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IoT-based motor speed monitoring using infrared sensor

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ABSTRACT

This paper presents the design and development of an Internet of Things (IoT)-based system for monitoring the speed of DC motors. Utilizing an ESP32 microcontroller integrated with infrared sensors, the system accurately measures motor speed by detecting pulses from a five-pointed star wheel attached to the motor shaft. The Arduino framework and Blynk platform are employed for real-time data visualization and remote monitoring. The system supports multiple motors, transmitting speed data to a cloud server via WiFi, allowing users to monitor performance remotely. Debouncing techniques and a moving average filter enhance data accuracy, while a correction factor refines RPM calculations. Threshold alerts notify users of excessive speeds, enabling proactive maintenance. This scalable solution is ideal for industrial applications requiring real-time monitoring and data-driven insights.

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1. INTRODUCTION

In marine systems, electric motors play a very important role in ensuring efficient and reliable operations. One of the critical aspects of electric motor performance in marine applications is motor speed, which directly affects the effectiveness of ship propulsion and other equipment that relies on the motor [1]-[3]. Various problems often arise related to controlling and monitoring the speed of electric motors in marine environments. Factors such as intense vibration, drastic temperature changes, and high humidity levels can affect the measurement accuracy and stability of electric motor operation [4]-[6].

Conventional methods for controlling speed that are still widely used in the marine industry are often not responsive enough to changes in operational conditions. As a result, this can lead to decreased operational efficiency, increased energy consumption, and even damage to the motor if not detected immediately [7]-[12]. Most equipment in the industry uses electric motors as its driving power source. Various types of electric motors are used for driving power, such as DC motors, induction motors, servo motors, and others [13]-[16]. In certain circumstances, problems are found where direct observation or measurement becomes difficult, especially in extreme environments or remote locations. To overcome this obstacle, the use of remote measurement methods is an effective solution to enable data collection without having to be at the physical location concerned. Visiting the location where the electric motor is operating to see the electric motor directly [17]-[20].

In an industry that has been connected to the internet network, these facilities are not only used as a means of communication between computers, but can also function as a communication channel between microcontrollers. The use of this internet network brings a number of advantages, including network cost efficiency because access can be done from various locations that have an internet network [21]-[25]. Conventional induction motor monitoring systems often make it difficult to obtain accurate and real-time data [26]-[30]. To facilitate data transfer without the need for direct transactions between humans, we need to use the Internet of Things, this technology allows data transfer without requiring direct interaction between humans or between humans and devices connected to the internet, opening up new opportunities in expanding connectivity and efficiency in everyday life [31]. Based on previous studies, so far monitoring of electric motors in industry has only been limited to monitoring the speed of motor rotation which is carried out using various control methods [32]-[36]. However, there is still no tool or module for monitoring electric motor speed in the industry that is specifically intended to monitor the speed of electronic equipment specifically. This is what prompted the author to create this IoT-based motor speed monitoring system.

2. METHOD

Design is an important aspect that must be done in determining the components that will be used in making the final assignment. This aims to ensure that the tool made can function as desired. The design and manufacture of the final assignment was carried out using the experimental research method. This study uses an experimental method to test the effectiveness of the proposed control and monitoring system, which includes the design and manufacture of hardware and software. The materials used include hardware such as the NodeMCU ESP32 microcontroller, Infrared Sensor and DC motor, as well as software developed using Arduino IDE and Blynk.

The process of making the tool begins with the manufacture of hardware, which involves placing all components in a safe place and in accordance with the design that has been made. After the hardware is complete, the next part is to program the sensors and other components using Arduino IDE stands for Integrated Development Environment, to ensure that the tool can operate as designed. The following block diagram shows all the components used in this final assignment. This diagram shows how each component relates to each other and how they function in the designed system. Figure 1 shows the block diagram of the proposed motor speed monitoring system.

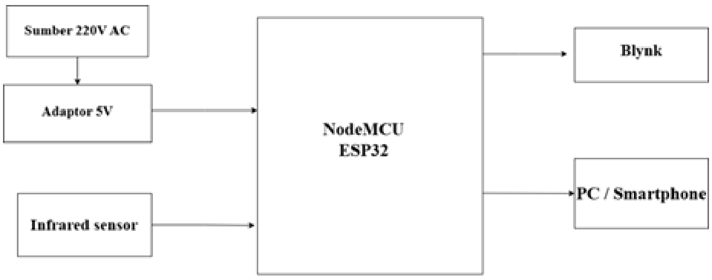

Figure 1. Block diagram of the proposed motor speed monitoring system

The block diagram in Figure 1 consists of: 1) The voltage source of this tool comes from 220V AC electricity, 2) The 5V adapter functions as a converter of 220V AC voltage to 5V DC voltage which will be the voltage source for ESP32 and Infrared Sensor, 3) NodeMCU is an open-source IoT platform, consisting of System on Chip ESP8266 and ESP32 hardware made by Espressif System, and firmware that uses the C++ programming language [10]. With a built-in WiFi module, this microcontroller is ideal for Internet of Things (IoT) applications. NodeMCU ESP32 will be the main brain of this tool, NodeMCU ESP32 will be connected to all connected units such as Infrared Sensor, PC, and Smartphone. 4) The infrared sensor is an electronic component that has the ability to detect electromagnetic radiation in the infrared spectrum. The Infrared Sensor as a detector/reader of measured motor speed parameters. 5) Blynk is a platform compatible with iOS and Android devices, designed to control various types of modules such as Arduino, Raspberry Pi, Wemos, and other similar modules, via an internet connection.

The working principle of this tool is to monitor motor speed in real time which can be monitored with IoT via the Blynk application. An infrared sensor is used to detect motor rotation. This sensor usually consists of an infrared LED and a photodiode. When the motor rotates, every time a slot or reflective mark passes the IR sensor, the signal will be interrupted or received by the photodiode. This signal change is counted as one motor rotation. The signal from the IR sensor is received by the ESP32 via one of the GPIO pins. The ESP32 counts the number of signals received in a certain period of time (for example, per second), then converts it into RPM (Number of Rotations per Minute). Furthermore, the ESP32 sends the RPM data to the Blynk server via a Wifi connection. The results of the motor speed monitoring will be displayed on the blynk application on the smartphone in real-time. With this working principle, the IoT-based motor speed monitoring tool can provide motor speed information in real-time via the Blynk application, allowing users to monitor and analyze motor performance remotely. Figure 2 shows the flowchart of the tool that was designed.

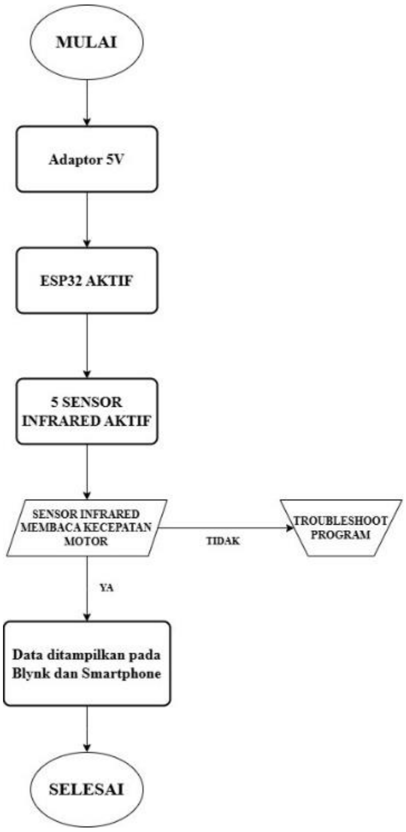

Figure 2. Flowchart of motor speed monitoring system

Figure 2 shows an IoT-based motor speed monitoring system that can display data in real time when the device is working. Users can start by ensuring that the power supply is active, when the power supply is active, the voltage entering the NodeMCU ESP32 microcontroller will be lowered first using a buck converter. When the ESP32 is active, the infrared sensor will be active and measure the motor rotation speed, the results of this infrared sensor measurement will be displayed on the LCD and the Blynk application on the smartphone or PC User.

Hardware design is an important step that must be done before starting the actual tool manufacturing process. By doing this design, we can estimate the components needed. In working on this final project, hardware design is very crucial, because hardware allows us to test whether the system is functioning properly or not. The design results of the Internet of Things-based motor speed monitoring system can be seen in Figure 3.

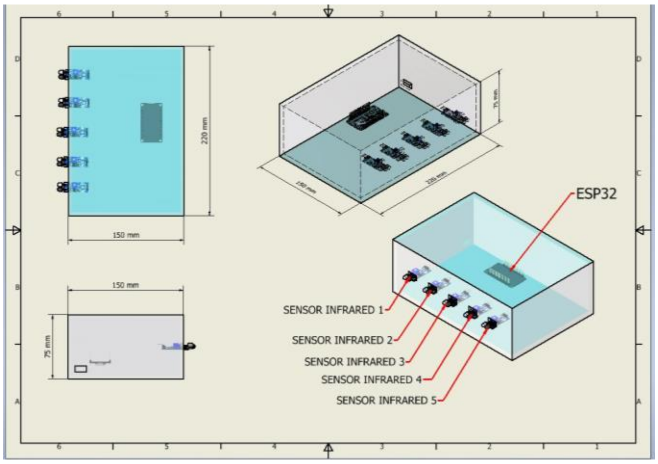

Figure 3. Design of motor speed monitoring tool

Figure 4 shows the circuit diagram of the motor speed monitoring system components, consisting of a Power Supply as an AC to DC voltage converter, a Buck Converter as a voltage reducer from the power supply, NodeMCU ESP32 as a microcontroller, an Infrared Sensor as a motor speed counter and an I2C LCD as an interface to display motor speed. NodeMCU ESP32 as a microcontroller will be the core for transferring input provided by the infrared sensor, and requires software or a series of programming to process data and run the tool so that this monitoring system runs properly..

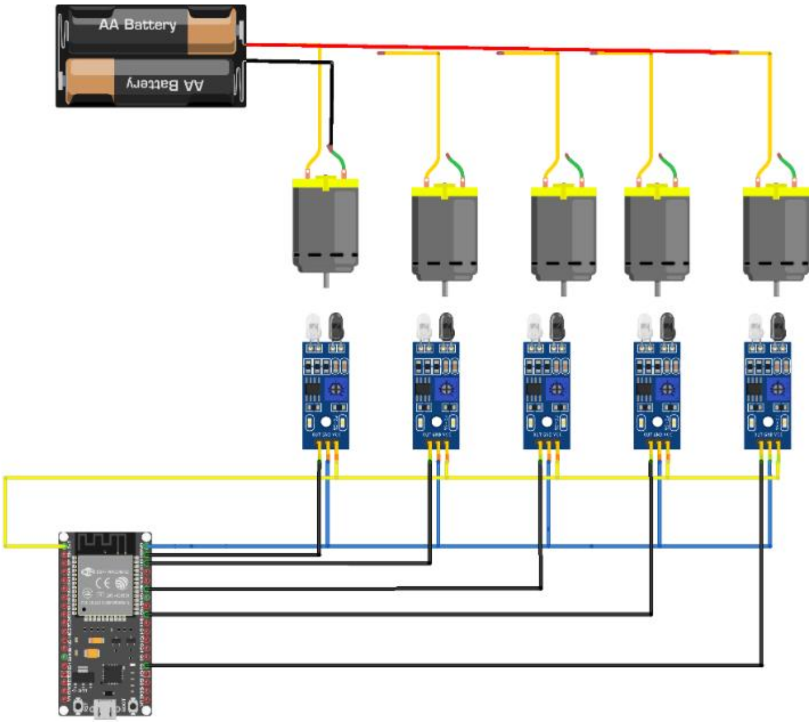

Figure 4. Schematic of the motor speed monitoring system component circuit.

In this monitoring system using NodeMCU ESP32, PC (Personal Computer), Blynk application, and smartphone as an interface for monitoring that will be programmed using Arduino IDE Blynk is a platform that can be used with iOS and Android devices, designed to control various modules such as Arduino, Raspberry Pi, Wemos, and other similar modules via internet connection. The monitoring display can be shown in Figure 5.

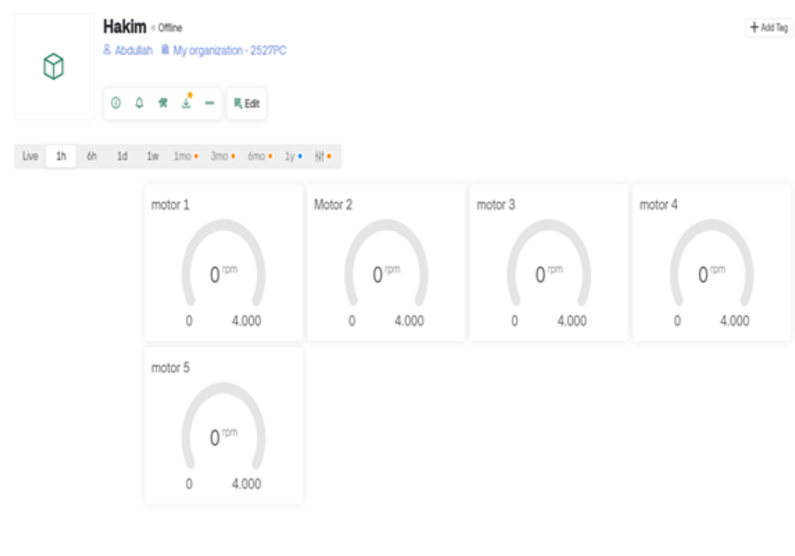

Figure 5. Monitoring view on Blynk

3. RESULTS AND DISCUSSION

The system testing was conducted through several stages, such as testing the connection and functionality of the hardware and testing the notification at a certain RPM limit. The test results showed that each component functioned well. The system can monitor motor speed in real-time, and provide automatic notification when the RPM exceeds the 156 RPM limit. The accuracy of RPM readings via infrared sensors has an error of less than 2%, indicating that this system is accurate and reliable for remote monitoring of motor speed. Figure 6 shows the results of the proposed hardware assembly..

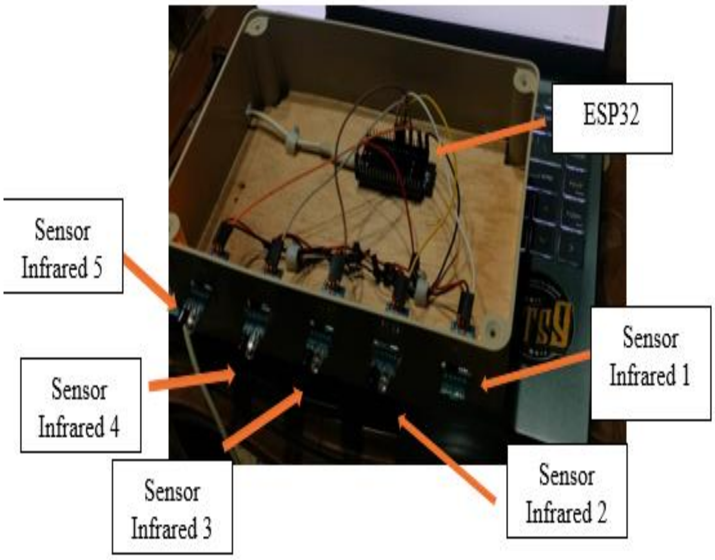

Figure 6. Overall tool set

Table 1 shows the test results. Based on the results of the RPM reading comparison test between the infrared sensor and the tachometer above, it can be seen that there is a relatively small difference in reading between the two measuring instruments. Infrared Sensor 3 shows the highest level of accuracy with an error of only 0.16% and a reading difference of 0.3 rpm, followed by Infrared Sensor 2 with an error of 0.26% and Infrared Sensor 1 with an error of 0.56%. Meanwhile, Infrared Sensors 4 and 5 show slightly higher errors, namely 1.02% and 1.84%. Overall, the percentage of errors from the five sensors is below 2%, indicating a very good level of accuracy. The smallest reading difference occurs in Infrared Sensor 1 with a difference of 0.1 RPM, while the largest difference occurs in Infrared Sensor 5 with a difference of 3.2 rpm. These results prove that the designed infrared sensor system has a high level of precision and accuracy in measuring DC motor speed, so it can be relied on for rpm monitoring applications.

Table 1. Results of motor speed measurement tests

No	Sensor	Infrared sensor (rpm)	tachometer (rpm)	Error (rpm)	Error (%)
1	Infrared 1	163	162,1	0, 1	0.56
2	Infrared 2	153	152,6	0,4	0.26
3	Infrared 3	187	187,3	0,3	0.16
4	Infrared 4	156	157,6	1,6	1.02
5	Infrared 5	177	173,8	3, 2	1.84

This motor speed monitoring tool is also equipped with an alarm. In testing, the alarm will be active if the speed is above 156 rpm. Table 2 shows the results of the alarm notification test when the speed is above 156 rpm. Based on Table 2, the system successfully sends a warning when the motor RPM exceeds the limit of 156 RPM, with a detected speed range of 153-182 RPM. The system provides a fast response with a time of 0.5 seconds to send a notification to the Blynk application, and each motor has its own notification event for easy identification. All sensors function very well in sending warnings, with consistent response times. The system also managed to distinguish normal and abnormal conditions correctly, where no notifications were sent when the RPM was within normal limits. This proves that the designed monitoring system can be relied on to monitor and provide early warnings of motor speed conditions that exceed safe limits.

Table 2. Notification test results with an upper limit value of 156 rpm

No	Sensor	Rpm	Notification status	Time (sec)	Information
1	Infrared 1	160	Appear	0,5	High_rpm_motor1
2	Infrared 2	153	Appear	0,5	High_rpm_motor2
3	Infrared 3	182	Appear	0,5	High_rpm_motor3
4	Infrared 4	168	Appear	0,5	High_rpm_motor4
5	Infrared 5	153	Appear	0,5	High_rpm_motor5

4. CONCLUSION

Based on the results of the tests and analysis conducted, this Internet of Things (IoT) based motor speed monitoring system shows reliable performance in real-time motor speed monitoring with a high level of accuracy (error below 2%). The use of an ESP32 microcontroller integrated with an infrared sensor and the Blynk platform allows efficient remote monitoring and provides notification when the motor speed exceeds the 156 RPM limit. This system is suitable for industrial applications where users can monitor motor conditions from a remote location, so that potential damage can be minimized and motor monitoring becomes more efficient. This monitoring system is expected to be an effective solution and can be further developed with the addition of features such as historical data storage and integration with a data-based maintenance system to improve motor performance and durability in the future..

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