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Voltage Sag And Swell Compensator For Distribution Transformer Using Series Voltage Regulator

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Abstract: A power quality issue, especially, voltage problem is the vital concern in most distribution systems today. So far, the voltage problem is mainly from under-voltage (voltage sag) condition due to a short circuit or a fault. Power quality in the distribution system is the important issue for industrial, commercial and residential applications today. The voltage problem is mainly considered from under-voltage (voltage sag) condition caused by short circuit or fault somewhere in the distribution system.

This paper presents a series voltage regulator for distribution transformer which improves the voltage sag/swell occurring at secondary side of transformer. The hysteresis voltage controller based series voltage regulator which connect after transformer secondary side is presented. The controller is comprises of Phase lock loop for reference voltage generation, the hysteresis controller is used for generation of gating signal. The complete system is developed in MATLAB. System is tested for different power quality disturbances which provide sufficient results for power quality disturbance improvement.

***Index Terms* -** Distribution transformer, series voltage regulator, voltage sag and swell

I. Introduction

Power quality problems like voltage sag, voltage swell and harmonic are major concern of the industrial and commercial electrical consumers due to enormous loss in terms of time and money. This is due to the advent of a large numbers of sophisticated electrical and electronic equipment, such as computers, programmable logic controllers, variable speed drives, and so forth. The use of this equipment often requires very high quality power supplies.

There are many different methods to mitigate voltage sags and swells, but the use of a custom Power device is considered to be the most efficient method. Switching off a large inductive load or Energizing a large capacitor bank is a typical system event that causes swells [1].

The Voltage swell, on the other hand, is defined as a swell is defined as an increase in rms voltage or current at the power frequency for durations from 0.5 cycles to 1 min. typical magnitudes are between 1.1 and 1.8 Per Unit (pu). Swell magnitude is also is also described by its remaining voltage, in this case, always greater than 1.0 pu. [2]. Voltage sags can occur at any instant of time, with amplitudes ranging from 10 – 90% and a duration lasting for half a cycle to one minute [3]-[4].

Voltage swells are not as important as voltage sags because they are less common in distribution systems. The voltage sag and swell can cause sensitive equipment modulation to fail, or malfunction, as well as create a large current unbalance that could blow fuses or trip breakers. These effects can be very expensive for the customer, ranging from minor quality variations to production downtime and equipment damage [5].

This paper presents series voltage regulator for distribution transformer which improves the voltage sag/swell at secondary side of transformer. In this approach the hysteresis voltage controller based series voltage regulator is used which connect after transformer secondary side. The controller is comprises of Phase lock loop for reference voltage generation hysteresis controller for generation of gating pulses. The complete system is developed in MATLAB. System is tested for different power quality disturbances which provide sufficient results for power quality disturbance improvement. The result shows the improvement in voltage profile.The MATLAB simulink model parameters are shown in table I.

II. PROPOSED APPROACH

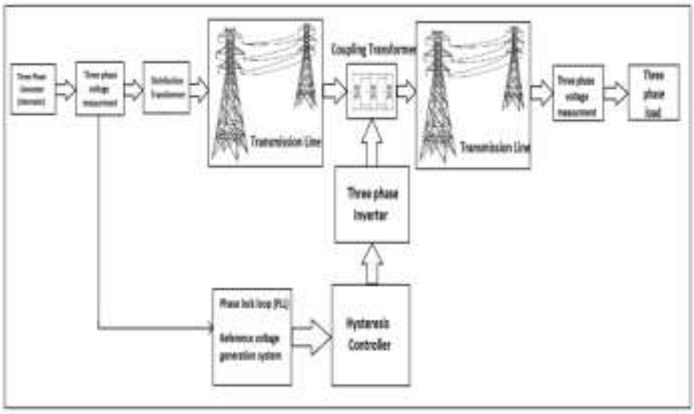

Fig.1. Block diagram of proposed approach

Figure 1 shows the generalized block diagram of proposed approach. In this approach, the coupling transformer connected in series with transmission line for insert of voltage or cancellation of voltage in phase with line voltage. The coupling transformer is control by controlling the inverter firing pulses using hysteresis controller.

III. SIMULATION MODEL

A .Without Series Voltage Regulator

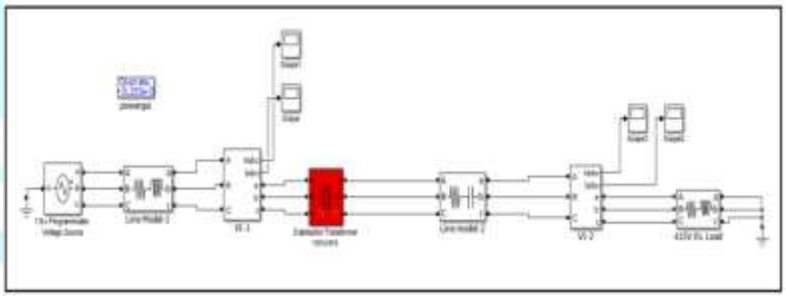

Fig.2. MATLAB simulink model of distribution transformer system without series voltage regulator

In figure 2, it is shows that three phase programmable voltage source (alternator) act as source for primary side of three phase 11KV/415V distribution transformer. Secondary side of transformer is connected to three phase distributed parameter transmission line model which supply the power to three phase RL load. Using programmable voltage source it is able to create voltage sag and swell event to primary side of distribution transformer. It is observed that, secondary side of transformer were generate same voltage sag and swell event in output side[6]-[7].

TABLE I. Matlab Simulink Model Parameter Specification

Sr No	Name of simulink block	Parameters
1	3 phase generator	Three phase to phase voltage = 11KV; Phase angle of phase A = 0 Degree; Frequency of supply = 50 Hz
2	Line 1	Inductance L = 0.5mH; Resistance R = 0.1 Ω
3	Line 2	Capacitance c = 6 µF; Resistance R = 6 Ω
4	Line 3	Inductance L = 1 mH; Resistance R = 50 Ω
5	Three phase load	Nominal phase to phase voltage = 400V; Nominal frequency = 50Hz; Active power = 10 KW; Inductive reactive power = 100 VAr
6	Distribution transformer	Primary side connected in star and secondary side connected in star, Nominal power = 100 MVA, Supply frequency = 50 Hz;

		Primary winding voltage V1= 11KV,Primary winding resistance = 0.00242 Ohm, Primary winding inductance = 0.00030812 H, Secondary winding voltage = 415 V, Secondary winding resistance = 3.4445 μΩ, Secondary winding inductance = 0.438 μH, Magnetizing resistance Rm = 605 Ohm, Magnetizing inductance Lm = 1.9258 H

B. With Series Voltage Regulator

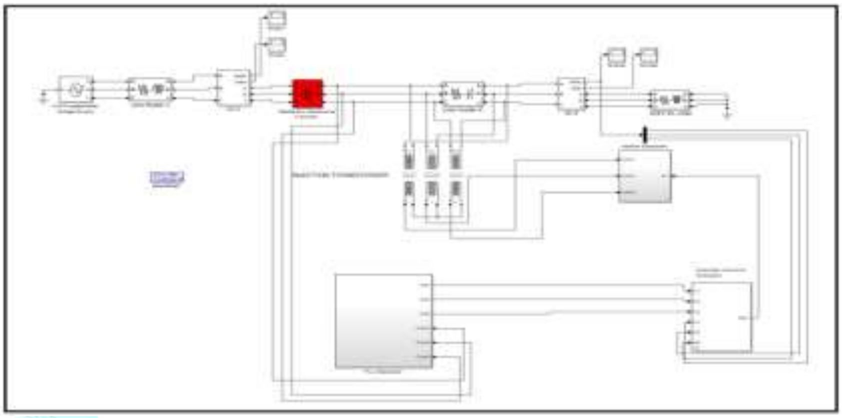

Fig.3. MATLAB simulink model of distribution transformer System with series voltage regulator

Figure 3 shows that, distribution transformer based power system in which series voltage regulator system using hysteresis controller is connected at secondary side of distribution transformer. An injection transformer is connected across the second transmission line in series manner. That injection transformer primary winding is energized by three phase inverter of 700 V DC supply. It is observed that, secondary side of transformer does not (discuss in MATLAB simulation results section) contain any voltage disturbances like harmonics, voltage sag and swell etc due to hysteresis controller based technique[8]-[13].

C. Controller Subsystem

A simple algorithm is developed to control the series and shunt filters. The series filter is controlled such that it injects voltages (V_{ca} ,V_{cb} ,V_{cc}) which cancel out the distortions and/or unbalance present in the supply voltages **(**V_{sa} ,V_{sb} ,V_{sc}**)** thus making the voltages at the PCC (V_{la} ,V_{lb} ,V_{lc}) perfectly balanced and sinusoidal with the desired amplitude. In other words, the sum of the supply voltage and the injected series filter voltage makes the desired voltage at the load terminals[14]-[16]. The control strategy for the series active filter is shown in figure 4.Series active filters(AF) are operated mainly as a voltage regulator.This type of approach is especially recommended for compensation of voltage unbalances and voltage sags from the ac supply.

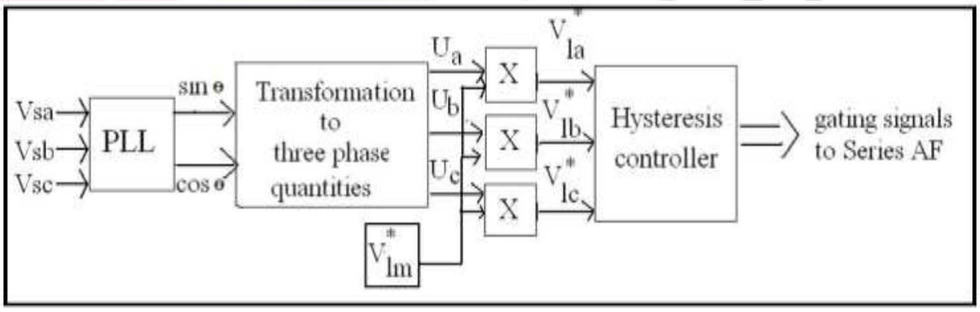

Fig.4. Controlling Scheme For Series Voltage Controller

Since the supply voltage is unbalanced and or distorted, a phase locked loop (PLL) is used to achieve synchronization with the supply. This PLL converts the distorted input voltage into pure three phase sinusoidal supply of RMS value of each phase equal to that of the fundamental (1 pu).Three phase distorted/unbalanced supply voltages are sensed and given to the PLL which generates two quadrature unit vectors (*SinΘ*,*CosΘ*)[17]-[21].

The sensed supply voltage is multiplied with a suitable value of gain before being given as an input to the PLL. The in-phase sine and cosine outputs from the PLL are used to compute the supply in phase, 120^0 displaced three unit vectors (u_a , u_b , u_c) using eqn.(1) as

$$\begin{bmatrix} u_a \\ u_b \\ u_c \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ \frac{-1}{2} & \frac{-\sqrt{3}}{2} \\ \frac{-1}{2} & \frac{\sqrt{3}}{2} \end{bmatrix} * \begin{bmatrix} \sin\theta \\ \cos\theta \end{bmatrix} \text{……………..} \quad (1)$$

The desired peak value of the PCC phase voltage is considered to be 338V. The output of the hysteresis controller is switching signals to the six switches of the VSI of the series active filter. The hysteresis controller generates the switching signals such that the voltage at the PCC becomes the desired sinusoidal reference voltage. Therefore, the injected voltage across the series transformer through the ripple filter cancels out the harmonics and unbalance present in the supply voltage[22]-[23].The MATLAB/Simulink model of the control scheme for series active filter is shown in figure 6.

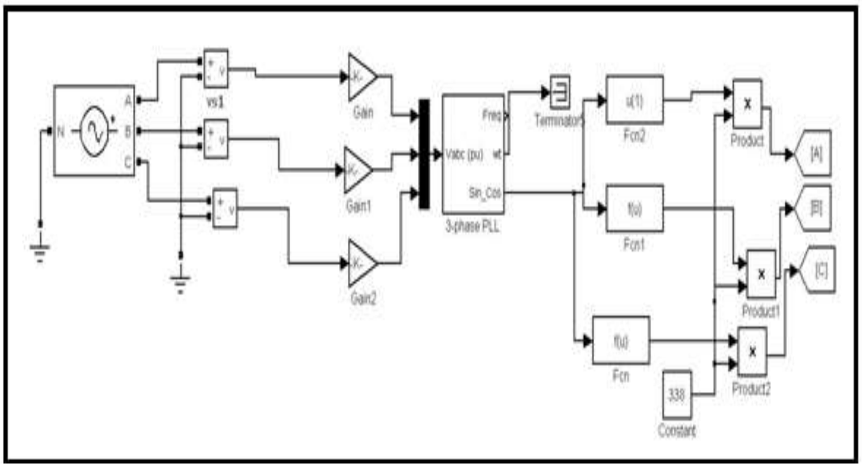

Fig.5. Reference Voltage Generation System Using PLL

The main advantage here to use a hysteresis band controller over a P-I controller is that the former does not require the specifications regarding the system parameters i.e. switching frequency, load angle etc. but the latter controller (P-I) requires an additional design criteria for its application[24-27].

IV. SIMULATION RESULTS

A. Without Series Voltage Regulator

Using programmable voltage, it able to generate voltage sag, swell and harmonics condition. In figure at 0.1 to 0.15 sec there is voltage sag, then after 1.15 to 2 sec the system is again normal, then after 0.25 to 0.3 sec system is in voltage sag condition.

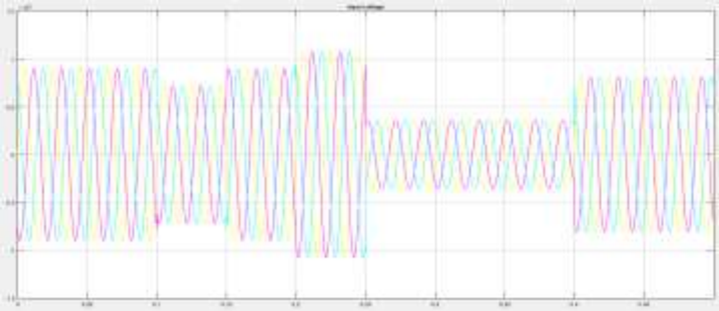

Fig.6. Sending End Voltage Of Transformer Primary Side Without Series Voltage Regulator

Figure.6 shows that three phase sending end three phase voltage of primary side of distribution transformer. That voltage was consisting of voltage sag and swell disturbance.

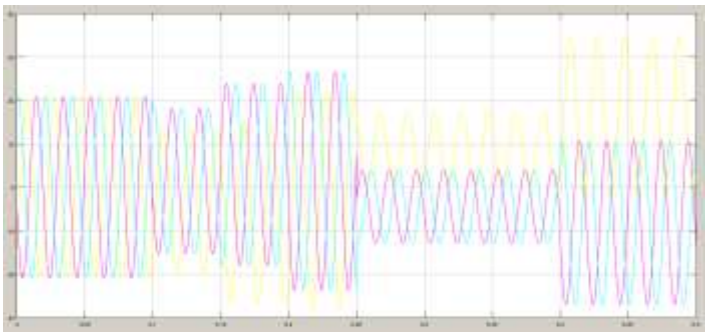

Fig.7. Sending End Current Of Primary Side Of Transformer Without Series Voltage Regulator

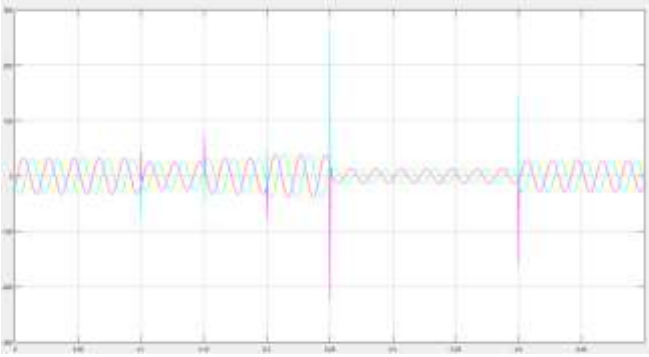

Fig.8. Receiving End Voltage At Secondary Side Of Transformer Without Series Voltage Regulator

Figure 8 shows that receiving end three phase voltage at secondary side of three phase distribution transformer. It is shows that, there are voltage disturbances present at receiving end i.e. secondary side of transformer [28]-[31].

B. With Series Voltage Regulator

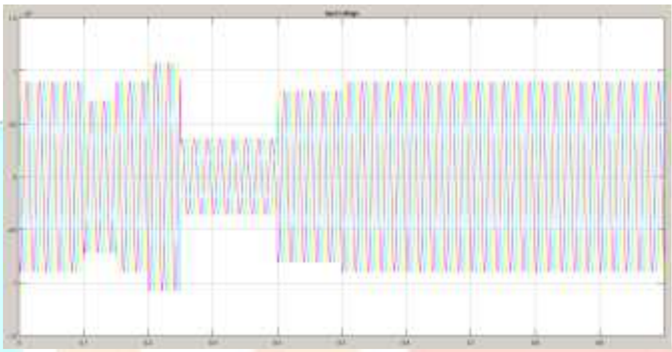

Fig.9. Sending End Voltage Of Transformer Primary Side With Series Voltage Regulator

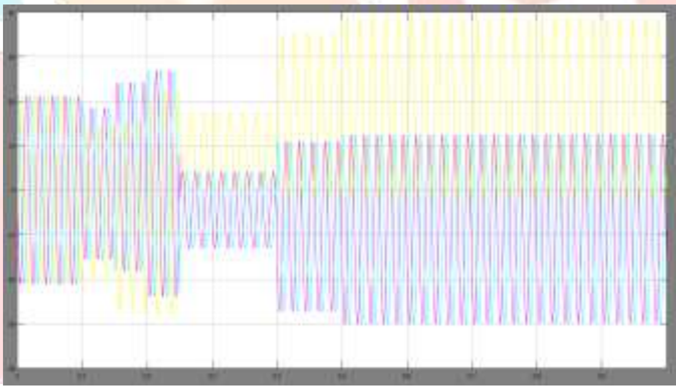

Fig.10. Sending End Current Of Primary Side Of Transformer With Series Voltage Regulator

Figure 9 shows that three phase sending end three phase voltage of primary side of distribution transformer. That voltage was consisting of voltage sag and swell disturbance.

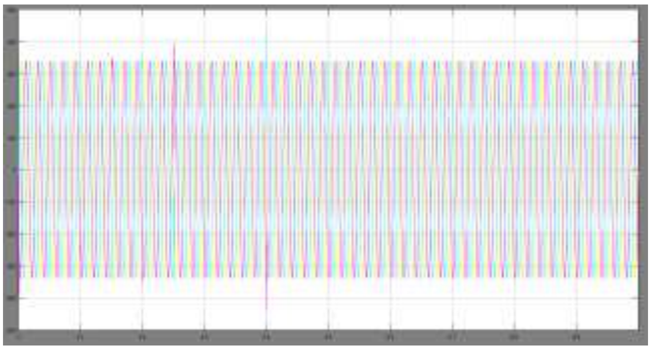

Fig.11. Receiving End Voltage At Secondary Side Of Transformer With Series Voltage Regulator

Figure 11 shows that, three phase receiving end voltage with series voltage regulator controller. It is shows that, there is no any voltage fluctuation present at secondary side of distribution transformer.

V. CONCLUSION

In this paper a hysteresis voltage controller based series voltage regulator system is presented. The system is specially designed for removal of voltage sag and swells disturbances at the secondary or load side of distribution transformer.The Phase lock loop (PLL) system for generation of reference voltage from source side of transformer is used. These voltage vectors are compared with load side voltage of distribution transformer. Depending on result of comparison, the hysteresis controller generates the firing pulses for inverter.The output of inverter system is then fed to the injection transformer system.From simulation result shows that voltage sag or swell disturbances is removed completely by using hysteresis voltage controller based series voltage regulator system at the secondary side of distribution transformer of 10 KW system.

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