

Development of Internet-Based SCADA Prototype for Substation Power Protection System

Muhammad Khalaf Fahmi Mohamad Rezal¹, Lam Hong Yin^{2*}

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

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

This project aims to improve the efficiency and safety of electricity distribution networks by developing an automated monitoring system. The main purpose is to gather and send essential electrical information including voltage, current, power, and temperature in real time. This information is crucial for identifying and addressing any issues in the power supply network. The system incorporates a relay mechanism, which acts as a safeguard, triggering when electrical parameters exceed pre-set thresholds. The project employs ESP32, a microcontroller, Adafruit INA219 current sensor, AHT10, temperature sensor, for the coordination of various substation system sensors. Those sensors continuously measure and acquired updated real time data on a live substation system for the monitoring on Human Machine Interface on Blynk.

1. Introduction

Enhance IoT-driven continuous inspection systems designed for substation testing and processing by elevating testing frequencies. Utilising this integrated approach, administrators can assess prevalent substation conditions, encompassing both steady-state and transient forces. Swift and error-free data testing incorporates additional data points related to logging, web connectivity, and specific details for individual analysis. Given the considerable distance between the generator and the load, the affordability of electrical energy facilitates extensive power trading across substantial distances [1]. The alarm was triggered due to the demand for power on the client side, a situation often associated with client-side power extensions. In standard power transmission, considerable energy is lost, highlighting subpar substation performance. To enhance the quality of force through alternative adjustments, it is essential to identify the specific requirements [2].

1.1 Background Study

The development of SCADA (Supervisory Control and Data Acquisition) systems for power systems began in the mid-20th century with centralized control and monitoring, utilizing proprietary communication networks and protocols. As power grids expanded, the limitations of these systems necessitated more scalable and versatile solutions. The advent of the Internet revolutionized SCADA development by integrating Internet-based technologies, leading to increased scalability, flexibility, and cost-effectiveness. This transition enabled the creation of distributed SCADA architectures, allowing for seamless communication between geographically dispersed power grid components. Internet-based SCADA systems now use high-speed internet connections to monitor power system parameters in real-time, enabling operators to quickly identify and respond to abnormal conditions, thereby reducing the risk of equipment failure and power outages.

An important aspect of Internet-based SCADA is the remote management and automation of devices within the power system, which enhances operational efficiency and adaptability to changes in demand and unforeseen events. The Internet of Things (IoT) plays a crucial role in this, providing robust networks for various applications through both wired and long-distance connections. Industrial IoT (IIoT) combines information retrieval, communication, and business readiness, facilitating the continuous functionality and management of energy systems. The introduction of IoT-based high-speed observation systems with recording functions for power system substations has improved maintenance techniques and reduced installation costs. As power systems evolve, incorporating green energy sources and HVDC transmission, the use of synchronous equipment and advanced substation automation systems continues to drive efficiency and reliability in energy management.

1.2 Problem Statement

Integrating SCADA systems into Internet-based architectures for energy systems presents significant challenges, particularly with cybersecurity. The convergence of SCADA and the Internet introduces new vulnerabilities, exposing power grids to unauthorized access, data breaches, and cyber-attacks [3]. Protecting these systems from evolving threats is crucial to ensure the operational resilience and security of critical energy infrastructure. Moreover, traditional SCADA substation systems face limitations such as short-range access controls, slow incident reporting and response, and inadequate continuous monitoring.

Additionally, the development of Internet-based SCADA systems encounters obstacles related to network reliability and latency. As energy systems become increasingly reliant on Internet connectivity, interruptions and delays can hinder real-time monitoring and control, essential for protecting energy systems. Ensuring reliable networks and minimizing data transmission delays are critical for maintaining SCADA system responsiveness during critical power events. Addressing these challenges is vital for the successful implementation of Internet-based SCADA systems, ensuring their robustness and adaptability in a rapidly evolving energy infrastructure environment.

1.3 Objectives

The objectives of the study are:

1. To design and develop hardware-related prototype for power system protection substation.
2. To develop internet-based SCADA system which can be controlled and monitored remotely.
3. To integrate and test the hardware with the internet-based SCADA system.

1.4 Scope of Study

The objectives for developing an Internet-based SCADA prototype for a substation power protection system include:

1. The power system protection scheme in a substation is an essential element in maintaining the reliability, safety, and performance of the electrical distribution network.
2. This scope outlines the key aspects involved in the design, implementation, and maintenance of such a scheme, with a focus on safeguarding equipment, personnel, and the uninterrupted supply of electrical power.

The prototype system includes three sensors: voltage, current, and temperature sensors, which monitor and log these parameters. The Blynk system will be used to control and monitor these parameters. The prototype is designed for an 11kV substation and will include several power system protection schemes. The scenarios simulated will involve over-temperature and surge protection, with both automatic and manual controls via the Blynk system and hardware.

2. Literature Review

The application of IoT applications by companies and organizations has surged at an unprecedented rate across various sectors, including automotive, utilities, healthcare, logistics, and home automation. With the rapid increase in connected devices, there is a pressing need to develop cloud-based middleware that can manage

numerous sensors and actuators. IoT frameworks, built with open-source software and hardware components, are designed to process and distribute data efficiently.

This is past related research that has been documented and will be the reference of this project. Next, a survey of basic knowledge about current technologies, techniques, and algorithms that can be implemented in Internet-based SCADA control and monitoring substations is performed and summarised in various tables for better understanding. Previous projects for building the system include substation monitoring system [4], substation monitoring and control using microcontroller and Global System for Mobile (GSM) [5], microcontroller-based remote monitoring of substation and control system through LabVIEW [6], Contribution to health monitoring and simulation of integrated substation monitoring.

3. Methodology

The proposed system's algorithm, depicted in Figure 1, begins with the initialization of the ESP WIFI module and the Blynk server, which sets up the essential communication infrastructure for wireless connectivity and remote data management. Once the ESP WIFI module is connected to the designated Wi-Fi network, the system establishes a link with the Blynk server to enable real-time data transmission and monitoring. Following this setup, the system connects to and starts reading data from various sensors: current, voltage, and temperature sensors. Detailed flowcharts outline the operational algorithms for each of these sensors, ensuring accurate data acquisition and processing. The temperature sensor measures critical parameters such as current, voltage, power, and temperature. These measurements are then transmitted to the Blynk server, allowing users to monitor the data remotely through the Blynk application. Simultaneously, the data is also updated on the serial monitor, providing a local real-time display for on-site monitoring and debugging. This dual-update mechanism ensures that the system's performance can be tracked both remotely and locally, enhancing its reliability and user accessibility. The comprehensive approach ensures seamless integration, accurate monitoring, and efficient management of sensor data.

3.1 Flowchart

Figure 1 illustrates the project flowchart for the Internet-Based SCADA Controlling and Monitoring of Substation System. The project workflow is divided into two major phases. The first phase, the Proposal Phase, is part of Final Year Project (FYP) I and includes the Problem Definition, Literature Review, and Methodology, establishing the project's foundation. The second phase, the Project Implementation Phase, is part of Final Year Project (FYP) II and involves the design and development of the system, including System Design and System Modification. During this phase, solutions are implemented, tested, and refined, with unsuccessful designs being replaced. The final report documents the project's Analysis, Discussion, and Conclusion.

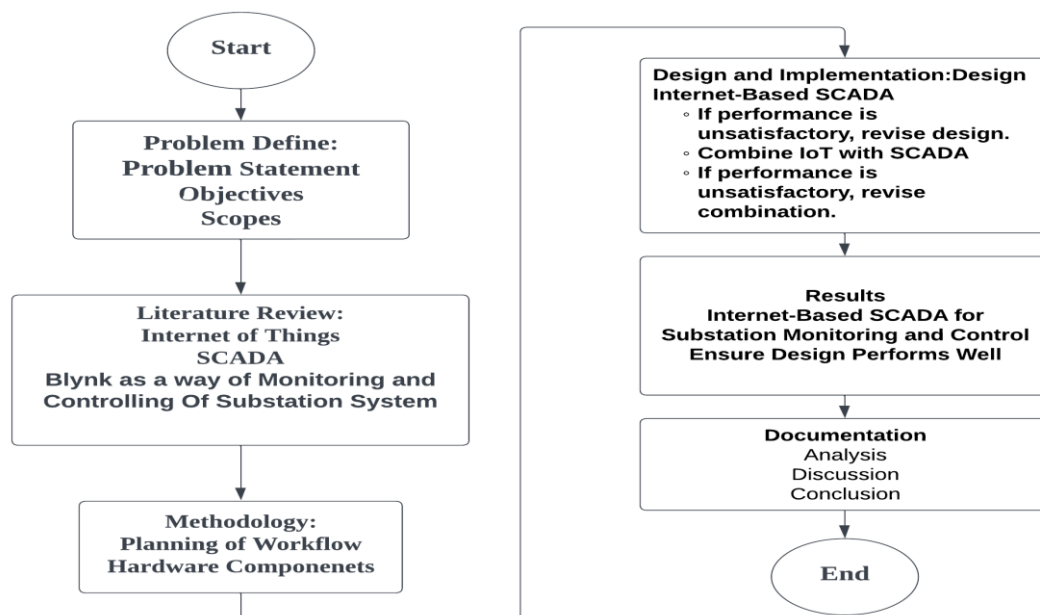


Figure 1: Flowchart of Project Development

Figure 2 illustrates the operating principles and system algorithms for this project, which are generative models with stochastic, passive elements called cover-up units. The OLED display manages IoT quality and utilization via a serial port, and a buzzer signals network malfunction. The ESP32 circuit breaker system initializes its hardware components and libraries (WiFi, Blynk, OLED display, INA219 sensor, and AHT10 sensor), connects to a specified WiFi network and the Blynk platform, and continuously monitors voltage, current, and temperature readings. These readings are displayed on the OLED and sent to the Blynk app. If readings exceed safety thresholds, the system triggers a relay to break the circuit and prevent damage, with alerts shown on the OLED and Blynk app for local and remote monitoring.

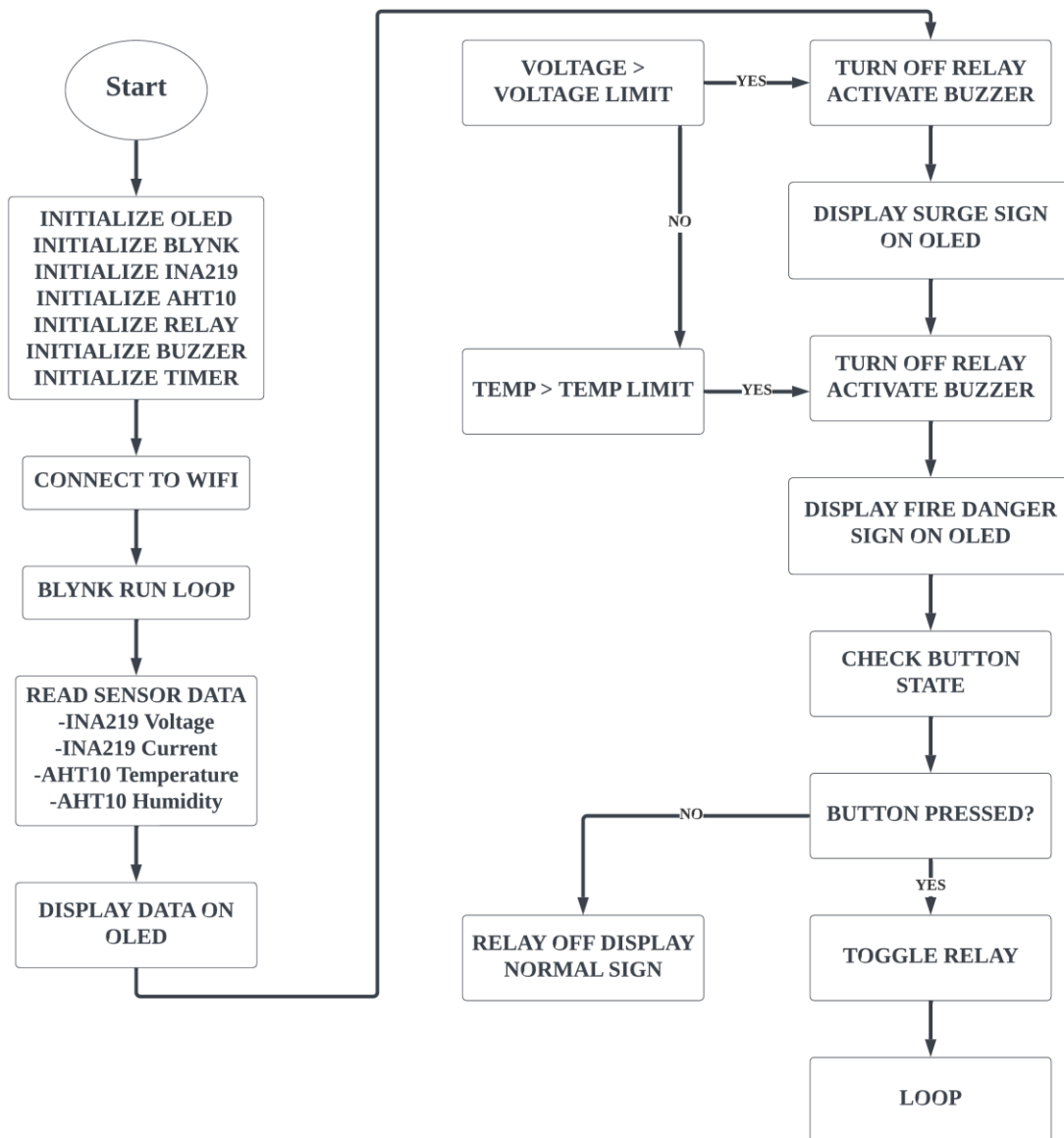


Figure 2: System Algorithm Flowchart

3.2 Block Diagram of System Algorithm

Figure 3 shows how the Blynk application displays current, voltage, and temperature separately for microcontrollers and remote devices. The smartphone app, using Blynk programming, monitors voltage and current to analyze voltage power quality. Test results are displayed on an OLED. The ESP32 board is preferred for complex, connected applications, while Arduino is recommended for simplicity and learning. Starting with devices and coding is advisable. Despite slight variations, most microcontrollers share many common components. Data collected is sent to the Arduino controller based on a deep conviction organization.

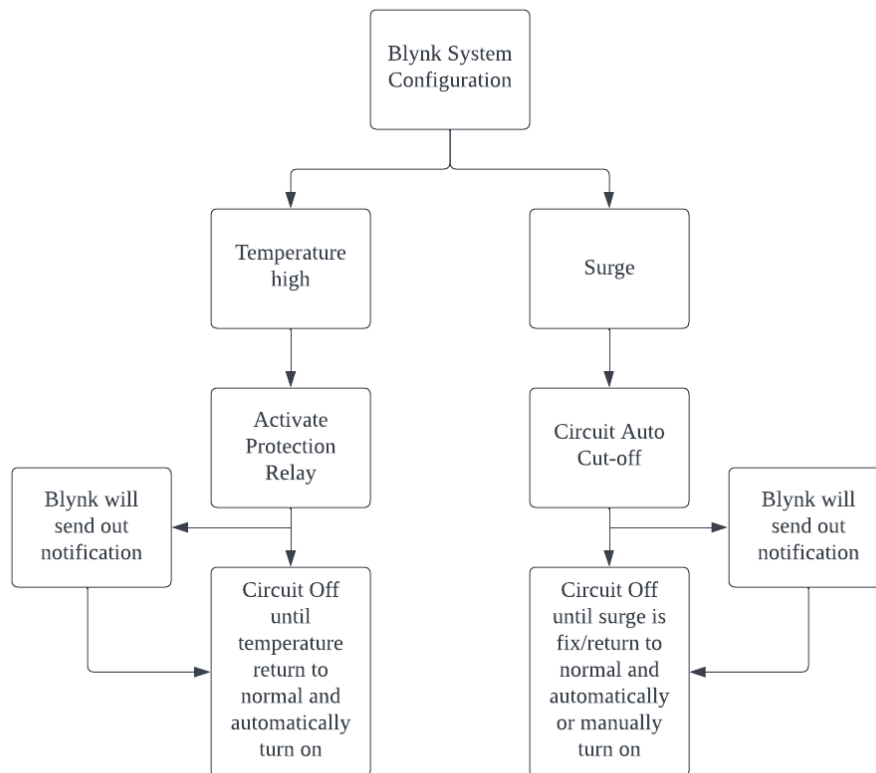


Figure 3: Blynk System Configuration

3.3 Connection of Blynk Cloud and ESP32

Figure 4 illustrates the equations and the initial draft of the code for the access point have been developed using the Arduino IDE software. To properly set up the library with Arduino IDE, you need to add a board manager to preferences. After selecting the sketch component, choose the ESP32 Board from the library management menu. The code design in Figure 3 connects the ESP32 Board to Wi-Fi and the Blynk Cloud. Completing the setup of the Blynk token is required, which can be obtained once the Blynk Cloud is up and running. To get the necessary IP address for connecting to Wi-Fi and monitoring Blynk applications, you must provide both the Wi-Fi network name and its password.

```

sketch_may5a.ino
1  #define BLYNK_TEMPLATE_ID "TMPL6m4qbRvs-"
2  #define BLYNK_TEMPLATE_NAME "Circuit Breaker"
3  #define BLYNK_AUTH_TOKEN "QlywP4PDKl3vfKDcxAB9Vs3pRYJVaujI"
4
5  #include <WiFi.h>
6  #include <WiFiClient.h>
7  #include <BlynkSimpleEsp32.h>
8
9  char ssid[] = "wifi"; //FOR CHANGE PRESET WIFI NAME/SSID
10 char pass[] = "password"; //FOR CHANGE PRESET WIFI PASSWORD

```

Figure 4: Code connection of Blynk

4. Results and Discussion

The hardware of this project has been developed by referring to the circuit design. Figure 5 shows the view of the project hardware that has been developed using Proteus 8 software. Figure 6 shows the final product that has been developed.

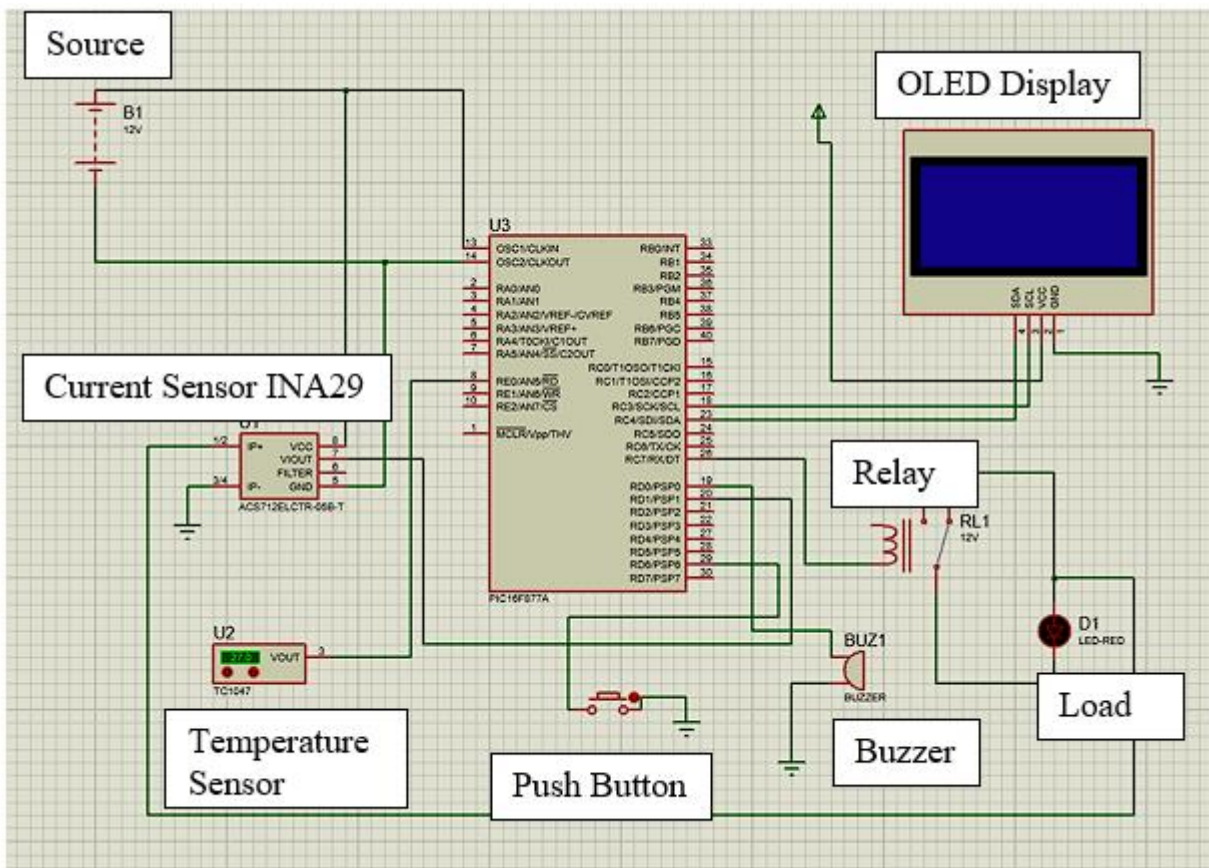


Figure 5: Circuit Diagram



Figure 6: Final Product

4.1 Results of Monitoring System

Figure 7 shows the provided graph depicts the voltage (V) against time (hour) over a day, ranging from 9:00 AM to 4:00 PM. The voltage remains relatively stable throughout the period, fluctuating slightly around 3.25 V. The voltage values do not show significant deviations, suggesting a consistent power supply during the monitored hours. The minor variations observed are within the range of approximately 3.22 V to 3.30 V.

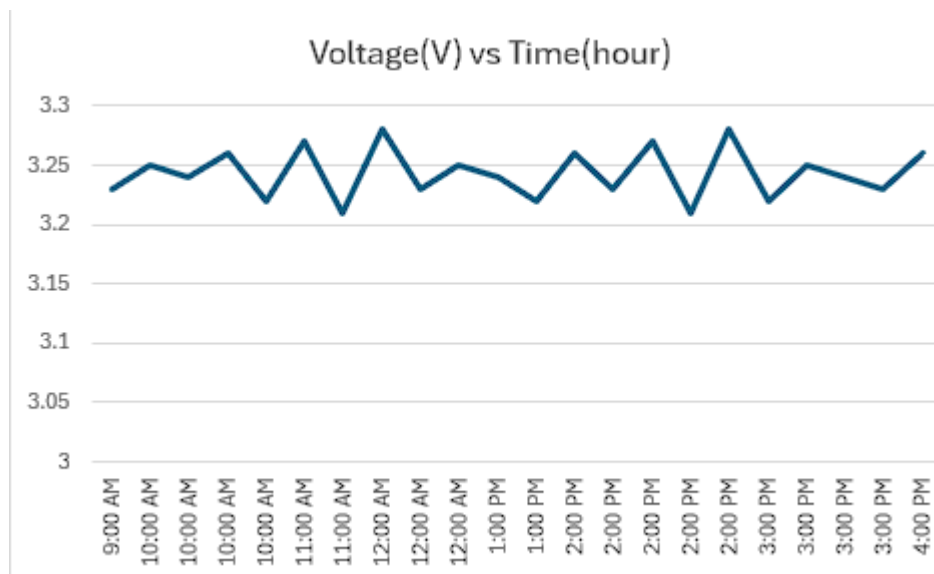


Figure 7: Voltage(V) against Time(H)

The provided graph shows power (W) versus time (hour) from 9:00 AM to 4:00 PM. The power fluctuates slightly around 110 W throughout the day, indicating a relatively stable power usage. The power values range approximately from 105 W to 115 W, with minor variations observed at different times. The stability in power readings suggests a consistent load or usage pattern during the monitored period.

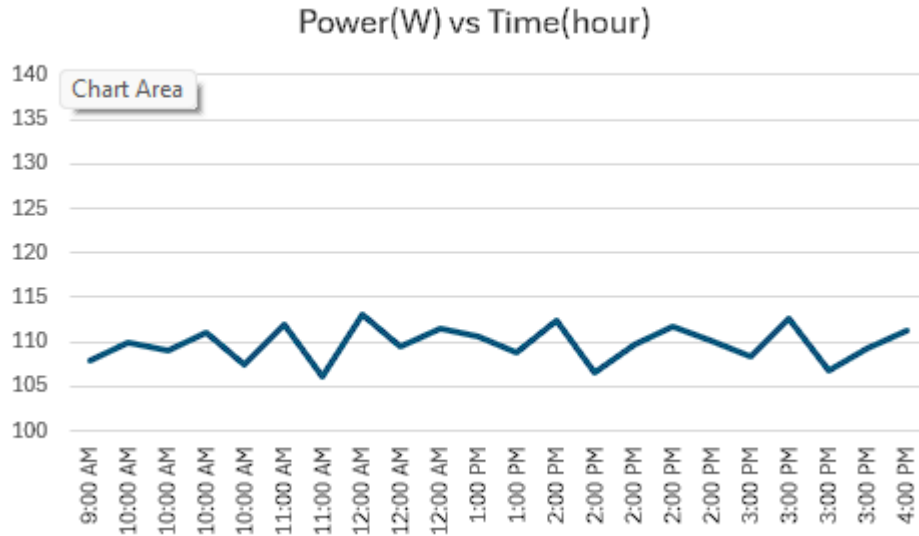


Figure 8: Power(W) against Time(H)

The graph shows current (mA) over time (hours) from 9:00 AM to 4:00 PM. The current stays mostly consistent, fluctuating around 110 mA. The values range from about 105 mA to 115 mA, with only slight variations observed throughout the day. This indicates a stable electrical load or usage pattern during the monitored hours.

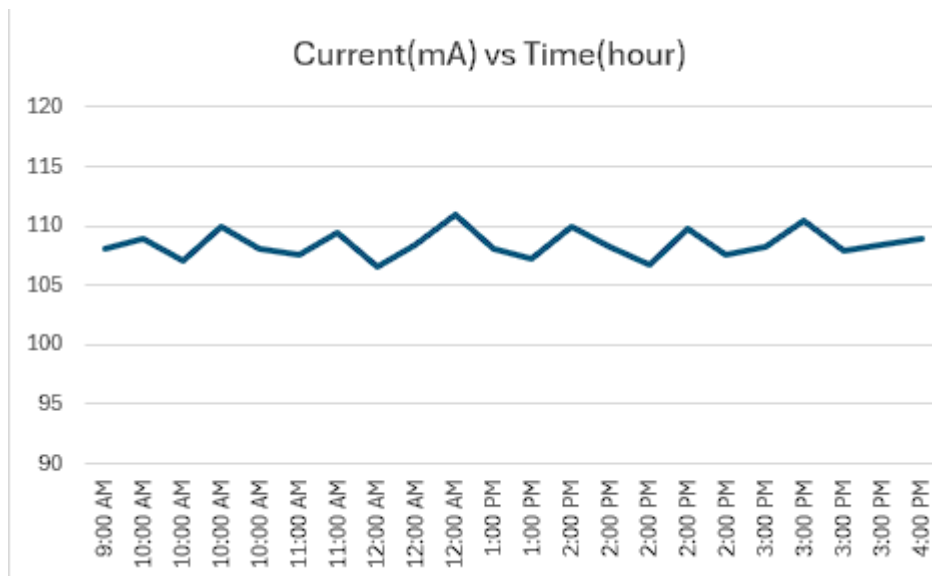


Figure 9: Current(mA) against Time(H)

5. Conclusion

The project successfully designed and implemented an Internet-Based SCADA system for remote control and monitoring of substation power protection. A thorough literature review and structured methodology ensured successful execution, with rigorous testing demonstrating the effectiveness of the implemented solutions. The system's ability to monitor and control the substation in real-time and respond to anomalies by disconnecting circuits when necessary was validated, highlighting the importance of continuous monitoring and automated responses for enhancing power distribution efficiency and safety. Overall, the project's findings offer valuable insights for future improvements in power system protection and monitoring.

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References

- [1] Hajikhani M., Labeau F. & Agba B. L. (2019). "Power Allocation for a Self-Sustainable Power Substation Monitoring System Using Wireless Transfer of Energy," *IEEE Access*, vol. 7, pp. 141456-141465.
- [2] Zhao L., Zhou Y. & Lee W. (2019). "Design of an Industrial IoT-Based Monitoring System for Power Substations," in *IEEE Transactions on Industry Applications*, vol. 55, no. 6, pp. 5666-5674.
- [3] Manar Alanazi, Abdun Mahmood, Mohammad Jabed (2022, November 25). *SCADA vulnerabilities and attacks: A review of the state-of-the-art and open issues*. *Computers & Security*. <https://www.sciencedirect.com/science/article/pii/S0167404822004205>
- [4] Amol Ram Kate, Girish Baban Dongare, Krishana Maroti Janwade, Payal Burande, Narendra P. Zinjad, "Substation Monitoring System", *International Journal for Research in Applied Science & Engineering Technology (IJRASET)*, ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887 Volume 6 Issue V, May 2018
- [5] Amit Sachan,(2012) "Microcontroller based substation monitoring and control system with GSM modem" ISSN: 2278-1676 Volume 1, Issue 6 (July-Aug. 2012), PP 13-21
- [6] Dr. Ghous Buksh Narejo, Engr. Shahyan Pervez Bharucha, Engr. Danny Zarir Pohwala, (2015) "Remote Microcontroller Based Monitoring of Substation and Control System through GSM Modem", *International Journal of Scientific & Engineering Research*, Volume 6, Issue 1, January-2015 714 ISSN 2229-5518 IJSER © 2015