Design of Smart Grids Protection Devices

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Abstract This project aims to improve the reliability and flexibility of the electric power system by implementing a solid protection system using relays and circuit breakers. These components help to reduce outages, enable quick network recovery, and enhance the system's readiness for emergencies. The relays and circuit breakers are programmed using Arduino and connected to an ESP32 piece, with the status displayed on a screen. This project can help improve the overall performance of the electric power system, making it more resilient and efficient.

Keywords Smart grids · Protection relays · Matlab Simulink

1 Introduction

The power system is an essential infrastructure that delivers electricity from the power plant to consumers through a network of transmission lines, substations, transformers, and other components [1]. However, this system has its limitations, and its reliability and efficiency can be improved through the integration of digital technology. The Smart Grid is the result of this integration, consisting of controls,

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computers, automation, and new technologies and equipment that work together to respond to rapidly changing electric demand. It allows for two-way communication between the utility and its customers and sensing along transmission lines, making it a more flexible and responsive system [2].

Smart Grid aimed at providing an economically efficient, sustainable power system with low losses and high levels of quality, supply security, and safety [3]. One of the crucial aspects of the Smart Grid is power system protection, which ensures maximum electrical supply continuity with minimal damage to human life, equipment, and property. This protection scheme requires a thorough understanding of the fault characteristics of individual power system elements and the tripping characteristics of various protective relays. Our project is to design to connect a protection system with the network through an ESP32 controller, which receives values from the network and accordingly sends signals to relays to separate the circuit or not if there are errors. The goal is to prepare a solid protection system that can quickly restore the network to a normal state and reduce the consequences of outages, ensuring a reliable and efficient power system.

The power system is susceptible to various types of faults and abnormal conditions, such as overloads, short circuits, under loads, over voltages, and under voltages. These conditions can cause damage to equipment, pose a threat to operators, and result in a significant increase in current flow beyond the rated values in certain parts of the system. Such scenarios can result in outages, inconvenience to users, and even potential hazards [4]. Therefore, there is a need for a reliable and efficient protection system that can detect and respond to any errors in the power system promptly. Our project aims to address this need by developing a protection system that can effectively monitor the network and take appropriate action to ensure the continuity of electrical supply while minimizing damage to equipment and property.

The objective of this project is to establish a robust protection system that can safeguard the grid from faulty and abnormal conditions in a short amount of time, while preventing any harm to the system. Additionally, this project aims to enhance the reliability of the network and enable remote control capabilities. By implementing a smarter grid, the electric power system will become better equipped to handle emergencies and minimize outages and their impacts. The two-way interactive capacity of the Smart Grid technologies will enable early detection and isolation of outages, preventing them from escalating into large-scale blackouts.

2 Methodology

In order to test the control system designed for frequency, current, and voltage disturbances, we simulated the system using MATLAB. For the implementation of the control system, we used an ESP32 microcontroller which has a Bluetooth connection. By sending signals to the relays in the system, we were able to manually control them. The ESP32 microcontroller was chosen for its ability to connect with Bluetooth and Wi-Fi with a simple code edit. The programming language used for this project was Arduino language and we utilized the Arduino IOT software. This allowed us to easily program and interface with the ESP32 microcontroller. Through the simulation and testing, we were able to evaluate the effectiveness of the designed control system and the ability of the ESP32 to act as a controller in the protection system.

Overvoltage occurs when the voltage in a system exceeds the maximum voltage that the device can handle. This may result in equipment damage and power outages. The ESP32 monitors the voltage if any of the phases is higher than a pre-set maximum voltage, preventing damage from overvoltage; it also monitors the voltage if any of the phases are below the pre-set minimum voltage, preventing damage from under voltage. An under-voltage condition can occur when the voltage in the system drops below the level required to operate the device, then the relay will be released.

ESP32-WROOM-32 is a powerful, generic Wi-Fi + BT + BLE MCU module that targets a wide variety of applications, ranging from low-power sensor networks to the most demanding tasks, At the core of this module is the ESP32-D0WDQ6 chip*. The chip embedded is designed to be scalable and adaptive. There are two CPU cores that can be individually controlled, and the CPU clock frequency is adjustable from 80 to 240 MHz also power off the CPU and make use of the low-power co-processor to constantly monitor the peripherals for changes or crossing of thresholds. ESP32 integrates a rich set of peripherals, ranging from capacitive touch sensors, Hall sensors, SD card interface, Ethernet, high-speed SPI, UART, I^2S andI^2C.

The integration of Bluetooth, Bluetooth LE and Wi-Fi ensures that a wide range of applications can be targeted, and that the module is all-around: using Wi-Fi allows a large physical range and direct connection to the Internet through a Wi-Fi router, while using Bluetooth allows the user to conveniently connect to the phone or broadcast low energy beacons for its detection. The sleep current of the ESP32 chip is less than 5 μA, making it suitable for battery powered and wearable electronics applications. The module supports a data rate of up to 150 Mbps, and 20 dBm output power at the antenna to ensure the widest physical range.

The module does offer industry-leading specifications and the best performance for electronic integration, range, power consumption, and connectivity.

The Simulink of the project is shown in Fig. 1.

The frequency relay (ANSI/IEEE C37.2 Device No. 81) operates when the system frequency is below or above a set value. The block diagram of the relay is shown in Fig. 2.

- Frequency relay connection with bus1, give signal to cb1.
- Frequency relay connection with bus5, give signal to cb2.

The connection of the ESP to the grid is shown in the following figure. ESP32 receiving value: display input values. Serial receive: Receive binary data via the serial port, which is the data coming from ESP32. ESP32: Send signals to from the blocks that have the specified tag. Because tag visibility is “scope bound”, the Goto tag visibility block was used to specify tag visibility (Fig. 3).

The block diagram of the relay is shown in Fig. 4. Whereas the undervoltage relay is shown in Fig. 5.

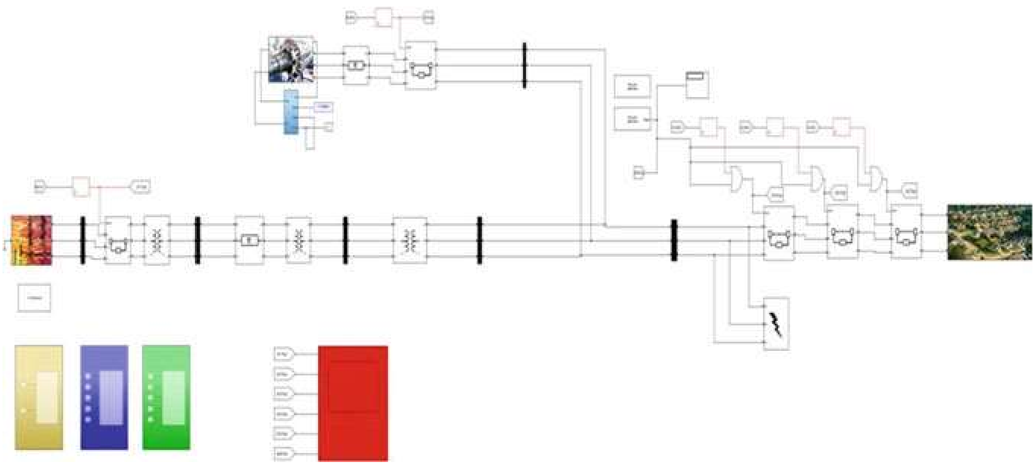

Fig. 1 Simulink of the project

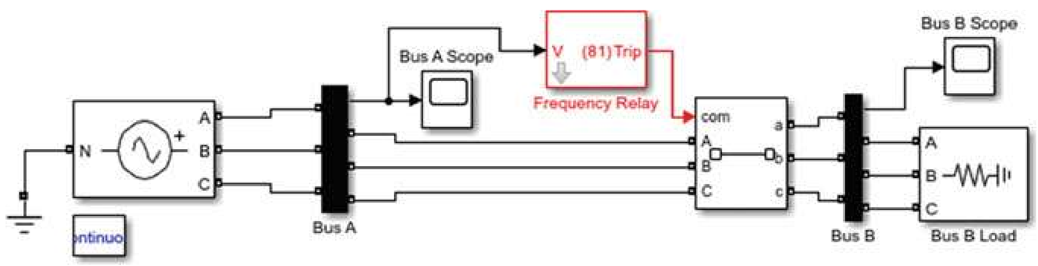

Fig. 2 Simulink of the frequency relay

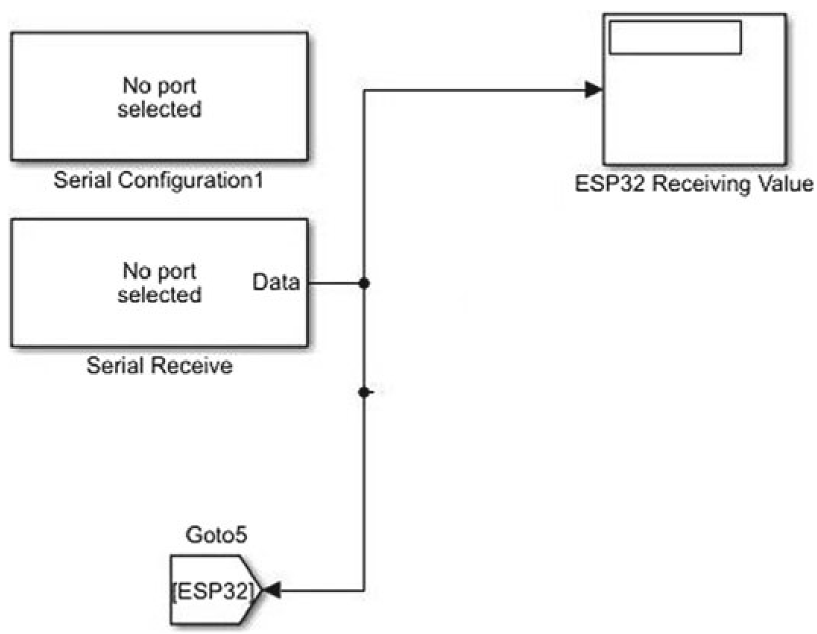

Fig. 3 Simulink of the frequency relay

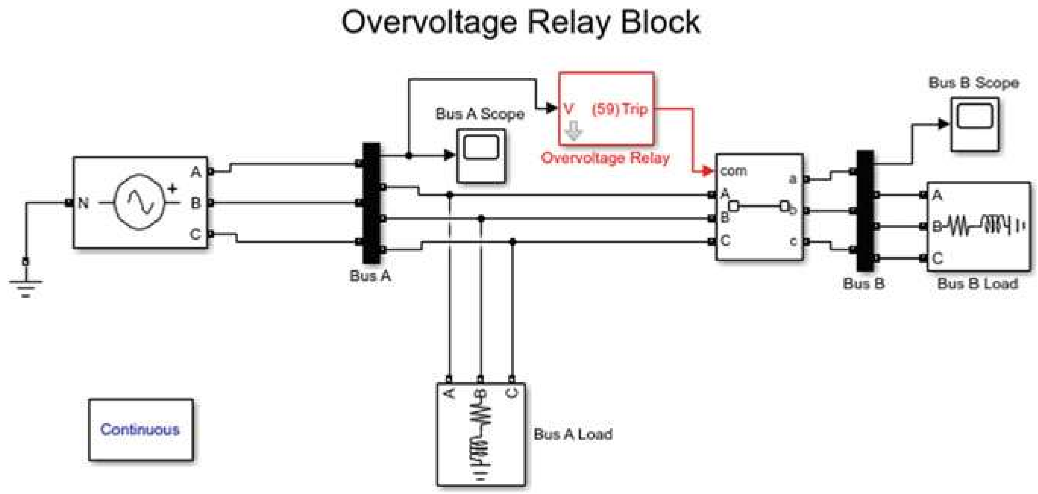

Fig. 4 Simulink of the overvoltage relay

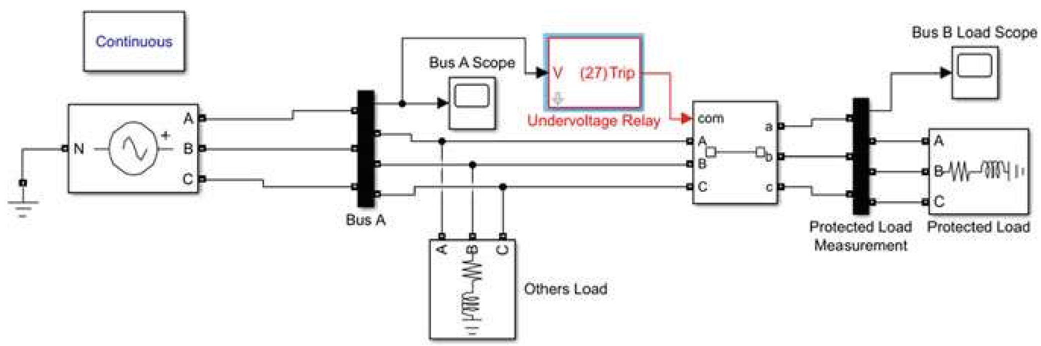

Fig. 5 Simulink of the overvoltage relay

The block diagram of the instantaneous overcurrent relay is shown in Fig. 6.

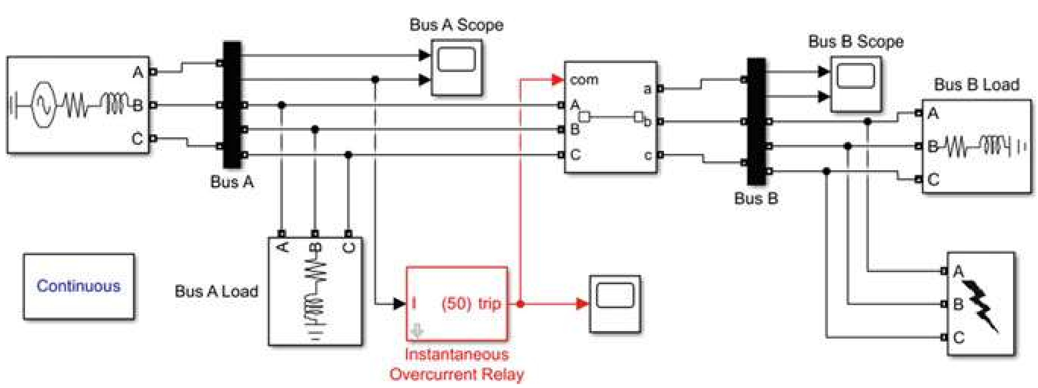

Fig. 6 Instantaneous overcurrent relay block diagram

3 Results

Figure 7 shows the voltage signals under normal condition.

The load signal is shown in the Fig. 8.

The relay signals are shown in the Fig. 9.

The frequency signal is shown in the Fig. 10.

Overfrequency relays signal is shown in the Fig. 11.

Signal of under frequency case is shown in the Fig. 12.

Underfrequency relays signal is shown in the Fig. 13.

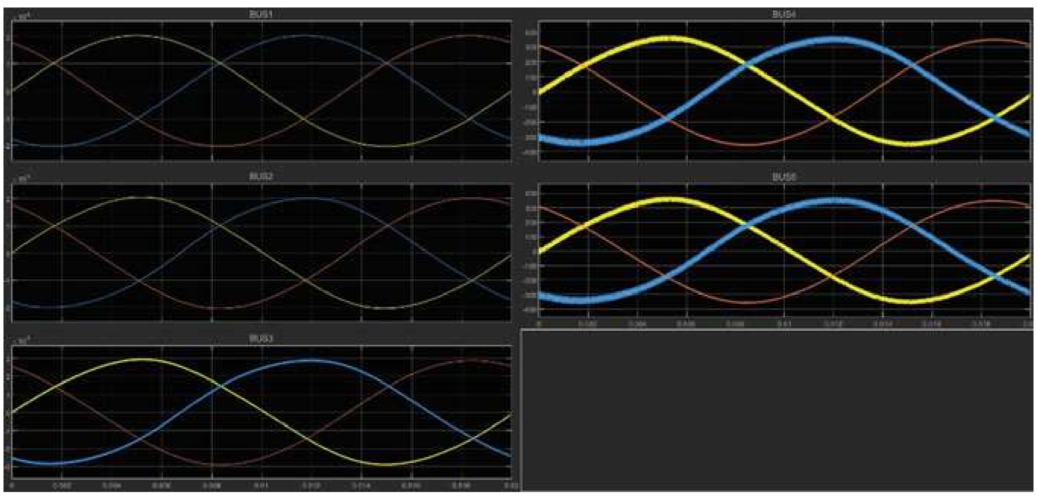

Fig. 7 The voltage signal is in the normal position

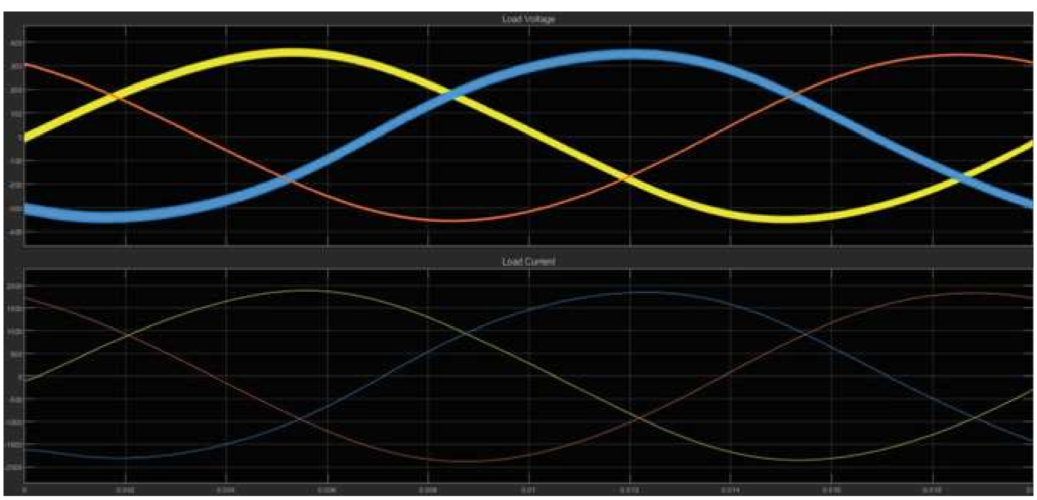

Fig. 8 The load signal is in the normal position

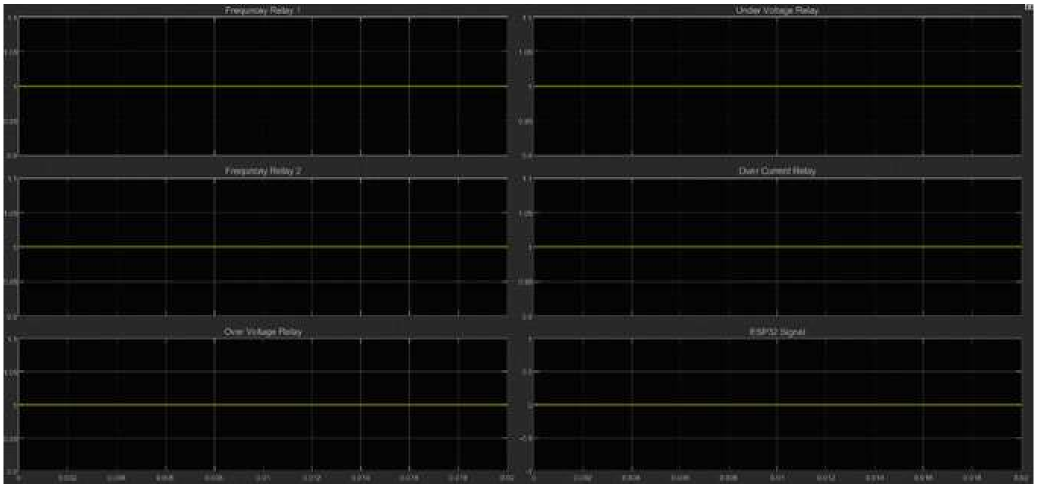

Fig. 9 The relay signal in the normal position

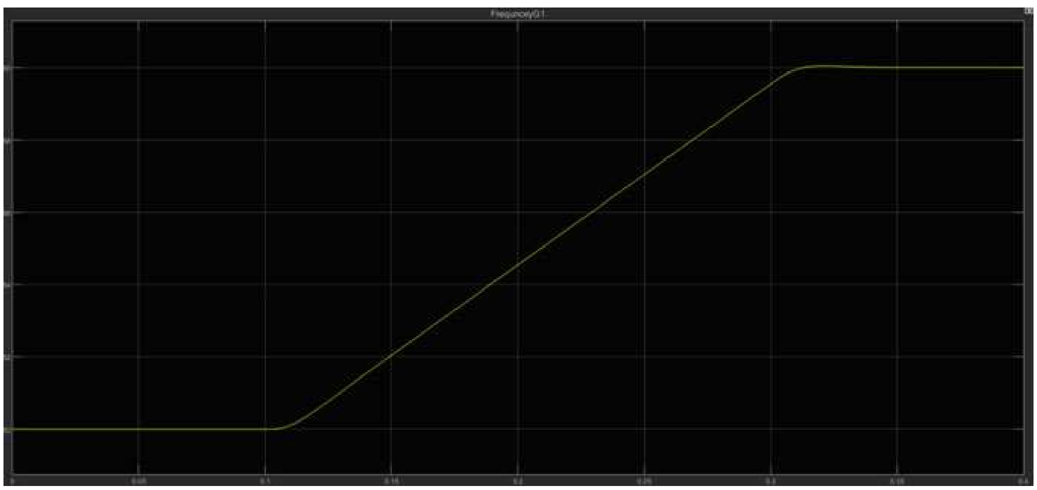

Fig. 10 Frequency signal

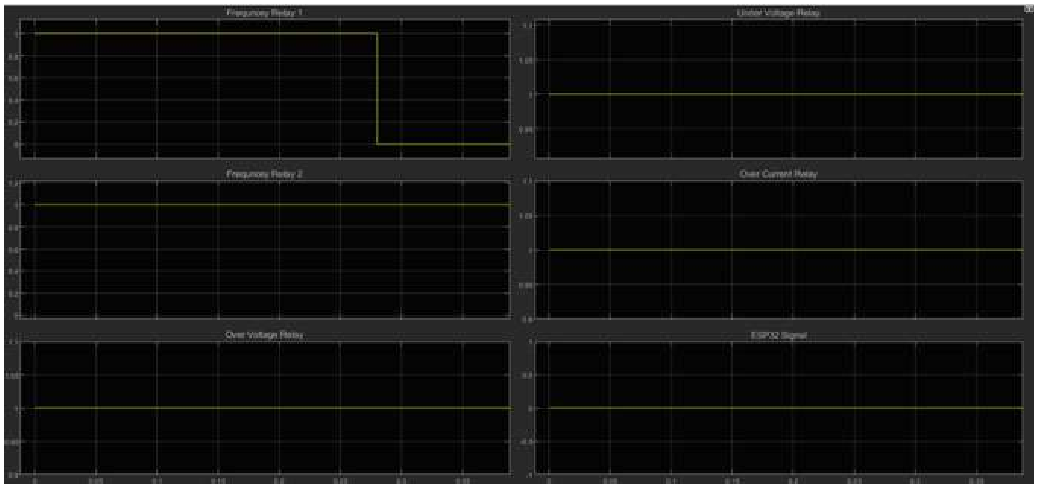

Fig. 11 Signal relay over frequency

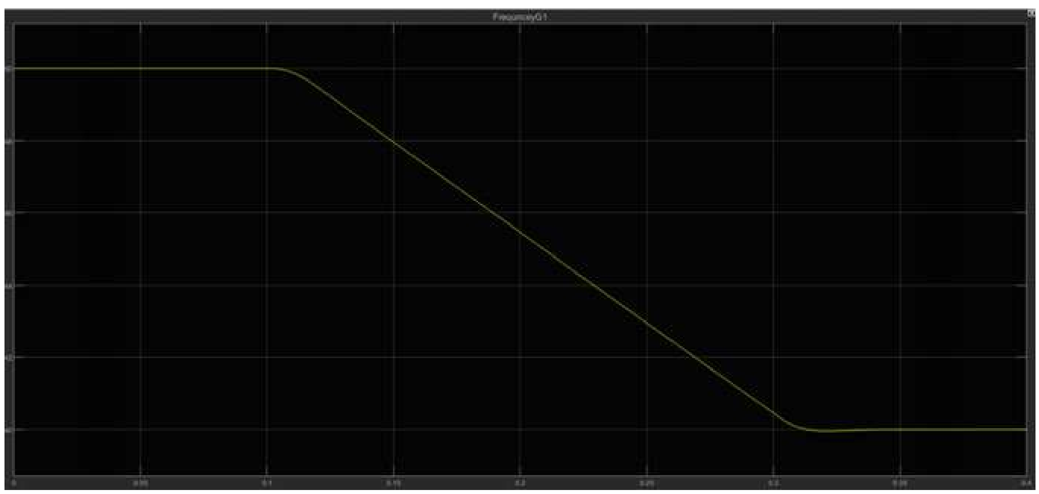

Fig. 12 Frequency signal

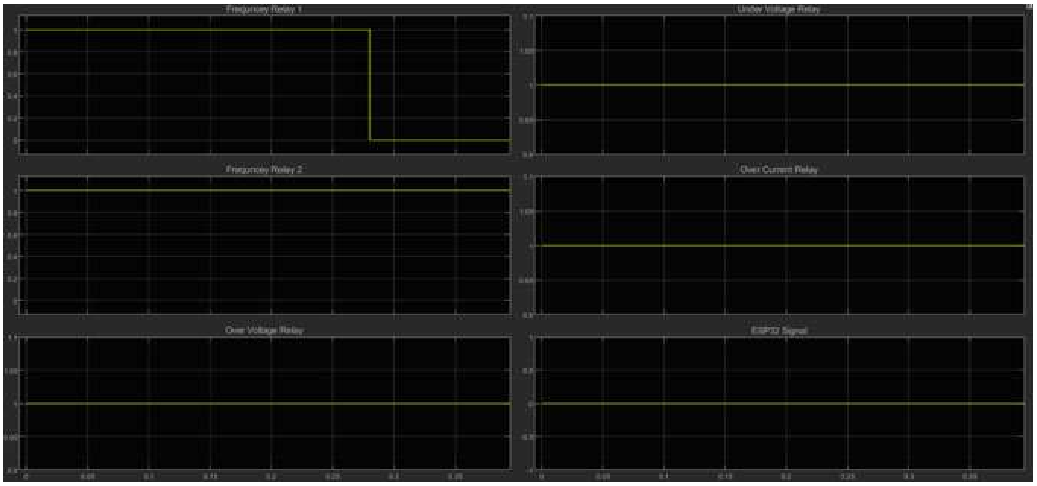

Fig. 13 Under frequency relay signal

4 Conclusion

In conclusion, our project aims to develop a protection system that can effectively monitor and respond to any errors in the power system, ultimately enhancing the reliability of the network and enabling remote control capabilities. By using an ESP32 microcontroller with Bluetooth connection, we can send signals to the relays in the system and manually control them. Our MATLAB simulation of the control system designed for frequency, current, and voltage disturbances has shown promising results, and we believe that the programming language used in Arduino IOT software will enable us to achieve our project goals. The implementation of a smarter grid will add flexibility to the electric power system and minimize the impact of outages, ensuring fast recovery and minimizing damage to equipment and property. We are optimistic that this project will make a significant contribution towards building a robust and reliable power system that can meet the demands of our modern world.

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