A Smart Optimization of Fault Diagnosis in Electrical Grid Using Distributed Software

Maheswari K. T[1]*, Dr P Sivakumar[2], Bharanikumar R[3], Rithick S[4]

[1] Associate Professor and Head, Department of Electrical and Electronics Engineering, Bannari Amman Institute of Technology, Sathyamangalam, Tamilnadu, India -638401.Email: *maheswarikt@gmail.com*
[2]Associate Professor and Head, Department of Business Administration (UG), Dr SNS Rajalakshmi College of Arts and Science, Coimbatore-641049. Email: *sivaatcas7007@gmail.com*
[3]Professor, Department of Electrical and Electronics Engineering, Bannari Amman Institute of Technology, Sathyamangalam, Tamilnadu-638401.Email: *bharanikumar.rbk@gmail.com*
[4]PG Student, Department of Electrical and Electronics Engineering, Coimbatore institute of technology- 641014

Abstract

Due to the sharp rise in air conditioners and household appliances over recent years, there has been a noticeable rise in the need for electrical power. The continuity of electricity-generated residential services and industrial platforms depends on an unbroken power supply. This conundrum persists in spite of multiple attempts to resolve it. DT is regarded as one of the key components of the electrical network which is necessary for the grid supply to be reliable. Because of its high overhead consumption and internal lack of frequent maintenance and monitoring systems, DT is constantly prone to malfunctions. Therefore, a remote-conditioned IoT monitoring and fault recognition is processed to improve grid consistency, transformer health verification, and maintenance procedures. This technology moves toward the deployment of the smart grid by fusing the electricity grid with an efficient and real-time wireless communication infrastructure. The SDN implementation is done in two steps: first, a controller is installed in each local zone; next, the main controller is installed between zones and connected to the core network. Redundant links make up the core network, which can recover from any future failures. Furthermore, distribution transformer fault prediction, a prediction system based on an artificial neural network algorithm, has been developed. For periodic prediction based on real-time sensor traffic to the proposed cloud, it is deployed in the management plane. Additionally, a local SDN-sense communication protocol has been devised for the local zone that guarantees dependable communication and local node selection for relaying DT sensor data to the main controller. To confirm that the suggested system is a viable and cost-effective way to manage future power grid interruptions and faults, an experimental verification has been conducted. This infrastructure can forecast and give real-time health monitoring.

Keywords: *Distribution transformer, Fault Prediction system, IOT Monitioring system, SDN technology, Electrical power grid.*

****Author for Correspondence*** E-mail: maheswarikt@gmail.com

1. INTRODUCTION

Usually, high power must be produced and provided to the homegrown and modern units on an every minute of every day premise. The source of power and dispersion organization of the electrical framework must be kept up with consistently to give constant power utilization. Customary appropriation transformers have a typical existence of 20-25 years; be that as it may, the greater part of these transformers are toward the end pattern of their life and are representing a discontinuous gamble to the power framework. The flow observing arrangement of the power matrix in Iraq is just connected with main electrical boundaries that give no wellbeing check position on the inward parts of the neighborhood appropriation organization. Absence of Occasional support and follow up checks is a main consideration in these monotonous DT disappointments that is because of non-laid out perceivability framework. In this manner, a vigorous observing and forecast framework is expected to lay out ongoing checking of every circulation unit of the nearby matrix [3] by utilizing SDN rule. Programming Characterized Systems administration or (SDN) is another programmable organization idea worldview that has been proposed as of late to work with the executives and information guiding of the organization. SDN is the idea of isolating the control plane from the information plane in which the sending equipment is isolated from the dynamic stage, for example, directing and control programming [4].

The division of the planes gives an adaptable, programmable and savvy network foundation. In the SDN organization, the approaches will be running on the regulator just as divergent to running them on every gadget as in the customary organization. The regulator will have a full outline of the organization geography and all hubs can be designed from sole place of the board. This approach will give a strong administration of enormous scope network with less above.

Every motor has a table called sending table that advances based on matching the approaching parcel to the table. The correspondence between the SDN and Open Stream switches is administered by the Open Stream convention. The Open Stream convention is a bunch of communications that are traded between the regulator and the switches over a protected associated channel[5]. The regulator sends change information to the switch hub like add, alter, and eliminate sections from the sending table. At the point when an approaching parcel enters the Open Flow switch, it maps the bundle data to the sending table, on the off chance that there is a match, it advances the parcel to the assigned port; in any case, it sends a question solicitation to the regulator to demand guidance from the regulator on where to send the bundle. The SDN regulator then, at that point, counsels its geography table and choose whether to send new principles or inform the change to drop the parcel.

In the paper proposed by Angel et.al., (2020) Smart Grid (SG) is a multidisciplinary idea connected with the power framework update and improvement. SG suggests continuous data with explicit correspondence necessities. Framework dependability depends on the best abilities for checking and controlling the lattice. Among different perspectives, SG applications include three primary difficulties, adequate ongoing fit estimation units, overseeing huge informational indexes, and two-way low-inactivity correspondences. Taking into account shortcoming identification and order a critical variable to SG dependability, this work gives a deliberate survey of SG deficiencies from the main exploration information bases and cutting edge research papers targeting making a far reaching grouping system on the significant necessities[6]. This paper remembers for detail the characterization of various issue situations in an extensive structure that includes framework level of use, e.g., transmission, conveyance, business, DG, and EV. To this end, we break down and demonstrate important subjects for future advancements connected with the observing and shortcoming recognition and grouping in SG frameworks.

According to Sanjeev Kumar et al. (2021), the fault location is a crucial component of any distribution system and transmission line. Finding the exact site of the fault can be a challenging task at times, requiring a significant amount of time. The service technician can quickly overcome a fault-free system with the aid of the precise fault location. In this study, the ESP module is used to easily identify the defect range, and the message is sent to the mobile device. Quick fault recognition offer the safety of equipment before any substantial damage. N.M.G.Kumar et al., Proposed Power dispersion organization. The primary factual perception is delivered utilizing wavelet deterioration and wavelet-based definite coefficients concerning Kurtosis and Skewness boundaries. For this goal, six unmistakable AI techniques are conveyed. They are assessed and contrasted utilizing obscure informational collections and shifting levels of unconventionality. One approach has been demonstrated to be the most reliable in finding the area of the issue transport.

The problem statement that arises in existing paper revolves around the challenge of effectively managing and analyzing the vast amount of data generated by distributed IoT sensors within the electrical grid [7-8]. Specifically, issues such as data integration complexity, scalability concerns, security vulnerabilities, and algorithm accuracy pose significant hurdles in achieving reliable fault diagnosis and grid optimization [9-11]. Additionally, ensuring regulatory compliance, addressing operational complexities, and managing costs further compound the challenges faced by project stakeholders [12]. Thus, the overarching problem lies in developing robust solutions to overcome these obstacles and implement an efficient and effective fault diagnosis system that enhances the reliability and resilience of the electrical grid. The electrical framework's power supply and dissemination network should be persistently kept in control to offer consistent power use[13].

A customary power lattice's administration, observing, and effectiveness are undeniably finished by human administrators who likewise coordinate organic market to keep up with the framework's reliable stability. The flow observing arrangement of the power matrix is just connected with foremost electrical boundaries that give no wellbeing verify status on the inward parts of the neighbourhood dispersion organization.

The main objective of this paper is the absence of occasional support is a central point in these tedious DT disappointments that is because of none stablished perceivability framework. Thr target of this task is to improve the dependability and productivity of electrical lattices by utilizing enhancement methods, carrying out a Product Characterized Organization (SDN) geography, and using SDN sink sensors over private transformers[14-16]. The articular objectives incorporate medical issue checking, shortcoming examination, and further developed administration of circulation organizations to expeditiously distinguish and address broken sections, tending to repetitive difficulties looked by power- framework administrators [17-19].

2. PROPOSED SYSTEM

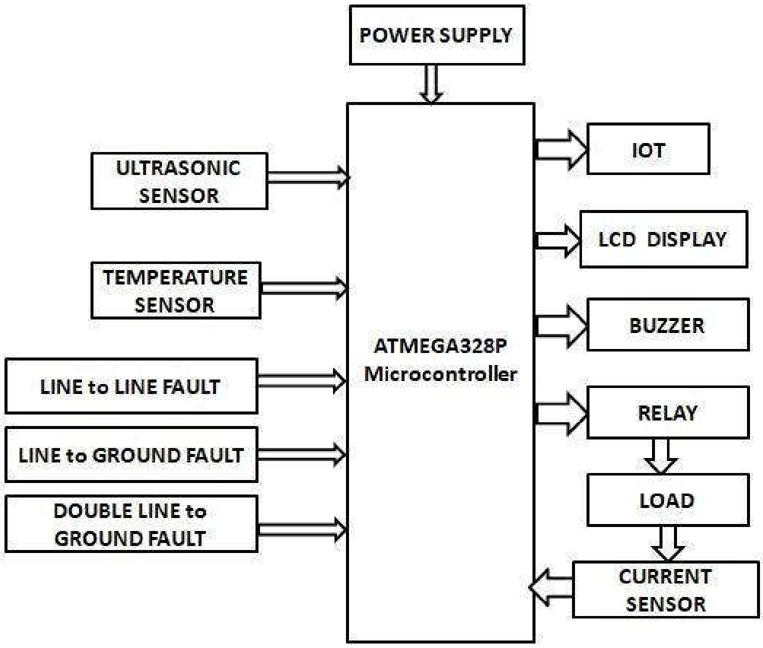

Figure 1. Block Diagram of Proposed System

The proposed system is a comprehensive monitoring and fault detection solution for distribution transformers and their associated distribution lines, leveraging distributed software-defined IoT architecture.([1] S. M. Chopdar and all,2022) Key components of the system include intelligent sensors for monitoring critical parameters such as current, temperature, and oil level, which are essential indicators of transformer health and performance. These sensors continuously collect data, which is then transmitted and updated in real-time through an IoT framework, enabling remote accessibility and centralized monitoring. Additionally, the system incorporates a smart fault detection mechanism for the distribution line, enhancing its ability to detect and respond to potential faults promptly. Through the integration of embedded technology and IoT connectivity, the proposed system offers a scalable, adaptable, and efficient approach to optimizing fault diagnosis in electrical grids, ultimately improving grid reliability and operational efficiency.

Fig 1 explains Dispersed sensors conveyed across the electrical lattice screen boundaries like voltage, flow, stickiness, and oil levels, giving constant information to blame determination. Found nearer to sensors, these gadgets pre process information, lessening idleness and transmission capacity use prior to communicating it to the focal handling unit (central processor). Gets information from edge gadgets and performs progressed information examination utilizing shortcoming location calculations and prescient investigation for issue finding.

The UI furnishes framework administrators with a graphical portrayal of the lattice's status and cautions them progressively when issues are recognized, working with brief reaction. Stores verifiable and ongoing information, empowering further examination, execution assessment, and improvement of issue analysis processes.

2.1 System Architecture

Portray the dispersed design including canny IoT sensor hubs conveyed across the network.Make sense of the functionalities of these sensor hubs, including information obtaining (voltage, current, temperature, and so forth), pre-handling, and nearby issue location calculations.([12] K. Wang et al,2018)Present the Product Characterized Systems administration (SDN) layer answerable for incorporated control, correspondence the board, and dynamic design of the organization.

2.2 Data Acquisition and Pre-processing

Detail the sorts of information gathered by the sensor hubs, incorporating voltage changes, current floods, temperature readings, and some other applicable boundaries. Make sense of the pre-handling methods utilized at the edge level to channel clamor, extricate basic elements, and decrease information volume for proficient transmission.

2.3 Distributed Fault Detection and Classification

Portray the execution of neighborhood inconsistency location calculations on the sensor hubs. ([2] M. A. M. NasrinMake,2021) sense of how these calculations dissect pre-handled information to distinguish potential issue marks.Present the idea of conveyed cooperative knowledge, where sensor hubs impart and share neighborhood discoveries to upgrade generally speaking shortcoming location precision.Notice the utilization of AI models prepared on authentic information to order unique issue types (e.g., shortcircuits, establishing flaws, and so on.).

2.4 Centralized Fault Diagnosis and Optimization

Make sense of the job of the SDN regulator in getting information from sensor hubs and planning shortcoming determination across the framework. Depict how the regulator influences progressed examination and AI calculations for complete issue ID and confinement. Feature the streamlining angle, where the framework progressively changes network setups (e.g., rerouting power stream) to separate blames and limit administration disturbances.

2.5 Communication and Security

Talk about the correspondence conventions utilized for information trade between sensor hubs, the SDN regulator, and possibly utility administration places. Underline the significance of powerful safety efforts to guarantee information uprightness, forestall cyberattacks, and safeguard basic framework foundation.

2.6 Performance Evaluation

Portray the strategies for assessing the adequacy of the proposed framework. This could include measurements like shortcoming recognition precision, confinement time, and decrease in by and large margin time.

3. HARDWARE AND SOFTWARE IMPLEMENTATION

3.1 Sensor Selection and Deployment

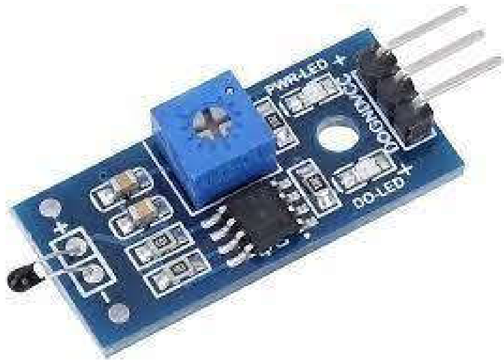

Figure 2. Temperature Sensor

Temperature Sensors: Select high-precision contact temperature sensors as shown in Fig.2 (e.g., RTDs, thermistors) to be mounted directly on the transformer's body (winding hot spots) and oil conservator (bulk oil temperature).

3.2 Oil Level Sensors

Figure 3. Ultrasonic Sensor

Utilize ultrasonic or differential pressure sensorsas given in Fig.3. to measure the oil level within the transformer tank. These sensors should be compatible with the transformer oil and operate within the expected temperature range.

3.3 Fault Detection Sensors

Figure 4. Current Transformer

Contingent upon the particular issue types focused on (e.g., impede, shortcoming, winding issue), various sensors may be required.Current transformers (Fig 4) can distinguish unusual current floods characteristic of shortcircuits. ([7] Maanvi Bhatnagar,2022) Dissolved Gas Examination (DGA) sensors can recognize explicit gases delivered during different shortcoming conditions inside the transformer.Partial Release (PD) sensors can recognize nascent shortcomings inside the transformer windings before they raise.

3.4 Data Acquisition Unit (DAQ) and Microcontroller

Figure 5. Arduino

Execute an Information Obtaining Unit (DAQ) to connect with the picked sensors. The DAQ ought to be equipped for taking care of the particular sign sorts from every sensor (e.g., vol tagefor RTDs, current for CTs). Coordinate a microcontroller unit (Fig. 5) (MCU) to deal with crude sensor information. The MCU can perform essential computations (e.g., temperature change), execute neighborhood irregularity recognition calculations (e.g., contrasting temperature readings with limits), and oversee correspondence with the SDN regulator.

3.5 Commucation Module

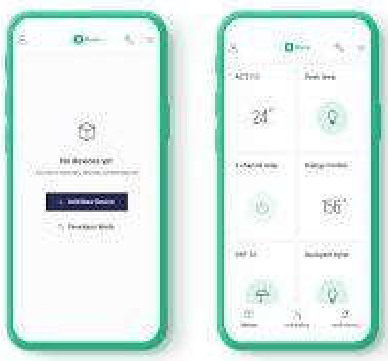

Figure 6. Blynk App

Outfit the sensor hub with a dependable correspondence module for information transmission to the SDN regulator. Contingent upon the arrangement situation, choices include Cellular network for wide region inclusion Low-Power Wide-Region (Fig 6) Organization (LPWAN) innovations like LoRaWAN for long-reach and low-power correspondence.Short-range remote conventions like Zigbee or WiFi for limited arrangements.

3.6 Blynk App Integration

The Blynk application fills in as a UI for fundamental checking and primer issue distinguishing proof.([3] H. A. Shiddieqy,2019) It shows continuous and verifiable sensor information (voltage, current, temperature, oil level) and alarms set off by nearby abnormality identification calculations. This furnishes field work force with an underlying consciousness of possible issues.

3.7 System Integration and Testing

When individual programming parts are created (sensor hub firmware, correspondence conventions, SDN regulator programming), exhaustive incorporation testing guarantees consistent information stream and usefulness across the whole framework. This incorporates testing information securing, correspondence unwavering quality, shortcoming recognition calculations, and organization advancement functionalities.

4. RESULTS AND DISCUSSION

4.1 Circuit Diagram

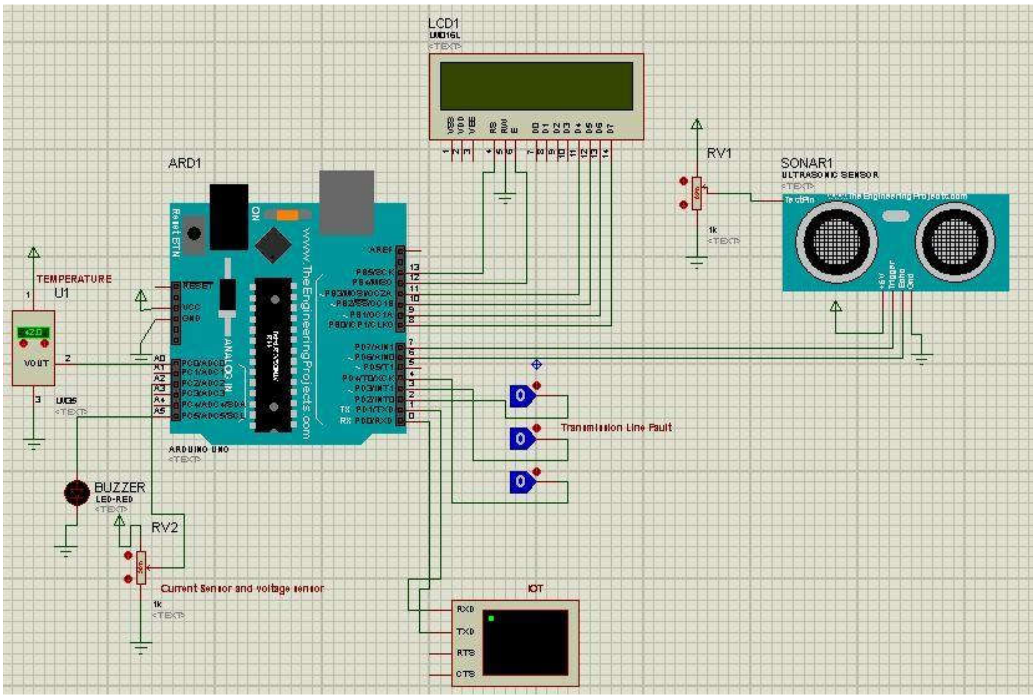

Figure 7. Circuit Diagram of Proposed System

Fig 7 explain a steady power source guarantees constant activity of the framework.Different sensors (e.g., voltage, current, mugginess) are associated with microcontrollers for information acquisition.Control and process sensor information, interacting with correspondence modules for information transmission. Use conventions like MQTT for information trade among microcontrollers and a focal handling unit (computer processor). Gets and processes information from microcontrollers, carrying out issue discovery calculations and communicating with UIs for perception and alarms.

4.2 Hardware Picture

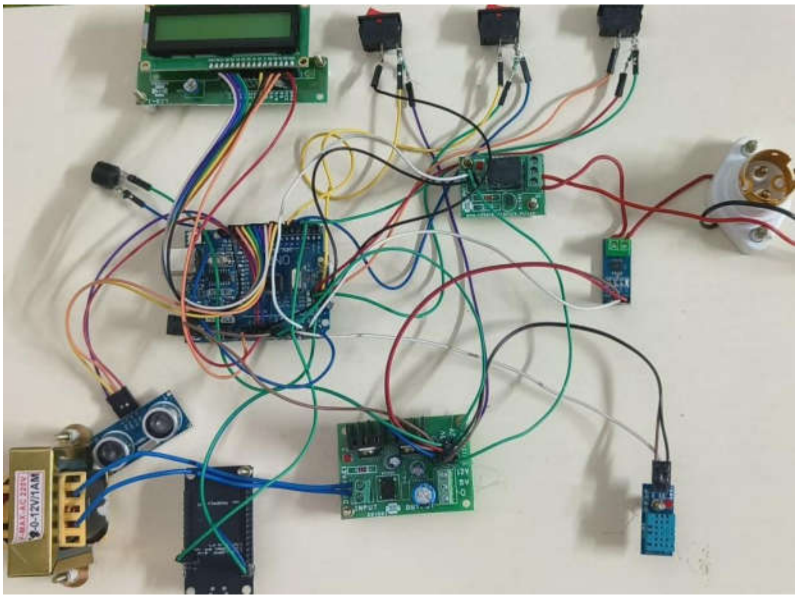

Figure 8. Hardware Circuit of Proposed System

Fig 8 explain the complete model of hardware with three types of sensor with current transformer and micro controller and with LCD display. The execution of a shrewd improvement framework for shortcoming determination in electrical networks, using conveyed programming characterized IoT design, yields a few critical outcomes and advantages. First and foremost, the framework essentially upgrades the productivity of shortcoming recognition and determination inside the network foundation. By conveying IoT sensors across different hubs of the network, constant information assortment becomes inescapable, taking into consideration the persistent observing of basic boundaries like voltage, current, and temperature. This consistent reconnaissance empowers quick ID and limitation of flaws, along these lines decreasing margin time and upgrading network unwavering quality.

Furthermore, the conveyed idea of the IoT framework guarantees a hearty and tough shortcoming conclusion component. Not at all like customary concentrated approaches, this appropriated design mitigates the gamble of weak links. Each IoT gadget works independently, working with decentralized direction and shortcoming separation. Thus, even despite correspondence disappointments or hub breakdowns, the framework can keep up with its symptomatic capacities, guaranteeing continuous network activity. Furthermore, the combination of cutting edge examination and AI procedures engages the framework with prescient abilities. By breaking down verifiable information designs, the framework can expect likely blames before they happen, empowering proactive upkeep and limiting the gamble of spontaneous blackouts. This prescient methodology upgrades framework dependability as well as streamlines upkeep plans, along these lines lessening functional expenses and improving by and large framework effectiveness.

4.3 Simulation Output

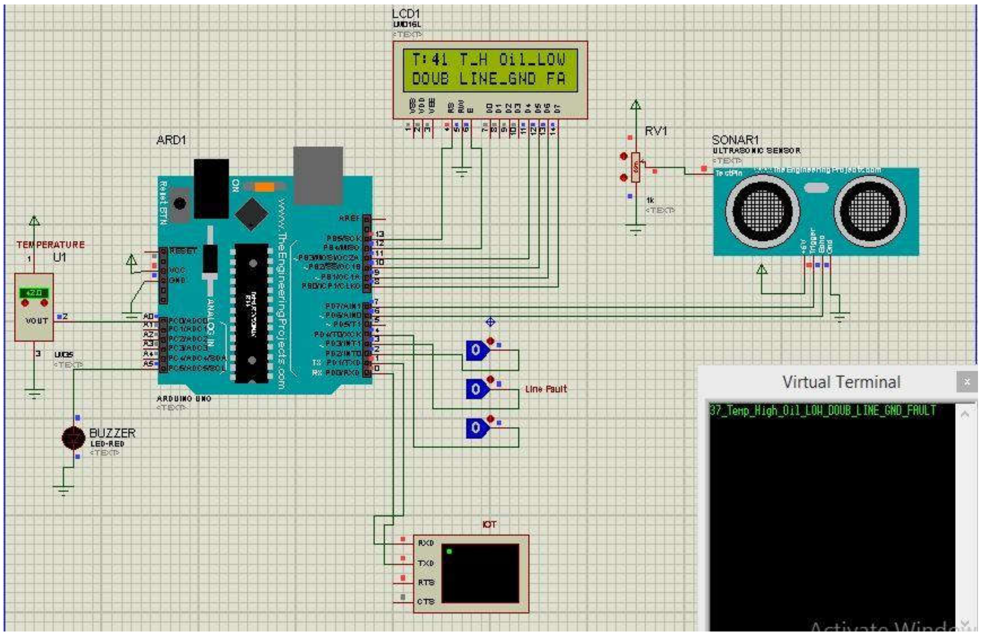

Figure 9. Output of Proposed System

Fig 9 Explains the issue explanation that emerges in existing ventures for A Savvy Enhancement of Shortcoming Finding in Electrical Matrix Utilizing Circulated Programming Characterized IoT Framework rotates around the test of successfully overseeing and examining the tremendous measure of information created by conveyed IoT sensors inside the electrical network. In particular, issues, for example, information joining intricacy, adaptability concerns, security weaknesses, and calculation precision present huge obstacles in accomplishing dependable shortcoming conclusion and network advancement. Moreover, guaranteeing administrative consistence, tending to functional intricacies, and overseeing costs further compound the difficulties looked by project partners. In this way, the overall issue lies in creating vigorous answers for beat these impediments and carry out a proficient and compelling shortcoming determination framework that improves the unwavering quality and flexibility of the electrical lattice.

4.4 Real Time Output

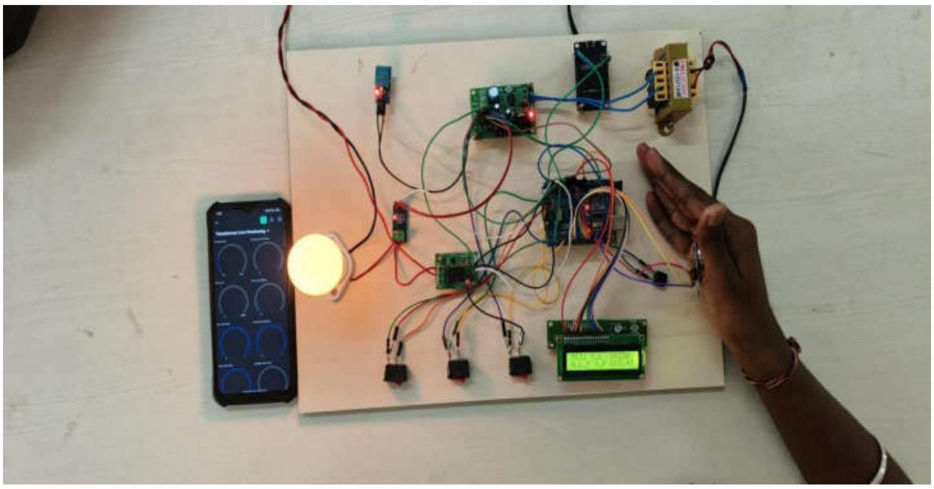

Figure 10. Oil level

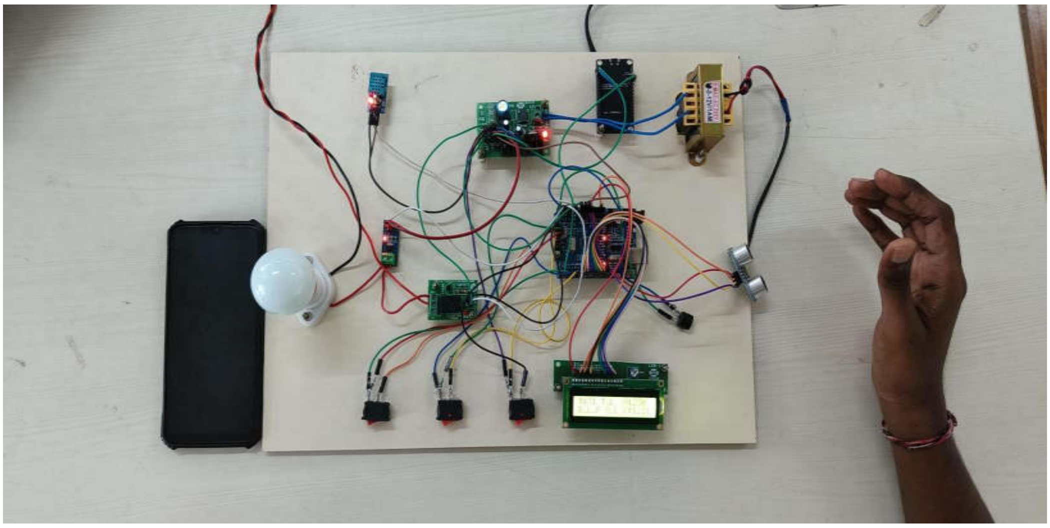

Fig 11. line to line

Fig. 10 shows the detection of oil level by the proposed hardware system.The smart optimization of fault diagnosis in electrical grids through distributed software-defined IoT systems represents a pivotal advancement with far-reaching implications for grid management. By leveraging IoT devices distributed across the grid infrastructure, this system enables real-time monitoring and analysis of critical parameters, facilitating rapid fault detection and localization. This distributed approach not only enhances the reliability of fault diagnosis but also ensures resilience against disruptions by decentralizing decision-making processes. Fig.11, 12 and 13 represents the detection of line to line, double line to line and double line to ground fault by the proposed fault diagnosis system.

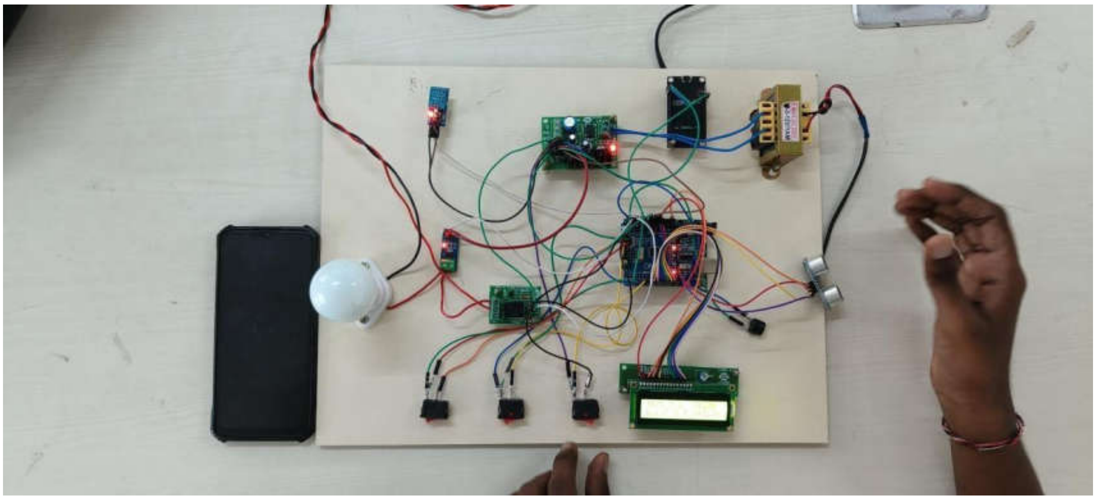

Figure 12. double line to line

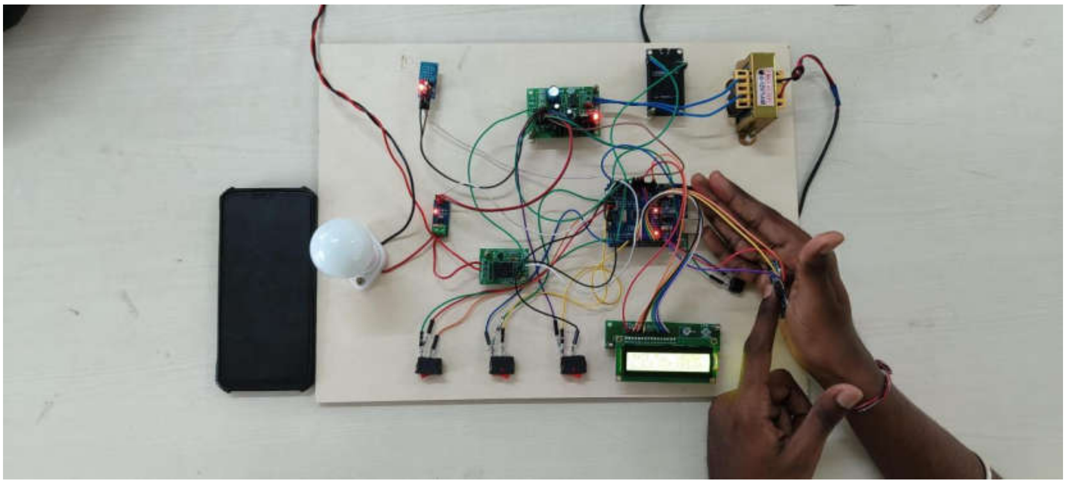

Figure 13. Double line to ground

Moreover, the product characterized nature of the framework offers unrivalled adaptability and flexibility. Through programming based calculations and designs, the framework can progressively conform to developing matrix conditions and prerequisites, upgrading shortcoming conclusion systems because of evolving requests. This flexibility is essential for tending to the intricacies and vulnerabilities intrinsic in electrical matrix tasks, considering proficient administration of shortcomings and relieving the gamble of far and wide blackouts. Furthermore, the execution of a savvy enhancement framework cultivates coordinated effort and data dividing between partners in the lattice biological system. By giving continuous experiences into framework execution and issue conditions, the framework empowers composed reaction endeavors, working with quicker reclamation of administration and limiting the effect of interruptions on end-clients. This cooperative methodology is fundamental for guaranteeing the strength and unwavering quality of present day electrical matrices notwithstanding developing difficulties and dangers.

5. CONCLUSIONS

In conclusion, the implementation of a distributed software-defined IoT system for fault diagnosis in electrical grids represents a significant advancement in grid monitoring and management. By integrating intelligent sensors and IoT connectivity, the proposed system enables real-time monitoring of critical parameters in distribution transformers and distribution lines, facilitating proactive fault detection and response. The system's scalability, adaptability, and remote accessibility contribute to enhanced grid reliability and operational efficiency, ultimately reducing downtime and maintenance costs while improving overall system resilience. Moving forward, further research and development efforts should focus on refining the system's algorithms for fault detection and diagnosis, as well as expanding its capabilities to accommodate emerging technologies and evolving grid infrastructure. Additionally, collaboration between industry stakeholders, policymakers, and researchers will be essential to address regulatory challenges and accelerate the adoption of smart grid technologies. By continuing to innovate and optimize fault diagnosis systems, we can pave the way for a more sustainable, reliable, and resilient electrical grid ecosystem.Through the deployment of distributed sensors and intelligent algorithms, the system can detect and diagnose faults accurately and swiftly, thereby minimizing downtime, reducing operational costs, and improving overall grid reliability. Moreover, the software-defined architecture enables dynamic reconfiguration of network resources and routing paths, ensuring efficient data transmission and communication among grid components. Furthermore, the integration of machine learning and AI algorithms facilitates predictive maintenance and proactive fault management, allowing for the identification of potential issues before they escalate into critical failures. This predictive capability enables utilities to adopt a preventive maintenance approach, optimizing resource allocation and maximizing grid uptime.

REFERENCES

1. S. M. Chopdar and A. K. Koshti, "Fault Detection and Classification in Power System Using Artificial Neural Network", 2022 2nd International Conference on Intelligent Technologies (CONIT), pp. 1-6, 2022.
2. M. A. M. Nasrin, A. M. S. Omar, S. S. M. Ramli, A. R. Ahmad, N. F. Jamaludin and M. K. Osman, "Deep Learning Approach for Transmission Line Fault Classification", 2021 11 th IEEE International Conference on Control System Computing and Engineering (ICCSCE), pp. 164-169, 2021.
3. H. A. Shiddieqy, F. I. Hariadi and T. Adiono, "Power Line Transmission Fault Modeling and Dataset Generation For AI Based Automatic Detection", 2019 International Symposium on Electronics and Smart Devices (ISESD), pp. 1-5, 2019.
4. J. Rajashekar and A. Yadav, "Transmission lines Fault Detection and Classification Using Deep Learning Neural Network", 2022 Second International Conference on Advances in Electrical Computing Communication and Sustainable Technologies (ICAECT), pp. 1-6, 2022.
5. Bhuyan, B. K. Panigrahi, K. Pal and S. Pati, "Convolutional Neural Network Based Fault Detection for Transmission Line", 2022 International Conference on Intelligent Controller and Computing for Smart Power (ICICCSP), pp. 1-4, 2022.
6. M. R. Bishal, S. Ahmed, N. M. Molla, K. M. Mamun, A. Rahman and M. A. A. Hysam, "ANN Based Fault Detection & Classification in Power System Transmission line", 2021 International Conference on Science & Contemporary Technologies (ICSCT), pp. 1-4, 2021.
7. Maanvi Bhatnagar, Anamika Yadav and Aleena Swetapadma, "Enhancing the resiliency of transmission lines using extreme gradient boosting against faults", Electric Power Systems Research, vol. 207, 2022.
8. Fezan Rafique, Ling Fu and Ruikun Mai, "End to end machine learning for fault detection and classification in power transmission lines", Electric Power Systems Research, vol. 199, pp. 107430, 2021, ISSN 0378-7796.
9. M. Bindi, A. Luchetta, L. Paolucci, F. Grasso, S. Manetti and M. C. Piccirilli, "Applications of Machine Learning Techniques for the Monitoring of Electrical Transmission and Distribution lines", 2022 18th International Conference on Synthesis Modeling Analysis and Simulation Methods and Applications to Circuit Design (SMACD), pp. 1-4, 2022.
10. F. Hao, X. Yang, G. Wang and Y. Feng, "Transmission Line Fault Diagnosis Based on Machine Learning", 2023 3rd InternationalConference on Consumer Electronics and Computer Engineering(ICCECE), pp. 847-850, 2023.
11. M. Wang, A. J. Vandermaar, and K. D. Srivastava,“ Review of condition assessment of

power transformers in service," IEEE Elect. Insul. Mag., vol. 18, no. 6, pp. 12–25, Nov./Dec. 2002.

12. K. Wang et al., "A survey on energy internet: Architecture, approach, and emerging technologies," IEEE Syst. J., vol. 12, no. 3, pp. 2403–2416, Sep. 2018.
13. S. Azodolmolky, Software Defined Networking With OpenFlow, vol. 21. Birmingham, U.K.: Packt Publ., 2003.
14. E. C. Fontana, "Powering software defined networks with an any rack capable power bus," in Proc. IEEE Int. Telecommun. Energy Conf., 2016, pp. 1–4.
15. T. D. Nadeau and K. Gray, SDN: Software Defined Networks: An Authoritative Review of Network Programmability Technologies. Newton, MA, USA: O'Reilly Media, Inc., 2013.
16. S. Bailey et al., "SDN architecture overview," Open Networking Foundation, Menlo Park, CA, USA, 2013. [Online]. Available: https://www. opennetworking.org/images/stories/downloads/sdn-esources/technicalreports/SDN-architecture-overview-1.0.pdf
17. Jaivir Singh , "Parametric excitation of optical phonons in weakly-polar narrow band gap magnetized semiconductors", RP Current trends in Engineering and Technology, Jan 2023 , pp.13-22.
18. Debasree Saha , "Potential of solid supported copper catalyst in sustainable organic synthesis", RP Current trends in Applied Sciences, Jan 2024, pp. 10-13
19. Harjit Pal Singh, "High-energy electron irradiation induced effects in LED chips", RP Materials Proceedings, Apr 2023 ,pp. 29-32.
20.