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IoT Based Load Sharing and Monitoring of a Transformer

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A B S T R A C T :

The transformer is a stationary, passive electrical device used to transfer power between circuits by stepping voltage up or down while maintaining a constant frequency. It operates efficiently from no-load to full-load, but overloading can reduce efficiency, overheat windings, and even cause fire. To address this, a load-sharing system is proposed where a secondary (backup) transformer is automatically activated via a microcontroller (ESP32 Micro controller) when the primary transformer exceeds a reference load value. This ensures both transformers share the load optimally and alternately operate under normal conditions. Sensors such as temperature and monitor transformer health in real-time. These are integrated with IoT platforms like Blynk enabling remote monitoring. The system enhances performance, avoids overloading, and enables predictive maintenance, thus reducing manual efforts and preventing costly failures. Additionally, real-time data acquisition helps in timely actions, ensuring protection, uninterrupted power supply, and improved transformer lifespan. The cloud-based display system ensures easy access to performance data for maintenance and diagnostics. The design supports domestic and industrial applications by preventing overheating, and power interruptions. This IoT-based intelligent transformer load-sharing and health monitoring system provides a highly efficient, reliable, and robust solution.

Keywords: IoT, Load Sharing, Remote Monitoring, Smart grid, Power Distribution, Energy efficiency.

Introduction

Electricity is the cornerstone of modern civilization, influencing nearly every aspect of daily life. From industrial operations to household consumption, the demand for uninterrupted and reliable power is ever-growing. At the heart of power transmission and distribution systems lies the transformer an essential apparatus responsible for stepping voltages up or down and ensuring that electricity is delivered at appropriate and safe levels for end users. This has led to widespread issues such as transformer overloading, overheating, and, in severe cases, failure resulting in power outages and costly equipment damage. Traditionally, transformers have been manually monitored and operated, but this method is becoming increasingly impractical due to the vast number of distribution points and the complexity of modern power systems. Overloading not only reduces the operational lifespan of transformers but also impacts the performance and safety of connected electrical equipment due to poor voltage regulation and power factor deterioration. One proven solution to alleviate this stress is the parallel operation of transformers, which enables load sharing and enhances system efficiency. However, this approach presents its own set of challenges, primarily the need for transformers with identical ratings and synchronized operation. To overcome these limitations and ensure continuous, safe, and efficient power delivery, automated transformer monitoring and load sharing systems are being developed using Internet of Things (IoT) technologies, microcontrollers like ESP-32 and cloud-based platforms such as Blynk. These smart systems monitor transformer health parameters such as temperature, current, and voltage in real-time, automate load sharing between transformers, and alert operators to abnormal conditions before failures occur and it shut down the excess load which is beyond limit. Such systems offer enhanced reliability, operational efficiency, and significant cost savings by enabling predictive maintenance and reducing manual intervention. This report aims to explore and integrate the ideas from multiple research efforts on automatic transformer load sharing and real-time monitoring using IoT. It will discuss the system design, components, and working principles, as well as the potential benefits and challenges in implementing such solutions in real-world power distribution networks.

Structure:

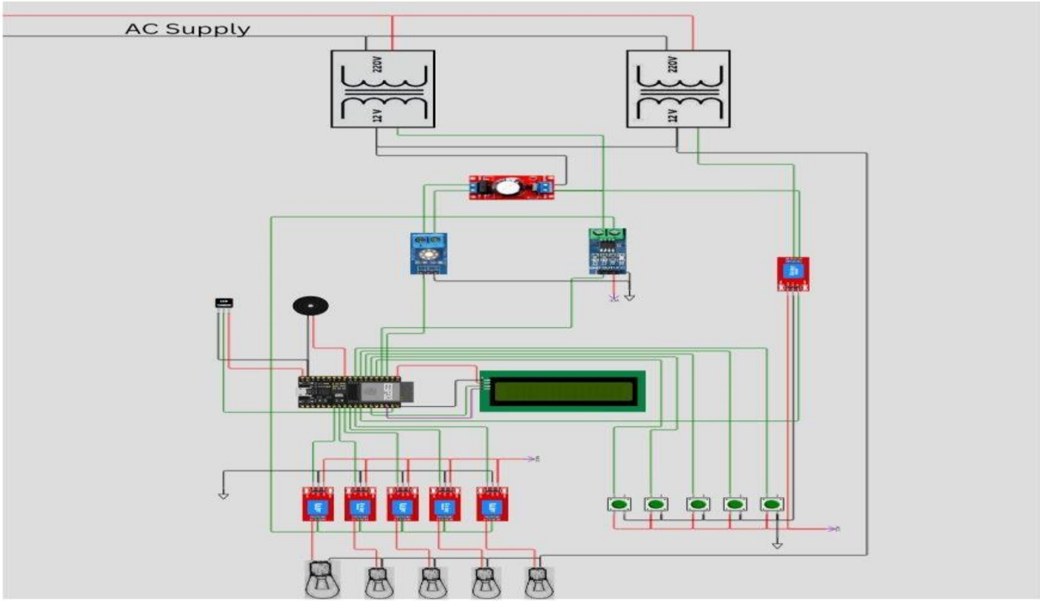
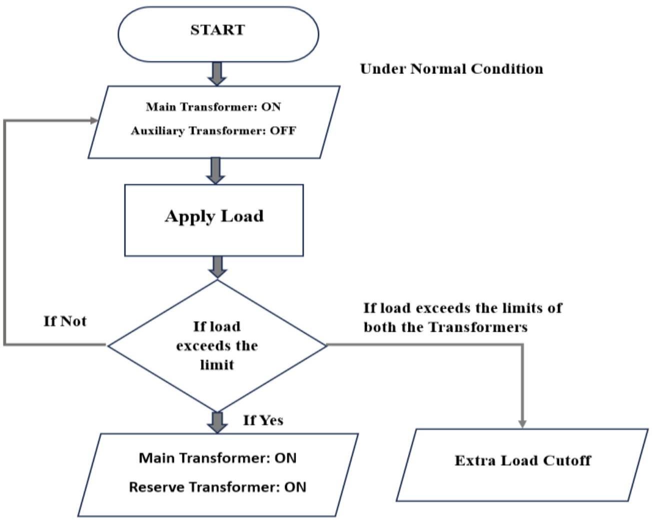


Fig.1 Circuit Diagram

The above circuit diagram represents the architecture of the 'Transformer load sharing and monitoring' integrated with IoT capabilities using ESP32 as the central controller. Here's a detailed explanation of the components and their interactions:

- **ESP-32 MICROCONTROLLER:** The ESP32, featuring 30 pins, is used to monitor transformer parameters such as current, voltage, and temperature in real time.
- **TRANSFORMER**: We are using two core type step-down transformers with a rating of 36VA each.
- **RELAY:** The relay is an essential device used for load switching operations
- **CURRENT SENSOR:** The current sensor with range of 30Amp is used for continuous monitoring of the transformer's current.
- **LCD (LIQUID CRYSTAL DISPLAY):** The LCD 20×4 is used to show real-time system information.
- **RECTIFIER:** The rectifier is used to convert AC into DC.
- **INCANDESCENT LAMP:** Five lamps of 21W are used in the project to represent electrical loads.
- **PUSH BUTTONS:** Five tactile push buttons of rating 24V,50mA are used in the project for manual load control
- **BUZZER:** The buzzer with voltage range of 5-12V is used as an alert device in the system.
- **BLYNK IOT:** IoT platform for remote monitoring via a smartphone or PC.

Methodology:



- Start Condition: The process begins under normal conditions, where the system is ready to manage loads.
- Main Transformer ON, Reserve Transformer OFF: Initially, only the main transformer is operational, and the reserve transformer is off, assuming the load is within the main transformer's capacity.
- Apply Load: The system applies the load to the transformers.
- Load Check: The system checks if the load exceeds the capacity limit of the main transformer.
    - If ‘No’, the system continues with the main transformer, and the process returns to load monitoring.
    - If ‘Yes’, the system moves to the next step.
- Main and Reserve Transformer ON: If the load exceeds the main transformer’s limit, the reserve transformer is turned on to share the load.
- Excess Load on Both Transformers: If the load exceeds the combined capacity of both transformers, the system proceeds to the shutdown.
- System Shutdown: If both transformers are overloaded, the system shuts down, and both the main and reserve transformers are turned off to prevent damage.

Working:

This work presents an IoT-enabled system developed to monitor, control, and manage electrical load distribution in real-time using smart transformer switching mechanisms. The system is designed to enhance the efficiency, safety, and reliability of transformer operations, particularly under varying load conditions. sensor modules include a temperature sensor and a current sensor, responsible for capturing real-time electrical and thermal parameters of the system. Additionally, pushbuttons are provided to allow manual variation of load conditions, enabling simulation of various operating states and fault conditions for testing purposes. The data gathered by the sensors is processed by the ESP32, which determines system behavior based on predefined load thresholds. Operational logic is based on transformer load sharing. Two identical transformers—TF1 (master) and TF2 (slave)—are configured in parallel and monitored continuously. Under normal conditions, TF1 independently handles the connected load.

When the load exceeds TF1's rated capacity, the system triggers a changeover relay, which connects TF2 in parallel to share the load. If the load remains within the range, only TF1 remains active. These states are displayed in real-time on an LCD screen for user awareness.

In extreme overload situations where the combined capacity of TF1 and TF2 is insufficient, the system automatically shuts down the excess load to prevent damage while continuing to balance the permissible load between TF1 and TF2. This approach safeguards the system from overloading, while a temperature sensor will gradually monitor the transformer temperature and at a certain level or threshold limit it will send alert signal through the IoT platform which can be monitored in Blynk app hence safeguarding overheating, and potential transformer failure.

The system supports remote monitoring through an open-source IoT platform, using the ESP32’s built-in Wi-Fi to transmit data over the Internet via Blynk app. This allows seamless integration with broader smart grid systems or cloud-based analytics

Components used:

Esp-32 Microcontroller:

The ESP32, featuring 30 pins, 3.3V DC operation at 15mA, and built-in Wi-Fi and Bluetooth, is used to monitor transformer parameters such as current, voltage, and temperature in real time. It automatically switches the load to a secondary transformer if the primary becomes overloaded, preventing damage and ensuring uninterrupted power supply. If both transformers are overloaded, the ESP32 safely shuts down the load. Sensor data is continuously transmitted to the Blynk platform for remote monitoring and control. The system is programmed in C and C++, combining control and monitoring in one smart, integrated solution.

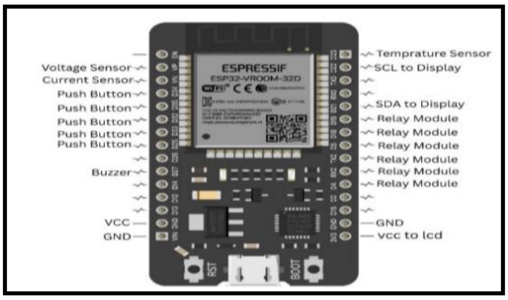


Fig.2 ESP-32 Microntroller

Transformer:

The transformer is the main device used in our project. We are using two core type step-down transformers with a rating of 36VA each. These transformers are responsible for supplying stable and smooth voltage to the consumers. Transformer enable the transmission of electrical power over long distances with minimal losses by stepping up or stepping down voltage levels. By adjusting the voltage, transformers ensure that electricity is delivered efficiently and safely to various end-users, whether in homes, industries, or commercial establishments. They are widely used in power generation, transmission, and distribution networks.

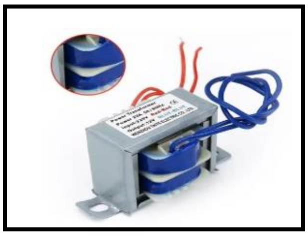


Fig.3 Transformer

Relay:

The relay is an essential device used for load switching operations. It allows a low-power signal to control a high-power circuit, acting as an automatic electrical switch controlled by signals from the controller. When the load on the primary transformer exceeds the set limit, the relay (rated at 5V control voltage, capable of switching up to 30V DC at 10 Amps) activates to shift the load to the secondary transformer. Relays ensure quick and safe switching without manual intervention, protecting the system from overload by disconnecting or redistributing the load. Based on real-time sensor data and control logic, the relay can also disconnect the specific load if both transformers are overloaded, improving system safety, reliability, and automatic load management.

Fig.4 Relay

Current Sensor:

The current sensor with range of 30Amp is used for continuous monitoring of the transformer's current. It helps measure the real- time current flowing through the transformer. The sensor sends the current data to the microcontroller for processing. This data is then used to decide whether load switching is needed. The current values are displayed on an LCD for local monitoring. The current sensor plays a key role in maintaining system safety and performance.

Fig.5 Current Sensor

Voltage Sensor:

The voltage sensor with the range of (0-25V) is used for continuous monitoring of the transformer's voltage. The sensor sends voltage data to the control system for analysis. If the voltage deviates from the normal range, corrective action can be taken This is a safety measure to prevent large circulating currents that could occur if there's a significant voltage difference between the two transformers at the moment of paralleling. This helps in preventing damage to connected electrical devices. The voltage readings are transmitted to the Blynk app for remote monitoring. Users can easily access live voltage data through their smartphones.

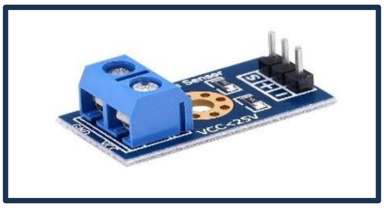


Fig.6 Voltage Sensor

Lcd (Liquid Crystal Display):

The LCD (Liquid Crystal Display) 20×4 (4 Rows and 20 Characters per Row) is used to show real-time system information. It displays key parameters such as current and transformer’s operational status is also shown on the screen. It provides a clear view of which transformer is currently active. The load status, including overload or shutdown conditions, is displayed. This allows users to monitor the system directly without needing external devices.

Fig.7 LCD Display

Rectifier:

The rectifier is used to convert AC (Alternating Current) into DC (Direct Current). It takes the 12V AC output from the step-down transformer as input. The rectifier ensures a stable DC voltage suitable for powering electronic circuits. This DC output is essential for operating microcontroller-based systems. It provides a constant and reliable power source free from AC fluctuations. This conversion is crucial for maintaining consistent operation of the control system. The rectifier helps ensure the entire system runs safely and efficiently.

Fig.8 Rectifier

Incandescent Lamp:

Five lamps of 21W are used in the project to represent electrical loads. Each lamp has a current rating varying from1.5 Amps to 1.9 Amps. These variations simulate real-world load fluctuations on the transformer. The bulbs are connected to the output of the transformer. They help in testing the load sharing and overload protection functions. As the load increases, the system monitors the current drawn by the bulbs. When the total load crosses the limit, load shifting is triggered automatically. These bulbs provide a visible indication of load status and switching operation. They are essential for demonstrating load control and system response.

Fig.9 Incandescent Lamp

Push Buttons:

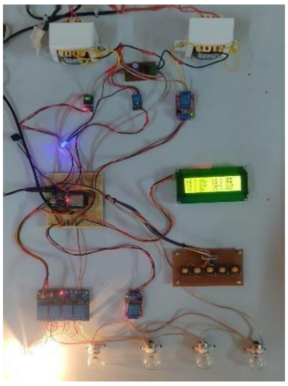
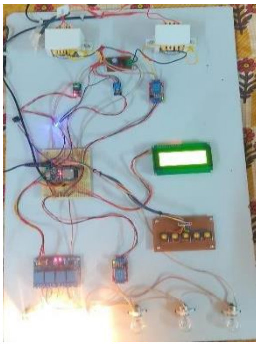
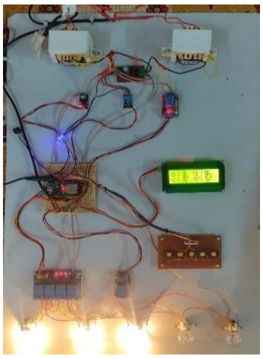
Five tactile push buttons of rating 24V,50mA are used in the project for manual load control. Each push button is assigned to one of the five individual loads (bulbs). Pressing a button connects or disconnects the corresponding load from the system. This setup allows manual testing of load switching functionality. It helps simulate varying load conditions during system operation. The buttons provide user control alongside the automatic switching logic. They are connected to the microcontroller’s digital input pins. Each button press is detected and processed to update the load status. This feature aids in demonstrating manual load control.

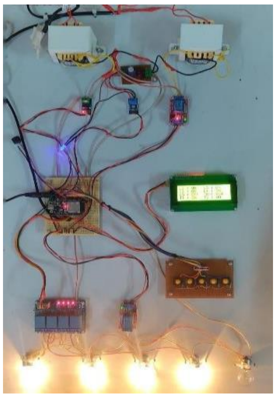
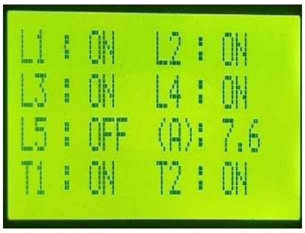
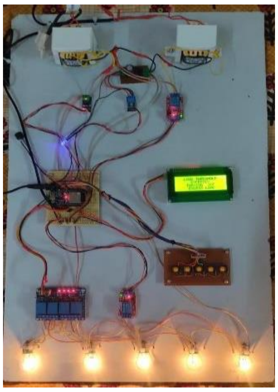
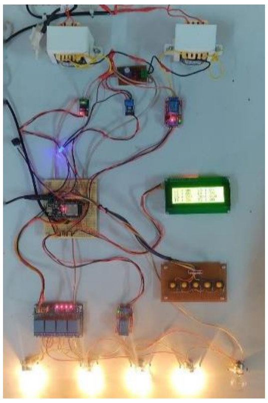
Fig.10 Push Button

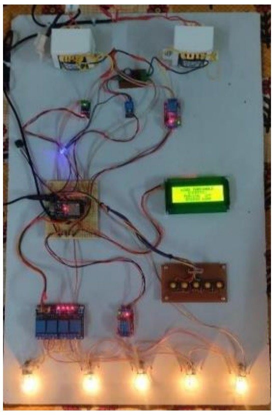
Buzzer:

The buzzer with voltage range of 5-12V is used as an alert device in the system. It provides an audible warning when the load exceeds the predefined limit. This helps in instantly notifying users of an overload condition. When an overload is detected, the microcontroller activates the buzzer. It beeps continuously or in a pattern based on the severity of the load. The buzzer enhances the safety and awareness aspect of the system. It ensures quick human response to abnormal load conditions. This alert feature supports both manual and automatic safety actions.

Result:

<table>
<tr><th>STATUS</th><th>MODEL</th><th>READINGS (Blynk)</th><th>READINGS</th></tr>
<tr><td>Load 1 ON</td><td></td><td></td><td>
I=1.9 V=11.78
Temp=29.56°C</td></tr>
<tr><td>Load 2 ON</td><td></td><td></td><td>
I=3.8 V=7.38
Temp=30.01°C</td></tr>
<tr><td>Load 3 ON</td><td></td><td></td><td>
I=5.7 V=9.32
Temp=30.19°C</td></tr>
</table>

Load 4 ON		 	 I=7.6 V=7.5 **Temp=30.25°C**
Load 5 ON		 	 **Over load alert**
After Load Shedding		 	 I=7.6 V=7.5 **Temp=30.25°C**

Temp limit exceeded threshold value above 40°C			Temp=45.19°C **Alert:** Transformer temperature above threshold.

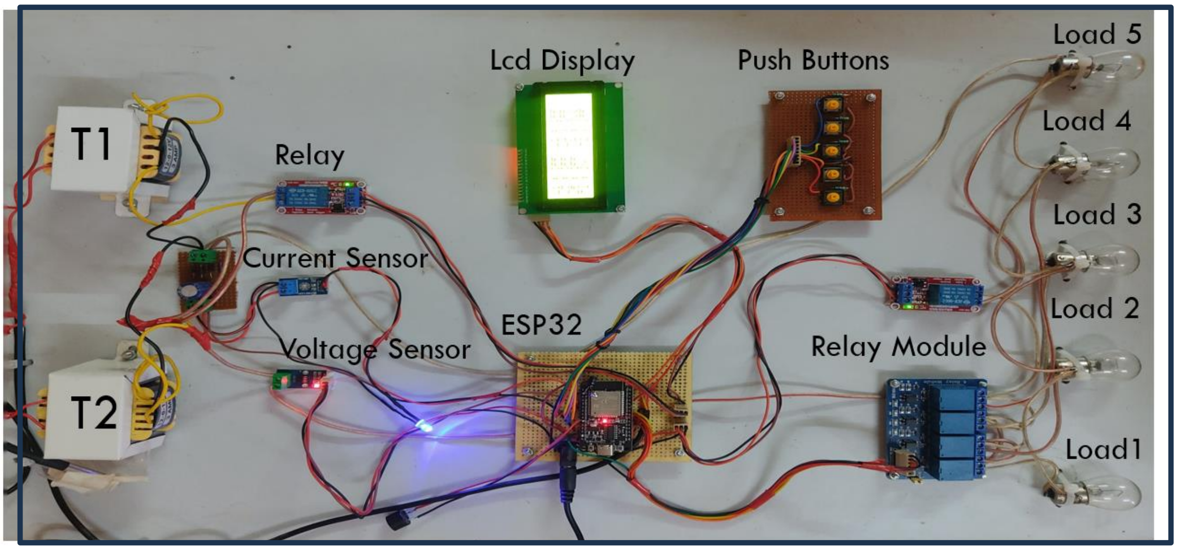


Fig.11 Project Model

Conclusion:

The IoT-based transformer protection and load-sharing automation system addresses key challenges in power distribution, particularly overheating and overload issues that can damage transformers. The system uses real-time monitoring to detect changes in electrical current, and when a transformer exceeds its load capacity, it automatically activates a secondary transformer to share the load, preventing damage and ensuring continuous power supply. The systems IOT Capabilities allow remote monitoring via mobile apps like Blynk, providing real-time data and notifications in case of abnormal conditions. This enhances operational efficiency and reliability by preventing transformer failures and minimizing downtime. Advanced sensors could further improve the system by providing more accurate data, while machine learning could predict potential failures, enhancing system performance. Redundancy and fault-tolerant mechanisms ensure the system remains functional even during failures, improving resilience. The integration of these technologies offers greater stability in power distribution, reducing operational interruptions and enhancing grid reliability. Ultimately, this IoT-based approach offers significant benefits for transformer protection, load- sharing, and predictive maintenance. It has the potential to revolutionize the management of electrical grids and improve overall system efficiency.

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