PROGRESS IN ENGINEERING APPLICATION AND TECHNOLOGY
e-ISSN: 2773-5303

PEAT

Vol. 6 No. 2 (2025) 206-215
https://publisher.uthm.edu.my/periodicals/index.php/peat

Development of Modular Arduino-Based Learning Kit for AC Motor Speed Control

Muhammad Syafiq Itqan Mohd Latif [1], Rasida Norjali[1]*, Norezmi Md Jamal[1]

[1] *Department of Electrical Engineering Technology, Faculty of Engineering Technology,*
Universiti Tun Hussein Onn Malaysia, 84600 Pagoh, Johor, MALAYSIA

*Corresponding Author: rasida@uthm.edu.my

DOI: https://doi.org/10.30880/peat.2025.06.02.022

Article Info

Received: 26 June 2025
Accepted: 11 August 2025
Available online: 30 October 2025

Keywords

Arduino, AC motor, speed control, modular learning kit,PWM (pulse width modulation), closed loop feedback, simulation in MATLAB, hand-on and vocational training

Abstract

This project presents an Arduino-based learning kit capable of teaching AC motor speed control,and real-time monitoring.This kit includes the Arduino microcontroller,motor drivers and sensors that measure speed,voltage,current and temperature.The users are able to use tools such as PWM and closed-loop feedback and continue to build upon their theoretical and practical knowledge.The learning kit includes a MATLAB to visualize the performance in real-time and the option to customize learning materials,allowing for unique curriculum designs.The modular nature of the learning kit is consistent with various learning curves.The learning kit suitable for learners at any point in education or training.The goal is to lessen the gap between the theory and practical sides of getting people invoved in control motor speed.

1. Introduction

The ability to control motor speed is vital for many commercial, industrial and educational use (Tir et al., 2017). The reliability and efficiency of AC motors is appealing, however they required control systems to best utilize them (Banik et al., 2023a). Motor control system are often expensive, complex and are not modular which are barrier to experimentation and innovation, because of open-source platforms like Arduino, it is now possible to design flexible and inexpensive motor control options. Arduino is easy to program, modular and interoperable with many different components, thus making it a compelling educational tool.AC motors are increasingly found in the industry and home applications, highlighting the need to understand their controls and operation (Sharma & Singh, 2021a). However, practical devices that allow for hands-on learning with AC motor speed regulation are often cost prohibitive or overly complicated for use by novice students (Patil et al., 2021). The current project addresses this lack of practical, engaging learning tools for AC motors through the development of a modular, Arduino-based learning kit designed to teach AC motor speed control in a developmentally appropriate manner (Sapmaz et al., 2022).

1.1 Problem Statement

The practical understanding of how to control and monitor the speed of an AC motor is an important part of electrical and mechanical engineering education (Rikwan & Ma'arif, 2023), but many of the learning kits and laboratory equipment specific to understanding motor control are often unaffordable, complicated and not accessible to many of the schools needed to provide this experience to their students, especially with limited budgets (Bich & Le, 2022). Additionally, the kits often lack modularity and flexibility, resulting in a lack of opportunities for students to explore control strategies or configure their setup to suit specific learning objectives. Industrial electric power applications (Umar et al., 2022).

Moreover, the lack of live monitoring and user-friendly interfaces in most current solutions limits the hands-on learning experience (Angalaeswari et al., 2016), creating a space between the theory users learn and the practice users need to be proficient in order to develop skills in designing and controlling AC motor systems (Ma et al., 2023). The project aims to fulfill an identified need for a low-cost, modular and accessible learning kit that incorporates contemporary tools like Arduino and real-time data visualization for efficient learning (Ma'Arif et al., 2019). The kit will allow students to experiment with speed control algorithms like PID control and visualize motor performance in real-time to connect theory with practice (Kamalapur et al., 2022a).

1.2 Project Objective

i. Create a modular physical system for ac motor speed control.
ii. Implement real-time control and monitoring of AC motor speed using both Arduino uno and simulation in MATLAB Simulink.
iii. Assess the performance of a PID algorithm for AC motor speed control.

1.3 Project Scope

i. Hardware development
  - Conceive and fabricate a modular hardware platform that contains Arduino microcontroller an AC motor (220v,1.5A,150W,1400RPM) motor driver circuits, tachometer, current sensor, Variable frequency drive (VFD) and inverter.

ii. Software Implementation
  - Interface the hardware with MATLAB Simulink for simulation data acquisition, parameter tuning, MATLAB (GUI) Graphic User Interface for plotting graph and visualization of system performance.

iii. Learning kit features
  - User-friendly input and output options should be provided to adjust the control speed of the system in real-time using display or computer interfaces. It would also be helpful to incorporate an approach that has modules replaceable or additive learning for example using different motors or drivers that would facilitate enhanced learning.

iv. Educational materials
  - Construct tutorials and example experiments that demonstrate the important concepts of controlling an AC motor such as speed control, feedback mechanisms, and energy efficiency. Write exercises that demonstrate the effect of different PID parameters and system arrangements on how students view signals when controlling an AC motor.

v. Safety and reliability
  - SSR Control Switch AC DC 10A represents a solid-state relay, which will be the primary protection device for this circuit due to an absence of moving physical parts. Because of this, power to a load can be applied and removed very quickly and precisely, which is especially important in applications that require quick on-off switching. The LS MC-9b AC1 20A / AC3 9A 3P Magnetic Contactor 240VAC 24VAC cut supply for single-phase in case of any fault whenever it gets energized.

2.0 Methodology

This chapter describes the methodology of data gathering and analysis, hypothesis testing, and research from the perspective of using MATLAB Simulink with Arduino for controlling AC motors with speed monitoring. In this section, the design of the study, data collection, experimental setup, and analytical techniques conducted to fulfil research objectives and verify the performance of the system are summarized. One will use a flowchart to give out the sequence of the project from start to finish, outlining the steps involved.

2.1 Project Flowchart

The project flowchart is illustrated in Fig 1 the project initiates with background research to gain insights into the system's requirements, design considerations, and system components. Developing a DOL circuit for an alternating current motor. The Direct-On-Line (DOL) circuit was developed because it is a very simple method to start an AC motor. Apart from the development of the software and coding, the IDE software and coding was developed for the Arduino UNO that would initiate the motor and provide load distribution. Perform Coding and Performance Testing on the code developed when implemented on the Arduino UNO, as well as system performance testing. The project will conclude when the AC motor is in its start-up phase. If it will not run, it would loop back to the troubleshoot circuit. If the motor does not run, it will be checked for errors within the circuit and revisions will be made with any adjustments to the circuit. The project will conclude when the AC induction motor is running continuously with no faults or errors.

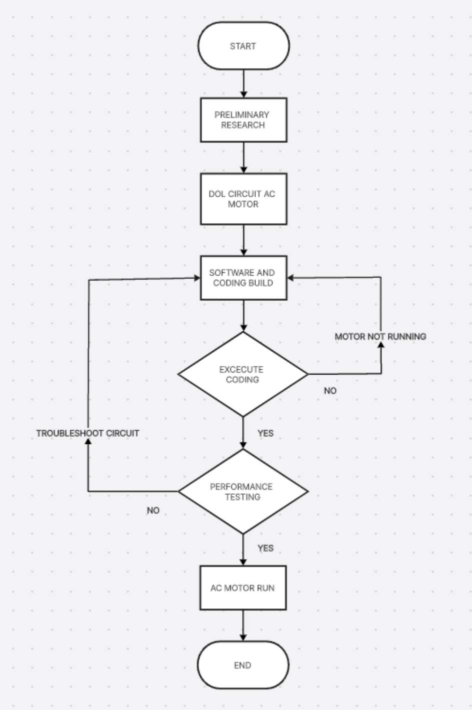


Fig.1 *Project flowchart design*

Fig 2 shows a block diagram of the overall AC motor speed control and monitoring system using an Arduino UNO with PID control capabilities. The Arduino UNO will be the main controller that uses PID control; the Arduino UNO will maintain an accurate motor speed by continually changing the input to maintain speed. As the input is changed, the PID controller will calculate the new input based on the difference between the desired speed and the actual speed. Furthermore, the Arduino will integrate with MATLAB and Simulink, as simulated logic will be used to analyze the motor performance and tune the PID parameters to ensure the controlled motor is performing at its best. An IoT platform will provide a real-time representation of motor data. The data from the IoT platform provides a visual of past motor performance, which in turn allows the user to make reliable comparisons of trends and increase motor efficiency. Overall, this system utilizes embedded control, simulated design and cloud-based monitoring for a complete motor control system.

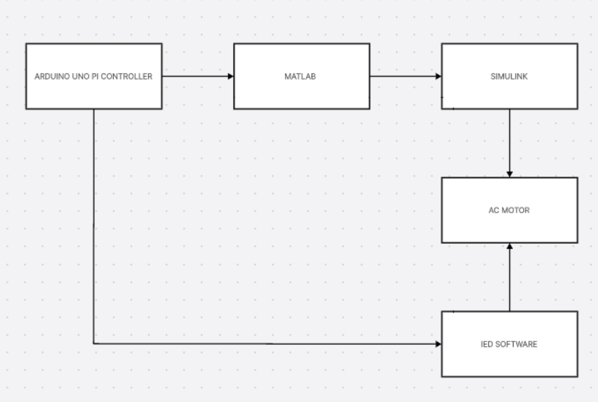


Fig.2 *Control speed AC motor*

2.2 Process Flowchart

The operation flowchart of the IoT-based AC motor control system is shown in Fig 3 the processes start with the initialization of Arduino UNO, the main controller system. The system interfaces with the mobile application Blynk to allow remote control to the speed of the motor. While the system is not receiving any control signal, it will keep searching. When an appropriate signal is acquired, the Arduino energizes the motor driver, which supplies the power, and the relay that connects the motor safely across the power source. The motor starts running, while the system maintains supervision of its operation. Should this be done successfully, the process comes to an end. In the case of any issue, the system reruns for troubleshooting to ascertain reliability. This arrangement enables safe remote control of the AC motor through a user-friendly IoT interface.

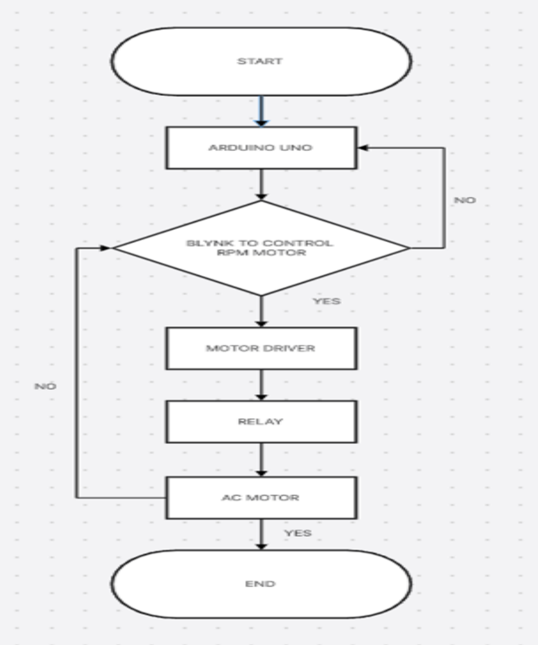


Fig.3 *Flowchart of the operation process*

2.3 Prototype Block diagram

In Fig 4 you will see the block diagram for the whole system. The Blynk mobile app acts as a wireless remote control sending speed commands to the Arduino UNO. The Arduino then, acting as the brain of the system, exercises PID control to compare what the speed should be with what it is and automatically make adjustments to the motor speed. You see the values on the Arduino serial monitor in real time including the target speed, current speed, and the amount of adjustment being made. A motor driver connects the low power Arduino unit to the high-power AC motor, boosting the low power control signals to also isolate the electronics. Therefore, the system is able to maintain speed once set automatically, as the Arduino will continually adjust, is classified as a smart and responsive system. You will see that it also provides not only wireless remote control of the motor speed, but for an additional level of convenience a way to monitor the status remotely via mobile device.

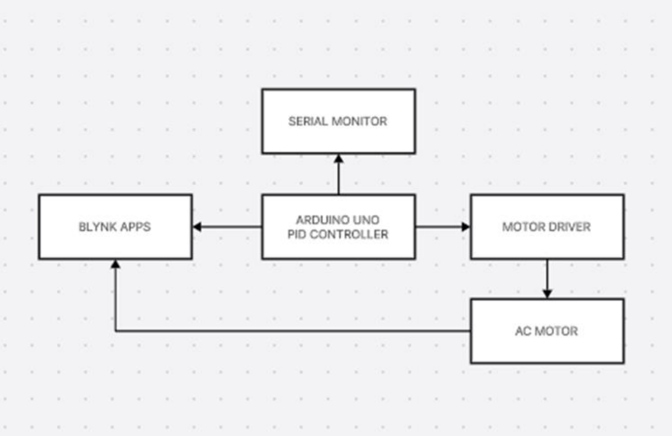
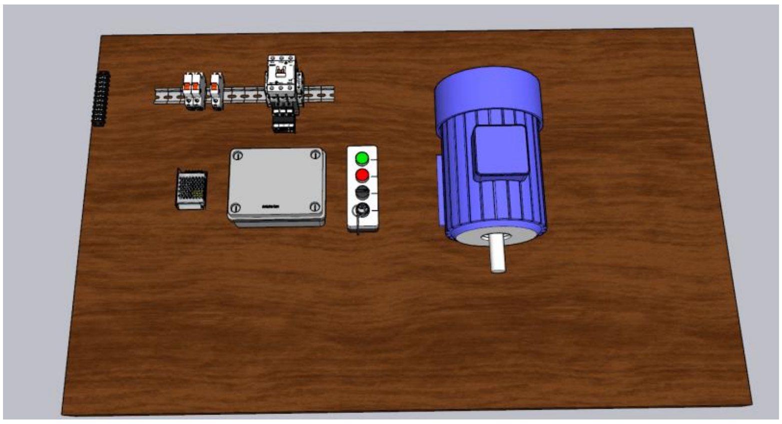


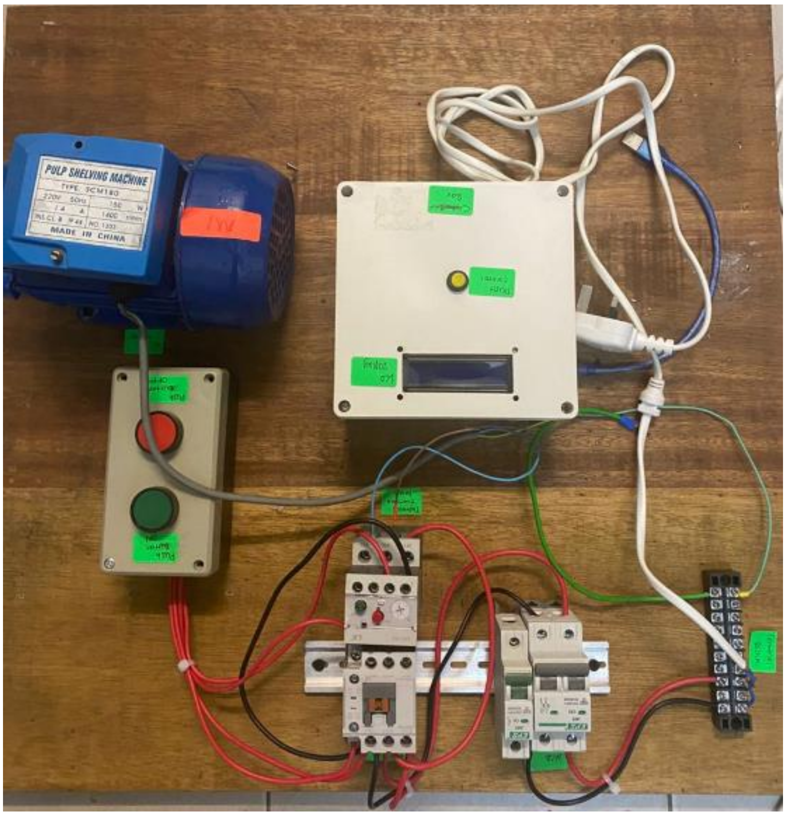
Fig.4 *Prototype Block diagram*

2.4 Design System

Fig 5 (a) represents the 3D design prototype of the project placement without wiring. The terminal block will be the connections for single phase, where the MCB will connect double pole and single pole. The MCB double pole will connect to the contactor and TOR (thermal overload relay). The contactor will connect the push button and motor with direct online single-phase circuit. The Arduino box will house all the electronic part such as Arduino and relays for controlling the motor speed. The Arduino will be powered with the AC to DC converter which will provide the Arduino with 5V power supply to turn ON Arduino. Fig 5 (b) show the actual design DOL circuit and the lamp will be tested as a motor for troubleshoot.



(a)



(b)

Fig.5 *3D Design prototype of the project: (a) Actual design prototype: (b)*

3.0 Result and Discussion

This chapter analyses results and discussions from experiments on MATLAB Simulink with PID controller. Firstly, the single-phase ac motor, voltage output voltage and current, power and speed of the single-phase is analyzed. The purpose of those tests is to verify and discover how the AC motor single-phase operates and differs from one another. So, we will discover the efficiency characteristics of the AC motor short and long term, in relation to its running characteristics. The purpose of these investigations is to show the AC motor speed control function and its effectiveness, this will illustrate all characteristics of the device when practically applied.

This is illustrated by the simulation results of tuning an induction motor with MATLAB Simulink; represented in fig.6 the results show the plots of three key elements relating to the assessment of motor performance of the main winding current (top); rotor speed (middle) and electromagnetic torque (bottom). Simulations like these are necessary exercises in control system design for induction motors with a goal of achieving the best results in terms of performance, stability and efficiency.

The top plot shows Main Winding Current, which is the current in the stator windings while the motor is running. The inrush current is evident in the initial spikes of the current. This waveform stabilizes after the motor reaches steady-state operation. As you have studied previously, proper tuning limits the oscillations while keeping the current to the motor within its limits.

The middle plot shows Rotor Speed, which is the rotor speed as a function of time, giving a sense of how the motor accelerates to the desired speed setpoint. The slow climb at the beginning is related to the transient behaviour of the motor during start-up. The tuning of the motor controller provided a smooth transition to the desired speed (setpoint). Factors such as excessive overshoot or long dwell times when coming to a stop may occur if the PID controller parameters are not set properly.

The bottom plot shows Electromagnetic Torque, which is how much torque was generated by the motor itself. The torque jumps about quite a bit initially due to the inertia of the motor and the load resistance. The oscillations in torque get smaller as the motor reaches steady-state operation. This demonstrates that good tuning of the system will keep torque limiting to a minimum, which will decrease the amount of mechanical stress on both the motor components as well help ensure that the loads do not simply jump to their steady-state values.

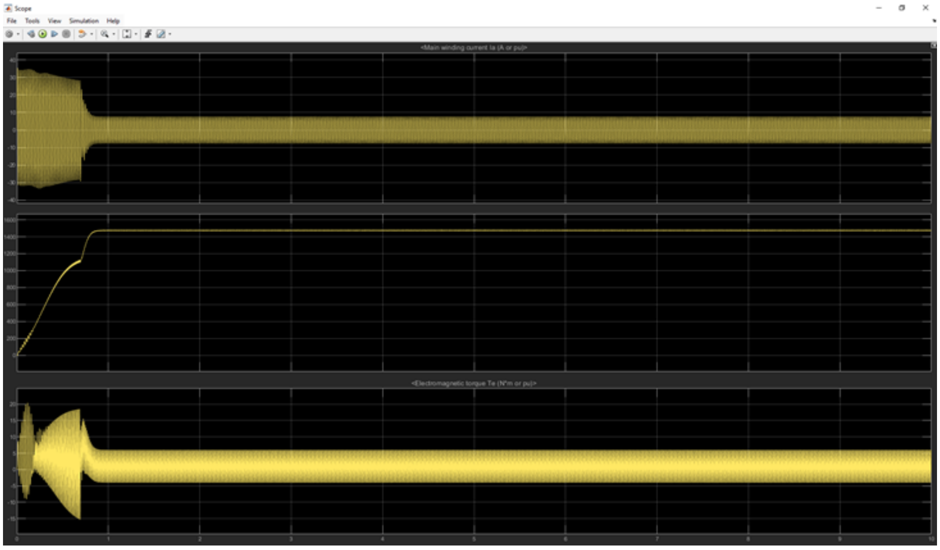


Fig.6 *Simulation MATLAB Simulink for Ac induction motor*

3.1 AC Motor Performance

Performance data for AC motors Table 1 includes key operational parameters of an AC motor as related to different speeds expressed in revolutions per minute, (RPM). The parameters in the table are voltage (V), current (A), frequency (Hz) and power (P). Given that the variables were plotted according to speed and the frequency shows a constant value of 50 Hz, all the values indicate that the motor operated at a fixed frequency, which was standard for AC systems in most parts of the world.

The power values are calculated using the formula for electrical power in AC circuits:

$$P = IV \tag{1}$$

Assuming a power factor of 1, the power can be directly computed as the product of voltage and current. For instance, at 1400 RPM, the power is 330V×6A=1980W,330V×6A=1980W, which matches the table value.

It should be noted that power output has fallen with an increase in motor speed meaning electrical output must be lower with decreased RPM. This is shown with all the reported values are zero at 0 RPM which essentially means the motor is not running. The table displays a nonlinear relationship between speed and power suggesting there are different efficiencies or loads associated with operational circumstances at each point. The data shown here provides important evidence for evaluating motor performance under specified conditions.

Subsequent analysis could begin with the derivation of efficiency and torque tendencies associated with the data collected above.

Table 1 *AC motor performance data table*

Speed motor [RPM]	Voltage [V]	Current [A]	Frequency [Hz]	Power [P]
1400	330	6	50	1980
1200	250	6	50	1500
1000	220	5.5	50	1210
800	180	2	50	360
600	140	3.5	50	490
400	110	5	50	550
200	60	4.5	50	270
0	0	0	50	0

The graphs illustrated in fig 7 and 8 describe the performance characteristics of a motor as a function of voltage, speed, and current. Fig 7 illustrates the relationship between input voltage and motor speed indicating that the input voltage and motor speed (RPM) would have a linear relationship leading to an increase in speed as input voltage increases. The graph starts at 0 RPM and 0 V, thus as the voltage increases the speed also increases with a linear gradient. At maximum speed, with maximum voltage, the motor speed is approximately 350 RPM, with the motor speed and applied voltage having a linear relationship. In general**,** then, it would be fair to say that speed could be controlled as a function of input voltage, which may turn out to be a practical discovery for applications where speed is required to be controlled.

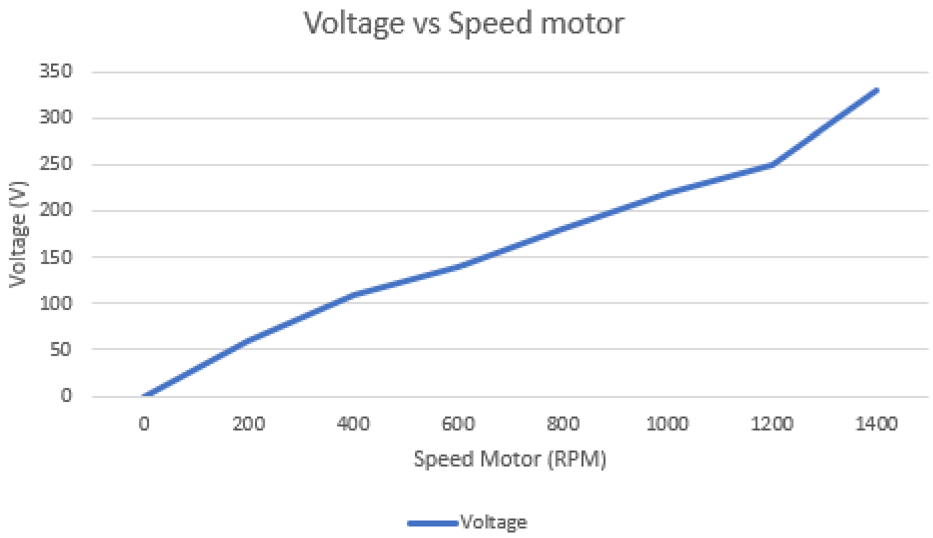


Fig.7 *Performance Voltage and Speed motor*

In figure 8 the voltage and current data presents a nonlinear relationship. Current stayed relatively level at around 1–2 A over the range of voltages we used first (0–60 V), however when the voltage was increased above that level the current skyrocketed to around 6–7 A at 330 V. The changing relationship may indicate some resistive or inductive properties in electrical systems for the motor, or, indicates the operating thresholds for the motor, where increasing voltage requires much higher levels of current. This data was important for the supply voltage and potential power demand of the motor, and our efficiency objectives, while designing power supplies and general energy use issues while system operational conditions change. All of these graphs when taken together provide a more compelling picture of the motor's electromechanical performance to support optimization, a custom analysis to specific settings or applications.

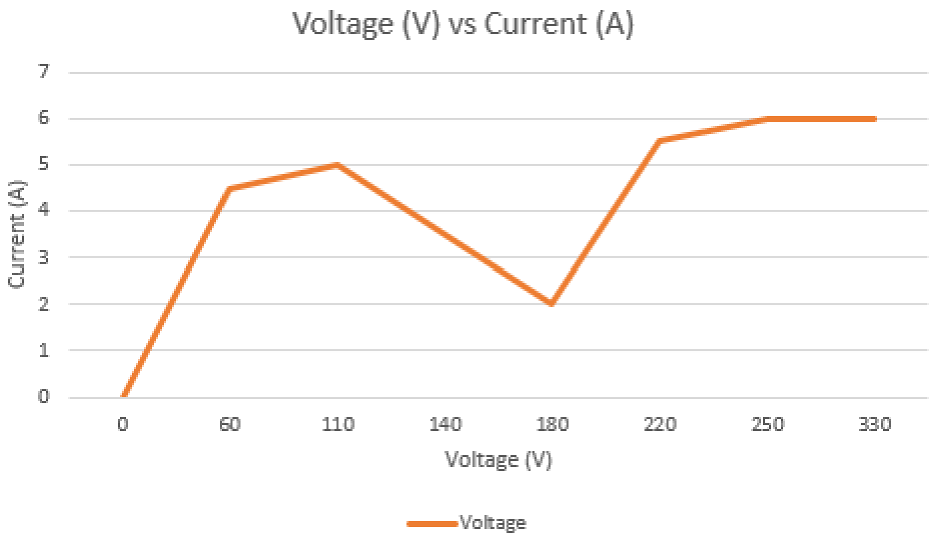


Fig.8 *Performance Voltage and Current*

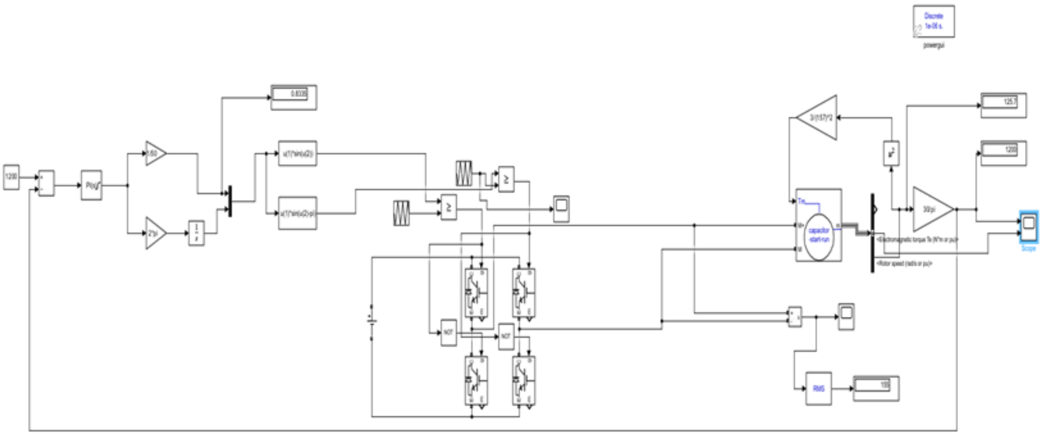


Fig.9 *MATLAB simulation Circuit for AC speed motor*

3.2 AC Speed motor graph result at setting 1400RPM

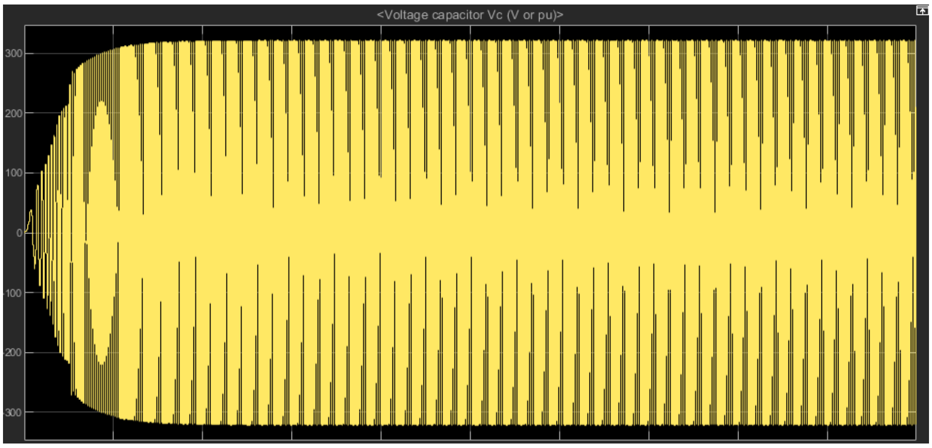


Fig.10 *Voltage AC motor*

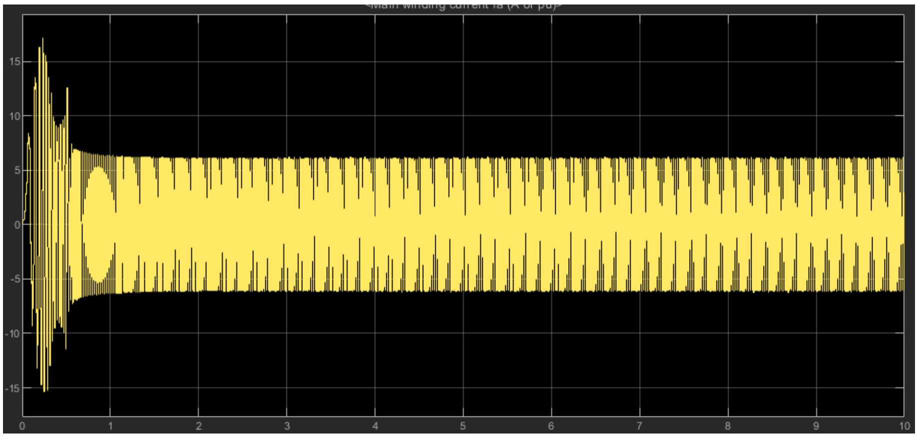


Fig.11 *Current AC motor*

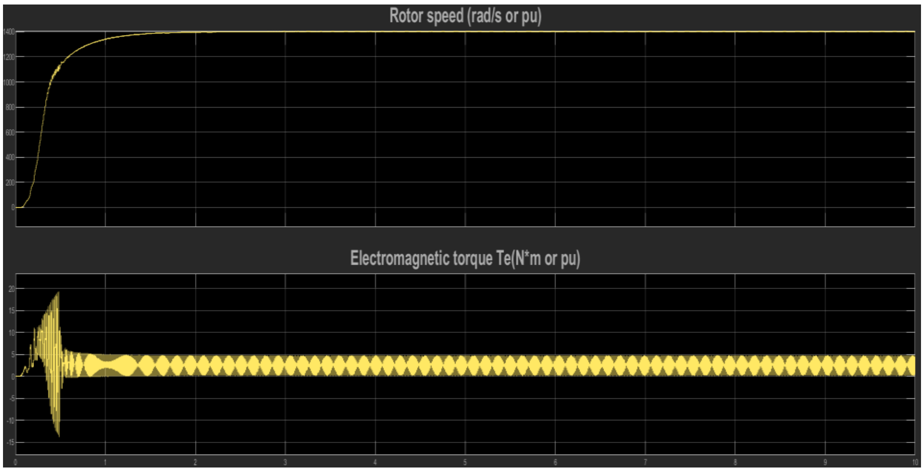


Fig.12 *PID for control 1400 RPM*

4.0 Conclusion

In conclusion, this kit provides a low-cost, realistic method of learning about AC motor speed control. Its modular configuration encourages experimentation and promotes understanding through real time of motor performance. As a hybrid learning tool, it can incorporate theoretical strength and textbook learning while simplifying a complex subject such as speed regulation. With the use of the open-source Arduino platform, it serves as a tool that is flexible, low-cost and a user-friendly solution for students and hobbyists. This instruction will fulfil theorized curriculum requirements toward synchronous motor control in classrooms, and create real-world applications for motor control.

4.1 Future Recommendation

To improve this kit by adding some advanced features to the kit would improve the kit even further. For instance, providing the kit with wireless features would allow remote monitoring and control, which is in line with trends related to Internet of Things (IoT). Another option would be adding an easy-to-use graphical user interface (GUI) feature to help visualize and control the data. This technologically advanced feature could also enhance the interaction and understanding for users. Documentation with specifics would also help support learners with different levels of expertise, as would video tutorials to help support the learning experience. Additionally, adding literature to support DC motors and stepper motors could enhance the kit's usability and make it appealing to a broader audience. Ultimately, these features could enhance the educational value of a kit and, along with adhering to established standards of education, increase its use in both industrial and research purposes.

Acknowledgement

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

References

[1] Banik, A., Umesh, J., Bhadade, G., & Gaikwad, A. (2023a). Speed Control of Single Phase Induction Motor using TRIAC and Bluetooth Device. 2023 IEEE 2nd International Conference on Industrial Electronics: Developments & Applications (ICIDeA), 516–521. https://doi.org/10.1109/ICIDeA59866.2023.10295264

[2] Sharma, U., & Singh, B. (2021a). Investigations on TRIAC Based Speed Controller for a Single-Phase Induction Motor Ceiling Fans. 2021 International Conference on Sustainable Energy and Future Electric Transportation (SEFET), 1–6. https://doi.org/10.1109/SeFet48154.2021.9375803

[3] Sang, Y., Li, F., Dai, Y., & Duan, F. (2015b). The practical control technology design for AC servo motor based on STM32 micro-controller. 2015 IEEE Advanced Information Technology, Electronic and Automation Control Conference (IAEAC), 1–5. https://doi.org/10.1109/IAEAC.2015.7428506

[4] Saad, M., Amhedb, A. H., & Al Sharqawi, M. (2021). Real time DC motor position control using PID controller in LabVIEW. Journal of Robotics and Control (JRC), 2(5), 342–348. https://doi.org/10.18196/jrc.25104

[5] Rikwan, R., & Ma'arif, A. (2023). DC Motor Rotary Speed Control with Arduino UNO Based PID Control. Control Systems and Optimization Letters, 1(1), 17–31. https://doi.org/10.59247/csol.v1i1.6

[6] Ma'Arif, A., Nabila, H., Iswanto, & Wahyunggoro, O. (2019). Application of Intelligent Search Algorithms in Proportional-Integral-Derivative Control of Direct-Current Motor System. Journal of Physics: Conference Series, 1373(1). https://doi.org/10.1088/1742-6596/1373/1/012039

[7] Metha, V. R., & Karvekar, S. S. (2018). Speed Control of Induction Motor using A Fuzzy Logic Controller and Direct Torque Controller. 2018 4th International Conference for Convergence in Technology (I2CT), 1–5. https://doi.org/10.1109/I2CT42659.2018.9058085

[8] Angalaeswari, S., Kumar, A., Kumar, D., & Bhadoriya, S. (2016). Speed control of permanent magnet (PM)DC motor using Arduino and LabVIEW. 2016 IEEE International Conference on Computational Intelligence and Computing Research (ICCIC), 1–6. https://doi.org/10.1109/ICCIC.2016.7919599

[9] Al Rakib, Md. A., Rahman, Md. M., Hossain, Md. M., Rahman, Md. A., Samad, M., & Abbas, F. I. (2022). Induction Motor Based Speed and Direction Controller. European Journal of Engineering and Technology Research, 7(6), 82–86. https://doi.org/10.24018/ejeng.2022.7.6.2868

[10] Arif, Y. C., Rakhmawati, R., Saksana, A., & Suhariningsih. (2019). Implementation of AC-AC Voltage Controller for Reduce Transient Current at Three Phase Induction Motor. 2019 International Seminar on Application for Technology of Information and Communication (ISemantic), 465–470. https://doi.org/10.1109/ISEMANTIC.2019.8884300

[11] B S, D. S., & V, P. (2022). Single Switch Controlled Single Phase Induction Motor. 2022 IEEE North Karnataka Subsection Flagship International Conference (NKCon), 1–4. https://doi.org/10.1109/NKCon56289.2022.10126669

[12] Bich, M. N. T., & Le, N. T. (2022). Digitalizing the Speed Control Circuit of Three-Phase Induction Motor Based on Pulse-Width Modulation using Proteus Software. 2022 International Conference on Engineering and Emerging Technologies (ICEET), 1–6. https://doi.org/10.1109/ICEET56468.2022.10007306

[13] Ma, K., Ma, L., & Kong, C. (2023). Research on Motor Control Technology of New Energy Vehicle Based on MATLAB. 2023 7th International Conference on Robotics, Control and Automation (ICRCA), 16–20. https://doi.org/10.1109/ICRCA57894.2023.10087680

[14] Kamalapur, G., Shivaleela, Aspalli, M. S., & Siddaling, B. (2022b). A Single Phase AC-AC Converter with Extinction Angle Control for Single Phase AC Motor. 2022 2nd International Conference on Power Electronics & IoT Applications in Renewable Energy and Its Control (PARC), 1–4. https://doi.org/10.1109/PARC52418.2022.9726633

[15] Tir, Z., Malik, O., Hamida, Med. Assaad., Cherif, H., Bekakra, Y., & Kadrine, A. (2017). Implementation of a fuzzy logic speed controller for a permanent magnet dc motor using a low-cost Arduino platform. 2017 5th International Conference on Electrical Engineering - Boumerdes (ICEE-B), 1–4. https://doi.org/10.1109/ICEE-B.2017.8192218

[16] Umar, M., Shaikh, I.-U.-H., & Ali, A. (2022). Speed Control of Direct Torque Control Induction Motor Drive using Fuzzy Adaptive PID Controller. 2022 19th International Bhurban Conference on Applied Sciences and Technology (IBCAST), 549–555. https://doi.org/10.1109/IBCAST54850.2022.9990515

Sapmaz, T., Etçi, H., Senol, I., & Oner, Y. (2022). Optimization of Three Phase Squirrel Cage Induction Motor. 2022 Global Energy Conference (GEC), 148–153. https://doi.org/10.1109/GEC55014.2022.9986878