MSW MANAGEMENT -Multidisciplinary, Scientific Work and Management Journal
ISSN: 1053-7899
Vol. 36 Issue 1, Jan-June 2026, Pages: 1802-1809

"IOT-Based Real-Time Monitoring of a Grid-Connected Hybrid Renewable Energy System with Solar, Wind, and Diesel Backup for Reliable Power Supply"

Pradeep Kumar
Research scholar, Department of Electrical and Electronics Engineering, Presidency University, Bengaluru, Karnataka 560119, India
pradeep.20233eee0005@Presidencyuniversity.In

Dr. Jisha L K
Assistant Professor-Selection Grade, Department of Electrical and Electronics Engineering, Presidency University, Bengaluru, Karnataka 560119, India
jisha@presidencyuniversity.in

Abstract—Energy is a critical factor for economic growth, environmental sustainability, and improving living standards, particularly where reliable and accessible energy services are essential. Solar photovoltaic (PV)-based DC microgrids have emerged as an effective solution for providing decentralized power. This research proposes an IoT-based smart microgrid system featuring an advanced control system for optimal operation and remote monitoring via the internet. The system integrates an energy storage system (ESS) to store excess solar energy and a diesel generator as a backup to ensure uninterrupted power supply during low solar availability or emergencies. It can detect branch failures, enabling authorities to manage the grid remotely in real time. Power ratings are continuously displayed through a monitoring interface. Simulation results demonstrate that the proposed system operates reliably, efficiently, and meets energy demands effectively.

Keywords—IoT, Advanced Microgrid, Power Monitoring System, Renewable Energy

I. INTRODUCTION

Decentralized electricity generation has recently improved its performance in the energy market. Emergency backup systems in hospitals, rural telecom tower stations, military applications, and powering off-grid islands are only a few of the applications for autonomous energy supply systems. The need for renewable energy systems is growing as fossil fuel prices continue to rise and energy demand in rural areas rises at the same time. As a result, there is a movement toward hybrid energy supply options that include renewable sources in order to minimize operating costs [1]. Renewable energy has become continued support and encouragement and is widely used in recent decades as countries have sought a cleaner and greener source of energy. Renewable energy sources have their own drawbacks, such as intermittent power supply due to changing weather patterns. This problem, however, can be solved by combining various renewable energy sources (RES) and energy storage systems (ESS) to create a microgrid climate. A microgrid is a low-voltage local distributed energy infrastructure with multiple kilowatts of distributed energy sources on a small scale. Microgrids are divided into two categories: grid-connected microgrids and islanded microgrids. By linking the microgrid to the main grid, operational performance and economics can be improved. In islanded mode, however, the supply can be more stable and reliable in places like mountains, islands, and remote areas where grid connectivity is difficult. Microgrids may also be categorized based on their composition, such as AC or DC microgrids. Grid synchronization and the need for reactive control are two of the many difficulties of an AC microgrid [2]. DC microgrid, on the other hand, has no such drawbacks [3]. Sub transmission systems are typically used to transfer small quantities of power from transmission systems to distribution levels. However, in recent years, this situation has shifted. A paradigm change occurred as a result of the introduction of renewable energy sources into delivery systems. The generation is now present in these networks, allowing transmission systems to be decoupled via the formation of microgrids. Distribution networks in urban areas are already developed and linked to the grid [4], so their operation and planning, such as grid expansion to the outskirts of town and transformer maintenance, are part of the electric sector companies' operating structure. Rural delivery systems, on the other hand, do not experience this. Three options are available for these devices, thanks to modern generating technologies. The first involves extending the grid from urban to rural areas. The second step is to build a microgrid in a rural area after conducting an analysis of the area's parameters, such as population and weather, in order to scale the generators and storage systems that will be used. The third and final choice is to combine grid expansion and microgrid deployment. In the event that the microgrid does not produce enough power to meet the load, the grid will step in to fill the gap. If the microgrid's generation exceeds its load, the energy may be exported to the main grid. Batteries and source disconnection (for generation surplus) or load shedding (for generation deficit) are used to stabilize the system if it is isolated. This thesis investigates those circumstances. The main goal of this research paper is to build an idea for an IoT-based smart microgrid for rural areas that will provide continuous power. This research paper has 7 sections. Section II discusses about literature review whereas section III discusses about engineering problem statement. Section IV represents the comparison, and section V shows the methodology and modeling. Also, section VI & VII represent results analysis and conclusion.

II. LITERATURE REVIEW

Many researchers have published many papers focused on microgrid systems for rural areas. A few papers focused on the smart IoT-based microgrid system have been released. For a deeper understanding, several thesis articles, conferences, and journals are analyzed below: Many researchers have been working on microgrid systems for the past few years. In 2019. Xianwen Zhu et al. [5] proposed a paper titled "Design and Development of a Microgrid Project at Rural Area." The design and implementation of a microgrid project in a rural area are presented in this paper. They spoke about how the microgrid system works in practice. Simulation and experiments were used to verify the viability of the proposed scheme. In 2018, Chakphed Madtharad et al. [6] suggested a project that was "Microgrid Design for Rural Island in PEA Area." They addressed

MSW MANAGEMENT -Multidisciplinary, Scientific Work and Management Journal
ISSN: 1053-7899
Vol. 36 Issue 1, Jan-June 2026, Pages: 1802-1809

the design of a microgrid power system for a rural island for which PEA determined that investing in a submarine cable was not economically feasible. In their paper, the HOMER Pro microgrid analysis method (HOMER Pro) was used to calculate the PV array's optimal sizing and BESS. The method for calculating the effective electricity tariff for microgrid systems proposed to the government was shown in that paper. In 2019, Mashood Nasir et al. [7] suggested, "Parametric Analysis of Centralized DC Microgrids for Rural Electrification," where they looked at several variables that could affect centralized DC microgrids' operational performance. They first looked at distribution losses in a typical system by varying critical system parameters, including distribution voltage, distribution conductor size, the amount of load to be transmitted to each connected rural building, and system size (number of subscribing houses). In 2020, Vinit Kumar Singh et al. [8] proposed "Dynamic Stability Study of Isolated Rural Microgrid Based on Load Characteristics." In their paper, they addressed four different types of loads with exponential voltage and frequency characteristics. In 2019, Gaurav Kumar Suman et al. [9] proposed "Microgrid System for A Rural Area - An Analysis of HOMER Optimized Model Using MATLAB." They looked at the fault incidence and reliability of one such device configured by HOMERquickstart for a small group in Gurmia, India. Since the chosen location had a good amount of solar and wind energy, effectively trapping these resources in the form of hybrid microgrid systems could solve major power issues while also superseding the old grids. Simulink was used in their paper to simulate an optimized model obtained from the HOMERquickstart kit. Various scenarios for interconnecting energy sources for the microgrid were considered, and their respective transient behavior in the event of faults was observed. In 2015, Matheus F. Z. Souza [10] suggested "On Rural Microgrids Design – A Case Study in Brazil," where he spoke about how to plan a rural microgrid in a developing world. The problem was solved by imagining a group of farmers living in a remote area and using nearby wind sources to produce electricity. The case under consideration assumes that there was enough energy in the month but that the peak time was supplied by batteries. The power of the wind sources, as well as the size of the batteries, were addressed in this context. The microgrid was feasible in real-world tests. In 2013, Zhaohao Ding et al. [11] proposed a project that was "An Autonomous Operation Microgrid for Rural Electrification." This paper proposed an intelligent microgrid as a rural electrification solution for Africa. This paper also included simulation verification and lab implementation. In 2017, Yemeserach Mekonnen et al. [12] proposed a project that was "Renewable Energy Supported Microgrid in Rural Electrification of Sub-Saharan Africa." They presented a comprehensive overview of the current renewable energy-based technologies for rural electrification in Sub-Saharan Africa. They also addressed energy scarcity and how it was linked to these countries' sluggish economies. Their paper will go over some of the latest advances in off- grid and microgrid technology. The difficulties that this development faces were addressed. Finally, they discussed the potential effects of off-grid renewable energies and the state and challenges of rural electrification. In 2016, Julia Sachs et al. [13] proposed a diagram called "A Two-Stage Model Predictive Control Strategy for Economic Diesel-PV-Battery Island Microgrid Operation in Rural Areas." Their paper used a two-layer model predictive approach to present an advanced control strategy for optimal microgrid operation. The first optimization layer posed an optimal control problem for calculating the optimal energy dispatch based on future power profiles' real-time forecasts. A boundary value problem was solved to change the diesel generator power in the second stage to increase the control strategy's robustness against prediction errors.

III. PROBLEM STATEMENT

Traditional microgrid systems are being used to generate electricity at the moment. Traditional power infrastructure makes it difficult to control energy. When energy leaves a power plant or substation, companies have no control of how it is delivered. Because of their age and weaknesses, traditional microgrid technology is prone to failure. When equipment fails, the end customer's system loses control, resulting in downtime. Due to shortcomings in traditional infrastructure, energy distribution must be manually controlled. All systems can be managed digitally if a smart microgrid can be built. As renewable energy sources, solar and wind energy can be used to fuel microgrids. To provide electricity for stabilization, a generator may be used. Authorities can see the power ratings digitally by adding a power monitoring device to the microgrid. It would be a one-of-a-kind feature if this monitoring device could detect the branch's electrical fault. Traditional electric generation requires a large amount of ground, while solar panels can be installed on the roofs of buildings and are both cost-effective and economical.

IV. COMPARISON WITH TRADITIONAL METHOD

The traditional microgrid is a one-way system in which power is produced at one end from a source and then distributed to those who need it. It is transmitted to each customer through a distribution transformer, which lowers the voltage at the user stage, after the long transmission. Furthermore, there is no digital device that can regulate the branch's electricity flow. Almost every conventional system lacks a power monitoring system and an automated generator. The figure of traditional method is given below in figure 1.

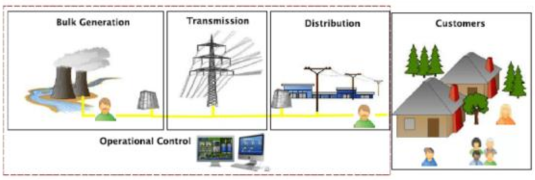

Fig. 1. Traditional Method

The whole system becomes useless if there is a mistake in producing or delivering electricity. And a man is always needed to keep the machine running. In addition, the conventional microgrid method necessitates a significant amount of ground.

In this smart microgrid system, on the other hand, the system would be operated digitally via IoT. To install the Solar PV, no workers are required, no land is required, and a generator will be used for high electric power output. And the generator would start using IoT, and a power monitoring device would be installed to see the branch's power rating and fault. The proposed model is given below in figure 2.

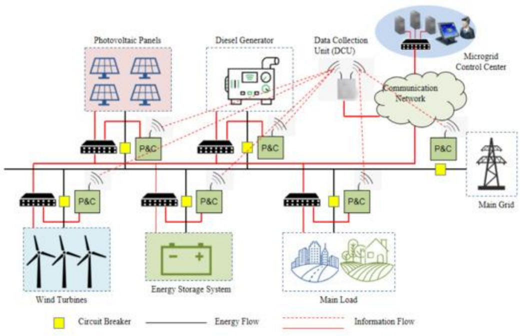

Fig. 2. Proposed System

V. METHODOLOGY & MODELING

In this section the methodology and modelling of the project will be discussed with block diagrams and simulations which will highlight the project's function elegantly.

A. Block Diagram of the Project

A microgrid powered by renewable energy sources are proposed in this research paper that will assist to mitigate some of the environmental problems associated with fossil fuel combustion. Solar and Wind power are used here to produce electricity in this project. Diesel generator is also used as a power source in this project as a backup source. Solar, wind, and diesel engine will produce electricity separately and the grid system would add them. There are three phase circuit breakers to save the microgrid. To get the expected results, this project was developed by the integration of bus connection systems, relay, transformer, etc. The whole method of this project is given below in fig. 3.

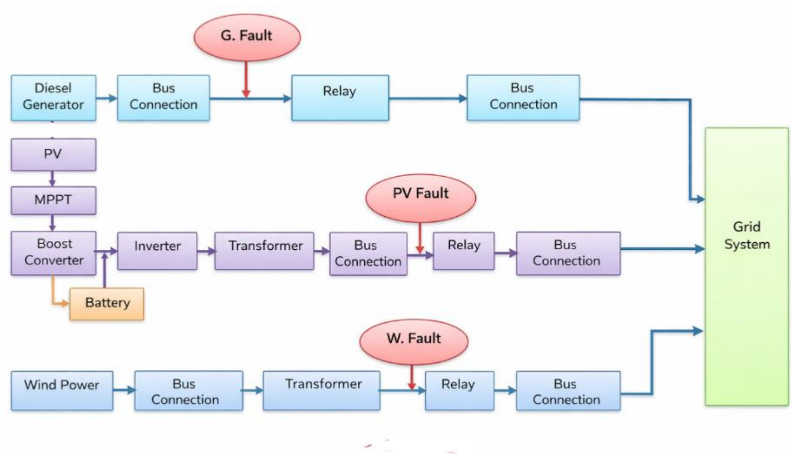

Fig. 3. Block Diagram for Power Production System

On the other hand, power monitoring system is connected to this microgrid system. In this system, the usage power ratings are measured and updated continuously to the display also the cloud server. This monitoring interface displays the current power status, Fault Status, Branch Status, etc. Three scopes are connected to Simulink file to see the power status individually. The controller unit measures the power ratings and displays them. Not only inner microgrid interface but also it updates the data to ThingSpeak cloud server periodically. The authority can see the status of the microgrid system from anywhere at any time. The block diagram is given in fig. 4.

MSW MANAGEMENT -Multidisciplinary, Scientific Work and Management Journal
ISSN: 1053-7899
Vol. 36 Issue 1, Jan-June 2026, Pages: 1802-1809

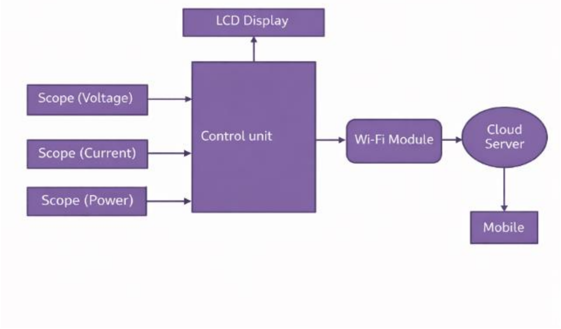

Fig. 4. Block Diagram for Cloud Communication System

The flowchart describes the operation of a microgrid system that integrates multiple electric energy sources, including a PV (solar) system, battery storage, diesel generator, and wind energy. All these sources supply power to the microgrid and continuously send operational data such as voltage, current, and power to a monitoring system. The system acquires this data through sensors and performs fault detection to determine whether any abnormal condition exists. If a fault is detected, the system activates the backup generator energy source and ensures a smooth transition to maintain uninterrupted power supply. If no fault is detected, the system notifies and isolates the issue within the microgrid while continuing normal operation. Overall, the flowchart represents a smart microgrid control strategy that ensures reliable, stable, and continuous power supply through real-time monitoring and automatic fault management

MSW MANAGEMENT -Multidisciplinary, Scientific Work and Management Journal
ISSN: 1053-7899
Vol. 36 Issue 1, Jan-June 2026, Pages: 1802-1809

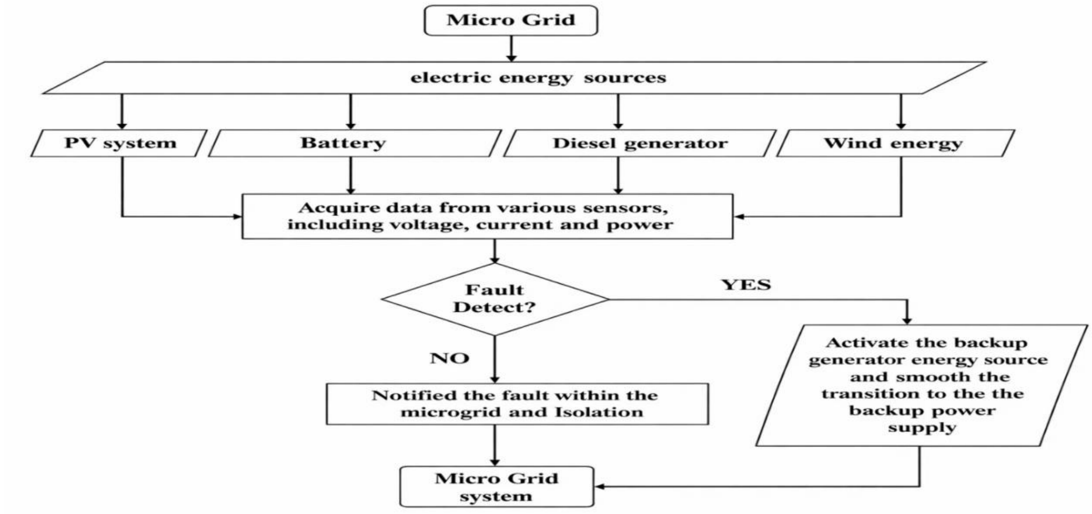

Fig. 5. Flowchart for the operation of a microgrid system

B. Simulation Of The Project

In fig.5, the simulated circuit has been shown where all the parts are integrated with each other. Also, an application interface has been developed to control the microgrid system that is shown in the picture. Everything is developed according to block diagram that has been discussed before.

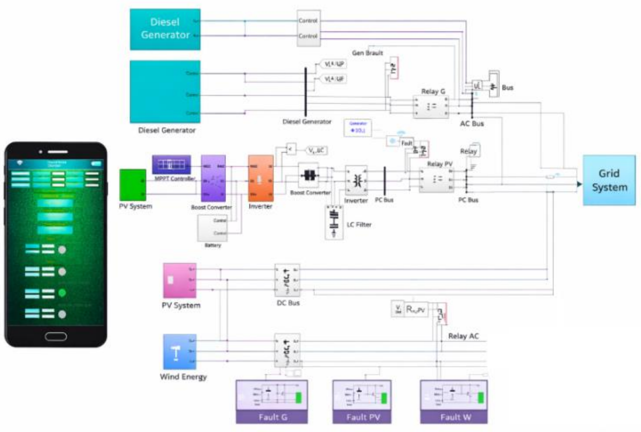

Fig. 6. Overall Simulated Circuit

The simulation of the grid system is mentioned in fig. 6.

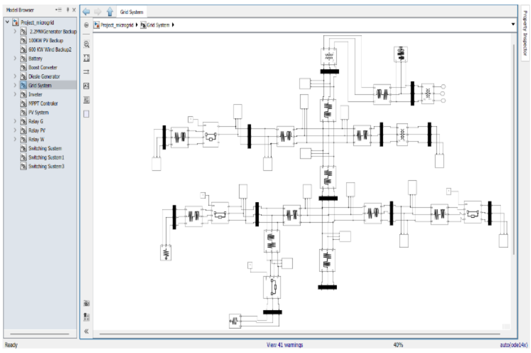

Fig. 6. Simulation of the Grid System

Diesel generator, PV system and Wind Energy are used in this Simulink. Diesel generator produces electric power by using fuel and delivers the power to the diesel generator bus. Then the power goes to the relay where the electric fault can be detected. On the other hand, solar power produces electric power by using sunlight and passes the power to the grid system. For better results, MPPT controller and Boost Converter are used. In this line, a 250V/25KV transformer is used and a relay is used to detect the fault automatically.

C. Control Unit

A controller unit was designed to control the microgrid system from the control room. Different kinds of interfaces have been added to show the value and to control them. The authority can turn on or off any branch at any time. The interface is containing the total current, power, voltage, faults, branch current, and branch voltages. The picture of the controller unit has been shown in fig. 7.

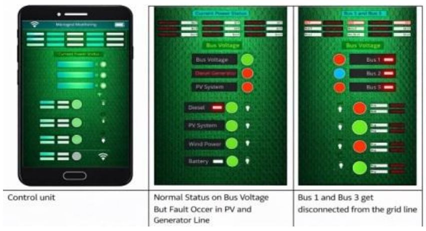

Fig. 7. Interface of Control Unit

D. Mobile Application

An android application has been designed for getting the output results in mobile phones. Three different platforms have been designed for three power sources that has been shown in the picture. From this platform, the authority would be able to see the real-time power of the microgrid system. This application is only applicable for authority. The main interface of the project's mobile application is given below in fig. 8.

Fig. 8. Interface of Mobile Application

VI. RESULTS & OUTPUT ANALYSIS

In this section, the individual results of solar power, wind power, and diesel generator will be discussed. In Part A, the results of MATLAB platform have been discussed whereas the part B will discuss about ThingSpeak Server results. Part C and D will discuss about the output and results of controller unit and android mobile application.

A. MATLAB Results Analysis:

1) Diesel Generator Bus Output

From the generator bus analysis, we get almost 16000kW, where the voltage is almost 2000V, and the current is 4000A. The diagram is given below in fig. 9. Here, the first graph represents the power ratings, the second graph represents the voltage ratings, and the final graph represents the current ratings.

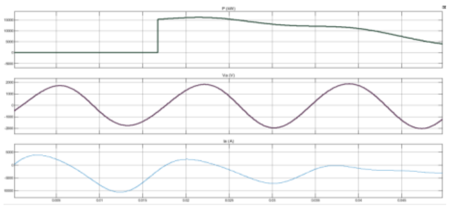

Fig. 9. Diesel Generator Bus Output

2) PV Bus Voltage and Current With & Without Filter

The graph of voltage and current of PV Bus with filter and without a filter has been shown in fig. 10. The first graph indicates the voltage graph, and the second graph indicates the current signal with filtration. On the other hand, the third graph indicates the signal without a filter.

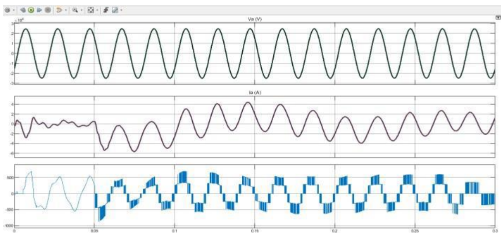

Fig. 10. PV Bus Voltage and Current with & without filter

3) PV Bus Output Power & Voltage

This figure 11 shows the output of the PV bus and its DC voltage. We get 100kW from PV bus. Here, the first graph represents the power ratings and the second one is voltage ratings.

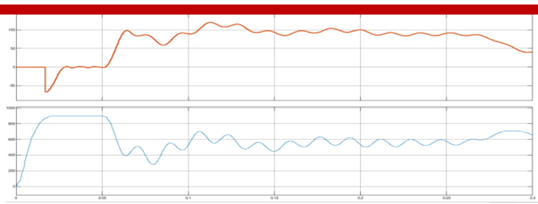

Fig. 11. PV Bus Output Power & Voltage

4) Wind Bus Output Voltage, Current & Power

From the Wind Bus, we get almost 5000kW. The output graph is given below in fig. 12. Here, the first graph shows the output of power, the second graph shows the voltage and the third one represents the current of the wind bus.

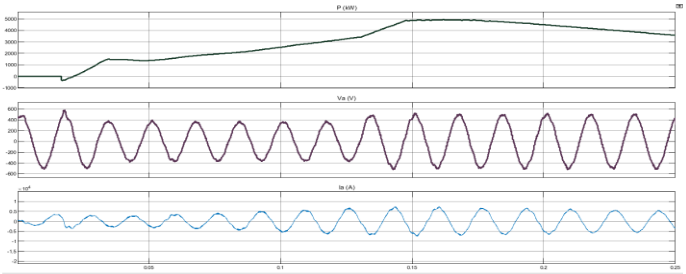

Fig. 12. Wind Bus Output Voltage, Current & Voltage

B. Results Analysis of Thingspeak Server:

As the suggested microgrid system is IoT-Based, so the authority can see the real-time data in cloud server. The authority can access this server from anywhere at any time with the help of a username and password. The results of the individual's section are given below sequentially. The ThingSpeak cloud server has been taken as a prototype server.

1) PV Results

Two field sections were created in the cloud server to analyze the PV module. One is PV voltage, whereas another is PV power analysis. We get 278.58kV in the ThingSpeak server from our designed PV system and get 100.36kW power from that. The results has been shown in fig. 13.

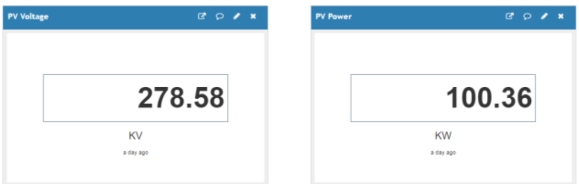

Fig. 13. PV Results in Thingspeak Server

2) Wind Result

Wind voltage and wind power are given in this analysis. We get 30.60kV and 136.14kW as power from this wind module. The output result is given below in fig. 14.

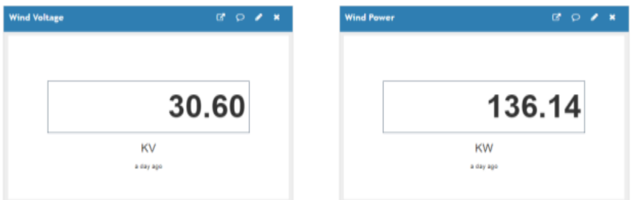

Fig. 14. Wind Results in Thingspeak Server

3) Generator Results

In this Generator analysis section, two fields were created for measuring the voltage and power. After running the Simulink file, we get 279.52kV as voltage and 2222.76kW as owner.

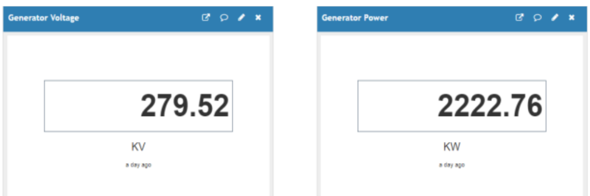

Fig. 15. Generator Results in Thingspeak Server

4) Fault Analysis

MSW MANAGEMENT -Multidisciplinary, Scientific Work and Management Journal
ISSN: 1053-7899
Vol. 36 Issue 1, Jan-June 2026, Pages: 1802-1809

Three notifications lights were added in this section to indicate the electrical fault of the branch. When the solar energy occurs fault, it indicates a fault on the solar energy bus. Similarly, the power quality is the main aim of smart grid integration. In this method effective monitoring and maintain power quality achieved by proposed IoT based hybrid smart grid. wind and the diesel generator do the same process in the ThingSpeak Server. This field is given below in fig. 16.

Fig. 16. Fault Analysis in Thingspeak Server

C. Results Analysis of Control Unit:

When the PV bus occurs at fault in the branch, then the control unit shows the fault. At that same time, the authority can turn off the branch electricity instantly. On the other hand, another bus will supply power continuously in another branch. The current and voltage also the power are the same as the ThingSpeak server. We get 278.58kV in the ThingSpeak server from our designed PV system and get 100.36kW power from that. Wind voltage and wind power are given in this analysis. We get 30.60kV and 136.14kW as power from this wind module. After running our Simulink file, we get 279.52kV as voltage and 2222.76kW as power. The output is given below in figure 17.

Fig. 17. Fault Analysis

D. Results Analysis In Mobile Application:

The output showed the exact results that we got in ThingSpeak Server as this application is reading the data from cloud server. If the branch was fault, this application also shows the red alert that has been shown in figure 19.

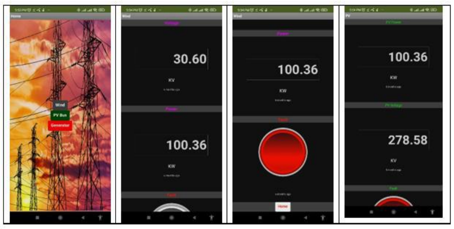

Fig. 18. Results Analysis in Mobile Application

VII. CONCLUSION

This research presented the design and implementation of an IoT-based monitoring and performance optimization system for a grid-connected hybrid renewable energy system integrated with an Energy Storage System (ESS) and diesel generator backup. The proposed system combines renewable energy sources with intelligent monitoring and control to ensure reliable, efficient, and sustainable power delivery. Through IoT technology, real-time data acquisition, remote monitoring, fault detection, and system analysis are achieved, enabling improved operational performance and faster decision-making. The integration of the ESS enhances system stability by storing excess energy during peak generation and supplying power during low-generation or outage conditions, while the diesel generator backup guarantees uninterrupted power in critical situations. Performance optimization strategies help balance load demand, improve power quality, reduce fuel consumption, and minimize operational costs. Overall, the proposed system improves reliability, energy efficiency, and environmental sustainability, making it a practical and effective solution for rural and grid-connected applications seeking smarter and cleaner energy management

REFERENCES

1. Qazi A., Hussain F., Rahim N.A., Hardaker G., Alghazzawi D., Shaban K., Haruna K. Towards Sustainable Energy: A Systematic Review of Renewable Energy Sources, Technologies, and Public Opinions. IEEE Access, 2019, vol. 7, pp. 63837- 63851. doi: https://doi.org/10.1109/ACCESS.2019.2906402 .
2. Humada A.M., Darweesh S.Y., Mohammed K.G., Kamil M., Mohammed S.F., Kasim N.K., Tahseen T.A., Awad O.I., Mekhilef S. Modeling of PV system and parameter extraction based on experimental data: Review and investigation. Solar Energy, 2020, vol. 199, pp. https://doi.org/10.1016/j.solener.2020.02.068 742-760.
3. Fadhel S., Delpha C., Diallo D., Bahri I., Migan A., Trabelsi M., Mimouni M.F. PV shading fault detection and classification based on I-V curve using principal component analysis: Application to isolated PV system. Solar Energy, 2019, vol. 179, pp. 1-10. doi: https://doi.org/10.1016/j.solener.2018.12.048.
4. Kumar N., Hussain I., Singh B., Panigrahi B.K. MPPT in Dynamic Condition of Partially Shaded PV System by Using WODE Technique. IEEE

Transactions on Sustainable Energy, 2017, vol. 8, no. 3, pp. 1204-1214. doi: https://doi.org/10.1109/TSTE.2017.2669525.
5. Bataineh K. Improved hybrid algorithms-based MPPT algorithm for PV system operating under severe weather conditions. IET Power Electronics, 2019, vol. 12, no. 4, pp. 703 711. doi: https://doi.org/10.1049/iet-pel.2018.5651.
6. Mosaad M.I., abed el-Raouf M.O., Al-Ahmar M.A., Banakher F.A. Maximum Power Point Tracking of PV system Based Cuckoo Search Algorithm; review and comparison. Energy Procedia, 2019, vol. 162, pp. 117-126. doi: https://doi.org/10.1016/j.egypro.2019.04.013.
7. Rahmann C., Vittal V., Ascui J., Haas, J. Mitigation Control Against Partial Shading Effects in Large-Scale PV Power Plants. IEEE Transactions on Sustainable Energy, 2016, vol. 7, no. 1, pp. 173-180. doi: https://doi.org/10.1109/TSTE.2015.2484261.
8. Batzelis E.I., Papathanassiou S.A., Pal B.C. PV System Control to Provide Active Power Reserves Under Partial Shading Conditions. IEEE Transactions on Power Electronics, 2018, vol. 33, no. 11, pp. 9163-9175. doi: https://doi.org/10.1109/TPEL.2018.2823426.
9. Babu V., Ahmed K.S., Shuaib Y.M., Manikandan M. Power Quality Enhancement Using Dynamic Voltage Restorer (DVR)-Based Predictive Space Vector Transformation (PSVT) With Proportional Resonant (PR)-Controller. IEEE Access, 2021, vol. 9, pp. 155380–155392. doi: https://doi.org/10.1109/ACCESS.2021.3129096.
10. Babu V., Ahmed K.S., Shuaib Y.M., Mani M. A novel intrinsic space vector transformation based solar fed dynamic voltage restorer for power quality improvement in distribution system. Journal of Ambient Intelligence and Humanized Computing, 2021, vol. 7, no. 1, pp. 173-180. doi: https://doi.org/10.1007/s12652-020-02831-0.
11. Ahmed J., Salam Z. An Accurate Method for MPPT to Detect the Partial Shading Occurrence in a PV System. IEEE Transactions on Industrial Informatics, 2017, vol. 13, no. 5, pp. 2151-2161. doi: https://doi.org/10.1109/TII.2017.2703079.
12. Abdulrazzaq A.A., Hussein Ali A. Efficiency Performances of Two MPPT Algorithms for PV System With Different Solar Panels Irradiancess. International Journal of Power Electronics and Drive Systems (IJPEDS), 2018, vol. 9, no. 4, pp. 1755-1764. doi: https://doi.org/10.11591/ijpeds.v9.i4.pp1755-1764.
13. Wang F., Zhu T., Zhuo F., Yi H. An Improved Submodule Differential Power Processing-Based PV System With Flexible Multi-MPPT Control. IEEE Journal of Emerging and Selected Topics in Power Electronics, 2018, vol. 6, no. 1, pp. 94–102. doi: https://doi.org/10.1109/JESTPE.2017.2719919.
14. Yilmaz U., Kircay A., Borekci S. PV system fuzzy logic MPPT method and PI control as a charge controller. Renewable and Sustainable Energy Reviews, 2018, vol. 81, pp. 994-1001. doi: https://doi.org/10.1016/j.rser.2017.08.048.
15. Pradhan A., Panda B. A Simplified Design and Modeling of Boost Converter for Photovoltaic System. International Journal of Electrical and Computer Engineering (IJECE), 2018, vol. 8, no. 1, pp. 141-149. doi: https://doi.org/10.11591/ijece.v8i1.pp141-149.
16. Nzoundja Fapi C.B., Wira P., Kamta M., Badji A., Tchakounte H. Real-Time Experimental Assessment of Hill Climbing MPPT Algorithm Enhanced by Estimating a Duty Cycle for PV System. International Journal of Renewable Energy Research, 2019, vol. 9, no. 3, pp. 1180-1189. doi: https://doi.org/10.20508/ijrer.v9i3.9432.g7705.
17. Gouda E.A., Kotb M.F., Elalfy D.A. Modelling and Performance Analysis for a PV System Based MPPT Using Advanced Techniques. European Journal of Electrical Engineering and Computer Science, 2019, vol. 3, no. 1, pp. 1-7. doi: https://doi.org/10.24018/ejece.2019.3.1.47.
18. Ali M.N., Mahmoud K., Lehtonen M., Darwish M.M.F. An Efficient Fuzzy-Logic Based Variable-Step Incremental Conductance MPPT Method for Grid-Connected PV Systems. IEEE Access, 2021, vol. 9, pp. 26420-26430. doi: https://doi.org/10.1109/ACCESS.2021.3058052.
19. Li S., Li J. Output Predictor-Based Active Disturbance Rejection Control for a Wind Energy Conversion System With PMSG. IEEE Access, 2017, vol. 5, pp. 5205-5214. doi: https://doi.org/10.1109/ACCESS.2017.2681697.
20. Kushwaha A., Gopal M., Singh B. Q-Learning based Maximum Power Extraction for Wind Energy Conversion System With Variable Wind Speed. IEEE Transactions on Energy Conversion, 2020, vol. 35, no. 3, pp. 1160-1170. doi: https://doi.org/10.1109/TEC.2020.2990937.
21. Afghoul H., Krim F., Babes B., Beddar A., Kihel A. Design and real time implementation of sliding mode supervised fractional controller for wind energy conversion system under sever working conditions. Energy Conversion and Management, 2018, vol. 167, pp. 91-101. doi: https://doi.org/10.1016/j.enconman.2018.04.097.
22. Reddy D., Ramasamy S. Design of RBFN Controller Based Boost Type Vienna Rectifier for Grid-Tied Wind Energy Conversion System. IEEE Access, 2018, vol. 6, pp. 3167-3175. doi: https://doi.org/10.1109/ACCESS.2017.2787567.
23. Sattar A., Al-Durra A., Caruana C., Muyeen S.M. Testing the Performance of Battery Energy Storage in a Wind Energy Conversion System. 2018 IEEE Industry Applications Society Annual Meeting (IAS), 2018, pp. 1-8. doi: https://doi.org/10.1109/IAS.2018.8544521.
24. Cheddadi Y., Cheddadi H., Cheddadi F., Errahimi F., Es sbai N. Design and implementation of an intelligent low-cost IoT solution for energy monitoring of photovoltaic stations. SN Applied Sciences, 2020, vol. 2, no. 7, pp. 1165. doi: https://doi.org/10.1007/s42452-020-2997-4.
25. Li Y., Cheng X., Cao Y., Wang D., Yang L. Smart Choice for the Smart Grid: Narrowband Internet of Things (NB-IoT). IEEE Internet of Things Journal, 2018, vol. 5, no. 3, pp. 1505 1515. doi: https://doi.org/10.1109/JIOT.2017.2781251.
26. Pawar P., Vittal K.P. Design and development of advanced smart energy management system integrated with IoT framework in smart grid environment. Journal of Energy Storage, 2019, vol. 25, pp. 100846. doi: https://doi.org/10.1016/j.est.2019.100846.
27. Hussain M., Beg M.M. Fog Computing for Internet of Things (IoT)-Aided Smart Grid Architectures. Big Data and Cognitive Computing, 2019, vol. 3, no. 1, pp. 8. doi: https://doi.org/10.3390/bdcc3010008.
28. Bera B., Saha S., Das A.K., Vasilakos A.V. Designing Blockchain-Based Access Control Protocol in IoT-Enabled Smart Grid System. IEEE Internet of Things Journal, 2021, vol. 8, no. 7, pp. 5744-5761. doi: https://doi.org/10.1109/JIOT.2020.3030308.