



Design and Implementation of Arduino-Based Automatic Load Sharing System for Distribution Transformers with Real-Time Monitoring

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Abstract—Distribution transformers often fail due to constant overloading. This is a major cause of unexpected power outages in rural feeders and small industrial setups. The proposed project presents a cost-effective prototype that uses a micro-controller to automatically balance the load between two step-down transformers. It also provides live current readings on an LCD display. The Arduino Uno R3 board serves as the decision-making unit, continuously monitoring the current load and comparing it to a set value. If the current through the primary transformer exceeds its rated capacity, a relay-controlled switching mechanism connects the secondary transformer in parallel. This allows the two transformers to share the total load. If the total load exceeds the safe rating, the overload is disconnected from the circuit to protect the winding. The prototype was tested on a 24 V, 3 A laboratory-scale prototype and was found to operate within a few milliseconds, maintain the load within the ratings, and accurately display the overload incidents on a screen. The proposed design can be used as an entry-level smart distribution control technique and can be enhanced with IoT/GSM modules for remote monitoring and controlling. **Index Terms**—Distribution Transformer, Automatic Load Sharing, Parallel Operation, Arduino Uno, Current Sensing, Overload Protection, Real-time Monitoring.

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I. INTRODUCTION

A reliable supply of electrical energy is an indispensable prerequisite for all modern operations, whether domestic lighting, healthcare machinery, classroom lectures, or manufacturing units. Although there may be abundant generation resources, the consumer side suffers from constant power fluctuations, largely because the transformer providing power to this zone operates with higher loads than the rating specified on its nameplate. This causes increased copper losses and increases the temperature of the winding and oil, leading to insulation failure and total collapse of the transformer. Traditional protective systems adopted in distribution networks include fuses and thermal magnetic circuit breakers. Both devices simply isolate the transformer in case of a fault, without redistributing the load

or provide any information about the status of the network before a fault occurs. Because faults in such regions are detected by technicians assigned to the region in question, there is little notice until the power supply is terminated. The need for such a system therefore lies in its ability to

- sense the current at all times,
- bring a second transformer online, before the first one fails, and
- display the live status of both transformers.

A prototype was designed using Arduino Uno owing to its affordability, large community support, and ease of interfacing with the sensors and relays. The remainder of this paper is organized as follows. Section II presents a literature review. Section III provides insights into the conditions that must be followed while operating the system in parallel. Section IV describes the suggested hardware design. Section V presents how the algorithm was implemented. Section VI discusses the results, and Section VII wraps up the study.

II. LITERATURE REVIEW

Several authors have addressed the issue of overloading distribution transformer. Early research has focused mainly on offline monitoring using data loggers, wherein data about the current and temperature are analyzed after collection, and transformers are replaced based on the analysis. Online monitoring was then adopted owing to the affordability of the microcontrollers. Monitoring systems based on GSM technology and sending an SMS message whenever the current exceeds a certain level have been proposed; however, these systems merely notify the operator without taking any action concerning the overload.

However, there is a well-known technique for the parallel operation of transformers, in which switching can be performed by experienced operators after checking the voltage ratio, polarity, and phase sequence. The automation process for deciding whether parallel operation can be performed with the help of an affordable control board such as Arduino has not been extensively explored. This study aims to address this gap.

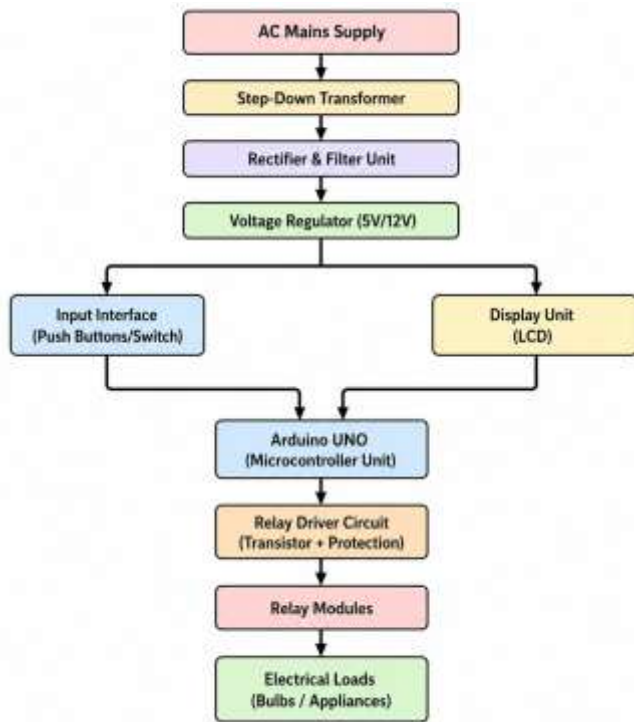


Fig. 1. Block diagram of the proposed automatic load sharing system.

III. CONDITIONS FOR PARALLEL OPERATION

Two transformers can operate in parallel only if certain conditions are met; otherwise, large circulating currents can occur even under no-load conditions. The conditions were as follows.

- 1) The ratio of the primary voltages of both transformers must remain constant.
- 2) The impedances must be the same, along with the X/R ratio.
- 3) The polarities of the secondary windings should be similar.
- 4) In case of three-phase transformers, the phase sequence must be alike; and
- 5) No phase shift occurs in the secondary winding.

In our experiment, both transformers used were of the same make and rating (24V, 3A).

IV. PROPOSED SYSTEM HARDWARE

A. Block Diagram

The block diagram of the proposed circuit includes an a.c. main supply input, two step-down transformers T1 and T2, current sensing on the secondary side, an Arduino Uno R3 board, a switching circuit operated by relays, resistive loads L1 – L4, which are switched via manual switches S1 – S4, and an LCD indicator.

B. Components Used

The bill of material of all the components used in the laboratory prototype is listed in Table I.

TABLE I
LIST OF COMPONENTS USED IN THE PROTOTYPE

S.No	Component	Rating	Qty
1	Step-down Transformer	24 V / 3 A	2
2	Arduino Uno R3	–	1
3	I ² C LCD	16×2	1
4	Relay Module	12 V	5
5	Rectifier Diode	1N4007	5
6	Filter Capacitor	200 μ F / 25 V	5
7	Indicator LED	3 mm, white	1
8	Current-limiting Resistor	1 k Ω	1
9	Load (bulb + holder)	230 V	4
10	SPST Toggle Switch	–	4
11	PCB	2×2, 2×6	2
12	Jumper Wires (M-F, F-F)	–	20
13	2-pin Mains Plug	230 V	1
14	Wooden Mounting Board	A4 size	1

C. Sensing and Switching

Current Sensing and Switching Operations The current in the secondary winding of transformer T1 was sensed through a current-sensing device, the output of which was an analog signal that was given as input at channel A0 of the Arduino. The microprocessor scales this signal to obtain the r.m.s. value of the current. There are five relays, of which one is used to establish the paralleling of T1 and T2, whereas the other four are used for switching operations.

V. WORKING PRINCIPLE AND ALGORITHM

A. Operating Modes

Three operating modes are defined as follows:

Mode 1 – Normal: Only T1 fed the load. As long as the measured current, I , remains at or below 3 A, the system operates. When switch S1 is turned on, L1 is turned on, consuming approximately 1 A of current, and when S2 is turned on, L2 is turned on, which increases the current to approximately 3 A.

Mode 2 – Parallel Sharing: Once S3 is turned on, the demand is almost 3 A, which exceeds the rating of T1. This situation is identified by the Arduino, which activates the parallel connection relay such that T2 connects to the secondary bus. At this point, both transformers equally shared the demand. Finally, when S4 is turned on, the entire demand is 4 A, evenly shared by both transformers.

Mode 3 – Overload Trip: In case the total demand exceeds the safety threshold (4 A for this prototype), the controller deactivates the previously activated relay and displays the message “OVERLOAD – LOAD DISCONNECTED” on the LCD.

B. Control Algorithm

The pseudocode executed in the Arduino is shown below.

```

Read value of I from current sensor
Display value of I on LCD
If (I <= I_rated) Disconnect T2
Else if (I_rated < I <= 2*I_rated)
  
```



TABLE II
EXPERIMENTAL RESULTS OF THE PROTOTYPE

Loads ON	I (A)	T_2 status	System State
L_1	1.0	OFF	Normal, T_1 alone
L_1, L_2	2.0	OFF	At rated capacity
L_1, L_2, L_3	3.0	ON	Parallel sharing
$L_1 - L_4$	4.0	ON	Equal sharing (2 A each)
> 4.0 A demand	–	ON	Last load tripped

Connect T2 in parallel Else
disconnect last load display
OVERLOAD

C. Need for Parallel Operation

The addition of another smaller transformer in parallel is much cheaper than replacing the existing transformer with a bigger one. Moreover, the setup enhances reliability because if one transformer breaks down, the other can carry half of the load on the bus, which is very important for emergency feeder lines.

VI. RESULTS AND DISCUSSION

A. Experimental Observations

The testing process involved toggling each load independently of the other three and recording the LCD value along with the status of the parallel relay. The results are presented in Table II.

B. Discussion

The findings show that the controller makes the right decision in every operational zone. The changeover from single transformer to dual transformers is smooth, and the value displayed on the LCD screen matches the value recorded using a clamp meter to within ± 5 .

C. Advantages

This system protects both the transformer and load circuits. It ensures reliability because of redundancy. It improves efficiency by balancing the load properly. It eliminates the need for switching operations and is cost-effective to build with easily accessible parts.

D. Limitations

Even small differences in the ratio of voltages or impedance can cause circulating currents between the two transformers. The breakers need a higher fault rating due to the parallel operation. The light-load efficiency is a bit lower because of the no-load losses from the second transformer. The control equipment should be checked regularly.

VII. CONCLUSION AND FUTURE SCOPE

An inexpensive automatic load-sharing system for distribution transformers using the Arduino platform was conceived, built, and tested. In this design, the current is sensed continuously; a second transformer is automatically connected in parallel when the primary transformer nears its maximum rating, and excess loads are disconnected if the aggregate demand exceeds the safety limits. Experimental studies have been carried out on a laboratory prototype with specifications of 24 V and 3 A, where it has been verified that the switching sequence during normal, sharing, and overload conditions has been accurately implemented, providing an indication through an I2C LCD display.

Several areas require further research. A device, such as an IoT or GSM module, could be incorporated to notify the operator about the power consumption pattern and overload events via SMS. Connecting the system to the SCADA system allows for the centralized monitoring of many transformers simultaneously. A data analysis tool can provide predictive maintenance of transformers by detecting abnormal current trends. Finally, the same concept, but with improved sensors and solid-state switches, could be applied to distribution feeders in the smart grid context.

REFERENCES

- [1] R. Shinde, A. Kulkarni, P. Nagapalle, P. Birad, and V. M. Panchade, "Automatic Load Sharing By Transformers With Cut Off & Overheat Protection Using Arduino," *International Journal of Creative Research Thoughts (IJCRT)*, vol. 13, no. 5, pp. m574–m583, May 2025.
- [2] J. Idehen, D. Okonkwo, M. Atu, and I. Onyegbadue, "Enhancing Energy Distribution Efficiency with Dynamic Transformer Rotation in 11kV Networks," *Lafia Journal of Scientific and Industrial Research*, pp. 30–43, 2026.
- [3] Y. K. Kirange, V. S. Patil, R. S. Patil, R. J. Patil, and P. D. Pandit, "Optimizing Power Distribution: Smart Load Sharing Mechanism Enhanced by Arduino Uno Integration," *International Journal of Ingenious Research, Invention and Development*, vol. 10, no. 3, pp. 161–174, 2024.
- [4] V. N. Chatse and G. D. Shingade, "Automatic Load Sharing of Distribution Transformer (IOT)," *International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)*, vol. 7, no. 1, pp. 273–277, July 2021.
- [5] S. Hemasilviavinothini, D. Charmila, M. Barath, S. Boobesh, and A. Ashok, "Automatic Load Balancing between Transformer Using Embedded System," in *2025 10th International Conference on Communication and Electronics Systems (ICCES)*, Oct. 2025, pp. 786–790.
- [6] P. Jenopaul and B. M. Praveen, "Analysis of transformer load balancing devices and their capabilities in EVSE connected distribution line," in *2025 8th International Conference on Circuit, Power & Computing Technologies (ICCPCT)*, Aug. 2025, pp. 295–299.
- [7] U. Subha, N. Dinesh, T. S. Kumar, K. S. Kumar, G. S. Reddy, and A. S. Kumar, "Real time monitoring of a distribution transformer based on IoT," *Int. J. Sci. Res. Sci. Eng. Technol.*, vol. 7, pp. 158–166, 2020.
- [8] A. A. Noman, P. Baidya, M. A. Hossain, P. Dev, K. Saha, and M. L. Hossain, "Design and Implementation IoT-Driven Distribution Transformer Health Monitoring System for the Smart Power Grid," *Eng. Proc.*, vol. 87, no. 1, p. 27, 2025.
- [9] R. R. Pawar and S. B. Deosarkar, "Health condition monitoring system for distribution transformer using Internet of Things (IoT)," in *2017 International Conference on Computing Methodologies and Communication (ICCMC)*, July 2017, pp. 117–122.
- [10] J. Rahul, K. V. Chary, M. Shreya, P. Nikhitha, K. Praveen, and N. Karuppiah, "ESP32-Based Smart Solar DC Microgrid with Priority Load Management," in *2026 Int. Conf. Visual Analytics and Data Visualization (ICVADV)*, February 2026, pp. 1445–1451.



- [11] O. O. Oladapo, P. W. Ho, and C. R. Sarimuthu, "Low-cost dual-factor programmable circuit breaker for demand-response load management in industrial microgrids," *Electric Power Systems Research*, vol. 254, p. 112705, 2026.
- [12] A. Muneer, F. Amjad, M. W. Jabbar, and U. Saleem, "Development of automatic switch for electric power transfer," *Eng. Proc.*, vol. 12, no. 1, p. 72, 2022.
- [13] W. M. O. Narvios *et al.*, "IoT based automatic transfer switch with monitoring and control system," in *AIP Conf. Proc.*, vol. 2502, no. 1, Oct. 2022, p. 020003.
- [14] X. Chen, Y. Hu, Z. Dong, P. Zheng, and J. Wei, "Transformer operating state monitoring system based on wireless sensor networks," *IEEE Sensors J.*, vol. 21, no. 22, pp. 25098–25105, 2021.
- [15] J. Ramesh, S. Shahriar, A. R. Al-Ali, A. Osman, and M. F. Shaaban, "Machine learning approach for smart distribution transformers load monitoring and management system," *Energies*, vol. 15, no. 21, p. 7981, 2022.
- [16] M. H. K. Khan, S. U. Islam, and M. Z. Islam, "Load-balancing system for the distribution network using a load-sharing approach," *Int. J. Smart Grid-ijSmartGrid*, vol. 8, no. 3, pp. 155–163, 2024.
- [17] A. Gouda, A. Farag, H. Mostafa, and Y. Gaber, "Smart electric grids three-phase automatic load balancing applications using genetic algorithms," in *Proc. Canadian Conf. Elect. Comput. Eng.*, Regina, Canada, May 2013, pp. 1–4.
- [18] A. P. Khandait, S. Kadaskar, and G. Thakare, "Real time monitoring of transformer using IOT," *Int. J. Eng. Res. Technol. (IJERT)*, vol. 6, no. 3, pp. 146–149, 2017.
- [19] T. B. Tedla, M. N. Davydkin, and A. M. Nafikov, "Development of an Internet of Things based electrical load management system," in *J. Phys.: Conf. Ser.*, vol. 1886, no. 1, 2021, Art. no. 012002.
- [20] A. Muneer, F. Amjad, M. W. Jabbar, and U. Saleem, "Development of automatic switch for electric power transfer," *Eng. Proc.*, vol. 12, no. 1, p. 72, 2022.