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Monitoring and speed control of AC motor using PWM technique

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ABSTRACT

This study focuses on how to monitor and regulate the speed of an AC motor using pulse width modulation (PWM) technology. PWM signals regulate motor voltage and enable continuous monitoring of voltage, current, and speed in addition to speed control. Comparing this technology to conventional techniques yields considerable advantages like enhanced power and speed control. PWM-based speed control can be implemented using circuits specifically designed for motor control or microcontrollers. It has been confirmed that PWM-based control can regulate the target motor under a variety of operating conditions and that it is reliable and efficient. To boost production and efficiency, this change management technique can be applied in a variety of industries, including robots, HVAC systems, and industrial automation. The study results show the significance of PWM technology for monitoring and controlling the speed of AC motors, providing productive and affordable solutions to a range of enterprises and sectors.

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1. INTRODUCTION

Currently, asynchronous motors are the most common drive type used in many places. The great scientist Nikola Tesla invented the induction machine. Approximately 50% of the world's electricity consumption comes from asynchronous motors. 90% of induction motors in the industry must be free of permanent magnets, brushes, commutator rings, and position sensors due to important features such as "self-starting "motors. Induction motors also have the advantages of simple operation, power and stability, good power control, low maintenance, efficiency, small, reliability, and cheaper than other types of motors. The main advantage of the asynchronous motor is that its speed is easy to control due to its high-speed control, high efficiency, and high starting torque. Due to all these advantages, asynchronous motors are widely used in industry, electric trains, cars, cranes, elevators, household appliances, and agricultural motors. It is frequently used in many applications [1]. The most common types of faults in a synchronous motors are divided into three main types:

- Electrical faults: Electrical faults are usually single-phase faults, return as faults, overvoltage, and overload. Occur in the form.sin and landsin.
- Mechanical failure: The most common mechanical failure includes broken rotor bars, stator and rotor winding defects, and bearing failure.
- Environmental errors: Environmental errors usually occur when the motor vibrates. Humidity and temperature. The environment of the induction motor, such as affects the operation of the induction motor [2].

In this article, the internet of things (IoT)-based asynchronous motor monitoring parameters such as voltage, current, speed, and temperature are introduced based on sensors and cloud. Since the speed of the asynchronous motor can be adjusted, the speed of the asynchronous motor is controlled with the help of pulse width modulation (PWM) technology. It can be easily controlled by controlling the input frequency power [3]. Regular monitoring of parameters ensures continuity of production and increases the reliability of engines in production. It can also prevent abnormalities in the asynchronous motor and detect the fault in the asynchronous motor early. If a mal function occurs in the motor, the sensor's values such as voltage, current, speed, and temperature should be measured and the measurement value of the sensor that will send a signal to Arduino Uno should be determined. and then set the command to respond from the cloud to the engine. After the crime is eliminated, a warning will be sent to the mobile phone for future work and it should not be repeated [4], [5].

The specific research objectives of the article are as follows:
- For security and commercial information communication in business or other fields, monitoring and control of a synchronous motors rely on the internet of things (IoT). Thanks to early diagnosis, there relevant process and damage to the engine can be reduced.
- Protect the motor from overload, overcurrent, and temperature.
- Avoid down time by starting and stopping the motor, start as synchronous motors with automatic control or manual control.
- A widely used motor method can be analyzed into current, voltage, speed, and temperature waveforms [6].

2. PWM–BASED METHODOLOGY FOR INDUCTION MOTOR MONITORING

2.1. Block diagram of induction motor monitoring system

The block diagram in Figure 1 shows monitoring parameters and the proposed speed-controlling system of an induction motor [7]. This block diagram shows four sensors to detect four parameters: voltage, current, speed, and temperature [8]. Monitor the abnormal condition of the motor with the help of sensors and send the current status of the asynchronous motor to Arduino Uno via Wi-Fi [9]. With the help of mobile, we will get information in the mobile application [10]. If a fault occurs in the asynchronous motor, it must be disconnected from the power supply. Whatever is being watched must be displayed individually on the LCD [11].

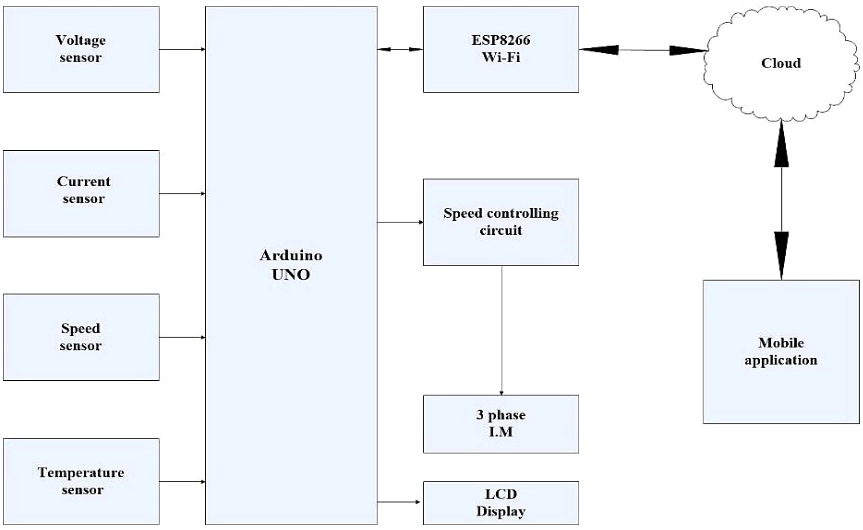

Figure 1. Block diagram of induction motor monitoring system

3. PROPOSED SYSTEM

The block diagram below is in Figure 2 represents detailed information about the planning process. It provides complete information about the planning process. This diagram shows how the current operation occurs, the actual signals flow from one to another, and what the major components are in the system [12].

3.1. Working

Figure 3 shows the circuit diagram and Figure 4 shows the hardware model for monitoring speed control of induction motors using the PWM technique. The block diagram depicts an IoT-based system designed to monitor and control the speed of an induction motor [13]. Sensors constantly monitor the voltage and current of the motor (if there are speed sensors and temperature sensors, their data will also be monitored) [14]. Sensor data is sent to the microcontroller unit (MCU). The MCU sends sensor data to ThingSpeak and connects to the cloud platform via the Wi-Fi module. Data is stored in ThingSpeak channels and can be viewed in the dashboard or accessed via the mobile app [15].

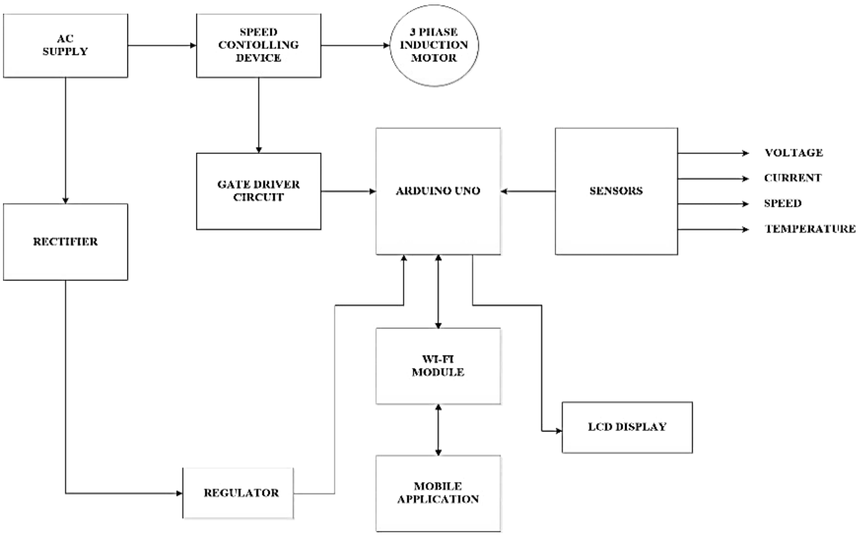

Figure 2. Overall block diagram of the proposed system

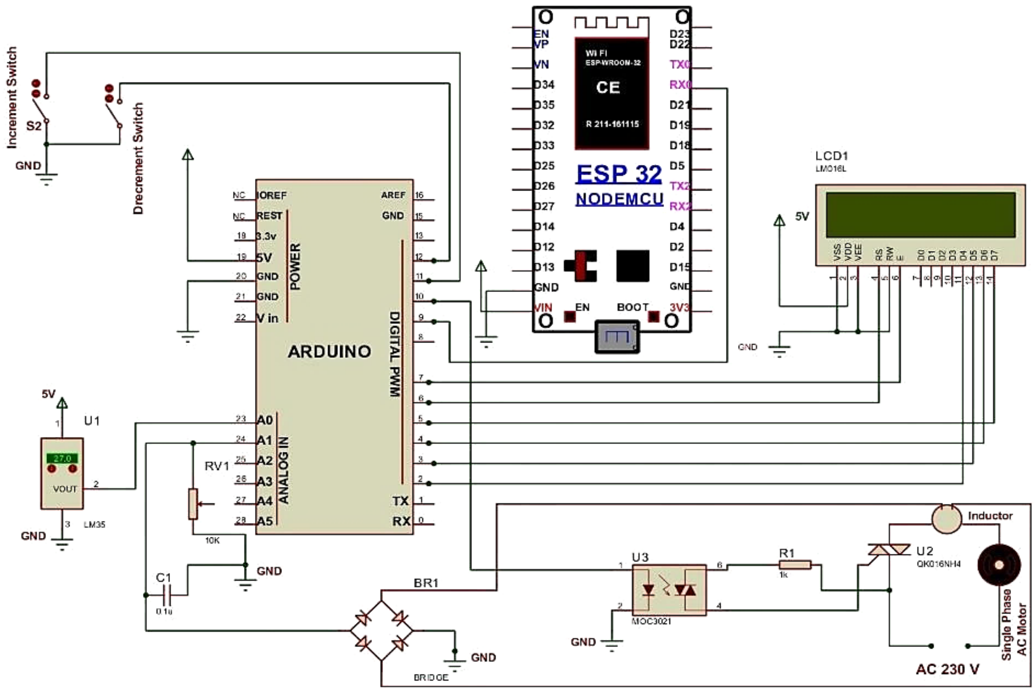

Figure 3. Circuit diagram of induction motor monitoring system

Figure 4. Hardware model of induction motor monitoring system

MCU uses a motor driver circuit to control the speed of the motor according to the loaded program or the command received from the mobile application. The MCU can also use sensor data (if available) to implement safety features, such as shutting down the system if it overheats or overloads [16]. Pulse width modulation (PWM) is a technology that controls the power sent to the device by turning the device on and off. By varying the duty cycle of the PWM signal (duration versus total cycle time) the average power delivered to the motor can be controlled. This provides speed control of the motor. Other advantages of PWM include reducing heat in the motor driver and increasing motor speed [17].

The operation of the system depends on many components and the Hardware model of the induction motor monitoring system as shown in Figure 4. Sensors, including current and voltage sensors, constantly monitor the performance of the motor [18]. The microcontroller (MCU) (usually an Arduino Uno in this case) acts as the brain, processing sensor data and controlling the motor driver circuit according to a program loaded into it [19]. The Wi-Fi module allows the MCU to connect to the network and send data to the ThingSpeak cloud platform for storage, visualization, and notification capabilities [20]-[22]. Data can also be accessed via a mobile app (not shown). The motor driver circuit controls the power sent to the motor and ultimately its speed [23]. LCD screen (optional) provides instant information about the motor such as speed, voltage, and current [24], [25].

4. RESULTS AND DISCUSSION

The experimental results highlight the exceptional performance of the pulse width modulation (PWM) technique in monitoring and controlling alternating current (AC) motors. Through precise manipulation of the width and frequency of voltage pulses, the PWM control system achieves remarkable accuracy in regulating motor speed within specified set points. The dynamic response of the PWM-controlled motors proves to be highly responsive, with minimal transient response time observed during speed adjustments. Moreover, the stable operation of PWM-controlled motors is notable, show casing reduced levels of noise and vibration compared to conventional control methods. This contributes to a quieter and smoother motor operation environment.

The result of speed control in rpm, motor live current, and voltage and temperature of the motor are displayed on LCD and in the ThingSpeak application, through the online mode. Figure 5 depicts the LCD, which also indicates that the above parameters are uploaded to the IoT server by displaying the symbols of the parameters like ‘S’, ‘T’, ‘C’, and ‘V’. The IoT dashboard is presented in Table 1, show casing induction motor parameters. The separate meters include voltage, current, date and time estimation, temperature, and speed. Table 2, represents the induction motor parameters of an LCD display. The separate meters include voltage, current, date and time estimation, temperature, and speed.

Figure 5. Sample LCD reading at a particular interval of time

Table 1. The IoT dashboard displays induction motor parameters

S.no	Temperature	Voltage	Current	Speed	Date
21	27	230	126	2	2024-02-02 12:44:54
22	28	230	98	1	2024-02-02 12:44:32
23	27	230	96	1	2024-02-02 12:44:21
24	25	230	99	1	2024-02-02 12:44:10
25	26	230	109	1	2024-02-02 12:44:00
26	26	0	0	0	2024-02-02 12:43:04
27	27	0	0	0	2024-02-01 12:35:33
28	30	230	123	2	2024-02-01 12:18:23
29	29	230	135	4	2024-02-01 12:18:09
30	27	230	121	3	2024-02-01 12:17:39

Table 2. Monitoring parameters of induction motors in LCD display

S.no	Temperature	Input voltage (v)	Output voltage (v)	Current (mA)	Speed (RPM)
1	33	0	12	0	0
2	34	230	130	109	1360
3	35	230	170	126	1821
4	37	230	200	130	2043
5	39	230	220	135	2332

4.1. The results area LSO obtained in graphical charts in the ThingSpeak mobile application

Figure 6 depicts the voltage graph, which typically illustrates the relationship between the duty cycle of the PWM signal and the voltage applied to the motor. Horizontal axis (time): represents time in the PWM cycle. Vertical axis (voltage): represents the voltage supplied to the motor. This is a straight line at a certain voltage level. It represents the desired voltage level required to maintain a constant speed for the motor under specific operating conditions. The constant voltage line represents the desired voltage level for maintaining a constant speed. To control the motor speed, the PWM duty cycle is adjusted such that the average voltage matches this desired voltage level. The constant voltage graph illustrates how the PWM duty cycle is adjusted to maintain a constant voltage level, thus controlling the speed of the induction motor.

Figure 7 depicts the current graph typically illustrates the relationship between the duty cycle of the PWM signal and the current drawn by the motor. Consequently, the motor draws a higher current as it accelerates from its starting speed to the desired operating speed. The current drawn by the motor increases proportionally with the duty cycle, indicating the motor's effort to overcome the increasing load and maintain the desired speed. The current graph illustrates how the duty cycle of the PWM signal affects the current drawn by the induction motor, providing valuable insights into the motor's speed control and performance characteristics.

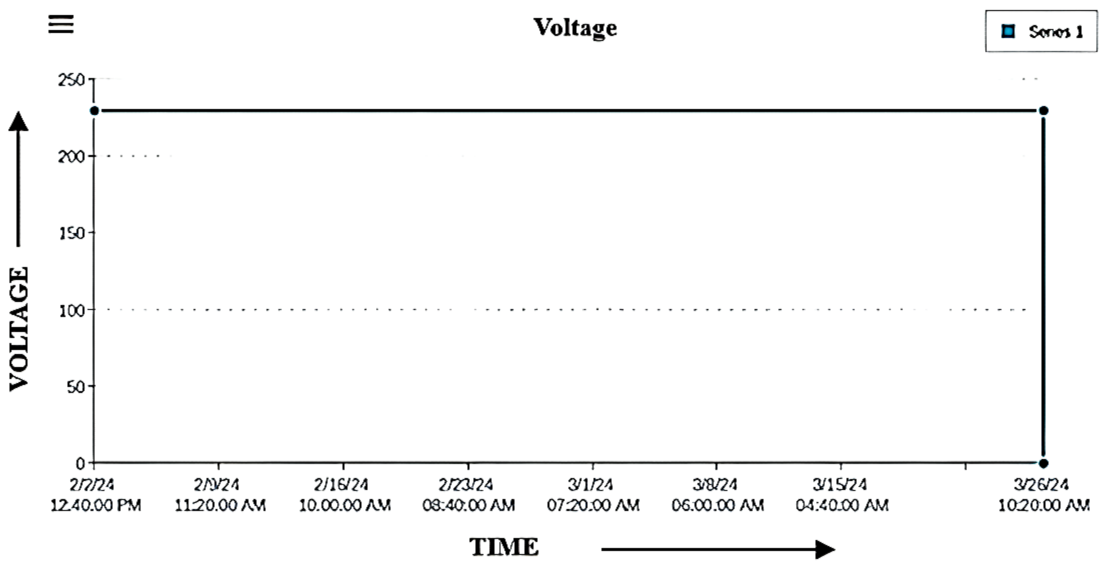

Figure 6. Monitoring parameter of per phase voltage waveform

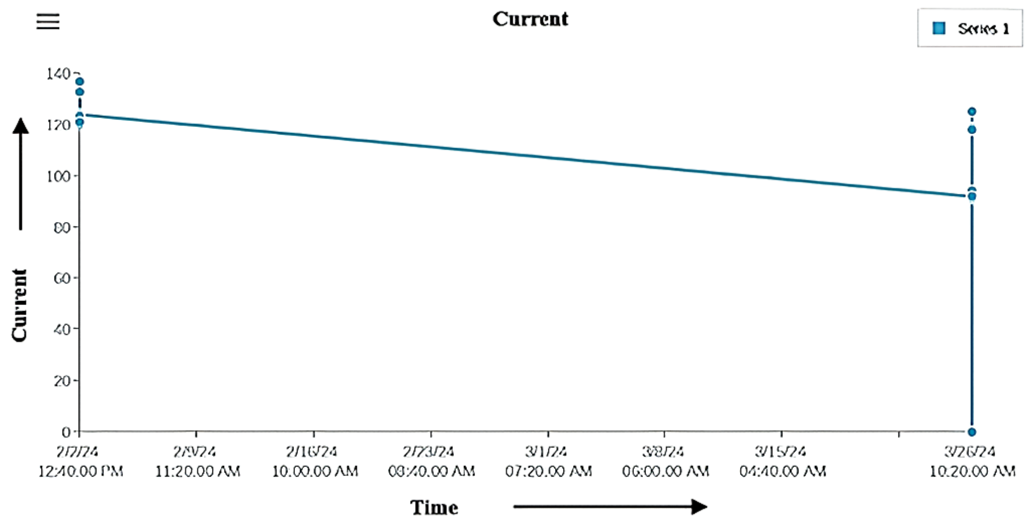

Figure 7. Monitoring parameter of per phase current waveform

Figure 8 depicts the adjusting of the width of pulses in a periodic waveform to regulate the motor's speed. In a speed graph, the x-axis typically represents time, while the y-axis represents motor speed. At lower frequencies of the PWM signal, the pulses are wider, providing more power to the motor, hence increasing its speed. As the frequency increases, the pulses become narrower, reducing the effective power delivered to the motor and thus decreasing its speed. The graph may show different segments corresponding to different PWM frequencies or duty cycles. For example, a higher duty cycle or frequency would lead to a higher speed, while a lower duty cycle or frequency would result in a lower speed. Overall, the speed graph demonstrates the relationship between the PWM signal characteristics and the resulting speed variations in the induction motor.

Figure 9 depicts regulating the motor's speed by adjusting the width of the pulses of the input voltage. The temperature graph in this context would show how the motor's temperature changes over time during operation. Initially, when the motor starts, the temperature might be relatively low. As the motor operates and PWM is applied to control its speed, the temperature starts to rise due to the increase in power dissipation and losses in the motor. The graph might depict a steady increase in temperature as the motor operates at higher speeds or experiences heavier loads. At some point, the temperature might reach a critical level where further operation could lead to overheating and potential damage to the motor. To prevent this, the PWM controller can adjust the speed of the motor or reduce the input voltage to maintain the temperature within safe limits. This dynamic control loop ensures efficient operation while protecting the motor from overheating.

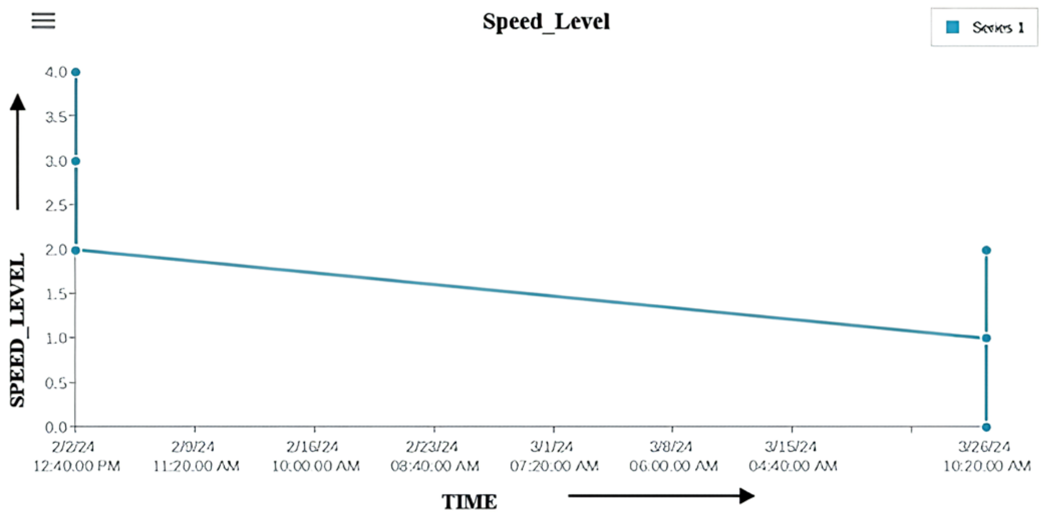

Figure 8. Monitoring of speed parameter

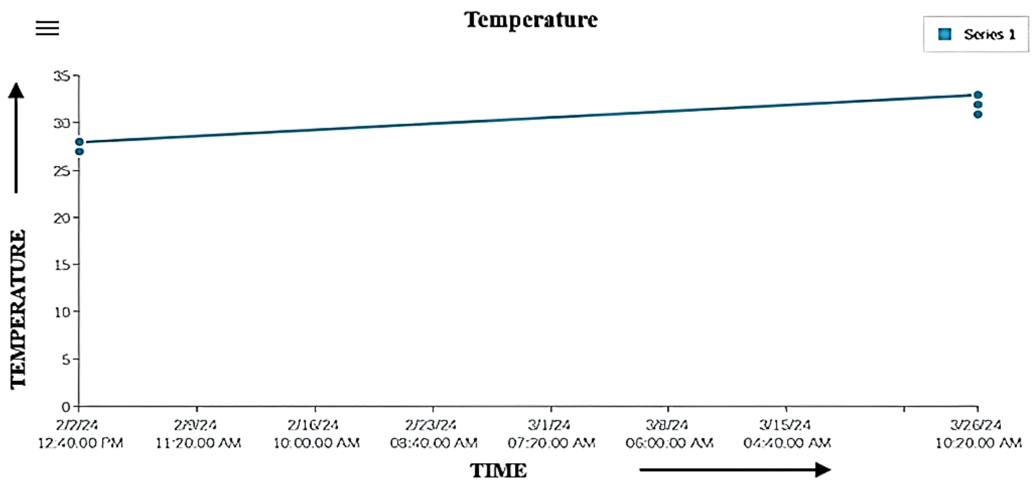

Figure 9. Monitoring of temperature parameter

5. CONCLUSION

In conclusion, the integration of Wi-Fi modules and the ThingSpeak app into the monitoring and speed control system of induction motors using the PWM technique represents a remarkable leap forward in motor control technology. By leveraging wireless connectivity and cloud-based data management, this project achieves unprecedented levels of accessibility, flexibility, and efficiency. Real-time monitoring and control capabilities empower users with remote management options, enhancing operational convenience and safety. The synergy between PWM control, Wi-Fi connectivity, and cloud-based data analytics underscores the potential for transformative advancements in industrial automation. This project lays a solid foundation for future innovations, promising enhanced productivity and sustainability in motor control systems.

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