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An IoT-based approach for real-time fault detection and localization in electrical distribution networks using ThingSpeak

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ABSTRACT

This paper presents a real-time monitoring, fault detection, and localization system for electrical distribution networks based on the ThingSpeak internet of things (IoT) platform. The proposed approach enables continuous acquisition and analysis of key electrical parameters, such as voltage and current. A MATLAB/Simulink model of the IEEE 33-bus distribution network is developed to simulate both normal operating conditions and fault scenarios. The generated data are transmitted to the ThingSpeak cloud platform for real-time visualization and analysis. The system enables rapid fault detection and accurate localization by analyzing variations in electrical signals. The results demonstrate that the proposed solution improves system reliability, reduces fault detection time, and provides an efficient and cost-effective tool for smart grid monitoring and supervision.

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1. INTRODUCTION

The electrical distribution network plays a critical role in delivering energy from generation systems to end users. However, these networks are frequently exposed to various faults such as short circuits, line-to-ground faults, and overload conditions. Traditional monitoring systems are often limited in terms of real-time capability and fault localization accuracy [1]. As a result, fault detection and isolation may be delayed, leading to equipment damage and service interruptions.

With the emergence of the internet of things (IoT), new opportunities have arisen for real-time monitoring and intelligent supervision of electrical systems. Cloud-based platforms such as ThingSpeak provide effective solutions for data acquisition, visualization, and analysis [2]. Furthermore, minimizing operational losses and improving voltage profiles have become essential for ensuring grid stability and reliability [3]. The use of IoT for real-time monitoring and fault diagnosis represents a significant advancement in optimizing system performance [4].

The smart grid is an advanced electricity network that integrates digital technologies and modern communication systems to efficiently deliver reliable, cost-effective, and sustainable power to consumers [5]. The development and deployment of smart grid technologies involve several challenges, but these challenges motivate stakeholders, including utilities, manufacturers, vendors, regulators, governments, and consumers, to address emerging issues [6]. According to [7], soft open points can significantly reduce power losses and

improve the voltage profile, as well as authors examine the effect of increasing the number of SOPs connected to distribution systems under different scenarios. In [8], a fuzzy logic-based protection technique is proposed to improve system performance under fault conditions. The smart grid has emerged as a key trend in modern power systems. It can be defined as an advanced electricity generation and distribution infrastructure capable of automating operations and managing the growing complexity and energy demands of the 21st century [9]. The transition from traditional power grids to smart grids requires the development of key technologies, including distributed energy resources (DER), energy storage systems, power electronics, and advanced management functions such as control, automation, monitoring, protection, and communication [10].

Most power utilities assess the reliability of their distribution systems using indices such as the system average interruption frequency index (SAIFI) and the system average interruption duration index (SAIDI) [11]. Moufid *et al.* [12] proposed a distribution network reconfiguration approach for power loss minimization using soft open points. Reliability indices such as SAIDI and SAIFI depend on parameters such as interruption duration and the number of customer interruptions, where shorter interruptions indicate higher reliability. However, monitoring in distribution networks remains limited due to their wide geographical coverage [13]. SCADA systems can detect faults, but locating and isolating them requires manual intervention, leading to restoration delays of up to 75 minutes [14]. Fault isolation often relies on manual operations, which can take several hours, leaving many customers without electricity during this period [15]. STATCOM can improve voltage stability and overall power system performance [16]. Maafa *et al.* [17] proposed a fuzzy logic-based smart control strategy for a wind energy conversion system using a cascaded doubly fed induction generator.

The central unit processes the data, generates alarms when predefined thresholds are exceeded, and enables operators to take corrective actions through a human-machine interface (HMI) [18], [19]. In addition, SCADA systems store historical data, enabling performance analysis and maintenance strategies [20]. However, despite their essential role, traditional SCADA systems present several limitations. Their centralized architecture introduces communication delays and reduces system efficiency [21]. Furthermore, scalability becomes challenging when applied to large and geographically distributed networks, limiting their flexibility and interoperability [22]. Their reliance on predefined thresholds also restricts early fault detection and reduces their capability to support predictive maintenance strategies [23]. Finally, handling the large volume of data generated by modern renewable energy systems remains a significant challenge [24]. This paper proposes a real-time fault detection and localization system using ThingSpeak, aiming to improve network reliability and operational efficiency.

2. SYSTEM ARCHITECTURE

2.1. Overview of the proposed system

The proposed system is designed to monitor electrical distribution networks in real time, detect faults, and identify their locations using the ThingSpeak IoT platform. It is organized into three main parts: data acquisition, communication, and cloud-based monitoring [25]. This architecture allows continuous measurement of key electrical parameters, real-time data transmission, and easy remote visualization. As a result, operators can quickly observe system behavior, detect any abnormal conditions, and locate faults efficiently. Figure 1 illustrates the proposed system architecture for real-time monitoring and fault localization in electrical distribution networks. The system is composed of three main layers: data acquisition, communication, and cloud-based monitoring. Electrical parameters such as voltage, current, and power are measured using sensors and transmitted via a communication interface (e.g., Raspberry Pi) to the ThingSpeak cloud platform. The platform enables real-time visualization, data analysis, fault detection, and location identification, allowing operators to efficiently monitor system performance and respond quickly to abnormal conditions.

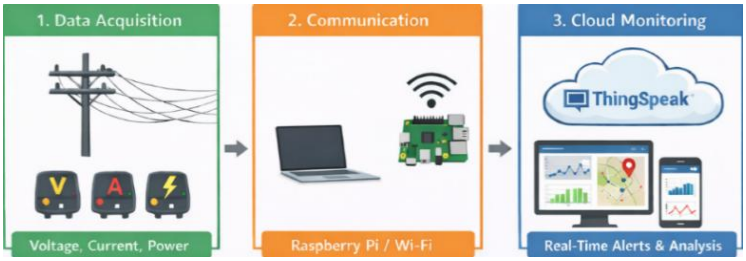

Figure 1. IoT-based architecture for real-time monitoring and fault detection in distribution networks using ThingSpeak

2.2. Data acquisition layer

The data acquisition layer is responsible for collecting the main electrical parameters from different points of the distribution network. In this work, the most important parameters are line voltage and line current, while active and reactive power can also be included if needed. Sensors are placed at suitable locations in the network to continuously measure these values. These measurements help provide a clear view of the system's normal operation. When a fault occurs, noticeable changes such as a drop in voltage or a rise in current can be observed. By continuously collecting this data, the system can easily monitor the network behavior and support the detection and localization of faults in real time.

2.3. Communication layer

In this study, the electrical parameters of the IEEE 33-bus distribution network, such as voltage and current, are generated using a MATLAB/Simulink model. These signals represent how the system behaves under normal conditions as well as during faults. The generated data are then sent directly to ThingSpeak using the HTTP protocol. Each parameter is assigned to a specific field in the ThingSpeak channel, making it easy to organize and visualize the data. The data are transmitted at regular intervals, which allows continuous monitoring of the system. This helps in quickly observing any changes in the network, such as voltage drops or current increases that may indicate a fault. Overall, this layer creates a simple and effective connection between the simulation and the cloud platform, enabling real-time monitoring and supporting fault detection and localization.

Table 1 presents the main electrical parameters of the IEEE 33-bus distribution network used in this study. These data include bus voltages as well as active and reactive power demands, which are essential for system modeling and fault analysis. Figure 2 shows the IEEE 33-bus radial distribution network used in this study [26]. The network has a tree-like structure supplied by a main substation, which makes it suitable for analyzing fault detection and localization. Due to its multiple branches, faults can affect several buses, leading to variations in voltage and current that can be monitored to identify the faulty section.

Table 1. The IEEE 33-bus distribution system data

Bus	Voltage (p.u)	Active power load (kW)	Reactive power load (kVar)
1	1.000	0	0
2	0.997	100	60
3	0.982	90	40
4	0.975	120	80
5	0.968	60	30
6	0.950	60	20
7	0.940	200	100
8	0.930	200	100
9	0.920	60	20
10	0.910	60	20

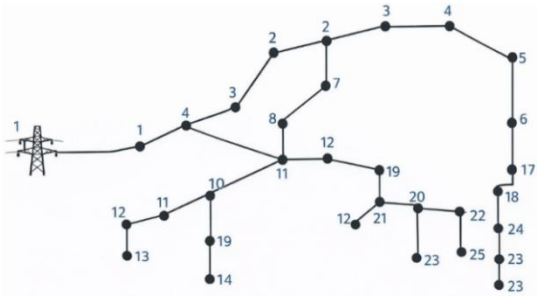

Figure 2. IEEE 33-bus distribution network

3. RESULTS AND DISCUSSION

3.1. Real-time monitoring

The proposed system was implemented using the IEEE 33-bus distribution network model in MATLAB/Simulink. The electrical parameters, including voltage and current, were continuously generated and transmitted to the ThingSpeak platform for real-time monitoring. Under normal operating conditions, the system shows stable behavior, with voltage and current values remaining close to their nominal levels. This confirms the correct operation of the distribution network and the effectiveness of the proposed monitoring approach.

3.2. Fault scenario analysis

To evaluate the system performance, a fault was introduced into the network model. The impact of the fault on voltage and current signals is illustrated in Figure 3. The results show that during normal conditions, the voltage remains stable around its nominal value. However, when the fault occurs, a significant voltage drop is observed, as shown in Figure 3. This behavior clearly indicates the presence of an abnormal condition in the network. In addition, the current response during the fault is presented in Figure 4. A sudden increase in current is observed at the fault instant, which is a typical signature of short-circuit or fault conditions in distribution systems. Figure 3 shows the current behavior during the fault condition. The sharp increase in current highlights the occurrence of a fault and provides a reliable indicator for fault detection.

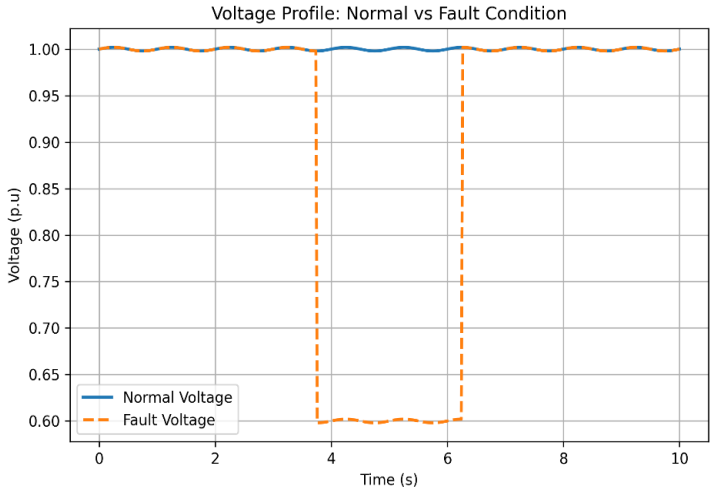

Figure 3. The impact of the fault on voltage

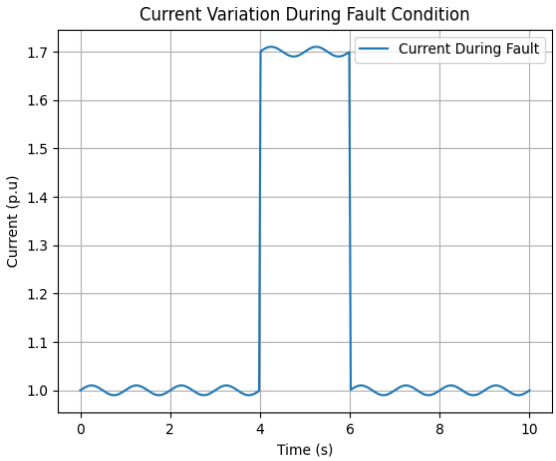

Figure 4. Current response during the fault

3.3. Fault detection performance

The fault detection capability of the proposed system is evaluated based on its response time. As shown in Figure 5, the system is able to detect the fault immediately after its occurrence. Figure 4 presents the detection signal of the system. The rapid transition of the signal indicates that the fault is detected with minimal delay, demonstrating the effectiveness of the real-time monitoring approach. Figure 6 presents the fault localization results using the ThingSpeak platform with geolocation capabilities. The electrical distribution network is mapped over a real geographic area in Morocco, where each bus is associated with a specific location. When a fault occurs, the system identifies the affected bus and highlights its position on the map. The fault location is clearly indicated by a red marker, allowing operators to quickly detect and locate the fault in real time. This approach enhances situational awareness and facilitates faster intervention and maintenance.

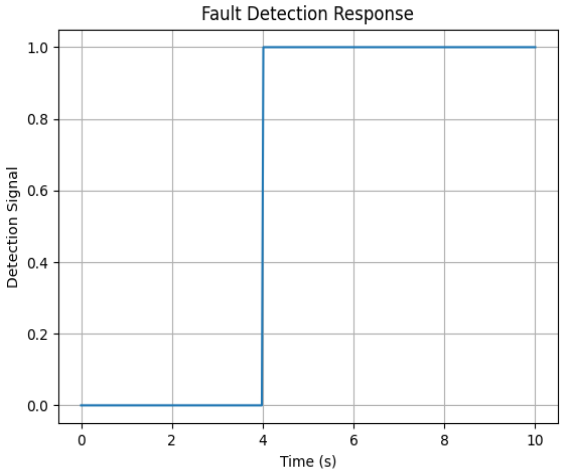

Figure 5. Fault detection response

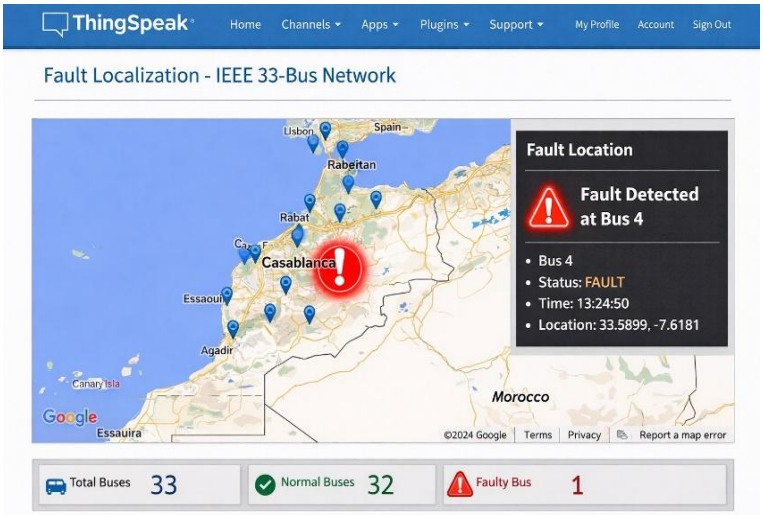

Figure 1. Real-time fault localization using ThingSpeak geolocation in a distribution network

4. DISCUSSION

Overall, the simulation results confirm the effectiveness of the proposed approach for real-time monitoring and fault detection in distribution networks. The voltage drops and current increase observed during fault conditions provide clear and complementary indicators of abnormal behavior. In addition, the fast response of the detection system highlights its capability to quickly identify faults, which is essential for improving network reliability and reducing outage time. The integration of MATLAB/Simulink with the ThingSpeak platform offers a simple, efficient, and low-cost solution for real-time supervision. These results demonstrate that the proposed system can be effectively applied to modern smart grid environments, where fast fault detection and accurate monitoring are required.

5. CONCLUSION

This paper presented a real-time monitoring and fault detection system for electrical distribution networks based on the ThingSpeak IoT platform. The proposed approach relies on a MATLAB/Simulink model of the IEEE 33-bus distribution network to generate electrical parameters such as voltage and current under both normal and fault conditions. The simulation results demonstrated that voltage drops and current increases are effective indicators of fault occurrence. In addition, the system was able to detect faults with a fast response time, highlighting its capability for real-time supervision. The integration of ThingSpeak enabled efficient data visualization and remote monitoring, providing operators with a clear and accessible

view of the system behavior. Furthermore, the use of geolocation allowed intuitive identification of the fault location, enhancing situational awareness and facilitating faster intervention.

Overall, the proposed system offers a simple, flexible, and cost-effective solution for monitoring and fault detection in distribution networks. It represents a promising approach for modern smart grid applications. As future work, more advanced fault localization techniques, intelligent algorithms such as machine learning, and real-time hardware implementation can be considered to further improve system performance and accuracy.

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AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

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Aboubakr El Makrini	✓		✓	✓			✓			✓	✓		✓	✓
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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

DATA AVAILABILITY

Derived data supporting the findings of this study are available from the corresponding author on request.

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