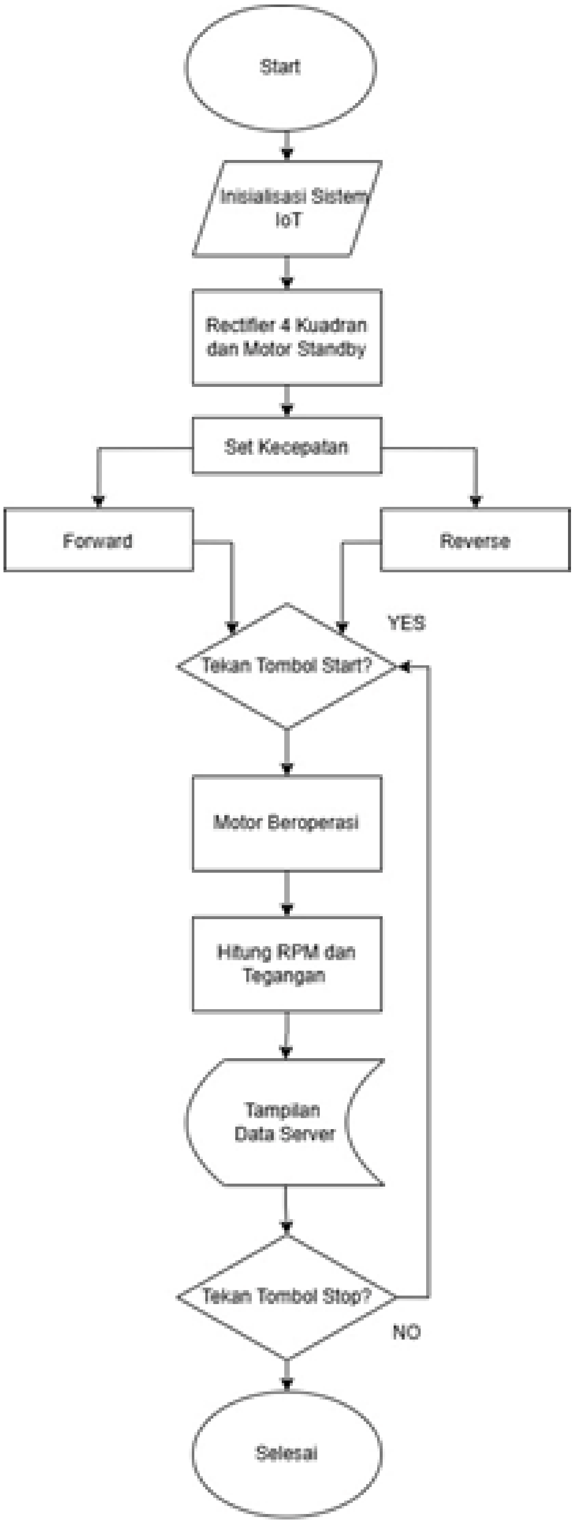

Figure 3. Flowchart of DC motor control system with controlled rectifier

3. RESULTS AND DISCUSSION

The DC motor speed control system using an IoT-based four-quadrant phase controller proposed in this study has been tested at various speeds to evaluate the accuracy of the reference speed entered into the IoT compared to the actual motor speed. The first test was conducted by inputting a motor speed into the IoT of 300 rpm. In this first test, the motor operated at a speed of 290 rpm with a voltage of 44 Volts and a current of 0.086 Ampere. The results of this test indicate that the input motor speed is close to the actual motor speed measured on the tachometer with an error of 10 rpm. Figure 4 shows a comparison of the device test at a speed of 300 rpm.

Figure 4. First test results

The second test was then conducted by inputting a motor speed of 500 rpm on the IoT. In this first test, the motor operated at 508 rpm with a voltage of 76 volts and a current of 0.097 amperes. The results of this test indicate that the input motor speed was close to the actual motor speed measured on the tachometer with an error of 8 rpm. Figure 5 shows a comparison of the device test at 500 rpm.

Figure 5. Second test results

The third test was then conducted by inputting a motor speed of 700 rpm on the IoT. In this first test, the motor operated at 725 rpm with a voltage of 107 volts and a current of 0.106 amperes. The results of this test indicate that the input motor speed was close to the actual motor speed measured on the tachometer with an error of 25 rpm. Figure 6 shows a comparison of the device test at 700 rpm.

Figure 6. Results of the third test

Based on the results of motor speed testing using the IoT system and a tachometer as a comparison, differences in actual speed values were obtained, indicating a discrepancy between the value read by the IoT sensor and the reference value from the tachometer. The results of the speed testing at several rotational speed points (RPM) are described in Table 1. The table above shows that the speed tolerance ranges from 1.60% to 3.57%, which is still considered acceptable for simple IoT monitoring applications. However, improving accuracy is still recommended, especially at high speeds.

Table 1. Experimental results

Speed IoT (rpm)	Speed Measurement (rpm)	Error (%)	Current (A)	Voltage (V)
300	290	3.33%	0.086	44
500	508	1.60%	0.097	76
700	725	3.57%	0.106	107

4. CONCLUSION

Based on the test results that have been carried out, the DC motor system with a 4-quadrant rectifier based on IoT shows excellent performance in controlling the speed and direction of the motor, with results close to expectations. During the test, the motor successfully operated in four quadrants with smooth rotational direction changes and responsive and good speed regulation. The test results also show that the system can be operated stably and has good control over voltage and current regulation. Although the test results are only approximate, some areas can still be improved, such as increasing the accuracy of speed regulation at very high loads and optimizing the IoT algorithm for faster data processing.

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