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JAITA

http://publisher.uthm.edu.my/ojs/index.php/jaita

e-ISSN : 2716-7097

Journal of Advanced Industrial Technology and Application

Electrical Machine Breakdown Monitoring System Using IoT

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DOI: https://doi.org/10.30880/jaita.2022.03.02.001
Received 01 June 2022; Accepted 01 September 2022; Available online 8 December 2022

Abstract: Nowadays, electrical machines of different types and designs are used in hybrid production systems. Electrical machines are needed to control and implement various mechanisms to produce final products. However, sometimes, electrical machines stop working and cause downtime. This affects workers' productivity during peak hours and reduces business profits. To overcome this problem, a suitable machine-monitoring system is required so that the problem can be addressed and rectified immediately. In this paper, an IoT prototype for an electrical machine failure monitoring system using Heltec LoRa ESP32 as the microcontroller to communicate with the Blynk IoT platform server was proposed and developed. The monitored parameter values are voltage, current and motion sensor readings. A ZMPT101b voltage sensor is used to measure the AC voltage, while an ACS712 current sensor is used to measure the AC current flowing through the machine. In addition, a tilt sensor is used to detect the vibrating motion of the motor. The measured values indicate machine health and are monitored using the developed Blynk IoT GUI platform, which is accessible from mobile phones and the web. A notification from Blynk application will be sent to users to alert them about a specific condition when a value measured and uploaded to the Blynk cloud exceeds the configured average. Three tests were performed using the serial monitor, the Blynk application and the multimeter, and the results showed that the lowest percentage of error between the voltage sensor readings extracted from the serial monitor and the multimeter was 1.19% and the lowest percentage of error between the current sensor readings extracted from the serial monitor and the multimeter was 17.63%. Overall, all parameter values were successfully displayed on the IoT platform. In future works, the accuracy of the current sensor can be improved by integrating a signal conditioning circuit to filter out noise.

Keywords: Blynk, breakdown monitoring, electrical machine, Heltec LoRa ESP32, IoT

1. Introduction

Nowadays, there are various electrical machines based on different types and designs being used to control and implement different mechanisms to produce products [1]. With the rapid growth of the technology of electrical machines in the manufacturing sector, the Internet of Things (IoT) plays a role in advancing the process of system development. Today, almost 45% of the world's electricity generation and 70% of the total industrial electricity consumed are powered by electric motors, and hence motor failures can cause huge financial, production and reputation losses in the industry [2].

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Condition monitoring is considered a key element for induction motors, ensuring that the cost of unplanned downtime and unexpected failures are continuously reduced and eliminated [3][4]. In 2015, 33% of global companies surveyed by a report considered themselves highly digital, but this share is expected to reach 72% by 2020 [5]. Global manufacturers are digitizing key functions of their internal horizontal and vertical supply chains. These digital innovations are expected to help companies reduce costs by 43% and increase revenue by 35% [6][7].

Since the manufacturing sector is an integral part of the global economy, accounting and operation, the entry of the Internet of Things that follows the evolution of architectural layer systems in computing and communication is necessary [8][9]. The production line is where automatic machines are located. When automatic machines reach their maximum production capacity, they may sometimes break down [2][10]. If operators have to be on standby for 24 hours, this will lead to a high-cost operation and require more manpower to identify the production problems. Machine downtime will reduce business profit [11][12].

A motor is a type of electrical machine that is prone to failure due to many reasons, such as misuse, improper maintenance, unhealthy power supply, ageing, and harmful environmental conditions [2]. Continuous monitoring of electrical and mechanical parameters ensures motor reliability. If an abnormal electrical or mechanical value is detected, the motor is automatically controlled [13]. If the machine breakdown is discovered late, it can affect productivity.

The main purpose of this project was to develop a prototype of an IoT-based motor breakdown monitoring system using voltage, current and motion sensors. The second objective was to develop a mobile phone software application to receive and display the monitored data. The final objective was to analyse the effectiveness of the sensing and monitoring system based on the accuracy of the sensors' measurements and the data transfer time between the sensors and the IoT monitoring device. The data collected and stored in the I-cloud can be reviewed and converted into graphs and pie charts to allow users to monitor the progress of the machine parameter measurements using the Blynk app. A notification message will be displayed on the user's phone to alert the user if the voltage, current and motion sensors' data measurements exceed the set range. The proposed electrical machine breakdown monitoring system using IoT can help plant management by providing an accurate machine status during operation. This is necessary to help engineers spot problems so that they can quickly attend to the problems.

2. Methodology

2.1 Block Diagram

Fig. 1 shows the block diagram of the system. The current sensor is connected as a series connection through the neutral wire, while the voltage sensor is connected in parallel through the neutral wire and live wire. The current sensor has a terminal with three pins which are Pin Vcc, Pin GND and Pin Vout. Pin Vcc of the current sensor is connected to Pin 3V3 of the Heltec LoRa ESP32 microcontroller, Pin Vout is connected to Pin 36 of the microcontroller and Pin GND is connected to the GND pin of the microcontroller. The voltage sensor has a terminal with four pins, which are Pin Vcc, Pin Vout and two GND pins. Pin Vcc of the voltage sensor is connected to the Pin 5V of the microcontroller, Pin Vout is connected to Pin 39 of the microcontroller and Pin GND is connected to the GND pin of the microcontroller. The tilt sensor has four pins, which are Pin A0, Pin D0, Pin Vcc and Pin GND. Pin Vcc of the tilt sensor is connected to Pin 3V3 of the Heltec LoRa ESP32 microcontroller and Pin A0 is connected to Pin 37 of the microcontroller, while Pin GND is connected to the GND pin of the microcontroller.

The tilt sensor will trigger a red or green LED to indicate whether there is motion by the motor of the electrical machine or not. The red LED represents motion undetected, while the green LED represents motion detected. The positive terminal of the green LED is connected to Pin 13 of the microcontroller, while the positive terminal of the red LED is connected to Pin 12 of the microcontroller. The negative terminals of both LEDs are connected to the GND pin of the microcontroller.

The mechanism of the tilt sensor is triggered when there is motion detected on the motor, and thus the tilt sensor will send the data through a digital pin on the microcontroller, which is Pin 13. This shows that the motor is functioning according to the voltage supplied to the electrical machine. However, if the tilt sensor senses no movement on the motor, the tilt sensor data will be read as 0, which shows the motor is not functioning according to the voltage supplied to the electrical machine. All data are uploaded to the Blynk cloud by using the Wi-Fi connection built into the Heltec LoRa ESP32 microcontroller. The data are analysed and retrieved on the Blynk IoT platform. The data are displayed on the web dashboard or in a mobile Blynk application.

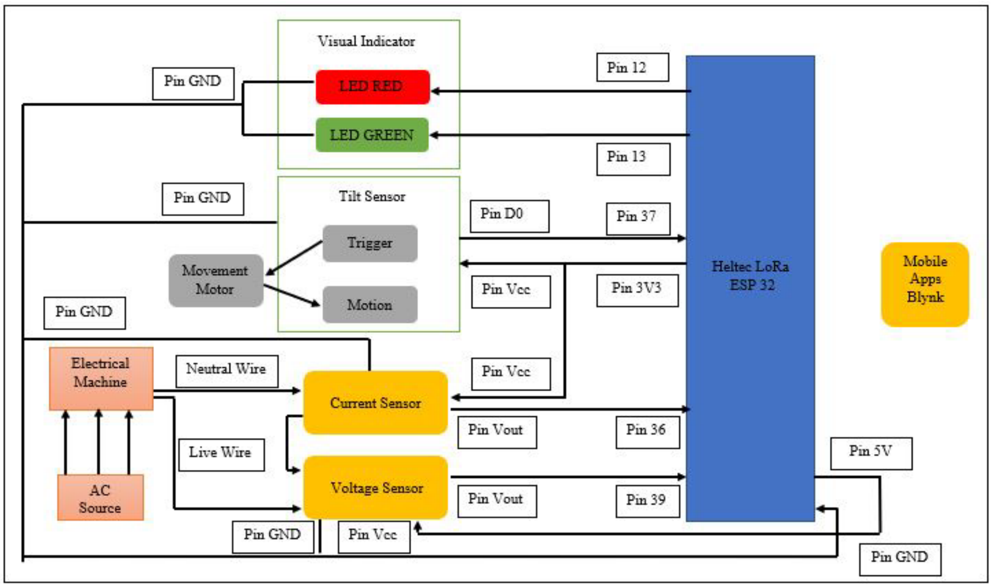


Fig. 1 - Block diagram of the system

2.2 Flowchart

The flowchart of the system is presented in Fig. 2. Each terminal on the voltage sensor and the current sensor is connected to the live and neutral wires of the motor. The tilt sensor, on the other hand, is attached to the motor's surface. The selected voltage sensor was the ZMPT101B voltage sensor, while the current sensor was the ACS712 current sensor. The ZMPT101B voltage sensor was chosen because it can measure up to 250V AC. The ACS712 current sensor was chosen because the current in the electrical machine will not exceed 2A. The data from the sensors are sent to the Heltec LoRa ESP32 microcontroller and analysed by a series of programs installed in the microcontroller, and then the data are sent and uploaded to the Blynk cloud.

If there are no readings from the sensor or if the readings are too small compared with readings during the typical on-state of the motor, this indicates that the motor is in the breakdown state. The LCD will display a warning error on the measurement board of the Heltec LoRa ESP32 microcontroller. A warning is also triggered in the Blynk application, which will notify users regarding the alarming condition.

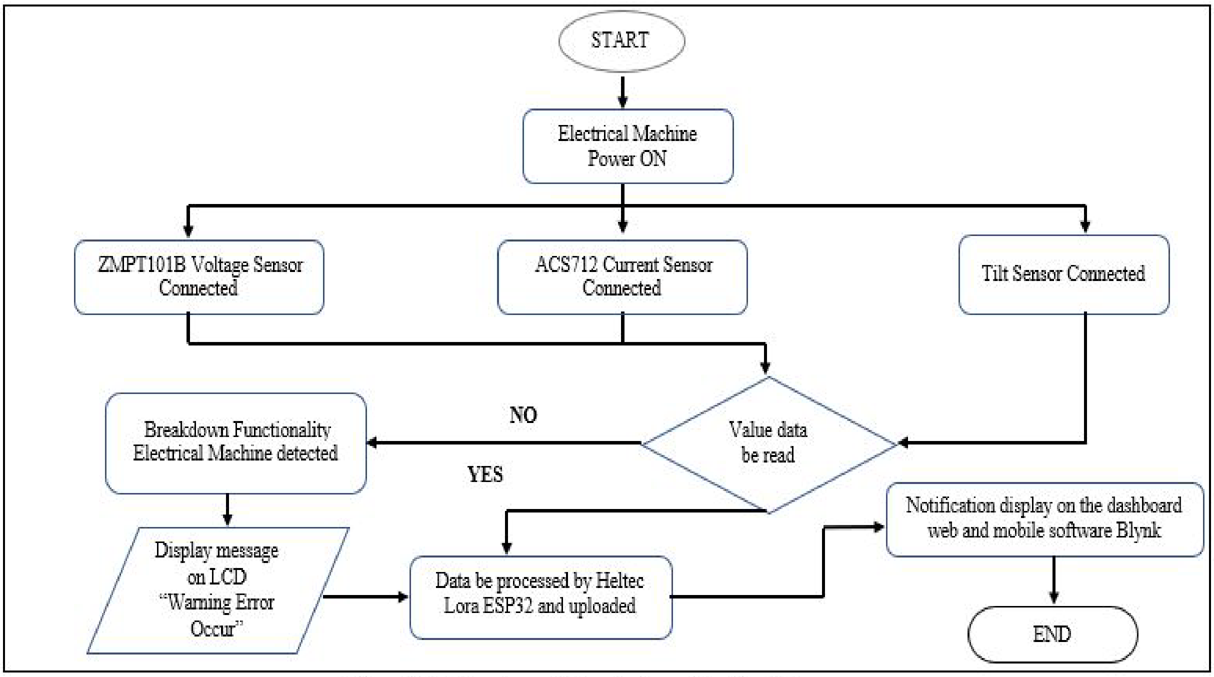
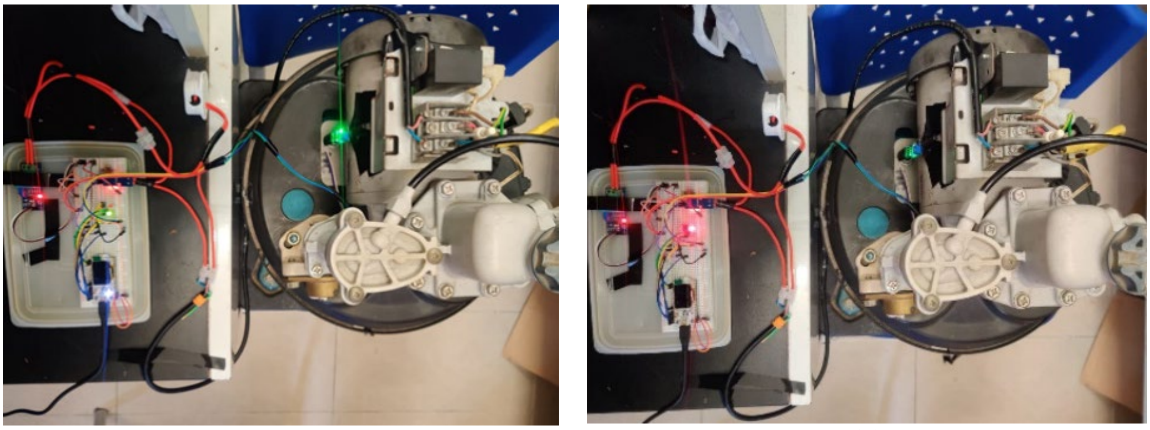


Fig. 2 - Flowchart of electrical machine breakdown monitoring system

3. Results and Discussion

Figs. 3 (a) and (b) show the prototype of the proposed system during the on-state and the off-state of the motor, respectively. The ZMPT101B voltage sensor and the ACS712 current sensor were placed in the circuitry of the measurement device, while the tilt sensor was placed right on the motor's surface to ensure that the vibration produced by the motor can be sensed effectively. As a precautionary step, a fuse was installed on the live wire. The function of the fuse was to avoid any unpredictable event from occurring and to save the electrical machine from damage.



(a) (b)

Fig. 3 - Electrical machine during (a) switch on; (b) switch off

Fig. 4 shows the graphical user interface (GUI) in the Blynk application, while Fig. 5 shows the notification message from Blynk as displayed on the mobile dashboard. When the user opens the Blynk application, the Blynk server will retrieve the data from the Blynk cloud to display the measurement values on all widgets added to the page. As shown in Fig. 6, the widget labelled "Value" shows voltage and current readings, while the SuperChart widget shows the readings in the form of a graph. The same widget can be used to show voltage and current readings. The Button widget shows the output from the tilt sensor, which indicates whether there is motion by the motor or not.

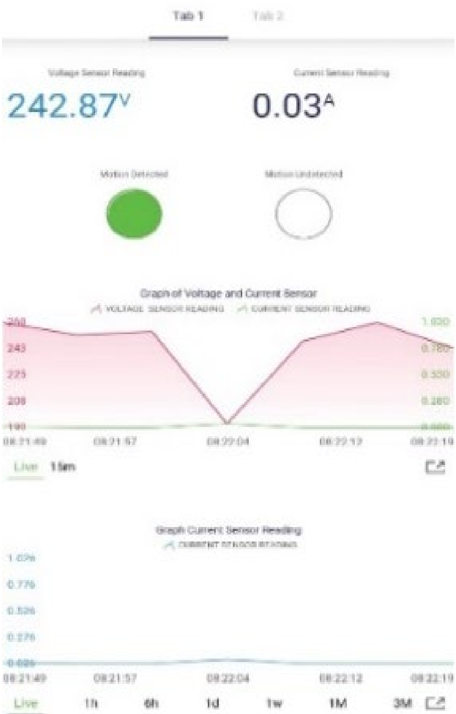


Fig. 4 - Graphical user interface in Blynk Application

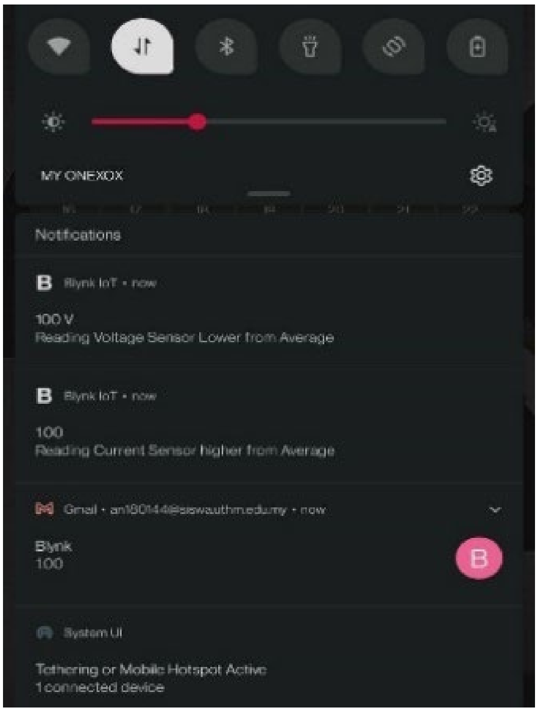


Fig. 5 - Notification message from Blynk Application displayed on mobile dashboard

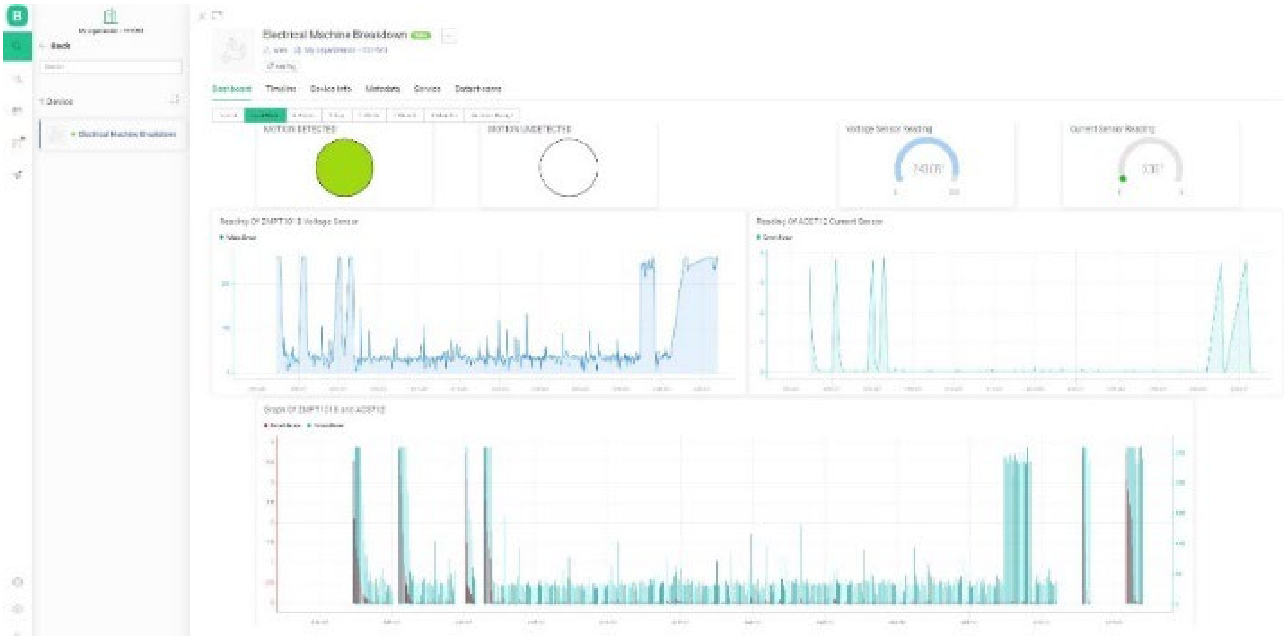


Fig. 6 - GUI of Blynk application on web dashboard

3.1 Voltage Measurement

Table 1 shows the voltage measurements extracted from the serial monitor, the Blynk application and the multimeter. All readings were taken simultaneously with the help of video recording. According to Table 2, the percentages of error between the voltage values measured by the ZMPT101B voltage sensor as extracted from the serial monitor and the multimeter were very low, ranging from 1.19% to 2.40%. The percentage of error was calculated using Equation (1).

$$\text{Percentage of error} = \frac{|\text{Experimental Value - Exact value}|}{|\text{Exact Value}|} \times 100 \qquad (1)$$

Table 1 - Voltage measurements

Trial	Serial Monitor (V)	Blynk App (V)	Multimeter (V)
1	249.68	247.20	246.74
2	251.53	246.75	247.08
3	247.71	242.55	241.90

Table 2 - Voltage measurement error

Trial	Percentage of error (%)		
	Between Serial Monitor and Multimeter Readings	Between Blynk Application and Multimeter Readings	Between Blynk Application and Serial Monitor Readings
1	1.19	0.19	0.99
2	1.80	0.13	1.90
3	2.40	0.27	2.08

3.2 Current Measurement

Table 3 shows the current measurements extracted from the serial monitor, the Blynk application and the multimeter. All readings were taken simultaneously with the help of video recording. According to Table 4, the percentages of error between the current values measured by the ACS712 current sensor as extracted from the serial monitor and the multimeter were quite high, ranging from 17.63% to 50.33%. The instability of the current readings might be due to the noise from wiring or due to the small number of trials conducted. This issue can be addressed and improved upon in the future by using multi-sampling readings, conducting multiple sensor calibrations and applying signal conditioning to reduce noise.

Table 3 - Current measurements

Trial	Serial Monitor (mA)	Blynk App (mA)	Multimeter (mA)
1	34.63	34.63	25.6
2	35.29	35.21	30.00
3	36.08	36.08	24.00

Table 4 - Current measurement error

Trial	Percentage of error (%)		
	Between Serial Monitor and Multimeter Readings	Between Blynk Application and Multimeter Readings	Between Blynk Application and Serial Monitor Readings
1	35.27	35.27	0
2	17.63	17.37	0.23
3	50.33	50.33	0

3.3 Tilt Sensor's Detection

Two green LEDs were used: one was installed on the motor and the other was installed on the breadboard. Fig. 7 shows the position of the tilt sensor on the electrical machine. Fig. 8 shows the green LED turned on when the motor was switched on during the experiment, while Fig. 9 shows the red LED turned on when the motor was switched off. The tilt sensor was able to detect the motion on the electrical machine.

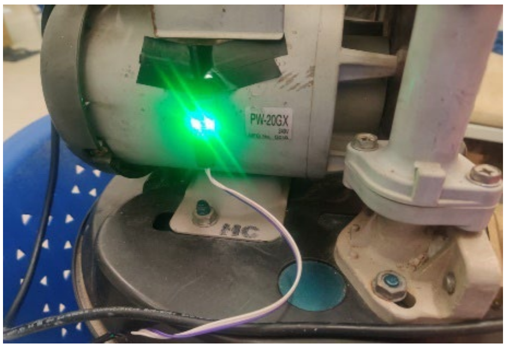


Fig. 7 - Position of tilt sensor

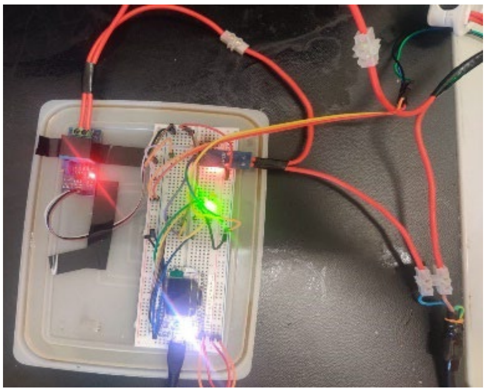


Fig. 8 - Green LED indicator turned on

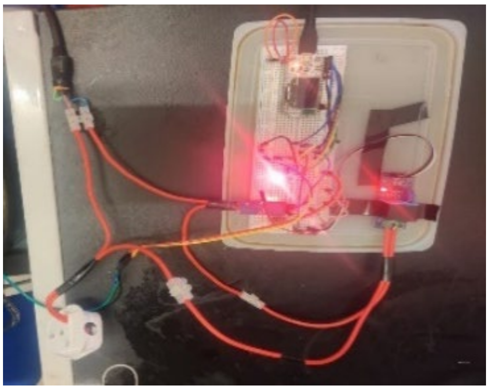


Fig. 9 - Red LED indicator turned on

4. Conclusion

In conclusion, a prototype based on the IoT-based motor breakdown monitoring system using voltage, current and motion sensors was successfully developed. The voltage sensor readings extracted from the serial monitor and the multimeter gave good percentages of error, ranging from 1.19% to 2.40%, while the current sensor readings' percentages of error extracted from the serial monitor and the multimeter were quite high, ranging from 17.63% to

50.33%. The mobile phone software Blynk was able to receive and display the monitoring data effectively with low percentages of error, with maximum percentages of error of 0.23% and 2.08% from the serial monitor readings of current and voltage, respectively. The errors might be due to the internet connection during the experiment.

As a recommendation for future development, the selection of the component of the ACS712 current sensor can be changed to further improve the system. Temperature measurement can also be added to monitor the condition of the motor if any unavoidable event occurs during the operation of the electrical machine. Furthermore, a water flow sensor consisting of a plastic valve to enable water to pass through can be added to indicate whether the motor is functioning or not.

Acknowledgement

The authors would like to thank the Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia, for its support.

References

[1] C. A. Rivera, J. Poza, G. Ugalde, and G. Almandoz, (2017). A Knowledge Based System architecture to manage and automate the electrical machine design process. *2017 IEEE International Workshop of Electronics, Control, Measurement, Signals and their Application to Mechatronics (ECMSM)*. Donostia, Spain. May 24-26, 2017. pp. 1-6

[2] S. Dol and R. Bhinge, (2018). SMART motor for industry 4.0. *2018 IEEMA Engineer Infinite Conference (eTechNxT)*. New Delhi, India. March 13-14, 2018. pp. 1-6

[3] S. Jamwal and S. L. Shimi, (2018). IoT Based Parameter Monitoring of Three Phase Induction. *Int. J. Create. Res. Thoughts*, *6*(2), pp. 484-489

[4] R. C. Parpala and R. Iacob, (2017). Application of IoT concept on predictive maintenance of industrial equipment. *MATEC Web Conf., 121*(2017), pp. 1-8

[5] C. S. Liu, S. X. Yan, and T. H. Lai, (2018). The establishment of an integrated automation production line with multiple monitoring and control loops. *2018 IEEE International Conference on Applied System Invention (ICASI).* Chiba, Japan. April 13-17, 2018. pp. 968-971

[6] H. P. Lu and C. I. Weng, (2018). Smart manufacturing technology, market maturity analysis and technology roadmap in the computer and electronic product manufacturing industry. *Technol. Forecast. Soc. Change*, *133*(August 2018), pp. 85-94

[7] F. Wu, Z. Miao, and C. He, (2020). Remote monitoring system for intelligent slaughter production line based on internet of things and cloud platform. *2020 11th International Conference on Prognostics and System Health Management.* Jinan, China. October 23-25, 2020. pp. 538-542

[8] I. Kovalenko, M. Saez, K. Barton, and D. Tilbury, (2017). SMART: A system-level manufacturing and automation research testbed. *Smart Sustain. Manuf. Syst., 1*(1), pp. 232-261.

[9] J. Y. Khan (2019). Introduction to IoT Systems, in Internet of Things (IoT), Jenny Stanford Publishing. *5*(January). pp. 1-24

[10] S. Ginting, J. W. Simatupang, I. Bukhori, and E. R. Kaburuan, (2018). Monitoring of Electrical Output Power-Based Internet of Things for Micro-Hydro Power Plant. *2018 International Conference on Orange Technologies (ICOT).* Bali, Indonesia. October 23-26, 2018. pp. 1-7

[11] W. Chen, (2020). Intelligent manufacturing production line data monitoring system for industrial internet of things. *Comput. Commun*., *151*(December 2019) pp. 31-41.

[12] Nur-A-Alam, M. Ahsan, M. A. Based, J. Haider, and E. M. G. Rodrigues, (2021). Smart monitoring and controlling of appliances using LoRa based IoT system. *Designs, 5*(1). pp. 1-22

[13] K. S. Rekha and D. S. Ravi, (2017). Induction Motor Condition Monitoring and Controlling Based on IoT. *Int. J. Electron. Electr. Comput. Syst., 6*(9). pp. 75-81