IoT Enabled Speed Control of Single-Phase Induction Motor

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Abstract— The Internet of Things (IoT) is taking great hold in today's technology since it facilitates comfortable and remote monitoring of machines using sensors. On the other hand, Single Phase Induction motors are most widely used in industry as well as home applications. Monitoring and controlling it is a very crucial task. This project is about monitoring several parameters such as the current, voltage, temperature, and speed of an induction motor, and controlling its speed by IOT. The faults are sensed using sensors and are stored in the cloud thereby enabling one to monitor the machine with reduced manual intervention. If the engine hasa faulty state (current), the user will be notified of this issue via the mobile application.

Keywords—Internet of Things (IoT), Blynk app, ESP32, IR Sensor, Induction motor.

1 INTRODUCTION

The invention of induction motors has made our lives much more convenient. Induction motors have several advantages over DC and synchronous motors: speed variation, high starting torque, ease of operation, and low-cost maintenance. Industry Relies on IM for Robustness, Control, and Ease of Use. The most important parameters affecting induction motor performance are speed, temperature, and changes in current at different loads. The current of an induction motor varies with load. As the current increases, the temperature increases. Failure to monitor and control induction motor temperature Leads to insulation failure and machine damage. Faults and failures in induction motors can be monitored and recorded using sensors. Timely fault detection can prevent motor and equipment damage. Nowadays, speed control and power monitoring are done manually and require constant human intervention. As technology advances, human intervention can be reduced by using IoT to transform manual control and monitoring into unattended monitoring. IoT offers many advantages such as remote control, real-time access to data, automation, increased operational efficiency, and better communication between devices. IoT establishes two-way communication between the cloud and systems, making data accessible from anywhere on the planet. The Application layer, Network layer, and Perception layer make up the three

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 https://doi.org/10.1051/e3sconf/202339101175

layers of the IOT architecture.

The perception layer is the physical layer made up of sensors. This layer helps capture parameters or gather necessary information from the environment. The network layer is responsible for communication between devices, systems, and servers. This also helps to process and transmit information collected by the sensors. The applicationlayer is the top layer and can be customized according to user needs. It is responsible for providing application-specific services to users.

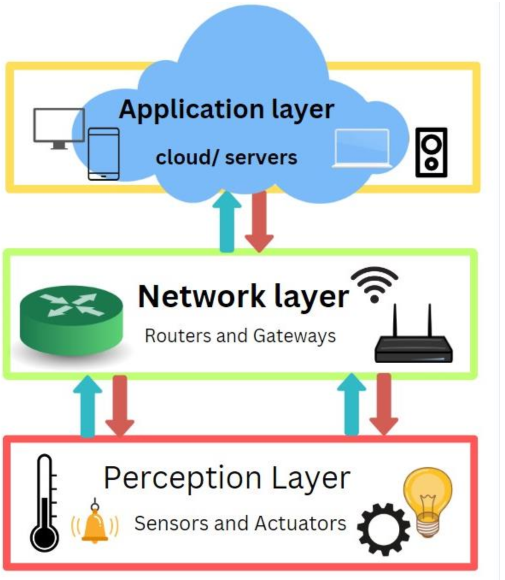


Fig. 1 IOT Architecture

2 SCHEMATIC REPRESENTATION

The following block diagram shows the overall system proposal.

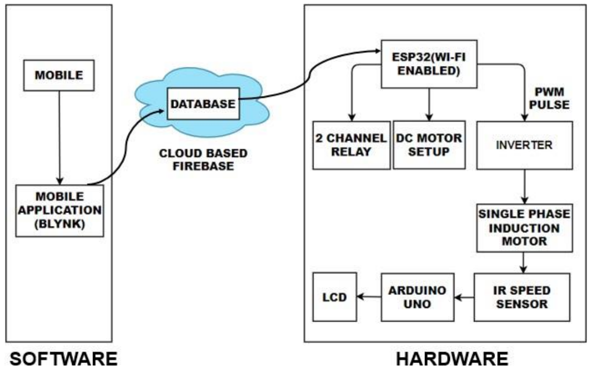


Fig. 2 Block diagram

The system mainly consists of hardware setup, software setup, and cloud-basedFirebase. The software setup consists of an app that helps control the speed and monitor the current, and voltage of the induction motor at various loads. This app is used to remotely connect to the hardware setup via an ESP32 WI-FI module. The cloud-based firebase acts as a communication bridge between the mobile app and esp32. In Cloud-based Firebase, all the information is collected and stored in a dedicated database. Using the Firebase authentication method, the data in the database can be altered, modified, and managed according to the hardware requirement. This remodeled data is transferred to ESP32 wirelessly as it is Wi-Fi enabled. In the hardware setup, the data received from Cloud-based Firebase acts as input to the ESP32 Wi-Fi module. Using ESP32 desired PWM signals were generated and forwarded to the inverter model. From the inverter model, sufficient voltage and current are produced and carried forward to the single-phase induction motor. The control pulse from the WI-FI module is given to the two-channel Relay for ON/OFF operation. One more pulse from the ESP32 is given to the DC Motor to control the speed of the DC motor. Now, two pulses from the WI-FI module are given to the inverter and the generated pulses are given to the induction motor. The resultant output is reflected on a single-phase induction motor where speed control can be achieved. An IR speed sensor is used to sense the speed of the induction motor using Arduino and is displayed on the LCD.

3 PWM GENERATION IN MATLAB

The pulse width modulation technique modifies an electrical signal's average output power by precisely dividing it into discrete parts and creating pulses by varying widths to simulate the amplitude of an analog input signal. Moreover, an amplitude with a low signal causes it to be off more frequently and an amplitude with a high signal causes the output switching transistor to be on more frequently. A continuously varying analog signal is convertedinto a series of digital signals using the PWM technique. A comparator is used to generate a PWM signal. The comparator compares the two input signals and produces a PWM signal asa result. The Sinusoidal wave (modulation signal) and the Triangular wave (carrier signal) arethe two input signals given to the comparator.

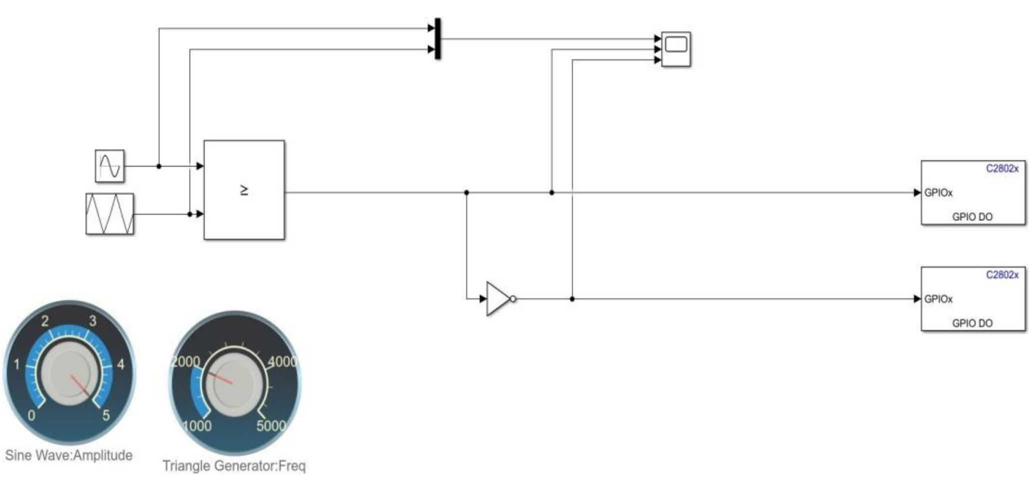


Fig. 3 Simulink Model of PWM Generation

https://doi.org/10.1051/e3sconf/202339101175

Table 1 PWM Parameters

Sine wave (MODULATION WAVE)	Frequency=50Hz,Amplitude=5
Triangle wave (CARRIER WAVE)	Frequency=20KHz, Amplitude=1

The output observed for the above Simulink model which is observed in the Matlab scope is shown in Fig 4. Where the sine wave is observed with 50Hz frequency and with an amplitude of 5 and the triangle wave is observed with 20KHz frequency and with an amplitude of 1.

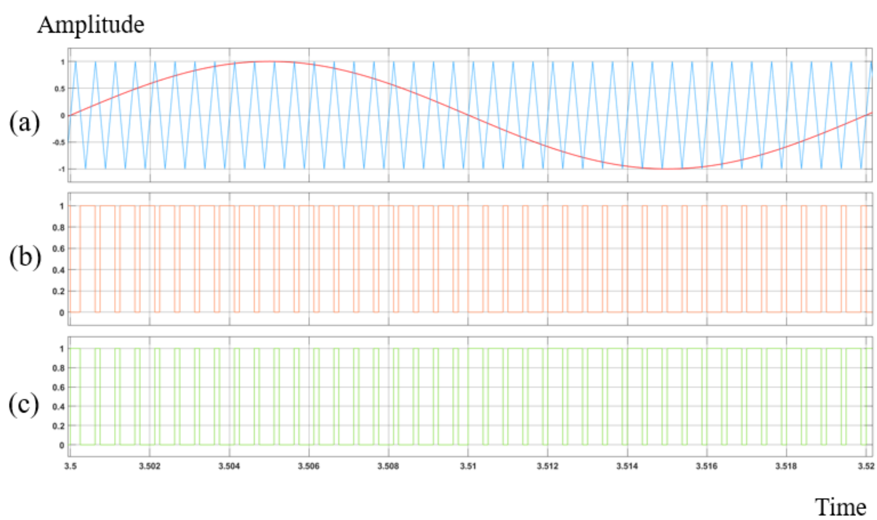
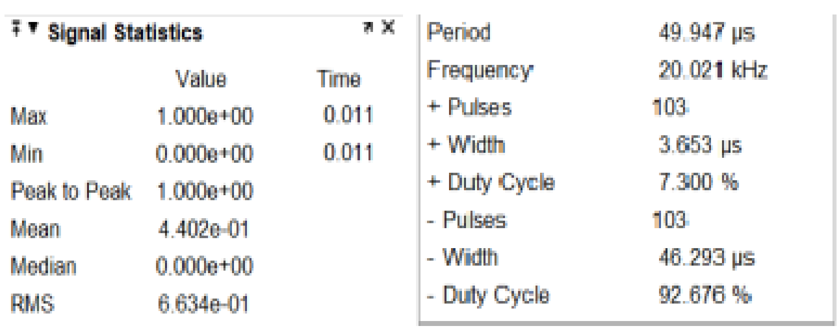


Fig. 4 PWM Technique for Speed Control

The pulse width modulation signal statistics are shown in Fig 5 where the maximum value, minimum value, peak-to-peak, median, mean, and RMS value are shown with certain frequency and time period.


Signal Statistics

	Value	Time
Max	1.000e+00	0.011
Min	0.000e+00	0.011
Peak to Peak	1.000e+00	
Mean	4.402e-01	
Median	0.000e+00	
RMS	6.634e-01	

Period	49.947 µs
Frequency	20.021 kHz
+ Pulses	103
+ Width	3.653 µs
+ Duty Cycle	7.300 %
- Pulses	103
- Width	46.293 µs
- Duty Cycle	92.676 %

Fig. 5 PWM Signal Statistics

4 HARDWARE IMPLEMENTATION

The Hardware components required for the proposed system are Induction Motor, ESP32(WI-FI Module), Inverter Module, the dc motor setup, and a two-channel relay wherethe control pulse is given to the two-channel relay for on/off operation and another pulse from the ESP32 is given to control the speed of dc motor. The inverter module receives the input from Node MCU. The inverter module's design allows it to take a single pulse and produce up to four distinct pulses. These pulses are now applied to the inverter switches, which turn on in turn to produce the required output. The inverter module is built to accept AC input, correct it, and then send it to the inverter for use since the inverter requires a significant quantity of DC power that is challenging to predict in practice. The induction motor now receives the inverter output and begins to run at its rated speed. According to theIOT application, the BLYNK app is used to control the motor's speed.

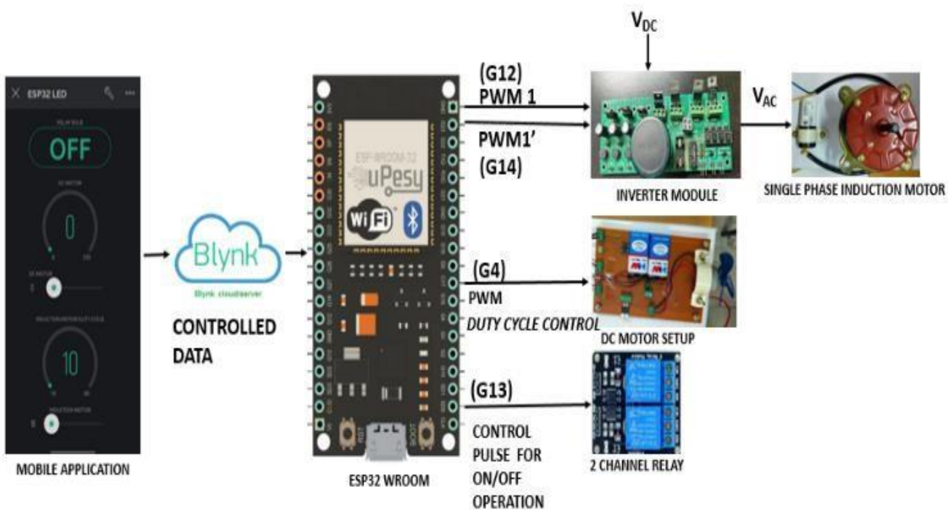


Fig. 6 Hardware implementation of speed control of induction motor.

An IR sensor is used to sense the speed of the induction motor and displays the measured value on the LCD board so that we can control the speed accordingly. Further, a load setup is added to the motor so that we can increase and decrease the load and check the current andvoltage drawn by the motor.

4.1 GENERATION OF PULSES

Pulse Width Modulation (PWM) provides a way to control specific analog quantities by varying the pulse width of a fixed frequency square wave. We have controlled the pulse width modulation (PWM) generated from ESP32 using the IOT platform. All the required parameters are set up in the platform by which we can control the duty cycle by varying the slider in the mobile application where the ESP32 is connected to the application through a firebase. The obtained waveforms are observed in a cathode ray oscilloscope by varying the duty cycles. The required setup connections are shown in Fig 7.

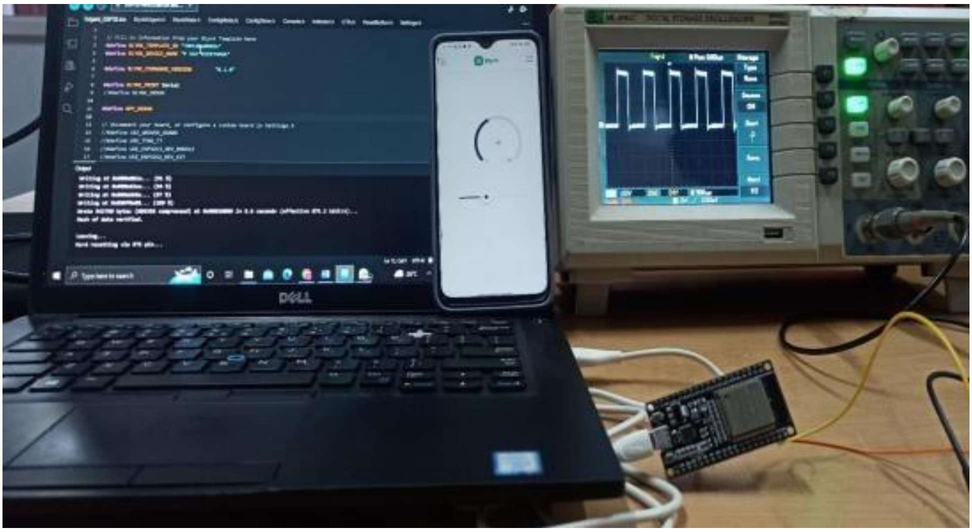
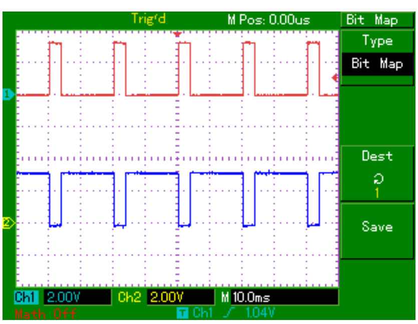
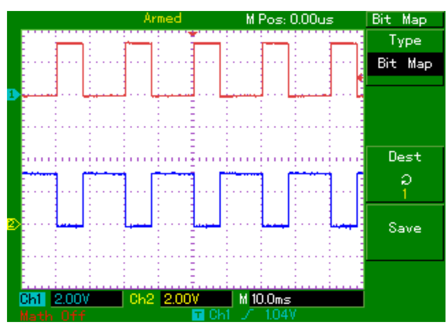


Fig. 7 Pulse generation

Two complimentary pulses required by the inverter module were generated. The outputs ofthe various generated pulses at different duty cycles are given below:





a. Pulse generation with 20% duty cycle

b. Pulse generation with 40% duty cycle

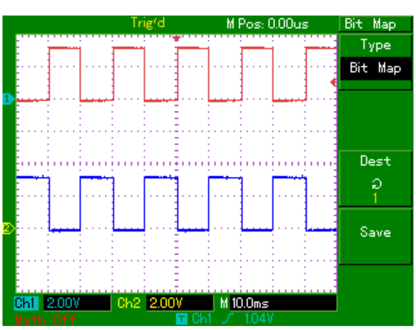
b.

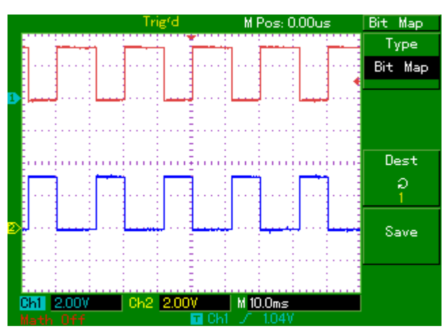
c.

d.

e.

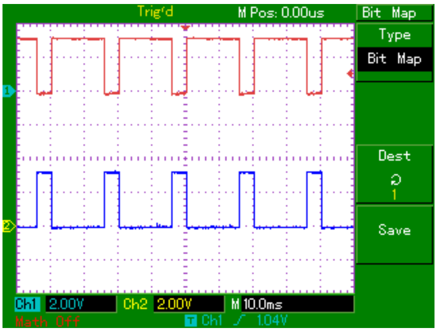
f.





c. Pulse generation with 50% duty cycle

d. Pulse generation with 60% duty cycle



e. Pulse generation with 80% duty cycle

Fig. 8 Pulse width Modulation generation

4.2 GENERATION OF COMPLIMENTARY PULSES THROUGH INVERTER

The generated PWM pulses are given to the inverter circuit in order to control the output v/f thus, controlling and monitoring the speed of the induction motor. The inverter circuit consists of a transformer to amplify the voltages. These PWM pulses are transmitted forward to optocouplers present in the inverter model for further functioning. The output is observed by the signals generated by optocouplers and they are reflected on the induction motor. The setup shown in Fig 9 is required for the generation of pulses.

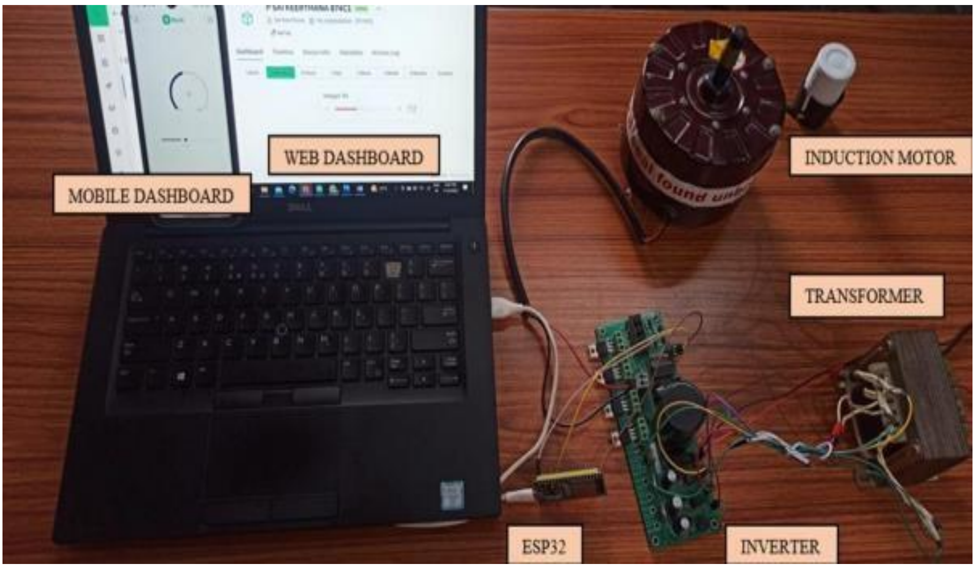


Fig. 9 Pulse generation through an inverter

The required pulse width modulations and their complementary pulses are obtained at the gate driver circuit at different duty cycles which are used to control the speed of the induction motor at certain currents and voltages. Here pulse generation through an inverter with 50% and 80% are shown in Fig 10.

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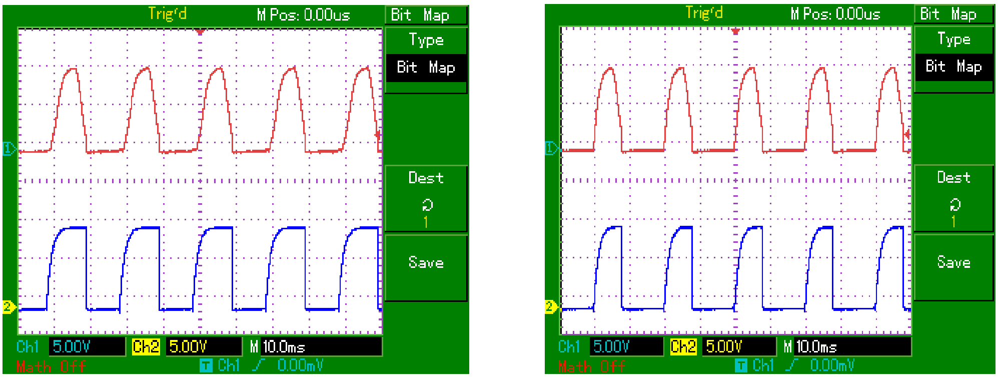

(a) **(b)**

Fig. 10 PWM Generation at Gate Driver Circuit: (a) Pulse generation through an inverter with 50% (b) Pulse generation through an inverter with 80%

5 RESULT

The following are the suggested work outcomes for the induction motor parameter regulating system. controlled the speed of the dc motor followed by the on/off operation of a bulb and controlled the speed of induction by sensing the speed using an IR sensor, by adding a load setup we monitored the current and voltage drawn under different load conditions. The hardware setup of the entire proposed model is shown in Figure 11.

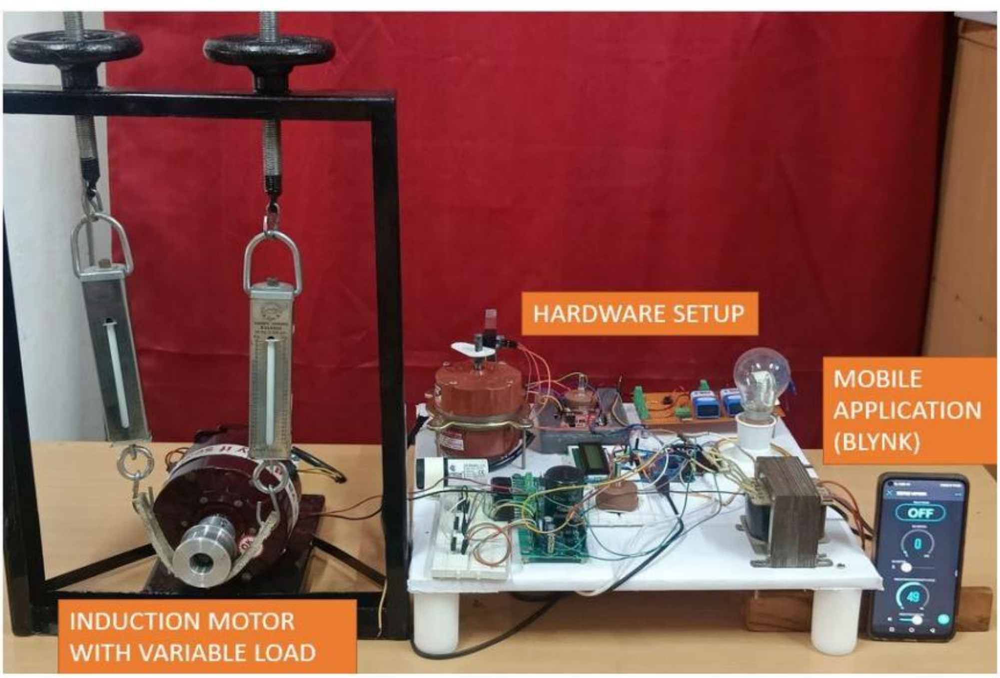

Fig. 11 Hardware setup

The respective values of voltage, current, and speed of the induction motor at different duty cycles areshown in Table 2.

Table 2 Rating of Induction Motor

DUTY CYCLE	VOLTAGE	CURRENT	RPM
30	273	0.3	2701
40	306	0.3	2899
45	315	0.4	2924
50	318	0.6	2934
55	318	0.6	2920
60	311	0.3	2901
65	296	0.3	2863
70	276	0.2	2761

6 CONCLUSION

The well-known and quickly developing IoT technology is demonstrated in this paper. The Internet of Things now plays a crucial role in everyday life. A future date the cloud and the millionaire of things should be coupled. IoT has recently expanded to a number of industries, including traction, agriculture, home automation, electric vehicles, industry, and the medical field. In this study, IoT-based condition monitoring parameters are presented, together with PWM-based motor speed control. The motor may be controlled in a safe and protectedmanner by assessing its operating characteristics. This analysis also aids in the calculation offresh data that can be used to engage with social media and other devices. By connecting to a hotspot module, a mobile application can display voltage, current, temperature, and speed waveform. Via the blynk application, the motor parameter was continuously monitored. Continuous monitoring of data values is necessary for industries for power consumption andmaintenance applications. If the motor exceeds its rated value it will be instantly disconnectedfrom the supply.

7 FUTURE SCOPE

Future IoT applications have a lot of potential. IoT applications for advanced human life are overused globally. Millions of items will be connected to the cloud. Many studies have also been conducted on IoT and its additional applications for human life's most basic needs. Defense services for security and surveillance are the subject of certain investigations, as are automated cars and traffic lights, the medical industry for body management and healthcare, and electronics and smart homes.

REFERENCES

1. Sudharani Potturi, P. Mandi and Dr. Rajashekar *Critical Survey on IOT Based Monitoring and Control of Single phase induction motor*, IEEE 16th Student Conference on Research and Development, Bangy(Malaysia)26-28Nov (2018).

2. Mehmet Şen and Basri Kul, *IoT-Based Wireless Induction motor Monitoring*, Department of Electrics and Electronics, Vocational School of Technical Sciences, Uludag University of Bursa Nilufer,16059, Bursa, Turkey, International Scientific Conference ElectronicsET2017, IEEE(2017).

3. Andi Adriansyah and Akhmad Wahyu Dani, *Design of Small Smart Home Control Systems Based on Wireless Sensor Networks and Power Line Communications*, IEEE,(2014).

4. Sattu, Shravani, Vinay Kumar Awaar, and Praveen Jugge, *Speed control of robust position sensorless PMBLDC motor by Fuzzy controller*, In *E3S Web of Conferences*, vol. 309, p. 01063. EDP Sciences, (2021).
5. Bharat Bohara and Sunil Maharjan, IoT Based Smart Home Using Blynk Framework, ZERONE SCHOLAR, (2016).
6. Venu Gopal Mangali, Shravan Kumar P, Vinay Kumar Awaar, and Praveen Jugge, *DSP based Voltage Source Inverter for an application of Induction Motor control*, eISSN: 2267-1242, E3S Web Conf. 184, 01057 (2020).
7. M.F. Othman, K. Shazali, *Wireless Sensor Network Applications: A Study İn Environment Monitoring System*, Procedia Engineering, **41**, 1204-1210, (2012).
8. Awaar, V.K., Jugge, P. & Tara Kalyani, Validation of Control Platform Using TMS320F28027F for Dynamic Voltage Restorer to Improve Power Quality, S. Journal of Control Automation and Electrical Systems, 30, no.4, pp 601-610, (2019).
9. B. V. Divya, N. Latha and P. Ashwini Kumari, *IOT Enabled Power Monitoring and Control of Single-Phase Induction Motor,* 2021 International Conference on Emerging Smart Computing and Informatics (ESCI), 2021, pp. 670-673, (2021).
10. Tan-Jan HO ID, et al *Robust Speed Tracking of Induction Motors: An Arduino Implemented Intelligent Control Approach,* 2018 **vol.8,** pp.159, IEEE Transactions on Industry Applications, (2018).
11. Shi. K. L., Chan, T. F. and Wong, Y. K., *Modelling of three phase induction motor using Simulink,* Record of the 1997 IEEE International Electric Machines and Drives Conference, USA, pp.WB3- 6, (1997)
12. Natick, M A, USA, *Simulink- Dynamic System Simulation for MATLAB*, the MathWorks, Inc, 2000, The MathWorks, Inc, , (2000).
13. G. L. Jat, K. Singh, A. Mahajan and Shimi S.L. Real time speed control of induction motor using new generation DSP controller, Second International Innovative Applications of Computational Intelligence on Power, Energy and Controls with their Impact on Humanity (CIPECH), 2016, pp. 90-95, (2016).
14. A. P. Junfithrana, I. Solikin, J. K. Hadi and M. Dedy Novianto, *Improving Electric Motor Performance by Handling Interference using IOT,* 2019 5th International Conference on Computing Engineering and Design (ICCED), pp. 1-5, (2019).
15. V. K. Awaar, P. Jugge and Tara Kalyani S, *Field test of cost-effective Voltage Source Inverter for driving an Induction Motor, 2015 Annual IEEE India Conference (INDICON),* New Delhi, ISBN: 978-1-4673-7399-9, pp.1-6, (2015).
16. G. Agrawal, H. Mohan and M. Pathak, *Improved Speed Sensorless Control of Induction Motor Drive Using Artificial Neural Network,* 2nd International Conference on PowerElectronics & IoT Applications in Renewable Energy and its Control (PARC), 2022, pp.1- 6, (2022).
17. S. Kai and Z. Yanlei, *A speed observer for speed sensorless control of induction motor,* 2nd Int Conference on Future Computer and Communication, 2010, pp. 263-267, (2010).
18. Awaar, Vinay Kumar, Praveen Jugge, S. Tara Kalyani, and Mohsen Eskandari *Dynamic Voltage Restorer–A Custom Power Device for Power Quality Improvement in Electrical Distribution Systems,* In Power Quality: Infrastructures and Control, pp. 97-116. Singapore: Springer Nature Singapore, (2023).
19. B. L. Widjiantoro, K. Indriawati and E. J. Simbolon, P*article Filter Based Speed Estimator for Speed Sensorless Control in Induction Motor,* 3rd International Seminar on Research of Information Technology and Intelligent Systems (ISRITI), pp. 295- 300, (2020).
20. A. Wakodikar and M. V. Aware, *Speed Sensorless Finite Set Model Predictive Speed Control of Induction Motor,* IEEE First International Conference on Smart Technologies for Power, Energy and Control (STPEC), pp. 1-6, (2020).
21. D. Wang and Y. Shi, *Sensor less Fuzzy Speed Control for Single Phase Induction Motors,* Sixth International Conference on Fuzzy Systems and Knowledge Discovery, pp. 163-165, (2009).