International Journal of Scientific Research & Engineering Trends
Volume 12, Issue 1, Jan-Feb-2026, ISSN (Online): 2395-566X

Implementation of an Automated Transformer Rewinding System

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Abstract- Transformer rewinding is generally a manual process that depends on skilled operators and predefined winding data, which may result in calculation errors and increased rewinding time. This project presents a bobbin-based automated transformer rewinding system using a microcontroller to improve accuracy and efficiency. The system accepts basic electrical inputs such as input voltage, output voltage, required output current and bobbin dimensions. Based on these inputs, the required number of winding turns is calculated using empirical transformer winding rules and an appropriate copper wire gauge is selected using the current density method. The system also verifies whether the winding can physically fit within the given bobbin dimensions by calculating turns per layer and total winding thickness. An Arduino UNO R4 controls an induction motor through a relay module, while a rotary encoder provides accurate turn counting. The calculated parameters and winding status are displayed on an LCD. This system reduces human dependency, minimizes errors and provides a cost-effective solution for transformer rewinding applications.

Keywords- Transformer rewinding, Automated coil winding, Microcontroller-based system, Wire gauge selection, Current density method, Rotary encoder, Transformer winding calculation, Embedded system automation, Bobbin-based winding system.

I. INTRODUCTION

The electrical power system requires transformers as its fundamental element for power generation and transmission and distribution and various electronic uses. Transformers function to transfer electricity between circuits by using electromagnetic induction while they maintain the circuit frequency and control the voltage output. Transformers find applications in various sectors including industrial sites, electrical substations, residential homes, battery chargers, and power supply systems. The entire power system depends on transformer reliability because their performance determines system efficiency and operational stability.

Transformer windings encounter operational failure during extended use because of multiple causes which include insulation breakdown and excessive heat and high current and physical stress and moisture exposure and natural aging processes. The failures cause short circuits which lead to reduced system efficiency and complete transformer failure. The transformer rewinding process restores equipment to original operational standards through the replacement of faulty windings with brand new components.
Highly proficient technicians at power plant facilities achieve their work through the manual operation of transformer rewinding equipment. The physical process requires multiple stages that start with determining the total number of turns and end with creating the actual winding on the bobbin after selecting the proper copper wire gauge and designing the winding layers. The calculations work through empirical formulas which operators use based on their professional expertise. However, manual rewinding has several limitations. Human errors in calculation, improper wire selection and incorrect turn counting can result in incorrect voltage output which leads to overheating and transformer lifespan reduction. The manual rewinding process requires excessive time and physical work while it produces random results which do not match established patterns.

Transformer operation requires correct calculation of winding parameters which include number of turns and turns per layer and winding thickness and wire gauge. The improper winding design will lead to higher copper losses and lower voltage regulation efficiency and rising temperatures. The winding design must ensure physical compatibility with the bobbin size to prevent insulation damage and mechanical system breakdowns.

Industrial processes have gained accuracy and efficiency and reliability through automation which became possible with embedded systems and microcontroller technology development. Microcontrollers can perform sophisticated

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operations through their capacity to process multiple functions at high processing speeds while they track system conditions along with their monitoring of motor functions. Automation decreases the need for human involvement which results in fewer mistakes and increased workflow efficiency.

Industrial control applications use microcontroller-based automation systems in motor control and robotics and CNC machines and automated manufacturing systems. Automated systems use rotary encoders to determine rotational movement and maintain precise control of turn counting. Automated winding machines which use microcontrollers and sensors and motor control systems will enhance transformer rewinding productivity.

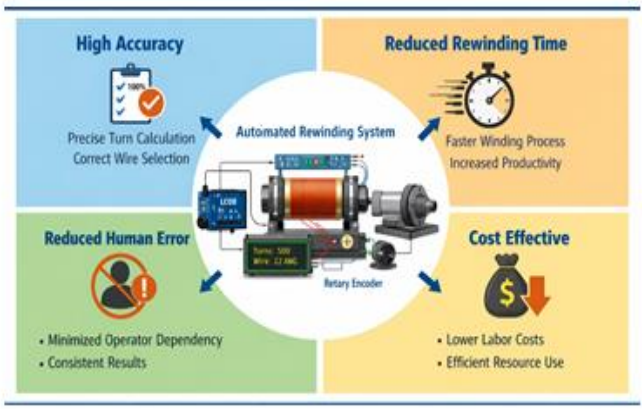

Fig. 1 Impact of Automated Transformer Rewinding system

II. LITERATURE REVIEW

Diana Celcan et al highlighted the importance of practical training for electrical engineering students, especially in understanding transformer operation. Limited laboratory infrastructure often creates differences between theoretical concepts and experimental results, as small power transformers behave differently from large power transformers. To address this issue, the study proposed a design procedure for small power transformers used in educational applications. This method helps achieve accurate operating characteristics. The procedure was successfully applied to design a 1 kVA dry-type single-phase transformer.

Faiz et al proposed an optimal transformer winding configuration and power electronic switches for designing a low-power electronic tap-changer. The optimization aimed to reduce the number of switches, minimize voltage and current stress, decrease transformer taps and improve voltage regulation accuracy while increasing voltage adjustment steps. A prototype electronic tap-changer was developed and tested. The results demonstrated improved performance, higher efficiency and better voltage control compared to traditional mechanical tap-changers, highlighting the advantages of electronic switching in transformer applications.

Manjrekar et al investigated the design of compact solid-state transformers using high-frequency transformers and switched-mode power converters. The study introduced AC-AC converter topologies with bidirectional switching devices such as IGBTs to reduce transformer size and magnetic core weight. By using a chopped AC link and reactive components, the system achieved efficient voltage transformation and isolation. The proposed design required only six switching devices, making it cost-effective. Simulation and experimental results confirmed improved performance, reduced size and practical feasibility of the solid-state transformer.

Mukaihata et al has reviewed the advent of microprocessors, the acceptance of a standardized interface system, and recent advances in computer and instrumentation technology have greatly reduced the cost and complexity of small automated-test systems. The principal interest in this paper is the type of system which incorporates a desktop computer as the controller interfaced with peripherals and equipment on a standard bus. Included examples demonstrate versatility, portability, high accuracy and precision, feasibility in assembly, and cost effectiveness.

Saracin et al presented the implementation of an experimental platform for an automatic transfer switch used to connect electrical loads to a backup power source during main supply failure. The system operates in automatic, manual and programmable logic controller modes. Grid fault conditions were simulated using voltage regulators and control circuits. The transfer operation depends on power supply status and minimum voltage levels detected through relays and controllers. The platform demonstrates reliable switching and introduces two technologies capable of achieving efficient backup power transfer.

Zinoviev et al has investigated the article evolution of the researches executed to Scientific laboratory `Energy optimization of power convertors' (EOPS) which can serve an innovative direction in the power electronics, connected with working out of power electronic transformers of an alternating current for needs electrical engineers and power is tracked. Three directions in construction of such transformers are considered: on converters with a direct connection, on converters with an intermediate link of the higher frequency and on converters with a DC intermediate link. The basic properties of converters of each direction are noted.

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The literature survey highlights various transformer design and automation techniques used to improve winding accuracy and efficiency. Previous studies have emphasized the importance of accurate turn calculation, wire gauge selection and automated motor control in transformer winding applications. Microcontroller-based automation and rotary encoder feedback systems have proven effective in improving precision and reducing human errors. These studies support the development of an automated transformer rewinding system that integrates calculation, wire selection and motor control to improve efficiency, accuracy and reliability.

III. DESCRIPTION OF THE EXISTING SYSTEM

The skilled technicians conduct all operations of the transformer rewinding process through their manual work. The process begins with identifying the transformer ratings which include both input voltage and output voltage and current capacity. The operator uses standard transformer equations and experience-based assumptions to calculate the required number of turns based on these values. The selection of wire gauge requires manual selection which uses approximate current density values as its primary method.

The winding process begins after all calculations have been finished through the use of either manual or semi-manual winding equipment. The technician uses hand operations to turn the bobbin or he can choose to operate it through a basic motor system while he counts the turns through manual methods or by using a mechanical counter. The method needs constant observation to achieve accurate counting of turns together with correct arrangement of layers. The process of winding needs to be performed without interruptions because any mistake in counting will result in faulty transformer output performance.

The proper verification process to confirm that calculated turn numbers will fit within bobbin dimensions does not exist in most situations. The overabundance of windings will result in either insulation damage or the need to restart the entire rewinding process. The system operates without automated speed control which limits its ability to maintain accurate motor operations with consistent performance.

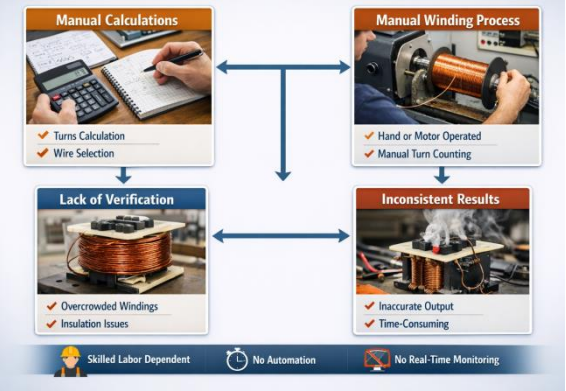

Fig. 2. Existing system of Transformer rewing system

The current system operates without any automation capabilities yet it does not provide real-time monitoring or intelligent calculation functions. The process requires too much time and has high labor demands while it needs operators to perform skilled work which increases the chances of errors and produces variable outcomes.

IV. CHALLENGES IN THE EXISTING SYSTEM

The existing transformer rewinding process faces several challenges that affect its accuracy, efficiency and overall reliability. One of the major limitations is the heavy dependence on skilled technicians to perform winding calculations and the physical rewinding process. The operator must manually calculate the required number of turns based on transformer voltage ratings, core dimensions and design parameters. Any mistake in these calculations can lead to incorrect output voltage, poor voltage regulation and inefficient transformer performance. Such errors may also cause overheating, insulation damage and reduced transformer lifespan. Another important challenge is the selection of the appropriate copper wire gauge. In conventional systems, wire gauge selection is often based on operator experience rather than precise calculation using current density methods. Incorrect wire selection can result in excessive current flow, increased copper losses and overheating. In some cases, undersized wire may fail due to thermal stress, while oversized wire may not fit properly within the bobbin, leading to insulation and mechanical issues. Accurate turn counting is also difficult in manual winding systems. Traditional methods rely on manual counting or mechanical counters, which are prone to human error. Even a small deviation in the number of turns can significantly affect transformer output and performance. Additionally, there is no proper verification to ensure that the winding fits within the bobbin dimensions, which may lead to improper winding and

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material wastage. The manual rewinding process is time-consuming, labor-intensive and lacks consistency.

V. PROPOSED SYSTEM

The proposed system is based on the theoretical concept of automating the transformer rewinding process using established electromagnetic principles and design calculations. The system aims to eliminate human errors associated with manual calculation and improve the accuracy, consistency and reliability of transformer rewinding. It follows a systematic approach that integrates transformer design theory, current density analysis and winding geometry evaluation to ensure proper transformer operation. The fundamental principle governing transformer operation is Faraday's law of electromagnetic induction, which states that the induced voltage in a winding is directly proportional to the rate of change of magnetic flux and the number of turns. Based on this principle, the number of turns required for the primary and secondary windings is calculated using standard transformer design equations. The number of turns is directly proportional to the applied voltage and inversely proportional to the magnetic flux density, operating frequency and core cross-sectional area. Accurate calculation of winding turns ensures proper voltage transformation, efficient energy transfer and stable transformer performance.

In addition to turns calculation, conductor selection is an important theoretical aspect of transformer design. The proposed system uses the current density method to determine the appropriate conductor size. Current density is defined as the amount of current flowing per unit cross-sectional area of the conductor. Maintaining an appropriate current density is essential to prevent excessive temperature rise, copper losses and insulation failure. By calculating the required conductor cross-sectional area based on load current, the system ensures that the selected wire can safely carry the required current while maintaining thermal stability and efficiency. Another key theoretical consideration is the physical feasibility of accommodating the winding within the bobbin dimensions. The proposed system evaluates the winding geometry by calculating the number of turns per layer, number of layers and total winding thickness. This analysis ensures that the winding can be properly arranged within the available space without causing mechanical stress, insulation damage or improper winding distribution. Proper space utilization improves transformer reliability and prevents winding failure. Furthermore, the proposed system follows a calculation-based and analytical approach rather than relying on operator experience or assumptions. This improves repeatability and ensures consistent transformer design outcomes. By integrating electromagnetic theory, current density principles and winding space analysis, the system provides a reliable theoretical framework for accurate transformer rewinding.

Block Diagram:

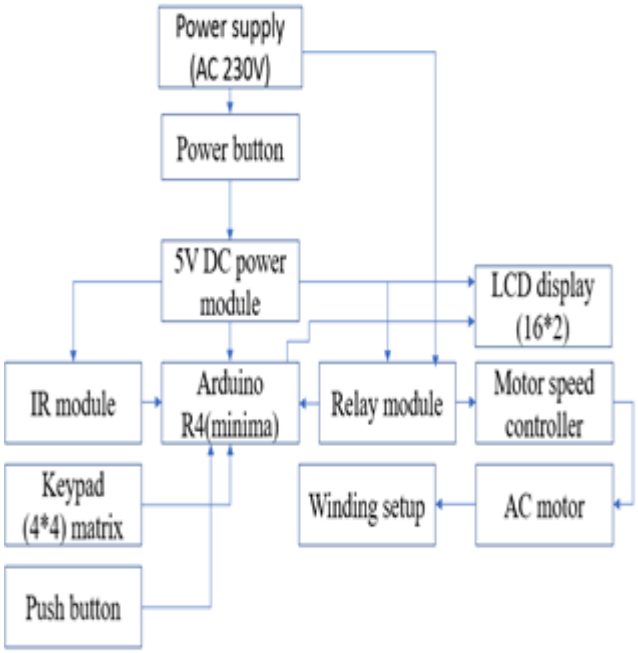

Fig. 3. Block diagram of the Proposed System.

The block diagram represents the overall structure of the automated transformer rewinding system, illustrating the interaction between power supply, control unit, input modules and output components. The system operates using an AC 230V power supply, which is connected through a power button for safe operation. This AC supply is converted into a regulated 5V DC using a DC power module to power the Arduino R4 Minima microcontroller and other low-voltage components. The Arduino functions as the central control unit, processing all inputs and controlling system operations. User inputs are provided through a 4×4 matrix keypad for entering transformer parameters and a push button for starting or stopping the process. An IR module is used to detect and count the number of turns during winding. Based on the received inputs and calculated parameters, the Arduino controls the relay module, which acts as a switching interface to operate the motor speed controller and AC motor.

Flow Chart:

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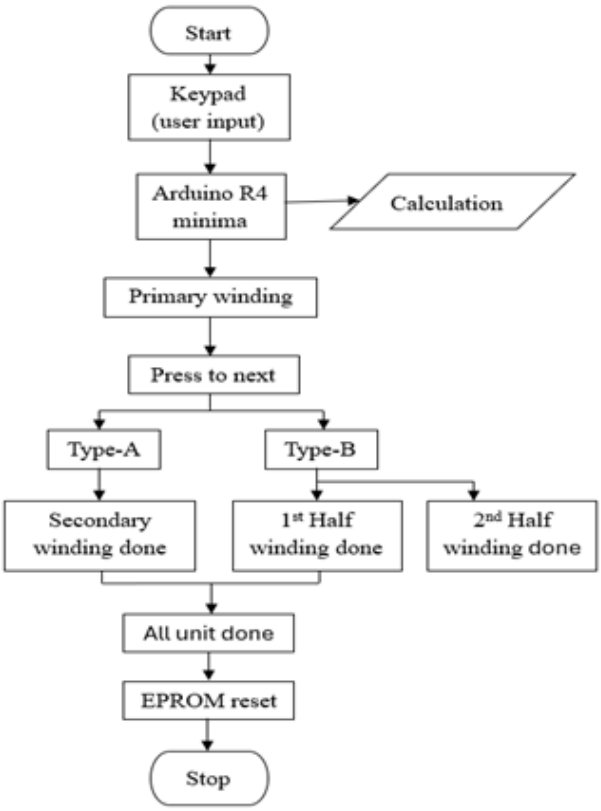

Fig.4. Flow Chart of Proposed System.

Hardware Implementation:

The hardware implementation of the automated transformer rewinding system is designed based on the integration of power supply, control unit, input modules and output driving components. The system operates using an AC 230V power supply, which is controlled through a power button and converted into regulated 5V DC using a DC power module. This regulated DC supply is used to power the Arduino R4 Minima microcontroller, LCD display and input devices. The Arduino R4 Minima serves as the main control unit, receiving inputs from the keypad, push button and IR module. The keypad is used to enter winding parameters, while the push button is used for system control operations.

Hardware components:

[i] Arduino R4 Minima: The Arduino R4 Minima is a microcontroller board that acts as the main control unit of the automated transformer rewinding system. It processes input data from the keypad, IR module and push button, and controls the relay module, LCD display and motor operation. It performs winding calculations, turn counting and motor control. The Arduino R4 Minima provides reliable performance, easy programming and multiple input/output pins for interfacing with system components.

Fig. 5. Arduino R4 Minima

[ii] Single Channel Relay Module: The single channel relay module is an electrically operated switch used to control high-voltage devices using low-voltage signals from the Arduino. It allows the microcontroller to safely control the AC motor and motor speed controller. The relay provides electrical isolation between the control circuit and power circuit, ensuring safe and reliable motor switching.

Fig. 6. Relay Module

[iii] LCD Display (16×2): The 16×2 LCD display is used to show system information such as number of turns, entered parameters and winding status. It provides real-time feedback to the user and improves system monitoring and usability.

Fig. 7. LCD Display

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iv] IR Module: The IR module is used to detect and count the number of turns during the winding process. It works by sensing interruptions or reflections of infrared light caused by the rotating shaft. The module sends signals to the Arduino for accurate turn counting. This ensures precise control of the winding process.

Fig. 8. IR Module

[v] AC Induction Motor: The AC induction motor is used to rotate the winding setup during the transformer rewinding process. It converts electrical energy into mechanical rotation, allowing copper wire to be wound around the bobbin. The motor provides smooth and continuous operation.

Fig. 12. AC Motor

[vi] 4×4 Matrix Keypad: The 4×4 matrix keypad is used for entering transformer parameters such as voltage, current and number of turns. It consists of 16 keys arranged in rows and columns. The keypad provides a simple and efficient interface for user input and system control.

Fig. 8. Matrix Keypad

[vii] Push Button: The push button is used to control system operations such as starting or stopping the winding process. It provides manual control and allows the user to interact with the system easily.

Fig. 9. Push Button

[viii] 5V DC Power Module: The 5V DC power module converts AC voltage into regulated 5V DC required for the Arduino and other electronic components. It ensures stable and safe power supply for proper system operation.

Fig. 10. Power Module

Working Of Proposed System

The proposed automated transformer rewinding system operates based on the integration of input modules, control unit and output driving components to perform accurate and efficient winding. When the system is powered using the AC 230V supply, the voltage is converted into regulated 5V DC through the power module to operate the Arduino R4 Minima and other electronic components. Once the system is activated, the user enters the required transformer parameters such as voltage, current and winding turns using the 4×4 matrix keypad. The Arduino microcontroller processes these inputs and calculates the required winding parameters based on transformer design principles. After receiving the input values, the Arduino activates the relay module, which allows power to be supplied to the motor speed controller and AC induction motor. The motor begins rotating the winding setup, causing the

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bobbin to rotate and allowing copper wire to be wound around the transformer core. During this process, the IR module continuously monitors the shaft rotation and sends signals to the Arduino for accurate turn counting. The microcontroller compares the counted turns with the calculated required turns. The LCD display provides real-time information such as entered parameters, turn count and system status, allowing the user to monitor the winding process. Once the required number of turns is completed, the Arduino automatically stops the motor by deactivating the relay module. This ensures precise winding and prevents over-winding. The entire process is automated, reducing human error, improving accuracy and increasing efficiency in transformer rewinding.

Implementation Of The Proposed System

The implementation of the proposed automated transformer rewinding system involves the integration of electrical, electronic and mechanical components to achieve accurate and controlled winding. The system is powered using an AC 230V supply, which is stepped down and converted into regulated 5V DC to operate the Arduino R4 Minima and associated modules. Proper grounding and isolation are ensured to maintain system safety and stability. The Arduino R4 Minima is programmed using embedded C through the Arduino IDE. The program includes routines for receiving input parameters from the 4×4 matrix keypad, processing winding calculations and controlling output devices. The keypad interface allows the user to enter transformer specifications such as required number of turns and other parameters. A push button is provided to initiate or stop the winding operation.

The relay module is interfaced with the Arduino to control the motor speed controller and AC induction motor. When the system starts, the relay activates the motor circuit, enabling rotation of the winding setup.

The IR module is positioned to detect shaft rotation and generate pulses corresponding to each turn. These pulses are counted by the Arduino to monitor winding progress in real time. The LCD display is connected to the microcontroller to provide continuous feedback, including entered values, current turn count and system status. Once the required number of turns is reached, the Arduino automatically deactivates the relay, stopping the motor precisely. The mechanical frame constructed using square metal pipes ensures structural stability and proper alignment of the winding setup. The implemented system demonstrates accurate turn counting, reliable motor control and efficient transformer rewinding with minimal manual intervention.

Fig. 11. Implemention of Proposed System

VI. RESULTS AND DISCUSSIONS

The automated transformer rewinding system was successfully implemented and tested under various operating conditions to evaluate its performance, accuracy and reliability. The system demonstrated precise control over the winding process by accurately calculating the required number of turns and stopping the motor exactly at the predefined value. The IR module provided consistent and reliable turn counting, ensuring that there was no deviation between the calculated and actual number of turns. During testing, the motor operated smoothly under the control of the motor speed controller, allowing uniform winding on the bobbin. The relay module effectively controlled the motor operation without delay or malfunction. The LCD display provided real-time updates of system parameters, including turn count and operational status, which improved monitoring and user interaction.

VII. CONCLUSIONS

The automated transformer rewinding system was successfully designed using the Arduino R4 Minima microcontroller, relay module, IR sensor, keypad, LCD display and AC induction motor. The system automated the winding process by performing accurate turn calculation and precise turn counting. The IR sensor ensured reliable turn detection, while the relay and motor control provided smooth winding operation. The system reduced human dependency and eliminated manual errors. The LCD display enabled real-time monitoring of system parameters. The proposed system improves winding accuracy, reduces rewinding time and enhances transformer performance. It provides a reliable and cost-effective solution

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for transformer repair and manufacturing, with future scope for advanced automation and monitoring.

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