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Development of Prototype Protection Scheme for Distributed Generation in Low Voltage Distribution Network

Joshua Suneil Selvan[1], Lam Hong Yin[1]*

[1] *Faculty of Engineering Technology, UTHM Kampus Pagoh, Hab Pendidikan Tinggi, Pagoh, Jalan Panchor, 84600 Panchor, Johor, MALAYSIA.*

*Corresponding Author: hylam@uthm.edu.my
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Abstract

The low-voltage LV distribution network is the last stage of the power network, which is connected directly to the end-user customers and supplies many dispersed small-scale loads. It is a worldwide practice to inject renewable energy sources RESs into the electricity grid, which is a subset of distributed generation DG capacity. In addition, different types of low-carbon technologies LCTs, such as electric vehicles are becoming widely used. A significant portion of RES and LCTs is penetrated into the LV distribution network, which poses a wide range of challenges. To address these challenges, there is a persistent need to develop traditional planning and operation frameworks to cope with these new technologies. Hence the setting for the traditional protection relays has become unsuitable to the future distribution system with high penetration of distributed generation. In order to ensure the quality and reliability of the power supply, the issues raised by DG need to be solved. In this study, the impacts of high penetration of distributed generated to existing protection schemes are investigated. The new protection schemes are designed for the distribution network with high penetration of DG. As for this project we propose developing a prototype which can ensure protection for distributed generation in the in (LV) distribution network. The prototype is designed in a way to detect overvoltage, undervoltage, overcurrent, undercurrent and power which is caused by distributed generation, and when the relay detects an overvoltage or any other fault in the circuit, it displays in the LCD screen, and the current flow is cut off. Summarily, this project can provide a better and more efficient protection for end-users.

1. Introduction

Malaysia has traditionally depended on conventional power generation, including natural gas, coal, and hydropower. As a signatory nation to the Conference of Parties to the United Nations Framework Convention on Climate Change, Malaysia has pledged to reduce its greenhouse gas emission intensity of GDP by up to 45% by 2030 by implementing clean, sustainable, and renewable energy (RE). Malaysia aims to increase renewables, excluding hydropower, to 20% of the generation mix by 2025. As part of the process, Malaysia is expected to expand renewable capacity from 6 to 14GW, rising from 18% to 30% of the generation mix. In Sarawak, the

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government has adopted the most ambitious climate initiatives among the Malaysian states and has announced targets to achieve over 70% RE in its power mix by 2030 [1]. The Energy Commission of Malaysia estimated the historical demand growth for electricity in Malaysia to be around 2.5% per year. The Malaysia Generation Development Plan 2019 projected that electricity demand for 2020-2030 is expected to grow at 1.8% per annum. Over this same period, Malaysia will need about 10.0 GW of new capacity to meet its demand growth, which will require replacing retiring plants and ensuring system reliability [2].

1.1 Background

The distributed generation system is a common occurrence in the low-voltage scenario as shown in the fig 1.0 below. As such the importance of DG penetration becomes more significant in the current Malaysian Energy Policy. Hence the undervoltage and overvoltage fluctuations could significantly affect the performance of connected systems [3].

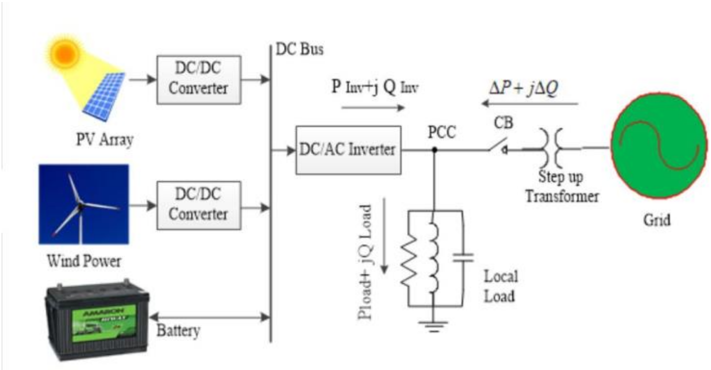

Fig.1: *Typical DG system* [4]

1.2 Aims and Objectives

The aim of the project is to understand the issues of undervoltage and overvoltage on systems that have high penetration distributed generation (DG) and demonstrate a working model that can detect these criteria so that effective power control and management of the low-voltage distribution system is meaningful. These are main objectives that are achieved during this project is designing and developing a prototype hardware of a low-voltage distribution system which can monitor and control software for overvoltage detection. Finally, to evaluate the performance of the designed hardware and software.

1.3 Problem Statement

The integration of distributed generation DG systems, such as renewable energy sources and small-scale power generators, into low-voltage distribution networks presents a unique set of challenges related to system protection. Existing protection schemes designed for traditional centralised power generation may not be adequate to address the dynamic and decentralised nature of distributed generation. Therefore, the development of a robust and efficient prototype protection scheme tailored specifically for low-voltage distribution networks with distributed generation is imperative. Sudden current and voltage surges cause damages to the equipment and power loss. By integrating IoT and creating a smart grid the distribution network will be always be in a standby mode to overcome scenarios mentioned above and save cost.

1.4 Scope of Project

Protecting low-voltage distribution systems against high-penetration distributed generation DG is a critical aspect of maintaining the reliability and safety of the electrical grid. As more renewable energy sources, such as solar panels and wind turbines, are integrated into these distribution systems, the protection scheme needs to evolve to address the challenges posed by high DG penetration.[5] The project's main scope is to integrate IoT using Blynk app to detect low voltage and high voltage. In case there is a sudden surge of DG in the distribution system which causes high voltage then the protective equipment such as circuit breaker or relay is used to isolate the fault area and cut off the current connection from reaching the load which can cause serious damage. By integrating IoT it will be much easier to collect data and get notified about the faults that occur which can be used for reference in the future to avoid such critical circumstance. Testing plans are developed to cover various faults scenarios like high and low voltage to evaluate the performance of the prototype. In summary, the scope of a protection scheme against high-penetration distributed generation in a low- voltage distribution system involves a comprehensive approach that addresses not only fault protection but also grid stability, communication, and compliance with standards. As the grid continues to evolve with increased DG integration, these protection schemes will become more critical to maintaining a reliable and resilient electrical system. The project's performance assessment will revolve around evaluating its reliability, efficiency, and overall effectiveness followed by the culmination of the project which involves the preparation and thorough documentation of a comprehensive report summarizing the project's findings and presenting recommendations based on the research and implementation outcomes.

2. Materials and Method

2.1 Materials

The prototype is made up of two microcontrollers which are Arduino Uno and ESP 32 which acts as central control unit and communication unit. Arduino Uno is used for the coding to determine the undervoltage, overvoltage, current and power. The prototype is programmed in a way when there is sudden voltage drop or overvoltage occurs due distributed generation the relay trips and stop the flow of current. ESP 32 is the microcontroller that acts as a WI-FI module that connects with the Blynk app via mobile hotspot. Internet of Things is implemented and the amount of current, voltage and power collected and send to the Blynk app in user's smartphone. The circuit consist of voltage sensor, current sensor, power supply of 12V 5A and protection devices such as relay and circuit breaker. By implementing IoT data collection has become much easier for future improvement. All the materials used in the project:

- Arduino Uno
- ESP32
- ACS712 Current Sensor
- Voltage Sensor ZMPT101B
- LCD 16×2
- Residential Circuit Breaker
- 5V Relay Module
- LED
- Buzzer
- Power Supply 5V 20A

2.2 Method

2.2.1 System Block Diagram

The fig 2, illustrates the block diagram of the project which will give a clear picture of the prototype circuit. The ESP 32 with WI-FI module is programmed to link with Blynk app via mobile hotspot. Arduino UNO is programmed to detect low- voltage and high current via voltage and current sensors. If there is a scenario of high current then the Arduino UNO signals the ESP 32 which then trips the relay and displays in LCD screen high voltage and sends notification to user's email via Blynk app.

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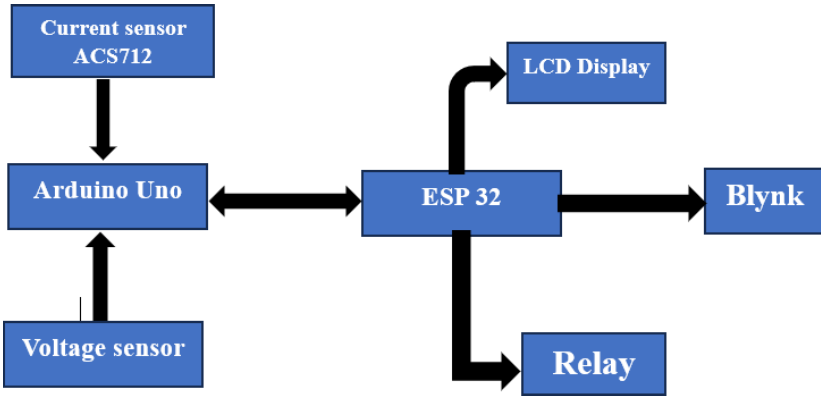

Fig. 2: *Block diagram of the project*

2.2.2 Schematic Circuit of Prototype

Fig 3 and fig 4, below shows the schematic circuit and animated circuit diagram of the prototype drawn in Fritzing software. Fritzing software libraries has all the sensors, microcontrollers and other electronic equipment used in the prototype thus making it easier to simulate without modifying the original source code as the same devices were used to build the prototype.

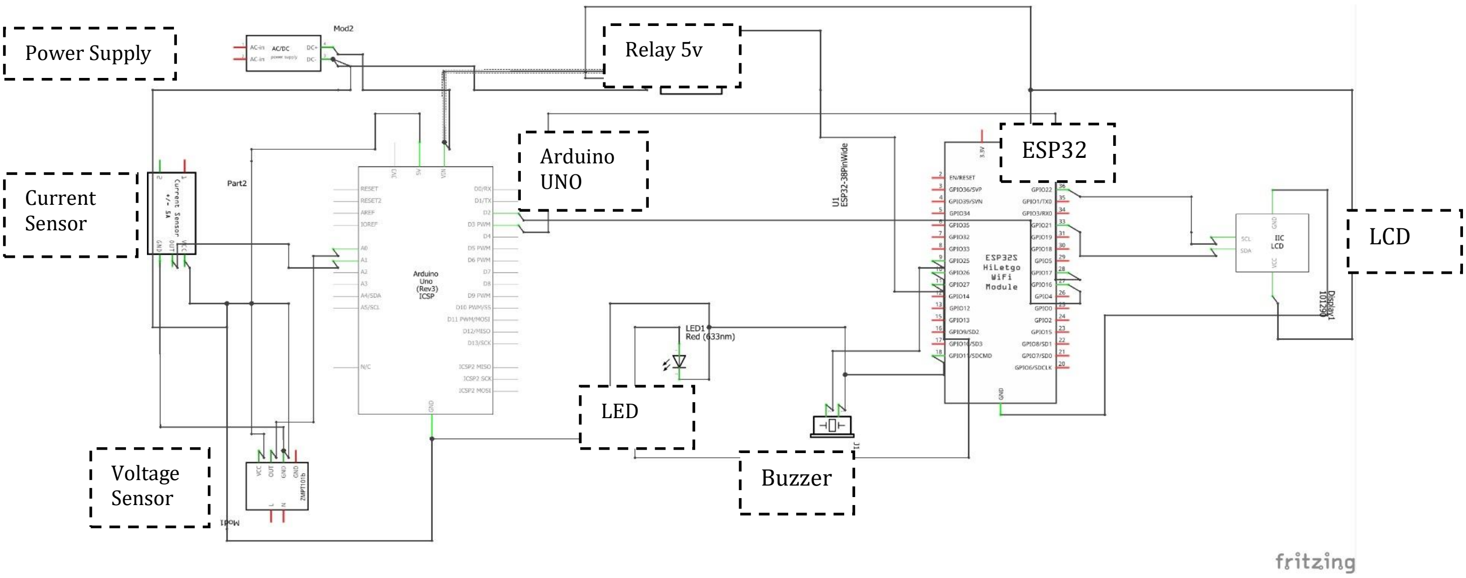

Fig. 3: *Schematic Circuit Diagram*

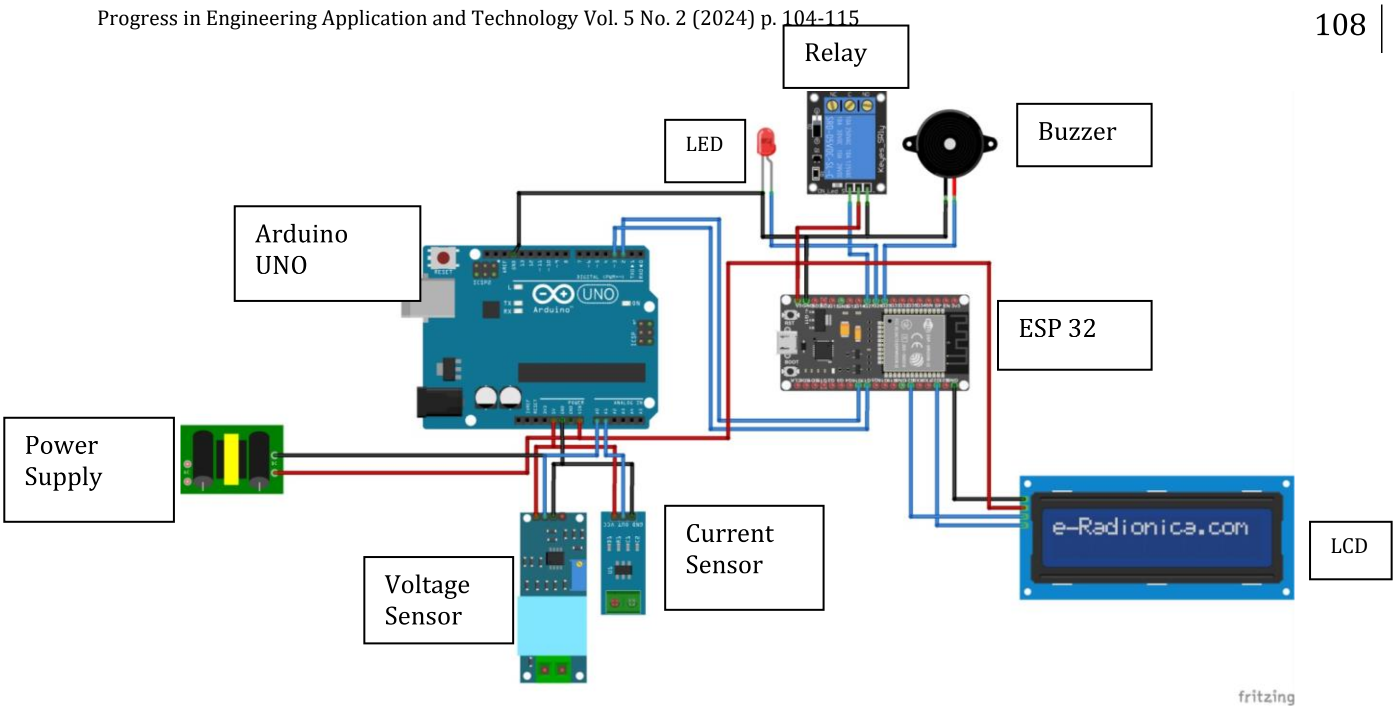

Fig. 4: *Animated Circuit Diagram*

2.2.3 System Flowchart

Fig 5, illustrates about the operating principle of the prototype. The prototype has to establish connection via mobile hotspot to connect with the Blynk app via specified Wi-Fi network as defined in the program code. Once connected the voltage and current value can be set in the Blynk app. Then, use the voltage adjuster in the prototype to increase or decrease the amount of voltage that can pass through the prototype to create a scenario of low voltage or high voltage. If the voltage is more than the set value in the Blynk app the relay trips cutting off current connection to the load and LED blinks and buzzer rings. An email notification is sent to the user. If the voltage set in the prototype is the same as the set value in Blynk app then power is supplied to the load.

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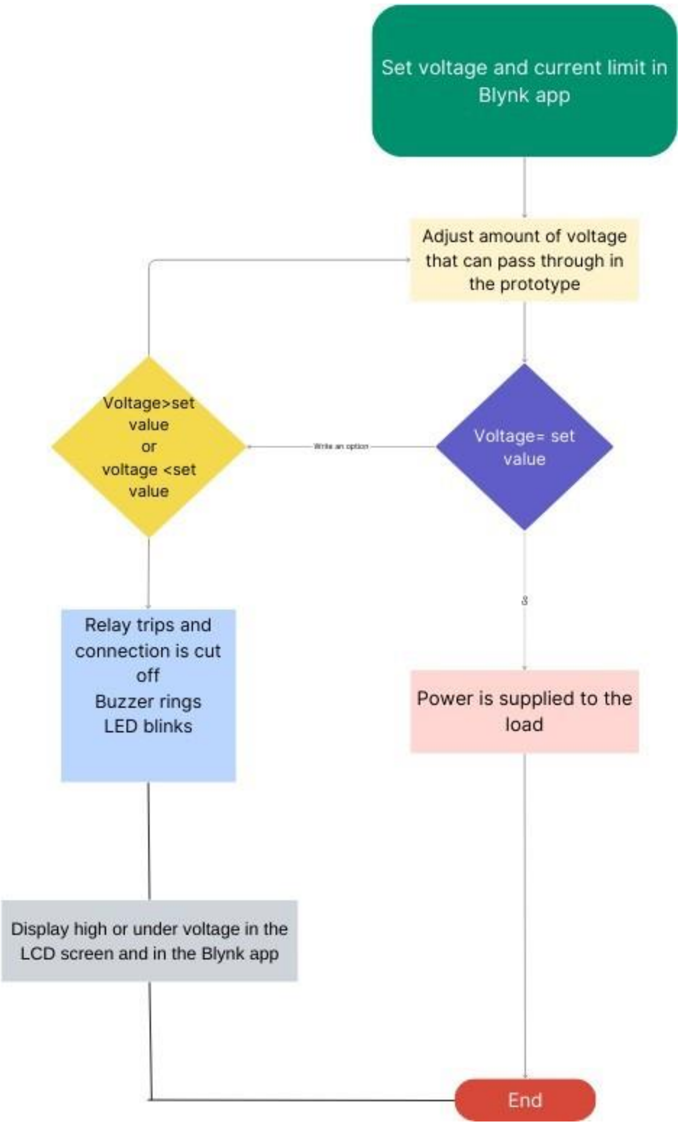

Fig5: *System Flowchart*

2.2.4 Structural Design of Prototype

The structural design of the prototype is designed in a way for easy maintenance and future improvement. The design allows air flow for ventilation to avoid overheat and easy access to repair if any fault occurs. The fig 6 below shows the prototype design drawn in AutoCAD.

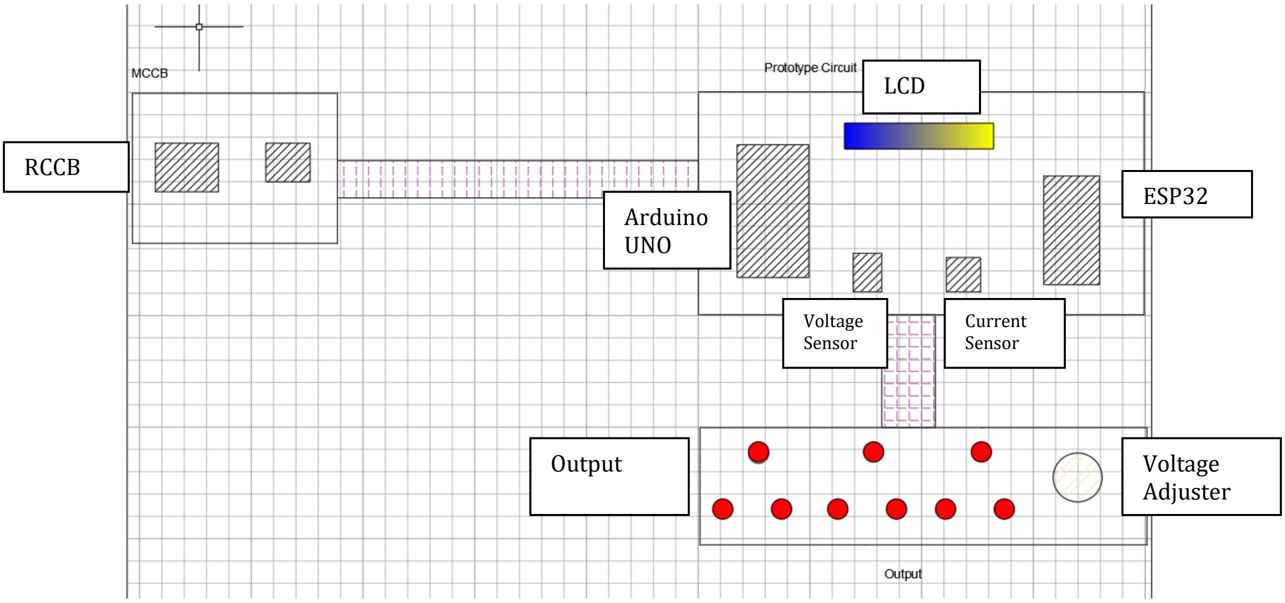

Fig. 6: *Structural Design of Prototype*

3. Result and Discussion

3.1 Actual Prototype

The fig 7 and fig 8 below illustrate the internal and external design of the prototype and design of the circuit.

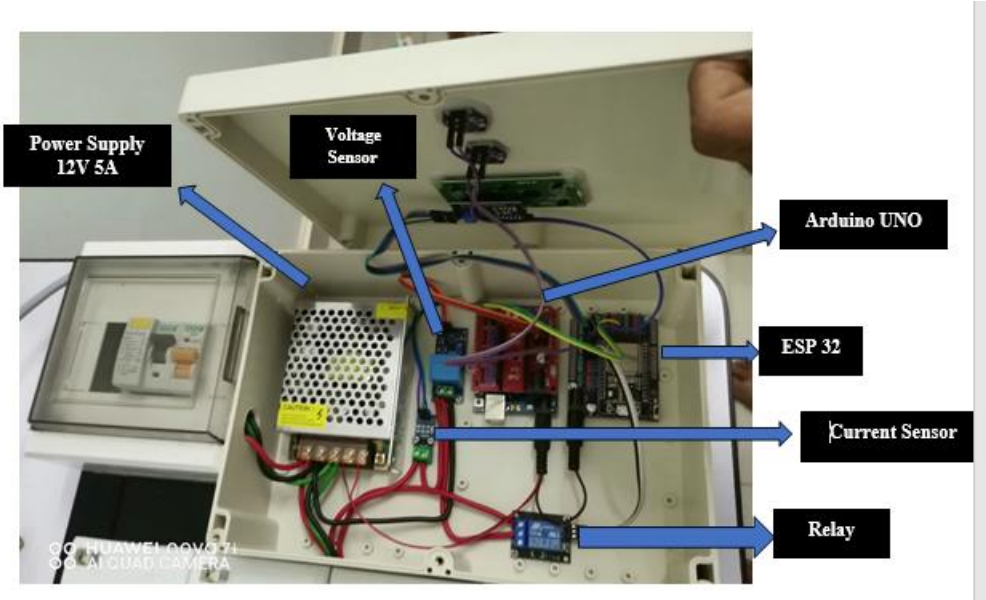

Fig. 7: *Circuit built of the prototype*

Fig. 8: *Actual structure of the prototype*

3.2 Prototype Testing Results

The prototype is programmed in way to create high current and low voltage situations by setting the voltage and current using the Blynk app and adjusting the voltage adjuster in the prototype to set high or low voltage values. When an overcurrent or low voltage occurs the circuit trips by disconnecting the load and the power supply. The figures below illustrate the function of the prototype in more detail.

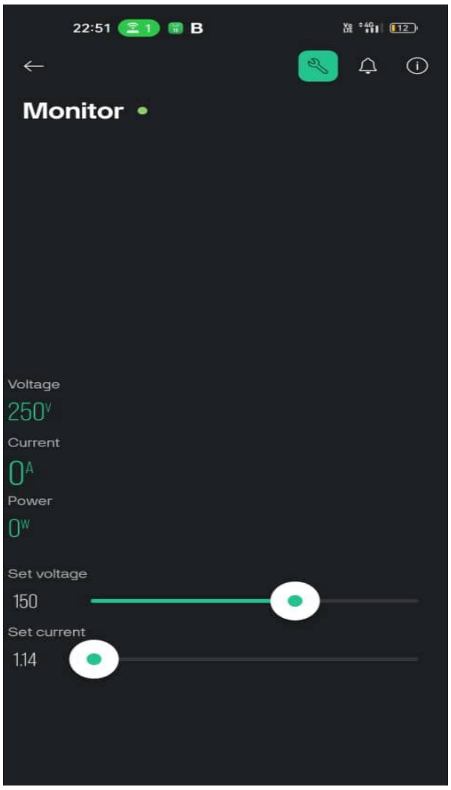

Fig. 9: *Set voltage and current value*

The fig 10 below shows the LED bulb is off due to low voltage as the voltage is decreased using the voltage adjuster in the prototype.

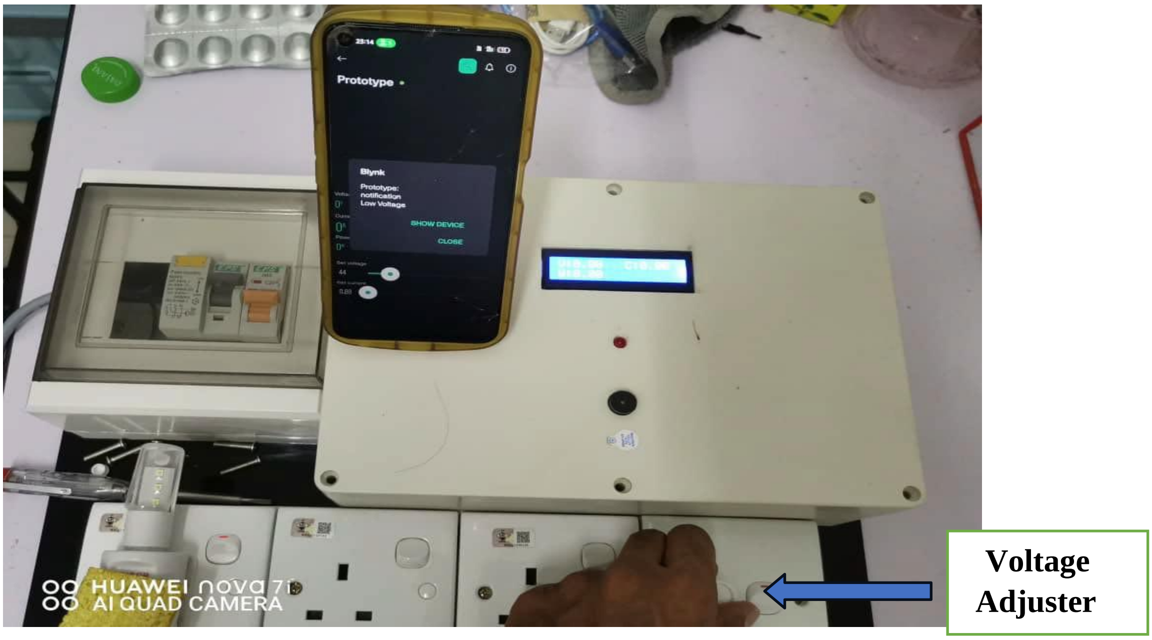

Fig. 10: *Adjust voltage to create low voltage or high current situation*

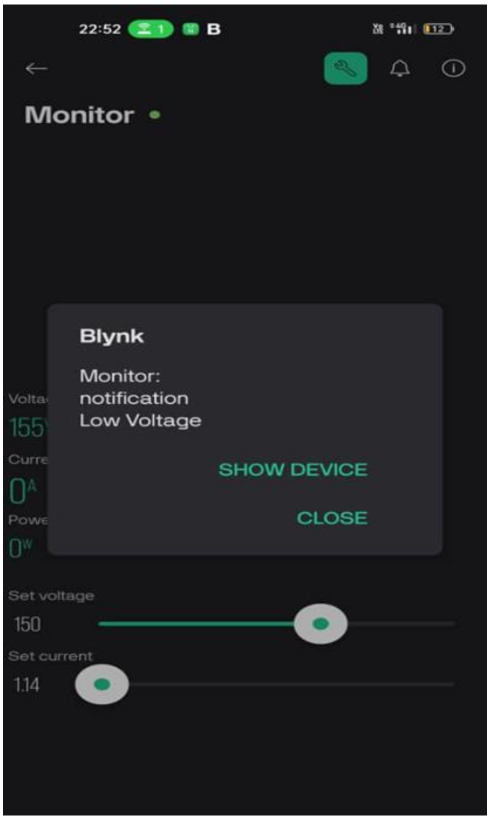

Fig. 11: *Blynk app notification for low voltage*

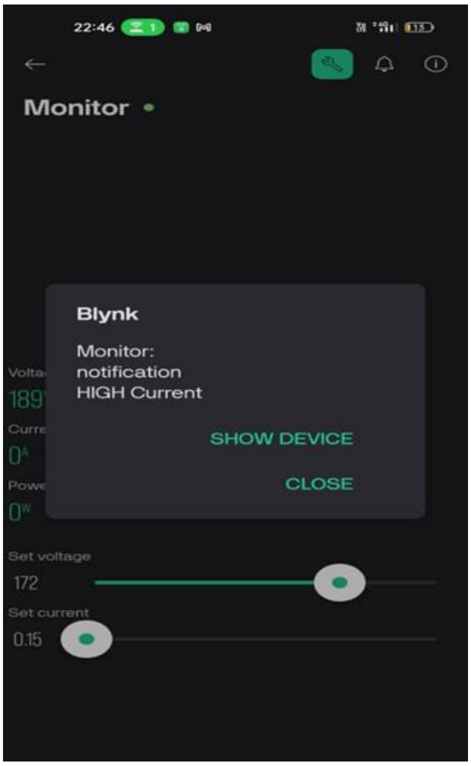

Fig. 12: *Blynk app notification for high current*

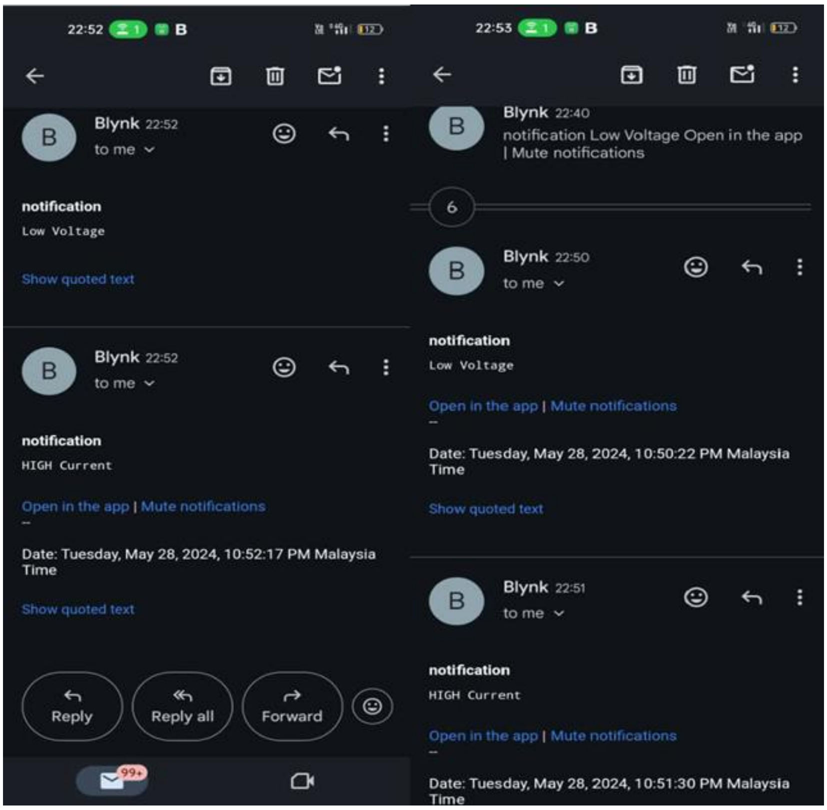

Fig.13: *Email notifications from Blynk app*

The fig 14 shows the LED light is on as sufficient amount of voltage and current being supplied to the load.

Fig. 14: *The LED bulb lights on*

4. Conclusion

The development of a prototype protection scheme for distributed generation in low- voltage distribution networks represent a significant advancement in ensuring the reliability, safety, and efficiency of modern power systems. This project has focused on creating a robust and adaptable protection scheme that addresses the unique challenges posed by integrating distributed generation into existing LV distribution networks. In conclusion, the prototype protection scheme for distributed generation in low-voltage distribution networks is a critical step towards enhancing the resilience and efficiency of modern power systems. With further development and validation, it holds the potential to become an integral component of future smart grid infrastructures, facilitating the widespread adoption of distributed generation and contributing to a more sustainable energy future. This project can be further improved by deploying smart sensors throughout the network to monitor voltage, current, and frequency in real-time. These sensors can quickly detect abnormalities and help in isolating faults and utilize machine learning for fault prediction and identification. Lastly, design the system with future advancements in mind, ensuring it can integrate new technologies and adapt to changing network demands.

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