

IoT-Based Automatic Load Sharing of Transformer Using ESP32

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Abstract:

Overloading of electrical transformers is a major problem in power distribution systems. Excessive loading can cause overheating, increased power losses, insulation deterioration, voltage instability, and premature transformer failure. This research presents an automatic transformer load-shifting system based on an ESP32 microcontroller, current sensor, relay switching circuit, and 16×2 LCD display. The system continuously measures the load current of the primary transformer using a current sensor. The measured value is processed by the ESP32 and compared with a predefined maximum current limit. When the transformer load remains below the specified limit, the connected load continues to operate normally. When the current exceeds the preset threshold, the ESP32 activates a relay arrangement to transfer a selected load to an alternate transformer. The LCD provides real-time information about current, transformer status, and load-shifting operation. The proposed system can reduce transformer overloading and improve the reliability and continuity of electrical power distribution.

Keywords—ESP32, IoT, Transformer, Load Sharing, Current Sensor, Relay, LCD, Overload Protection, Power Distribution.

I. Introduction

Electrical transformers are essential components of power distribution networks because they transfer electrical energy between different voltage levels. Distribution transformers are generally designed to operate within a specified load capacity. When the connected electrical demand exceeds this capacity, the transformer may experience excessive current and temperature rise.

Traditional transformer load management systems may depend on manual switching or conventional protection devices. Although circuit breakers and fuses can protect equipment from severe faults, they normally disconnect the load rather than intelligently redistribute it.

The proposed system introduces an automatic load-shifting technique using an **ESP32 controller, current sensor, relay switches, and 16×2 LCD display**. The ESP32 continuously monitors the current flowing through the transformer load. When the measured current exceeds a predefined threshold, the controller commands the relay circuit to transfer a predetermined load from the overloaded transformer to a standby or alternate transformer.

The main objective is to maintain transformer loading within a safe operating range while minimizing unnecessary interruption to consumers.

II. Problem Statement

Transformer overloading is commonly caused by:

- Increase in consumer demand
 - Uneven distribution of loads
 - Addition of new electrical equipment
 - Seasonal demand variations
 - Improper load management
 - Failure or unavailability of another transformer
- Continuous operation under overload conditions can increase transformer temperature and reduce its service life.

Therefore, an automated system is required that can:

1. Monitor transformer load current continuously.
2. Detect when the current exceeds a predefined limit.
3. Automatically shift a selected load to another transformer.
4. Display current and system status.
5. Reduce manual intervention.
6. Improve transformer utilization and reliability.

III. Objectives

The objectives of the proposed research are:

- To develop an automatic transformer load monitoring system.
- To measure transformer load current using a current sensor.
- To process the measured current using an ESP32.
- To establish a programmable overload threshold.
- To automatically operate relay switches when the threshold is exceeded.
- To shift selected loads from an overloaded transformer to an alternate transformer.
- To display current and transformer status on a 16×2 LCD.
- To reduce the possibility of transformer overheating and overload-related failures.

IV. Basic Operating Concept

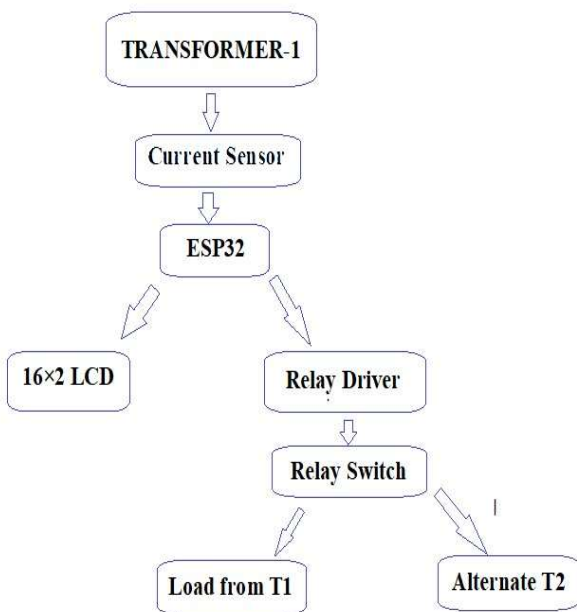


Fig. 1. Basic operating concept of the proposed system.

V. Proposed System Architecture

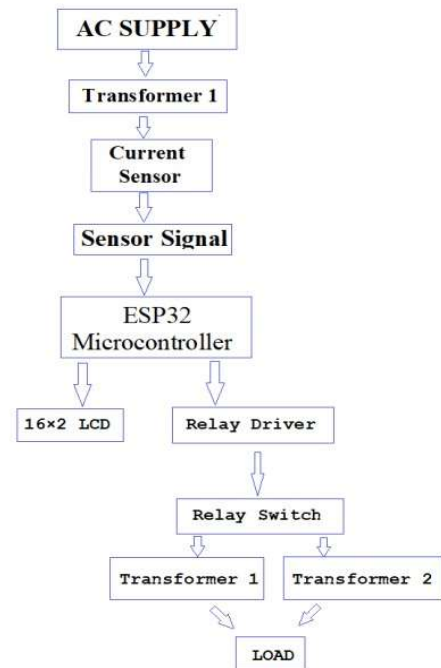


Fig. 2. Proposed system architecture.

VI. System Components and Their Function

TABLE I. SYSTEM COMPONENTS AND THEIR FUNCTION

Component	Function
ESP32	Main control and processing unit
Current Sensor	Measures transformer/load current
16×2 LCD	Displays current and system status
Relay Module	Performs load-transfer switching
Transformer-1	Main transformer
Transformer-2	Alternate/standby transformer
Power Supply	Provides regulated DC power
Connecting Wires	Electrical connections
Load	Demonstration electrical load

VII. Software Implementation

The ESP32 program performs the following functions:

1. Initializes the LCD.
2. Configures the current-sensor input.
3. Configures relay outputs.
4. Reads current continuously.
5. Calculates the measured current.
6. Displays the current on the LCD.
7. Compares current with the preset threshold.

8. Verifies persistent overload.
9. Activates the load-transfer output.
10. Displays the new transformer status.

VIII. Advantages

The proposed system provides several advantages:

- Automatic transformer load monitoring
- Automatic load shifting
- Reduced risk of prolonged overload
- Improved transformer utilization
- Reduced manual intervention
- Real-time current display
- Low-cost prototype implementation
- ESP32 provides scope for IoT expansion
- Faster response than manual load management
- Improved continuity of supply for selected loads

Applications

The proposed concept can be applied or developed for:

- Distribution transformer load management
- Industrial electrical distribution
- Commercial buildings
- Manufacturing plants
- Agricultural electrical systems
- Educational demonstration systems
- Smart-grid research
- Automatic load-management systems
- Backup transformer systems

Important: The numerical values shown in the laboratory test table are illustrative example values from the source draft, not measured experimental results. They must be replaced with actual prototype readings before publication.



Fig. 3. Prototype hardware setup of the developed load-sharing system.

IX. Results and Discussion

The proposed system is expected to continuously monitor transformer current and respond when the programmed threshold is exceeded. During normal loading, the ESP32 maintains the primary transformer connection and displays the measured current on the LCD.

When the measured current exceeds the preset threshold for the specified verification period, the controller initiates the load-transfer sequence. The selected load is then transferred to the alternate transformer, subject to the switching and protection arrangement.

A representative laboratory test can be organized as follows:

TABLE II. REPRESENTATIVE LABORATORY TEST RESULTS

Test Condition	Measured Current	System Response
Low load	10 A	Transformer-1 normal
Medium load	18 A	Transformer-1 normal
Near limit	24 A	Transformer-1 normal
Overload	27 A	Overload detected
Persistent overload	28 A	Load-transfer sequence initiated
After transfer	Reduced T1 current	Transformer-1 loading reduced

These values are example test values, not measured experimental results. Actual research-paper results should be replaced with readings obtained from the prototype.

XI. Conclusion

This research presents an automatic transformer load-shifting system using an ESP32, current sensor, 16×2 LCD display, and relay-based switching control. The system monitors transformer load current continuously and compares it with a predefined threshold. When an overload condition persists, the controller initiates a load-transfer operation to an alternate transformer, thereby reducing the load on the overloaded transformer.

The LCD provides real-time information about current and transformer status, while the ESP32 provides flexible control and future IoT capabilities. The concept can help improve transformer utilization,

reduce overload-related stress, and increase the reliability of electrical distribution systems.

For practical deployment, however, the low-voltage ESP32/relay prototype must be replaced or interfaced with appropriately rated **industrial contactors, current transformers, protection relays, interlocks, and automatic transfer equipment** designed for the actual transformer voltage and fault levels.

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