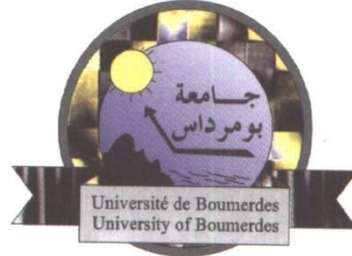


People's Democratic Republic of Algeria
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Institute of Electrical and Electronic Engineering
Department of Power and Control

Project Report Presented in Partial Fulfilment of the Requirements
of the Degree of

MASTER

In Electrical and Electronics Engineering

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Title:

**Design and implementation of overhead fault
passage indicator**

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Dedication

I would like to dedicate this thesis to my loving parents, who have been a constant source of support, encouragement, and inspiration throughout my academic journey. Your unwavering belief in my abilities and sacrifices you made have played a significant role in my success. I am forever grateful for your love and guidance.

To my dear sisters **Kaouthar, Hadjer, Assil**, my brother **Brahim** and and loving aunts **Linda** and **Ibtissem**, thank you for your continuous encouragement, understanding, and words of wisdom. Your presence in my life has brought joy and strength during challenging times. I am fortunate to have you by my side.

I would also like to express my heartfelt appreciation to all my friends, who have stood by me and provided unwavering support throughout this academic endeavor. Your friendship and camaraderie have made the journey memorable and enjoyable.

To my binone **Hocine** who has been an integral part of this project.

To my parents, sisters, brother, and friends, this achievement would not have been possible without your love, encouragement, and belief in me. Thank you for being my pillars of strength. This thesis is dedicated to all of you with deep gratitude and love.

DRIADI Soumeya

To my beloved family, my beloved parents, sister and brothers, whose unwavering love and support have been my constant source of strength throughout this academic journey, I dedicate this thesis. Your encouragement, understanding, and sacrifices have been the cornerstone of my success. From the late nights of studying to the moments of self-doubt, you have stood by my side, providing guidance and motivation. I am grateful for the countless sacrifices you have made to ensure that I had the opportunity to pursue my education and reach for my dreams. This achievement is as much yours as it is mine. I also extend my heartfelt appreciation to my friends, whose laughter, encouragement, and companionship have brought joy and balance to my life. Your presence has provided a welcome respite from the demands of academia and reminded me of the importance of friendship and shared experiences. This thesis is dedicated to my cherished family and friends, whose unwavering support has made this milestone possible.

BENYAHIA Hocine

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Abstract

A LabVIEW-based implementation approach is adopted in this study to design and develop an overhead fault The designed and implemented overhead fault passage indicator (FPI) system is a reliable and efficient solution for monitoring and detecting faults in electrical distribution systems. The system utilizes LabVIEW software, an ESP8266 microcontroller, and Google Firebase for data communication and storage. Through the development process, the LabVIEW code is designed to retrieve sensor data from Google Firebase using the HTTP client protocol. This data is displayed on the system's user-friendly interface, allowing for real-time monitoring and analysis of the electrical system's performance. Various tests have been conducted to validate the effectiveness of the FPI system. Threshold verification tests have been performed to ensure accurate detection of overcurrent and undercurrent conditions within the predefined threshold values. Sensitivity tests have been conducted to assess the system's ability to detect minor deviations from the normal current range. In simulated fault scenarios, such as short circuit and open circuit conditions, the FPI system has demonstrated its capability to promptly detect and indicate the presence of faults through the activation of an LED indicator. This helps prevent potential hazards and minimize downtime. The results of the implemented FPI system have demonstrated its effectiveness in enhancing the safety and reliability of electrical distribution systems. The system has shown accurate fault detection, real-time monitoring capabilities, and timely response, leading to improved system performance and reduced maintenance costs. These outcomes validate the value of the FPI system as a reliable tool for ensuring the integrity and efficiency of electrical distribution networks.

List of Abbreviations and Terms

FPI	Fault Passage Indicator
FCI	Faulted Circuit Indicator
SCADA	Supervisory Control And Data Acquisition
DCU	Data Concentrator Unit
GSM	Global System for Mobile communication
IED	Intelligent Electronic Device
DC	Direct Current
GND	Ground
VCC	Voltage Common Collector
ADC	Analog to Digital Converter

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Introduction

1. Introduction

1.1 Problem formulation

This comprehensive study on Fault Passage Indicators (FPIs) aims to address the challenge of locating faults within electrical networks to enhance the safety and reliability of distribution systems. The thesis begins with Chapter 1, which formulates the problem statement and provides an introduction to the historical background and motivations behind the research. The second chapter offers a detailed overview of overhead fault passage indicators, covering their working principles, types available in the market, components involved, and installation considerations. This chapter synthesizes existing knowledge, providing a comprehensive understanding of FPIs and laying the foundation for the design and implementation work in the following chapters. The third chapter focuses on the design and implementation of the fault passage indicator system. It describes the methodology employed, including component selection and subsystem integration. It presents the technical details of the implemented solution, highlighting design considerations, challenges faced, and strategies employed to overcome them. It showcases the practical implementation of the FPI system and demonstrates how it effectively addresses the identified problem. For the fourth chapter, it shifts the focus to testing the implemented fault passage indicator system. It outlines the experimental setup and testing procedures used to evaluate the system's performance. The chapter presents the results obtained from the testing phase, discussing the observed behavior of the FPI in various scenarios. It includes a comprehensive analysis of the collected data, highlighting trends or patterns of interest. Additionally, the chapter provides a detailed discussion of the results, their implications, and their alignment with the research objectives and expectations.

1.2 History

The historical development of fault detection systems in electrical networks has seen a progression from conventional methods to intelligent techniques and machine

learning-based approaches. Conventional methods, such as impedance-based setups, were simple and cost-effective but lacked accuracy for large power system networks. Intelligent methods emerged as more accurate alternatives, although they required training data and were time-consuming. Variable structure systems, utilizing variable structure observers, showed promise in fault detection. Each approach has its strengths and weaknesses, with conventional methods being economical but inaccurate, intelligent methods being more accurate but time-consuming, and variable structure systems offering potential for fault detection. Several research papers and reviews explore fault detection technologies and practices, including situational awareness enhancement through fault passage indicators, transient fault detection in Malaysian distribution networks, and fault detection methods in power transmission systems[1] .

1.3 Motivation

Our motivation for undertaking this project on the design and implementation of a fault passage indicator (FPI) stems from our passion for electrical engineering and our drive to contribute to the improvement of fault detection systems in electrical networks. We are inspired by the crucial role FPIs play in identifying and locating faults, minimizing power outages, and reducing economic losses for consumers and industries. By developing an advanced FPI, we aim to enhance the reliability, stability, and efficiency of electrical networks, ultimately making a positive impact on the industry and society as a whole. Through this project, we seek to apply our knowledge and skills to address real-world challenges and contribute to the advancement of fault detection technologies.

Overview about fault passage indicator

2. Overview about fault passage indicator

2.1 Introduction

Fault Passage Indicators (FPIs) are devices used to indicate the passage of a fault current in a power distribution system. They are designed to provide information about the location and type of fault, as well as to improve system reliability and reduce the duration of power outages. FPIs can be electromechanical, electronic, or digital, and can be mounted on overhead or underground power lines. They are typically used in conjunction with protective relays and other protective devices to enhance the performance of power distribution systems.

2.2 What is fault passage indicator

The fault passage indicator (FPI) is a device strategically located on overhead lines in a distribution system to provide an indication when it detects fault current passing through the line [2]. The FPI has the ability to distinguish fault current from normal load current flowing through the feeder. When a fault current exceeding a predefined reference value is detected, the FPI activates a local indication light, signaling the presence of a fault at that specific location. The FPI is designed to detect various types of faults, including phase-to-phase faults, as it is installed on each phase of the network. Initially, fault circuit indicators (FCIs) were simple devices that used high-magnitude magnetic flux fields to mechanically move or rotate a flag, indicating the passage of fault current. These devices required manual resetting after each operation but significantly reduced troubleshooting time when properly reset. As the demand for reliable power supply increased, FCIs evolved to meet the requirements. Public Utility Commissions and customers emphasized the need for better power quality, and fault indicators played a crucial role in achieving faster identification of trouble locations, thereby reducing outage durations. The incorporation of microprocessor and communication technologies enabled FCIs to store data, enhancing their adaptability to different circuit load parameters. Further advancements focus on integrating fault

indicators into smart automated distribution systems, although the economic justification for standalone implementation remains challenging. Troubleshooting personnel still need to patrol faulty circuits during outages. However, instantaneous notification of fault progression through communication systems can be beneficial, especially if remote reconfiguration capabilities are available. Ongoing trials and developments are exploring the integration of fault indicators into smart distribution systems to improve overall system performance and reliability [1] .



Figure 1. *Overhead line fault passage indicators*[3]



Figure 2. *Medium voltage overhead line Fault passage indicators*[3]

2.3 FPI types

2.3.1 Overhead line fault passage indicator

Non-communicable

In the case of a non-communicable type, the FPI will give alarm physically on-site by blinking the RED Ultra bright LED [4] .

Communicable

in the case of a communicable type the FPI gives alarm physically on-site as well as send the data to the SCADA centre through DCU over GSM/GPRS. The illustration below provides a basic topology of a communicable system [5] .

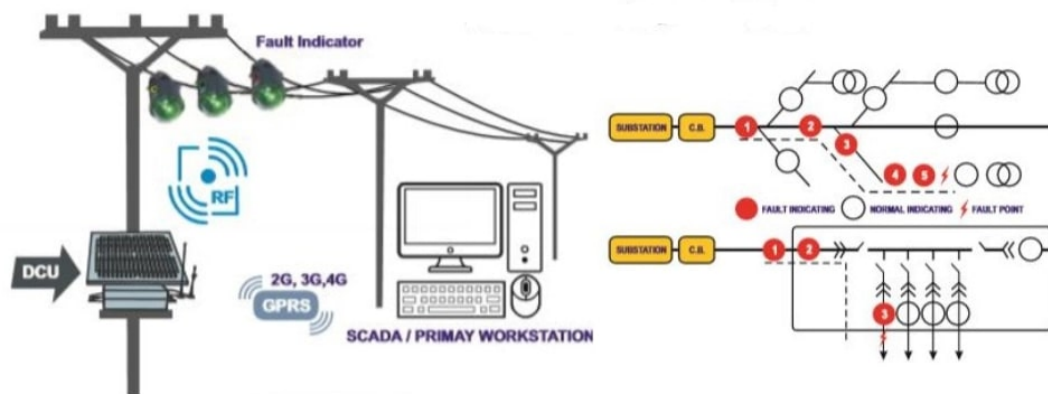


Figure 3. System network topology[1]

2.3.2 Underground fault passage indicator

Underground fault passage indicators are designed to detect faults in underground power networks, minimizing downtime and improving operation. They detect electrical signals from underground cable faults and provide visual and remote indications of faults. These indicators can locate various fault types, including grounded and transient faults. Installed in substations, cut-off cabinets, or support posts, they offer information on

permanent faults and event counts. With directional or amperometric versions, they use indicators and relay outputs to signal faults or failures, aiding in fault location.

2.4 FPI components

2.4.1 Sensor

The sensor in an overhead fault passage indicator (FPI) has the role of detection and indication of faults within an electrical distribution network. Its primary function involves monitoring the electrical parameters of the overhead power line, enabling the identification of abnormal conditions that may suggest the occurrence of a fault.

2.4.2 LED

Overhead fault passage indicators incorporate LED lights as indicators for detecting faults in electrical distribution networks. These indicators are typically located on the FPI device itself, ensuring visibility for field technicians and maintenance crews. The LEDs used are exceptionally bright and provide a 360-degree visibility. The fault indication is achieved through flashing LEDs, which are visible even at night, ensuring clear visibility under various lighting conditions. This ensures that fault indications remain easily noticeable, whether in bright sunlight or dim lighting. LED technology is chosen for its energy efficiency, a critical factor for FPIs powered by batteries or low-power sources. LEDs consume minimal power, allowing FPIs to operate for extended periods without frequent battery replacements. Moreover, LEDs have longer lifespans compared to traditional light sources, making them well-suited for FPIs exposed to outdoor environments that require long-term reliability. Their robustness against vibrations and shocks further ensures their durability in overhead installations [2] [1] .

2.4.3 Communication tool

To facilitate communication between overhead fault passage indicators (FPIs) and a data concentrator unit, communication tools such as a short-range radio interface or fiber optic lines are employed. These tools are integrated into the FPI system itself.

2.4.4 Power supply

Fault passage indicators require a power supply to operate which can be either AC or DC.

2.5 SCADA integration with FPI

Fault passage indicators (FPIs) have the capability to be seamlessly incorporated into SCADA systems, enabling real-time monitoring and control. Through this integration, FPIs can establish communication with the SCADA control center, allowing for visual or remote indication and accurate fault location determination. By combining line topology and fault indicator position information with specialized software, the exact fault point can be identified. In the context of smart grids, FPIs can be deployed to collect fault information utilizing wireless capabilities, facilitating prompt and efficient actions in response to faults [6] [7] .

2.6 FPI Installation and placement

In general, the FPI installation should be performed by trained personnel following the instructions provided by the manufacturer. The FPIs are usually installed on the overhead lines, either on the cross-arms or on the poles. The installation height should be selected to ensure the best sensitivity to the fault currents, and to prevent the FPIs from being damaged by the vegetation or the vehicles passing underneath. The FPIs should also be mounted on the line section with the lowest fault impedance, and in such a way that the fault currents flow through the FPIs in the expected direction. The FPIs can be connected directly to the power line conductors, or indirectly through the distribution transformers or capacitive voltage transformers (CVTs). The installation of FPIs on the distribution transformers requires special attention to avoid the risk of transformer damage or malfunction. The FPIs can be integrated with other protective devices, such as reclosers or sectionalizers, to improve the overall system protection performance [3].

2.7 FPI parameters

Several parameters are used to describe the performance of FPIs:

2.7.1 Sensitivity

The sensitivity of FPIs can be adjusted by setting the trip current threshold, which is the current level at which the FPI triggers a signal indicating a fault has occurred. The trip current threshold can be set to a low value to increase the sensitivity of the FPI, but this can also make the FPI less selective and more prone to false alarms. The sensitivity of FPIs can also be affected by external factors such as electromagnetic field interference. Overall [8] .

2.7.2 Accuracy

the accuracy of fault passage indicators (FPIs) is an important parameter that determines their effectiveness in detecting faults. Accuracy is the measure of the difference between the actual value of the fault current and the value measured by the FPI [9] .

2.7.3 The frequency range

The frequency range of an FPI is the range of frequencies over which the device is designed to operate.

2.7.4 Voltage and current

The voltage and current levels describe the range of values that the FPI can measure.

2.7.5 The response time

The response time is the time required for the FPI to detect a fault and send a signal to the control center.

2.8 FPI working principle

By strategically placing FPIs at regular intervals along the line, the device can identify faults downstream from its installation point by monitoring the electromagnetic field surrounding the conductor. During a fault condition, when a high current flows through the conductor for a brief period (di/dt) and then abruptly drops to zero as the circuit breaker trips, the FPI senses this rapid change in the magnetic field. This information is used to trigger alarms both on-site and remotely at the SCADA center. The FPI comprises essential components such as a sensor, a data processing controller, indication mechanisms, a reset interface, and a power system. These design features ensure that the FPI is compact, easy to install, and reliable. Typically, the FPI includes a visual indication of faults, often using LEDs or flags. Some advanced models may incorporate additional circuits for memory and communication capabilities. All fault indicators, including those for earth faults and short circuits, continuously monitor the network. Whenever a fault current surpasses the predetermined trip value, the FPI promptly indicates the presence of a fault. To minimize false indications, most fault indicator models utilize microcontrollers to analyze the measured fault signal. This analysis helps prevent incorrect alarms caused by peaks associated with switching operations. By employing this technology, the FPI provides accurate fault detection, improving the overall efficiency and reliability of the power distribution system [1] .

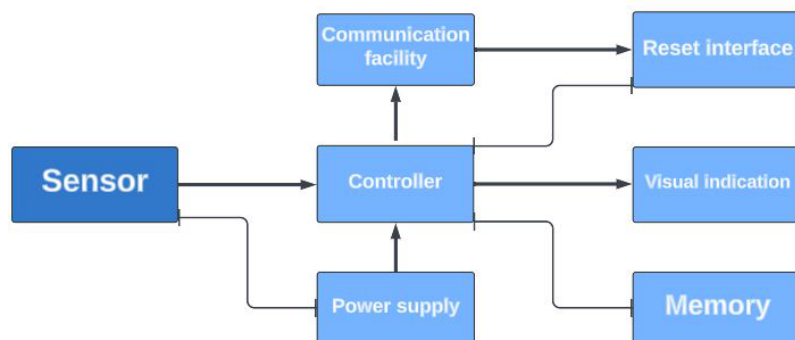


Figure 4. Block diagram of FPI working principle

2.8.1 Fault detection

To ensure efficient fault detection and location identification, fault passage indicators are strategically positioned at critical points along the power line, such as the beginning of branches on the main trunk. When a fault occurs, the fault passage indicator activates flashing LEDs to indicate the direction of the fault location. This visible indication allows field crew members to easily identify the fault location from a distance, enabling quick response and resolution. Furthermore, the fault passage indicator tracks the path of the fault current from the feeding point to the fault location. It utilizes GSM/GPRS technology to transmit relevant information to monitoring systems like KOMORSAN or SCADA. Additionally, the fault passage indicator sends fault notifications to the maintenance team via SMS or email, ensuring timely awareness and facilitating efficient fault management.

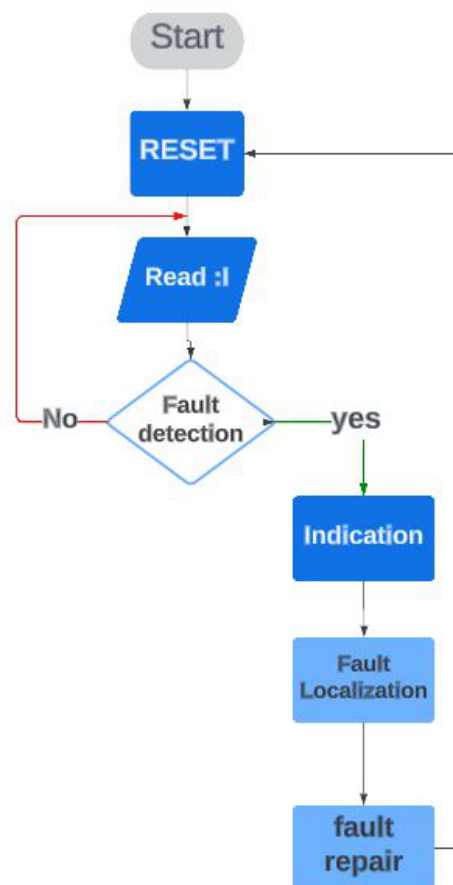


Figure 5. FPI fault detection flowchart

2.8.2 Data concentrator unit

A data concentrator unit functions as a device capable of receiving fault signals transmitted by sensors through either 433MHz or fiber optic connections, and subsequently relaying these signals to the central station via GPRS/3G/4G LTE technology. Acting as an intermediary between fault passage indicators (FPIs) and the SCADA system, the data concentrator unit facilitates the transmission of fault-related information, encompassing both the location and type of the fault. FPIs possess the ability to identify permanent and transient faults occurring in feeder cables and overhead lines, with the indication either provided by the unit itself or relayed back to the control room through SCADA. In medium voltage grids, fault passage indicators have proven to be a cost-effective measure for enhancing grid reliability, effectively reducing overall outage duration by guiding the fault localization process. The comprehensive system comprises a line fault indicator, a data concentrator unit, and a central monitoring station, with the added possibility of remote software configuration and updates. In summary, data concentrator units are versatile devices applicable in a range of scenarios, contributing to the improved dependability of electrical distribution systems.[10]



Figure 6. *Data concentrator unit*[11]

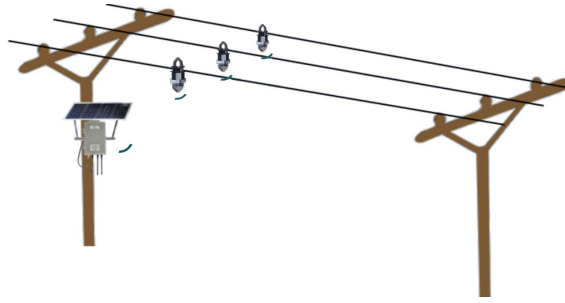


Figure 7. *Data concentrator unit in disribution system*

2.8.3 Monitoring central station

Monitoring central stations determine fault locations and deploying necessary resources. To facilitate this process, fault passage indicators (FPIs) can offer visual indications or communication to the central station. FPIs possess the capability to detect both permanent and transient faults occurring in feeder cables and overhead lines, with the indication being either provided by the unit itself or transmitted back to the control room via SCADA. The master station monitoring system utilizes specialized software that combines line topology and fault indicator position information to precisely determine the point of fault occurrence. Visual indications provided by the FPIs assist utility crew members in identifying fault locations from a distance, resulting in quicker response times for servicing the faults. The efficacy of using FPIs is validated by comparing it with fault location methods based on Intelligent Electronic Devices (IEDs). By strategically placing FPIs at appropriate locations throughout the distribution network, the time taken to locate faults is reduced, spanning the gap between the last indicator that detected fault current and the subsequent indicator. In conclusion, monitoring central stations are vital for optimizing resource deployment and expediting fault servicing processes, ultimately leading to faster turnaround times. [12]

2.9 FPI in distribution system

2.9.1 System parameters

The fault detection systems are specifically designed to operate on 33 kV and 11 kV overhead networks, considering the specific characteristics of these networks:

- Nominal operation voltage: 30KV for 30 KV networks and 10 KV for 10KV networks.
- System maximum voltage: 32 KV and 8 KV
- Frequency: 60 Hz.
- No. of phases: 3 Phases.
- System fault current:
- Types of neutral earthing:
 - For 30 KV:Earth through earthing transformer .
 - For 10 KV:Solidly grounded system [4]

2.9.2 Specifications

inrush restraint

Fault passage indicators incorporate design features that effectively minimize false tripping caused by current inrush during the circuit energization process. These design elements are implemented to ensure that the fault passage indicators accurately detect and indicate genuine faults without being triggered by transient current surges that occur during the initial power-up of the circuit.

Automatic reset

The automatic reset control parameters of fault passage indicators encompass voltage, current, time, as well as their combinations. These parameters are carefully configured to enable the fault passage indicators to automatically reset based on specific thresholds and time criteria. By considering voltage, current, and time in various combinations, the automatic reset control ensures effective and reliable operation of the fault passage

indicators.

Proximity effect

Proximity effect refers to the magnetic induction impact of load or fault currents flowing through nearby wires, cables, or ground conductors. This phenomenon can potentially disrupt the normal functioning of fault passage indicators, leading to issues such as false tripping, failure to trip, or incorrect resetting.

trip level

The trip level of a fault passage indicator refers to the specific current threshold at which the indicator will activate and perform its intended operation. It represents the minimum current value that triggers the fault passage indicator to respond and indicate the presence of a fault condition.

2.10 FPI advantages

Fault Passage Indicators (FPIs) have several advantages, including:

- Increased grid reliability: FPIs are a cost-effective solution to increase grid reliability by detecting permanent and transient faults on feeder cables and overhead lines. This can reduce the total outage time by guiding the locating of faults.[13]
- Improved fault passage detection systems: FPIs can be integrated into the SCADA Control Center, which can improve fault passage detection systems.[14]
- Strong evidence of benefits: According to research, the evidence on benefits of FPIs is strong, whereas the policy concerns regarding resource mobilization, market comovements, contagion, and volatility are largely unwarranted.[15]
- Cost-effective: FPIs are a cost-effective solution to increase grid reliability.[16]
- Attract foreign portfolio investments (FPIs): Relaxation of capital controls to attract foreign portfolio investments (FPIs) became an integral part of development strategy. FPIs can contribute to market development and growth.[17]

2.11 Conclusion

In conclusion, Fault Passage Indicators (FPIs) play an important role in detecting and pinpointing faults within power distribution systems. These indicators possess diverse variations and consist of essential components such as sensors, communication modules, and control units. FPIs can be seamlessly integrated with SCADA systems, enabling remote monitoring capabilities. Through strategic placement along power lines, FPIs effectively identify faults by analyzing parameters such as current and voltage. The utilization of FPIs brings about notable benefits including enhanced fault detection, minimized downtime, and heightened operational efficiency.

Design and implementation

3. Design and implementation

3.1 Introduction

In this chapter, we will focus on implementing the Fault Passage Indicator (FPI) system. Our goal is to bring the FPI system to life by selecting and integrating the necessary components, configuring the software and hardware, and establishing the required connections. Through this implementation process, we aim to create a functional FPI system that can effectively detect faults in electrical systems.

3.2 System architecture

The fault passage indicator system's architecture can vary depending on the specific model and application. Key components include the current sensor resistor, which measures the power line's current and plays a vital role in fault detection. The Arduino ESP8266 acts as a microcontroller, processing the input from the current sensor resistor and transmitting the output to the database in our case google firebase. The database serves as a storage system for the collected data, facilitating data management, analysis, and reporting. LabVIEW, a software platform, provides a graphical user interface (GUI) that presents the fault data in an intuitive format, enhancing visualization and interpretation capabilities. These components work together to create an effective fault passage indicator system.

3.2.1 Connections and interactions

The fault passage indicator system comprises interconnected components: the current sensor resistor measures power line current and sends the signal to the Arduino ESP8266, which processes it and communicates the output to the database. The database serves as a repository for fault data, enabling analysis and reporting. LabVIEW, in turn, presents the collected fault data in an accessible and user-friendly format, facilitating effective

visualization and interpretation.

3.2.2 Google firebase

The database employed in fault passage indicator systems serves the purpose of storing the collected data. The database architecture typically follows a client-server model, where the Arduino ESP8266 acts as the client and the database management system serves as the server. In terms of data storage, the fault data is organized into tables within the database, with each table representing a specific data category such as fault type, location, and time.

3.2.3 Labview

LabVIEW serves as a SCADA system in fault passage indicator systems, enabling remote monitoring and control. It displays the collected fault data in a user-friendly format, facilitating operator monitoring and appropriate action during fault occurrences. LabVIEW integrates into the system architecture, with the Arduino ESP8266 transmitting the fault data for display in LabVIEW. Communication between the Arduino ESP8266 and LabVIEW is established using a serial communication protocol. LabVIEW's functionality encompasses real-time display of fault data, empowering operators to monitor the system remotely and respond to faults as needed. Additionally, LabVIEW can be customized to present the fault data in a format tailored to the specific application and system requirements.

Flowchart

The flowchart illustrates the sequential steps involved in the fault detection system. It begins with the ASC712-30A current sensor, which senses the current in the system. The Arduino ESP8266 microcontroller reads the current values and transmits them to a database in our case Google firebase. From the database where the information is stored for future reference. At the same time it connects to the SCADA system, specifically LabVIEW's front panel in our case, enabling remote monitoring and control. A comparison is then conducted to determine if there is an undercurrent or overcurrent condition. If a fault is

detected, there is a time delay of 3 seconds before activating the LED indicator. Conversely, if no fault is identified, the process loops back to the ASC712-30A current sensor to re-sense the current. This flowchart provides a visual representation of the fault detection system's operational flow and control.

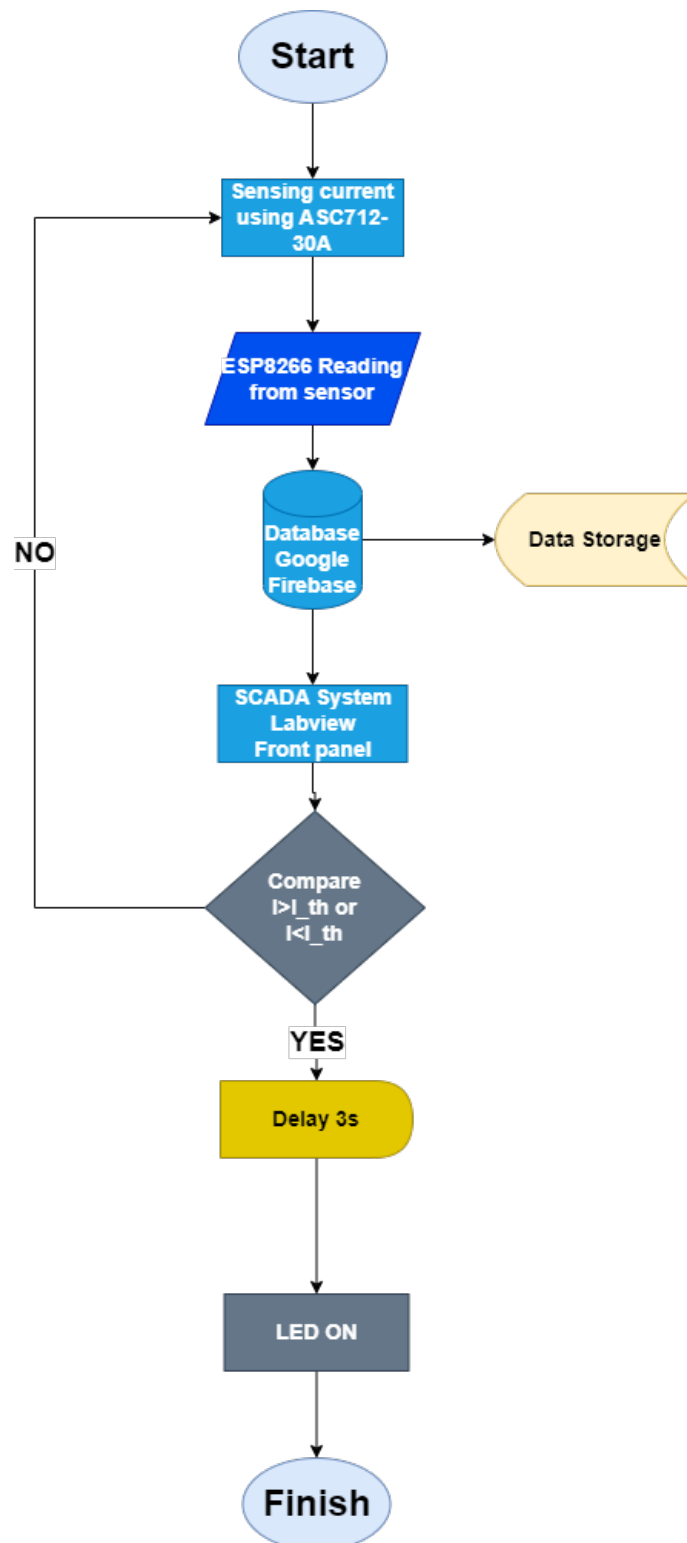


Figure 8. FPI system flowchart

3.3 Implementation

The implementation of our fault passage indicator system encompasses various components and functionalities. It includes hardware components such as the ACS712 current sensor, ESP8266 microcontroller, and LED indicator. The software aspect involves programming the microcontroller and implementing data transmission to Google Firebase. Additionally, the communication part focuses on establishing connectivity between the ESP8266, Firebase, and the LabVIEW front panel. Overall, the implementation combines hardware, software, and communication elements to create a functional fault passage indicator system.

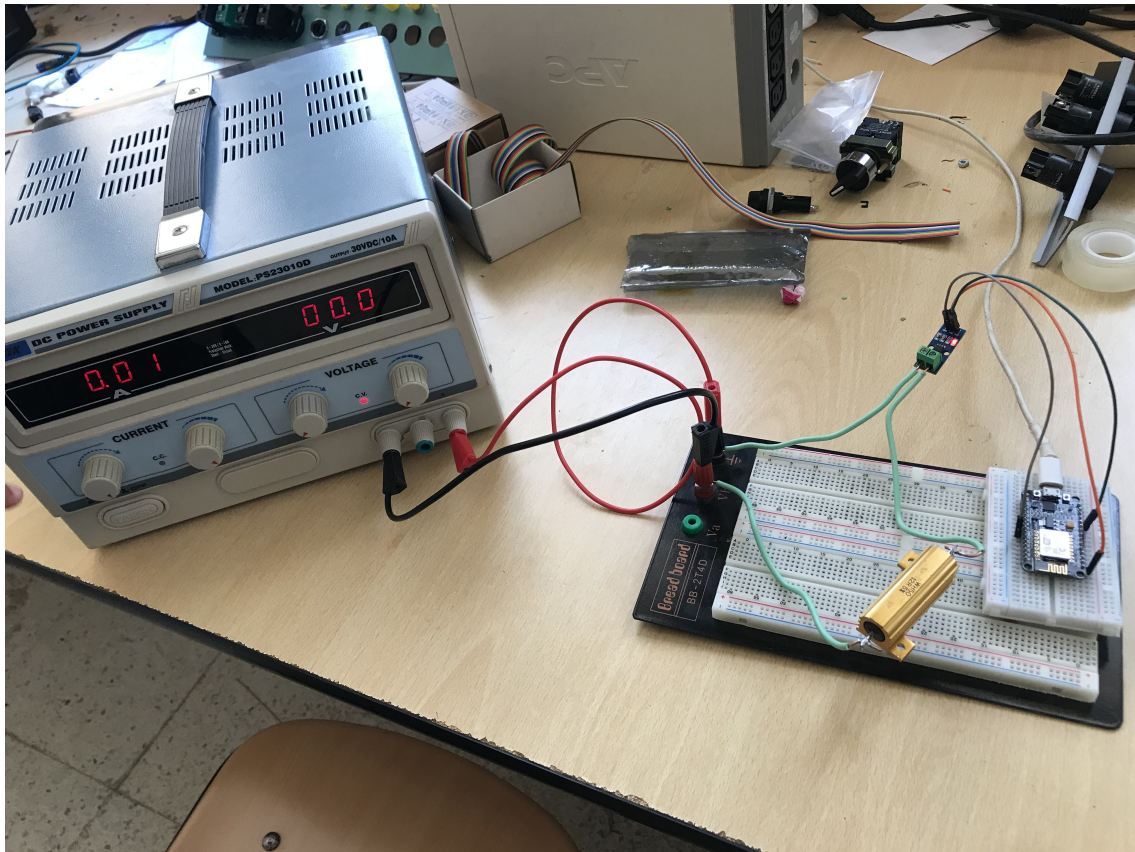


Figure 9. Implemented circuit with supply

3.3.1 Hardware part

Arduino ESP8266

We have used the Arduino ESP8266 microcontroller in our fault passage indicator

system, as it offers essential functionalities for our project. The microcontroller effectively processes the input signal from the current sensor resistor and transmits the output signal to the database. We programmed the Arduino ESP8266 using the Arduino IDE and established communication with other devices using various protocols, including Wi-Fi, Bluetooth, and serial communication. To power the Arduino ESP8266, we provided a DC power supply or through a built-in battery. During the programming process, we took into account the limited memory capacity of the Arduino ESP8266. To ensure accurate fault detection and reliable operation, we incorporated error handling within the code and implemented backup power supplies to ensure uninterrupted operation during power outages. Additionally, we prioritized the use of reliable and secure communication protocols to guarantee accurate and secure transmission of data.

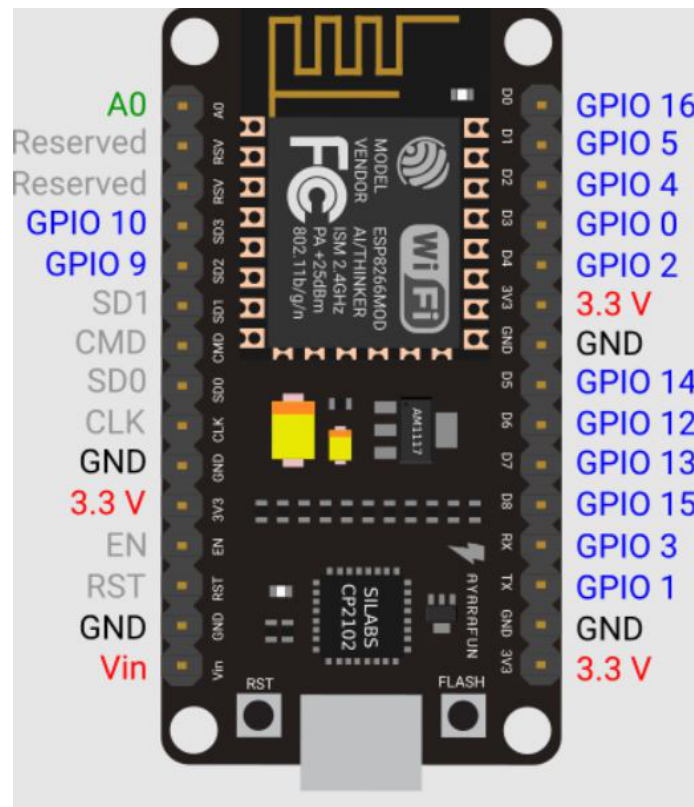


Figure 10. *Arduino ESP8266*[18]

ACS712-30A Current sensor

The current sensor as an important component of our fault passage indicator system. The current sensor, typically a current sensor resistor, plays a vital role in providing the input signal necessary for fault detection in the system. We ensured that the sensitivity of

the current sensor resistor was appropriately adjusted to achieve accurate fault detection. Additionally, we focused on achieving a fast response time for the sensor to enable prompt detection of faults. By connecting the current sensor resistor to the power line, we were able to accurately measure the current flowing through it, meeting the specific requirements of our application.

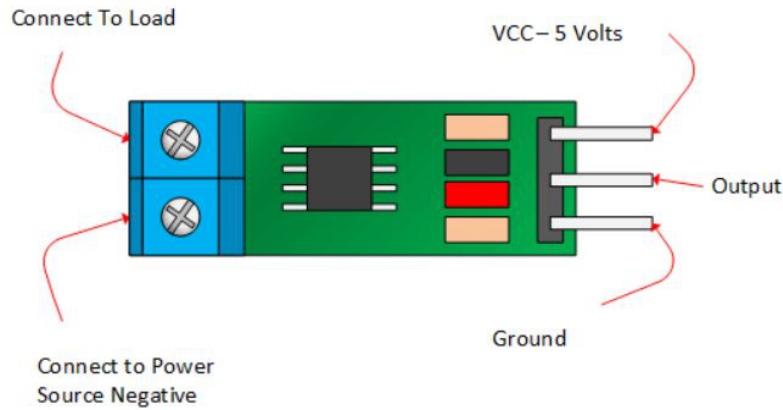


Figure 11. ASC712-30A[19]

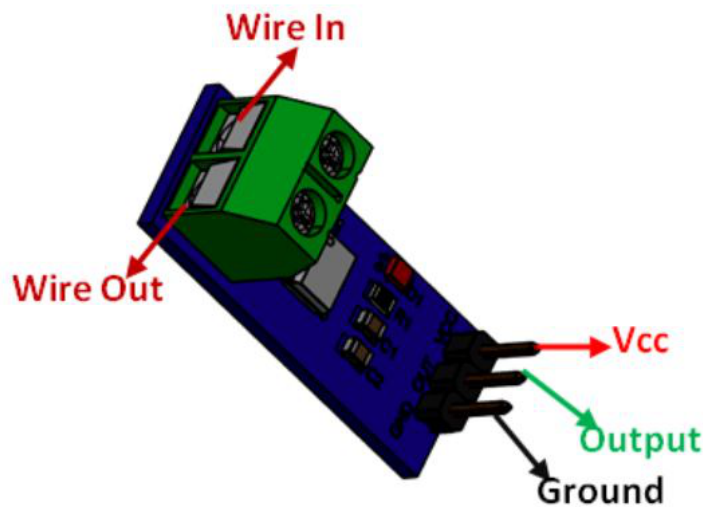


Figure 12. SC712 current sensor[20]

LED

We have incorporated an LED into our fault passage indicator system to provide visual indication of fault conditions. The LED serves as a visual indicator that activates when a fault is detected by the system. By carefully programming the system, we were able to control the LED to turn on or off based on the fault status. This visual feedback enhances the usability and user-friendliness of the system, allowing for quick identification of faults. The LED's integration was seamlessly achieved by connecting it to the appropriate output pins of our microcontroller, enabling us to visually communicate the occurrence of faults in real-time.

ESP8266 and ACS712 interfacing

We have successfully interfaced the ACS712-30A current sensor with the ESP8266 module. Our hardware connection involved connecting the VCC and GND pins of the sensor to the appropriate power supply and ground, respectively, and linking the OUT pin to one of the ESP8266's analog input pins. By writing code, we were able to read analog data from the ACS712 sensor using the ADC capabilities of the ESP8266. This code was developed using the Arduino IDE and programmed onto the ESP8266. Once the analog data is obtained, we transmit it over WiFi to our SCADA system for further analysis or processing. To facilitate WiFi communication, we have installed the ESP8266WiFi library for Arduino.

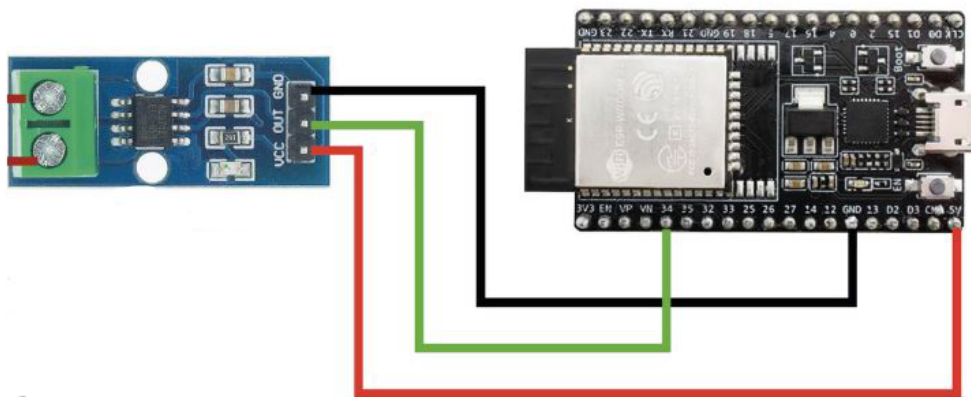


Figure 13. *ESP8266 ACS712 interfacing*[21]

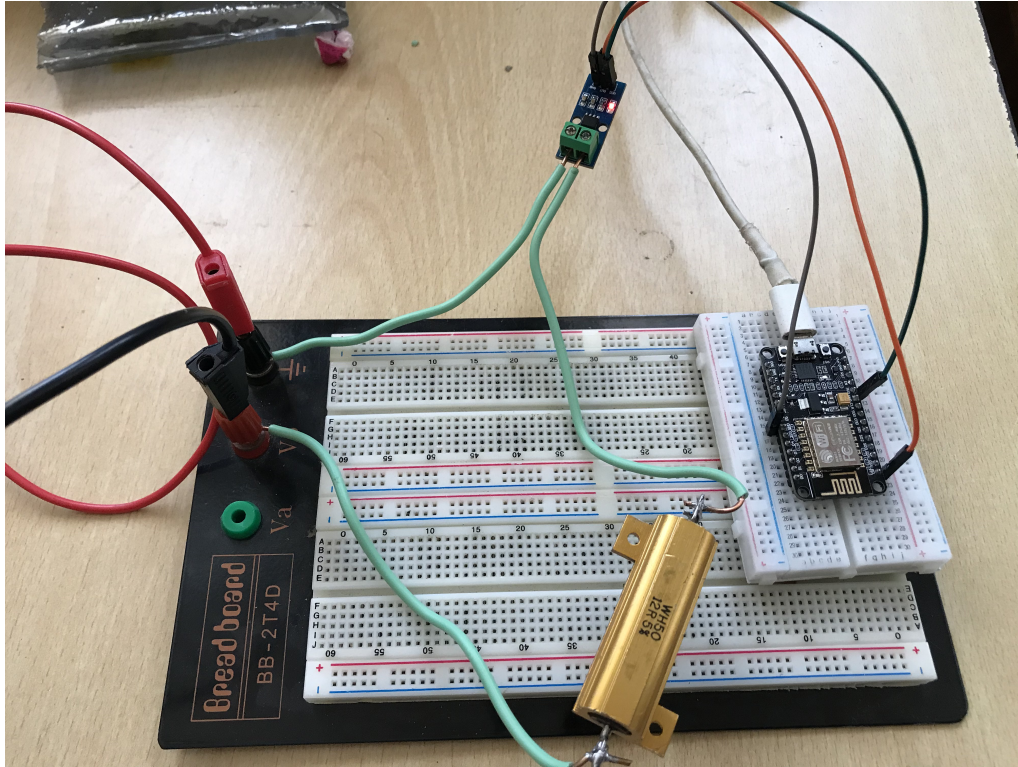


Figure 14. *Circuit implementation*

3.3.2 Software part

Block diagram

We have developed the LabVIEW code using LabVIEW's data communication function to retrieve sensor data from Google Firebase using the HTTP client protocol. We display the acquired data on the front panel of LabVIEW. In LabVIEW, we achieve this by specifying the URL of the relevant database and establishing a connection to the "get" function of the HTTP client protocol for data communication. This allows us to read the sensor values and compare them to detect any faults. When a fault is detected, we activate an LED, as shown below:

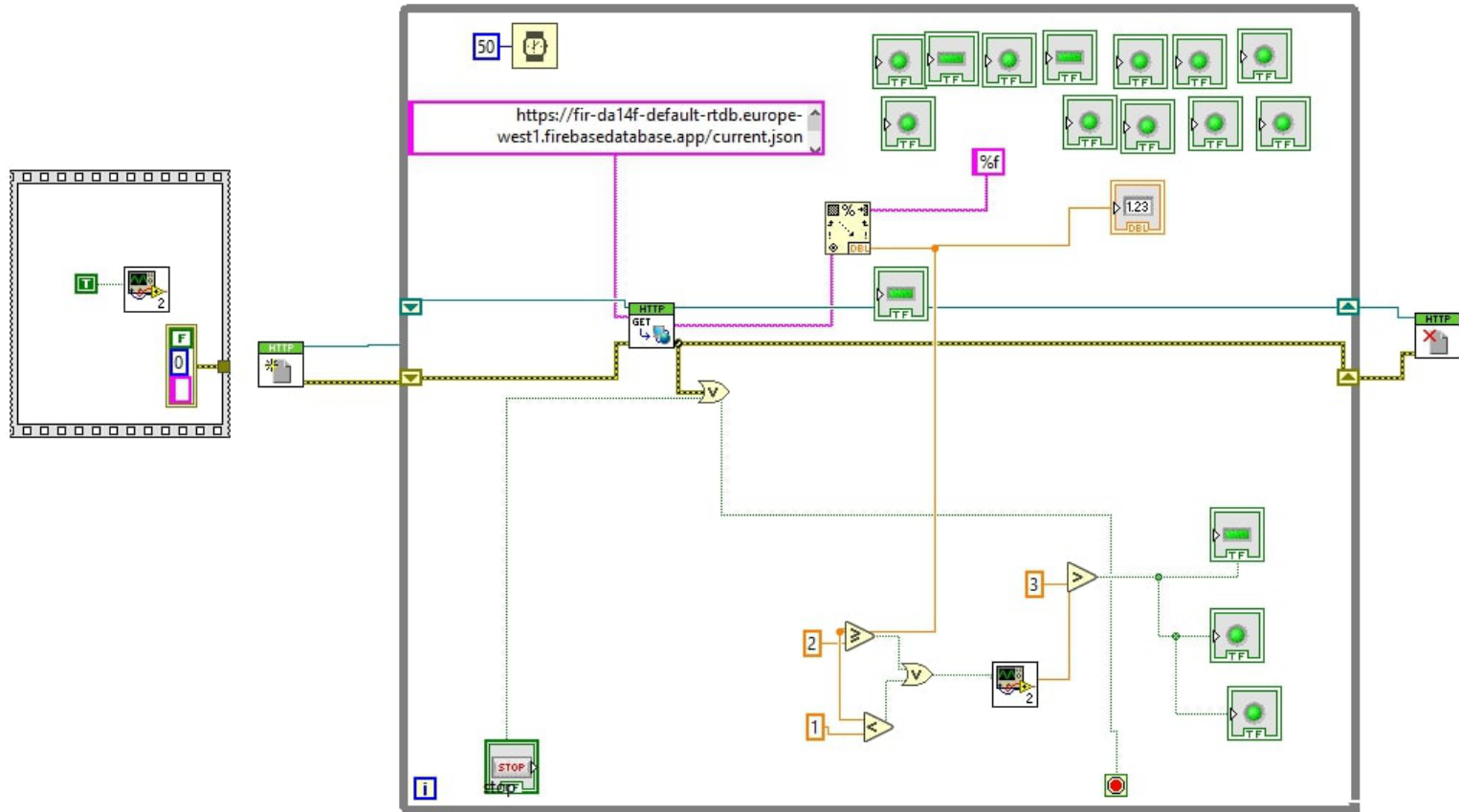


Figure 15. Block diagram

In this previous code, the LabVIEW program establishes a connection to the specified URL, representing the Google Firebase database, and retrieves the sensor data. The code then proceeds to compare the sensor values to determine if a fault has occurred. If a fault is detected, the LED on the front panel is activated using the 'TurnOnLED' function to indicate the presence of the fault. The following section of the code demonstrates the utilization of the "get" function from the communication protocols to retrieve the data value from Google Firebase and display it on the front panel, the LabVIEW code establishes a connection to the specified URL, representing the Google Firebase database. Using the HTTPClient module, the GET function is invoked to retrieve the data from the database

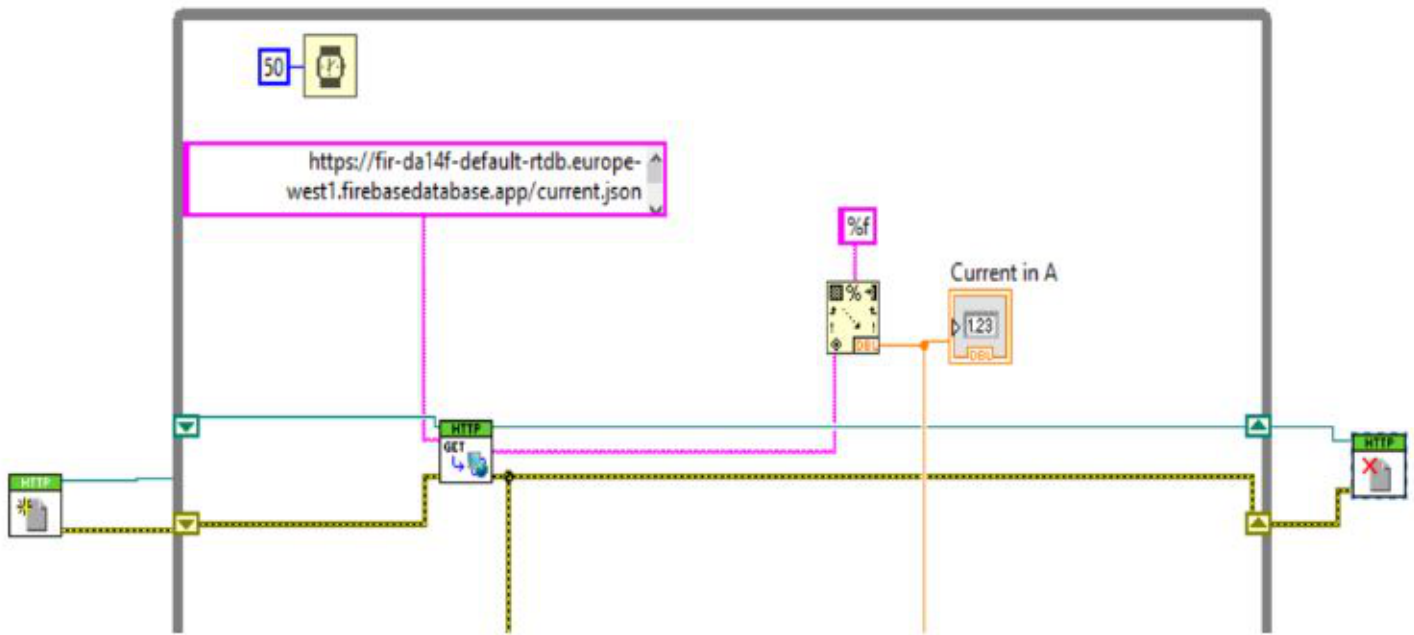


Figure 16. the utilization of the GET function

To ensure accurate fault indications and mitigate potential errors attributed to factors like inrush current proximity effect, the LabVIEW code incorporates a time delay. The following part of the code snippet exemplifies how the front panel interface compares the sensor readings and waits for a specific duration before indicating a fault :

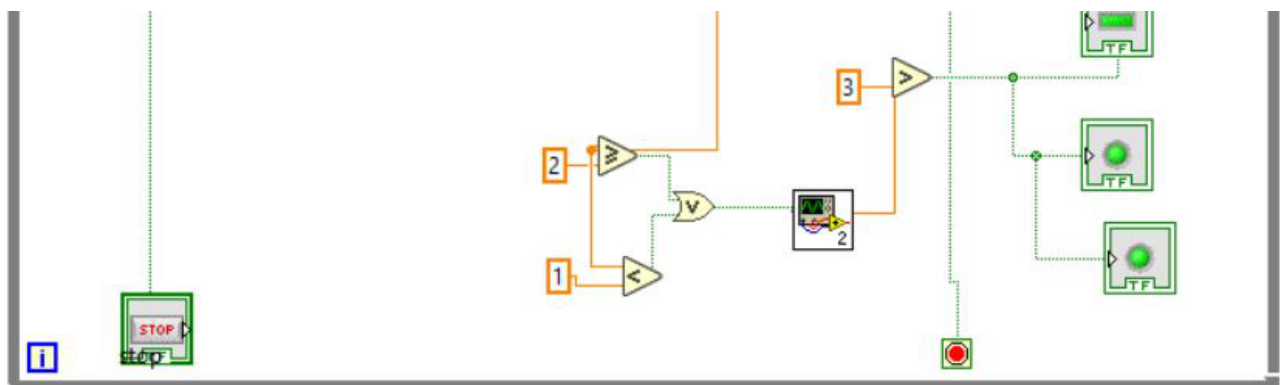


Figure 17. Sensor readings comparison

To implement a time delay in LabVIEW, a timer has been developed using the

branch of the distribution system, we have integrated Fault Passage Indicators (FPIs) in each phase. Through LabVIEW, we have developed a comprehensive interface that allows operators to monitor and analyze the data obtained from the FPIs.

Additionally, the SCADA system enables real-time monitoring and data logging. It captures the current readings from the FPIs at regular intervals and stores them for further analysis and historical reference. This functionality allows operators to track the performance of the electrical distribution system over time and identify any recurring patterns or issues.

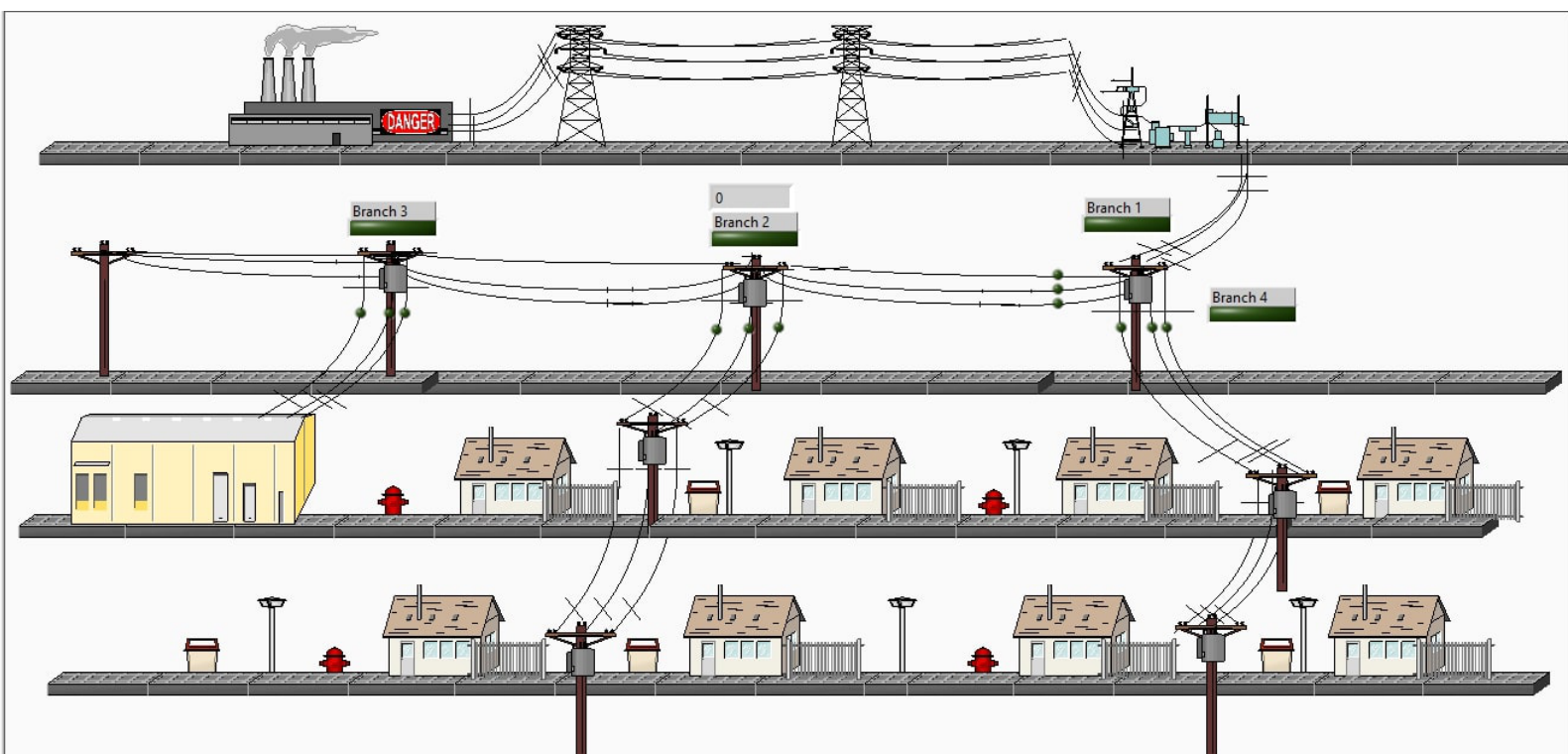


Figure 19. LabVIEW Front Panel as SCADA System

Google firebase

We have successfully used Firebase, a platform that helps us store and manage data efficiently. It offers two types of databases: the Realtime Database and Cloud Firestore. These databases allow us to store data securely and keep it updated in real-time. By integrating Firebase with LabVIEW and ESP8266, we can improve SCADA systems, which help monitor and control processes. This integration lets us store and access data from sensors and devices easily, making monitoring and control more effective. We follow three steps to achieve this integration.

- Create a Firebase platform

In order to access the real-time database in Firebase, our primary goal was to create a Firebase Project and obtain the URL and API code. These components are essential for establishing connections between LabVIEW, ESP8266, and the Firebase Realtime Database. By acquiring the URL and API code, LabVIEW and ESP8266 were able to effectively connect to and interact with the real-time database. This enabled seamless data exchange and synchronization between the different components, facilitating efficient communication and data management.

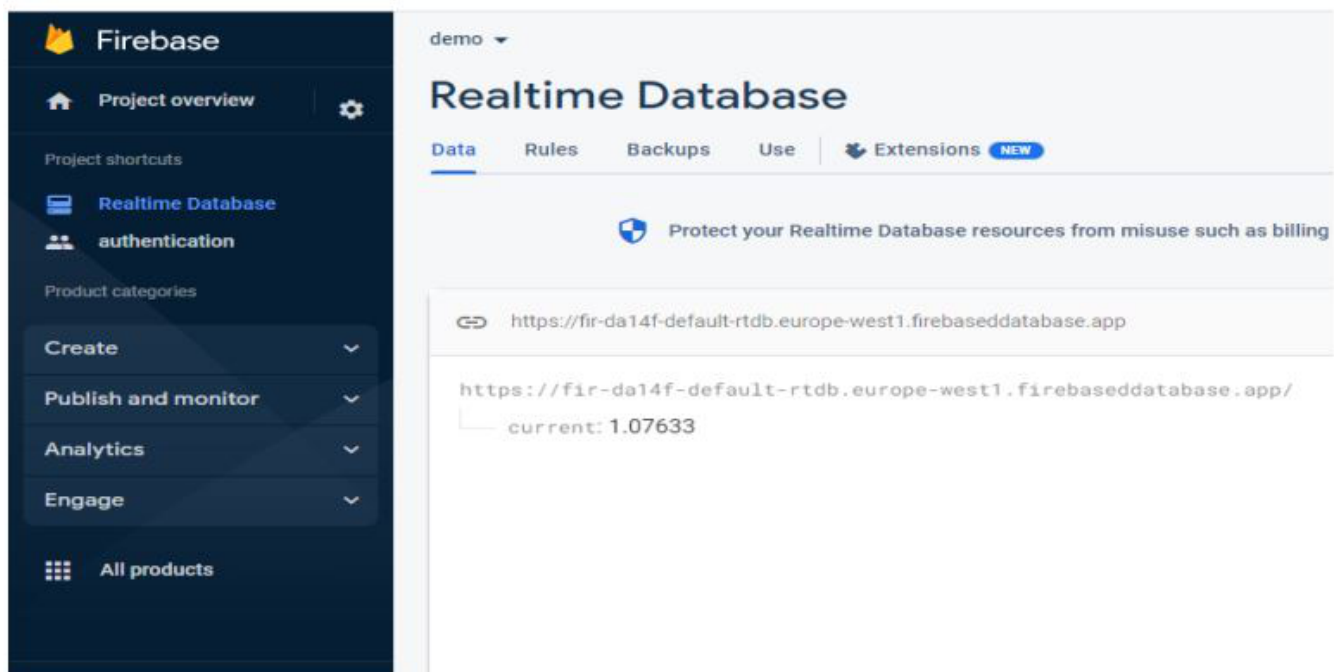


Figure 20. URL

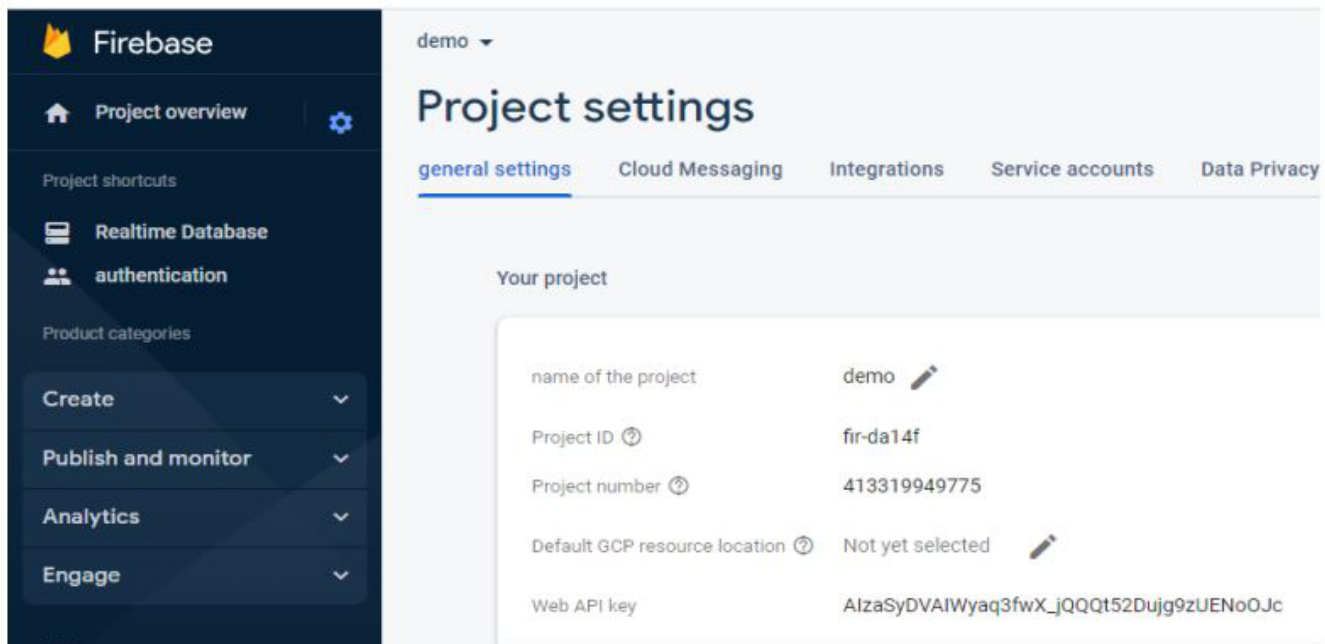


Figure 21. API

■ ESP8266:

To Store data to the Firebase Realtime Database, We have successfully utilized Firebase to control the ESP8266 and display sensor readings from anywhere in the world. With Firebase's backend services and the ESP8266 microcontroller, we were able to transmit sensor data to Firebase's Realtime Database or Cloud Firestore. This integration allowed for real-time data synchronization, enabling remote monitoring and access to sensor readings from any location. The system ensured secure communication between the ESP8266 and Firebase, providing a reliable and scalable solution for displaying sensor data globally. To establish a connection between Firebase and the ESP8266, we implemented a crucial link in the Arduino code. This code enabled the ESP8266 to communicate with the Firebase Realtime Database by incorporating the appropriate API and network credentials, facilitating effective connection and access to real-time data.

3.3.3 Communication part

Communication between Firebase and ESP8266

In our implementation, we provide a detailed explanation of the communication setup

between the ESP8266 and Google Firebase. This process involves several steps, such as establishing a connection to the Firebase database, creating the required API endpoints, and configuring the ESP8266 to transmit sensor data to Firebase. By establishing a connection to Firebase, we enable seamless data transfer between the ESP8266 and the Firebase database. The creation of API endpoints ensures that the data is properly organized and accessible within Firebase. Additionally, we focus on configuring the ESP8266 to effectively send sensor data to Firebase, ensuring reliable and accurate data transmission.

Communication between Firebase and LabView

In our implementation, we have successfully set up the communication between the ESP8266 and Google Firebase. This involved establishing a connection to the Firebase database and creating the necessary API endpoints. We configured the ESP8266 to send sensor data to Firebase, ensuring reliable data transmission. Additionally, we focused on the interaction between the LabVIEW front panel and Firebase, enabling the retrieval of data from Firebase for display and monitoring purposes. Throughout the communication process, we ensured a bidirectional flow of data between the ESP8266, Google Firebase, and the LabVIEW front panel. By implementing data synchronization and real-time monitoring features, we achieved efficient and up-to-date data exchange between the different components, enhancing the overall functionality of the system.

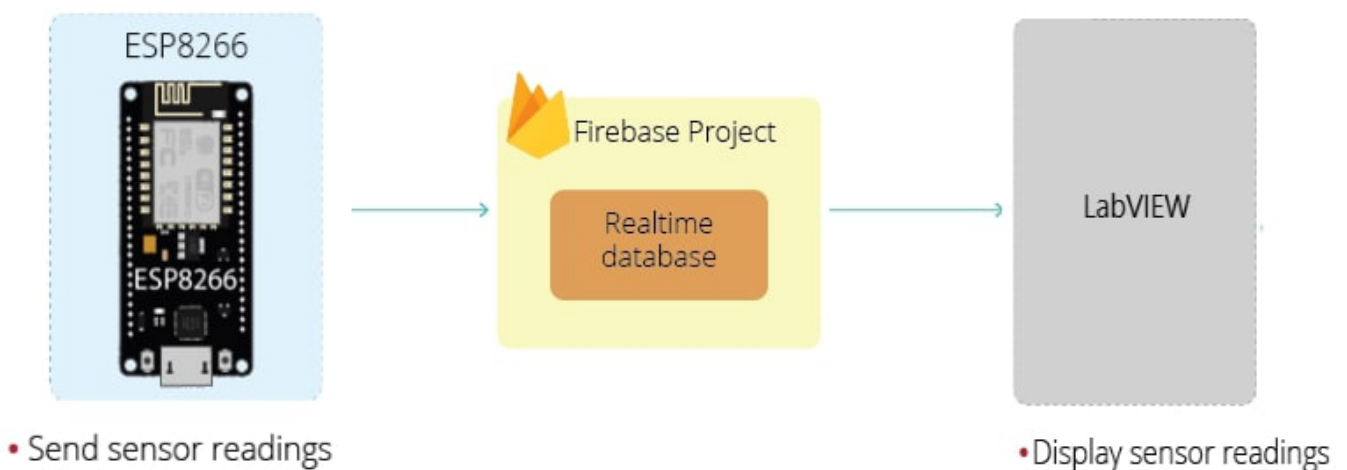


Figure 22. Communication Flow: ESP8266 to Google Firebase to LabVIEW

3.4 Conclusion

In conclusion, this chapter detailed the implementation of the Fault Passage Indicator (FPI) system. We successfully selected and integrated the required components, configured the software and hardware, and established the necessary connections. Through this process, we have developed a functional FPI system capable of detecting faults in electrical systems. The implemented system provides an effective solution for improving the reliability and safety of electrical networks.

Testing, results and discussion

4. Testing, results and discussion

4.1 Testing

4.1.1 Threshold Verification Test

The Threshold Verification Test of the Fault Passage Indicator (FPI) system involved systematically varying the current levels and closely monitoring the system's response to verify the predefined threshold values for overcurrent and undercurrent detection. This test aimed to ensure that the FPI system accurately detected and indicated fault conditions at the predetermined thresholds, enabling precise fault identification and prompt corrective actions. By validating the chosen threshold values and confirming the proper functioning of the FPI system, this test contributed to enhancing the safety, reliability, and efficiency of the electrical distribution system.

Undercurrent test

During the undercurrent test, the Fault Passage Indicator (FPI) system was subjected to varying current levels below 1A to evaluate its sensitivity in detecting and indicating undercurrent conditions. The purpose of this test was to assess the system's ability to accurately identify and signal low current levels, which could indicate abnormal operating conditions or potential faults in the electrical distribution system. To conduct the test, the current levels were systematically adjusted in small increments, ranging below 1A. At each current level, the FPI system was closely observed to determine if it properly detected and indicated the undercurrent condition. This involved monitoring the behavior of the LED indicator or other visual cues provided by the FPI system. The test aimed to ensure that the FPI system had sufficient sensitivity to detect even subtle decreases in current below the defined threshold.

Overcurrent test

During the overcurrent test, the Fault Passage Indicator (FPI) system was subjected to increasing current levels above 2A to evaluate its response and accuracy in detecting and indicating overcurrent conditions. The objective of this test was to assess the FPI system's ability to effectively identify and signal excessive current levels, which could indicate faults or abnormal operating conditions in the electrical distribution system. The overcurrent test involved gradually increasing the current levels applied to the FPI system, starting from a value above 2A. At each specific current level, the behavior of the FPI system was closely observed and recorded to determine if it promptly detected and indicated the overcurrent condition. This typically involved monitoring the LED indicator or other visual indicators provided by the FPI system.

Normal operation

During the normal operation test, the Fault Passage Indicator (FPI) system was subjected to current levels ranging between 1A and 2A to evaluate its performance under typical operating conditions. The purpose of this test was to assess the FPI system's sensitivity and accuracy in detecting and indicating subtle variations within the normal current range. In this test, small adjustments were made to the current levels within the specified range of 1A to 2A. The behavior of the FPI system, particularly the LED indicator or other visual indicators, was closely monitored to observe its response to these slight variations. The goal was to ensure that the FPI system accurately detected and indicated these subtle changes, which are characteristic of normal operating conditions. In the normal operation test, we increased the current to a level within the expected operating range, such as 1.5A. Throughout this process, we closely monitored the FPI system's response.

4.1.2 Step Response Test

During the rapid current variation test, we intentionally subjected the Fault Passage Indicator (FPI) system to sudden changes in current levels, with durations shorter than the FPI's time delay of 3 seconds. We rapidly increased and decreased the current values within this timeframe while closely monitoring the behavior of the LED indicator. The

main objective of this test was to evaluate the FPI system's responsiveness to rapid and transient current variations occurring in less than 3 seconds.

4.1.3 Fault test

short circuit

In the Short Circuit Test, we intentionally created a short circuit condition to evaluate the FPI system's response. By directly connecting the positive and negative without any resistance in between.

Open circuit

In the Open Circuit Test, we intentionally created an open circuit condition by disconnecting the electrical load from the system.

4.1.4 Sensitivity Test

During the Sensitivity Test, our aim was to evaluate the Fault Passage Indicator (FPI) system's sensitivity by making small adjustments to the current levels within the range of approximately 1-2 amps. The purpose of this test was to assess the FPI system's ability to detect and indicate subtle changes in current within its normal operating range. To conduct the test, we carefully adjusted the current levels within the specified range while closely observing the behavior of the LED indicator. The LED indicator serves as a visual indication of the FPI system's response to the varying current levels.

4.2 Results and discussion

4.2.1 Threshold verification test results

Undercurrent test result

The undercurrent test was conducted to evaluate the performance of the FPI system in detecting undercurrent faults. The measured current during the test was 0.568 A, which

falls below the undercurrent threshold of 1 A. As expected, the LED indicator turned on, indicating the presence of an undercurrent fault. This result confirms the accuracy and sensitivity of the FPI system in detecting even minor deviations from the expected current range.

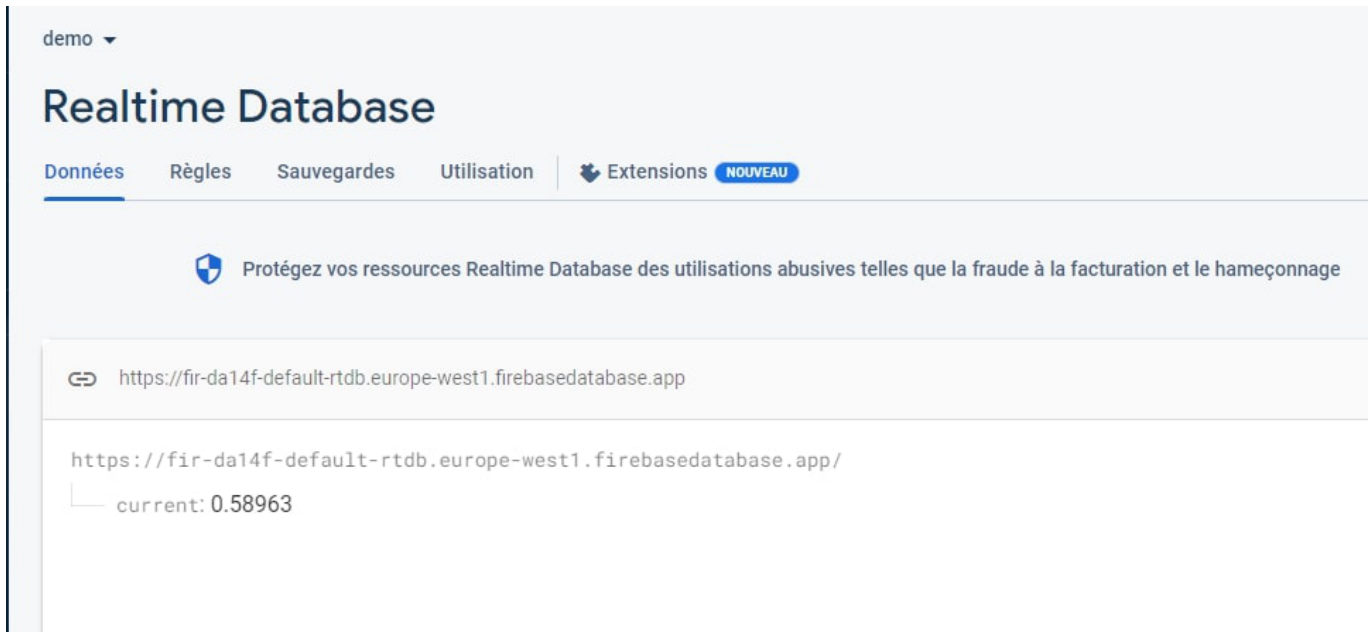


Figure 23. *Firebase undercurrent test result*

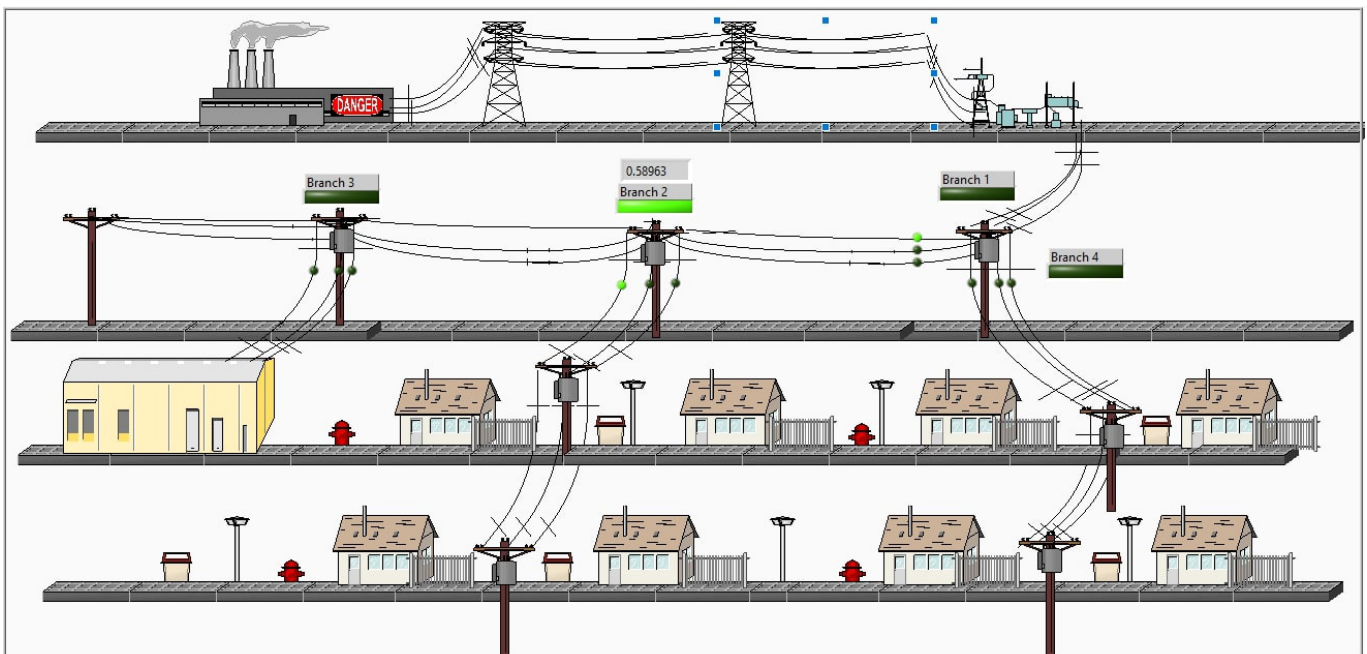


Figure 24. *Undercurrent test result*

Overcurrent test result

The overcurrent test aimed to assess the ability of the FPI system to detect and indicate overcurrent faults. During the test, the measured current value was 2.29131 A, exceeding the overcurrent threshold of 2 A. As expected, the LED indicator turned on, providing a clear indication of the overcurrent fault.

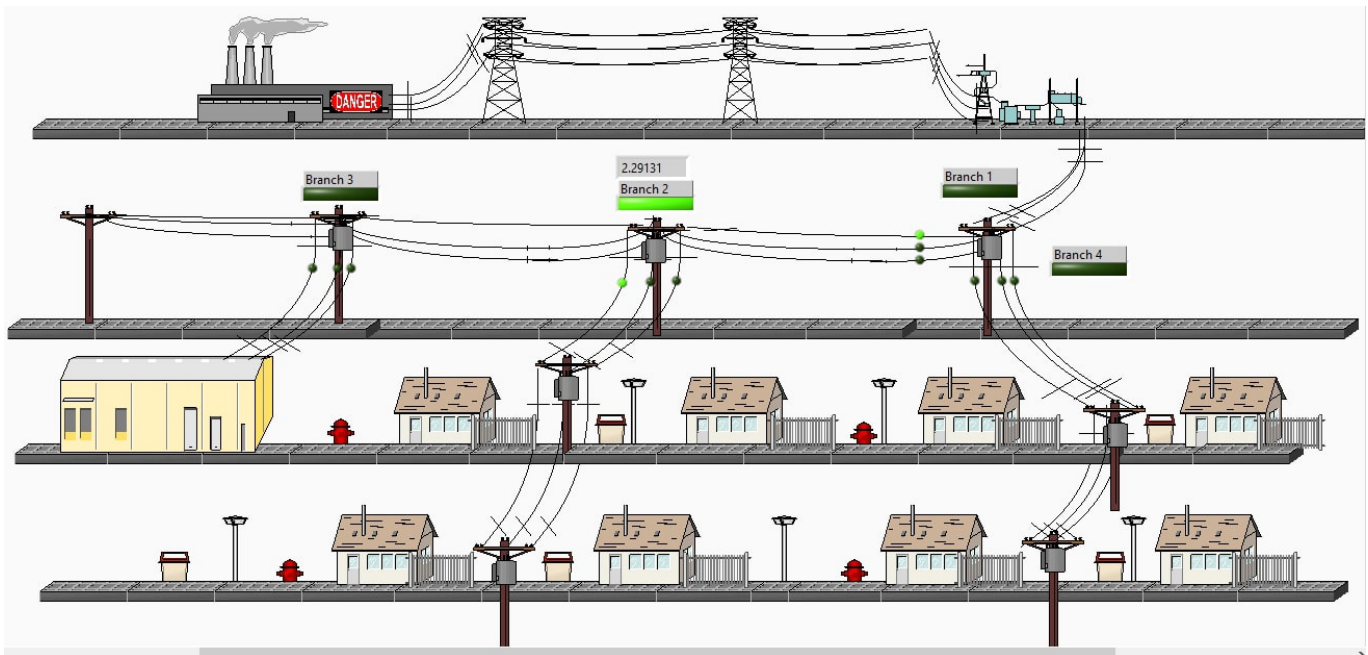


Figure 25. Overcurrent test result



Figure 26. Firebase Overcurrent test result

Normal operation test result

During the normal operation test, where the current was measured at 1.36122 A, it is important to note that the threshold values for the FPI system were set at 1 A for the undercurrent and 2 A for the overcurrent. The test result revealed that the LED indicator remained off, indicating that the measured current fell within the normal operating range. This demonstrates the FPI system's ability to accurately differentiate normal operating conditions from fault conditions, providing reliable indications without triggering false alarms. By maintaining the LED indicator off during normal operation.

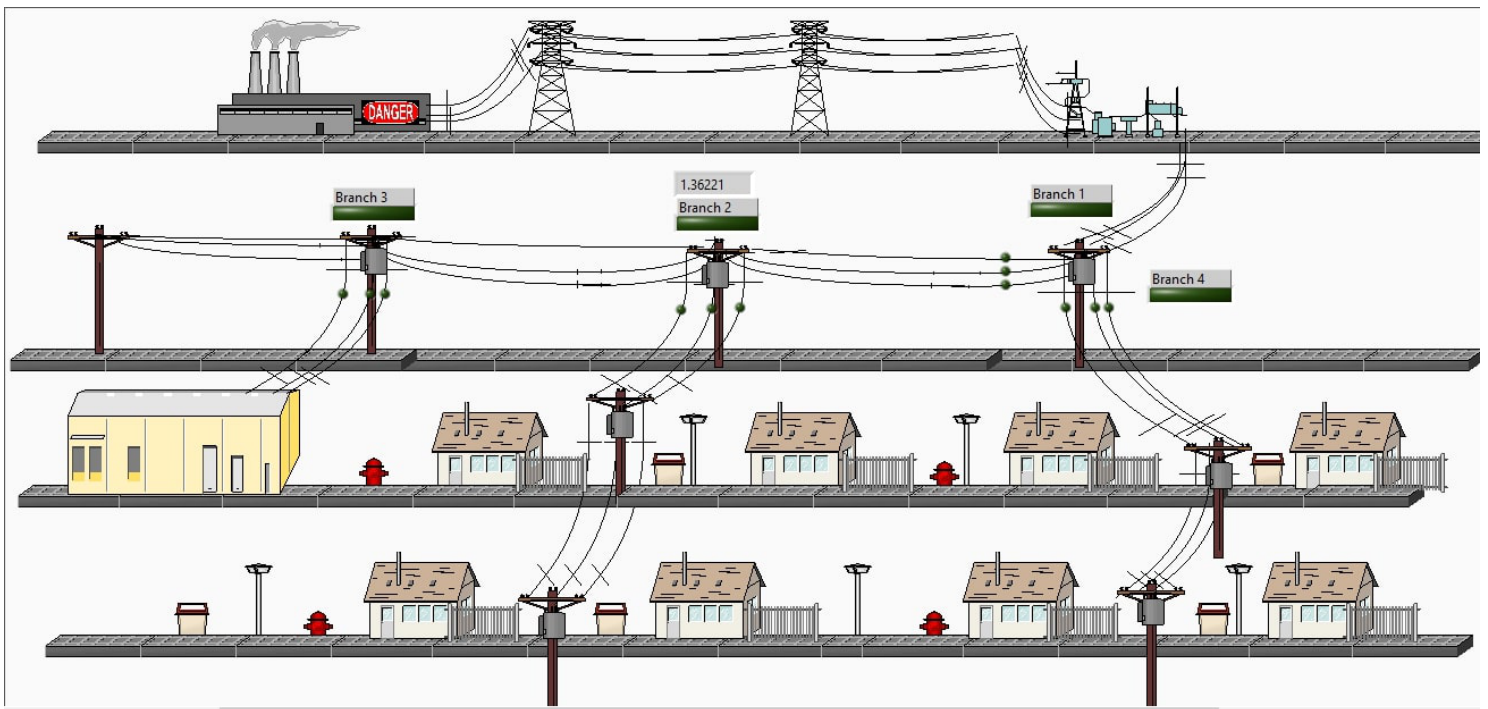


Figure 27. Normal operation test result



Figure 28. *Firebase normal operation test result*

4.2.2 Step response test results

During the step response test, it was observed that the LED of the FPI system remained off when subjected to sudden changes in current levels. This was due to the fact that the inrush current time was shorter than the time delay of 3s programmed into the FPI system. The purpose of the time delay is to prevent false indications triggered by transient current fluctuations, such as inrush currents that occur during the startup of electrical equipment.

4.2.3 Fault simulation test results

Short circuit test result

resulting in a very high fault current. The LED indicator turned on in this test, indicating the successful detection of the short circuit fault by the FPI system.

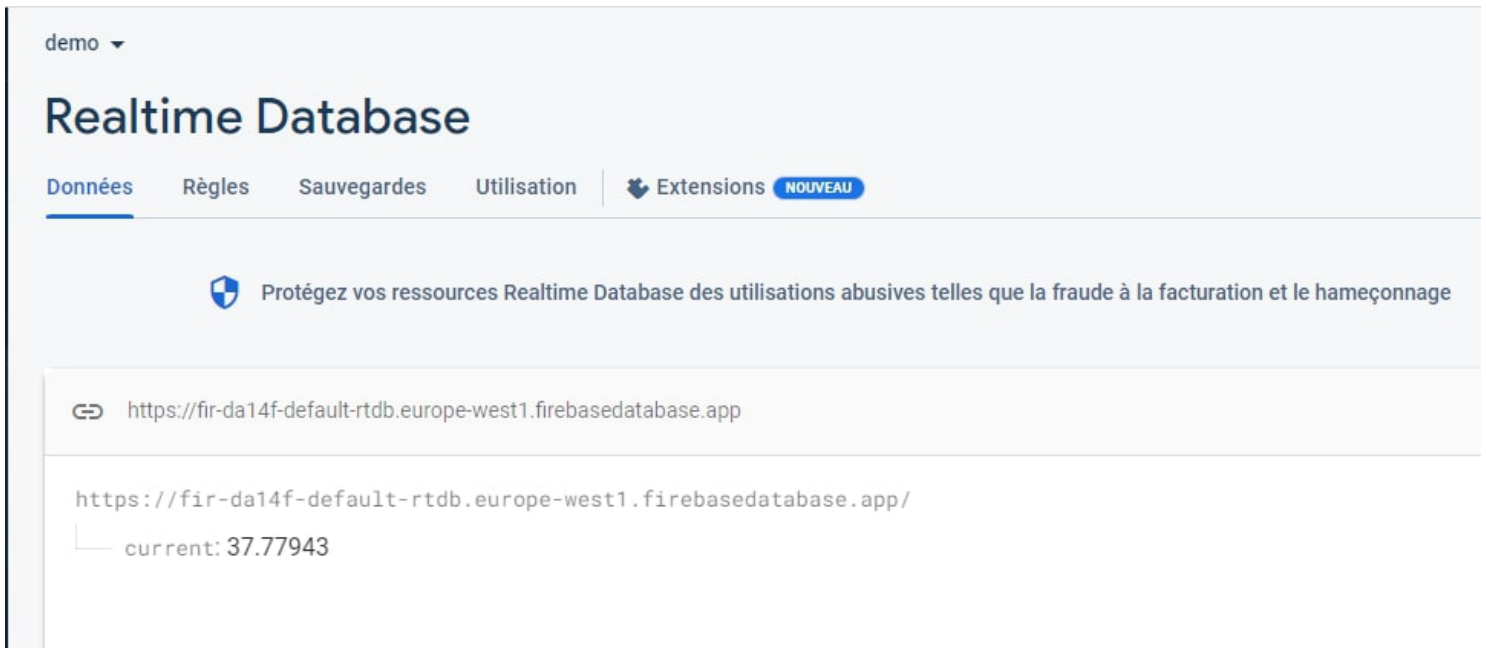


Figure 29. Firebase short circuit test result

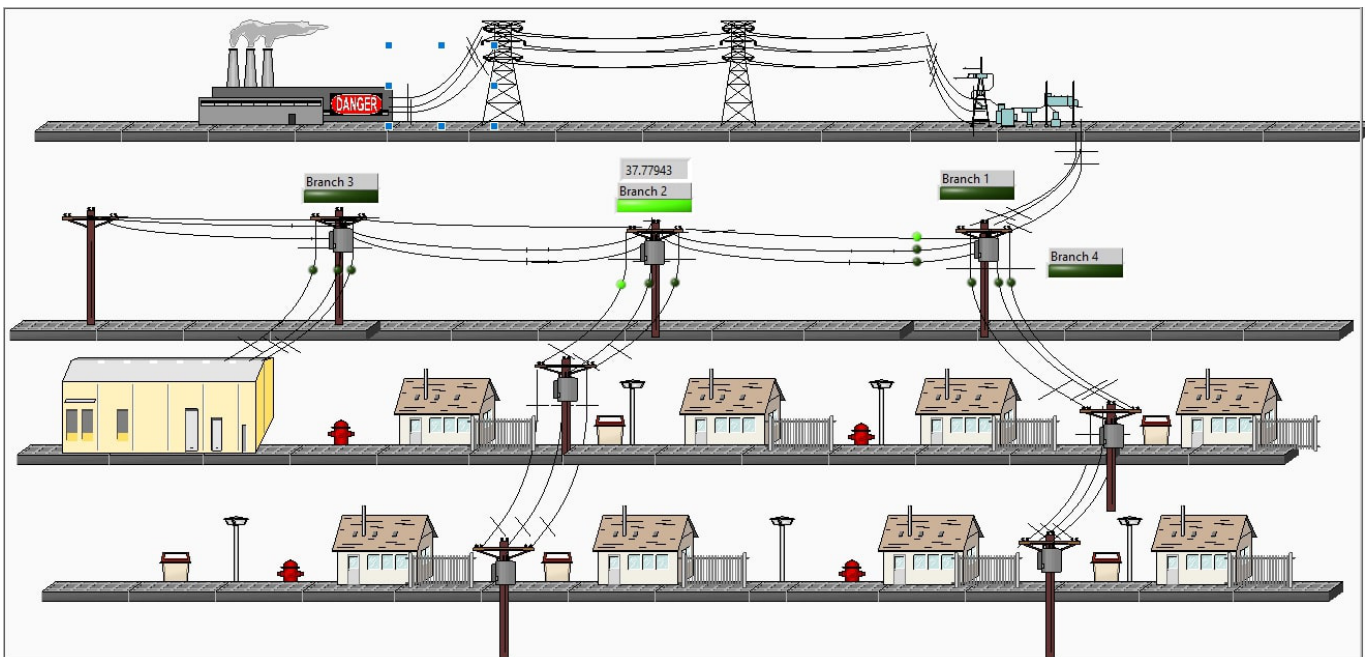


Figure 30. Short circuit test result

Open circuit test result

The open circuit test was conducted to evaluate the FPI system's response to open circuit faults. In this particular test, the measured current value was 0.07576 A, indicating the absence of current flow due to an open circuit condition. As expected, the LED

indicator turned on, indicating the detection of an open circuit fault.



Figure 31. *Firebase open circuit test result*

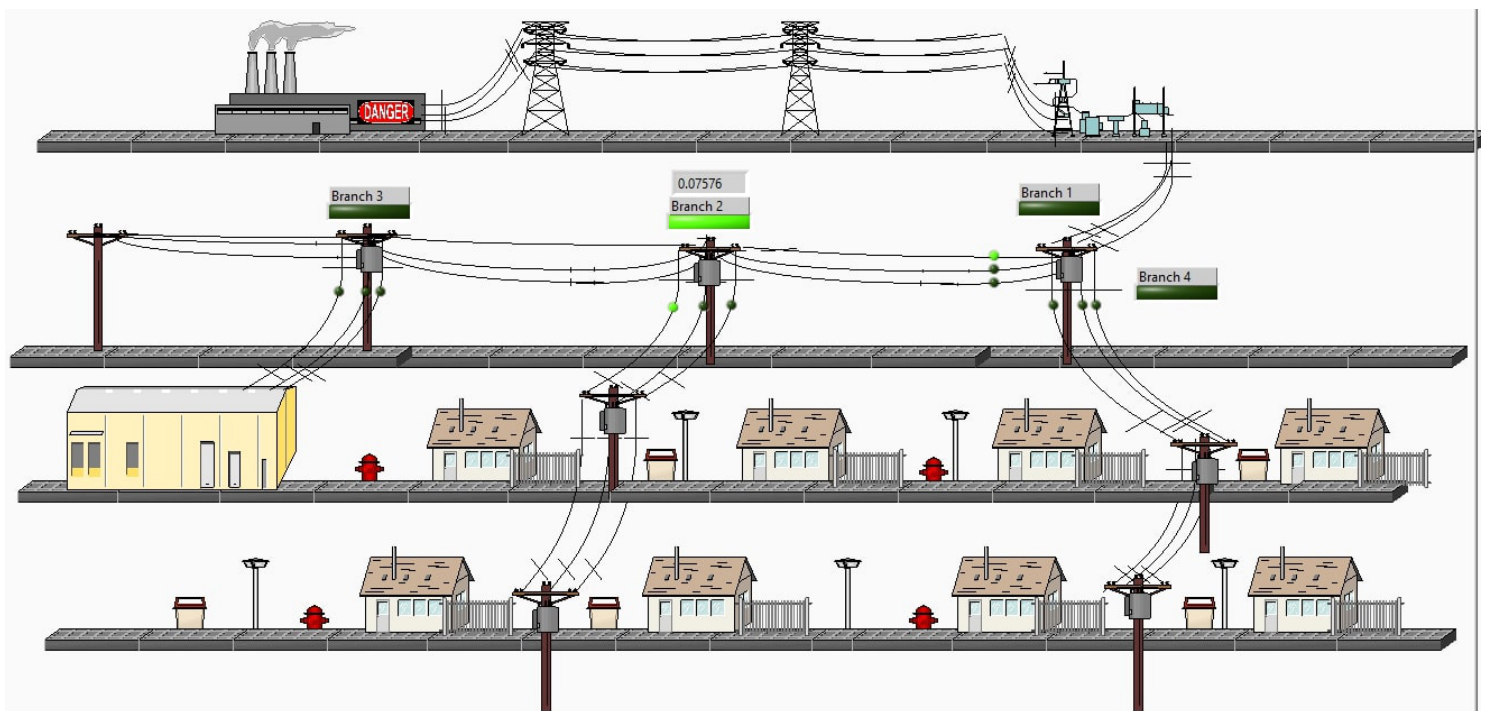


Figure 32. *Open circuit test result*

4.2.4 Sensitivity test results

During the sensitivity test, it was observed that the LED indicator of the FPI system remained off when small adjustments were made to the current levels within the approximate range of 1-2. Despite the slight variations in the current, the LED did not respond

and remained off. This result indicates that the sensitivity of the FPI system might be set at a higher threshold, requiring more significant changes in the current levels to trigger a response. The purpose of this sensitivity setting is to ensure that the FPI system focuses on detecting and indicating significant variations in current levels that are indicative of fault conditions, while disregarding minor fluctuations within the normal operating range.

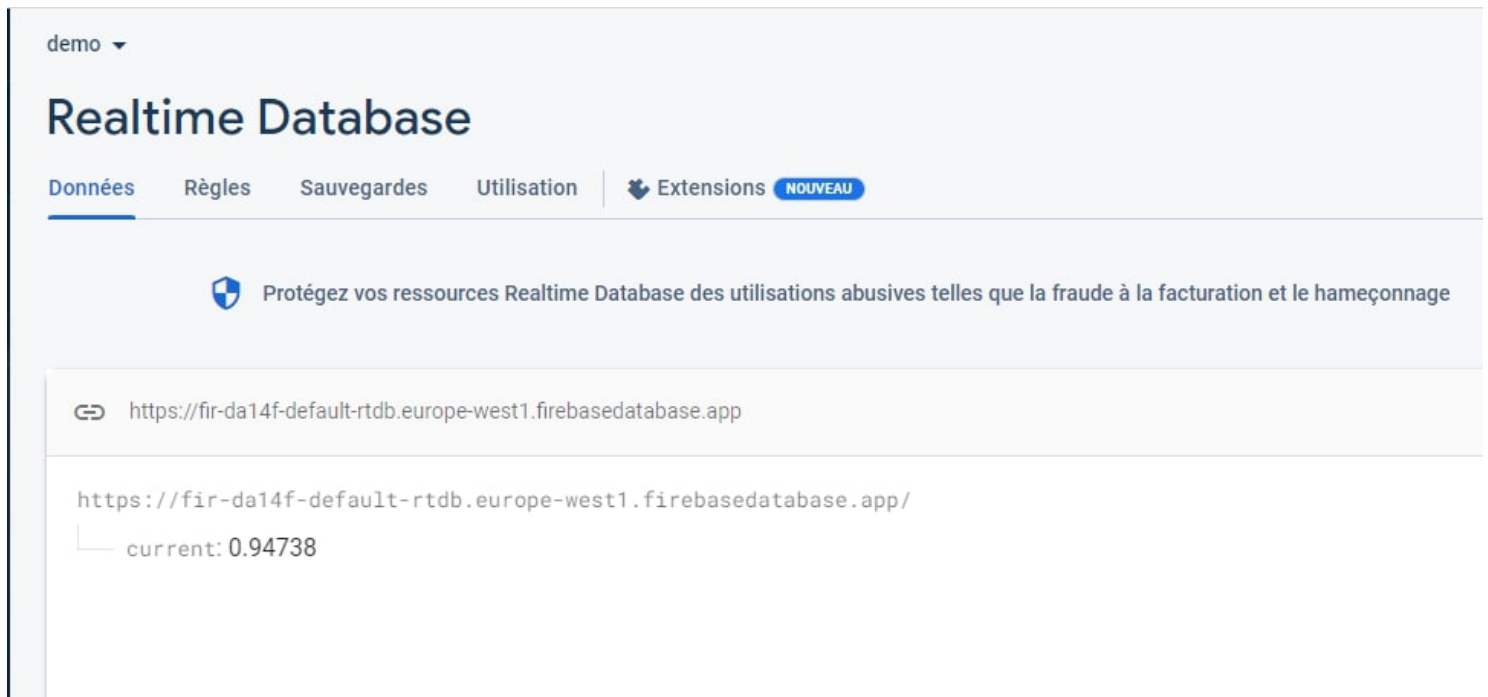


Figure 33. Sensitivity test result on firebase

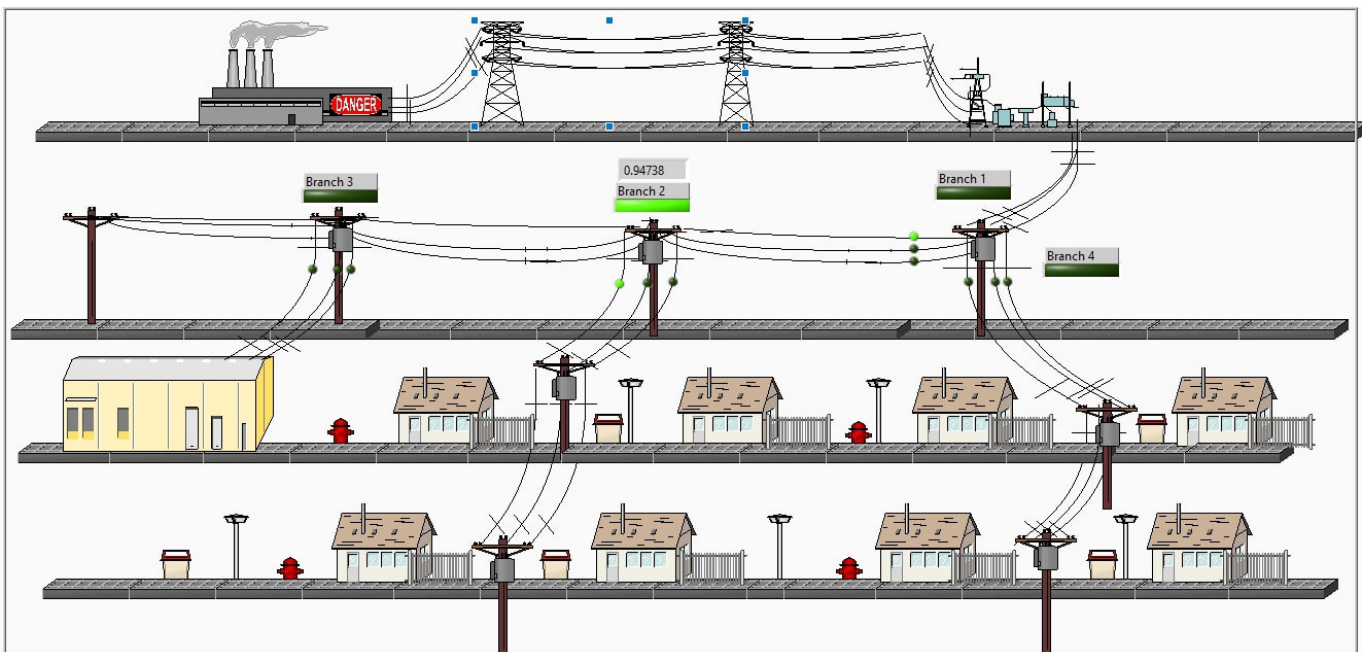


Figure 34. Sensitivity test result

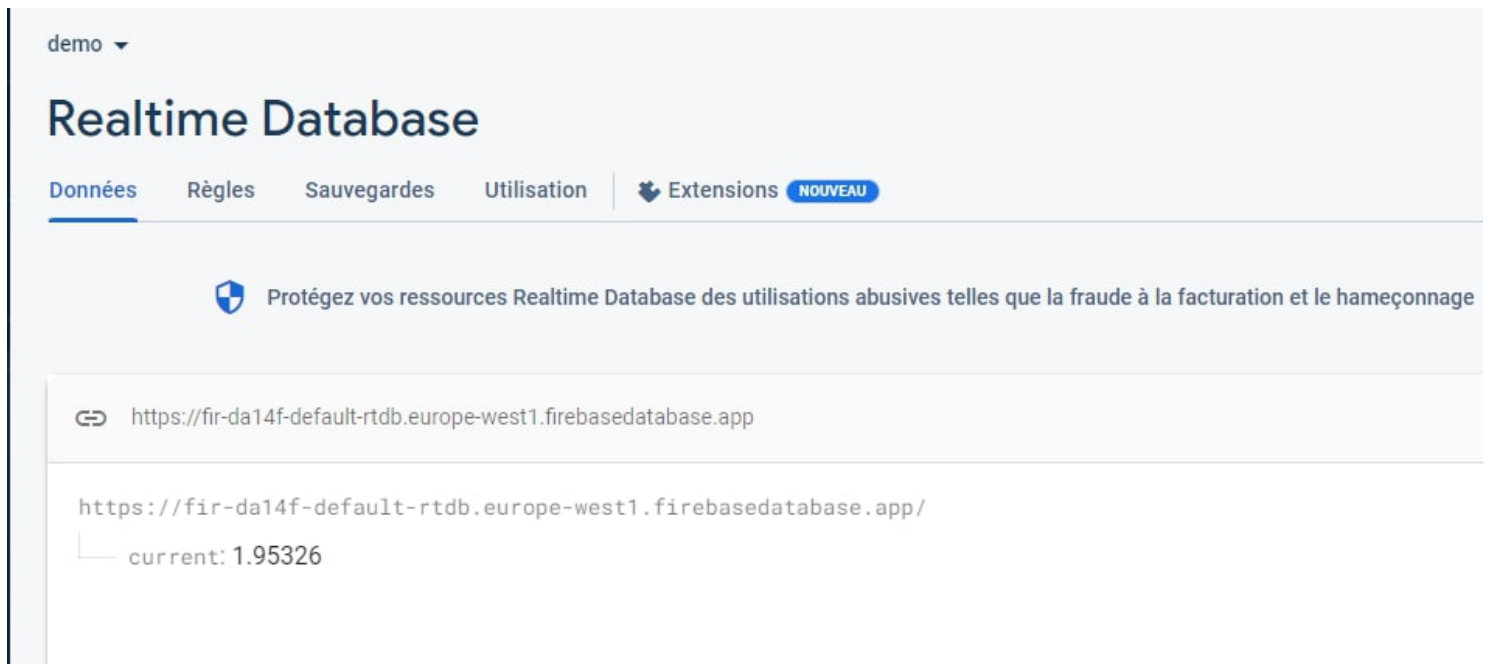


Figure 35. Sensitivity test result on firebase

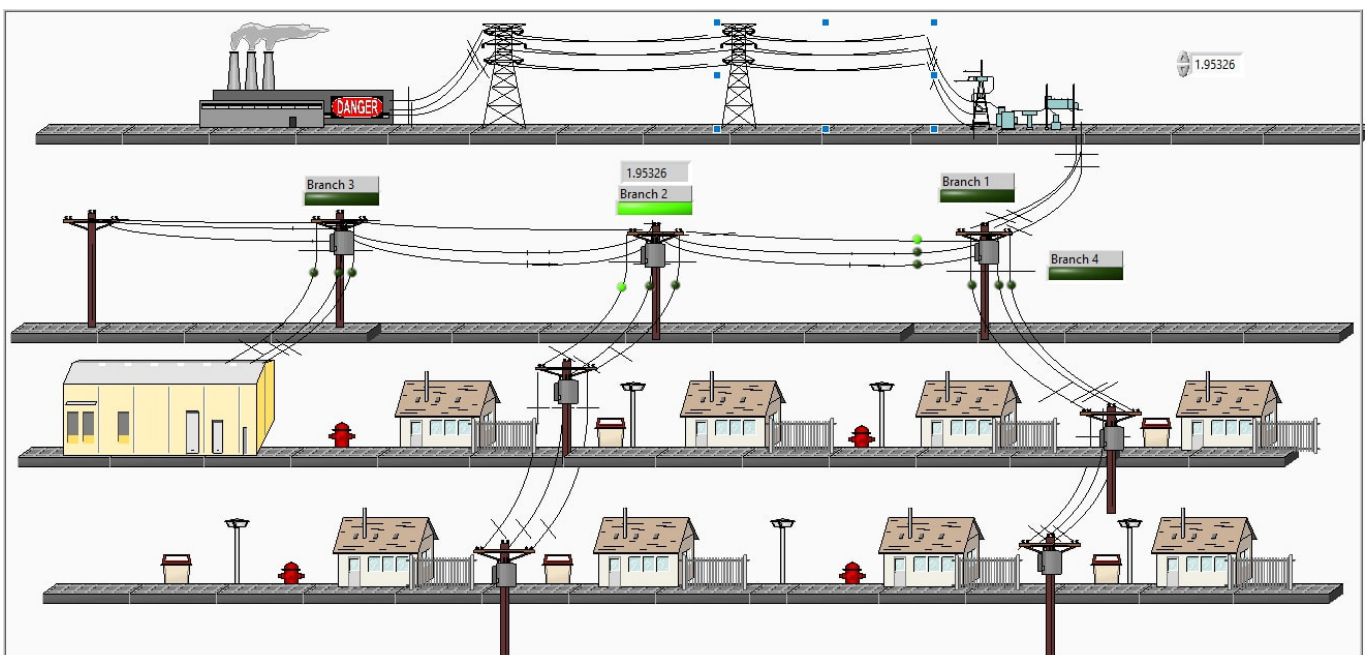


Figure 36. Sensitivity test result

5. General conclusion

In conclusion, the design and implementation of the overhead fault passage indicator system aimed to enhance the reliability and efficiency of overhead distribution systems. The system successfully detected and indicated faults in real-time, providing valuable insights for utilities and operators. The implementation involved developing LabVIEW code to communicate with Google Firebase and retrieve sensor data. Various tests were conducted to validate the system's functionality and performance, including threshold verification, normal operation, step response, short circuit, open circuit, and sensitivity tests.

The results demonstrated the accurate response of the fault passage indicator system to different fault scenarios. It effectively detected and indicated overcurrent, undercurrent, short circuit, and open circuit conditions. The system's sensitivity was evaluated, and it exhibited the ability to detect subtle variations in current levels. Moreover, the system operated within specified time limits, effectively distinguishing inrush currents from sustained faults.

By implementing the overhead fault passage indicator system, improved fault detection and identification were achieved, leading to enhanced reliability and reduced downtime in distribution systems. The system's user-friendly interface facilitated easy monitoring and interpretation of the acquired data. False alarms were minimized, ensuring that genuine fault conditions were promptly addressed while maintaining the system's integrity during normal operation.

Overall, the design and implementation of the overhead fault passage indicator system have contributed to the advancement of fault detection techniques in overhead distribution systems. The system's successful performance highlights its potential to improve the reliability and safety of electrical infrastructure, benefiting both utilities and end-users. Further research and development can focus on optimizing the system's capabilities, exploring additional features, and expanding its applications in various power system environments.

Future work

There are several potential areas for further improvement and exploration in the field of overhead fault passage indicators. Firstly, research can be conducted to enhance the fault detection algorithms and algorithms to mitigate false alarms, increasing the system's accuracy and reliability. Additionally, incorporating advanced communication protocols and networking technologies can enable real-time data transmission and remote monitoring capabilities, facilitating more efficient fault management and system control. Furthermore, the integration of intelligent analytics and machine learning techniques can provide valuable insights into fault patterns, enabling predictive maintenance and proactive fault management strategies. Lastly, expanding the application of fault passage indicators to different voltage levels and system configurations, such as underground distribution systems, can broaden the scope and impact of these systems in improving power system reliability.

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