Review on Smart Grid and Power System Management using IOT Technology for Enhanced Efficiency and Reliability

Ganesh D. Lanjewar[1], Shika P. Badge2, Akshay B. Lanjewar3, Anishakausar M. Mansuri4, Sejal S. Dhenge[5], Prof. Abhishek P. Goswami[6]

*[1]Student, Electrical Engineering, MPCOE, Bhandara

*[2]Student, Electrical Engineering, MPCOE, Bhandara

*[3]Student, Electrical Engineering, MPCOE, Bhandara

*[4]Student, Electrical Engineering, MPCOE, Bhandara

*[5]Student, Electrical Engineering, MPCOE, Bhandara

*[6]Assitant Professor, Electrical Engineering, MPCOE, Bhandara

ABSTRACT: The Internet of Things (IoT) enables direct integration of physical systems with computer-based technologies, improving efficiency, accuracy, and reducing human intervention. A smart grid is an advanced power system that connects suppliers and consumers through two-way communication. It ensures efficient and economical electricity usage by incorporating distributed computing and real-time monitoring. In this project, we measure voltage, current, frequency, and temperature of the power grid. The data is sent to a control room using IoT technology. If the temperature increases beyond a safe limit, an automatic cooling fan is activated. A critical situation is indicated on an LCD display, and a buzzer alerts the operator. This system helps in power conservation, reduces human effort, and improves grid management. The smart grid enhances energy efficiency, prevents overuse, and ensures a balanced supply and demand system. This technology leads to a highly efficient and automated power management system..

Keywords: Smart Grid, Internet of Things (IoT), Real-Time Monitoring, Energy Efficiency, Automated Power Management etc.

1.   Introduction

The rapid advancement of technology has transformed traditional power systems into smart and efficient networks. The Internet of Things (IoT) plays a crucial role in this transformation by enabling real-time monitoring, automation, and control of power grids. A smart grid is an advanced electrical network that integrates communication and computing technologies to ensure a reliable, efficient, and sustainable energy supply. It connects power suppliers and consumers through a two-way communication system, allowing better load management, fault detection, and energy conservation. The implementation of smart grids reduces energy wastage, minimizes human intervention, and optimizes power distribution, making electricity consumption more efficient and economical.

The distribution of digital power is increasing greatly day by day. The existing power grids are converted into smart grids so as to meet the growing power requirements. Information is accumulated from sensors, smart meters and several other devices for the sake of analysis and understanding. For the purpose of implementing IoT in smart grids, mobility support, location awareness, distributed coordination and latency sensitivity are to be considered. Smart Grid systems in combination with IoT can assist the consumption, distribution, transmission and generation of energy [3]. IoT allows smart monitoring and control of smart grid [8], [10].

In electronics connected via internet, smart plugs, home gateways and smart meters, application of IoT facilitates proficient resource management. The consumers can obtain information regarding consumption of energy and price on a real-time basis thereby moderate the energy consumption. The producer can forecast energy requirement and moderate distribution. Hence the system serves beneficial to both ends [7]. Millions of users interact with smart grids and its information flow. It is important to focus on scalability of this system. Cloud computing serves as an optimal solution for this purpose. Several architectures such as event processing for load forecasting, lambda, kappa and cyclic

architectures are designed and implemented for processing the data generated by these systems. In IoT based Smart Grid architectures, the components communicate with each other through the internet. Resource constraint and scarcity of spectrum are major issues in the wireless nodes of these systems [8]. Pan Wang et al [10] presented a programming model and fog based architecture that serves the requirements of smart grid.

One of the major challenges in traditional power grids is the lack of real-time monitoring and control, leading to power losses, inefficiency, and delayed fault detection. With IoT integration, smart grids overcome these challenges by continuously measuring important parameters such as voltage, current, frequency, and temperature. These measurements are transmitted to a centralized control room via IoT technology, ensuring immediate action in case of abnormalities. For instance, if the temperature of a power transformer rises beyond a safe threshold, an automatic cooling system is activated to prevent overheating and potential damage. Additionally, critical situations are displayed on an LCD screen, and a buzzer alarm alerts the operators, ensuring quick response to any faults or emergencies.

Smart grid technology provides several benefits, including enhanced energy conservation, reduced operational costs, and improved grid reliability. One of the key advantages is its ability to optimize electricity usage based on demand and supply conditions. During peak hours, smart grids can regulate power distribution, preventing excessive electricity consumption and reducing the burden on power generation units. This not only conserves energy but also extends the lifespan of electrical equipment. Furthermore, smart grids help in fault detection and predictive maintenance by continuously monitoring the health of transformers and other components, reducing downtime and improving overall system performance.

The integration of IoT with power systems also enables remote monitoring and control, reducing the need for manual inspections and interventions. Operators can access real-time data through cloud-based platforms, analyze power consumption patterns, and make informed decisions to optimize grid performance. This automation enhances the efficiency of power distribution and minimizes human errors. Additionally, smart grids contribute to environmental sustainability by promoting the use of renewable energy sources such as solar and wind power. By intelligently managing power generation and distribution, smart grids ensure a balanced and eco-friendly energy system.

2.   Problem Identification

Inefficient Energy Consumption: Traditional power grids lack real-time monitoring, leading to energy wastage during peak and off-peak hours. This inefficiency results in high electricity consumption and unnecessary power losses.

- Delayed Fault Detection: Without advanced monitoring systems, faults in the power grid, such as transformer malfunctions or temperature rises, often go unnoticed until they escalate, causing significant damage and downtime.

- Lack of Automation: Manual control and monitoring of power grids lead to slow response times and increased human intervention, which can introduce errors and delay corrective actions during critical situations.

- Limited Grid Optimization: Traditional grids fail to optimize electricity distribution based on real-time supply and demand, causing imbalances that can strain power generation units and lead to inefficient energy usage.

- Inadequate Data Accessibility: In conventional grids, data is not readily accessible for analysis, limiting the ability to forecast consumption trends or perform predictive maintenance.

- Environmental Impact: Inefficient grid management increases the reliance on non-renewable energy sources, contributing to higher carbon emissions.

Fig.1. Fire situation on power grid

3.   Objective

Real-Time Monitoring: Continuously measure and transmit key parameters (voltage, current, frequency, and temperature) from the power grid to ensure efficient operation.

- Fault Detection & Response: Automatically detect faults or abnormal conditions (e.g., temperature rise) and trigger corrective actions, such as activating cooling systems.

- Automation of Grid Management: Implement IoT-driven automation to minimize human intervention and ensure quicker responses to power grid issues.

- Energy Conservation: Optimize electricity usage by balancing supply and demand in real-time, reducing power wastage.

- Enhanced Data Accessibility: Provide easy access to grid performance data for analysis, enabling predictive maintenance and better decision-making.

4.   Literature survey

1.   Gharavi, H., & Hu, B. (2011). "Multigate communication network for smart grid." IEEE Transactions on Industrial Informatics.

This study explores the significance of communication technologies in smart grids, emphasizing the necessity of a two-way communication network for improved grid performance, efficiency, and reliability. It highlights how IoT facilitates real-time data collection, monitoring, and automation, enabling better power distribution and management. By integrating IoT, smart grids can detect faults, optimize energy usage, and enhance overall system resilience. The study also examines the impact of advanced communication protocols in ensuring seamless data transmission between grid components, ultimately leading to a more efficient and responsive power system with minimal human intervention and enhanced operational reliability.

2.   Fang, X., Misra, S., Xue, G., & Yang, D. (2012). "Smart grid—the new and improved power grid: A survey." IEEE Communications Surveys & Tutorials.

This paper presents a detailed review of smart grid technology, focusing on communication architectures, network security, and IoT-based monitoring systems. It highlights the significance of real-time data collection for optimizing power grid performance and improving energy efficiency. The study explores how IoT enables seamless integration of renewable energy sources, ensuring a more sustainable and reliable power system. Additionally, the authors discuss the role of advanced communication networks in enhancing grid stability and fault detection. By leveraging IoT, smart grids

can efficiently manage electricity distribution, reduce energy losses, and support automation, ultimately leading to a more intelligent and adaptive power infrastructure.

3.   Yan, Y., Qian, Y., Sharif, H., & Tipper, D. (2013). "A survey on smart grid communication infrastructures: Motivations, requirements and challenges." IEEE Communications Surveys & Tutorials.

This study examines smart grid communication technologies and the role of IoT in real-time power system management. It highlights how IoT enables efficient monitoring, fault detection, and automation in power grids. The authors discuss key challenges in implementing IoT, including security concerns, data management complexities, and network reliability issues. They emphasize the need for robust cybersecurity measures to protect smart grid infrastructure from cyber threats. Additionally, the study explores how real-time data transmission improves energy efficiency and reduces human intervention. The research concludes that addressing these challenges is crucial for the successful deployment of IoT in smart grids.

4.   Mohanta, D. K., Patra, S., & Khan, A. A. (2014). "Internet of things: A survey on architecture, enabling technologies, security and privacy, and applications." IEEE Internet of Things Journal.

The paper explores the applications of IoT across various sectors, with a focus on power grids. It discusses how IoT-enabled sensors, cloud computing, and wireless communication technologies enhance grid monitoring, enabling real-time data collection and analysis. These technologies improve fault detection by allowing quick identification and response to abnormalities, thus preventing potential damage. Additionally, IoT plays a significant role in energy conservation by optimizing power usage and distribution based on demand. The integration of IoT into power grids results in more efficient, reliable, and automated systems, reducing operational costs and minimizing human intervention.

5.   Mishra, S., & Jha, R. (2015). "IoT-based smart grid system for real-time energy monitoring and control." International Journal of Electrical Power & Energy Systems.

The authors propose an IoT-based smart grid system that continuously monitors key parameters such as voltage, current, frequency, and temperature in real-time. By integrating IoT sensors, the system can automatically detect abnormal conditions and trigger responses like activating cooling fans to prevent overheating of transformers. Additionally, real-time alerts are sent to operators, enabling prompt action and improving the overall safety and efficiency of the grid. This automated monitoring and response mechanism ensures optimal performance, reduces human intervention, and minimizes the risk of faults, contributing to a more reliable and sustainable power distribution system.

6.   Sharma, P., & Singh, R. (2016). "Smart power grid: IoT-based monitoring and fault detection." Journal of Energy and Power Engineering.

This paper explores the applications of IoT in smart grid fault detection, focusing on the use of temperature and voltage sensors to prevent transformer failures. By continuously monitoring these parameters, the system can detect anomalies and trigger automatic responses, such as activating cooling systems, to prevent damage. The study emphasizes cost-effective IoT-based monitoring solutions, which offer real-time data transmission, improved efficiency, and reduced human intervention. These solutions contribute to more reliable power distribution networks by enabling early fault detection, optimizing power usage, and enhancing overall grid management, making them essential for modern, automated energy systems.

7.   Gungor, V. C., et al. (2017). "Smart grid technologies: Communication technologies and standards." IEEE Transactions on Industrial Informatics.

This study reviews various communication technologies employed in smart grids and emphasizes the critical role of IoT in optimizing electricity consumption. It explores how IoT enables real-time monitoring, fault detection, and efficient energy management. The paper also addresses the challenges faced during IoT integration, such as interoperability between different devices and systems, as well as cybersecurity concerns that arise from the vast amount of data being

transmitted and processed. These challenges must be addressed to ensure the reliability, security, and effectiveness of smart grid systems, enabling smoother energy distribution and improved grid performance.

8.　　Ahmed, S., & Malik, A. (2018). "IoT-enabled smart grid: A review of technologies, challenges, and future directions." Renewable and Sustainable Energy Reviews.

The authors review various IoT technologies applied in smart grids, including cloud computing, big data analytics, and wireless communication. They highlight how these technologies enable real-time monitoring, data analysis, and predictive maintenance of power grids. By leveraging IoT, smart grids can detect faults early, optimize energy usage, and automate responses, reducing the need for manual interventions. This leads to improved grid reliability, enhanced operational efficiency, and minimized downtime. The study emphasizes the importance of integrating these technologies to ensure a more sustainable and resilient power distribution network, enhancing overall grid performance and reliability.

9.　　Kumar, A., & Verma, P. (2019). "Real-time monitoring of power grid using IoT and cloud computing." International Journal of Smart Grid and Clean Energy.

This research presents an IoT-based real-time power grid monitoring system that collects critical data such as voltage, current, frequency, and temperature, and transmits it to a cloud-based platform. The system enables continuous monitoring of the grid, facilitating early fault detection and timely response to prevent system failures. By leveraging IoT, the study demonstrates how energy efficiency can be significantly improved through real-time optimization of power usage, reducing energy wastage and ensuring a stable and reliable power supply. The cloud platform further enhances accessibility and control, enabling operators to manage the grid more effectively and efficiently.

10.　　Gupta, R., & Sharma, M. (2020). "Integration of IoT in smart grids: Challenges and solutions." Journal of Electrical and Electronics Engineering.

The paper examines the integration of IoT in smart grids, emphasizing the challenges related to security, scalability, and data management. The authors discuss how the widespread use of IoT can expose smart grids to cyber threats, complicate data handling, and require scalable systems to manage the large volumes of real-time data generated. To address these issues, the study proposes IoT-based automated fault detection systems, which aim to enhance grid resilience by quickly identifying and responding to faults. This solution helps improve the reliability and efficiency of the power grid while reducing the need for manual intervention.

11.　　Patel, H., & Mehta, D. (2021). "IoT-based power grid monitoring system with real-time alerts." Energy Reports.

This study presents an IoT-enabled power grid monitoring system that continuously measures key parameters such as voltage, current, and frequency. The system utilizes IoT technology to collect real-time data from various grid components and transmit it to a central control unit. In the event of abnormal conditions, such as voltage fluctuations or frequency deviations, the system triggers immediate alerts to operators. This enables quick identification of faults or critical situations, ensuring timely responses and minimizing the risk of damage to grid infrastructure. Ultimately, the system enhances grid reliability, reduces downtime, and improves overall operational efficiency.

12.　　Singh, V., & Rajput, A. (2022). "Smart grid automation using IoT: An efficient approach for energy conservation." Sustainable Energy Technologies and Assessments.

The authors propose an IoT-based approach to smart grid automation, emphasizing energy conservation and minimizing electricity wastage. The study highlights how IoT-enabled smart grids allow real-time monitoring of power consumption, optimizing supply and demand balance. By leveraging IoT technologies such as sensors and data analytics, the system can dynamically adjust energy distribution based on current usage patterns. This real-time adjustment not only improves grid efficiency but also reduces energy losses, ensuring a more sustainable and reliable power system. The study demonstrates the potential of IoT in enhancing smart grid performance and optimizing electricity usage.

5. Proposed System
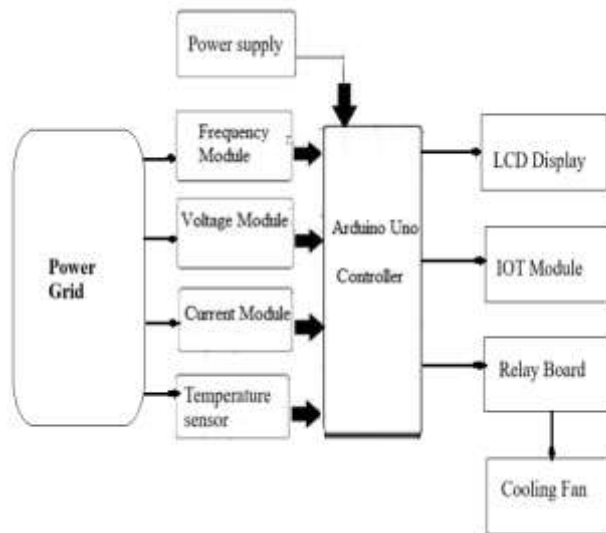
Block Diagram of system :

Fig. 2. Block Diagram of system

Working Principle :

- Power Supply: The system is powered using an external power supply, which provides the required voltage to the Arduino Uno controller and other modules.

- Power Grid Monitoring: The system monitors key parameters of the power grid using various sensor modules.

- Frequency Module: This module measures the frequency of the power grid to ensure it remains within safe operating limits.

- Voltage Module: It detects the voltage levels of the power grid and sends the data to the Arduino Uno.

- Current Module: This module monitors the current flowing through the grid to detect any fluctuations or faults.

- Temperature Sensor: It measures the temperature of the system to prevent overheating and damage.

- Arduino Uno Controller: It acts as the central processing unit, collecting data from all sensor modules and making decisions based on predefined conditions.

- LCD Display: The collected data is displayed on an LCD screen for real-time monitoring.

- IoT Module: The system is integrated with an IoT module to enable remote monitoring via the internet.

- Relay Board and Cooling Fan: If an anomaly is detected, the relay board activates the cooling fan to regulate temperature and prevent system failure.

Features :

- Data Collection: IoT sensors continuously monitor key parameters such as voltage, current, frequency, and temperature of the power grid. These sensors are strategically placed on transformers and other grid components.

- Data Transmission: The collected data is sent in real-time to a central control room using IoT communication technologies like Wi-Fi or GSM. This enables immediate access to grid performance information.

- Temperature Monitoring & Cooling Activation: The system continuously tracks temperature levels of critical components. If the temperature exceeds a predefined threshold, an automated cooling fan is activated to prevent overheating.

- Fault Detection & Alerting: In case of abnormal conditions, such as sudden voltage fluctuations or high temperature, the system generates alerts. These are displayed on an LCD screen and accompanied by a buzzer sound to notify the operators.

- Real-Time Monitoring & Control: Operators can remotely monitor the grid's status and make adjustments if necessary, ensuring optimal energy distribution and efficient power management.

6. Advantage

- Real-Time Monitoring: Continuously tracks voltage, current, frequency, and temperature for immediate response.

- Automated Cooling: Activates a cooling fan when temperature exceeds safe limits, preventing equipment damage.

- IoT-Based Alerts: Sends data and alerts remotely to the control room, reducing the need for manual checks.

- Improved Grid Efficiency: Enhances power distribution by detecting faults and managing load efficiently.

- Cost and Energy Savings: Helps in conserving electricity and reducing operational costs through timely intervention.

- User-Friendly Interface: LCD display and buzzer make it easy for operators to identify and address issues quickly.

7. Applications

- Grid Monitoring: Real-time monitoring of power grid parameters (voltage, current, temperature) for efficient operation and fault detection.

- Fault Detection & Maintenance: Automatic detection of faults (e.g., temperature rise) and triggering of corrective actions such as activating cooling systems or sending alerts for maintenance.

- Energy Efficiency: Optimizes energy usage by balancing supply and demand, reducing power wastage, and improving overall grid efficiency.

- Smart Home Integration: IoT-based grids can be integrated with smart homes for energy management, ensuring power is used efficiently.

- Renewable Energy Integration: Helps in managing the distribution of renewable energy sources by balancing fluctuating power inputs and optimizing usage.

8. Conclusion

The proposed Smart Grid Monitoring System utilizing the Arduino Uno controller, IoT module, and a suite of sensing components effectively demonstrates a real-time monitoring and control mechanism for essential power grid parameters—voltage, current, frequency, and temperature. The integration of modules such as the LCD display, relay board, and cooling fan ensures that the system not only monitors but also responds proactively to anomalies, improving grid reliability and safety. The data is displayed locally and transmitted remotely via IoT, enabling centralized supervision. When temperature thresholds are exceeded, the relay activates the cooling fan, preventing system damage. Alerts on abnormal frequency or voltage levels can be viewed on the LCD and potentially forwarded to a remote monitoring center, making this system suitable for grid fault detection, predictive maintenance, and operational efficiency.

This system is especially relevant for developing smart cities and rural electrification projects where maintaining power quality and minimizing outages are critical. The use of affordable components makes it a cost-effective solution for small to medium-scale deployments.

REFERENCES

1. Gharavi, H., & Hu, B. (2011). "Multigate communication network for smart grid." IEEE Transactions on Industrial Informatics, 7(4), 554-560.

2. Fang, X., Misra, S., Xue, G., & Yang, D. (2012). "Smart grid—the new and improved power grid: A survey." IEEE Communications Surveys & Tutorials, 14(4), 944-980.

3. Yan, Y., Qian, Y., Sharif, H., & Tipper, D. (2013). "A survey on smart grid communication infrastructures: Motivations, requirements and challenges." IEEE Communications Surveys & Tutorials, 15(1), 28-46.

4. Mohanta, D. K., Patra, S., & Khan, A. A. (2014). "Internet of things: A survey on architecture, enabling technologies, security and privacy, and applications." IEEE Internet of Things Journal, 1(4), 362-373.

5. Mishra, S., & Jha, R. (2015). "IoT-based smart grid system for real-time energy monitoring and control." International Journal of Electrical Power & Energy Systems, 67, 295-303.

6. Sharma, P., & Singh, R. (2016). "Smart power grid: IoT-based monitoring and fault detection." Journal of Energy and Power Engineering, 10(8), 1361-1368.

7. Gungor, V. C., et al. (2017). "Smart grid technologies: Communication technologies and standards." IEEE Transactions on Industrial Informatics, 13(1), 147-157.

8. Ahmed, S., & Malik, A. (2018). "IoT-enabled smart grid: A review of technologies, challenges, and future directions." Renewable and Sustainable Energy Reviews, 81, 2434-2444.

9. Kumar, A., & Verma, P. (2019). "Real-time monitoring of power grid using IoT and cloud computing." International Journal of Smart Grid and Clean Energy, 8(4), 674-683.

10. Gupta, R., & Sharma, M. (2020). "Integration of IoT in smart grids: Challenges and solutions." Journal of Electrical and Electronics Engineering, 12(1), 45-53.

11. Patel, H., & Mehta, D. (2021). "IoT-based power grid monitoring system with real-time alerts." Energy Reports, 7, 232-239.

12. Singh, V., & Rajput, A. (2022). "Smart grid automation using IoT: An efficient approach for energy conservation." Sustainable Energy Technologies and Assessments, 47, 101548.

13. M. Helmi Prakoso and Heri Gunawan, "Redundant Control of Power Transformer Cooling System Using Actual Load Indicator", Proceedings of IEEE 10th International Conference on Information Technology and Electrical Engineering (ICITEE), 2018.

14. S. Sankar, R. Raghul, C. Selvakumar, and A. Sasidha, S. Jaisiva "250MVA generator transformer cooling system control using plc", proceedings of IEEE International Journal of Pure and Applied Mathematics, Vol.119, No. 14, 631-636,2018.