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Voltage Compensation of OLTC Transformer using PI Controller

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ABSTRACT: Onload tap changing(OLTC) transformers are widely used for voltage compensation in power systems. Large number of non-linear loads results in voltage imbalance problems.This may damage consumer appliances and increased fault levels. The proposed system employs PI controller for voltage instability problems.PSCAD platform is used for simulation. The proposed system has been investigated for short duration voltage variations and with harmonics condition and the results are presented.

KEYWORDS: Harmonics, On load Tap Changer(OLTC),PI Controller, Voltage compensation .

I.INTRODUCTION

Time-varying loads from industrial and domestic consumers cause voltage fluctuations in nowadays. Voltage control using traditional voltage regulators cannot meet this situation as continuous tap changes reduces the life time of mechanical taps due to arcing phenomena[1-3].Voltage control using shunt compensation methods are ineffective and expensive[4],[5].Series compensation by centralized onload tap-changing(OLTC) transformers or feeder-specific compensators is thus a proper method for grid voltage regulation[6]. During conditions of frequent voltage fluctuations, OLTC transformer has to change taps and this leads to wear and tear of taps. Mechanical maintenance problems are araised and leads to financial problems. Thus introduced power-electronic-assisted OLTC for voltage regulation as it combines mechanical taps and IGBT switches. Mechanical taps having high overload capacity used in steady state conditions and IGBT switches are used in tap changing situations [6].Addition of power-electronic switches increases losses to the system and thus PI controller is introduced to the system.

In this paper, unlike earlier works that use thyristors, back-to-back series connected insulated-gate bipolar transistors(IGBTs) with antiparallel diodes are used for the two electronic switches[7-10].Due to the increase use of sensitive and critical equipment pieces such as communication network, process industries and precise manufacturing processes, the issues related to power quality attained more concern. Power quality problems such as transients, sags, swells and other distortions to the sinusoidal waveform of the supply voltage affect the performance of these equipments. OLTC transformers for series voltage compensation can be connected differently for HV and LV networks. The structure consisting of windings with three taps is the best case for certain voltage steps [1].

II.VOLTAGE REGULATION THROUGH OLTC TRANSFORMERS

OLTC transformers are connecting in a grid system as series compensators which can perform voltage stability after compensation. They are performing well in generating stations and substations for on-load and off-load purposes respectively. Off-load tap changing is interrupting supply and thus not applicable in metropolitan cities. To meet new functionalities and new requirements, grid need to be improved and have to provide new services. Grid extension is a good idea for voltage enhancement but it requires additional installation cost and additional cable supports. Voltage regulation through OLTC transformers is better for end-line consumers as voltage drop in transmission can be minimized to a greater extent.

OLTC transformers connection can be centralized compensation and feeder-specific de-centralized compensation. Centralized compensation provides same amount of compensation and it is cost-effective but it fails in network with non-uniform amount of load. Feeder-specific de-centralized compensation is suitable for networks with non-uniform

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feeder length [6].A fast and continuous control of transformer voltage can be achieved by transformer tap changing. Continuous regulation of secondary voltage is possible with on-load tap changers. Transformer turns ratio also changes with changing of taps. Control equipments and protection equipments is complicated by the integration of distributed generation but it is necessary to meet the consumers load demand. This paper focusing on feeder-specific de-centralized compensation for the best results in output. Non-uniform loads consist of PV panels, electric vehicle charging, wind farms which have varying outputs and are necessary for a compensated output.

III.CONNECTION SCHEME

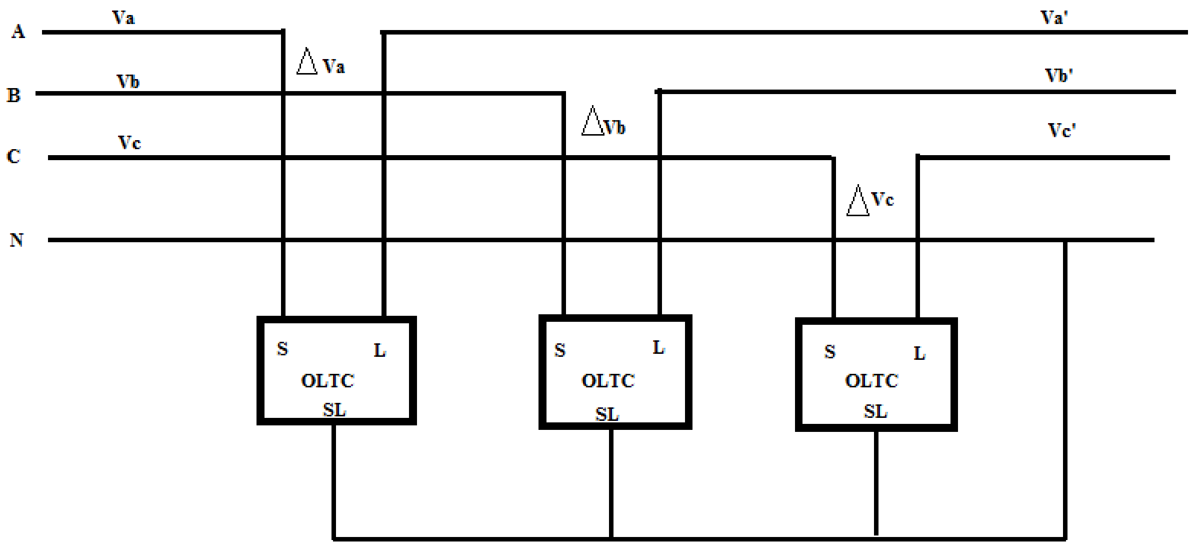

Fig. 1Y Connection of OLTC transformer to a three phase network

Series compensators are arranged in Y connection with a neutral available. Va, Vb, Vc are the phase voltages in phases A,B,C respectively in fig.1.Three OLTC transformers are provided for each phase with ΔVa,ΔVb,ΔVc as compensating voltages. Thus independent regulation of each phase can be achieved. Also, compensating voltages are derived from the phase voltages of each phase. Each phase voltage after compensation is Va′,Vb′,Vc′. Thus load voltage of each phase after series compensation can be expressed as

$$Va' = Va + \Delta Va \quad (1)$$
$$Vb' = Vb + \Delta Vb \quad (2)$$
$$Vc' = Vc + \Delta Vc \quad (3)$$

The point S is the connection to the series compensator from the grid side and point L is the connection to the load after compensation. The point SL is the connection to the neutral which can be grounded.

IV.SIMULATION OF THE PROPOSED OLTC SYSTEM

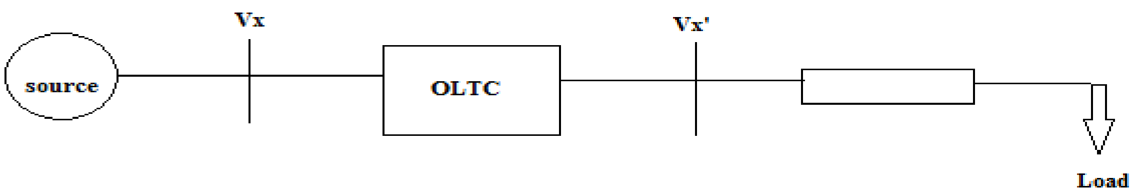

Fig.2 Single line diagram of OLTC system that was used in simulation

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The LV three-phase OLTC system was modelled based on the single line diagram in Figure 2.Vx is the voltage from the source side and Vx′ is voltage to the load after compensation.

Parameters of the OLTC system with PI controller

Parameter	LV
Voltage level(line-line,rms)	400V
Base voltage	230V
Frequency	50Hz
Connection scheme	Wye
1-phase OLTC units required	3
Load resistance	5Ω

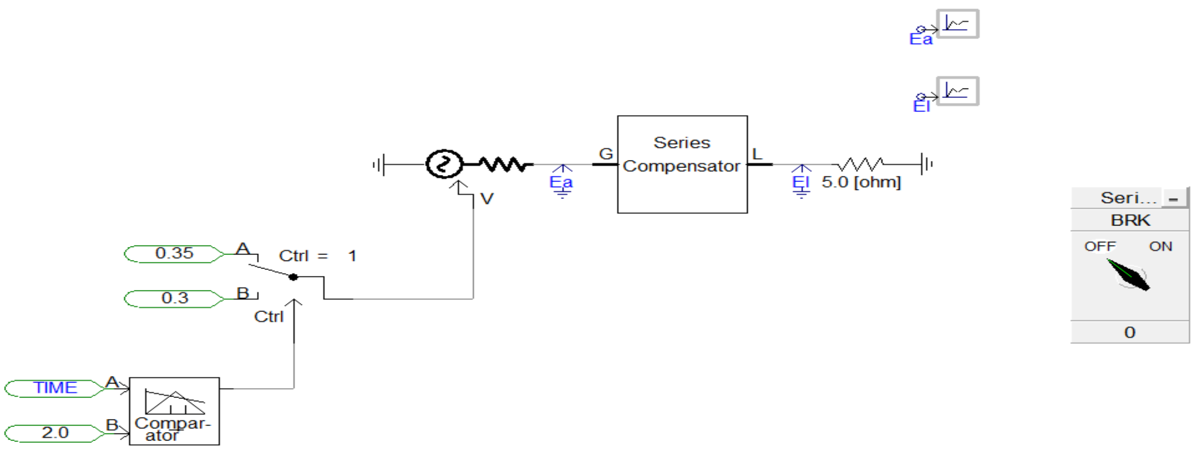

Figure 3.Simulation model with series compensator

Series compensators are OLTC transformers connected in series to the system as shown in fig. 3.A 5 ohm resistor is used as the non-linear load. Ea is the source voltage and El is the load voltage. Simulation time of 2 sec. is provided in the comparator to change the channel selector at the specified time. A sag of 0.3kV is provided till 2sec. by selecting channel B and 0.35 kV is selected afterwards by selecting channel A.

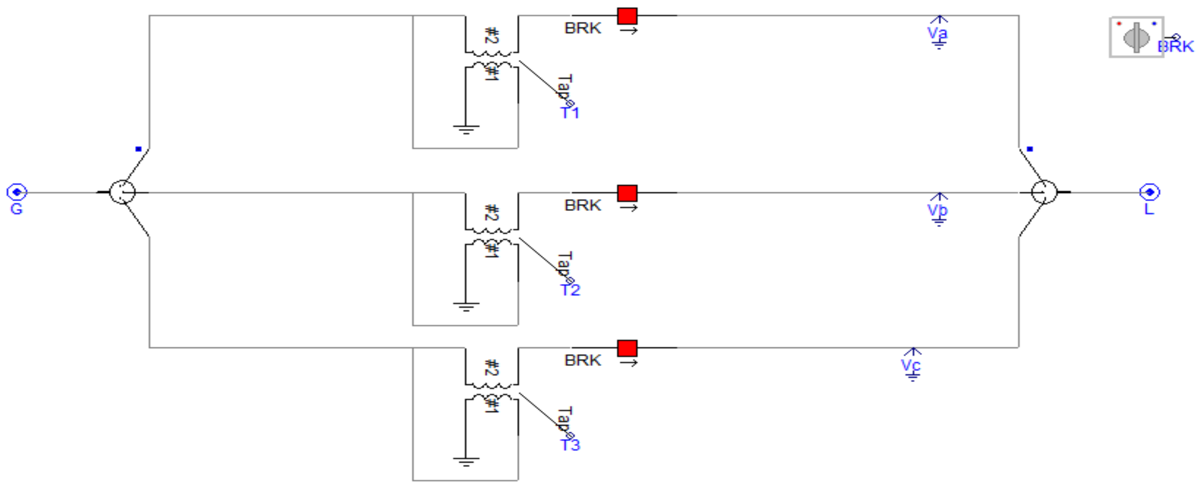

Figure 4.Simulated OLTC representation in series compensator

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OLTC transformers are represented by single phase two winding autotransformers with its primary winding grounded as in fig. 4.Three such transformers are used with its taps enabled to represent as an OLTC transformers. Breakers are in OFF position as it shows its red indication and it is used as a mechanical switch. Va,Vb,Vc are the phase voltages representation after compensation.

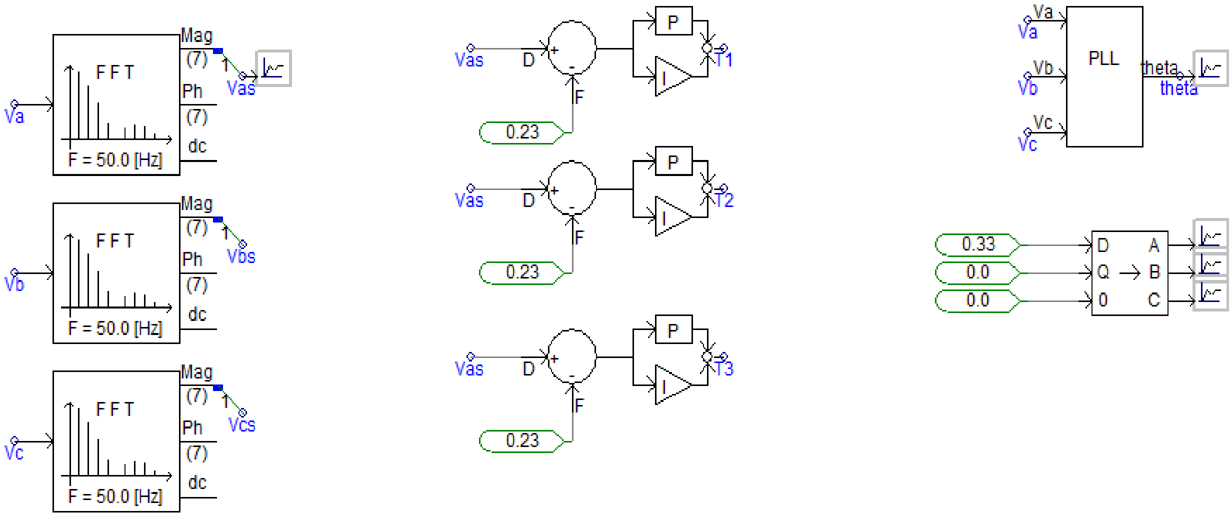

Figure 5.Controller for the OLTC transformer

PI controller is the controller designed for tap control and voltage regulation as shown in fig.5.Measured voltages Va,Vb,Vc are given as input to the FFT and from its magnitude output, RMS values of voltages Vas,Vbs,Vcs are obtained. Difference of measured RMS voltages and desired voltage of 0.23 is given as input to the PI controller. PI controller will produce the error value and it is used as compensating voltage to the system.PLL is used to transform the voltage from DQ frame to ABC frame and theta is obtained.0.33 is set as the reference voltage to verify the results.

V. RESULT AND DISCUSSION

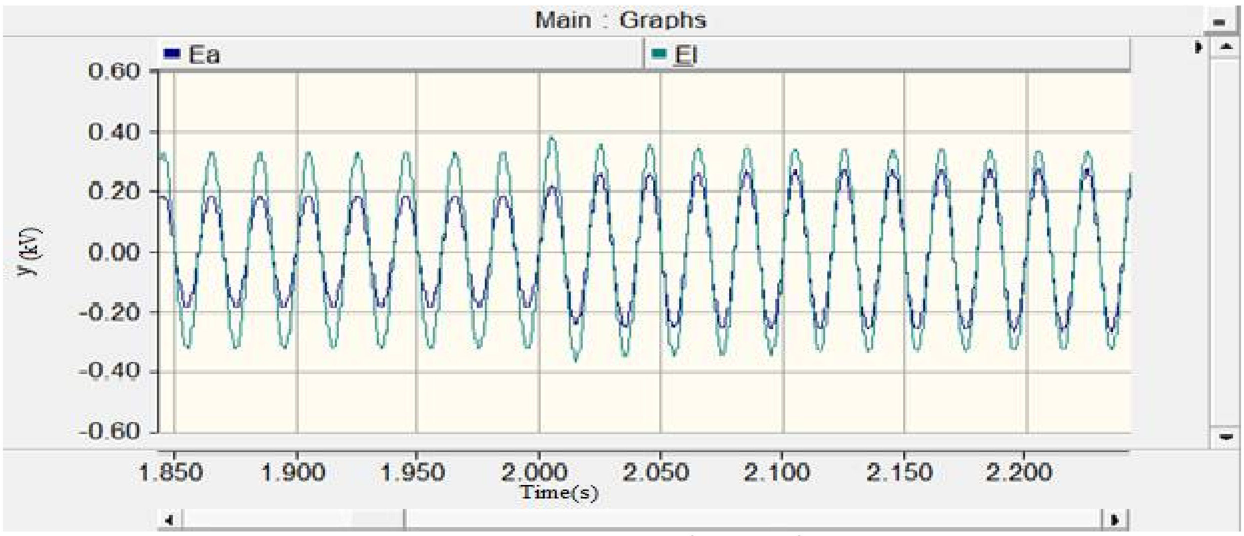

Figure 6. Steady-state phase voltages before and after compensation

Figure.6 shows dip in grid voltage upto 2sec. and it is the sag provided to test whether the series compensator is working properly or not. After 2sec. sag is eliminated and it compensates the sag completely after 0.1 sec. Ea shows the grid voltage and El shows the load voltage.

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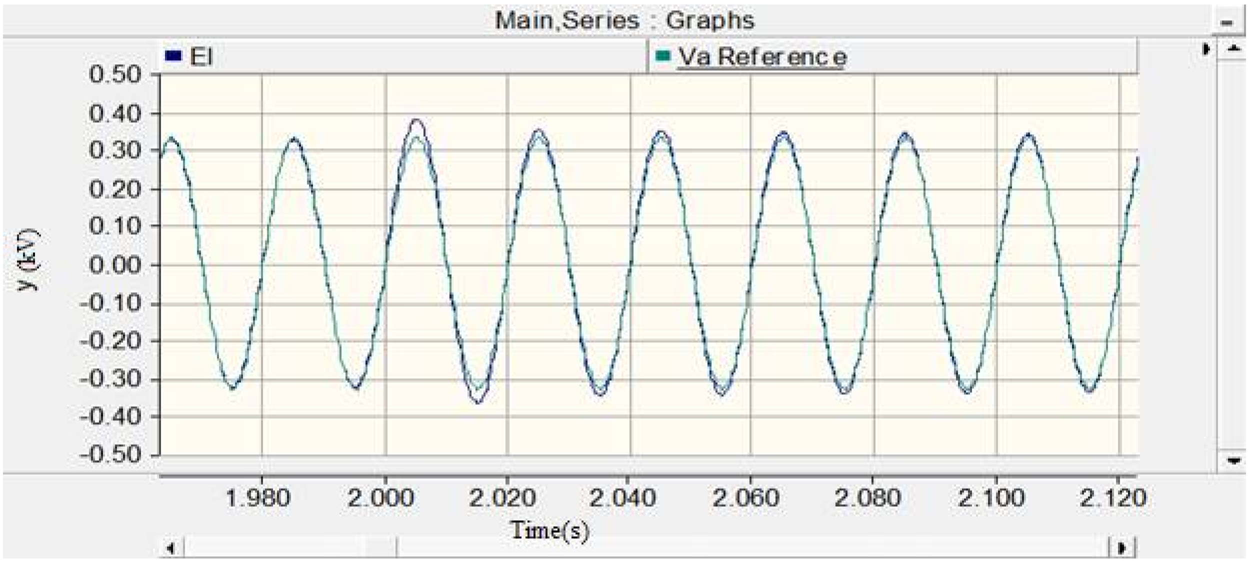

Figure 7.Load voltage (El) and reference voltage (Va) before and after compensation

Figure.7 shows the variation of load voltage and reference voltage with respect to sag phenomena. A hike is formed after sag compensation and it is regulated to its nominal value within seconds. For the better verification graphs shows a single phase fluctuation and it is settled to its normal value as same as the reference voltage.

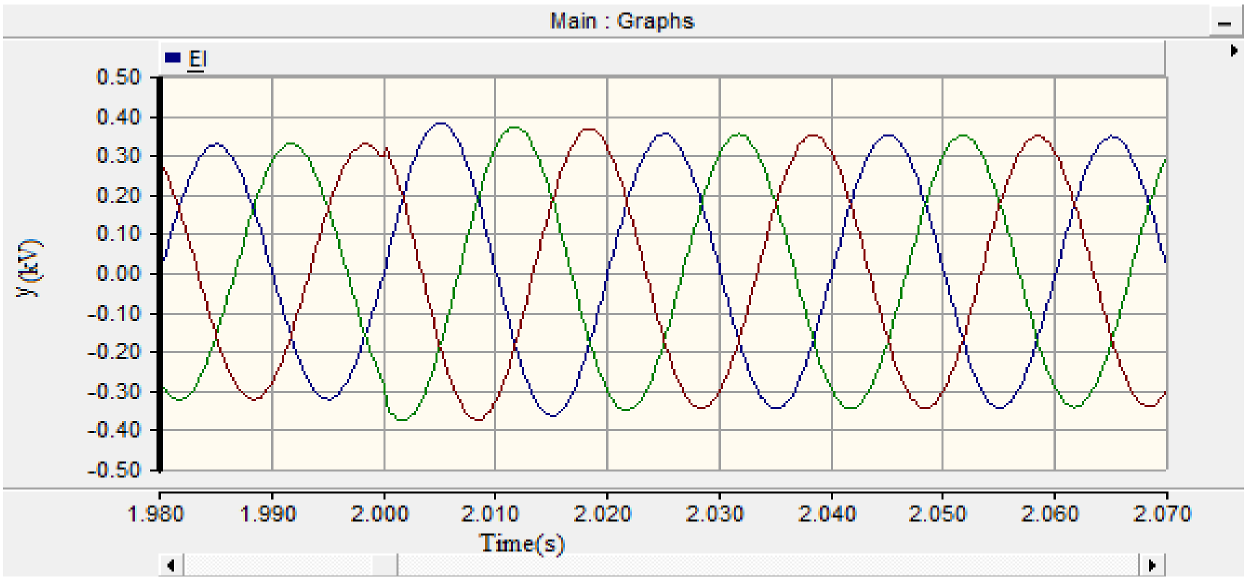

Figure 8.Load voltage variation with and without sag

Figure.8 shows load voltage in its three phase representation having dip and compensated voltage after 2sec.Amplitude differences completely exhibits the necessity of series compensator at the time of grid disturbances. It prevents appliances being faulty and damages to the transmission components.

VI.CONCLUSION

Voltage fluctuations due to the disturbances in the grid are observed in the distribution network. OLTC transformer based series compensator with PI controller is introduced to the system. Working of the PI controller is tested with sag phenomena and its efficiency in voltage regulation proves its application in different areas. Simulation results show sag

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is well compensated and disturbances in the supply voltage are not affected to the load voltage because of transformer switching. PI controller is used to reduce the voltage error and the aim is achieved in this paper.

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