Enchancement Of Voltage Quality In Power Sytem Through Series Compensation

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Abstract: *Voltage sag & swell creates useless dispute at the customer side as well as utility side. In this paper, dynamic voltage restorer device based on voltage source converter topology is used to compensate voltage sag & swell. Dynamic Voltage Restorer (DVR) is a power electronic device that is utilized to improve voltage stability i.e. To reduce the power quality problems in electrical power system network. Usually DVR is installed between load feeder and source in the distribution system. In this paper approach to compensate voltage sag & swell by using dynamic voltage restorer base on sin template generation is discussed. Simulation is done in MATLAB software and results are obtained.*
Keywords: *Dynamic voltage restorer, voltage sag, sensitive load, non linear load.*

I. Introduction

Power quality is simply the interaction of electrical power with electrical equipment. In recent year power quality (PQ) has become a major concern to both power utilities and power customer due to vastness and complexity of modern power system, occurrence of fault and frequency of normal switching action is increasing rapidly, the fault and switching action often produce disturbances. These disturbances can give rise to equipment damage, failure, malfunction and degradation of electrical power quality. In power system the term disturbance denote phenomenon in voltage and current with a short and long duration. Now, disturbance is seen as a potential power quality problem.

Custom power devices are used to improve the quality of power. In 1995 the thought of custom power is first explained by Hingorani. The reflection of custom power (CP) identifies with the consumption of electronic controllers for power system network. There are number of custom power units which are given below, Distribution Statcom (D-STATCOM), Dynamic Voltage Restorer (DVR), Unified power quality conditioner, Active Power Filters, Battery Systems (BESS),Distribution Series Capacitors (DSC), Surge Arresters (SA),Uninterruptible Power Supplies (UPS), Solid State Fault Current Limiter, Solid-State Transfer Switches (SSTS), and Static Electronic Tap Changers (SETC). The CPD devices are either connected in series or in shunt or combination of both. Power system make sure good quality of electrical power supply which means voltage and current wave form should be balance and sinusoidal. moreover, the voltage level torque on the system should be within dependable limit, generally within 100+ -5% of their rated value if the voltage is more or less.

The issue in electricity power sector delivery is not confined to only energy efficiency and environment but more importantly on quality and continuity of supply or power quality and supply quality electrical power quality is the degree of any deviation from nominal values of the magnitude and frequency power quality may also be defined as the degree to which both utilization and delivery of electric power affects the performance of electrical equipment from the perspective, a power quality problem is define as any problem manifested in voltage ,current and frequency deviation that result in power failure or mis-operation of customer equipment. The presence of voltage disturbances at the point of common coupling (PCC) results in failure of sensitive industrial equipment, which produces grid component failures, such as transformers, and economical losses. Dynamic voltage restores are a adequate solution to mitigate the voltage sag and protect sensitive loads against the most important voltage disturbances voltage sag. A Dynamic voltage restorer is the voltage source converter that injects a series voltage in the line. The dynamic voltage restorer is able to work like series active powers filter. The paper deals with compensation of voltage sag & swell by using DVR based unit vector template generation control strategy. Currently they are based on converters and connect to low and medium voltage distribution system in shunt or in the series. Series active power filters must operate in conjunction with shunt passive filters in order to compensate load voltage and current harmonics. DVR operates as a controllable voltage source power. Both schemes are implement preferable which voltage source inverters with a dc bus

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having a reactive element such as a battery. One of the most common power quality problems today is voltage dips. Voltage sag is a small time (10 ms to 1 minute) event for the duration of which is diction in r.m.s. voltage magnitude occurs. It is often set only by two parameters, magnitude and duration. The voltage sag magnitude is ranged from 10% to 90% of nominal voltage (which corresponds to 90% to10% remaining voltage) and with a duration from half a cycle to 1 min .In a three-phase system a voltage sag is by nature a three- phase phenomenon, which affects both the phase-to-ground and phase to- phase voltage the voltage sag is cause by the sag.

II. Configuration Of DVR

The various components of dynamic voltage restorer are injection transformer, harmonic filter, voltage source converter and energy storage control [9].
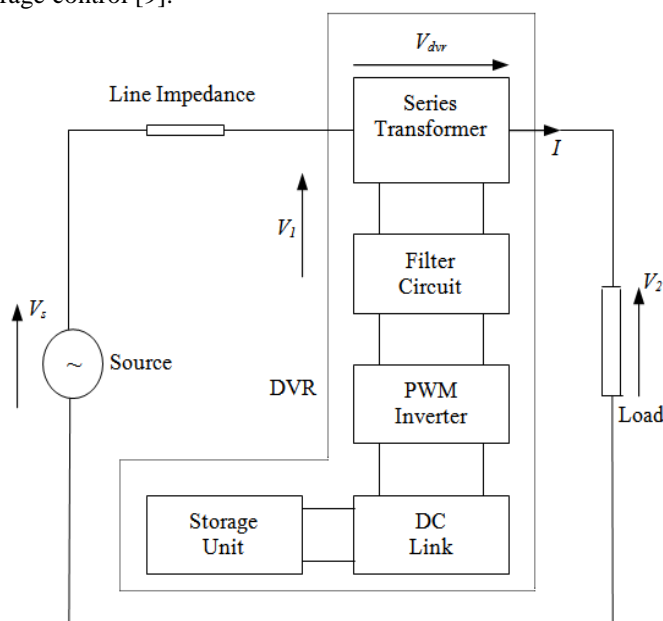

Fig.1 Basic block diagram of DVR

The dynamic voltage restorer (DVR) is a series connected device for compensate the unbalance and balance voltage sags. The dynamic voltage restorer used to mitigate the supply voltage related problem by injecting voltage series with the line to achieve distortion free voltage at the load terminal the series converter can be represented by following equation.

$V_{inj}(\omega t) = V_L(\omega t) - V_S(\omega t)$ (1)

Where, $V_{inj}(\omega t)$, $V_L(\omega t)$ and $V_S(\omega t)$ represent the series converter injected voltage load voltage and actual source voltage respectively.

The schematic diagram of DVR system is shown in "Fig.1", The DVR has mainly two parts,
a) Power circuit
b) Control circuit and PI controllers.

Power circuit consists of voltage source converter (VSC), series connected injection transformer, passive filter and energy storage device. In DVR, control circuit is used to derive the parameters like magnitude, frequency and phase shift of the control signal that has to be injected through DVR. As per this control signal, an injected voltage is generated by the power circuit. The DVR corrects voltage sag for conditions to maintain the load voltage to sensitive loads within acceptable tolerances. The DVR is designed for compensate voltage sag of a various magnitude for various durations. As the connection of transformer in distribution network is of delta-star type, zero sequence voltage will not propagate through transformer; hence only restoration of positive sequence and compensation of negative sequence voltage is required The VSC utilizes insulated gate bipolar transistors (IGBTs). It is supplied from an energy source, and provides compensated AC voltage with the help of inverter. A passive filter is used to suppress the switching harmonics and corrects the shape of voltage to be injected. Connection of DVR with the distribution line is made through an injection transformer that is connected in series with the line. The three single phase injection transformer is used to inject the missing voltage at the PCC.

The main objective of this paper is to compensate the symmetrical voltage sag as well as unsymmetrical voltage sag.

Selection Of DC Capacitor
The selection of dc bus capacitance is selected based on transient energy required during changed in the load Considering that energy store in the capacitor is for meeting the energy demand of the load for fraction of power cycle.[18]

$$(½)\{C_{DC}(V^2_{DC} - V^2_{DC1})\} = 3V_f I_f \Delta t \tag{4}$$

Where,
V_{DC} is rated voltage, V_{DC1} is the drop in voltage allowed during the transient, Δt is the time for which support is required and C_{DC} is the DC bus capacitance.

III. Control Strategy And Praposed Methdology

This section is described by the proposed control strategy of dynamic voltage restorer. The unit vector template generation (UVTG) technique is used to control the dynamic voltage restorer the controlled block diagram DVR for generating reference voltage signal is as shown in fig.2.[2]
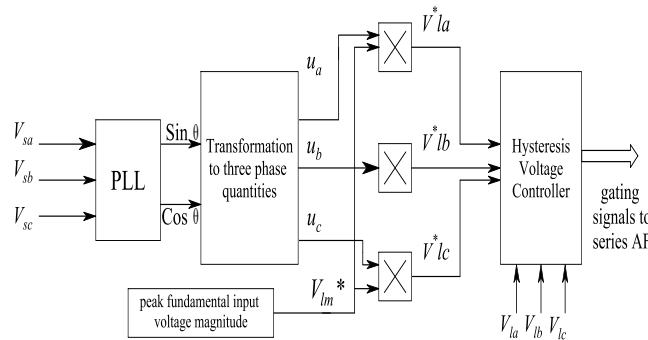

Fig.2 Control block diagram of series APF.

The component of series APF (DVR) is controlled to appropriate voltage between the point of common coupling and load so that voltage become balance and distortion free and maintain desire magnitude.[2] [3]

The overall control scheme of series AF is shown in Fig.4.1. The load Reference voltages are generated using Phase Locked Loop (PLL). The control algorithm is based on the extraction of Unit Vector Templates from the distorted input supply. These templates will be then equivalent to pure sinusoidal signal with unity (p.u.) amplitude

A series active filter controlled in such a way that the injected voltage (v_{ca}, v_{cb}, v_{cc}), which cancel out the unbalance and/or distortions present in the supply voltages (v_{sa}, v_{sb}, v_{sc}), thus maintaining 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. The distorted supply voltage is given to PLL which gives synchronization with the supply [15].Three phase distorted/unbalanced supply voltages are sensed and given to the PLL which generates two quadratureunit vectors ($\sin\theta$, $\cos\theta$). The sensed supply voltage is multiplied with a suitable value of gain before being given to the PLL. The two quadrature in phase unit vector of PLL are used to compute the supply in phase, 120^0 displaced three unit vectors (u_a, u_b, u_c) using equation (1).

$$\begin{pmatrix} Ua \\ Ub \\ Uc \end{pmatrix} = \begin{pmatrix} 1 & 0 \\ -1/2 & -\sqrt{3/2} \\ -1/2 & \sqrt{3/2} \end{pmatrix} \begin{pmatrix} \sin\theta \\ \cos\theta \end{pmatrix} \tag{2}$$

The computed three in-phase unit vectors then multiplied with the desired peak value of the PCC phase voltage (V_m), which becomes the three-phase reference PCC voltages as:

$$
\begin{pmatrix} Vla \\ Vlb \\ Vlc \end{pmatrix} = Vm \begin{pmatrix} Ua \\ Ub \\ Uc \end{pmatrix}
$$

(3)

The desired peak value of the PCC voltage under Consideration is 338V (=415sqrt (2)/sqrt(3)).The Computed voltages from reference voltages from eqn.(2) are then given to the comparator along with the sensed three phase PCC voltages(V_{La}, V_{Lb} and V_{Lc}).[3]

For getting the distortion free load voltage this load voltage must be equal to the reference load voltage.

Now this reference voltage is compare with load voltage which gives the error signal as shows in fig.(3)
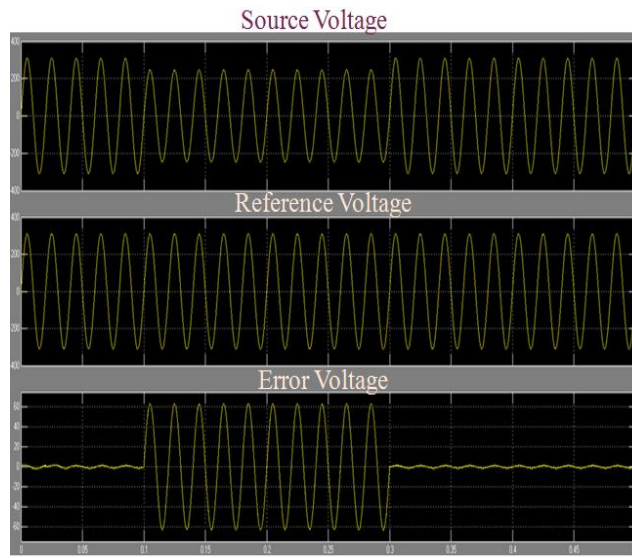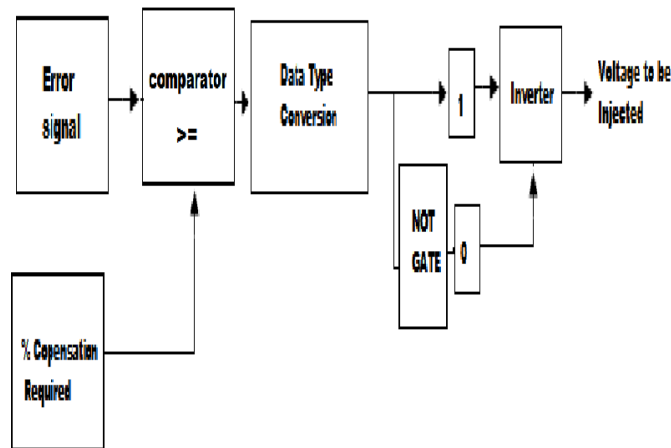

Fig.3 Generation of error signal.

Fig.4 Generation of triggering pulses

Fig.4 shows generation of triggering pulses from error signal and % compensation required. Error signal and required % compensation are compared and data type of the output is changed to Boolean. Logical operation with the Boolean signal generates the required triggering pulses to the inverter that generates the voltage to be injected.

Simulation of control algorithm

The basic functions of a controller in a DVR are the detection of voltage sag, distortion, and harmonic events in the system; computation of the correcting voltage, generation of trigger pulses to the sinusoidal PWM based DC-AC inverter, correction of any anomalies in the series voltage injection and termination of the trigger

pulses when the event has passed. The controller may also be used to shift the DC-AC inverter into rectifier mode to charge the capacitors in the DC energy link in the absence of voltage sags. The control scheme for the proposed system is based on the comparison of a voltage reference and the measured terminal voltage (Va, Vb, Vc).The voltage sags is detected when the supply drops below value 20% of the reference voltage. The error signal is used as a modulation signal that allows to generate a commutation pattern for the power switches (IGBT's) constituting the voltage source converter. The commutation pattern is generated by means of the sinusoidal pulse width modulation technique (SPWM); voltages are controlled through the modulation. The PLL circuit issued to generate a unit sinusoidal wave in phase with mains voltage.
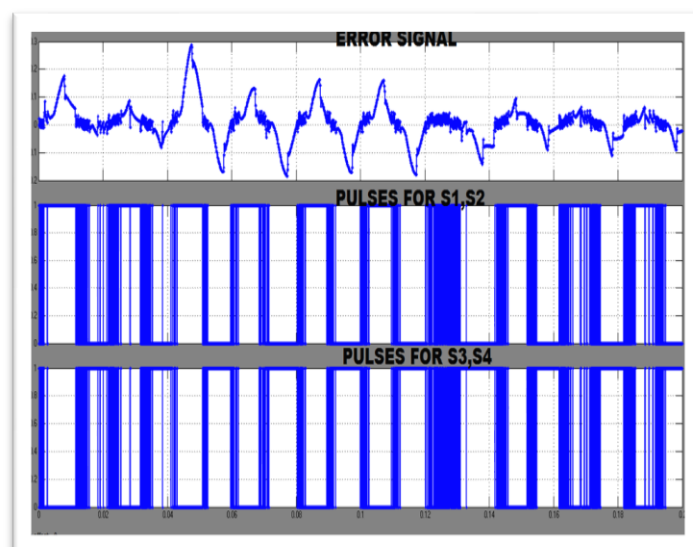

Fig.5 triggering pulses

The output of the comparator is switching signals to the twelve switches of the VSI of Series APF. It will generate the switching signals such that the voltage at PCC becomes the desired sinusoidal reference voltage. Therefore, the injected voltage across the series transformer through the ripple filter cancel out both balance and unbalance voltage sag present in the supply voltage.
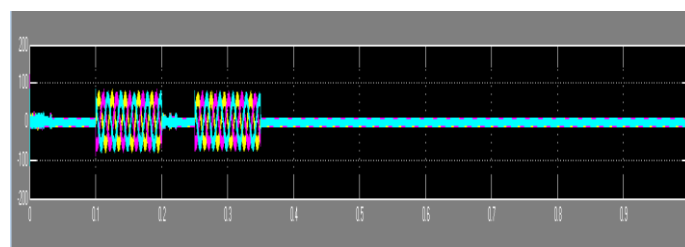

Fig.6 Injection transformer output

Fig. 6 shows voltage to be injected in series with the load voltage. Injected voltage is the approximate sine wave voltage due to transformer winding inductance.

IV. Simulation And Results
In this section the MATLAB simulation and result are presented dynamic voltage restorer (DVR) voltage sag mitigation based on sine template method technique there are two cases analyzed for the DVR i.e. voltage sag and voltage swell based on UVTG control technique which are given below.
CASE I: 20%   Balance voltage sag compensation.
Generally in case of power system this sag comes about due to faults or beginning of sudden large load. Following figure shows generalized power system.
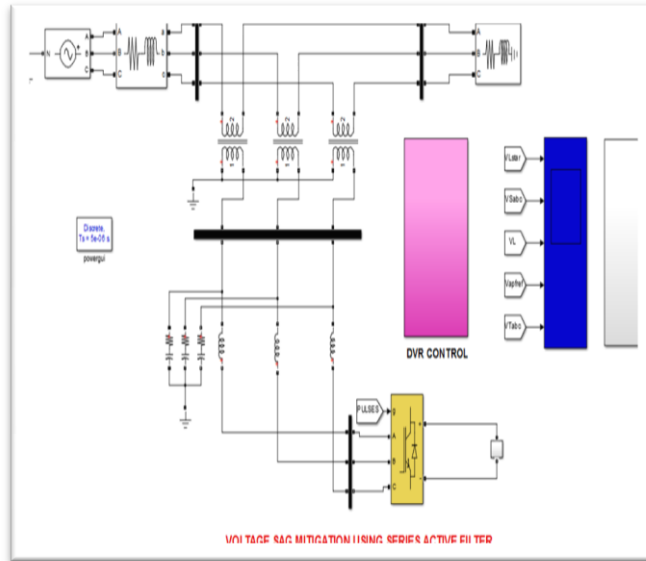
Fig.7 Shows Simulation of system when programmable voltage source

The simulation result of 20% supply balance voltage sag created in all three phase with the help of three phase programmable voltage source at 0.1s and cleared at 0.3sis shown in fig. when the supply voltage sag is created at 0.1s the dynamic voltage restorer comes into operation and inject the missing voltage during the sag.
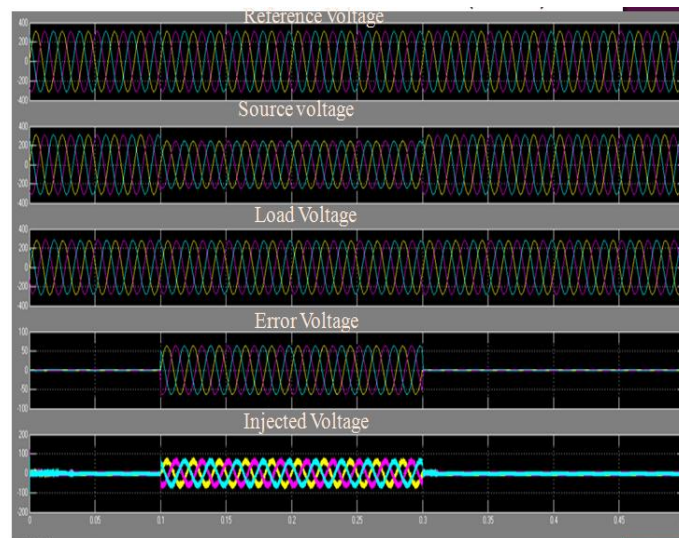

Fig.8 Simulation and results of Case I

System voltage	Voltage sag	Injected voltage	Mitigated voltage
380V	0.2pu	0.10*2	1pu

Table 1. Observed Output of Case I

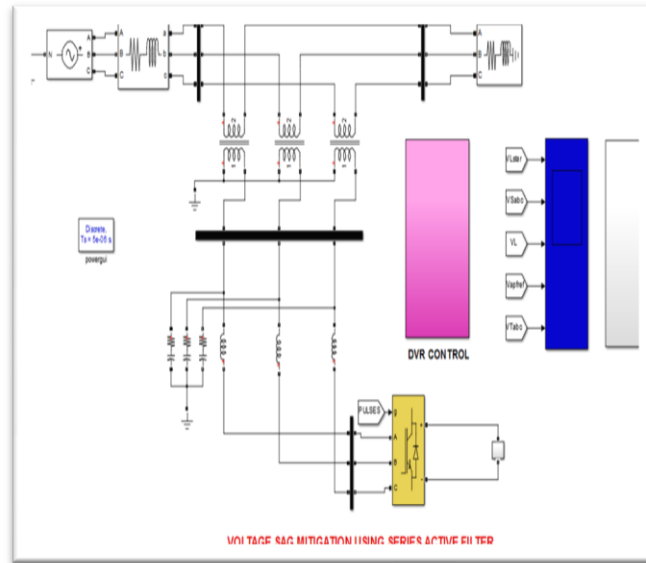**CASE II**: 25% balance voltage sag compensation.

Fig.9 Shows Simulation of system with three phase programmable voltage source

The simulation result of 25% supply balance voltage sag created due to three phase programmable voltage sorce for duration 0.1s and cleared at 0.3s is shown in fig. when the supply voltage sag is created at 0.1s the dynamic voltage restorer comes into operation and inject the missing voltage during the sag.
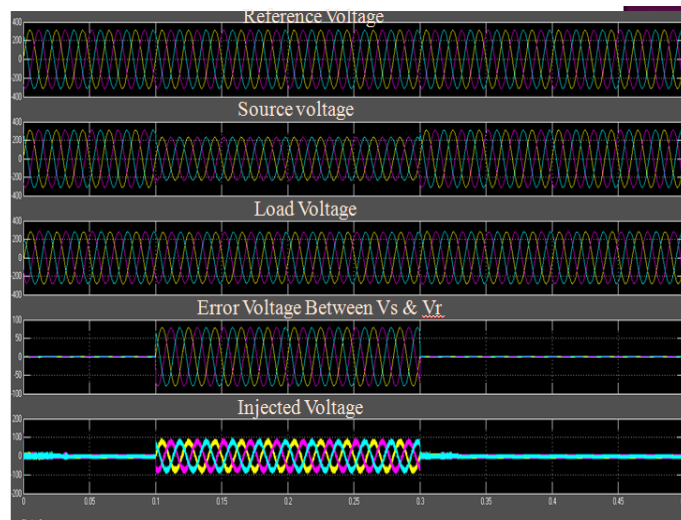

Fig.10 simulation and result for voltage in case II

Table 2. Observed Output of Case II

System voltage	Voltage sag	Injected voltage	Mitigated voltage
380V	0.25pu	0.125*2	1pu

Case III: 20% balance Swell compensation

The simulation result of 20% supply balance voltage swell created by three phase programmable voltage source for duration 0.25s and cleared at 0.35s is shown in fig. when the supply voltage sag is created at 0.25s the dynamic voltage restorer comes into operation and inject the missing voltage during the sag.

Fig.11 simulation and result for voltage in case III

Table 3. Observed Output of Case III

System voltage	Voltage sag	Injected voltage	Mitigated voltage
380V	0.25pu	0.125*2	1pu

From both the cases, it is verified that, voltage injected by inverter = 1–Sag Voltage (pu) and 1- swell voltage (5)

V. Conclusion

The modeling and simulation of a DVR using MATLAB has been presented in this paper. A proposed control system based on unit vector template generation (UVTG) for DVR. The MATLAB simulink models have been simulated to verify effectiveness of proposed control technique   The simulation shows that the DVR performance is Satisfactory in mitigating voltage sag. Simulation results also show that the DVR compensates the sags quickly and provides excellent voltage regulation. The DVR can handles both balanced and unbalanced situations without any difficulties and injects the appropriate voltage component to correct rapidly any anomaly in the supply voltage to keep the load voltage balanced and constant at the nominal value.

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