IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

A Novel Intelligent Overload Protection Scheme For Transformers

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Abstract: Smart appliances that are more dependable and efficient must be developed in order to build and create smart grids. We will create a cost-effective solution for the distribution transformer to prevent thermal overload in order to contribute to smart work. Overloading damages the greatest distribution transformer in India, but because of its high cost, no intelligent protection is yet in place. Overload reduces efficiency and increases the risk of overheating or burning the secondary winding. Therefore, the transformer can be protected by lowering the additional load. A transformer safety sensor timer circuit can be used to do this. The transformer safety feature immediately cuts off the excess load when it above the reference value. As a result, damage can be avoided and transformer safety devices operate effectively in overload and overheat situations.

***Index Terms* -** Transformer, Thermal Overload Protection, Sensor, Extra Load, Efficient

I. INTRODUCTION

Mineral oil, often known as transformer oil, serves two purposes in transformers: cooling and insulating. Maintaining the high quality of mineral oil is crucial because of this. Reduced mineral oil quality indicates an issue with the transformer's insulation, which leads to issues with the transformer itself. Temperature increases in mineral oil are the primary factor lowering transformer oil quality. The core and winding of transformers are the primary causes of the transformer's temperature increase. The transformer winding's current rises in tandem with the transformer's rising load [1]. The resistive loss in the transformer winding is the result of this higher current. Losses will rise in tandem with the transformer winding's current. Heat is produced as a result of this loss, and the rate at which heat is produced in a transformer is directly correlated with the current passing through its winding. Controlling the mineral oil's temperature is therefore essential. There are no load losses, or eddy current losses, in the transformer's core when there is no load. The result of this is that the mineral oil's temperature rises and its insulating qualities fall. Because transformers are static devices, their failure rate is far lower than that of rotating devices. Although there is little chance of a fault, if it does happen, the transformer needs to be immediately withdrawn from the system. Transformers must be protected against potential flaws since minor issues might escalate into major ones that could be extremely dangerous if they are not promptly fixed. When it comes to small distribution transformers, series fuses are frequently used in place of circuit breakers.

A transformer's overheating is mostly caused by overloads and short circuits. If the transformer's temperature rises above the safe level in a thermal overload protection system, the transformer is cut off from the system. The modify circuit is added within the secondary winding to finish it. This embedded circuit disengages the system from the secondary winding after detecting the transformer's temperature. Once more, this control circuit determines the transformer's temperature. If the temperature is within standard limits, these circuits will connect the transformer to the system. The control circuit's operation is programmed in this type of overload protection. The transformer's temperature determines what happens in the control circuit [2].

The primary objective of this research is to design a robust and reliable protype system that mitigates the risks associated with transformer overloading. By employing an automated load-sharing mechanism, integrated with an Arduino microcontroller, the intention is to facilitate seamless switching between primary and backup transformers. This ensures that each transformer operates within its optimal load range, thereby enhancing efficiency and longevity. The overarching purpose of implementing this system is multifaceted:

1. To prevent thermal overloads in transformers by ensuring balanced load distribution.
2. To facilitate automatic switching between primary and backup transformers during abnormal load conditions.
3. To provide adequate maintenance opportunities for both transformers by alternating their usage, thereby extending their operational lifespan.
4. To guarantee uninterrupted power supply by ensuring that at least one transformer remains functional at all times.

The methodology adopted for this system revolves around the integration of Arduino microcontrollers to automate the load-sharing process between the primary and backup transformers. Sensors are incorporated to monitor the load conditions continually. When an overload is detected in the primary transformer, the Arduino microcontroller triggers the backup transformer to share the load. Conversely, during normal load conditions, the system alternates between the two transformers, ensuring equitable distribution and optimal performance. This dynamic switching mechanism is designed to pre-emptively address potential overloading issues, thereby fortifying the system's resilience and reliability.

II. Literature Review

Transformers are essential components in the power distribution network, tasked with voltage conversion and the handling of substantial electrical loads. However, their susceptibility to overload poses significant operational risks, including overheating and potential damage, which can disrupt the power supply and incur high maintenance costs. Recent advancements in technology have led to the development of systems that enable load sharing among transformers, effectively managing overload conditions through intelligent control systems. These innovations employ microcontrollers, IoT technology, and cloud communication to enhance system monitoring, reliability, and efficiency. This literature review explores various approaches and technologies implemented to protect transformers from overload, highlighting the integration of parallel transformer systems, real-time monitoring, and automated control mechanisms that ensure continuous operation and system longevity.

Ragavapriya et al. [3] Author worked on the protection of transformers from overload by employing a load-sharing mechanism between two transformers, controlled by an embedded controller in 2023. This system not only prevents overheating and potential fires by balancing the load when it exceeds a preset threshold but also monitors transformer performance using IoT technology. The advantages include uninterrupted power supply, reduced risk of short circuits, and elimination of overload and overheating issues. Data on transformer health and load management is transmitted and displayed via a cloud-based communication protocol, enhancing system reliability and safety.

Krishanan et al. [4] investigated the protection of transformers from overload by using a microcontroller to enable load sharing between two transformers in 2016. When one transformer's load exceeds a set threshold, the system activates a second transformer to balance the load, thus preventing overheating and potential damage. The system includes a sensing unit to monitor current, a control unit to manage operations, and a microcontroller that processes signals and controls a relay, with a GSM modem to notify the control station of any switching. This modular approach enhances reliability, provides uninterrupted power, and protects against short circuits.

Ambalkar et al. [5] proposed a work on transformers which is a crucial yet bulky and costly component of power systems, that operate continuously and are prone to overload and overheating, which can damage insulation and disrupt supply in 2015. To mitigate this, employing multiple transformers in parallel allows for load sharing, reducing the risk of overload on any single unit. This method ensures that if one transformer exceeds its capacity, another can take on the excess load, maintaining a steady, uninterrupted power supply to consumers and preventing service interruptions from transformer failures.

Chougular and Patil [6] worked on transformers, critical and costly components in power systems, which face potential overload and damage when subjected to loads exceeding their capacity. To prevent this, employing multiple transformers in parallel ensures load sharing, effectively distributing the increased load to avoid overheating and damage.

Vani [7] used a microcontroller to monitor the load on the primary transformer and activate a secondary transformer when the load surpasses a predefined threshold. This setup includes sensors, a control unit, and a GSM modem for communication with the control station. The primary benefits of this approach include enhanced transformer protection, continuous power supply, and safeguards against short circuits.

Ahmad et al. [8] managed the growing energy demands and prevented transformer overload, operating multiple transformers in parallel is recommended. When primary transformers exceed their capacity, auxiliary transformers take over the additional load, utilizing fuzzy logic for efficient load distribution, thereby ensuring uninterrupted power. Research also explores the effects of power re-energization in residential areas on high-voltage-medium-voltage transformers, particularly the cold load pick-up phenomena exacerbated by renewable energy sources which is used by Raoofsheibani et al. [9].

III. Proposed Methodology

The research methodology for this work is structured into several phases, including system design, component selection, hardware implementation, experimental testing, and performance evaluation. The approach ensures a systematic development and validation of the proposed protection system.

The first phase involves the design and architecture of the system. The primary objective is to develop a mechanism that monitors and protects a distribution transformer from thermal overload conditions by automatically disconnecting excessive loads beyond the rated capacity. A step-down transformer (230V to 12V, 750mA) is used as the main power source, and a load switching network is implemented to distribute and manage loads efficiently. The system includes four loads (L-1, L-2, L-3, and L-4), with the first three connected in parallel and the fourth connected through a timer sensor circuit. The design incorporates a temperature sensor to detect overheating conditions and an Arduino Uno microcontroller to process current readings and display real-time data on an LCD screen.

In the component selection phase, suitable hardware is chosen to achieve the intended functionality. A bridge rectifier is used to convert AC to DC output for stable operation. The Arduino Uno microcontroller serves as the central processing unit, monitoring the load current and making real-time decisions regarding load disconnection. The temperature sensor continuously monitors the heat generated by the transformer, and relays and switches are used for load management. A timer sensor circuit is integrated to control the delayed connection/disconnection of one of the loads based on current variations. A resistor (R-1) and an LED light are included for additional safety and indication purposes.

The implementation and working mechanism involve integrating all the components into a functional system. The transformer supplies power to the four loads, with manual switches (S-1, S-2, S-3, and S-4) provided for individual control. Under normal operating conditions, the transformer efficiently handles the connected loads. However, when the total load exceeds the rated capacity of 750mA, the extra load is automatically disconnected to prevent overheating and damage. If the transformer temperature reaches a critical threshold, the entire load system is disconnected, ensuring complete protection of the transformer. The LCD display provides real-time voltage, current, and load status updates, aiding in monitoring and maintenance.

To validate the system, experimental setup and testing are carried out under normal and overload conditions. The transformer is tested with different load configurations to measure its performance in real-time. The response of the overload protection mechanism is observed, and the effectiveness of load disconnection under excess current conditions is recorded. The system's ability to detect overheating and initiate complete shutdown is also tested. Various simulated scenarios, such as gradual load increase, sudden overload, and excessive heating, are implemented to evaluate the reliability and accuracy of the system.

This comprehensive research methodology ensures a well-structured and scientifically validated approach to transformer overload protection, providing a reliable, automated, and cost-effective solution for transformer safety in distribution networks.

IV. Result And Discussion

In this work, basically we have used a transformer of 230/12V, 750 mA and bridge type full wave rectifier is used to rectify the AC output of secondary of 230/12V step-down transformer as shown in fig.1. And we used temperature sensor for overheat and used Arduino Uno to sense current rating and displayed on LCD display, In this research work we are using the 4 load (L-1, L-2, L-3, L-4) as shown in fig.2. Three loads 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 as shown in fig.3. And we are using the four 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.

Transformer used here is a stepdown transformer and is called main transformer. 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 four switches, each for single load. Over current (750mA) and voltage(12V) set in the sensor circuit. If the transformer reached overheat condition, then total load will disconnect from transformer and transformer will safe. Fig. 4 basically shows the connection of 16x2 LCD display to Arduino uno microcontroller board. Fig.5 shows the designed prototype working model prepared for proposed methodology. And the prototype is validated in real time scenarios.

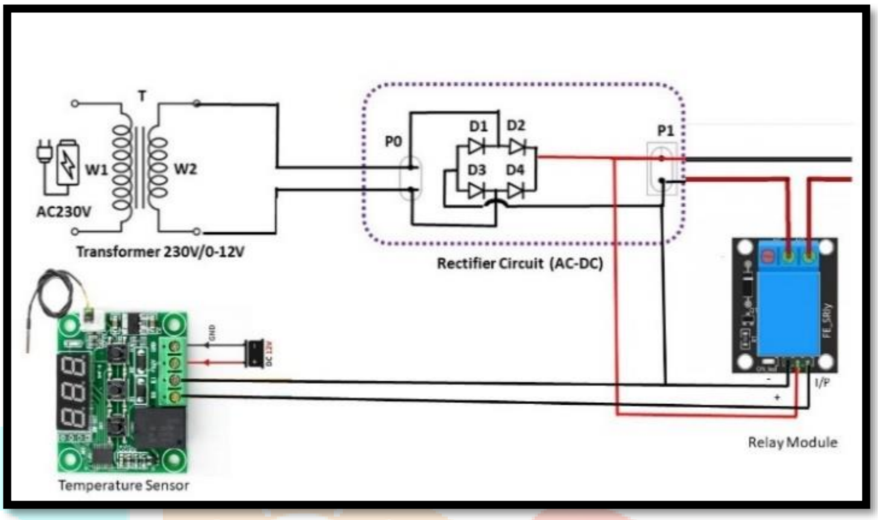

Fig.1 Power Supply Unit connection to temperature sensor

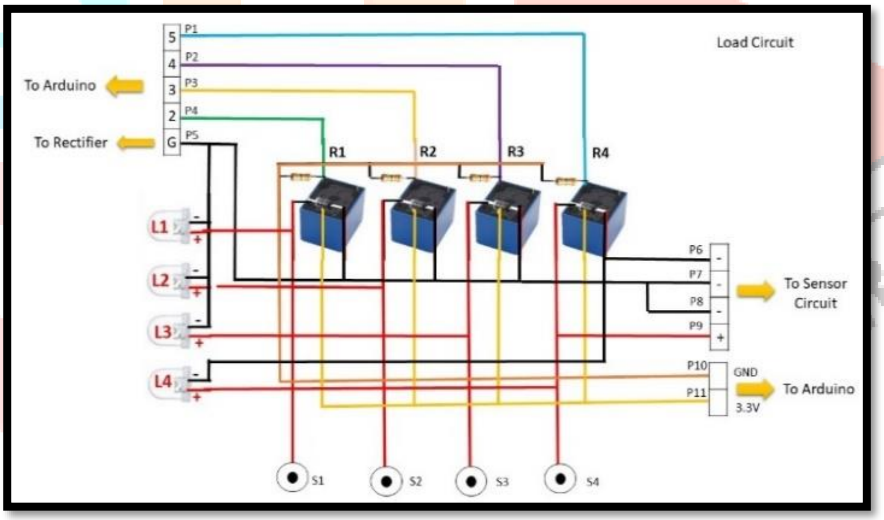

Fig.2 Connection diagram for four loads

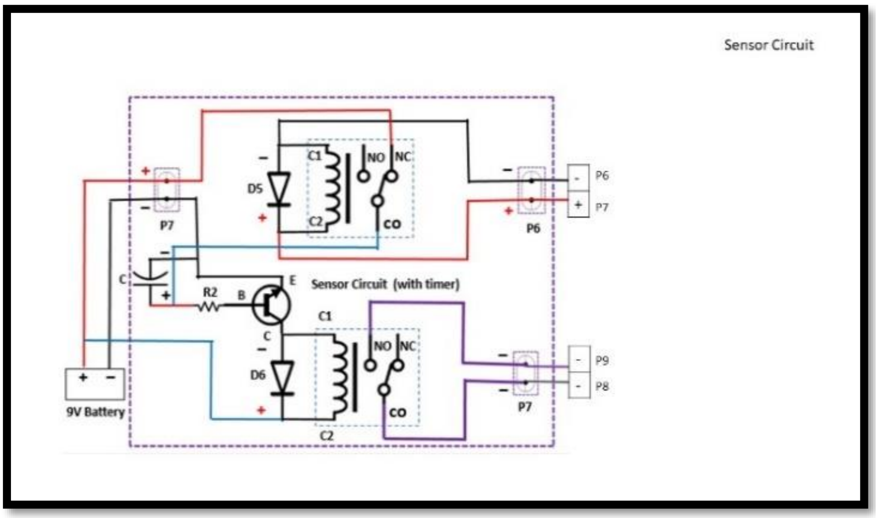

Fig.3 Connection/ disconnection of loads using sensor circuit

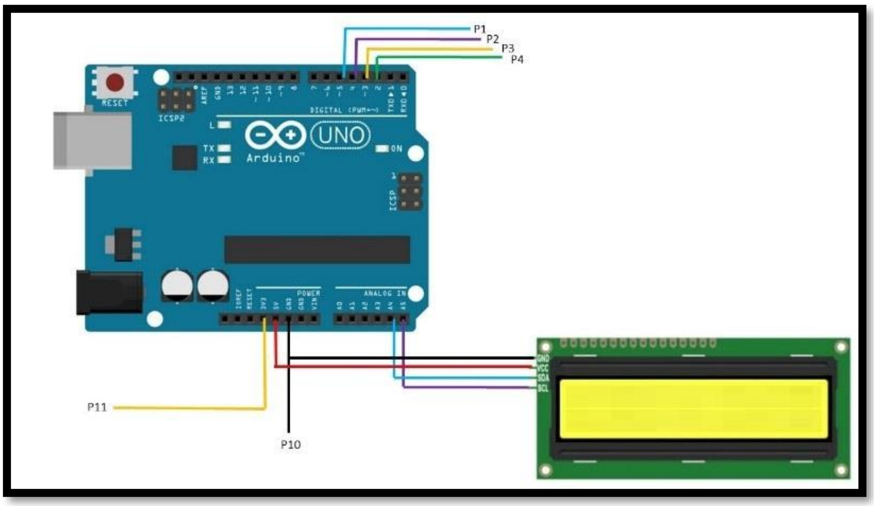

Fig.4 16x2 LCD display connection to Arduino uno microcontroller board

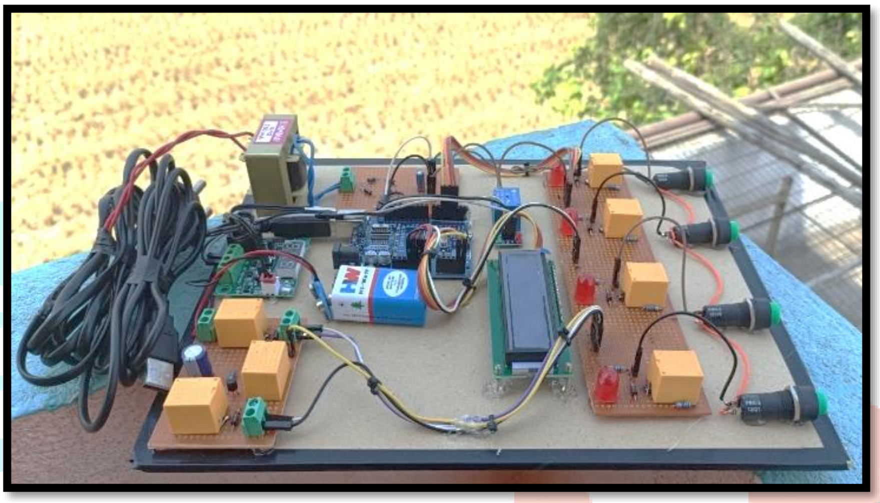

Fig.5 Designed working model prototype

V. Conclusion

This proposed prototype system will raise system reliability, decrease manual interference, and increase system efficiency. Using a switchover relay and microcontroller circuit, the protype unit automatically shares the load between two transformers operating in parallel. It safeguards against overloading and overheating, ensuring that the consumer receives an uninterrupted power supply. In conclusion, the implementation of the automatic load-sharing system for transformers using an Arduino UNO demonstrates significant benefits in load distribution efficiency, reliability, and safety. Continued advancements in technology and ongoing research efforts hold the potential to further enhance the capabilities and effectiveness of such systems in modern power distribution networks.

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