International Journal of Advanced Computer Research (ISSN (print): 2249-7277 ISSN (online): 2277-7970)
Volume-2 Number-4 Issue-6 December-2012

Fine Voltage Control Using Oltc by Static Tap Change Mechanism

S.V.M. Bhuvanaika Rao[1], B.Subramanyeswar[2]
Department of Electrical and Electronics Engineering, Affiliated to JNTU Kakinada University
PVP Siddhartha Institute of Technology, (PVPSIT) Vijayawada, A.P, India
Head of EEE Department[1], M.Tech Student[2]

Abstract

In this paper, a novel model of fully electronic on load semiconductor tap changer for power transformer has been proposed. With high power semiconductor devices, problems associated with conventional mechanical on load tap changers which includes excessive conduction losses and arcing in the diverter switch have been properly rectified. In this work Simulink model was designed with GTOs as switching devices embedded in taps. Step change of voltage is achieved changing taps by switching GTOs and fine voltage with error less than ±0.1% is obtained by sequential firing control between GTOs in the system, which is not possible in conventional automatic OLTC control system.

Keywords

Fine Voltage control, Tap changer, semiconductor tap changer, GTO embedded OLTC transformer, Sequence voltage control.

1. Introduction

When the load in a power network changes it consequently affects voltage profile at load end. To maintain the load voltage within permissible limits, Power transformers are equipped with tap changing system. The tap changer alters transformer turns ratio in a number of predefined steps which results change in secondary side voltage (Load end).On load tap changing power transformers are an essential part of any modern power system ,since they allow voltages to be maintained at desired levels despite load changes. The problem with conventional tap changer is its mechanical structure of complicated gear mechanisms of selectors, diverters and switches. These arrangements are slow in response and susceptible to contact wear condition and deterioration of insulating oil, thus requires regular maintenance. In this paper, focus is being given to power transformer with on load tap changer where the complete mechanical control is replaced with static semiconductor switches belonging to thyristor family such as GTOs which are capable of controlled turn on and off. These modern GTO thyristors had the advantages of high power handling capability and long life, thus suitable for use as selector. The proposed tap selector consists of bi-directional GTOs connected in anti-parallel ,thus selection of particular tap is done by switching GTOs in that respective tap. The application of semiconductor or solid state devices in designing the tap changer have advantage of faster response, almost maintenance free and better performance when compared to conventional tap changers.

In this paper, improvement is achieved by maintaining the supply voltage changing tap setting via GTO assisted selector and fine voltage control through sequential switching of GTOs embedded in taps. The results obtained from this experiment shows that the proposed static tap changer is able to monitor voltage supply and maintain load voltage with error less than ±0.1%.

The Figure 1 below represents control scheme of a conventional OLTC transformer. Automatic OLTC controls within ±10% change of nominal voltage. The upper most tap represents -10% change to nominal voltage, while lower most tap represents +10% change. In the below figure 1, V_{min} refers to -10% and V_{max} to +10%. OLTC transformer reduces the error in voltage till secondary voltage is within the dead band operating tap positions. Tap changing results step change in voltage.

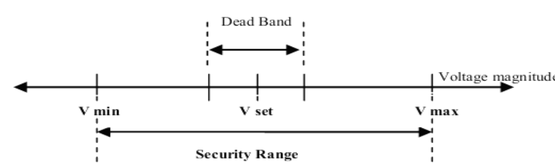

Figure 1: Voltage control representation

The voltage in between two steps i.e., between two taps can be obtained through static/semiconductor tap changing systems with sequence control with voltage error less than ±0.1%.

2. Static/Semiconductor Tap Changer

The basic circuit scheme of automatic static OLTC with sequential controllers is shown in figure 2. GTOs are used as switching devices to turn on the selected tap of the power transformer. The bi-directional GTOs in addition, performs voltage control between taps by sequential switching.

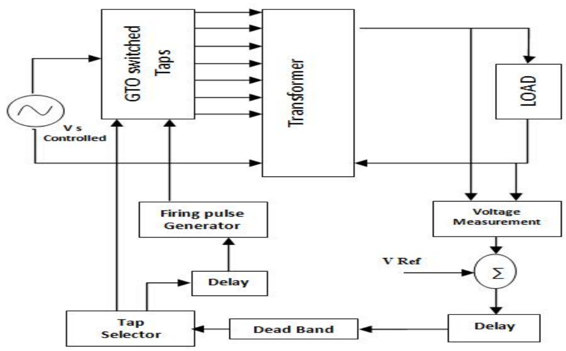

Figure 2: Block diagram of automatic OLTC with sequence control

The proposed control mechanism is addition of static devices such as GTOs to the automatic OLTC of a transformer for obtaining secondary voltage in close tolerance.

3. Basic Control Mechanism

The voltage at load end / secondary side of automatic OLTC transformer is measured and compared with the preset value. If the difference is within the dead band, no operation takes place and if the difference lies outside the dead band an appropriate lower or raise correction will start after a pre-determined delay. This process will be repeated until the secondary voltage is within the inner dead band. The main purpose of time delay is to prevent unnecessary 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 fine secondary voltage.

4. Sequence Voltage Control

An attempt is made to adjust output voltage by controlling GTOs in between taps. The control of GTOs is achieved through firing angle control. A typical output waveform using sequence modulation method is shown in figure 3.

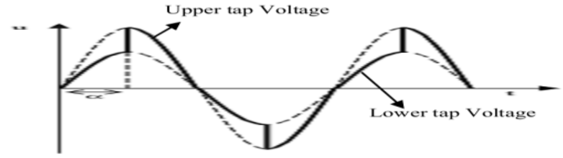

Figure 3: Firing angle control of voltage

In this method of control, output voltage can be represented as a function of α (firing angle), as given below

V_{rms} is $f(\alpha)$

$$= \sqrt{\frac{1}{\pi}\left\{\int_0^{\alpha} (V_{lt}\,\mathrm{Sin}(\omega t))^2\, d(\omega t) + \int_{\alpha}^{\pi} (V_{up}\,\mathrm{Sin}(\omega t))^2\, d(\omega t)\right\}}$$

α firing angle
V_{lt} Peak Value of Lower tap voltage
V_{up} Peak Value of Upper tap voltage
V_{rms} Resultant rms value

Using above stated equation varying firing angle, voltage control in between taps can be obtained.Once preset value is reached the firing angle representing preset value is maintained constant.

Condition :1

V_{ref} > Present selected Tap Voltage

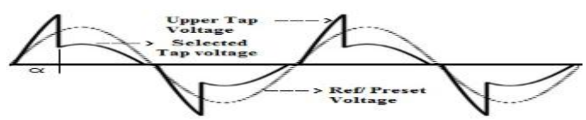

Figure 4: Firing control between upper tap voltage & selected tap voltage

In this condition firing control is being performed between *Present selected tap and upper voltage tap, to increase the voltage further to reach preset voltage* as given above in figure 4

Condition: 2

V_{ref} < Present selected Tap Voltage

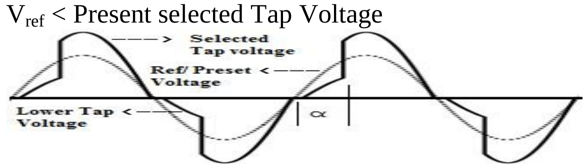

Figure 5: Firing control between lower tap voltage & selected tap voltage

In this condition firing control is performed between Present selected tap and lower voltage tap, to reduce the voltage further to reach preset voltage as given in above figure 5

5. Simulation Circuit

A simulation model of static OLTC with sequence control is modeled with 7 Tap 132Kv /11Kv, 16MVA automatic OLTC with taps on primary side (HV side) is shown below in figure 6**.**

Automatic OLTC controls within ±10% change of nominal secondary voltage. The upper most tap represents -10% change to nominal voltage, while lower most tap represents +10% change. For convenience Taps on primary side are numbered from -3 to 3 with center tap as 0, representing total 7 taps on primary side. Simulation model of automatic OLTC is designed to maintain 11kv on secondary side i.e., with 132kv on primary side at Tap 0 position reflects 11kv on secondary side.

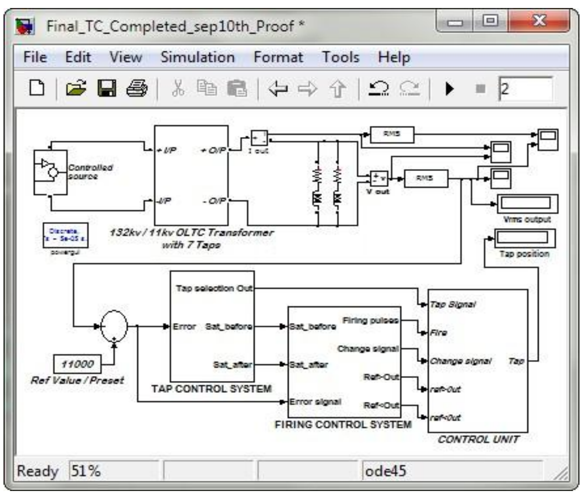

Figure 6 Simulink model of automatic static tap changer with sequence control

Simulation starts with automatic OLTC at tap 0 position. Operation of present automatic OLTC involves two controls .One Sequence control mechanism starts when secondary voltage at load end changes from ±0.1% to ±3.3% of 11kv and the second one tap changing mechanism operates if load voltage change is above ±3.3% of 11kv after a pre-defined delay. The tap changing operation occurs till secondary voltage is within preset dead band i.e., +3.3% to -3.3%.Once tap operation stabilizes tap position, with delay sequence control follows to reduce the voltage change to 0.1% of 11kv.Hence due to tap changing mechanism we can reduce the large difference in voltage change to ±3.3% of 11kv, but 11kv may or may not be obtained. To reduce voltage change precisely to 0.1% of 11kv sequential control method is used. Present simulated model equipped with sequence control is tested for voltage rise and fall and simulation results of both with and without sequence control are presented below in detail.

6. Simulation Results

The performance of automatic OLTC is tested for two cases, first one for rise in voltage and the second one for drop in voltage. These rise and drop in voltage is created by pre-programmed voltage source at primary end. Results of automatic OLTC with and without sequence control for voltage changes are simulated and compared.

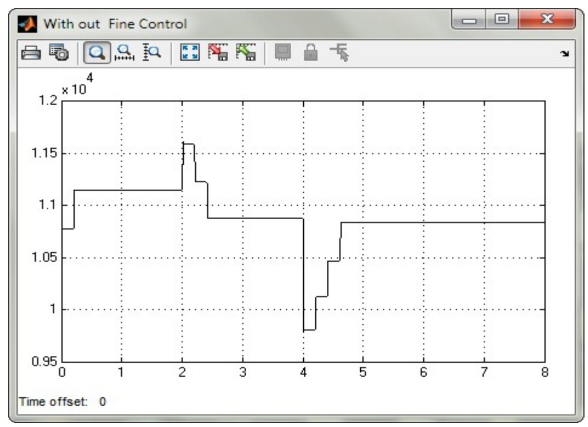

Figure 7 Simulation result without sequence control but with GTO assisted tap changer

Simulation is performed with sudden load change at start and programmed source voltage changes (transformer primary voltage) at two instances i.e., at t=2 and at t=4.Drop in the secondary voltage from 11kv can be observed at starting resulting voltage drop to 10.78kv at load end shown in figure7. Voltage difference being outside the dead band ±3.3%, tap operation takes place from 0 to +1 resulting 11.14kv which is within dead band. At t=2 instance source voltage suddenly increased from 132kv to 142kv resulting 11.59kv outside dead band ±3.3% on secondary end, then OLTC operates to limit error within dead band by switching taps in upper direction from +1 to -2, resulting 10.88kv, again at t=4 source voltage changes to 124kv resulting drop in secondary voltage to 9.8kv .Hence automatic OLTC reacts to reduce that change by operating taps from -2 to +2 stabilizing voltage at 10.83kv .OLTC with sequence control is simulated for same voltage changes at same instances and results obtained are shown in figure 8.

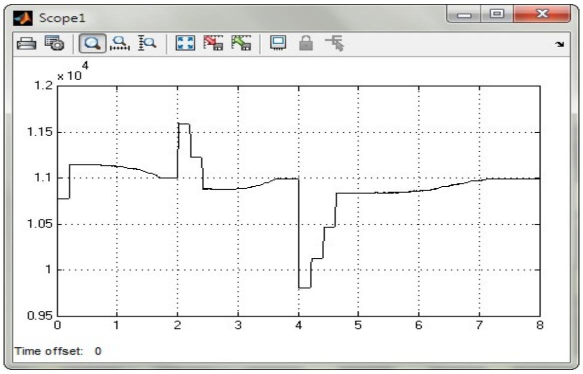

Figure 8 Simulation result with sequence control and GTO assisted tap changer

As in automatic OLTC without sequence control, Tap changing continues till secondary voltage is within dead band. Once tap switching is completed with some delay the firing angle control system varies firing angle between taps to reduce error to 0.1% on secondary side, sequential control system stabilizes the firing angle once error is within ±0.1% of 11kv.To show the full functioning of automatic OLTC with sequence control the same programmed source voltage changes are used. Simulation is started with sudden load change resulting in voltage drop from 11kv to 10.78kv. Error being outside dead band ±3.3% tap changes from 0 to +1 takes place resulting 11.14kv .Once OLTC stabilizes at tap +1 with some delay, sequential control system starts between Tap 0 and Tap +1 to reduce error to within ±0.1% resulting 11kv, which can be observed in figure 8. Similarly at t=2, the source voltage suddenly increased from 132kv to 142kv resulting 11.59kv on secondary side. The automatic OLTC operates to decrease difference by switching taps in upper direction from +1 to -2, resulting 10.88kv followed by sequence firing control between Tap -2 and Tap -1 to reduce error within ±0.1% of 11kv resulting 10.99kv.Again at t=4 source voltage changes to 124kv resulting drop of secondary voltage to 9.800kv .Hence Voltage difference is reduced by operating taps from -2 to +2, stabilizing voltage at 10.83kv followed by sequential firing control between Tap +2 and Tap +1 to reduce error to ±0.1% of 11kv resulting 11kv.Taps that are operated during simulation process of Automatic OLTC with and without sequence control for load and pre programmed source changes are shown in below figure 9.

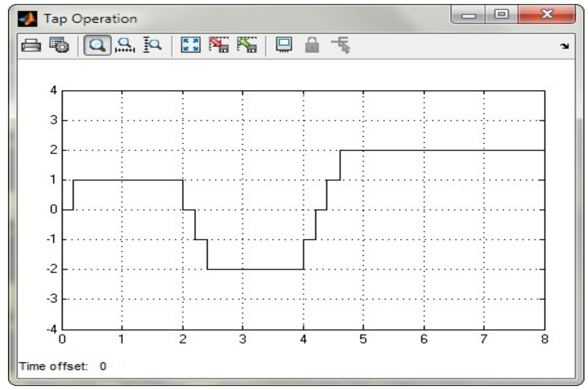

Figure 9 Automatic OLTC tap operations for changes in load and source

7. Results

Comparison of secondary voltage of automatic tap changer without and with sequence control is tabulated below in brief .The performance of Automatic OLTC with sequence control is compared with Automatic OLTC without sequence control for drop and rise in primary voltage levels at two instances at T=2 and at T=4. In table 1 and table 2 ,With (AVR) tap changer represents Automatic OLTC without sequence control and AVR tap changer with sequence control represents Automatic OLTC with sequence control mechanism. The voltages changes at instant T=2 are represented in table 1 similarly at T=4 in table 2 .The change of primary voltage at instant T=2 is tabulated as, before instant T=2 and after instant T=2 it represents voltage changed from 132kv to 142kv at T=2.This change in primary voltage reflects change in secondary voltage from reference 11kv to 11.59kv. The OLTC secondary voltage of AVR tap changer ,after tap operation changes from 11.59kv to 10.88kv at T=2 and at the same instant AVR tap changer with sequence control, after tap operation and sequence control improves voltage from 11.59kv to 10.99kv as mentioned in table 1.Similarly in table 2 ,voltage changes at instant T=4 are mentioned for drop of primary voltage from 142kv to 124kv.In both instances we can observe the secondary voltage of Automatic OLTC with sequence control performs better than Automatic OLTC without sequence control, maintaining secondary voltage close to reference voltage (11kv) with error less than ±0.1%.

Table 1: Voltage changes at instant T=2 in Simulink

Transformer control	At instant T=2			
	Primary Voltage		Change in Secondary voltage	
	Before	After	Before control operation	After control operation
With (AVR) tap changer	132kv	142kv	11.59kv	10.88kv
AVR tap changer with sequence control	132kv	142kv	11.59kv	10.99kv

Table 2 Voltage changes at instant T=4 in Simulink

Transformer control	At instant T=4			
	Primary Voltage		Change in Secondary voltage	
	Before	After	Before control operation	After control operation
With (AVR) tap changer	142kv	124kv	9.8kv	10.83kv
AVR tap changer with sequence control	142kv	124kv	9.8kv	11kv

8. Conclusion

In this paper, conventional mechanical OLTC is replaced with GTO assisted tap changer with sequence control. The new model designed will eliminate contact wear, arching and replacement costs which are associated with their mechanical counter parts. The absence of movable mechanical parts makes it lighter, quicker and more efficient. The sequence control added to the GTO assisted OLTC maintains transformer secondary voltage within ±0.1% tolerance.

The new model can perform better voltage control than the conventional OLTC transformer and will increase the overall system reliability

References

[1] Ronan ER, Sudhoff SD, Glover F, Galloway DL, A power electronic-based distribution transformer. IEEE Trans Power Deliv 17(2):537–543, (2002).

[2] R. Shuttleworth, A.J. Power, X. Tian, H. Jiang, and B. A. T. Al Zahawi,"A novel thyristor-assisted tap changer scheme," in *CIRED 97, IEE Conference Publication No. 438*, pp.1.28.1-1.28.5, June 1997.

[3] R. C. Degeneff, "A new concept for solid-state on-load tap changers," in *CIRED 97, IEE Conference Publication No. 438*, pp. 1.7.1-1.7.4, June1997.

[4] J.Arrillaga, R.M.Duke, New Zealand Electricity New Zealand. "A static alternative to the transformer On Load Tap Changer", IEEE Transaction on power Apparatus and Systems, vol.2 pp 5-99, 2000.

[5] Narain G. Hingorani, Lasz lo Gyugyi., "Understanding FACTS: Concepts and Technology of Flexible AC Transmission Systems", IEEE Press,1999 .

[6] R. M Mathur and R. K. Verma, Thyristor-based FACTS Controllers for Electrical Transmission Systems, IEEE press, Piscataway, 2002.

[7] ABB Technologies, On load tap changer selection guide 2006.

[8] Hietpas SM, Naden M Automatic voltage regulator using an AC voltage-voltage converter. IEEE Trans Ind Appl 36(1):33–38, (2000).

[9] Hao Jiang, Roger Shuttleworth, Bashar A. T. Al Zahawi, Xiaolin Tian and Andrew Power, "Fast response GTO assisted novel tap changer," *IEEE Transactions on Power Delivery*, vol. 16, no. 1, pp. 111-115, Jan. 2001.

Dr. S.V.M. Bhuvanaika Rao B.E, M.E (Power Systems), PH.D has an industrial experience of 28 years in power plant commissioning, switchgear and protection. At present he is working as Head for the Department of E.E.E, Prasad.V Potluri Siddhartha institute of technology, Vijayawada.

B.Subramamyeswar received B.Tech degree in Electrical and Electronics Engineering from JNTU Hyderabad in the year 2007, presently pursuing M.Tech in the stream of Power System Control and Automation in Prasad .V .Potluri Siddhartha institute of Technology, Vijayawada.