SOLID STATE ON LOAD TAP CHANGER FOR TRANSFORMER USING ARDUINO

Vivek Thomas Chacko[1], Mohamed Noufal P[2], Nidhin Mohan P[3], Sriram Vinod B[4], Eldhose K A[5]

[1,2,3,4]*Student, Electrical and Electronics Engineering, Mar Athanasius College of Engineering, Kothamangalam*
[5]*Professor, Dept. of Electrical Engineering, Mar Athanasius college, Kerala, India*

Abstract - *The on-load tap changing (OLTC) regulators have been widely used since the introduction of electrical energy. They ensure a good regulation of the output voltage in presence of large variations of the input voltage with typical response time from several milli-seconds to several seconds. Earlier mechanical type of on load tap changers were into practice. But they had considerable limitations and drawbacks like arcing, high maintenance, service costs and slow reaction times. In order to overcome these limitations and drawbacks electronic (or solid-state) tap-changers were developed. The continuous growth of power semiconductor devices, such as the insulated gate bipolar transistor (IGBT), Triac, Thyristor, has allowed the development of quick operating OLTC regulators. The major idea in the solid-state-assisted tap changer is that solid-state switches with more controllability, operates during the tap-changing process instead of mechanical switches which helps in reducing the arcing phenomena during the tap-changing process. In this paper implementation of a fast OLTC regulator is presented. The control strategy is Arduino-based, ensuring flexibility in programming the control algorithms. The experimental results demonstrate that the fast OLTC is able to correct several disturbances of the ac mains besides, the long duration in variation in time is much lower than the one corresponding to the traditional regulators.*

***Key Words*: On-load tap changer, voltage regulator, static switch, Optocoupler, OLTC.**

1. INTRODUCTION

The main application of a tap-changer regulator is to regulate the amplitude of the output voltage. The major objective of the controller in the tap-changer system is to minimize the fluctuation of voltage amplitude with respect to the reference voltage of the regulation bus. This bus should be far from the secondary of the transformer. The controller must regulate the voltage within a given range [1]. Power quality is also one of the most important thing these days. Both the power utilities and consumers are quite concerned with the quality of the power supply. This needs the supplies to be at its optimum value so that the cost is efficient; otherwise problems such as over voltage, under voltage, voltage swell, voltage sag, noise and harmonic caused by the disturbances in power supply could be disastrous. Several methods have been suggested and applied as the solution of these problems. One of the methods is by employing an on-load power transformer with tap changing, where the output voltage of the power transformer remains constant irrespectively to the input voltage or variation of the load. The existing mechanical on-load tape changing power transformer has few disadvantages as it produces arcing, requires regular maintenance, service costs, and slow reaction times [2]. With the use of high power semiconductor devices such as Triac, IGBTs, Thyristor, problems related with the mechanical on-load tap changing power transformer have been eliminated. In order to overcome these limitations and drawbacks, new circuits and configurations for tap-changers have been introduced. These may be classified into two groups [4].
A. Electronically assisted (or hybrid) on-load and
B. Fully electronic (or solid-state) tap-changers
The first circuit for the hybrid tap-changer was presented in 1996 [5]. This structure reduces the arcing considerably. However, its major disadvantage is that although two thyristors are ON over short periods during the tap-changing process, it is permanently connected to the circuit of the deviation switches and it probably gets burnt. This may therefore reduce the reliability of the system. Advantages of solid state tap changer include:

1. Avoids arcing during tap changing.
2. Less maintenance cost as compared to mechanical tap-changer.
3. Low cost.
4. Fast operation as compared to mechanical OLTC.

1.1 Block Diagram

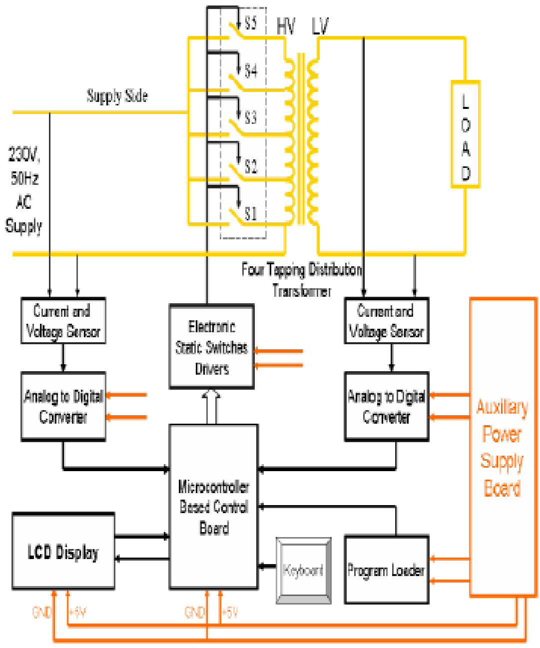

Fig -1: Block Diagram

The block diagram in figure 1, shows all the major components that is required for a solid state OLTC controlled by a microcontroller (arduino). A transformer with taps on the primary side is taken. The input voltage variations are recognised by the voltage sensor (rectifier circuit) at the primary side. This voltage is then given to a ADC of the arduino which converts the analog, alternating voltage at the sensor output to a digital value. Arduino triggers the desired electronic static switch (Triac) as per the programming logic. These static switches are connected to the taps of the transformer. So, triggering a switch means selecting the tap. An extension of this operation is applicable to the secondary side of the transformer too. The terminal voltage of the transformer falls due to loading. The voltage dip in the secondary can be sensed by a voltage sensor. The ADC at the secondary side produces the necessary digital signal. Then as per programming the desired tap can be selected. This paper proposes a solid state tap changer taking into consideration of input voltage variations at the primary side of the transformer.

1.2 Transformer Design

A transformer was designed as shown in figure 2. The transformer was provided with 5 taps each at 10V difference on primary side. The secondary voltage was designed to be at 230V having 1150 turns.

Primary voltage taps: 210V 220V 230V 240V 250V.
Number of Turns: 1050 1100 1150 1200 1250.
turns respectively. Transformer is based on the equation,

$N2 / N1 = V2 / V1$

Here N1, V1, N2, V2 are primary and secondary voltage and turns respectively.

Here N2 as well as V2 is constant. So as per the above equation, V1/N1 should be constant. Or in other words, for an increase in voltage there should be a proportionate increase in the number of turns.

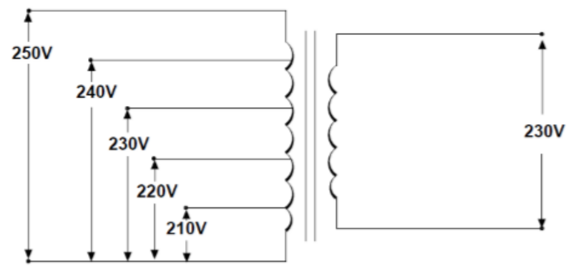

Fig -2: Transformer Design

1.3 Switching Circuit

An optocoupler based switching circuit is shown below in figure 3. The optocoupler houses a led and an optically triggered triac. When a high signal is given to pin 1 of optocoupler (MOC3041) the led within the optocoupler glows which in turn optically triggers the internal triac (figure 4). As a result the triac in the load side(figure 3) receives a gate pulse and connects to the 240V ac side. Thus a high signal to the optocoupler can connect the load to 240V load side. The optocoupler acts as a gate driver to the triac.

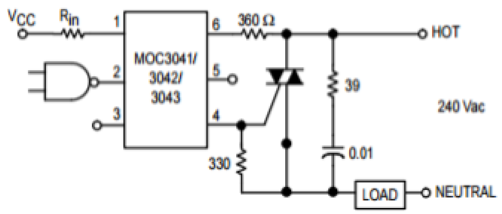

Fig -3: Switching of Triac by Optocoupler (MOC3041)

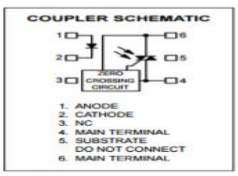

Fig -4: Schematic of Coupler

1.3 Voltage Sensor: Rectifier Circuit

A rectifier circuit is shown in figure 5. The secondary voltage of the step down transformer was rectified using a bridge rectifier. The main purpose of this circuit was to make the stepped down ac voltage of transformer to a fairly approximate dc (though pulsating dc was obtained).The arduino can only respond to analog values having less amplitude variation and not to the sine wave obtained on transformer secondary.

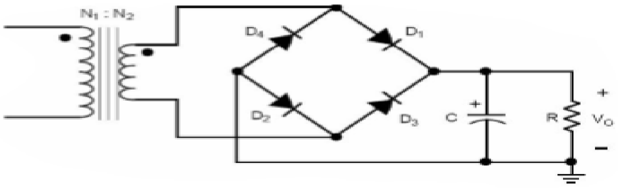

Fig -5: Bridge Rectifier

2. CIRCUIT DIAGRAM

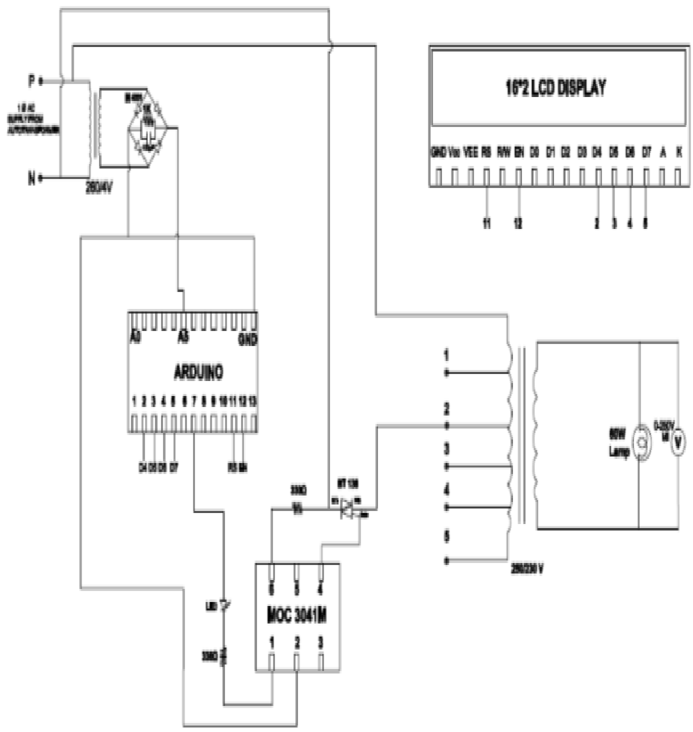

Fig -6: Circuit Diagram

2.1 PROGRAM FLOW

Tap selection logic is shown in figure 7. The arduino continuously reads the value of the input voltage using it's analog pin. It checks whether the input voltage is within prescribed voltage limits. If the voltage is within the predetermined limits the tap corresponding to that input voltage is selected. If not, arduino checks for another condition. This process is repeated until a match is obtained.

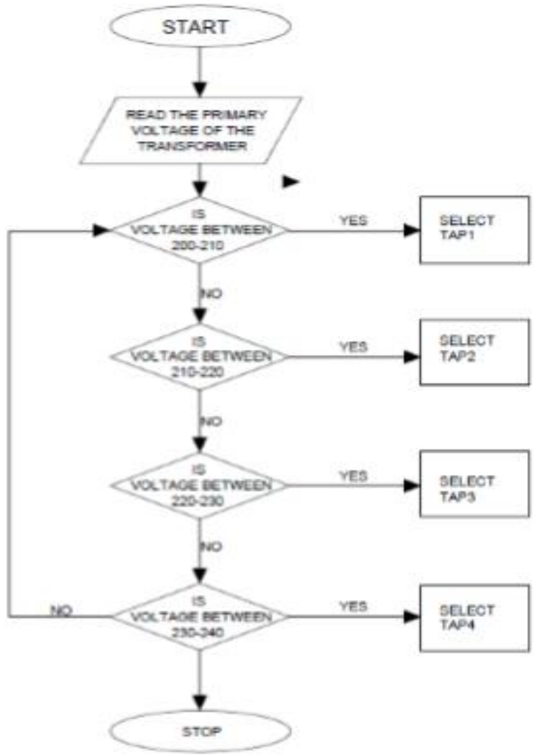

Fig -7: Tap Selection Logic

2.2 WORKING

The input voltage variations are stepped down to(0-4V) range by step down transformer. This voltage is rectified by using a bridge rectifier. This pulsating voltage was given to analog(A5) pin of arduino. As per the programming logic, the arduino triggers the triac connected to desired tap, using the optocoupler switching circuit. Thus the output was held at a constant voltage of 230V for input voltage variations

3. HARDWARE IMPLEMENTATION AND RESULTS

The input voltage variations were detected and the triacs connected to the corresponding taps were triggered with the help of arduino. The lamp load had a constant voltage of 230V irrespective of input voltage variations. Finalised hardware is shown in figure 8.

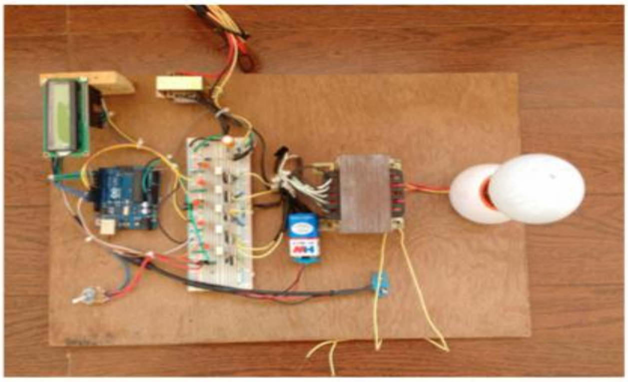

Fig -8: Completed hardware

4. CONCLUSIONS

In this work a fully electronic tap changer with five taps that located at high voltage side of transformer is designed and built. Any variation at the output voltage of the distribution transformer will be sensed by the microcontroller and compare with the reference value as per the program. This will produce appropriate command to trigger the appropriate triac for change in the suitable tapping of transformer. The system stability is improved, because of quick response. Because of static devices, maintenance cost is reduced due to elimination of frequent sparking. Output voltage can be regulated in the range of 5 V of nominal voltage. The proposed OLTC has got several advantages they are:

1. Avoids arcing during tap changing.
2. Less maintenance cost as compared to mechanical tap-changer.
3. Low cost.
4. Fast operation as compared to mechanical OLTC.
5. Less labour required as compared to mechanical OLTC.

ACKNOWLEDGEMENT

We take this opportunity to extend our sincere thanks to all the members of the Department of Electrical & Electronics Engineering, Mar Athanasius College of Engineering, Kothamangalam for sharing their valuable comments during the preparation of the project.

REFERENCES

[1] Jawad Faiz, Behzad Siahkolah, New Controller for an Electronic Tap ChangerPart II: Measurement Algorithm and Test Results, IEEE Power delivery, vol. 22, no. 1, January 2007
[2] Design of On - Load Fully Electronic Tap-Changer with Triac Switch by M. Ardebili Electrical Engineering Department of K.N. Toosi University of Technology Tehran, Iran.
[3] H. Jiang, R. Shuttleworth, B. A. T. Al Zahawi, X. Tian, and A. Power, Fast response GTO assisted novel tapchanger, IEEE Trans. Power Del., vol. 16, no. 1, pp. 111115, Jan. 2001.
[4] P.Bauer R.schoevaars, ”Bidirectional Switch for a Solid State Tap Changer”, Power Electronics Specialist Conference, 2003. PESC ’03. 2003 IEEE 34th Annual, Volume 1, 1 5-1 9 June 2003 Page(s):466 - 471 vol.1
[5] B. Kasztenny, E. Rosolowski, J. Izykowski, M. M. Saha, and B. Hillstrom,Fuzzy logic controller for on-load transformer tap-changer, IEEE Trans. Power Del., vol. 13, no. 1, pp. 164170, Jan. 1998.