I J C T A, 10(8), 2017, pp. 313-320 ISSN: 0974-5572

Design of Triac Based on Load Tap Changer for Constant Load Voltage

N.M. Lokhande[1], Shubham R. Kulkarni[2], Vinit S. Ghone[3], Vishal R. Kikale[4] and Rushikesh M. Patharkar[5]

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 milliseconds to seconds. Earlier mechanical type of on load tap changers were into practice. But they had considerable limitations and drawbacks like arcing, high maintenance, service cost and slow reaction times. In order to overcome these limitations and drawbacks electronic tap changers are developed. The continuous growth usage of power semiconductor devices, such as the Insulated gate bi-polar transistor (IGBT), Triac, MOSFET, GTO has assisted us for the functioning of OLTC regulators. It is also helpful in fixing other problems such as flicker and sags, under voltage, over voltage and noise.

The major idea in the solid state assisted tap changer is that they provide us more control during the tap-changing process instead of mechanical switches which helps in reducing the arcing phenomena. In this paper implementation of a fast OLTC regulator is present providing tapping on the primary side. The objective is to reduce losses and have a faster switching. The variation in time switching response is much lower than the one corresponding to the traditional regulators. In this paper we are using primary tapping instead of secondary tapping to reduce the switching losses and to get constant output voltage on load side with faster switching response.

Keywords: Triac; Transformer; On-load tap changer

1. INTRODUCTION

The On-Load Tap Changer (OLTC) has been generally used since the introduction of electrical energy. The main application of a tap changer is to control the magnitude of the output voltage. The major purpose of the controller in the tap changer system is to minimize the voltage sag and swell with respect to the reference voltage of the regulation bus. The controller must regulate the voltage within the permissible values. The existing mechanical On load tap changer in distribution transformer has few disadvantages such as arcing, requires periodic maintenance, service cost, and slow response time. With the implementation of high power semiconductor devices such as MOSFET, GTO, IGBTs, problems associated with the mechanical on-load tap changing transformer have been eliminated. In order to overcome these limitations and drawbacks stated, new circuits and configurations for tap changers have been introduced. The mechanical switch in the hybrid switch produces the load current resulting in low steady state losses. During the tap change process, the OLTC uses semiconductor switches viz. IGBT/MOSFET, thus achieving arc free tap change and longer life of switches. Power quality is also one of the most important aspects these days. Power quality has been a major concern in power system operation and control. This issue is becoming more critical considering the smart grid with unstable renewable energy source, such as solar panel and wind turbine. Several measures can be taken to stabilize power transmission and enhance power quality, such as voltage regulation devices, reactive power compensation, large-scale energy storage, etc. 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.

[1-5] *Emails: netralokhande@gmail.com, kulkarnishubham68@gmail.com, vinit.ghone1096@gmail.com, vishalkikale@gmail.com, and patharkarrushi@gmail.com*

In this paper to overcome above problems we propose triac device on load tap changer with primary tappings which reduces the switching time and achieves constant output voltage.

2. LITERATURE REVIEW

[1]Gautham Ram Chandra Mouli, Pavol Bauer, Thiwanka Wijekoon, Ara Panosyan. “Design of a Power electronic assisted OLTC for Grid Voltage Regulation”. On load tap changing voltage regulators and sub transmission transformer use taps made of mechanical switches that can be operated under load. Under conditions of voltage fluctuation due to DG (distributed generation), the mechanical switches undergo frequent wear and tear during tap changing process due to the arcing phenomenon. This results in reduced lifetime of the switches and requires repeated maintenance. Nevertheless these mechanical taps have the ability to handle high overload capacity and low on-state losses. However electronic tap changers use semiconductor switches which don’t have any arcing problems. This provides flexibility in operation but suffer from much higher steady state losses. By combination of the advantages of both electronic and mechanical tap changers, triac tap changers are obtained. The fundamental technique is to use the mechanical switches in steady state to ensure low steady state losses. The use of semiconductor switches is to provide arc free tap changing process. The high overload capacity of mechanical switches is of advantage if fault conditions occur during steady state operation. Therefore the performance of hybrid OLTC for high fault current does not change.

This paper describes the design of a triac based OLTC that provides voltage regulation, efficient and has a longer life. Unlike earlier works that use thyristor, back-to-back series connected IGBTs with anti-parallel diodes are used for the two electronic switches. The OLTC has been customized for application in both high and low voltage distribution networks. A low level control mechanism and protection scheme is also developed, thus providing characterized design for building a preliminary model. The voltage fluctuation problem in distribution network occurs due to DG. Frequent voltage sag, swell and overvoltage are observed in the distribution network owing to large scale renewable energy integration like photo voltaic panels.

A design of OLTC autotransformer using no load switches (NL1, NL2) as shown in Fig.1. The OLTC taps are made from a combination of no-load switches and a single semiconductor-mechanical hybrid

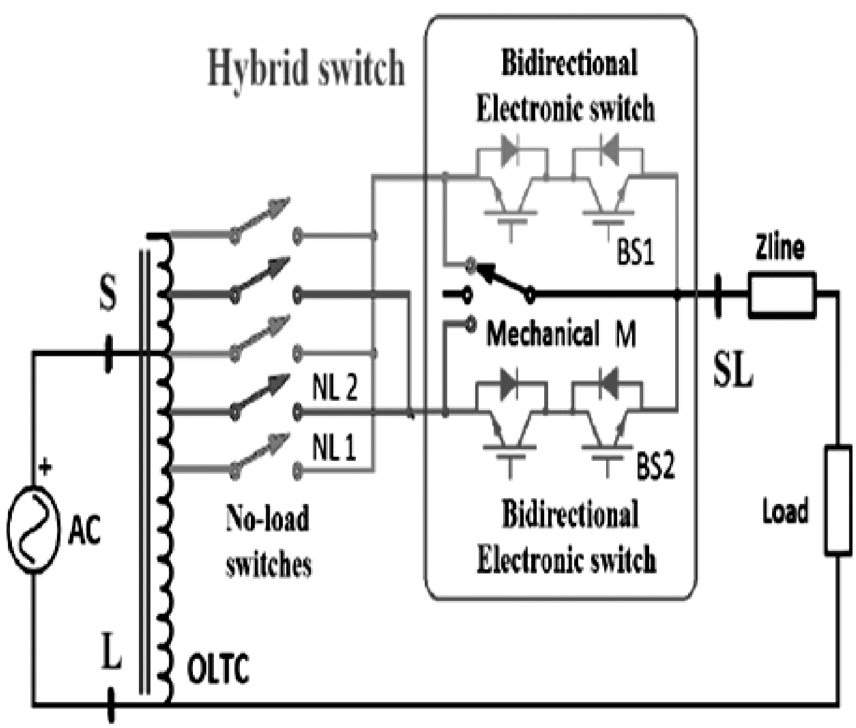


Figure 1: OLTC autotransformer using no-load switches (NL1, NL2) and hybrid switch made of two electronic switches BS1, BS2 and a mechanical switch M.

switch. The OLTC makes use of a mechanical switch during steady state and a semiconductor switch during tap change resulting in the both benefits of lower steady state losses and no arcing during the tap change. This provides the OLTC to sustain a long lifetime when working in conditions of frequent voltage fluctuations. The OLTC can provide both positive and negative compensation of the grid voltage. The operation mechanism of changing one taps at a time.

The use of polarity based commutation on back to back connected IGBT/MOSFET provided a convenient method for performing a tap change without the occurrence of an open or short circuit and without the need for current-limiting impedance and arc free switching. The OLTC has been customized for application in both high and low distribution network. Open-delta connection using two OLTC units and star connection using three OLTC units have been found to be most suitable for control of line voltages.

[2] S.V.M. Bhuvanaika Rao, B.Subramanyeswar," Fine Voltage Control Using OLTC by Static Tap Change Mechanism" In this paper, the topic of the paper is being concentrated and elaborated to distribution transformer with on load tap changer where the entire mechanical control is superseded with static semiconductor switches which are from thyristor family in which controlled turn on and turn off is possible like GTO. The modern GTO thyristors had the merits of high power handling capability and long life, thus suitable for use as selector. The proposed tap changer consists of bi-directional GTOs connected in opposite direction, thus selection of particular tap is done by switching GTOs in that respective tap.

The basic circuit combination of automatic static OLTC with controllers is as shown in Fig. 2. GTOs are used as switching devices to turn on the selected tap of the power transformer. The bi-directional GTOs are used for voltage control between taps. The proposed control mechanism is addition of static devices such as GTOs to the automatic OLTC of a transformer for obtaining secondary voltage.

The voltage at load end or secondary side of automatic OLTC distributed transformer is measured and compared with the present value. The voltage control representation is shown in Fig.3. If the difference is within the permissible dead band no operation takes place. If the difference lies outside

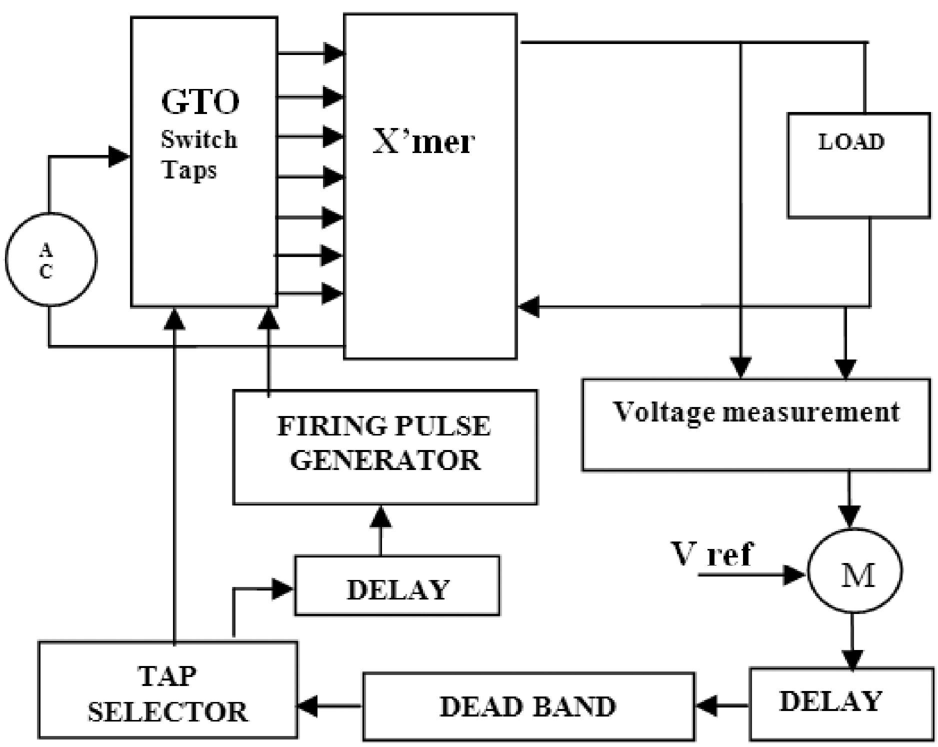


Figure 2: Basic circuit combination of automatic static OLTC the dead band an appropriate lower or raise correction will start after a pre-determined delay.

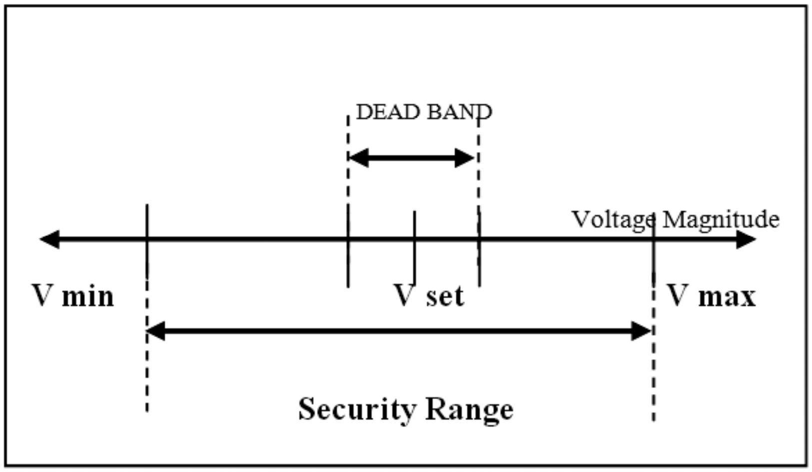


Figure 3: Voltage control representation

This process will be repeated until the output voltage is within the inner dead band. The main objective of time delay is to prevent unwanted tap operations due to temporary voltage fluctuations. Tap changing is done by switching GTOs in respective taps. In addition to the above automatic tap control a sequence control is introduced between taps for obtaining constant output voltage.

In this paper, traditional mechanical OLTC is replaced with GTO assisted tap changer with sequence control. The newly proposed prototype will exclude contact wear, arcing and replacement costs of contacts which are associated with their mechanical counter parts. The absence of movable mechanical parts makes it lighter, faster and more efficient. The sequence control added to the GTO assisted OLTC maintains transformer secondary voltage within ±0.1% tolerance. The novel model can perform better voltage control than the traditional OLTC.

[3] Nikunj R. Patel, Makrand M. Lokhande, Jitendra G. Jamnani, “Solid-State On Load Tap-Changer for Transformer Using Microcontroller” Block diagram for OLTC power and control scheme is shown in

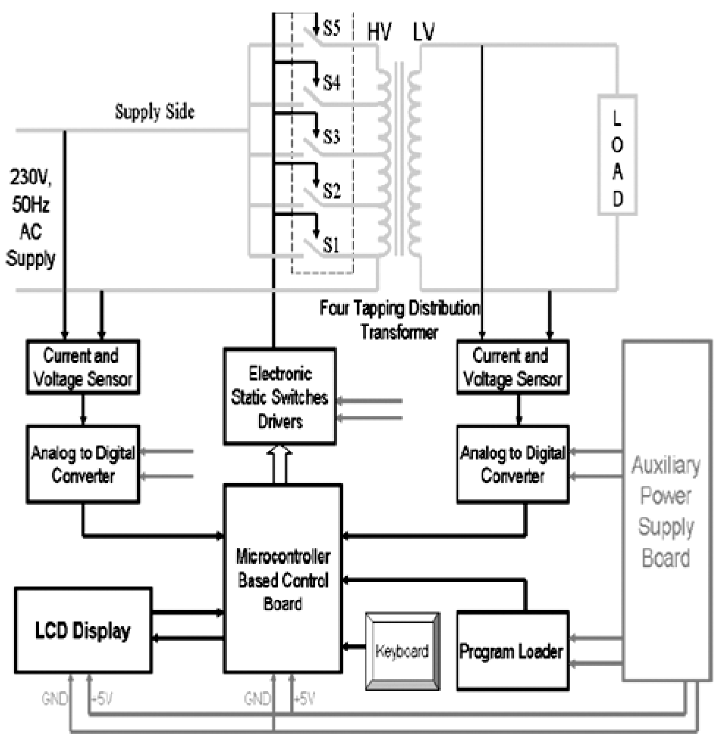


Figure 4: Block diagram for OLTC power and control scheme

Fig. 4. There are number of windings on both sides of the transformer. Also, there are various switches on both side of the transformer. The operations of various blocks are elaborated below:

2.1. Current and Voltage Sensor

The current and voltage sensors are present on both sides i.e. primary and secondary side of transformer. Current and voltage sensors sense the values of current and voltage on both sides. It is useful for the calculation of the voltage drop on output side. The current and voltage values are displayed on the LCD display.

2.2. Analog to Digital Converter

As microcontroller understands the digital values, this ADC is interfaced with it. It converts the analog values into digital form.

2.3. Electronic Static Switches

The Electronic static switches are used to select the single or multiple output terminals. This operates the terminal at the load side in the circuit.

2.4. Microcontroller

For the smooth and sharp output, this microcontroller is used in this circuit. Microcontroller operates all the circuit. Using programming, we are able to change the working of this microcontroller. Also, we can change the output using some connections and coding.

2.5. Program Loader

The program loader is used to write a program. We are able to change the program or reinstallation.

2.6. Keyboard

The keyboard is used to type program which is further connected to the program loader.

2.7. Auxiliary Power Supply Board

This auxiliary power supply board is an external supply to the various components such as Microcontroller, Analog to Digital Converter, Keyboard, program loader, LCD display.

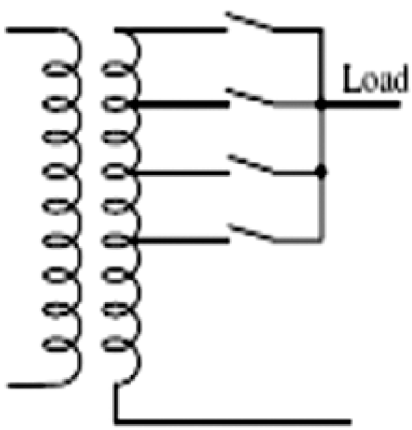
2.8. LCD Display

This liquid crystal display (LCD) displays values of input and output supply, and voltage drop at the load side. It is directly connected to the Microcontroller which works on the auxiliary power supply.

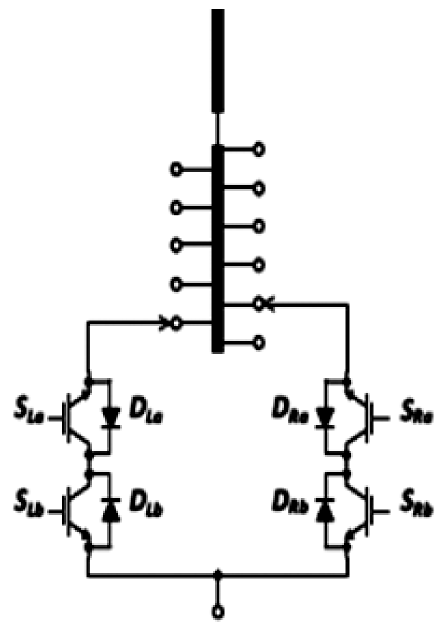
[4]Nan CHEN, Lars E. JONSSON,”A New Hybrid Power Electronics On-load Tap Changer for Power Transformer” The concept of power electronics tap change (PE OLTC) has been proposed to address the drawback of traditional on load tap changer. In general the PE-OLTC is classified into two types, a) Full PE on load tap changer, in which no mechanical moving part is used. b) Hybrid on load tap changer, in which the function of mechanical switch and power electronic switch are combined for different objective. Fig.5. It shows the examples of on-load tap changing structure. For applications of higher tap changing frequency, the full PE solutions will show more benefits. But for higher voltage and power rating applications, number of semiconductor component used in on load tap changer will play an essential role affecting hardware cost as well as reliability, and then hybrid OLTC appears to be an attractive solution. However, problems get

solved on how to reduce arcing during tap changing process from mechanical switch to semiconductor. However this solution could have issue on reliability, due to the complexity on its auxiliary circuit and control.

A new Hybrid OLTC design has been presented targeting in power transformers applications with lower expected cost. Practical design requirements on current and voltage stress level were discussed with solution provided. PE OLTC technologies and their potential functional advantage in power transformer applications are explained. Experimental result with minimized setup is provided to verify the theoretical prediction, as well as to provide reference data for full system design. General conclusion from this paper is a Hybrid on load tap changer for power transformer is technically feasible. However, to promote utilization of such technology, we need to provide either even low cost solution, or solution enable new functionality which traditional OLTC does not. And that also is the main reason why in this study we prefer to choose self-turn-off device to formulate hybrid-OLTC topology:



(a) Linear selector



(b) With diverter

Figure 5: Example of on-load taps changer structures

New function needs faster operation and shorter response time. The technologies described in this paper are those needed to design and build a practical PE-OLTC product, in a right time for future power grid.

[5] A. J. L. Joannou, D.C. Pentz "Implementation of a Primary Tapped Transformer in a High Frequency Isolated Power Converter "This paper investigates a new converter topology to drive primary tapped transformers. For implementing primary tappings some modification are done in the system. This topology can maintain a load voltage for a much wider source voltage variation without major sacrifices in efficiency, output voltage regulated easily and power factor is determined. To maintain consistency in the measurements, similar components were used for the new converter design.

The operating concept of the primary tapped transformer topology can be seen in the block diagram of converter topology is shown in Fig. 6. To maintain the isolation between the tapped primary and the secondary of the transformer, the load voltage measurement is isolated. The source voltage is also measured and fed to the controller. The controller then uses these measured quantities to decide which transformer ratio and what duty cycle to use that will yield the optimum converter efficiency and maintain the output voltage. At low duty cycles the converter efficiency is low and at high duty cycles the efficiency is considerably better.

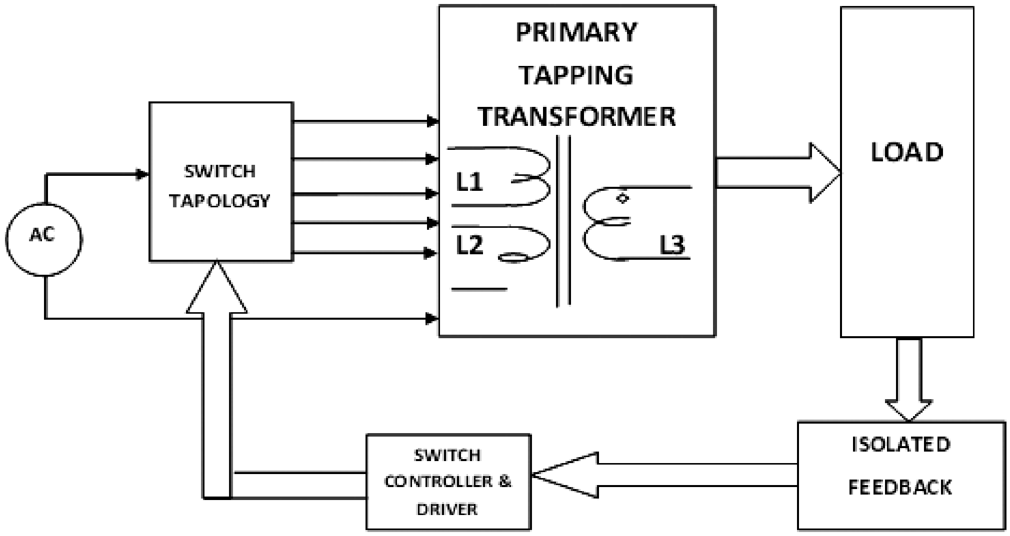


Figure 6: Block diagram of converter topology

3. PROPOSED TRIAC BASED ON LOAD TAP CHANGER

3.1. Description

The block diagram for triac device based on load tap changer with primary tapping is shown in Fig.7. Usually tappings for a transformer are provided at the secondary side for constant output voltage.

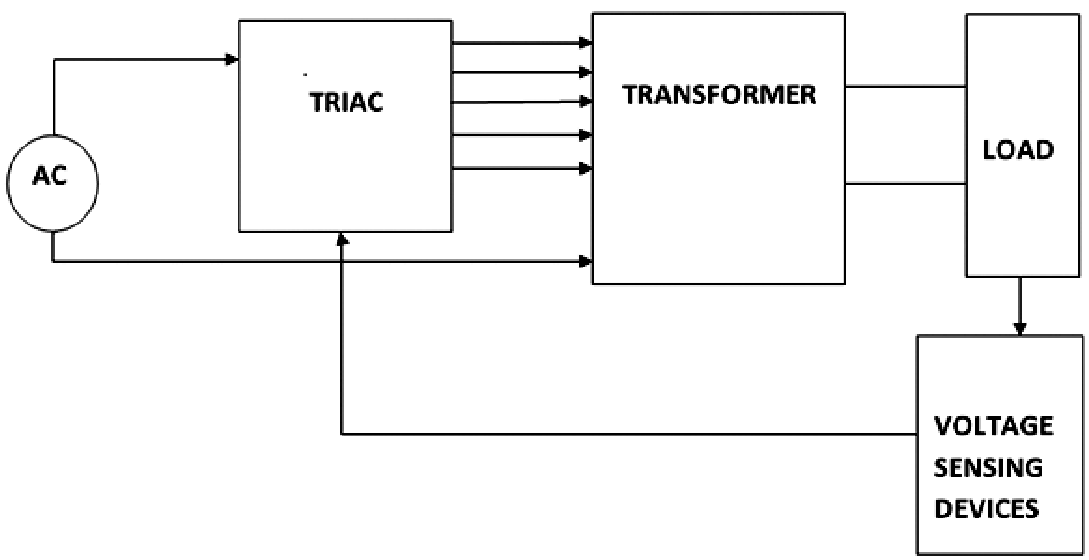


Figure 7: Block diagram of triac device based on load tap changer with primary tappings

3.2. Transformer

The transformer is designed with tapings on the primary side of it rather than the secondary side of transformer which is generally tapped for constant output voltage. Changing the input supply is possible as transformer is designed and provided with primary tapings so we get a constant output voltage on the secondary side of it.

3.3. Voltage sensing devices

The voltage sensing devices are present on both the side i.e. in input side and output side. Voltage sensing devices sense the value of voltage on both side of transformer. It is useful for triggering as well as unlatches the Triac. This voltage sensing device will compare to its present value given to the sensor.

3.4. Triac devices

Triac works on AC. It can be used in circuits for frequency conversion, voltage adjust and control. It also has a quicker response which will highly assist in switching.

3.5. Concept

In this proposed system as the voltage either on the primary side or the load side changes, the voltage sensing device senses the change in the value of voltage and accordingly the triac device is triggered and appropriate anti parallel thyristor is selected and the tap is changed accordingly using triac devices giving us a constant output voltage.

4. CONCLUSION

In existing system we used mechanical type on load tap changer having limitation and drawbacks like arcing, high maintenance, service cost, losses in switching, slow response of mechanical taps. These factors cause several disturbances and fluctuations in the system reducing the stability and reliability of the system. Due to this the life of switches gets shortened and cause arcing problems. In our system as we use power electronic devices. There are no mechanical losses, reduction in arcing problems, faster response for switching increasing the reliability and stability of the system. Triac devices are used as maintenance cost is low.

In proposed system triac devices triggers the appropriate thyristors for change in the suitable tapings of the transformers improving the power quality and stability of the system giving a faster response than the conventional tap changers. Any variation in the output voltage of the transformer is sensed by the voltage sensing device and the appropriate triac devices and the tap will get selected. As triac devices is a static device it has several advantages such as it will eliminate the contact wear making the switching process lighter, quicker and more efficient.

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