Final Year Project Showcase Batch 2019
Year 2023

Department: Electrical Engineering

Programme: Electrical Engineering

1

Project Idea

1- Project Title:

Power Outage Detection and Localization Model on Low Voltage Distribution Networks

2- Project Idea Explanantion:

a- Introduction:

In the context of low voltage (LV) distribution networks, the persistent challenges of ineffective fault detection, imprecise fault location tracing, and delayed fault management pose substantial hurdles for power system operators. Currently, power companies rely on manual interventions and monitoring systems situated on primary distribution lines to respond to unforeseen or **unplanned** power outages occurring on LV distribution lines. This outdated approach results in operational inefficiencies, undue strain on healthy equipment, and customer inconvenience, particularly when outages linger, leading to prolonged downtimes and undermining the overall reliability of the distribution network.

b- Significance of the Issue:

Recognizing the paramount importance of power systems in ensuring stability and uninterrupted electricity supply, it's crucial to address these issues. More than **80%** of power system outages can be attributed to faults within distribution networks, underscoring the urgency of the problem. These faults can disrupt the power system, potentially causing severe damage or even blackouts if unattended. Swift identification and rectification of potential power failure causes are essential to maintain system stability and reliability. The expansive nature of electrical networks on secondary distributions, coupled with the inherent likelihood of encountering faults and power outages, requires a modernized and efficient approach to fault detection and localization. Recent advancements in real-time monitoring, localization, and control capabilities, driven by the integration of smart grid technologies, offer new possibilities for improving fault surveillance and normalization within these secondary or low voltage distribution networks.

The integration of intelligent technologies into the power system's smart grid infrastructure has the potential to automate and optimize conventional fault monitoring methods effectively. However, many regions around the world still lack definitive intelligent fault monitoring and localization mechanisms for secondary or low voltage distribution networks. This absence of automated fault monitoring imposes restrictions on improving customer experiences during power outages. Conventional outage management practices, relying on customer reports and manual fault tracing, lead to prolonged outage durations and adversely affect distribution system performance metrics tied to customer satisfaction.

c- General Proposal:

To address these challenges and revolutionize fault management in LV distribution networks, this project proposes the development and implementation of an IoT-based outage management application. This application will work in conjunction with a custom map to enable real-time fault detection, accurate fault location tracing, and efficient fault management in low voltage networks. Integrating such a monitoring system with existing SCADA systems within smart grids can lead to more efficient fault monitoring and handling mechanisms, ultimately reducing power restoration times, and enhancing distribution network reliability. This proactive approach also improves electricity distribution infrastructure, boosts customer satisfaction, and elevates overall grid performance by proactively addressing power outages caused by faults in low voltage networks.

3- <u>Project Idea Significance and Motivation:</u>

1. To introduce an autonomous power outage detection and management system for low voltage distribution networks.
2. To enable automated reporting of power failures to electric utilities for unplanned outages on residential networks.
3. To minimize the delay and inconvenience for customers in reporting power failures to electric utilities.
4. To facilitate real-time data acquisition of power failures with location tracing anywhere on low voltage distribution networks.
5. To contribute in improving the SAIFI and SAIDI distribution performance metrics.

2

Process

1- <u>Our Project Development Objectives/Milestones/Focus Areas:</u>

1. Simulated a 220V/12V low voltage distribution system on a parallel feeder distribution scheme using Arduino Microcontrollers and digital sensors. Introduced single line to ground faults on distribution lines to demonstrate power outages.
2. Developed a functional prototype that replicated the simulation design for monitoring, reporting, and management of faults on the low voltage distribution lines.
3. Implemented a remote monitoring and management system for the prototype on an IoT Cloud application.
4. Generated customer notifications and traced location coordinates during fault conditions on the prototype.
5. Visualized fault location coordinates on a custom map design.
6. Validated and tested the system's performance under both manual and automatic fault isolation processes.

<u>2- Project's Scope of Work:</u>

1. The simulation and prototype design are focused on a single-phase 220/12V small residential model, comprising two transformers, each supplied through a parallel feeder distribution scheme originating from a 220V voltage source.
2. The primary focus of the system is the creation and management of single line to ground faults, a common occurrence in low voltage distribution networks. It does not encompass other fault types.
3. The custom map function, available within the IoT Cloud widget list, is utilized for the visualization of fault location coordinates.
4. The design incorporates standard voltage level components, selected within the constraints of the overall budget for the project.
5. The system's performance may be impacted by potential reductions in the efficiency of its components.

<u>3- Working Methodology:</u>

a- Overview:

The project focused on developing a two-microcontroller-based IoT application tailored to monitor a single-phase 220/12V low voltage model within a parallel feeder distribution scheme, supplying power to two low voltage transformers. Each transformer was equipped with an Arduino microcontroller and a Wi-Fi module to ensure continuous online monitoring of the system. The project specifically emphasized the integration of Single-Line-To-Ground faults, responsible for creating power outages in the loads connected to each transformer. The data acquired by the sensor-based system is transmitted through the Arduino and Wi-Fi modules in both normal and abnormal conditions for real-time updates on an IoT Cloud dashboard, which served as the project's control room. In the event of a fault occurrence, precise location coordinates obtained through GPS sensors by the microcontrollers were reported on the IoT Cloud dashboard for inspection. The IoT application worked in conjunction with a custom map design to visualize and evaluate the coordinates of the fault spots in the system. Upon successful completion of data visualization and location tracing, instructions for fault management were executed. These instructions included implementing strategies such as feeder load sharing or manual fault removal, both used to restore power. Furthermore, the project encompassed the ability to initiate automated customer notifications during successful fault tracing and inspection stages.

b- Parallel Feeder Distribution Scheme:

The project utilized a parallel feeder distribution system, a popular scheme deployed on distribution networks to ensure supply reliability. This scheme features two radial feeders running in parallel, connected to a distribution transformer, with each feeder serving a group of loads. This configuration introduces redundancy, enabling continued power supply if one feeder becomes non-operational. Load distribution among available lines is even, ensuring uninterrupted power delivery even in the event of a fault. This approach minimized service interruptions and aligned with the project's design focus.

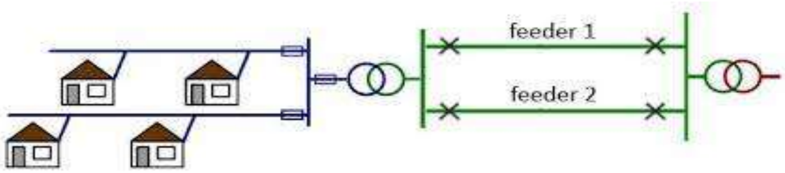

Figure 1: Parallel Feeder Distribution Scheme

c- Prototype Implementation:

The prototype design closely followed a structured sequence of operations: Fault, Power Outage, Detection, Localization, Reporting, Management, and Power Restoration.

1. **Fault:** Unplanned faults, specifically Single-Line-To-Ground (SLG) faults, were simulated independently on each lane's PMT and the corresponding street distribution pole.

2. **Power Outage:** Power outages were induced, affecting connected loads due to fault conditions.

3. **Detection:** Arduino microcontrollers detected outages by analyzing the relaying system and LV distribution line current.

4. **Reporting:** Continuous remote monitoring occurred under normal conditions, but monitoring got affected when power outages were reported on the cloud dashboard.

5. **Localization:** GPS sensors collected precise location coordinates, and were reported to the cloud by microcontrollers under fault conditions.

6. **Management:** Fault resolution instructions were generated, based on GPS coordinates inspection and messaging updates from microcontrollers. Two approaches were considered:

    a) **Manual Approach:**
    When street poles were affected by faults, their coordinates were traced and sent to the dashboard. Customers were notified via email updates, alongside dispatch emails that were sent upon successful location verification. The rectification

process involved manual intervention and visiting the system for power restoration.

b) Automatic Approach

In the case of PMT-side faults, messaging updates were immediately acted upon without waiting for PMT-side GPS coordinates or sensor reactions. This fault occurrence was considered more critical as it impacted primary feeder protection. Instant messaging alerts triggered automatic fault resolution through load sharing and relay closing mechanisms with no customer interaction.

7. **Power Restoration:** Power was restored based on management instructions, with manual restoration requiring system intervention, while automatic instructions lead to instant power restoration through remote control.

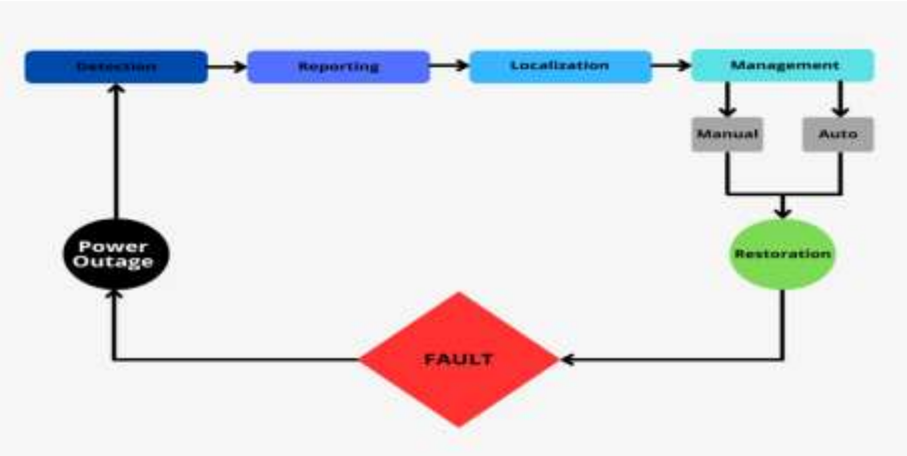

Figure 2: Project's Sequence of Operations

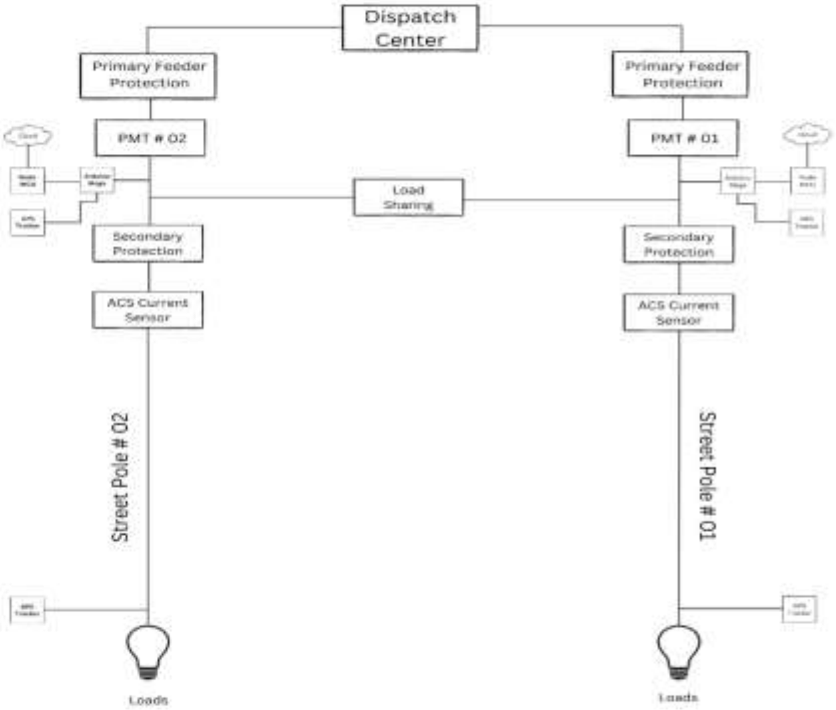

Figure 3: Prototype Block Diagram

d- Blynk IoT Cloud Implementation:

Bidirectional data exchange played a pivotal role in enabling fault detection, localization, and management processes between Arduino Mega, NodeMCU, and an IoT cloud dashboard. The IoT Cloud dashboard designed on Blynk employed several widgets to visualize and respond to the system's status, including Virtual Terminal, Chart, Labels, Fault Alarm, and Custom Map, each serving a distinct purpose in comprehending and responding to the system's operational conditions. These widgets worked in conjunction to provide insights into the system's real-time performance.

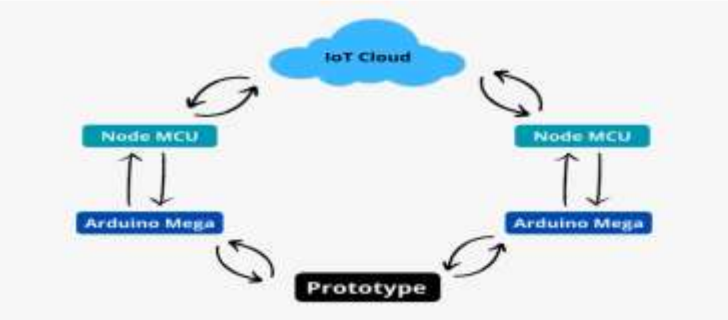

Figure 4: Bidirectional Data Sharing between Prototype and IoT Cloud Dashboard

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Outcome

The project's performance and functionality were evaluated across various cases:

Case 1: No Fault

The prototype operated under normal conditions, where it received a single 220V supply, and the street pole loads were powered at a reduced voltage of 12V. The IoT cloud dashboard displayed normal monitoring with routine messaging alerts and a plot of LV distribution line current.

Case 2 & 3: Pole Fault on PMT 1 and Pole Fault on PMT 2

These cases involved the deliberate creation of Single-Line-to-Ground (SLG) faults using the pole switches. Despite both poles being supplied by a parallel-connected 220V source, the faults were independent. Manual intervention was required post-cloud inspection. Location coordinates were acquired, and customer notifications were generated. During either of these cases:

- Pole relay tripping indicates a power outage.
- LCD displays emergency pole fault messages for affected individuals.
- Normal cloud monitoring is compromised, fault updates are sent to the dashboard which causes a fault alarm to ring.
- Location coordinates of poles are received.
- Automated emails for customer satisfaction and location tracing are generated in process.
- Coordinates are inspected and verified, and dispatch messages are sent.
- Power is restored by manual fault management that involves closing the fault switch.

Case 4 & 5: Fault near PMT 1 and Fault near PMT 2

These cases involved the deliberate creation of Single-Line-to-Ground (SLG) faults using the PMT fault switches. In both cases, PMT faults are interlinked as they are fed from the supply in a parallel feeder distribution scheme. Automatic fault management occurs as soon as updates appear on the cloud. Location coordinates are obtained after fault management with no need for customer notification. Load sharing ensures system reliability. During either of these cases:

- PMT relay tripping and corresponding primary feeder relay tripping indicate a power outage.
- LCD displays emergency PMT fault messages for affected individuals.

- Normal cloud monitoring is compromised, fault updates are sent to the dashboard which causes a fault alarm to ring.
- Automatic fault restoration takes place via load sharing for the distribution scheme once updates start to appear.
- Location coordinates of PMTs are received for later on-site inspection.

4

Evidence (Theoretical Basis)

In conclusion, this project aimed to revolutionize the management of faults in low voltage distribution networks, enhancing their reliability and efficiency. The core objective was to develop an Internet of Things (IoT) application capable of swiftly detecting and managing single-line-to-ground faults, a primary cause of power interruptions in such networks. Real-time fault updates provided by the application facilitated prompt fault management and informed decision-making for control room operators. By minimizing outage inconveniences and enabling proactive fault handling, the project aimed to ensure uninterrupted power supply, bolstering grid reliability and customer satisfaction. Conventional outage management approaches can be time-consuming; the proposed smart grid technology integrates IoT cloud computing to enhance fault monitoring and normalization. Throughout the project, there was a meticulous focus on practical fault detection and localization within a specific distribution scheme. By combining IoT technology, cloud connectivity, and data visualization, the project envisages smarter fault detection and resolution in low voltage networks, benefitting both utilities and consumers. Successful real-life implementation of this project could significantly contribute to improving overall power distribution infrastructure, enhancing reliability, and ultimately elevating customer satisfaction in the face of unplanned power outages resulting from single-line-to-ground faults.

Table 1: System Timelines

S.NO	Category	Time taken during each step of project's sequence of operation
1-	System Startup (Initialization of GPS Sensors)	5-10 minutes
2-	Arduino to NodeMCU (Serial Communication)	1 minute
3-	NodeMCU to Cloud Dashboard	< 1 minute

4-	LV Distribution Line Current Updating Interval	< 1 minute
5-	Arduino Messaging Alerts	< 1 minute
6-	Fault Alarm	1-2 minutes
7-	Location Coordinates Tracing	< 1 minute
8-	Customer Notification	< 1-2 minutes
9-	Fault Management (Manual)	1-5 minutes
10-	Fault Management (Automatic)	<1 minute

5

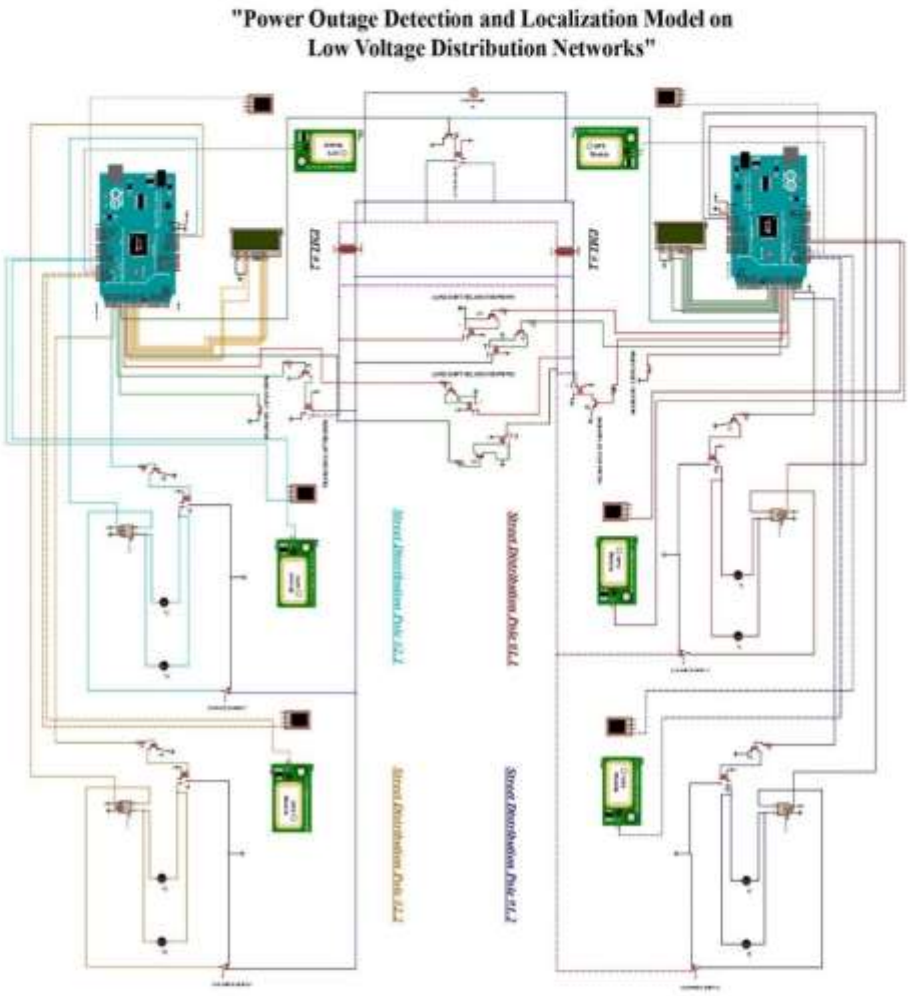
Impact on Sustainability of Urban Regions or SDG-11 "Sustainable Cities and Communities"

The project has the potential to make a significant impact on Sustainable Development Goal (SDG) 11: Sustainable Cities and Communities by:

1- Enhancing Energy Reliability: The project can improve fault management in low voltage distribution networks, ensuring a more reliable energy supply in urban and rural areas.
2- Reducing Disruptions: The project can ensure swift fault detection for minimizing power interruptions, supporting the uninterrupted operation of critical services and improving the quality of life for residents.
3- Optimizing Resource Use: Proactive fault handling can help utilities to optimize resources, leading to cost savings and sustainable resource management.
4- Infrastructure Enhancement: By addressing a critical component of urban energy systems, the project also contributes to the enhancement of energy distribution infrastructure.
5- Community Satisfaction: Minimized outages and reduced inconvenience lead to higher community satisfaction, promoting sustainable practices.
6- Technology Integration: The project uses innovative IoT and cloud technology, aligning with SDG 11's call for technology adoption to create sustainable and efficient cities.

6	***Competitive Advantages or Unique Selling Propositions***
a	***Attainment of any SDG*** Although the project primarily targets SDG 11, it also has positive impacts on SDGs 7, 9, 13, and 17 by enhancing energy efficiency, promoting innovation in infrastructure, contributing to climate action, and fostering partnerships for sustainable development. **SDG#07: Affordable and Clean Energy** **Directly Achieved:** The project enhances energy distribution efficiency and reliability, indirectly contributing to the goal of affordable and clean energy by reducing power outages and losses. **SDG#09: Industry, Innovation, and Infrastructure** **Directly Achieved:** The development of an IoT-based application demonstrates innovation in infrastructure, improving the efficiency of energy distribution infrastructure in urban areas. **SDG# 13: Climate Action** **Indirectly Achieved:** By reducing power interruptions, the project helps to minimize the reliance on backup power sources, potentially reducing greenhouse gas emissions associated with backup power generation. **SDG#17: Partnerships for the Goals** **Indirectly Achieved:** Collaboration with stakeholders, including utilities and consumers, to implement the IoT application aligns with the spirit of partnerships for achieving sustainable development goals.
b	***Environmental Aspect*** The project offers a competitive advantage by significantly improving energy efficiency and reducing carbon emissions. This is achieved through an IoT-based application that automates fault detection and resolution, minimizing energy waste and the necessity for emergency power generation during outages. The positive environmental impact begins immediately as the system responds in real-time to faults, leading to increased energy efficiency. This aligns with global efforts to reduce carbon emissions and promotes sustainable energy practices.
c	***Process Improvement which Leads to Superior Product or Cost Reduction, Efficiency Improvement of the Whole Process*** **Challenges:** Our project seeks to address several issues in the current fault management process. Two of them are: ***1- Delayed Fault Detection:*** In the existing systems, fault detection can be slow, leading to prolonged power outages. We recommend real-time fault detection to minimize downtime. ***2- Customer Inconvenience:*** Prolonged outages result in customer dissatisfaction. Our project aims to provide a solution that proactively addresses faults, minimizing customer inconvenience. **Recommendations** To overcome these challenges, we recommend process improvement by: ***1- Enabling Real-time Monitoring:*** Implementing real-time monitoring to detect faults as soon as they occur, ensuring prompt action. ***2- Automating Fault Management Processes:*** Automating fault management processes to reduce response time and improve accuracy. ***3- Promoting Customer Interactions***: Providing timely updates to customers about outages and restoration progress to enhance satisfaction.

d	***Capture New Market*** Our project itself may not be a direct driver of capturing new markets, it can indirectly enable such opportunities by improving service quality and attracting interest from new customer segments or initiatives related to energy infrastructure modernization. **1- Expanding Service Areas:** If the project successfully improves fault management in real life, utility companies may extend their service areas into regions or communities that were previously underserved due to reliability issues. This expansion can be seen as capturing a new market. **2- Attracting New Customers:** Better reliability and reduced downtime can make utility services more attractive to businesses and industries that rely heavily on uninterrupted power. This can lead to capturing new customers in specific sectors. **3- Enhancing Smart Grid Initiatives:** The project's integration with smart grid technologies may attract the interest of government initiatives or policies aimed at modernizing energy infrastructure. This could lead to new opportunities and market segments related to smart grid deployment.
7	***Target Market*** The target audience and end-users of this project encompass a diverse range of stakeholders, including: **1- Utility Companies:** The primary beneficiaries are utility companies responsible for low voltage distribution networks. They will utilize the IoT-based outage management application to enhance the reliability and efficiency of their distribution infrastructure. **2- Residential Customers:** Families and individuals will experience fewer inconveniences due to power interruptions, improving overall quality of life. **3- Students:** Educational institutions will benefit from enhanced electricity supply reliability, ensuring uninterrupted learning environments. **4- Industries:** Industrial sectors relying on uninterrupted power supply, such as manufacturing, healthcare, data centers, and more, stand to benefit from improved fault management, reducing costly downtime. **5- Businesses:** Commercial establishments, including offices, retail outlets, and restaurants, can enjoy increased operational stability and reduced revenue loss during power outages. **6- Government Initiatives:** Government bodies or agencies focusing on smart grid modernization and sustainable energy solutions may find value in adopting this technology to achieve their objectives. **7- Energy Conservation Efforts:** Entities and individuals committed to energy conservation and reducing carbon footprints can leverage improved fault management timelines to contribute to sustainability goals. **8- Community Development:** Projects aimed at improving the reliability of electricity supply in communities, especially in remote or underserved areas, can utilize this technology to enhance living standards.
8	***Team Members*** *(Names along with email address*

	Muhammad Bilal bilalejaz500@gmail.com Muhammad Haris m_haris99@hotmail.com Muhammad Hamza Irshad hamza.irshad6001@gmail.com Ali Asghar aliasghar.1701012@gmail.com
9	***Supervisor Name*** Ayesha Khan (Lecturer, Electrical Department) ayeshakhan@neduet.edu.pk ayeshakhan@cloud.neduet.edu.pk
10	***Pictures***  **Figure 5: Project Simulation Design**

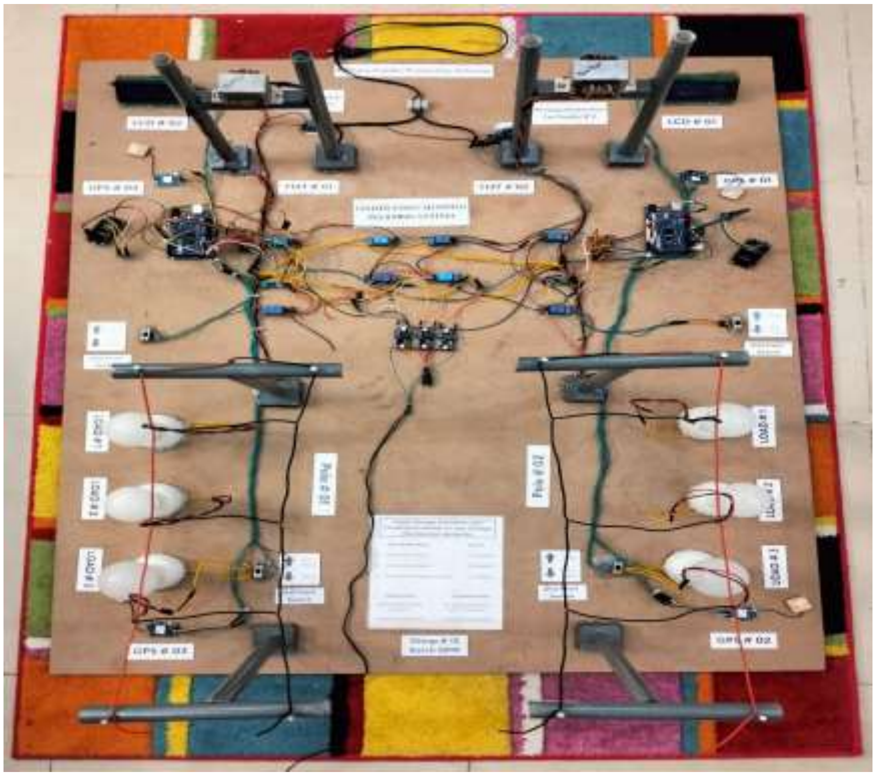


Figure 6: Prototype Implementation

Figure 7: Primary Feeder Protection for PMTs with two separate LCDs and GPS sensors.

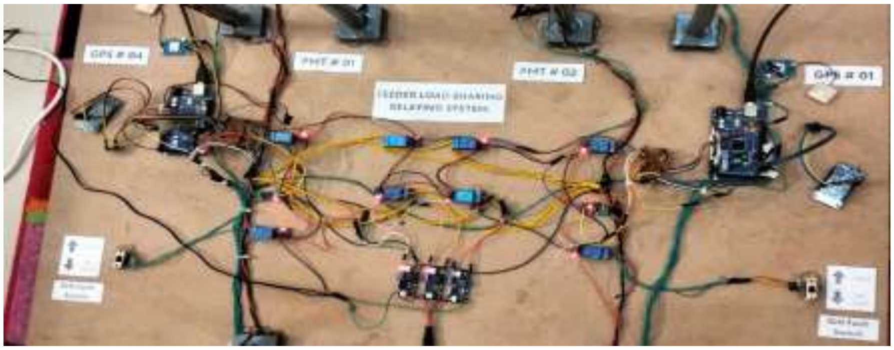


Figure 8: Monitoring, Protection and Automatic Fault Management Devices Installed on PMT Secondaries of the distribution network

Figure 9: Street Distribution Pole with three 12V,7W AC light bulbs and individual GPS Sensors

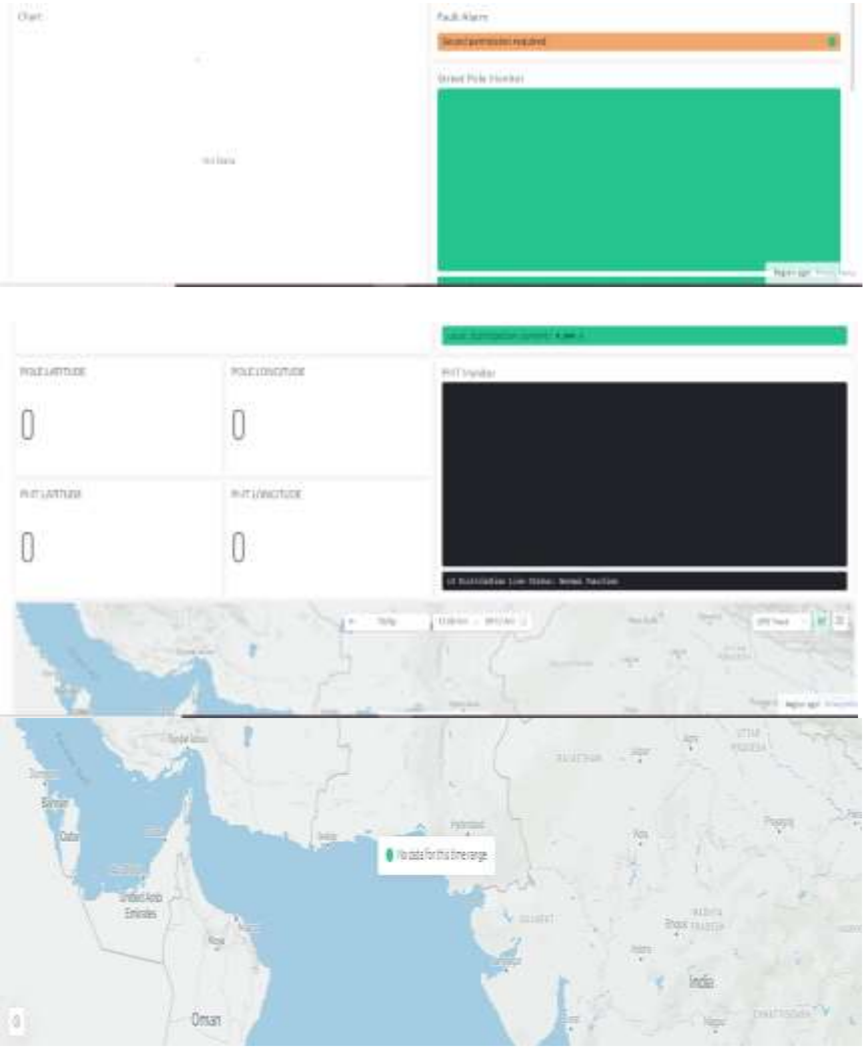


Figure 10: IoT Cloud Dashboard Design on Blynk

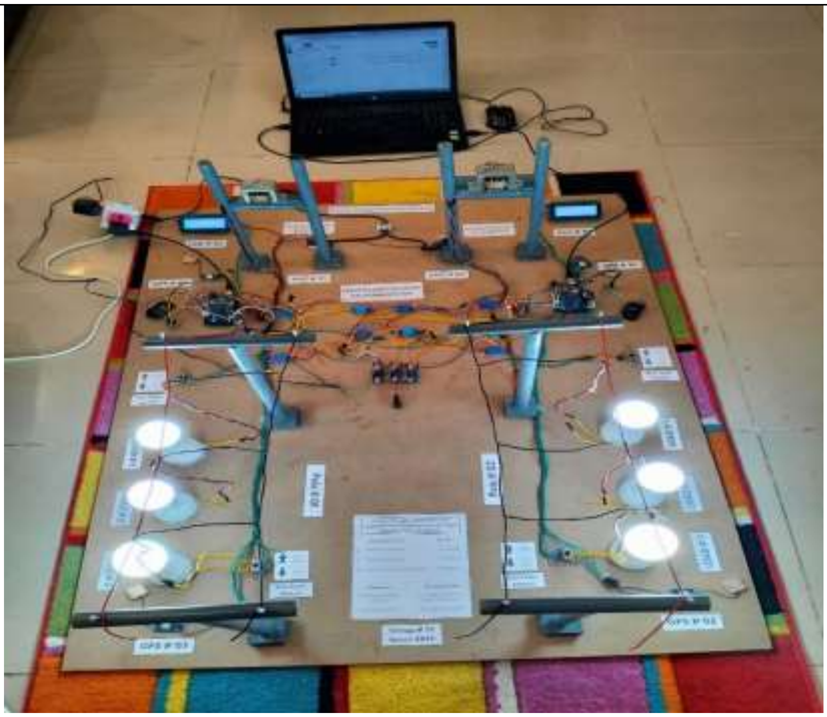
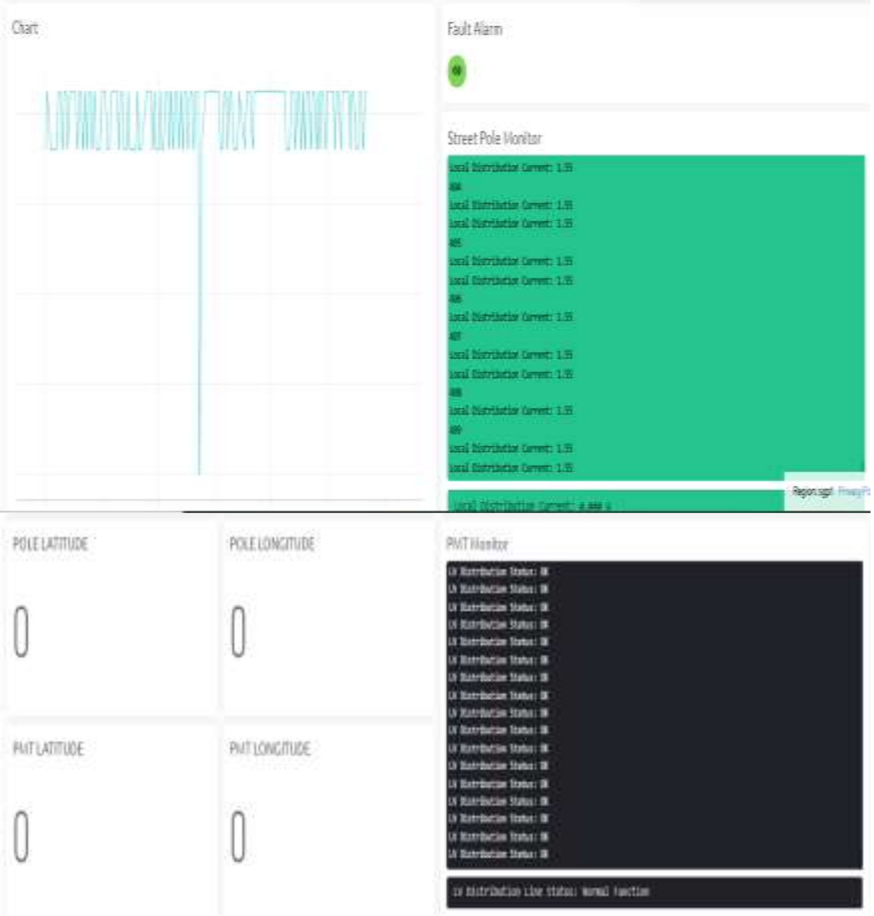


Figure 11: Functional Prototype



POLE LATITUDE: 0
POLE LONGITUDE: 0
PMT LATITUDE: 0
PMT LONGITUDE: 0

Figure 12: Live Data Reporting on IoT Cloud Dashboard (No Fault Condition)

Figure 6.4 SLG Fault on Loads of PMT 1

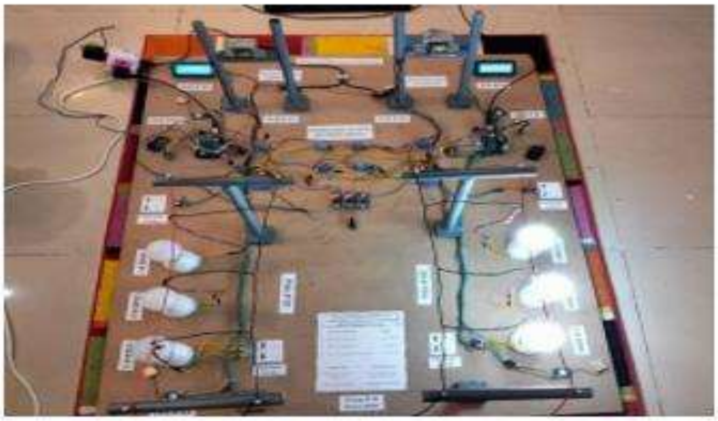


Figure 6.5 SLG Fault on Loads of PMT 2

Figure 13: Street Distribution Poles During Single Line to Ground Faults

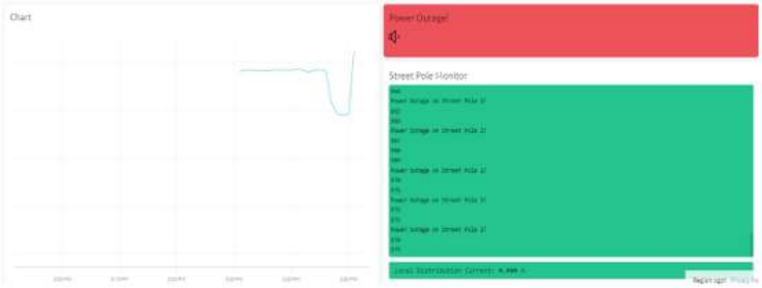


Figure 6.6 Street Distribution Pole monitoring alert

POLE LATITUDE
24.96104

POLE LONGITUDE
67.19415

PMT LATITUDE
0

PMT LONGITUDE
0

```
LV Distribution Status: OK
LV Distribution Status: OK
LV Distribution Status: OK
LV Distribution Status: OK
LV Distribution Status: OK
LV Distribution Status: OK
LV Distribution Status: OK
LV Distribution Status: OK
LV Distribution Status: OK
LV Distribution Status: OK
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LV Distribution Status: OK
LV Distribution Status: OK
LV Distribution Status: OK
LV Distribution Status: OK
```

```
LV Distribution Line status: Normal function
```

Figure 6.7 Location Coordinates Tracing

Figure 14: Location Tracing, Fault Alarm (in red) and Pole Fault Messaging Alerts (in green) during street pole faults

	 Figure 6.9 PMT 1 or PMT 2 Fault Scenario under Fault!  POLE LATITUDE 0 POLE LONGITUDE 0 PMT LATITUDE 24.961 PMT LONGITUDE 67.19421 Figure 6.10 IoT Cloud status during any of the two PMT faults **Figure 15: Location Tracing, PMT Fault Messaging Alerts (in black) during PMT faults with instant load sharing between feeders for automatic fault management**  **Figure 16: Affected location's coordinates mapped using Blynk's Map Widget**	
11	***Video***	https://clipchamp.com/watch/LwEQro94Dem ***Note:*** *This video was recorded just before the project submission in the department. The project working shown in the video link is just an overview and not the overall project demonstration. Also, the location coordinates display on IoT Cloud dashboard in the video is hindered because of slow internet connectivity and* ***must not be considered.***