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MITIGATION OF BALANCED & UNBALANCED VOLTAGE SAG/SWELL BY USING DYNAMIC VOLTAGE RESTORER

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Abstract

The dynamic voltage restorer (DVR) is one of the modern devices used in distribution systems to protect consumers against sudden changes in voltage amplitude. It gives that the use of DVR & hybrid active filters improves the quality of power by voltage profile improvement and by the mitigation of harmonics in the supply current. Here emergency control in distribution systems is analyzed by using the proposed multifunctional DVR control strategy. The proposed algorithm is applied to some disturbances in load voltage caused by induction motors starting, and a three phase short circuit fault. Also, the capability of the proposed DVR has been tested to limit the downstream fault current. The current limitation will restore point of common coupling (PCC) (the bus to which all feeders under study are connected) voltage and protect the DVR itself. The idea here is that the DVR acts as a virtual impedance with the main aim of protecting the PCC voltage during downstream fault without any problem in real power injection in to the DVR. The DVR normally installed between the source voltage and critical or sensitive load. The simulations are performed using MATLAB/SIMULINK's SimPower Toolbox. The simulation and experimental results demonstrate the effective dynamic performance of the proposed configuration.

KEYWORDS : DVR (dynamic voltage restorer), PCC(point of common coupling), power quality, voltage profile, MATLAB Simulink.

I. INTRODUCTION

Now a day, because of large use of sensitive and nonlinear loads in electrical power systems and the rapid growth of renewable energy sources, the power quality problems are very important. The most regular power quality situations are voltage dip, voltage swell, and harmonic contents and so on. Voltage sag defined as decrease in voltage magnitude of between 0.1 to 0.9 p.u. & voltage swell is that of over 1.1 p.u. During voltage sag the power delivered to the load is reduced. The definition of voltage dip is dependent upon two parameters, size and duration. Voltage sag & swell can cause sensitive equipment (such as found in semiconductor or chemical plants) to fail, or shutdown, 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 down-time & equipment damage.

There are number of custom power units which are given below, Distribution Statcom (D-STATCOM), Dynamic Voltage Restorer (DVR), Unified power quality conditioner (UPQC), Active Power Filters, Battery Systems (BESS), Distribution Series Capacitors (DSC), Surge Arresters (SA), Uninterruptible Power Supplies (UPS), Solid State Fault Current Limiter (SSFCL), Solid-State Transfer Switches (SSTS), and Static Electronic Tap Changers (SETC) [2]. The CPD devices are either connected in series or in shunt or combination of both.

The DVR is recognized as successful sort of custom power unit due to its following advantages:
1) It has capacity to manage the active power flow. 2) It has less cost compared with others. 3) It requires less maintenance. 4) it has higher energy capacity. 5) DVR is more minor in size and expenses less compared with the DSTATCOM, likewise DVR recompenses the voltage dip , voltage swell, it can additionally included different features for example power factor correction and harmonics elimination. For higher power sensitive loads where energy storage capabilities of UPS (uninterrupted power supply), become very costly. DVR provides more cost effective.
DVR can implemented at both a low voltage & medium voltage levels and gives to protect high power applications from voltage disturbances. DVR uses a combined feed-back & feed -forward control to obtain good transient & steady state responses. The Hysteretic Voltage Control can provide fast transient response without additional loop compensation. The effect of DVR on the system is experimentally investigated under both faulted & non-faulted system states for a variety of linear & non-linear loads. At the end, MATLAB/SIMULINK model based simulated results were presented to validate the effectiveness of the proposed control method of DVR.

II. CONVENTIONAL METHODS

A filter circuit (as the name suggests) filters stuff. In our case, the circuit allows sinusoids of a certain frequency to appear at the output, it attenuates sinusoids at other frequencies. That is, the circuit does not allow them to appear at the output. We will see how in the next section. The main types of filter circuits are:

i . **Low-pass filter**: This circuit allows frequencies below a specific frequency to pass through. Higher frequencies are attenuated. The RC circuit considered above is a low pass filter circuit. We will see how in the next section.

ii **. High-pass filter**: Allows frequencies above a specific frequency to pass through. Lower frequencies are attenuated.

iii **. Band-pass filter**: Frequencies in a specific range (or band), example: [1 kHz, 1 MHz] pass through. Frequencies above 1 MHz and below 1 kHz are attenuated.

Iv**.Band-reject filter**: Frequencies in a specific range (or band), example: [1 kHz, 1 MHz] are attenuated. Frequencies above 1 MHz and below 1 kHz are allowed to pass through.

Filter circuits can also be classified as passive or active. Passive circuits contain only impedances. They are not capable of amplifying the output signal.

III. PERFORMANCE OF DVR

The power quality problems (sags, swells, harmonics etc.) can be overcome by using the concept of custom power devices which is introduced recently. One of those devices is the Dynamic Voltage Restorer (DVR),which is the most efficient and effective modern custom power device used in power distribution networks. The location of DVR is as shown in the Fig.1. DVR is a recently proposed series connected solid state device that injects voltage into the system in order to regulate the load side voltage. It is normally installed in a distribution system between the supply and the critical load feeder at the point of common coupling (PCC). Other than voltage sags and swells compensation, DVR can be also added to other features like: line voltage harmonics compensation, reduction of transients in voltage and fault current limitations.

IV. WORKING PRINCIPLE

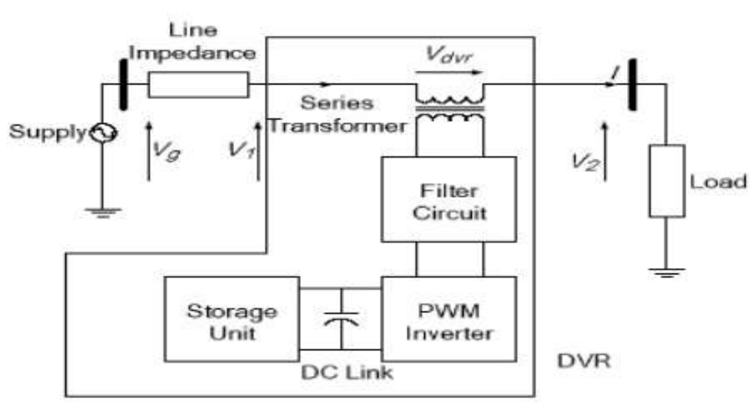

Fig.1 schematic diagram of DVR

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The basic principle of the Dynamic voltage restorer (DVR) is to inject a voltage of require magnitude and frequency , so that it can be restore the load side voltage to the desired amplitude & waveform even when the source voltage is unbalanced or distorted. The DVR can generate or absorb independently controllable real &reactive power at the load side. A DVR consisting of an injection transformer , voltage source converter, energy storage unit & filter as shown in fig.1. Voltage source converter is used to generate part of supply voltage which is missing. Injection transformer connects the DVR to the distribution system & converts the voltages from the VSC to the incoming supply voltage. Passive filters eliminates the unwanted harmonic components generated by the VSC. The energy storage such as battery is responsible to supply energy storage in dc form. A DC link voltage is used by the VSC to synthesize an AC voltage in to the grid & during a majority of voltage dips active power injection is necessary to restore the supply voltages.

V. SYNCHRONOUS REFERENCE FRAME (SRF) THEORY:

The conventional SRF method can be used to extract the harmonics contained in the supply voltages or currents. For voltage harmonic compensation, the distorted voltages are first transferred into two-phase stationary coordinates using $a-\beta$ transformation (same as in $p-q$ theory). After that, the stationary frame quantities are transferred into synchronous rotating frames using cosine and sinus functions from the phase-locked loop (PLL). The sinus and cosine functions help to maintain the synchronization with supply voltage and current. Similar to the $p-q$ theory, using filters, the harmonics and fundamental components are separated easily and transferred back to the $a-b-c$ frame as reference signals for the filter. The conventional SRF algorithm is also known as $d-q$ method, and it is based on $a-b-c$ to $d-q-0$ transformation (park transformation), which is proposed for active filter compensation . Several APF and DVR application works presented in the literature are about improving the performance of the compensator.

In the SRF-based APF applications in three-phase four-wire (3P4W) systems, voltage and current signals are transformed into the conventional rotating frame ($d-q-0$). In the SRF method, the transformation angle (ωt) represents the angular position of the reference frame which is rotating at a constant speed in synchronism with the three-phase ac voltage. In non- linear load conditions, harmonics and reactive currents of the load are determined by PLL algorithms. Then, currents with the same magnitude and reverse phase are produced and injected to the power system in order to compensate neutral current, harmonics, and reactive power. In the stationary reference frame, $a-\beta-0$ coordinates are stationary, while in the SRF , $d-q-0$ coordinates rotate synchronously with supply voltages. Thus, the angular position of the supply voltage vector shows the angular position of the SRF.

VI. NEW PROPOSED METHOD OF DVR:

The control block of the DVR proposed in synchronous reference frame theory which is used for the control of self supported DVR. The voltage at PCC is converted to rotating reference frame using abc-dq0 conversion using low pass filter(LPF) harmonics and oscillatory components of voltage are eliminated.

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The components in d-axis & q-axis are 3 phase reference supply voltage (VLa*,VLb*,VLc*) are derived using sensed load voltages ,terminal voltages (Vta, Vtb, Vtc) and dc bus voltage (Vdc) of the DVR.

$$V_{sd} = V_{sd}(ac) + V_{sd}(dc)$$
$$V_{sq} = V_{sq}(ac) + V_{sq}(dc)$$

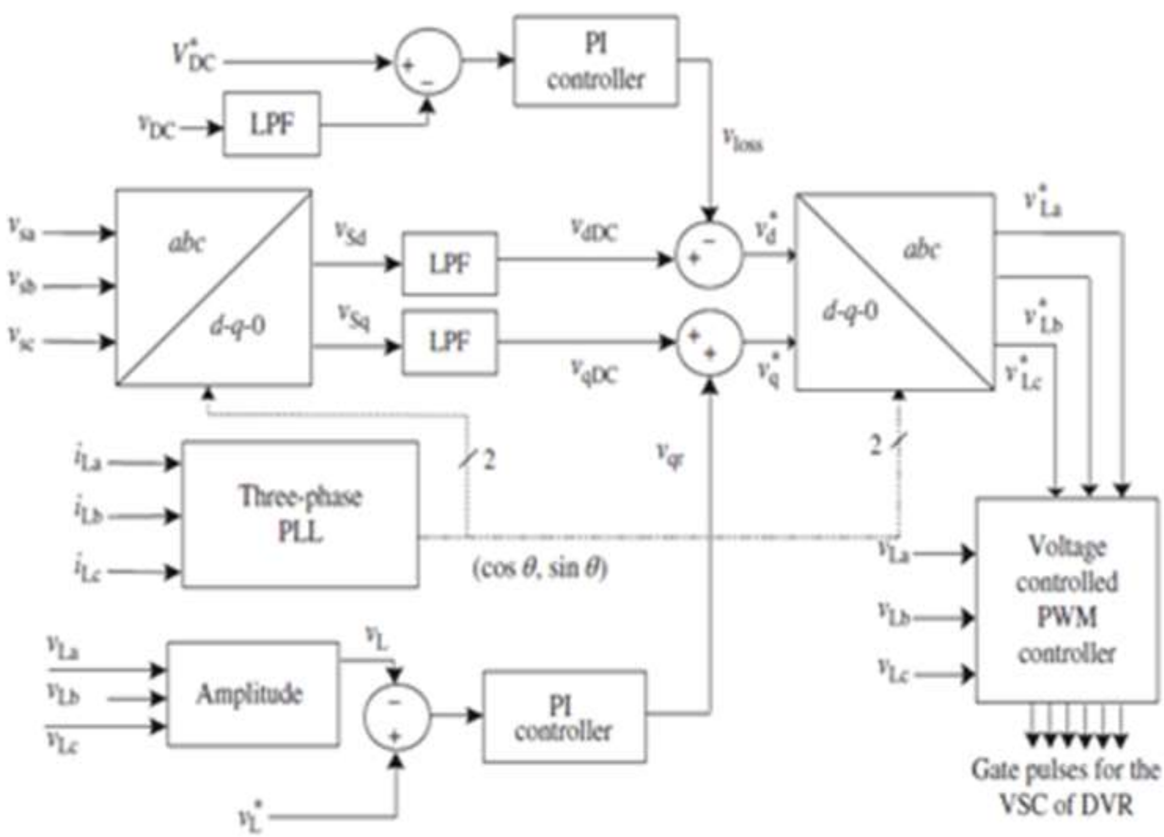

Fig 2. Synchronous reference frame theory based method for control of supported DVR

SRF method is used to obtain the direct axis (Vd) and quadrature axis (Vq) components of load voltage. By park's transformation three phase load voltage is converted to dq0 frame. To synchronize these signals with the terminal voltage a three phase PLL is used. The dq components are passed through LPF to extract dc components of Vd* and Vq*. To maintain dc bus voltage of self supported capacitor, the error between sensed dc voltage and reference dc voltage (Vdc*) are given to a PI controller and its output (Vcad) is considered as loss component of voltage and is added to the dc component of Vd to generate Vd* the reference d – axis load voltage as to regulate the amplitude of the load voltage (VL) another PI controller is used. The amplitude VL at PCC is calculated as

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VL=(2/3(VLa2 + VLb2+VLc2))1/2

The amplitude of load voltage and output of PI controller is considered as reactive component of voltage(Vqr) for voltage regulation of load terminal voltage added with dc component of Vq to generate Vq*.The reference q-axis load voltage is givenas

VLq*=Vsq(dc)+Vqr

The resultant voltages (Vd*,Vq*,Vo) are again converted into the reference supply voltages using reverse Park's transformation.Reference supply voltages (VLa*, VLb*,VLc*) and the sensed load voltages(VLa, VLb,VLc) areused in PWM current controller to generate gating pulses for the switches.

VII. SIMULATION RESULTS :

In this system a DVR is introduced in the distribution system to compensate voltage sag./swell. The DVR connected system consisting of a three phase supply, three phase critical load, and the series injection transformer is modeled in MATLAB/SIMULINK environment along with a sim power systtoolbox and is shown in Fig-3.

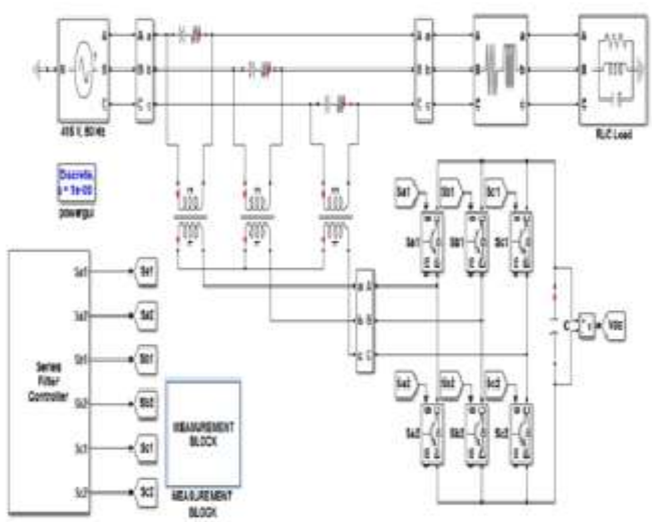

Fig 3. MATLAB/SIMULINK CIRCUIT DIAGRAM FOR DVR

The function of the DVR will injects the missing voltage in order to regulate the load voltage from any disturbance due to immediate distort of source voltage.

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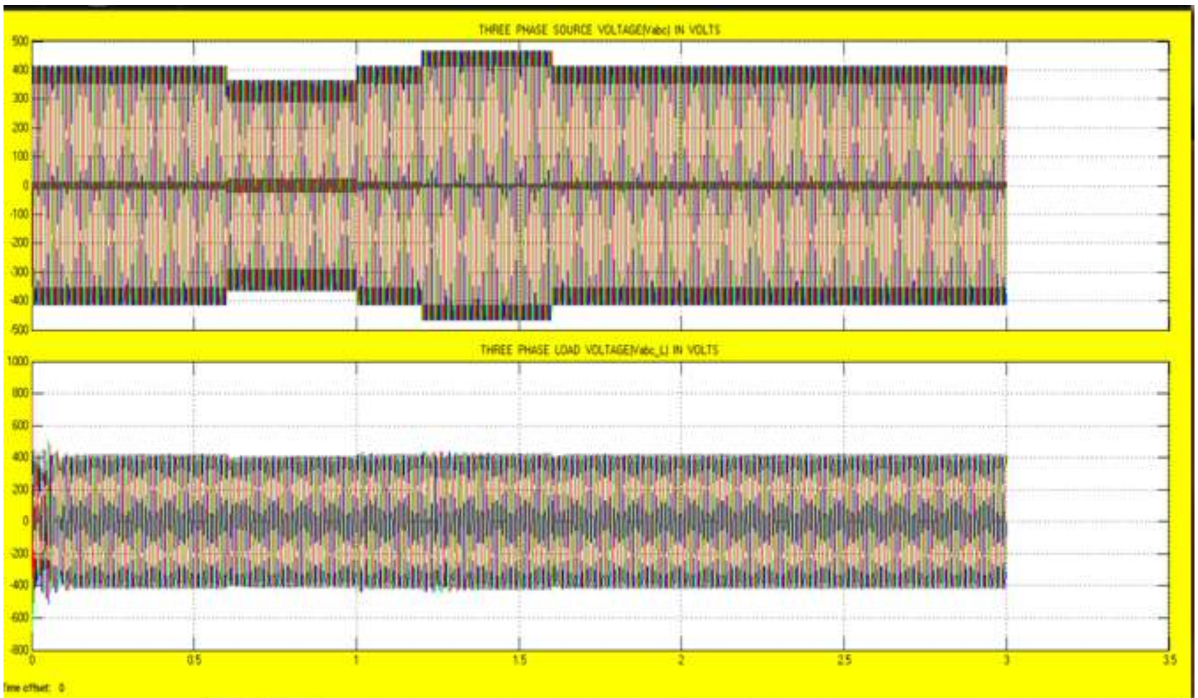
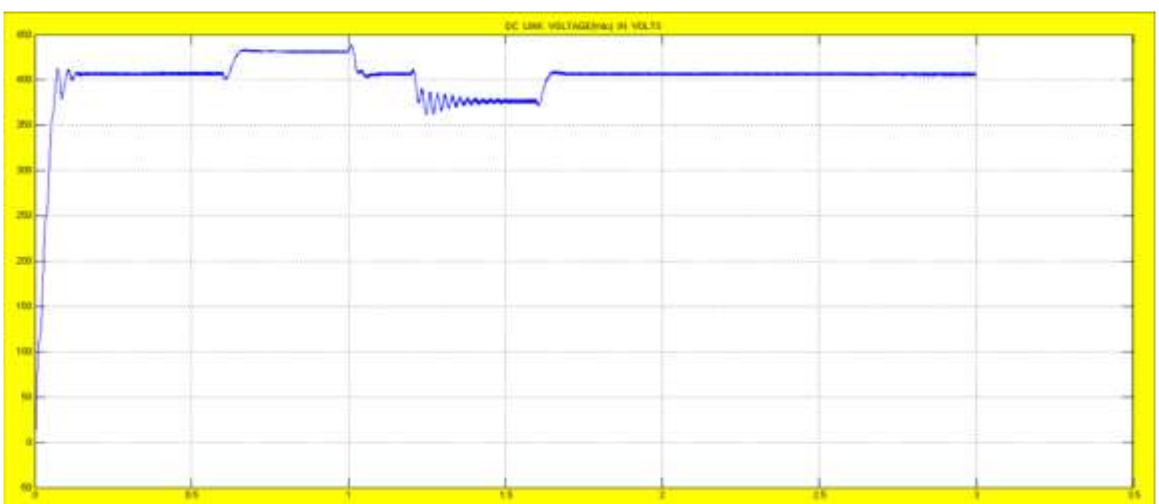
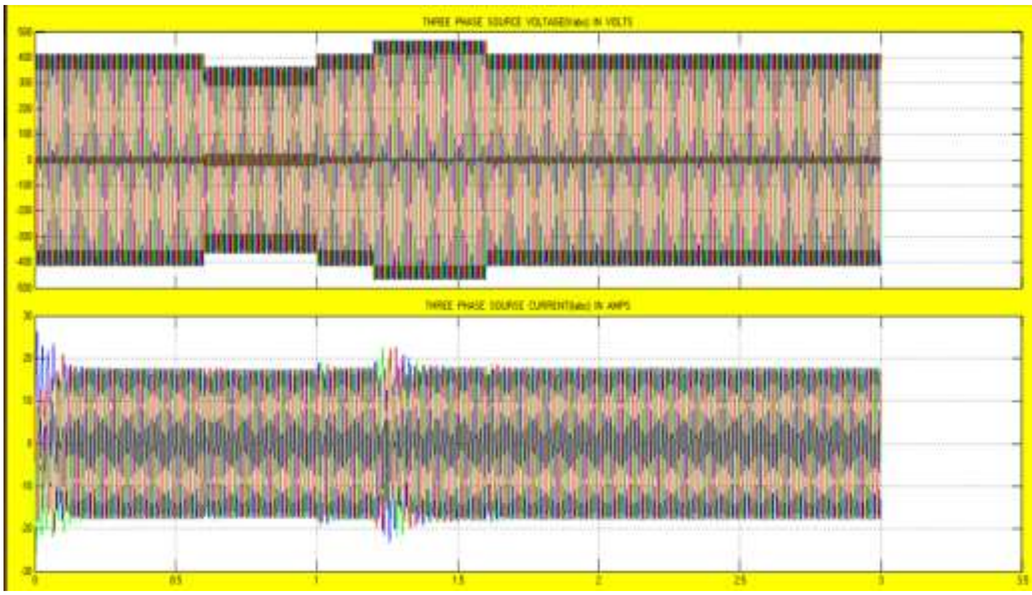


FIG(A): THREE PHASE SOURCE VOLTAGE
FIG(B): THREE PHASE LOAD VOLTAGE



FIG(C) : DC LINE VOLTAGE FOR CAPACITOR



FIG(D): THREE PHASE SOURCE VOLTAGE
FIG(E): THREE PHASE SOURCE CURRENT

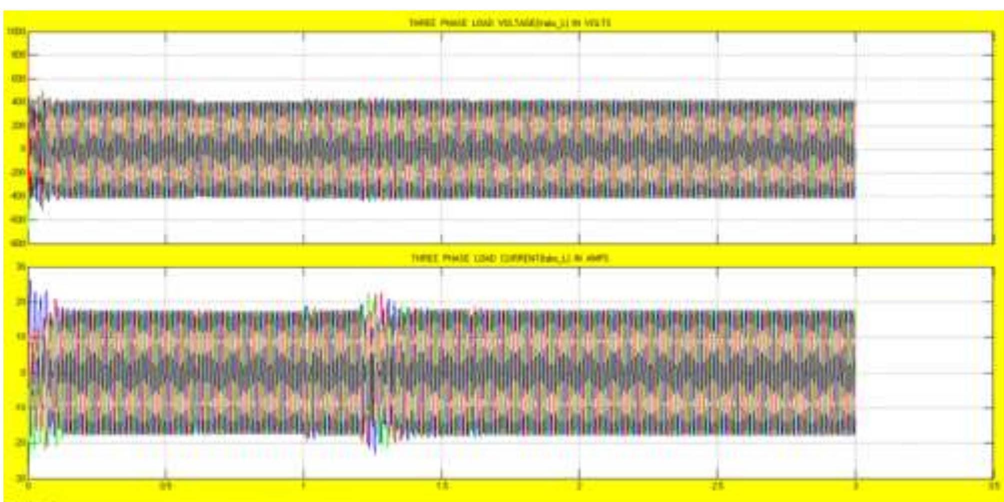


FIG (F): THREE PHASE LOAD VOLTAGE
FIG(G): THREE PHASE LOAD CURRENT

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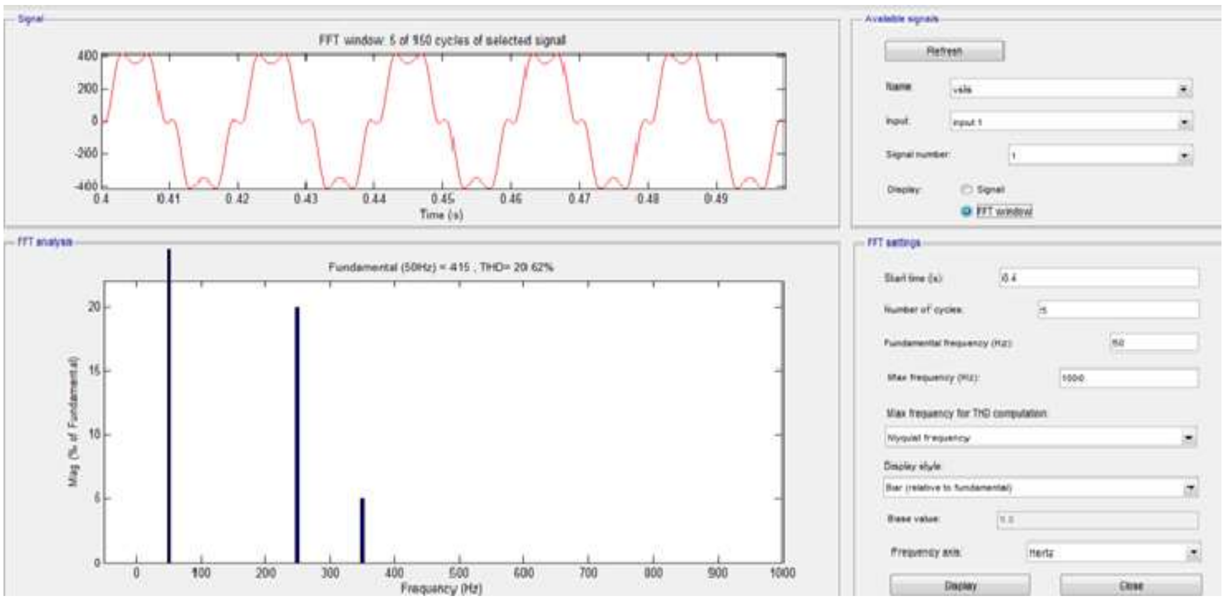

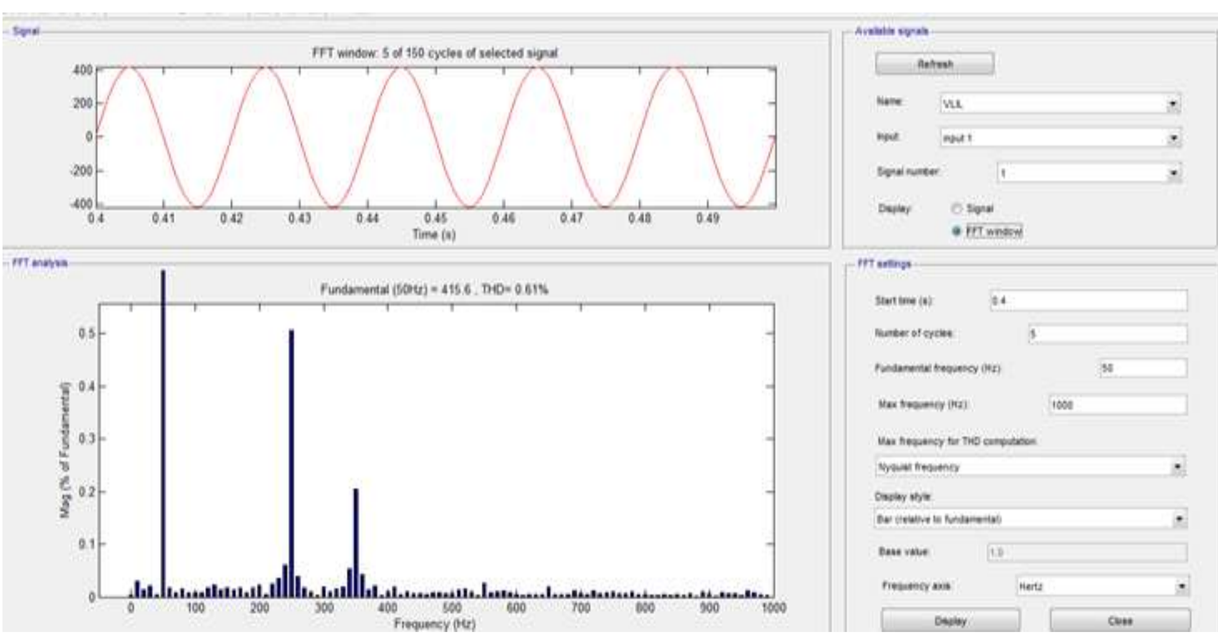

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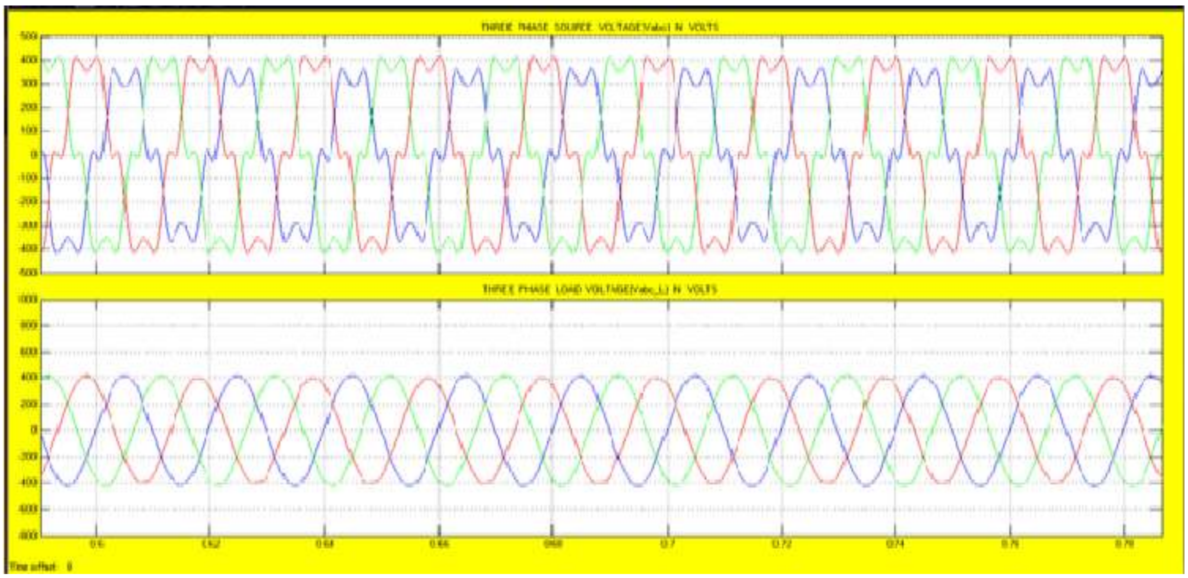

FIG: THREE PHASE SOURCE VOLTAGE & LOAD VOLTAGE FOR UNBALANCED SAG

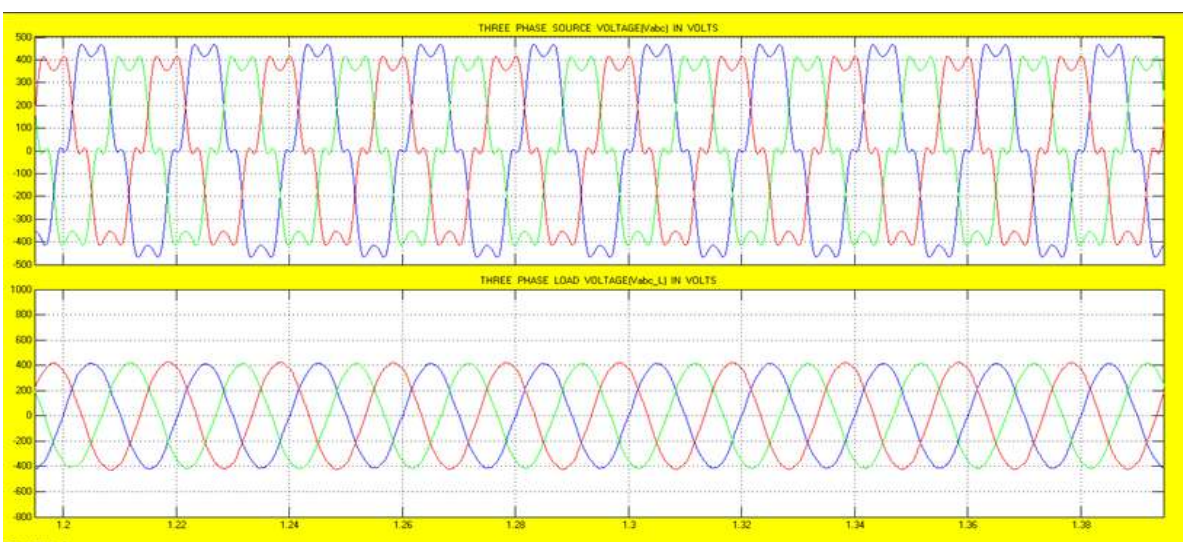

FIG: THREE PHASE SOURCE VOLTAGE & THREE PHASE LOAD VOLTAGE FOR UNBALANCED SWELL

VIII. CONCLUSION

The main concern of consumers is the quality and reliability of power centers at various load center where they are located. Power quality problems especially voltage sag/swell will effect the industrial loads. To overcome the negative impact of power quality such as voltage sag/swells on equipment and business, DVR is an efficient device. Its advantages are lower cost, small size, and its fast dynamic response to the disturbance. The reference voltage has been generated using SRF theory. The modeling and simulation of a DVR is done in MATLAB/SIMULINK. The experiment shows that the proposed DVR successfully mitigate the voltage sag and also capable of providing self-support to its dc bus capacitor.

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