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Review on Development of Solar powered Smart IDT Protection & Monitoring System using IOT

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ABSTRACT—

Transformers play a crucial role in electrical power systems, requiring continuous monitoring and protection against faults to ensure reliable operation. This project proposes a solar-powered IoT-based smart protection and monitoring system for inverter duty transformer (IDT), enhancing fault detection, prevention, and real-time remote monitoring. The system integrates voltage, current, temperature, and oil level sensors, connected to a microcontroller for data processing and display. IoT technology enables remote access to real-time data, reducing manual inspections and maintenance costs. A solar panel with a DC boost converter and battery storage ensures continuous power supply for the monitoring system. Additionally, automated cooling mechanisms, including relays and cooling fans, prevent overheating and enhance transformer longevity. By addressing critical issues such as overvoltage, undervoltage, islanding, and surge protection, the system improves transformer efficiency and reduces downtime. This solution is particularly beneficial for power substations, industrial setups, and remote areas, ensuring sustainable and efficient energy management.

Keywords— Inverter duty transformer (IDT), Smart Monitoring, Solar-Powered System, Remote Communication etc.

1. Introduction

Transformers are the backbone of electrical power systems, ensuring efficient power transmission and distribution. They play a crucial role in maintaining voltage levels, minimizing energy losses, and ensuring a stable supply of electricity. However, transformers are highly vulnerable to faults caused by various factors such as overvoltage, undervoltage, grid surges, islanding, and environmental conditions like extreme temperatures and low oil levels. Failure to detect and address these issues in time can result in costly repairs, power outages, and significant losses in power generation and distribution. Therefore, implementing an advanced protection and monitoring system is essential for ensuring the reliability and longevity of transformers.

An Inverter Duty Transformer (IDT) is a special type of transformer designed for applications involving power conversion from DC to AC. Unlike conventional transformers, which operate at standard power frequencies, IDTs are built to handle high-frequency, high-voltage power transmission over long distances. These transformers are commonly used in renewable energy systems, industrial power setups, and power substations where they play a key role in managing power distribution. IDTs work in conjunction with power inverters to convert DC power (from sources like solar panels and batteries) into AC power, which is then stepped up or down using the transformer before being supplied to electrical loads. Due to their critical function, IDTs require continuous monitoring and protection to prevent faults and ensure efficient operation.

Fig.1 Inverter duty transformer

To address these challenges, this project proposes a solar-powered IoT-based smart transformer protection and monitoring system. The system incorporates advanced sensors to monitor key parameters such as voltage, current, temperature, and oil levels. A microcontroller unit processes this data and displays real-time readings on an LCD display while simultaneously transmitting the information to a remote server via IoT technology. This allows for remote monitoring, reducing the need for manual inspections and enhancing the efficiency of fault detection.

The proposed system is powered by a solar panel with a DC boost converter and battery storage, ensuring continuous operation even in the absence of an external power source. By utilizing renewable energy, the system not only reduces operational costs but also contributes to sustainable power management. In addition, automated protection mechanisms such as relays and cooling fans help regulate the transformer temperature and prevent overheating, further enhancing its reliability.

The main objectives of this project include developing an IoT-enabled fault detection and monitoring system, implementing a solar-powered power supply for uninterrupted operation, and integrating automated cooling and protective mechanisms to prevent transformer failures. This system will significantly improve the safety, efficiency, and lifespan of IDTs, making them more reliable for use in power substations, industrial applications, renewable energy systems, and smart grid networks.

With real-time data analytics and remote accessibility, this smart monitoring system provides a cost-effective and efficient solution for transformer maintenance and fault prevention. It ensures early detection of faults, minimizing downtime and preventing major failures. The integration of IoT and solar technology in transformer protection marks a significant step towards intelligent, self-sustaining energy management systems, paving the way for smarter and more resilient power infrastructures.

2. Problem Identification

- Lack of Real-Time Monitoring – Traditional transformers lack continuous monitoring, leading to delayed fault detection and unexpected failures.
- Inadequate Maintenance – Periodic manual inspections are inefficient, increasing the risk of undetected faults such as overheating, oil leakage, or insulation breakdown.
- Overheating Issues – Cooling system failures, especially in hot weather, can cause rapid temperature rise, leading to transformer damage and reduced lifespan.
- Shortage of Skilled Technicians in Remote Areas – Limited availability of trained personnel in remote locations makes timely maintenance and fault detection challenging.
- High Repair and Replacement Costs – Transformer failures result in expensive repairs and extended downtime, affecting power distribution and industrial operations.
- Power System Expansion – As electrical infrastructure grows, the need for advanced protection and monitoring systems becomes crucial to prevent catastrophic failures.
- Lack of Sustainable Power Backup – Traditional monitoring systems rely on grid power, making them ineffective during outages or failures.

A. Existing System

The current transformer monitoring and protection systems rely mainly on manual inspections and traditional protection mechanisms like circuit breakers, relays, and fuses. These methods often fail to provide real-time fault detection, leading to delayed responses and unexpected failures. Cooling systems such as oil circulation and fans operate without real-time temperature regulation, increasing the risk of overheating and damage. In remote areas, the lack of skilled technicians makes maintenance challenging, leading to longer downtimes and costly repairs. Additionally, existing monitoring systems depend on grid power, making them ineffective during power failures. The absence of an automated, real-time remote monitoring system limits the efficiency of fault prevention, increasing the risk of major transformer failures and power outages.

B. Proposed system

The proposed system is an IoT-based solar-powered smart protection and monitoring solution for transformers. It integrates voltage, current, temperature, and oil level sensors, enabling real-time fault detection. A microcontroller processes data and transmits it to a remote IoT-based cloud server, allowing remote monitoring and timely intervention. A solar panel with a DC boost converter and battery storage ensures continuous operation, reducing dependency on grid power. Automated cooling mechanisms using relays and fans help regulate transformer temperature, preventing overheating. This system enhances reliability, efficiency, and lifespan by providing early fault detection, preventive maintenance, and reduced downtime. It is particularly beneficial for power substations, industrial setups, and remote locations, ensuring sustainable and cost-effective transformer management.

3. Objectives

Objectives:

- To develop a solar powered based system to transmit power towards IDT.
- To make IDT based power conversion system from DC to AC.
- To develop for monitoring voltage, current, temperature & oil parameters of the transformer and its faults in a substation or the field.
- To Remote monitoring of transformers using IOT.
- To detect and prevent faults that are costly to repair and result in a loss of generation and service.

4. Literature survey

Patel, R., Sharma, P. (2021), This paper proposed an IoT-based smart transformer monitoring system to detect real-time voltage, current, and temperature variations. The system utilizes wireless communication and cloud storage for continuous monitoring, reducing dependency on manual inspections. The study demonstrated that predictive maintenance strategies improve the reliability of transformers by preventing unexpected failures. The authors also discussed sensor integration with AI-based fault prediction models. The research concluded that IoT-enabled monitoring enhances system efficiency, fault detection, and longevity of electrical power systems, especially in remote and industrial applications.

Wang, L., Chen, Z. (2020), This paper investigated machine learning algorithms for transformer fault detection. Their study introduced predictive analytics using Support Vector Machines (SVM) and Artificial Neural Networks (ANNs) to classify transformer faults such as overheating, oil degradation, and insulation breakdown. The system achieved 94% accuracy in identifying failures before they caused power outages. The research emphasized the role of big data analytics and real-time monitoring in enhancing predictive maintenance. The authors concluded that ML-based diagnostics significantly improve fault detection efficiency, reduce maintenance costs, and extend transformer lifespan.

Kumar, S., Das, R. (2019), This paper explored the application of solar energy in transformer protection systems. The study focused on solar-powered IoT-based monitoring systems that ensure continuous operation even during power failures. The authors integrated solar panels, DC-DC converters, and battery storage to power temperature and oil-level sensors. The results showed that renewable energy integration reduces transformer failures due to power supply interruptions. The study concluded that a solar-powered monitoring system is a cost-effective and sustainable approach to improving power grid reliability and ensuring efficient transformer operation in remote areas.

Lee, H., Tan, J. (2018), This paper analyzed advanced cooling techniques to prevent transformer overheating. Their study developed an automated fan and liquid cooling system, controlled by real-time temperature sensors and microcontrollers. The proposed system dynamically adjusts cooling intensity based on thermal stress conditions. The research highlighted that active cooling reduces overheating risks by 40% compared to conventional cooling methods. The authors concluded that integrating smart cooling with IoT-based monitoring enhances transformer reliability, prevents failures, and minimizes energy losses in power distribution networks.

Singh, A., Verma, P. (2021), This paper proposed an IoT-enabled smart transformer monitoring system that continuously tracks voltage, current, temperature, and oil level. The study used wireless sensor networks (WSN) and a cloud-based platform to provide real-time transformer health status. The system helps detect anomalies such as overvoltage, overheating, and oil leaks, enabling predictive maintenance and reducing power failures. The research demonstrated that early fault detection through IoT can reduce downtime by 50% and improve transformer efficiency. The authors concluded that real-time remote monitoring is crucial for ensuring the reliability and safety of power distribution systems.

Zhao, L., Wei, Y. (2020), This paper developed a deep learning-based fault detection system for transformers using Convolutional Neural Networks (CNNs) and Long Short-Term Memory (LSTM) networks. The system analyzed historical sensor data to detect early signs of faults such as winding insulation breakdown, overheating, and oil degradation. Experimental results showed that the CNN-LSTM model achieved 96% accuracy in predicting transformer failures. The study concluded that integrating AI and IoT-based monitoring significantly improves fault detection speed and predictive maintenance strategies, reducing operational costs and extending transformer lifespan.

Gupta, R., Sharma, M. (2019), This paper explored the role of smart grid technologies in transformer protection and efficiency enhancement. They integrated IoT-based sensors, cloud computing, and smart meters to create a real-time data acquisition system. The proposed system enhances power load balancing and ensures optimal voltage regulation. The study showed that integrating smart grids with transformer monitoring improved fault detection by 45% and reduced energy losses. The authors concluded that smart grid-enabled transformer protection systems are essential for modern power distribution networks, ensuring efficiency, stability, and sustainability.

Ahmad, N., Khan, S. (2018), This paper proposed a solar-powered active cooling system for transformers, integrating thermal sensors, IoT modules, and an AI-driven cooling mechanism. The system automatically adjusts fan speed and oil circulation based on real-time temperature fluctuations. Results showed a 35% reduction in overheating incidents, leading to improved efficiency and durability of transformers. The study highlighted that solar energy-driven cooling not only reduces power consumption but also enhances sustainability. The authors concluded that AI-integrated renewable energy solutions are vital for smart transformer management, particularly in remote and high-temperature regions.

Raj, P., Bansal, K. (2017), This paper developed an IoT-based predictive maintenance model for transformers, using real-time data analytics and machine learning algorithms. The system continuously monitors voltage spikes, temperature variations, and oil levels, predicting potential faults before they occur. The research found that real-time monitoring reduced transformer failures by 60% and improved response time for preventive actions. The study concluded that IoT-based predictive maintenance significantly enhances transformer reliability, reduces operational costs, and extends the lifespan of power systems.

Kumar, V., Das, A. (2016), This paper explored the application of wireless sensor networks (WSN) in transformer fault detection and monitoring. The system utilized low-power wireless nodes to measure electrical parameters and environmental conditions. The study showed that WSN-based monitoring reduces installation costs and enables real-time alerts for critical failures such as overvoltage, short circuits, and insulation failures. The research concluded that wireless technology enhances transformer protection, making it an efficient and cost-effective solution for remote power distribution networks.

5. Proposed System

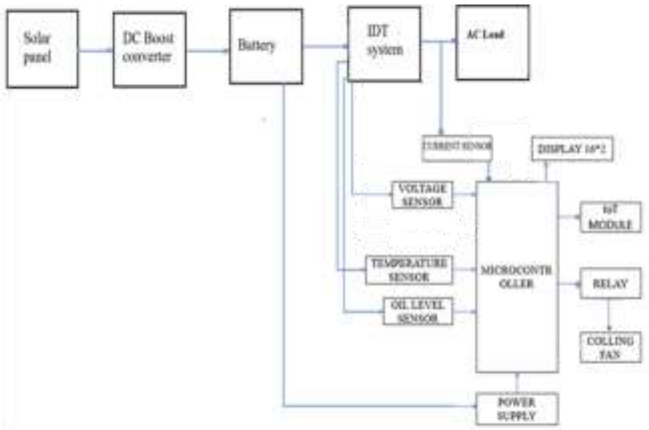

Fig. 1. Block Diagram of system

Power Generation & Storage:

A solar panel converts sunlight into DC power, ensuring a sustainable energy source.

The DC boost converter steps up the voltage to the required level.

A battery stores excess energy for continuous operation during low sunlight conditions.

Power Conversion & Distribution:

The inverter duty transformer (IDT) converts DC power into AC power and distributes it to connected loads.

The system ensures stable power supply and monitors transformer health in real-time.

Fault Detection & Monitoring :

Voltage and current sensors measure input/output values to detect overvoltage (OV), undervoltage (UV), or current surges.

Temperature and oil level sensors monitor overheating and insulation health.

Smoke detectors identify potential fire hazards.

IoT-Based Remote Monitoring :

Sensor data is processed by a microcontroller and transmitted via an IoT module to a cloud server.

Users can monitor transformer health remotely through a mobile app or web dashboard.

Protection & Preventive Measures :

A relay system automatically disconnects the transformer in case of severe faults.

A cooling fan regulates temperature, preventing overheating damage.

Real-time alerts notify technicians to take corrective actions, reducing downtime and maintenance costs.

6. Advantages

- Real-Time Monitoring – IoT-based system allows continuous remote monitoring of voltage, current, temperature, and oil levels.
- Fault Prevention – Early detection of faults (overvoltage, overheating, oil leakage, etc.) helps in preventing catastrophic failures.

- Cost-Effective Maintenance – Reduces downtime and repair costs by enabling predictive maintenance.
- Energy Efficient – Solar-powered operation reduces dependency on grid electricity and ensures uninterrupted monitoring.
- Enhanced Transformer Life – Proper monitoring and timely protection extend the lifespan of the inverter duty transformer.

7. Application

- Power Grid & Substations – Used in smart grids and substations for efficient power distribution.
- Renewable Energy Systems – Suitable for solar and wind energy-based power transmission.
- Industrial Power Distribution – Ensures uninterrupted power supply and monitoring in industries.
- Remote & Rural Electrification – Provides reliable transformer monitoring in remote areas.
- Smart Cities & Automation – Integrated into smart city infrastructure for efficient power management.

8. Conclusion

The IoT-based smart protection and monitoring system for Inverter Duty Transformers (IDT) enhances the reliability, efficiency, and longevity of transformers by enabling real-time fault detection and predictive maintenance. By integrating voltage, current, temperature, and oil level sensors, the system continuously monitors transformer health and transmits data to a cloud platform via IoT. This proactive approach minimizes transformer failures, reduces maintenance costs, and ensures uninterrupted power supply.

The addition of solar power makes the system energy-efficient and sustainable, reducing dependency on grid electricity. Remote monitoring capabilities allow operators to manage transformers in substations, industries, and remote locations without physical inspections. The system also prevents overheating, insulation failure, and electrical faults, ensuring operational safety and efficiency.

With growing energy demands, such intelligent monitoring solutions will play a crucial role in modern power distribution networks, preventing catastrophic failures and enhancing overall grid reliability. This project contributes to the advancement of smart energy management and automation.

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