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Transformer Safety Device

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Abstract
Transformer Safety Device is a protective system designed to prevent transformer overloading and ensure reliable power distribution. This system continuously monitors the load on the transformer and automatically disconnects the most recently added load when overloading occurs. By eliminating excessive burden on the transformer, this approach prevents overheating, reduces the risk of failure and enhances operational safety. The device operates without microcontrollers, relying on electromechanical relays and load management techniques for effective overload protection. This simple yet efficient system improves transformer lifespan and ensures stable power supply.

Keywords: Arduino, Transformer, IoT, Remote Control, Energy Efficiency

1. Introduction

In modern power distribution systems, transformers are among the most critical and widely used electrical devices. They serve the primary function of stepping up or stepping down voltage levels, enabling efficient transmission and distribution of electric power across long distances. In India, distribution transformers are frequently used in both urban and rural environments to ensure a stable supply of electricity to homes, industries, and agricultural units[1]

Despite their importance, transformers are often subjected to harsh operating conditions, such as frequent overloading, unbalanced loads, and voltage fluctuations. These conditions can result in overheating of transformer windings, insulation failure, and, ultimately, permanent damage or catastrophic failure. Overloads, in particular, are one of the leading causes of transformer breakdowns, which may cause power interruptions and increased operational costs due to repairs and replacements[2]-[3].

The Transformer Safety Device project is an embedded system-based solution aimed at addressing this issue. By employing a microcontroller (Arduino UNO) along with a current sensor, the system is capable of continuously monitoring the current load on a transformer. Once the current exceeds a predefined safe limit, the system automatically disconnects the extra load via a relay, thus preventing potential overload damage[4].

This safety mechanism is particularly useful in low-budget distribution systems where real-time monitoring and control are limited. It not only ensures the protection of the transformer but also improves reliability, reduces maintenance efforts, and extends the life span of the equipment. This project can be considered a prototype model that has the potential for large-scale application in rural and urban power distribution networks[5]-[6].

The simplicity, scalability, and low cost of the design make it suitable for implementation in developing regions, where frequent transformer failures are a major challenge. Furthermore, this system forms a foundation for advanced developments such as IoT-based transformer monitoring and integration with smart grid infrastructure.[7]

2. Proposed Work

This Project aims to to design and develop a microcontroller-based Transformer Safety Device using an Arduino platform that can detect and respond to overload conditions in a power distribution transformer. The project seeks to enhance the operational safety and longevity of transformers by implementing a real-time monitoring and protection mechanism that can automatically disconnect the transformer from the load in the event of an overload, thereby preventing overheating, insulation failure, and potential transformer damage.

This system is intended to act as a preventive tool in power systems, especially in rural and semi-urban areas where transformers are often subjected to unpredictable loads, lack of supervision, and delayed maintenance. By integrating sensors, control logic, and automated switching, this device will serve as a prototype model demonstrating how intelligent protective mechanisms can be deployed in practical, low-cost scenarios

Electricity is transmitted from the power plant to residences via an intricate system known as the power distribution grid. A residence or commercial establishment extracts power from the transmission grid and then reduces it to the distribution grid for effective use. This cycle may occur in several stages. The transition from "transmission" to "distribution" takes place at a power substation. It has transformers that reduce transmission voltages (ranging from tens to hundreds of thousands of volts) to distribution voltages (often below 10,000 volts). It possesses a "bus" capable of bifurcating the distribution power in many directions. The substation often has circuit breakers and switches to facilitate disconnection from the transmission grid or to isolate certain distribution lines when required. The transformer is an essential element in the electric power transmission and distribution system. Issues related to overloads, voltage fluctuations, and thermal impacts are prevalent. The repair process is time-consuming and entails significant costs. This study focuses on safeguarding the transformer during overload conditions..

Overloading diminishes efficiency and might cause the secondary winding to overheat or perhaps burn out. Therefore, it is possible to safeguard the transformer by reducing the additional load. A timer circuit for the transformer safety sensor can accomplish this. When the load is above the reference value, the transformer safety mechanism instantly disconnects the excess load. Consequently, transformer safety devices operate effectively during overload conditions, thereby preventing damage. This proactive approach extends the lifespan of the transformer and ensures consistent performance throughout its operation. By implementing such safety measures, we can mitigate the risk of catastrophic failures and maintain a reliable energy supply.

For residential appliances, commercial, and industrial loads, the transmitted voltage must be reduced to a distribution level. The reduction may occur in several stages. In substations, the voltage is reduced from transmission levels (ranging from tens to hundreds of thousands of volts) to distribution levels (often below 10,000 volts). A sensor circuit is engineered to record data from the master transformer; if an overload condition is detected, additional load will be promptly withdrawn to safeguard the transformer. Upon activation, the load will operate via the transformer. When the load on a transformer exceeds its rated capacity, the safety device will immediately disconnect it.

2.1 Block Diagram

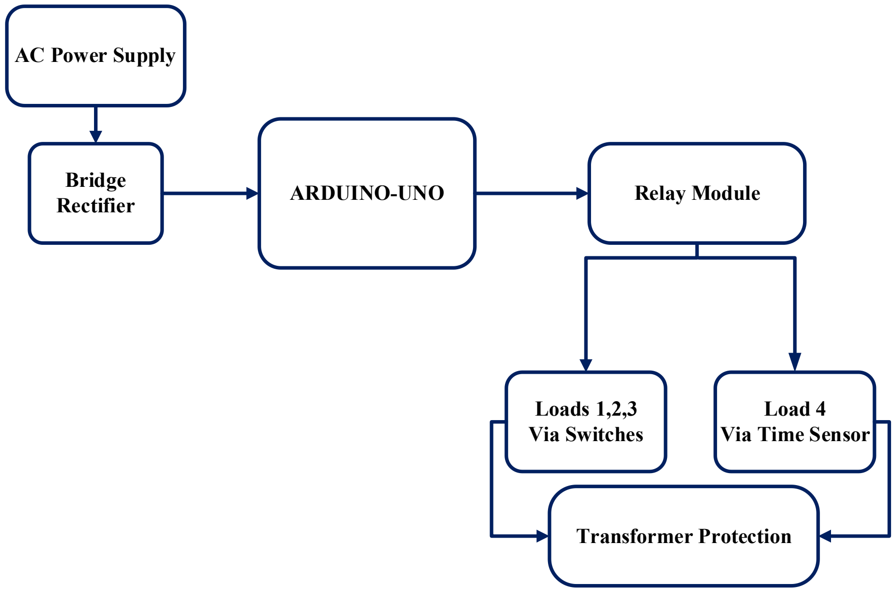

Figure 1. block diagram of Proposed Work

AC Power Supply: The AC power supply serves as the primary energy source for the entire transformer safety system. It delivers alternating current (AC) voltage, typically from a wall outlet or a utility line. This is the input needed to initiate the power conversion and monitoring system. The AC source is vital not only for powering loads but also for energizing the Arduino-based control and monitoring circuitry. The voltage level is often 220V or 110V, depending on regional standards. However, most microcontrollers and relay modules operate at low DC voltages, necessitating conversion, which happens next through the bridge rectifier.

Bridge Rectifier: The bridge rectifier converts AC voltage into DC voltage to power the Arduino and relay module. It uses four diodes arranged in a bridge configuration to achieve full-wave rectification. This means that both halves of the AC waveform are utilized, improving efficiency. The output is pulsating DC, often followed by a capacitor filter to smooth the signal. This is a critical stage since microcontrollers cannot operate on AC power directly. The rectifier ensures the system receives stable DC voltage for continuous operation.

Arduino UNO: The Arduino UNO acts as the brain of the system. It is a microcontroller board that reads inputs from sensors or switches and controls outputs like relays. In this transformer safety device, it monitors operational logic, such as timing for load 4, switch status for loads 1–3, and abnormal conditions in the transformer. It runs embedded code that defines how the system behaves in different scenarios, including fault detection or scheduled switching. Its reliability and open-source ecosystem make it an excellent choice for automation and control applications.

Relay Module: The relay module acts as a bridge between the low-voltage control signals from the Arduino and the high-voltage AC loads. Each relay in the module is an electrically operated switch that allows or interrupts the flow of current to connected devices. The relays isolate and protect the microcontroller from the high-power sections while enabling the Arduino to control AC loads safely. When the Arduino sends a HIGH or LOW signal to the relay input pin, it triggers a coil to switch the connected device ON or OFF. This component is essential for controlling transformers and electrical loads reliably.

From these components the protection unit communicates with the Arduino, which takes necessary action such as isolating the transformer, shutting down certain loads, or activating alarms. In critical scenarios, this section ensures the transformer does not operate under unsafe conditions, thus preventing fires, equipment damage, or service outages. It is the most crucial feature for ensuring long-term operational integrity of power distribution setups.

2.2 Working

Here, used Transformer 12V, 750mA, 7805 three terminal voltage regulator is used for voltage regulation. Bridge type full wave rectifier is used to rectify the AC output of secondary of 230/12V step-down transformer. And used Arduino to sense current rating and printed on LCD display, in this project we are using the 4 load (L-1, L-2, L-3, L-4), 3 load are connected in parallel through Transformer. And last load also connected through transformer with the help of timer sensor circuit, which will connect and disconnect the load by sensing the current. And we are using the 4 switch (S-1, S-2, S-3, S-4) which will connect in series with each load, and we are using R-1 resistor for protection of 3mm LED Light load.

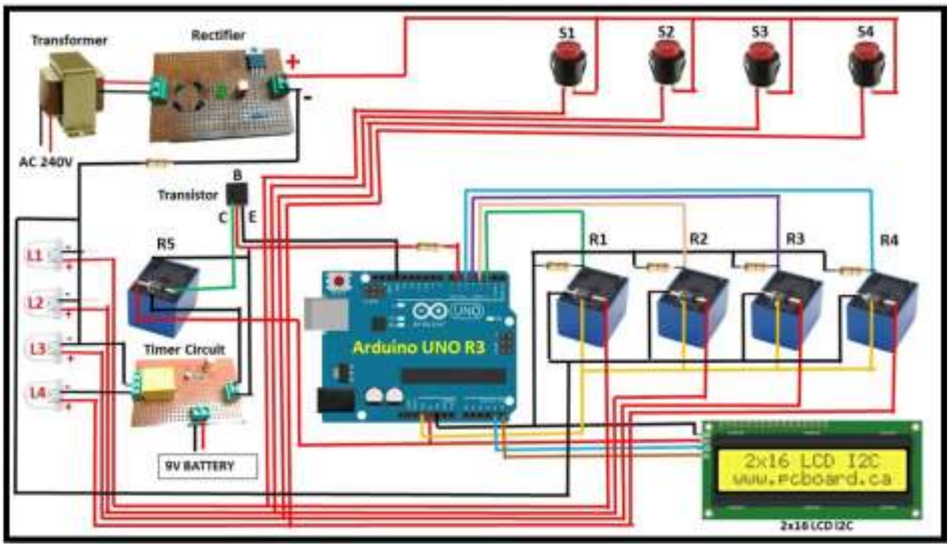

Figure .2 Working Diagram of Proposed Work

Transformer is a stepdown transformer, and we called main transformer, transformer has its own load handling capacity. (750Ma) In case of a normal operation the transformer takes the load but as the load is beyond the rated capacity of main transformer, then extra load is disconnected automatically and protect the transformer. Load switching network is provided to ON/OFF the load on the transformers which is connected to load bank. we are using the 4 switches for each load. Over current (750mA) and voltage(12V) set in the sensor circuit. As we keep the switch S1 ON Then the load L1 Will be on, and 188 mA current will flow through transformer. And switch S2 ON then load L2 Will be on and 376 mA current will flow through the transformer and we will on the S3 Switch the load L3 will be on and 564 mA current will flow through the transformer, all data Printing in LCD display with help of Arduino then we will on the last load L4 then current will increase the maximum set value of sensor circuit that time sensor will disconnect the extra load L4 with in 5sec. and transformer will be safe condition.

2.3 Components Used

S.Np	COMPONENTS	RATING	QYT
1	Transformer	12 V/ 750mA	1
2	Wood Board	A4	1
3	PCB Board	4 x 4	2
4	PCB Board	3x 6	1
5	On/off 2 pin switch	One Way	4
6	5 MM Led white colour	5 mm	4
7	Resistor	330 ohms	1
8	Resistor	1k ohms	8
9	Resistor	10k ohms	1
10	2 pin Screw terminal	2 pin	3
11	3 pin Screw terminal	3 pin	1
12	Diode	NI4007	10
13	IC Regulator	12V	1
14	Battery Clip		1
15	Battery	9v	1
16	LCD	I2C	1
17	Arduino UNO	R3	1
18	NPN Transistor	BC547	2
19	Capacitor	25v 1000uf	1
20	Relay	6v	6
21	Strip single line I - type Pin Male header	1x7	1
22	Jumper Wire	Female to Female	7
23	Jumper Wire	male to female	5
24	2 PIN plug	230V	1
25	Double Sided Foam tape	Normal size	1
26	Push Switch 2pin	Reset	1

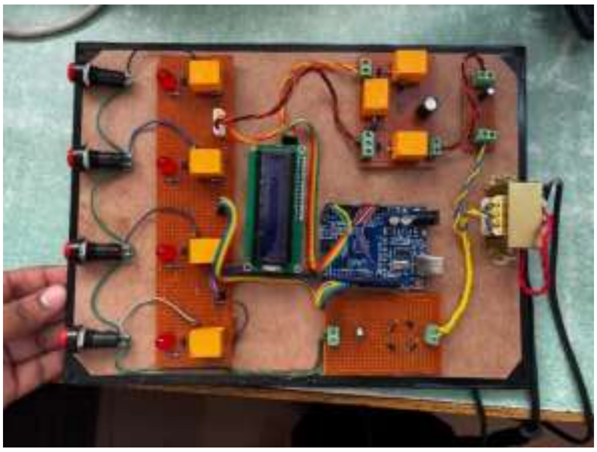

Figure .3 Schematic Diagram of Proposed Work

3 Conclusion

The Transformer Safety Device was rigorously tested under various load scenarios to evaluate its reliability, responsiveness, and overall performance. The primary goal was to observe how effectively the device could detect overload conditions and protect the transformer from damage. The results validate the successful implementation of a transformer safety mechanism. The system responded within 5 seconds upon detecting an overload condition and efficiently protected the transformer by isolating the excess load. The Transformer Safety Device not only meets its intended technical objectives but also stands as a model for how small-scale innovations can contribute to improving the reliability and efficiency of the power distribution sector.

4 Future Scope

While the current implementation provides essential functionality, the project can be greatly enhanced in the following areas to make it more suitable for industrial applications and smart grid integration.

Three-Phase System Compatibility: The existing system is designed for single-phase transformers. Future versions can be adapted for three-phase systems by adding multiple current sensors and using a higher-capacity microcontroller to monitor and manage all three phases effectively.

Automatic Reset Mechanism: The current system requires a manual reset after an overload condition is cleared. Introducing an automatic reset after a specified cooldown period or once the load drops below a safe threshold can make the system more autonomous.

Integration with SCADA Systems: For large-scale power utilities, this system can be integrated into Supervisory Control and Data Acquisition (SCADA) systems, enabling centralized control, diagnostics, and network-wide monitoring.

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