

Controlling the Variac Through Arduino with Remote Access Control Using the Stepper Motor

C. Jeeva, Tejas Malik, Ratnesh Kumar Singh, Aman Aditya

Abstract: *In this paper being presented, we propose designing the controlling system using an Arduino Uno microcontroller board for an auto-transformer attached to a permanent magnet stepper mechanism. We can create a control model by employing a stepper motor regulated with an Arduino Uno board. In the presented method of Arduino plug-in control-based design, altering between states is attained by event triggering or provisional modification like a manual operator input which is maintaining the probable voltage output in autotransformer. The system involves the interconnection of drivers to the stepper motor connected to the autotransformer with the help of gear arrangement. The stepper motor was controlled through an Arduino Uno microcontroller board and as per the program requirements as per the application output through variac. The Arduino is fueled by a battery and a LED is linked for its indication.*

Keywords: *Arduino Uno, Alternating current source, command algorithm, Auto-Transformer, Stepper Motor, Drivers, microcontroller board.*

I. INTRODUCTION

In the existing situation the variac are generally controlled manually by rotating the variac control knob i.e. by increasing or reducing the resistance as the knob is rotates by 360° and inspecting the voltmeter for preciseness and accurateness. This system is not only irksome but also the errors crept in and much time is taken to rectify the errors. Thus, a control system is designed which not only controls the outturn voltage as per the requirement, but it also provides accuracy with preciseness in output. Everyday original and inexpensive control apparatuses are established. One of the existing control apparatus and very trendy is the Arduino micro-controller board. Arduino Uno is basically a free open source application based on microcontroller having essential I/O (input and output) abilities. It can be encoded on every operating system with the Programming Language.

The use of Arduino with stepper motor is proposed here in which through using some programmable codes as per the requirements of the application the steps of stepper motor is controlled which is connected to the variac and hence acting as an automated rotary knob for rotation, thus ultimately controlling the desired output voltage. The programming is through the god of all computer languages i.e. Embedded “C”. The Arduino contains an Atmega minicomputer and digital I/O pins with added advantage of analog I/O pins. For the connection of stepper motor to the microcontroller board, a driver named ULN2003 is used. Here, it is notable that rotation of stepper motor and in turn, the variac knob can be controlled distantly, using rotary encoder which is interfaced with stepper motor with the virtue of wi-fi module, over a specified range. Thus, controlling the auto-transformer voltage from a certain distance, within the specific range of module.

II. EXISTING WORK

Automation is happening rapidly everywhere in the world through modifying or automating the process, but there has been sluggish development in automating the core electrical equipment's. The naïve nature of technology clearly states that the use of Arduino for the automation of the core electrical equipment has been mostly in the pilot level. The state of undertakings is analogous everywhere in the realm. There has been various proposed model for the automation of variable voltage transformer but has not been implemented successfully through the remote access control. In India, during the event of Innovation organised by the multi-national company “Accenture”, a team from B.P Poddar Institute of Management and Technology, Kolkata proposed the automated working of variac with the of stepper motor through the Arduino, but the remote access control. Electrical equipment manufacturer company “Voltamp”, based in Mumbai, India manufactures auto-transformer which is motorised in nature. Certain models are existing in the world in which the variac is controlled remotely with the help of PLC/PC. An Arduino regulated variable ac power source has been put forward by the scholars of Sakarya University, Turkey which is grounded on the source of Finite state Machine (FSM) employing DC motor. The existing system lacks in precision and accuracy while getting the desired output voltage and sometimes adjusting knob is time consuming process.

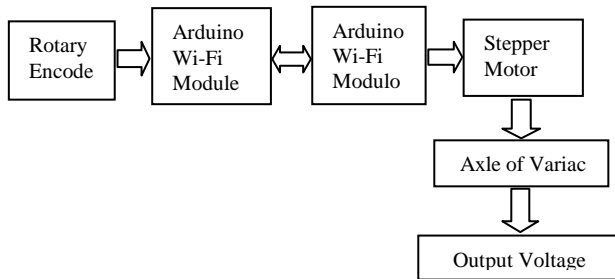


The process is extremely conventional and thus can be automated as per the industry standards. The other challenges include automation of controlling the variac, designing of control for the variac with respect to the industry standards and in an economical manner which can, not only deliver the output as required but also reduce the technical labour as well as financial distress.

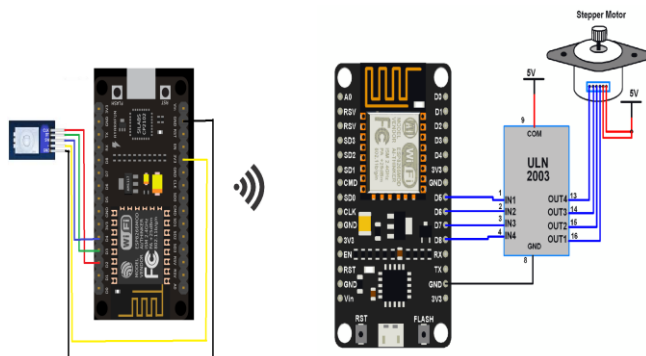
III. PROPOSED WORK

3.1 Process Flow

This work is about communicating a stepper motor (which is connected to variac sliding brush) with a rotary encoder via Wi-Fi module installed on the Arduino microcontroller board (NodeMCU ESP8266). ESP8266 is reasonably priced standalone with built in WiFi module. The NodeMCU are the elite way to program and research with ESP8266. NodeMCU is open source bundled software based ESP8266 WiFi soc. So, this means that an auto transformer voltage can be controlled anywhere and anytime. Due to its portability, the stepper motor can be operated within 1.8 km of range. The stepper motor cannot be completely coupled to the Arduino. So, a driver named ULN2003 is used to interface motor to the microcontroller board. By this, the stepper motor will follow the rotary encoder with same speed and position of its axle. An Arduino to Arduino wireless communication is set up that means an Arduino is coupled to the rotary encoder and stepper motor.



(Fig-3.1.1 Process Flow Block Diagram)



(Fig-3.1.2 Circuit Diagram)

3.2 Programmable Interface

Arduino microcontroller board is an O.S.P. (Open Source Platform) used for linking electrical apparatuses with the processor. Furthermore, it is used for computerization of a network. According to this paper, Arduino is programmed to rotate the stepper motor portably and wirelessly from our

finger tips. A wi-fi module is attached with Arduino on rotary encoder as well as another wi-fi module on the Arduino, which relates to the stepper motor. Software named “Arduino IDE” is a tool for programming the required codes of the research. The following software contains the specified program and is generated and compiled on Arduino Uno hardware. Wi-fi module installed on the Arduino gives the distant access control over the stepper motor. Arduino is most accurate, stable and efficient hardware for industrialization and computerization.

3.3 Rotary Encoder

Rotary Encoder also called as channel encoder, is an electro-machine-driven mechanism which is exercised for revealing the angular locus of a rotating channel and converts position of the axle to an electrical signal, either analog or digital signal, according to rotational movement. In this paper, it is used with Arduino which is programmed to rotate the stepper motor and hence, the sliding brush of variac. The rotary encoder is the initialization or input side of this set-up. As the axle of the rotary encoder is rotated, the stepper motor follows the same instruction. It determines the turning angle and locus of the channel encoder and permits the result to Arduino microcontroller board. The stepper motor rotates in the similar direction, with the same speed and same number of rotational angle and position.

3.4 Stepper Motor

Stepper or Stepping motor is brushless electric motor which rotates in equal step angles to complete full rotation. Stepper motor is the output side of this proposed model. It rotates with the commands of rotary encoder and provides desired output voltage by controlling the position of variac sliding brush contact. As the stepper motor rotates, the sliding brush of variac rotates with same speed and same direction. The stepper motor cannot be directly connected to Arduino as it needs a driver named ULN2003 for its interfacing to the microcontroller board. The driver ULN2003 is a collection of seven NPN Darlington transistors connected in an array. Therefore, as the position of the sliding brush on secondary winding changes, the output voltage varies. In the proposed model of automatic variable voltage transformer, the stepper motor is a driver which rotates the knob of variac accordingly. Now the shaft of stepper motor (NEMA 17) is interfaced with variac. The connection of the stepper motor with transformer is achieved with the help of gears. Here, two external helical gears are used and while connecting the stepper motor to the auto-transformer with the help of gears proper care was taken to overcome the friction and rotational inertia for the required rotation and movement of the axle to get the desired output. A peripheral gear has teeth formed on its superficial of a cylinder and thus 2 gears are linked in cross configuration. Here the cross arrangement of the two gears not only make the system compact in size but also resourceful as well as competent. Here the sum of teeth of gears is purposely taken to be 200, since the step angles of 1.8° has to be achieved in the stepper motor. As the total number of steps in 1 full rotation will be: -

$$360^\circ / 1.8^\circ = 200 \text{ steps.}$$

The gear used on the stepper motor shaft and the one used on the axle of variac must have the gear ratio 1:1,

because as the power is transmitted from one gear to other; speed, direction, and force should be essentially same. Therefore, as the stepper motor rotates with the input from the rotary encoder, it in turn rotates the primary gear connected to the motor which in turn rotates the secondary gear which is connected to the axle of variac and thus ultimately rotating the shaft so that the desired output voltage from the variac is obtained. The data from different samples were taken from different manufacturers for the torque requirements to rotate the brushes of auto-transformer. The average of the data was taken and thus approximately the torque was calculated to be 11.5 N-cm for the proper rotation of shaft. Therefore, the stepper motor needs to transmit at least of 11.5 N-cm of torque with the gear arrangement to the shaft of variac. The stepper motor used in the model is NEMA-17 (42BYG228). This model is having unipolar drive system with,4 poles,2 windings. The holding torque of the motor is 19.61 N-cm which is appropriate for moving the brushes of variac axle by means of external helical gears in crossed configuration. It is to be notable that strength of gears is much to be considered as the breakdown of gear may cause whole system failure.

3.5 Distant Access Control

Though there are numerous ways to establish distance access control, but as per our model we have achieved this distance access control by the process of wireless communication which is efficient than some of the other conventional methods and the range of operation can be approximately 1.8 km. To establish a wireless fidelity the feature of inbuilt wi-fi module of Arduino is used. Rotary encoder here acts as position sensor to regulate the position of stepper motor. As per our hypothesis we have described above about the stepper motor and the sliding brush are connected and auto-transformer position is fixed. Whereas the rotary encoder is portably used and can also access the stepper motor from anywhere within the range of wi-fi module i.e. approx 1.8 km. Here the connection is established by using two wi-fi module which are ready to communicate with each other and in turn stepper motor gets connected to shaft wirelessly. The ESP8266 can host an application or unload all networking function from another processor. As the axle of the rotary encoder is moved the stepper motor is also rotated by the same speed and angle which in turn rotates the sliding brush of autotransformer and we get the desired output voltage. This whole process is executed using a wireless communication between the stepper motor and rotary encoder.

IV. RESULT ANALYSIS

3.1 Theoretical

As per the name plate rating, the maximum output voltage which and total number of turns in autotransformer which is used in laboratory: -

Total number of turns in winding = 256

Total output voltage = 270 V

So, for 360° step angle, the output voltage is 270 V.

Therefore, for n° step angle, the output voltage is: -

$$\frac{270}{360} * n$$

For calculating total number of turns covered according to step angle: -

In 360° step angle, the total number of turns covered in secondary winding is 256. So, for n° step angle the total number of turns covered in secondary winding: -

$$\frac{256}{360} * n$$

(Table 4.1 Observation Table - Theoretical)

Step Angle (Θ)	No. of turns per step angle (N ₂)	Output Voltage per step angle (E ₂)
45°	32	33.75 V
90°	64	67.5 V
135°	96	101.25 V
180°	128	135 V
351°	250	263.25 V

3.2 Practical

Input supply to the autotransformer is 230 V. So, using transformer ratio: -

$$\frac{E_2}{E_1} = \frac{N_2}{N_1}$$

where, E₂ is the output voltage of autotransformer

E₁ is the input voltage of autotransformer

N₂ is the total turns in secondary winding of autotransformer

N₁ is the total turns in primary winding of autotransformer

In autotransformer,

N₁ = Total number of turns in autotransformer – N₂

So here,

N₁ = 256 - N₂

$$\frac{E_2}{230} = \frac{N_2}{256 - N_2}$$

(Table 4.1 Observation Table - Practical)

Step Angle (Θ)	No. of turns per step angle (N ₂)	Output Voltage per step angle (E ₂)
45°	32	32.85 V
90°	64	65.71 V
135°	96	98.57 V
180°	128	131.43 V
351°	250	256.70 V

As shown above, from the theoretical calculations and the practical observations the output voltage is nearly equal for different step angles as per the required output which not only implies that the results are verified but also proves the system to be efficient, sufficient and effective. The practical observations obtained above are also supported for its accuracy by the transformation equation of transformer.

$$\frac{E_2}{E_1} = \frac{N_2}{N_1}$$

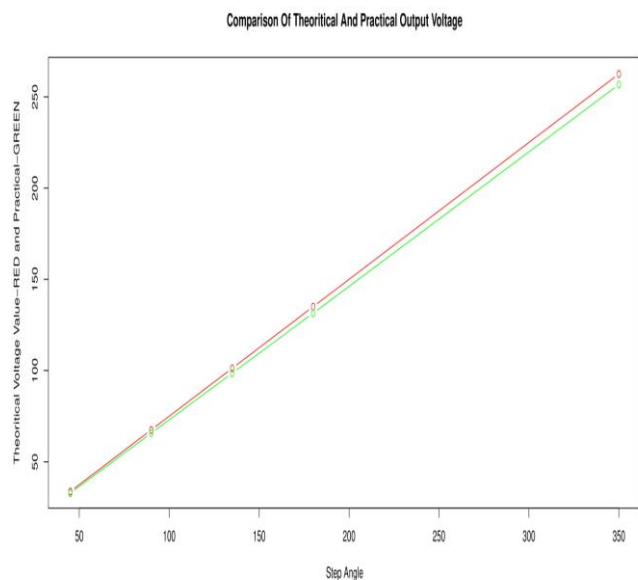
Here,

N₁ = 256 - N₂

$$\frac{E_2}{230} = \frac{N_2}{256 - N_2}$$



Where the output voltage from this formula comes out to be nearly equal with respect to the practically observed output. Thus, again verifying the observed result. As shown follows is the graphical comparison of the practical and theoretical output voltages, where the two curve shows nearly same linearity. Thus, showing nearly no difference between the theoretical and practical voltages.



(Fig 4.3 – Theoretical and Practical Graph)

V. RESULT

Computerized automation is pivotal for the reason of its precision over analog systems and components in controlling variac. Due to automations increasing usage, our proposed work can be implemented for controlling voltage from distant area. Our proposed model not only includes the principles of industrialisation but also an introduction to the concepts of Internet of things. The benefit we get from our model is that it completely eliminates man work or manual labour. Our idea also includes about principles of basic electrical machines and mechanics of gear system. We have endeavoured to apply precision over the existing instruments by modifying its process of operation. The circuit construction is very easy and simple due to less number devices used in it. It is a direct plug in and plug out system. This is an efficient system that will open future opportunities for development of other devices which operate on analog system. The technology with respect to voltage controlled variac comes at high cost. The foregoing would help the market which is currently manufacturing dial based analog varices with no digital control. Arduino, the programmable interface is used under this proposed model. There will be a Wi-Fi installed over the Arduino which would help communicate rotary encode with stepper motor. Arduino would sense the output of the rotary encoder real time and control the sliding brush of the auto transformer. Hence, we will get our desired output voltage without any issues. As per our analysis, our propose model can withstand any sort of problems faced in manual working

of an autotransformer. This project goes beyond the current single and three phase auto transfer which is used in various technical activities. The underlying idea of our project is computerization of existing technology. The proposed new model is more accurate than existing auto transformers. This is an efficient and precise way of changing voltage of the variac.

VI. CONCLUSION AND FUTURE SCOPE

We have proposed or designed an integration of Wi-Fi module, rotary encoder and Stepper Motor for mechanization or automation of variable voltage transformer through Arduino control. Wi-Fi module provides us with the facility of distant access control along with help of rotary encoder. The method is simple can be easily implemented with respect to India and elsewhere in the world. The development in this automation process will not only be of great benefit to the industry but also increase the efficiency of various other operations where an auto transformer is required. Wireless transmission of our integrated system can be useful for adjusting output of electric train transformer. This system can be used in various substations away from the control room. Due to its advantage of portability and wireless transmission, the output can adjust anywhere within its range. Furthermore, using the technology Internet of Things (IOT), our incorporated system will surpass any other existing models of manually controlled variac. This technology would be useful for various other sectors. It can further be used for domestic appliances at commercial places. The idea is still at a nascent or developing stage which with research in depth and efficient design, can be easily deployed.

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Tejas Malik has completed his 10th and 12th from Indraprastha International School and his B. tech from SRM Institute of Science and Technology. He is currently working in DXC technologies. He is an eager beaver and is fascinated by the new technological innovations and advancements happening all around the world. In the context, He make concerted efforts in keeping himself abreast with exciting and emerging technologies beyond his core engineering field. Besides his academics, he kept himself engaged in activities and programs at his college and school. His involvement in various social events has allowed him to work closely with his peers while supporting the school and college community, which experiences have helped him develop strong leadership and communication skills.



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