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Automatic Load Sharing Distribution of Transformer Using IoT

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Abstract **- The "Automatic Load Sharing Distribution of Transformer using IoT" project focuses on optimizing the power distribution between two transformers automatically using an Arduino Uno SMD controller. The system continuously monitors the voltage and current of both transformers through sensor modules to calculate their real-time loading conditions. When one transformer experiences an overload or underload, the controller intelligently redistributes the connected loads using relays to maintain balanced operation. The status of each transformer — including voltage, current, and load percentage — is displayed on a 16x2 LCD, while a buzzer provides audible alerts during abnormal or fault conditions. The project integrates IoT functionality using an ESP8266 module to send transformer performance data to an online monitoring platform such as ThingSpeak or a cloud-based dashboard. This enables remote supervision, timely fault detection, and preventive maintenance. The system enhances power reliability, reduces transformer overloading, and extends operational lifespan, making it valuable for small industries and urban power distribution networks.**

Keywords: Automatic load sharing, Transformer protection, Arduino Uno SMD, IoT monitoring, Voltage sensor, Current sensor, Relay switching, Load balancing, Power distribution, ThingSpeak.

I. INTRODUCTION

Transformers are essential components in electrical power distribution systems, responsible for maintaining voltage stability and ensuring reliable energy transfer from the grid to consumers. In many substations and industrial networks, multiple transformers are operated in parallel to share the overall electrical load. However, unequal load distribution among these transformers is a frequent problem. When one transformer becomes overloaded while another remains underloaded, it results in reduced efficiency, overheating, insulation failure, and potential transformer damage. Such imbalances not only increase power losses but also reduce the overall reliability and lifespan of the system.

Conventionally, the process of monitoring and redistributing loads between transformers is carried out manually by maintenance personnel. This approach is inefficient, time-consuming, and prone to human error, particularly during peak demand or in remote installations where continuous supervision is difficult. As a result, there is a strong need for an intelligent, automated system capable of real-time monitoring and load balancing to ensure safe and efficient transformer operation.

The Automatic Load Sharing Distribution of Transformer using IoT project offers an effective solution to this problem. The proposed system employs an Arduino Uno SMD microcontroller as the central controller, interfaced with voltage and current sensors for each transformer. These sensors continuously measure the operating parameters and send the data to the controller, which calculates the load percentage of each transformer. If an imbalance or overload is detected, the system automatically transfers a portion of the load from the overloaded transformer to the other through relay modules, ensuring both transformers operate within safe limits.

To enhance monitoring and accessibility, the system integrates Internet of Things (IoT) technology using an ESP8266 Wi-Fi module. Real-time transformer parameters such as voltage, current, and load status are transmitted to an online platform like ThingSpeak, allowing remote monitoring through mobile or web applications. A 16x2 LCD display provides local visualization of system status, while a buzzer generates audible alerts in the event of overload or faults.

This automated IoT-based system minimizes manual intervention, prevents transformer damage, and ensures efficient load sharing in real-time. It enhances the operational reliability of power distribution networks and represents a step forward in implementing smart grid technologies, where automation and remote monitoring play a crucial role in sustainable and intelligent energy management.

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II. LITERATURE REVIEW

1. "Automatic load sharing of distribution transformer for overload protection" — BMC Research Notes, 2020 — Abraham Hizkiel Nebey [1]

This paper investigates a rule-based automatic load-sharing system between two distribution transformers to protect them from overload. The author models three operating cases: both transformers normal; one overloaded and the other normal; both overloaded. In the overloaded case the system shares the load via relays or disconnects loads entirely to protect the transformers. The work shows that automatic switching helps avoid failures and supply interruptions.

Key contribution: Application of an automatic switching mechanism to mitigate transformer over-load conditions in a rural context.

2. "Machine Learning Approach for Smart Distribution Transformers Load Monitoring and Management System" — Energies, 2022 — Jayroop Ramesh, Sakib Shahriar, A. R. Al-Ali, Ahmed Osman, Mostafa F. Shaaban [2]

This article proposes an IoT-based monitoring system for distribution transformers, combining sensor modules (three-phase current, oil level, temperature) with cloud IoT infrastructure and machine-learning anomaly detection (Isolation Forest) for fault prediction. It addresses deficiencies in sparse SCADA monitoring and aims to detect anomalies in advance.

Key contribution: Integration of IoT + ML for predictive monitoring and management of transformer loads, rather than just load-sharing.

3. "Automatic Load Sharing of Distribution Transformers to Reduce Overall Losses in Distribution Network" — E3S Web of Conferences, 2021 — V. Ravikumar, S. Ranjith, T. Bhavyasree [3]

This paper presents a "stop-start" topology for parallel transformers where one transformer is de-energised and another energised when load crosses thresholds, thereby reducing losses in the distribution network. The authors simulate different load conditions and demonstrate energy savings.

Key contribution: Focus on minimising electrical losses through automatic switching of transformers in parallel, not just overload protection.

4. "Automatic Load Sharing of Transformer and Parameter Monitoring" — International Journal of Research in Engineering, Science and Management (IJRESM), 2022 — V. V. Chouguler, L. S. Patil [4]

This paper presents a microcontroller-based system that monitors transformer load and connects a second transformer when the first exceeds a reference value. The system uses sensors, an Arduino, and a GSM module for alerting.

Key contribution: Practical implementation combining load-sharing control and remote alerting (via GSM) rather than full IoT.

5. "Automatic Load Sharing of Distribution Transformer (IoT)" — International Journal for Research in Applied Science & Engineering Technology (IJRASET), 2024 — V. N. Chatse& G. D. Shingade [5]

This recent paper outlines an IoT-enabled automatic load sharing scheme for distribution transformers. It emphasises automation and remote monitoring via microcontroller, sensors and IoT cloud connectivity to protect transformers from over-load and to maintain reliable supply.

Key contribution: Combines load sharing automation with IoT connectivity and data-analytics features for modern energy infrastructure.

III. GAP ANALYSIS

These papers show a progression from simple relay-based load sharing and overload protection (Nebey, Chouguler) toward more advanced IoT/ML integrated systems (Ramesh, Chatse). They cover key themes: overload detection, parallel transformer switching, load balancing, condition monitoring, and remote/IoT connectivity. However, gaps remain for your project's focus: many do not handle multiple individual loads (e.g., 5 loads) switching, nor do they integrate real-time load percentage computation, multi-relay per-load control, and cloud dashboard display exactly as your design. Also, some do not emphasise voltage & current sensors paired and full load-sharing logic as you propose.

IV. METHODOLOGY

The methodology for the Automatic Load Sharing Distribution of Transformer using IoT involves both hardware and software implementation to achieve efficient, real-time transformer load management. The system is divided into five major stages — sensing, processing, load control, monitoring, and IoT integration.

1. Sensing Stage:

Each transformer is connected to voltage and current sensors that continuously measure the electrical parameters.

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The voltage sensor detects the output voltage of the transformer, while the current sensor (such as ACS712) measures the load current. These sensors provide accurate real-time data to the controller for load calculation.

2. Processing Stage:

The sensed data is sent to the Arduino Uno SMD, which acts as the main control unit. The Arduino processes the voltage and current readings to determine the total load on each transformer. Based on the pre-set threshold values, it compares the load levels between the two transformers.

3. Load Control Stage:

If the Arduino detects that one transformer is overloaded while the other is underloaded, it activates the relay modules to redistribute the load. Each load is connected through relays, allowing the controller to automatically switch loads between the two transformers. This ensures balanced load sharing and protects the transformers from overloading.

4. Monitoring and Alert Stage:

A 16x2 LCD display is used to show real-time information, including voltage, current, and load distribution status of both transformers. In case of an overload or fault condition, a buzzer is triggered to alert maintenance personnel immediately, allowing for timely action.

5. IoT Integration Stage:

For remote data access and continuous monitoring, an ESP8266 Wi-Fi module is used to send transformer performance data (voltage, current, and load status) to a cloud platform such as ThingSpeak. Users can monitor the system in real time using a mobile device or web interface.

Through these stages, the system provides an intelligent and automated way to maintain balanced load distribution, enhance transformer life expectancy, and ensure uninterrupted power supply with IoT-based remote monitoring and control.

V. SYSTEM DESIGN

The block diagram shown represents the Automatic Load Sharing Distribution of Transformer using IoT system. It demonstrates how two transformers work together under the control of an Arduino Uno SMD controller to share load intelligently and monitor system parameters in real time.

Transformers (Transformer 1 and Transformer 2):

Two transformers are used to supply electrical loads. Both transformers are connected in parallel and monitored continuously. When one transformer is overloaded, part of the load is automatically shifted to the second transformer to maintain balanced operation.

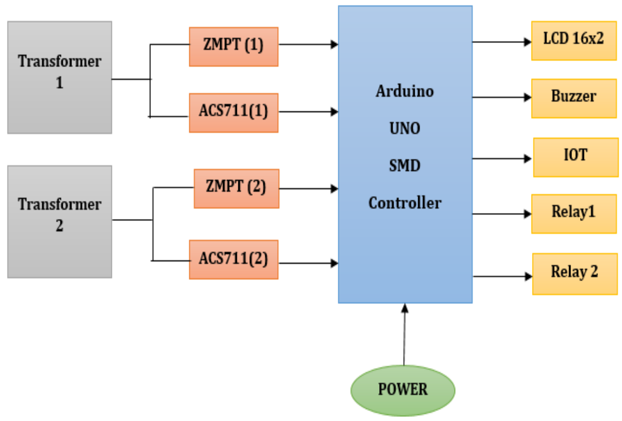

Figure 1: Block Diagram

Voltage Sensors (ZMPT101B Modules):

- Each transformer has a ZMPT voltage sensor module connected to measure the AC output voltage.
- These sensors provide scaled-down voltage signals to the Arduino’s analog input pins.
- The readings help determine voltage fluctuations and identify load imbalances or faults.

Current Sensors (ACS711 Modules):

- Each transformer’s output line passes through a current sensor (ACS711) to measure load current.
- These sensors convert the current flow into proportional voltage signals for the Arduino.
- The Arduino uses this data to calculate load current, detect overload conditions, and take corrective actions.

Arduino Uno SMD Controller:

- Acts as the central processing unit of the system.
- Receives voltage and current data from both transformers through the sensors.
- Executes the algorithm for automatic load sharing by comparing load currents.
- If one transformer exceeds a set threshold, it activates relay switching to transfer part of the load to the second transformer.
- Controls the display, buzzer, relays, and IoT module for system feedback and monitoring.

Output Components:

- LCD 16x2 Display: Displays voltage, current, load percentage, and system status for both transformers.

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- Buzzer: Alerts the user in case of transformer overload or abnormal operating conditions.
- IoT Module (ESP8266/ESP32): Sends real-time data (voltage, current, transformer status) to an online platform such as ThingSpeak for remote monitoring and data logging.
- Relays (Relay 1 and Relay 2): Control load shifting between transformers based on Arduino commands. When overload is detected, relays automatically switch some loads from the overloaded transformer to the other.

Power Supply:

- Provides regulated DC power to the Arduino controller, sensors, relays, LCD, and IoT module.
- Ensures stable operation and isolation from the AC side through step-down and regulation circuitry.

The system continuously measures the voltage and current of both transformers using ZMPT and ACS711 sensors. The Arduino processes this data and decides how to distribute the load efficiently. In case of an overload on one transformer, the controller triggers the relays to transfer part of the load to the other transformer. The status is displayed on the LCD and transmitted via IoT for remote supervision. The buzzer provides a local alert for immediate attention.

This setup ensures efficient load sharing, improved transformer life, reduced human intervention, and real-time monitoring through IoT integration.

VI. RESULT AND DISCUSSIONS

The Automatic Load Sharing Distribution of Transformer using IoT system was successfully designed and implemented using Arduino Uno SMD, voltage and current sensors, relays, buzzer, 16x2 LCD, and ESP8266 Wi-Fi module. The system achieved real-time monitoring and automatic load balancing between two transformers with five loads connected through relay control.

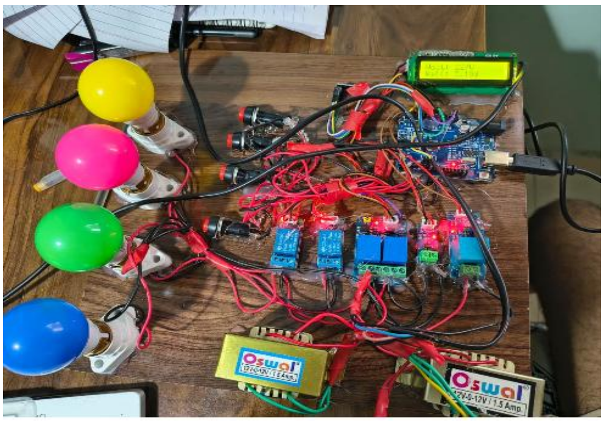

Figure 2: Proposed Hardware

During testing, both transformers initially shared the load equally under normal conditions. When the load on Transformer 1 exceeded its rated limit, the Arduino detected the overload through sensor readings and automatically shifted a portion of the load to Transformer 2 by activating the relay switches. The LCD display showed the voltage, current, and load percentage of each transformer, and the buzzer produced an audible warning when overload conditions occurred. The IoT platform (ThingSpeak) displayed real-time voltage and current data, allowing remote users to observe transformer performance and detect imbalances through graphical dashboards.

The experimental results confirmed that the system maintained balanced load distribution, preventing any transformer from being overloaded. Data logging via IoT also enabled tracking of transformer behavior under varying load conditions, supporting predictive maintenance and improved power management. The response time of the system was fast enough to handle dynamic load variations effectively without interrupting power supply.

Overall, the developed system demonstrated improved efficiency, reliability, and automation in power distribution. It eliminated the need for manual supervision, reduced transformer stress, and enhanced system safety through continuous monitoring and automatic control. The successful implementation validates the feasibility of integrating IoT and embedded systems in modern smart grid applications, offering a scalable solution for real-world transformer load management.

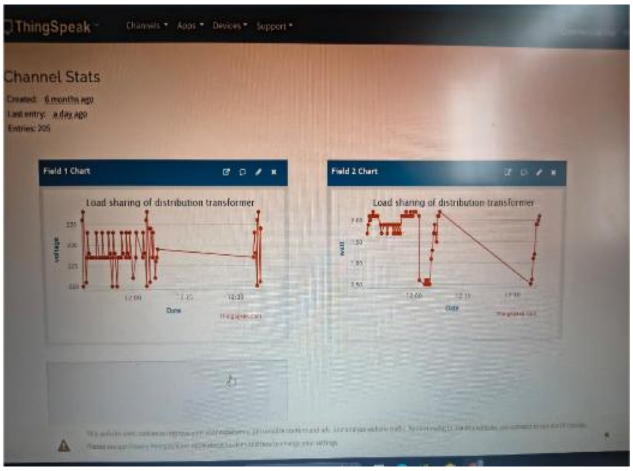

Figure 3: IoT Output

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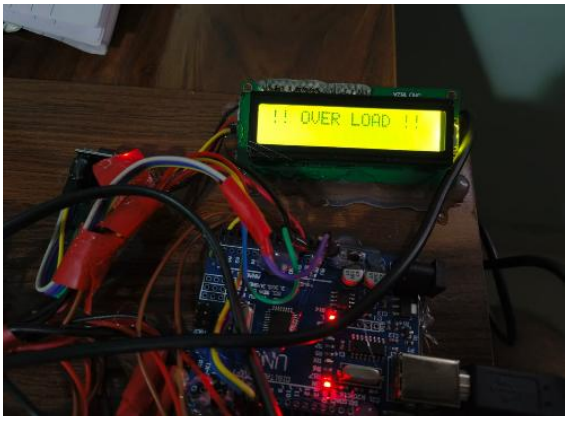

Figure 4: Overload Condition: LCD Output

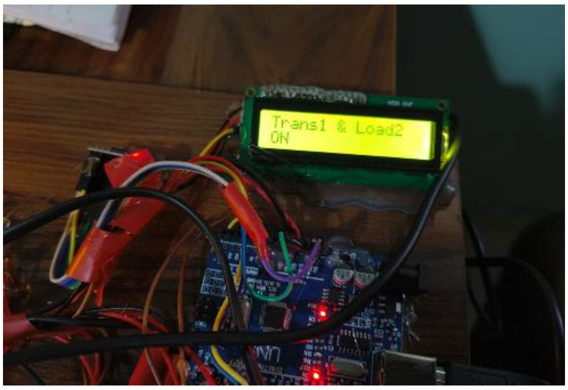

Figure 5: LCD Output: Transformer 1 and Load 2 ON

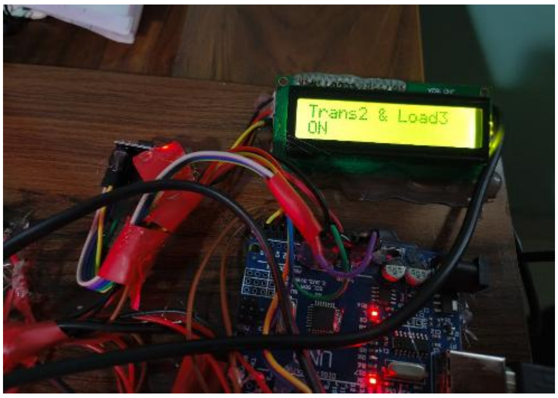

Figure 6: LCD Output: Transformer 2 and Load 3 ON

VII. CONCLUSION

The Automatic Load Sharing Distribution of Transformer using IoT project successfully demonstrates an efficient, intelligent, and reliable method for managing load distribution between transformers. By integrating Arduino Uno SMD, voltage and current sensors, relays, and IoT technology, the system ensures that transformers operate within safe limits and that electrical loads are shared automatically without human intervention. The implementation of real-time monitoring through IoT platforms like ThingSpeak enables remote supervision, allowing users to track transformer performance, detect overloads, and take preventive action promptly.

The experimental results showed that when one transformer experienced an overload condition, the system effectively transferred part of the load to the second transformer, maintaining balance and preventing potential damage. The inclusion of a buzzer alert and LCD display enhanced system transparency and user awareness. Overall, the project not only enhances power system reliability but also reduces energy losses and maintenance costs while supporting the concept of smart grid technology.

In conclusion, the proposed system offers a cost-effective and scalable solution for transformer load management and can be extended for use in industrial, commercial, and rural power networks. It represents a step forward toward intelligent automation in power distribution, promoting safer, smarter, and more sustainable energy systems.

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