International Journal Of Advance Research, Ideas And Innovations In Technology

ISSN: 2454-132X
Impact factor: 4.295
(Volume 5, Issue 1)
Available online at: www.ijariit.com

Power electronics assisted OLTC for grid voltage regulation

Bhagyashri Sherkhane
bgsherkhane@gmail.com
Zeal College of Engineering and Research, Pune, Maharashtra

Snehal D. Dharme
snehal.dharme@zealeducation.com
Zeal College of Engineering and Research, Pune, Maharashtra

ABSTRACT

High utilization of co-generation has given rise to the occurrence of voltage fluctuations in the electrical distribution network. The paper provides a brief idea of the designing of the partially rated, Power Electronic assisted On Load Tap Changer (OLTC) transformer. Most of the tap changers implemented traditionally are the mechanically operated which are having their own advantages and disadvantages such as arcing during switching, high maintenance due to mechanical contacts, service cost and slow reaction time for the operation. Implementation of electronic tap changer has drastically removed the most of shortfall which can be observed at mechanical tap changer. The rapid growth in the field of electronic industries has allowed us for the use of power semiconductor devices, such as the Insulated gate bipolar transistor (IGBT), TRIAC, MOSFET and GTO has assisted us for the proper functioning of OLTC regulators. This paper uses TRIAC as voltage regulation. The paper gives an idea for designing of a fast-acting OLTC regulator with tapings on the primary side (hv side) hence allowing to reduce losses and to have faster action.

Keywords— *OLTC, Voltage regulation, Voltage fluctuation*

1. INTRODUCTION

The objective of this proposed system is to provide a microcontroller-based tap-changer controller which can accurately control a traditional tap-changer and yet comprises with a simple in design and less expensive than which is presently available in microcontroller-based tap-changer controllers. The power distribution companies are concerned about the quality of the electrical power supplied to the customers. To minimize the fluctuation of voltage amplitude with respect to the reference voltage the tap changer system is used. The practical bus should be far away from the secondary side of the transformer. The controller of tap changer must be able to regulate the voltage within a prescribed range. Traditionally the mechanically operated tap changer was used which had many drawbacks in terms of arcing, time of operation but later electronically operated tap changer (Hybrid switch) was introduced which compensate the drawbacks of traditional tap changer. Voltage flicker and voltage sags, under voltage, over voltage and noise can be minimized with the implementation of Hybrid Switch[1-2]. But controlling the electronically based tap changer for the specific voltage is not possible due to the use of Thyristors. Implementation of the TRIAC based electronic tap changer has increased the reliability of the system by maintaining the output voltage constant. The proposed circuit design of switches allows for the conduction of the two thyristors in each tap during the tap-changing period which helps in improving the reliability of the system and reducing arcing in the contacts with the desirable tap change.

2. VOLTAGE FLUCTUATION AND CONTROLLING

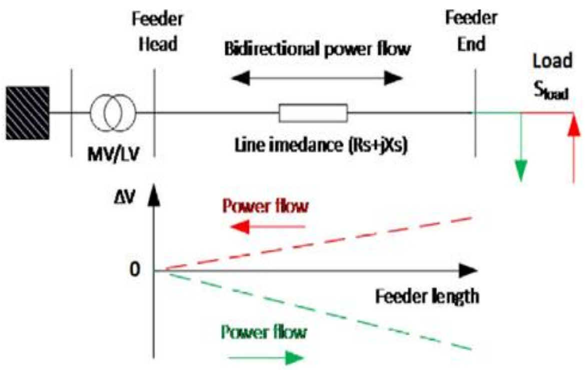

Fig. 1: Voltage regulation and power flow

The term of voltage flicker is present in all the distribution grid. In the power grid, downstream power flow occurs which causes a voltage drop at the feeder and results in under voltage. OLTC mechanism in transmission transformers is provided with static switches which are utilized to compensate for line drops with the setting of the higher value of voltage present at the feeder head.

Mainly increase in hybrid generation in recent years has been added in the LV distribution network, it seems to be increased in the coming future [6]-[7]. The voltage control has become more complicated due to heavy load injecting causing more voltage fluctuation such as electric vehicle charging. The frequent variation in the load voltage (up-to±10%) is caused due to variation in the hybrid power generation owing to short and long duration fluctuation in the wind and solar generation [3]-[6]. Upstream power in the feeder during the adequate conditions of solar and wind which results in the overvoltage at feeder end. The below figure 1 shows, variable load voltage present at line end is represented by Vline, and Vline can be calculated as subtraction between feeder/line head ($\bar{E}$) voltage and feeder/line end $\bar{v}$ voltage.

$$\text{Vline} = E \angle \delta - V \angle 0 = Zs\bar{I} \quad (1)$$
$$\text{Sload} = v\bar{I}\_1^* = Pi + jQi$$
$$\text{Vline} = (RsP1 + XsQ1)/V + j\,(XsP1 - RsQ1)/V \quad (2)$$

Thus the voltage variation is proportional to the total impedance (Zs=Rs+jXs) of the line, apparent power (Sload=Pi+jQi) injected through the load and voltage of the line end. The adverse effect of voltage swell, over and under voltage, voltage sag and large-scale Hybrid generation have been mentioned in the [5]-[6]. The tolerance of customer utilization has been addressed in the [6] which mentions that the utilization point should not exceed above the tolerance of ±10%.

It is more complicated in reality as shown in figure 1 due to:
1. The feeder has non-uniform load distribution along the line.
2. The load on the distribution line does not remain constant but
3. varies according to time.
4. Lengths of the feeders are unevenly emanating from busbar.

The purposed system should be able to maintain the desired voltage level throughout the distribution line. The design system must be cost-effective, efficient and helps in compensating the voltage fluctuation in terms of overvoltage and under-voltage.

3. BLOCK DIAGRAM AND ITS DESCRIPTION

Figure 2 shows the main components of the proposed power electronic assisted OLTC controller by using a nano V3 microcontroller. The tapings are provided on the primary side. The voltage sensor (rectifier circuit) which are implemented on the primary side, senses the variation of the input voltage. This voltage is applied to the different analogue pins of the microcontroller. The static electronic switch TRIAC operates depending upon the programming logic provided for desired voltage. These TRIAC based switches are connected to the taps on the primary side of the transformer. The activation of such switches on the primary side means selecting the desired taps.

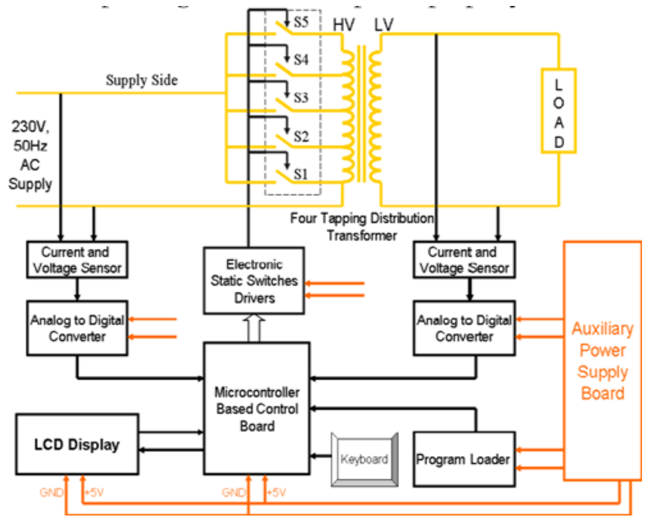

Fig. 2: Block Diagram

The addition of primary side operation is also applicable to the secondary side. The voltage sensor is provided for the detection of the transformer voltage. The taps with the solid state are proposed at the primary side with taking into account changes in input voltage.

The proposed system design is done by using a 1KVA transformer. For high power levels, the classical regulators are been replaced with the help of proposed topology. The semiconductors devices are economical in nature thus can be used for fast OLTC regulator suitable for high power applications.

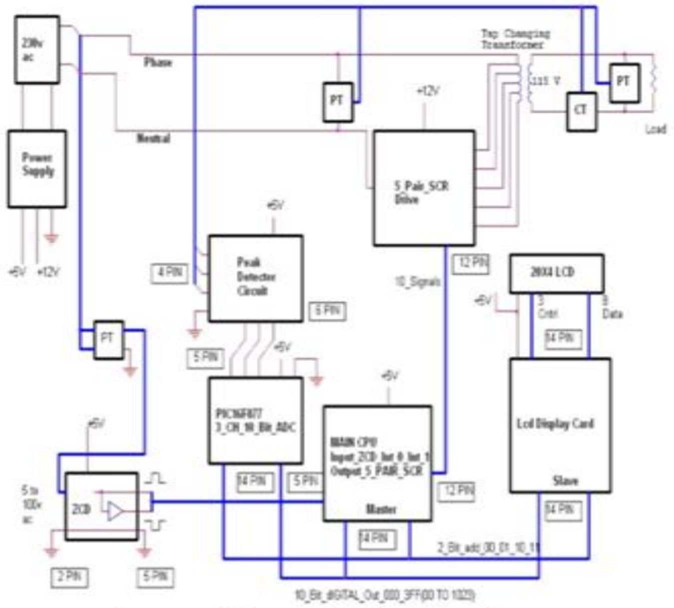

Fig. 3: Circuit diagram

Bidirectional in current and voltage main switches (S1-S5) are used. It has Double unidirectional switch (SCR). The bidirectional switch configuration is advantageous by using only one unidirectional switch whose ultimate output is simpler in control. However, increased in conduction losses due to the use of more semiconductor in series and switching stress of transistor is also higher. To control the flow in both directions separately it is not possible using this configuration because the controller is operated with a two-step commutation technique and it has no influence on the commutation process. The same gate signal is used for controlling the main switch in both the possible direction of the current. Only two-step commutation strategy can be used in this case, which causes the problem of short circuit current between the taps during the commutation process.

3.1 Switch circuit

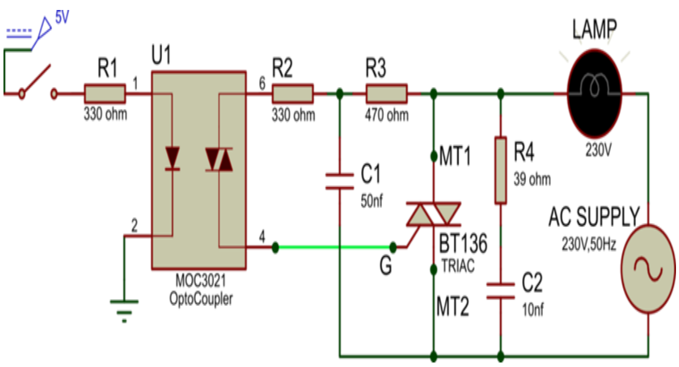

Fig. 4: Triggering circuit for TRIAC

Switching circuit for TRIAC using optocoupler is shown below in figure 4. The optocoupler consists of an LED and a DIAC. When a high signal is applied to pin 1 of optocoupler (MOC3021), the LED illuminates inside the optocoupler, which causes optically activation of DIAC. As a result TRIAC gate signal is obtained from the output of the DIAC. This signal makes TRIAC conducting and connects to the appropriate tap depending upon the voltage. The optocoupler acts as a gate controller for TRIAC.

3.2 Voltage sensor (Rectifier circuit)

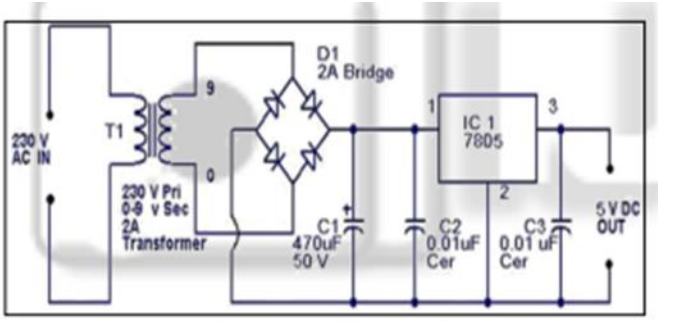

Fig. 5: Rectifier circuit

The microcontroller and display require 5V DC supply for their operation. This can be achieved by using step-down transformer 230V/12V AC and further 12 V, AC supply is converted to 5 V DC using bridge rectifier circuit, capacitor and LM7805 voltage regulator.

4. FLOWCHART

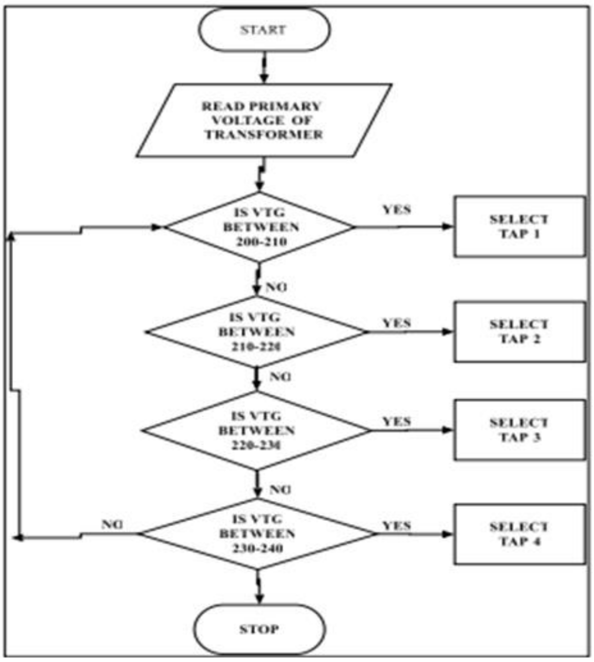

Fig. 6: Flowchart

From the figure, the microcontroller continuously gathers the value of the changed input voltage using its analogue pin. It performs the comparison of the input value with the prescribed value and checks if the input voltages are in the desired voltage limits. Tap selection is done depending upon corresponding input voltage with the condition specified as the input voltage should be in predetermined voltage limits, if not then the controller checks for another condition. This process is continued until the specified conditions are met.

5. RESULT

Controlling of over-voltage and under-voltage conditions is also carried out using this circuit and limits for the tap changing for the desired voltage is given in the below table.

Table 1: Tap Changing Limits

Tapings	Voltage Limits
Tap-1	180>V<210
Tap-2	210>V<220
Tap-3	220>V<230
Tap-4	230>V<240
Tap-5	240>V<250

For Under voltage and Overvoltage conditions limits are:

Table 2: Protection for under voltage and over voltage limits

Under voltage	V<180
Overvoltage	V>.250

If the voltage is less than 180v and greater than 250v then all the tapings are inoperative until the desired voltage is applied.
The design of the actual circuit is shown below:

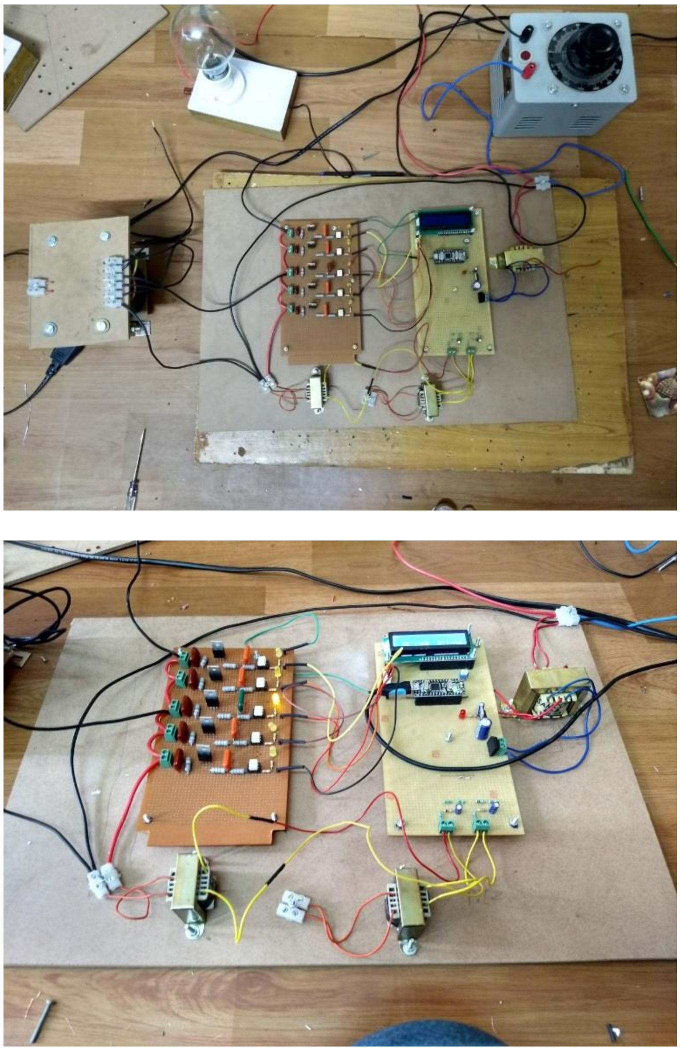

Fig. 7: Shows actual snap of designed circuit

6. CONCLUSION

In this paper, electronic tap changer is designed and located on the high voltage side of the transformer, as five taps are provided corresponding static switches must be built. The variation in the input voltage is detected by the microcontroller and compared with the predefined value according to the program. This will produce an appropriate signal for triggering of TRIAC depending upon the voltage level. With use, static switches stability of the system is improved due to the rapid response as well as reduce in maintenance costs due to the elimination of the frequent arcing during the tap changing process. The input voltage controlling range can be set at 10 V of the rated.

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