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Automatic Transformer Winding Machine: Design, Analysis, And Practical Implementation

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Abstract: Transformers are important devices used in electrical and electronics appliances for voltage transformations. Traditional methods of transformer windings are done manually by experienced personnel. These methods are time consuming and difficult to achieve accurate count of the windings. To address these challenges, the mechanical process is automated by integrating a digital counter into the transformer winding machine to determine the total number of turns in both the primary and secondary windings respectively. In this paper, the design, implementation and testing of an automatic transformer winding machine is presented. It comprises of an automatic winding mechanism, a microcontroller program that can manipulate geared motor movement and a digital counter for counting transformer winding. The winding machine is a table-size limited for carrying out coil windings for small transformers of 10kV with an input and output voltages of 230V- 12VAC and a range of 0- 5000 turns. The device is a fully automated, very efficient & easy to maintain, accurate in counting and control and overall reduction in operating costs as compared to manually operated machines.

Keywords: Transformer, Winding, Counter, Turns-ratio, Coil

I. INTRODUCTION

Globally today, transformers have become basically important devices in electrical/electronics appliances. To construct any transformer, there must be coil windings basically in two sections; the primary winding and the secondary windings. These windings consist of number of turns in the primary (Np) and number of turns in the secondary (Ns). Conventionally, transformer windings are done manually by experienced personnel. This method takes a very long period to achieve accurate count of the windings. Recently, there have been an advancement in automation to many things that are done by using different instruments i.e to minimize the use of power, increased systems accuracy and reducing the time required for getting result, through automation process (Mulik & Rajkumar, 2015).

Automation in transformer winding process has been applied for effective, accurate, less time required and less manpower (Sarkar, Isaac, & Young, 2012). In this paper, microcontroller was utilized to control geared motor, counting circuit by the use of hall sensor that senses magnet, as well as LCD for display, and a buzzer representing the sound system. This project automatically reduces man power requirement during transformer winding process and to minimize time. The machine can be used not only as a coil winding but as well as thread winding of metal wire (Sarkar, Isaac, & Young, 2012). This transformer winding machine could serve as a learning equipment for practical applications to wind a mini transformer.

The dependence of skilled manpower for production of transformer winding and high cost of production due to the manual operation has been a great challenge in transformer production. The manual manufacturing of transformers requires long period and careful human effort. In order to mitigate these challenges, the mechanical process is automated by integrating a digital counter into the transformer winding machine. This will lead to reduction in operating costs and enhance large scale manufacturing.

This paper focuses on the design, implementation and testing of an automatic transformer winding machine (ATWM). It comprises of the design of an automatic transformer winding mechanism, writing a program that can manipulate stepper motor movement by the use of microcontroller and construction of a digital counter for counting transformer winding.

The winding machine is a table size limited for carrying out coil windings for small transformers of 10kV with an input voltage of 230V and output voltage of 12VAC, the number of turns the machine can wind is in the range of 0- 5000 turns. The size of the copper wire for winding other machines like large turbine, heavy transformers etc. that has 14 to 34 Standard Wire Gauge (SWG) or specifically 0.078-0.3125mm diameter copper wire is beyond the machine capability. It is specifically designed for transformers used in indoor electronics appliances like electric fan, grinder and transistor radio etc., commonly found in the household.

The device is a fully automated system for quality production to be achieved in minimum time intended to minimize manpower interference in large transformer production in less time. The device is very efficient &and easy to maintain, accurate in counting and control and overall reduction in operating costs as compared to manually operated machines.

II. REVIEW OF RELATED WORK

Automated precision coil winder has been constructed by Eseosa (2013) by the use of a microcontroller because of its low- power, high performance CMOS 8-bit microcontroller with 8 kilobytes programmable flash memory. It uses stepper motor, a form of synchronous motor, which rotates at precise angular distance (called step) for each pulse that is delivered to its driver circuit. An LCD to display the output number of turns and other readings, and a keyboard is used for the genetic 4x4 input keypad formed by an array of push button switches (Eseosa & Uhuwmwangho , 2013).

In a similar design developed by Shafie (2013), the project is controlled by two stepper motor using Arduino program, the two stepper motors which are bipolar and unipolar, the stepper motor is brushless and synchronous electric motor that converts digital pulses into mechanical shaft rotation. The unipolar stepper motor is used to move the carriage that controls the coil position and the round bobbin. The advantages of stepper motors over stopper AC to DC motors include no feedback requirement for position or speed control (open loop operation), non-cumulative positional errors, precise electric speed control using digital technology and compact size for driving large loads at low speed (Sarina, 2013).

Arduino has also been used in transformer winding automation because it is a complete, breadboard friendly, and small board based on ATMega 328 which operates on 5VDC and a servo motor that operates at a typical 5V producing a torque of 2.5kg/cm with an operating speed of 0.15/60^{o}. It uses Geared DC motor aimed at minimimizing the scale and cost of the system, the geared DC motor is easy to control, program, and also cost effective (Sonaskari, Saurabh , Neema, & Prateek , 2021). The project uses potentiometer placed in semi-circular pattern placed between two terminals.

The use of Relay (Double pole Double Throw), two different electrical circuit and magnetic device that connect to an electromagnetic relay could also be used for winding machine. In this design, transformers are used to step down the supply from input voltage 230V to 15VAC which is converted to 15VDC through rectifier and a filter circuit (Ikhankar, Rakhi , Ankita , & Trupti , 2016). In this work three DC motors are used for different purposes i.e first motor for rotation of winding platform wheel inside the chamber, second for moving the winding platform in or out of chamber and third for opening and closing of door. The time is set in sequential controller and observed so that the time that has been set is working or not at regular interval and the moisture and temperature are also measured by using moisture sensor and thermostat (Ikhankar, Rakhi , Ankita , & Trupti, 2016)

Another design of automatic winding machine by Nakshane (2019) uses a stepper motor which has a torque (kg.cm). The motor is carefully sized to the application in respect to torque and speed and an Arduino which is a microcontroller, motor driver which is breakout board for allegro's A4988 micro stepping bipolar stepper motor. It features adjustable current limiting, over current and over-temperature protection and five different micro step resolutions. It operates from 8V to 35V and can deliver up to approximately 1A per phase without a heat sink or forced air flow. A Bluetooth HC o5 is used for wireless communication. This module can be used in a master or slave configuration. In the coil winding machine, two stepper motors are used one for rotation motion and another is used for linear motion. These two stepper motors run in synchronization such that the revolution of shaft slider advances according to the diameter of bobbin (Nakshane, Gulshankumar, & Mohan, 2019).

III. DESIGN ANALYSIS

The design procedure follows the block diagram presented in figure 1 using readily available components listed and analysed in the subsequent pages.

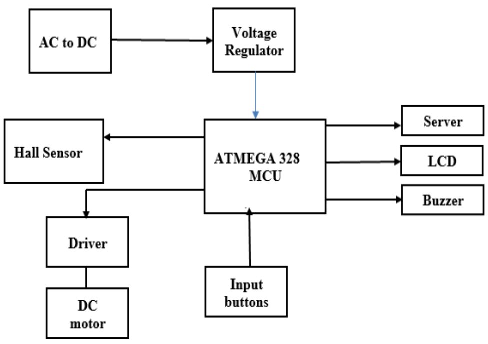

Figure 1: Block diagram of Automatic Transformer Winding Machine

The AC to DC circuit uses an adaptor that steps down voltage with rectification circuit which steps down 230VAC to12VAC before converting to 12VDC as an output.

DESIGN PROCEDURE

The structural parts of the construction is made up of a wood and conduit pipes based on our proposed design. The control box consists of the central processing unit with a breadboard made up of the components that control the system. The system is controlled by ATMEGA 328 which is a single chip programmed with many instructions on it. This chip requires only 5VDC to operate and the expected supply is 12VDC. LM319 voltage regulator is utilized in the circuit to manipulate the input voltage to 5VDC to power the microcontroller.

GEARED MOTOR CONNECTION

Geared motor is connected to the chip which is used to drive the bobbin or core during winding process, but it requires a 12VDC to operate. Initially we have already regulated our voltage from the supply to 5V, so we use MOSFET between the motor and the microcontroller so that the MOSFET will open the gate by increasing the voltage to 12V required by the geared motor. The microcontroller instructs the geared motor to ON/OFF based on the design.

Figure 2: Geared motor

DESIGN OF LCD DISPLAY UNIT

The LCD operates with 4.7V to 5.3V, it is connected to the microcontroller which supply input voltage to it and at the same time instructs the LCD to display when necessary.

Figure 3: LCD display

HALL SENSOR CONNECTION

The hall sensor is connected to the chip, it senses the presence of magnet which is placed under the shaft of the geared motor and a magnetic steel attach to the rotor of the geared motor, it is operated with 5V from the chip. Under normal condition of this sensor, the resistance will be high but immediately it senses magnet the resistance becomes low and the chip senses that signal and count on the display. The hall sensor helps in terms of accurate winding count.

Figure 4: Hall sensor

BUZZER CONNECTION

The Buzzer is connected to a chip which receive voltage signal from the microcontroller, immediately the microcontroller sends a signal to it, it will make a beep sound.

Figure 5: The buzzer

MICRO SERVO

The micro servo is connected to the chip which has a mechanical moving part used as a distributor to a bobbin or core that is placed to the rotor of the geared motor. It also controlled by the microcontroller and a regulator is connected to the servo for controlling the speed of the movement. There are input buttons which serve as a keyboard that input/select data to the control box.

Figure 6: Micro servo

IV. IMPLEMENTATION OF THE ATWM

The design has four input buttons, switching button which is connected between the voltage regulator and the supply input, while up button, down button and OK buttons are all connected to the chip for it to receive an input signal. All these devices are connected to the microcontroller which instructs them according to the program that has been programed on it, that can allow it to control all the devices at a time so fast in such a way that it reacts in less than 4 second.

The automatic transformer winding machine requires 12VDC input in which the supply is 230VAC that pass through the process of stepping down and rectification circuit. An adaptor which converts the input supply from 230VAC to 12VDC for the input to the machine is connected directly to the voltage regulator to control the voltage to 5V for to the microcontroller chip which is in charge of controlling all the main components in the control box.

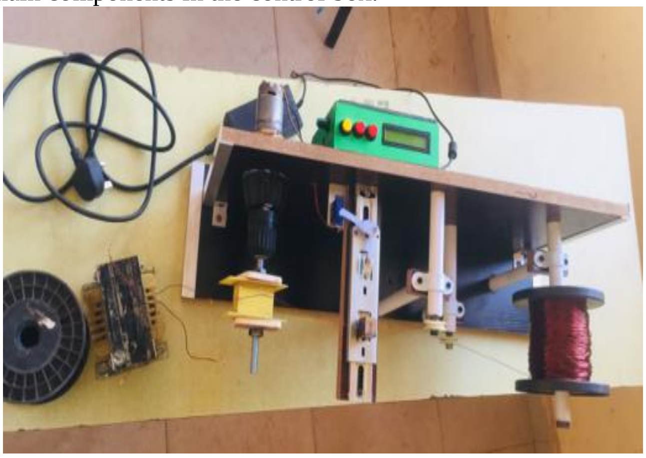

Figure 7: Assembled transformer winding machine and accessories

A sample of a transformer has been done, that steps down 220V to 12VAC by using automatic process and accurate result has been obtained, using a voltmeter to measure the primary voltage and secondary voltages, the results are presented in figure 8 and 9 respectively.

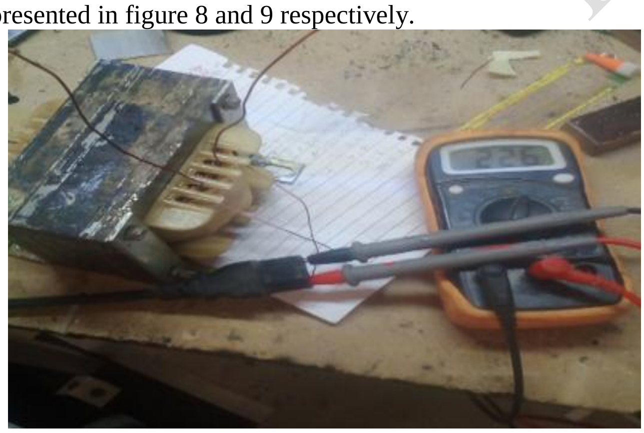

Figure 8: Designed sample transformer showing input voltage (226VAC)

Figure 8: Designed sample transformer showing output voltage (12.0VAC)

V. CONCLUSION

This Automatic transformer winding machine has been designed for use basically to eliminate the dependence of skilled man power in the process of winding. It is also effective and efficient with accurate results in the turns-ratio. This machine can be employed in industries for production of small transformers with ease. It could also be used in institutions for conducting practical on transformer windings. This machine is not only designed for coiling transformer, it can be also used in thread or wire industries for coiling.

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