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PERFORMANCE ANALYSIS OF DISTRIBUTION SYSTEM USING DYNAMIC VOLTAGE RESTORER

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ABSTRACT

Increased use of sensitive and nonlinear loads in electrical power systems and the rapid growth of renewable energy sources lead to poor power quality. The most regular power quality situations are voltage dip, voltage swell and harmonics. Among these, voltage sag is considered as the most severe power quality problem and a Dynamic Voltage Restorer (DVR) is recognized as a successful sort of custom power unit for voltage sag mitigation due to its capacity to manage active power flow, less cost and higher energy capacity. The major problem sag and swell not only occur by the disturbed power quality but also due to high system tapping at the point of common coupling in the system. The non linear load is also creating the same problem at the load end. The Dynamic Voltage Restorer is recognized as the best solution for distributed system. This modeling, simulation and analysis of advanced DVR system for solving sags and swell problem. The PI control scheme is used for generating the gate pulse for IGBT bridge converter.

Index Terms: Dynamic Voltage Restorer (DVR), Hysteresis Band Controller, Nonlinear Load, Voltage-Source Converter (VSC)

I. INTRODUCTION

The electric power utilities must provide their consumers with uninterrupted sinusoidal voltage at the desired magnitude and frequency. Recent technological advancements have led to a rapid growth in the number of nonlinear loads present in the power distribution system which adversely affects the quality of power supply. These nonlinear loads distort the supply voltage waveform. This results in various power quality disturbances [1].

Most of the electronic devices used today are sensitive to the power disturbances and hence are more susceptible to degradation of power quality. For some of the sophisticated devices, a momentary disturbance can lead to scrambled data, communication interruptions, system crashes and failure of equipment [2]. Power Quality problems include disturbances like voltage sags, voltage swells, voltage unbalance, harmonics, power frequency variations, flicker, impulse transient and interruptions. Voltage sags are recognized as the most frequent, severe and costly power quality problem damaging sensitive loads. According to IEEE Standard 1100-1992, sag is ` a reduction in the rms value of AC voltage, for durations from 0.5 cycles to about 1 minute, at the power frequency [1].

In this paper, a simple generalized control algorithm for the self-supported DVR is developed based on the basic SRFT. This novel algorithm makes use of the fundamental positive sequence phase voltages extracted by sensing only two unbalanced and/or distorted line voltages. The algorithm is general enough to handle linear as well as nonlinear loads. The self supported DVR maintains balanced sinusoidal load voltage with desired magnitude against any supply voltage quality problem even when the load is unbalanced and nonlinear in nature.

The algorithm based on instantaneous symmetrical components along with the complex Fourier transform to protect unbalanced and nonlinear load discussed is computationally demanding and requires huge memory space. The approach discussed here is comparatively simple as it needs only the extraction of the fundamental positive-sequence phase terminal voltages, thus making it computationally simpler with the least memory requirement. The proposed fundamental positive-sequence extractor requires the sensing of only two line voltages of supply. This reduces the analog-to-digital converter (ADC) requirements of a digital controller and corresponding sensing element. Moreover, it is able to extract three fundamental positive-sequence phase voltages irrespective of the distribution system configuration such as three-phase, four wire or three-phase, three-wire system where the neutral is not available for sensing phase voltages.

In this paper, a hybrid structure of the self-supported DVR is considered in which a shunt capacitor filter is used to provide the low impedance path for higher order harmonics of the load currents. The DVR is realized by three single-phase H-bridge VSCs with a constant switching frequency hysteresis band voltage controller.

1.1 Basic Configuration and Operation

DVR is a device that keeps the load side voltage undisturbed by injecting voltage into the system. It is generally installed in series with the distribution system at the point of common coupling between the supply and the critical load feeder. Fig.1 shows the basic components and connection of a DVR

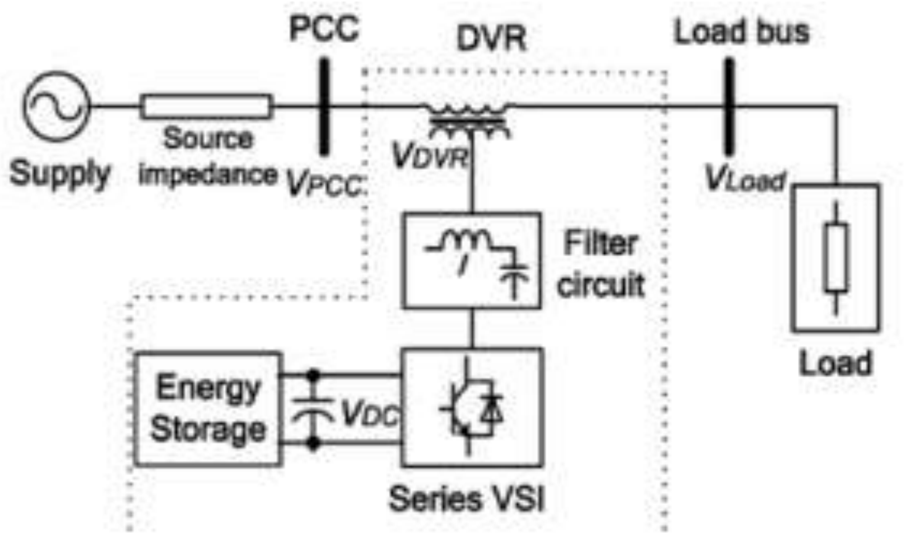

Fig.1.Basic DVR Topology

A sag in the system voltage is identified by the control circuitry of DVR which in turn generates the firing pulses for the inverter. The voltage to be injected into the system is generated by the inverter which is coupled to the distribution system via the injection transformer. The harmonic contents in the inverter output are filtered out by a harmonic filter. The DC source is used for satisfying the real power requirement for voltage sag compensation [3].

II. POWER CIRCUIT TOPOLOGIES FOR DVR

Power circuit topologies for DVR are broadly classified into two; one uses stored energy and the other uses no significant energy storage [4, 5]. The system topologies are;

1. Topologies with stored energy

i. Constant DC-link voltage

ii. Variable DC-link voltage

2. Topologies with power from the supply

i. Supply side connected passive shunt converter

ii. Load side connected passive shunt converter

Among these, the DVR configuration with stored energy is discussed in this paper. The topologies with constant DC link voltage as well as variable DC link voltage are discussed below.

2.1 Constant DC-Link Voltage

A DVR with constant DC-link voltage illustrated in fig. 2 is expected to have superior performance and an effective utilization of the energy storage. An additional converter is expected to convert energy from the main storage to a small DC-link and thereby control and stabilize the DC-link voltage. The stored energy can be delivered from different kinds of energy storage systems such as batteries, flywheel storage or SMES. The DVR with a constant voltage is here considered to be a reference topology by which the other DVR topologies are evaluated. It offers a constant DC-link voltage at all times and does not increase the current drawn from the supply. This configuration is also known as Battery Supported DVR as the DC link voltage is always constant [5]. The performance of this system is improved compared to the variable DC link solution, but the equipment costs are higher as energy storage is needed and a separate high-rated power converter is necessary [4].

2.2 Variable DC Link Voltage

The DVR with variable DC-link voltage is illustrated in fig. 3. It offers benefits in simplicity due to only one high rated converter and only DC-link capacitors as the energy storage. The voltage injection capacity depends on the actual level of the DC-link voltage and energy saving control strategies are urgent to fully utilize the energy storage system. As this DVR configuration is capable of compensating power quality problems with the help of its self supporting DC bus, this type is generally referred to as Self Supported DVR. The DC-link voltage can be utilized only down to a certain DC-link voltage level. Hence, the range of power disturbances that can be compensated by this type of DVR configuration is limited [4,5].

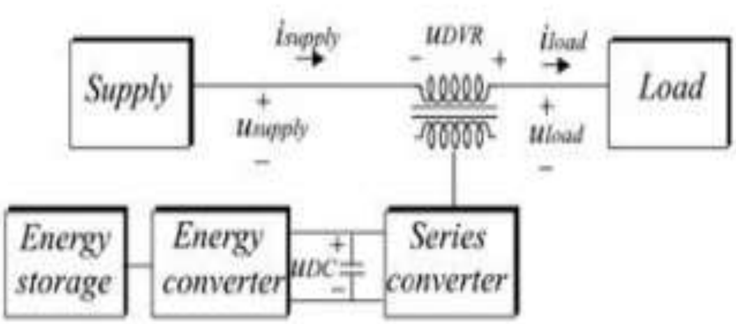

Fig.2 DVR with Constant Dc Link Voltage

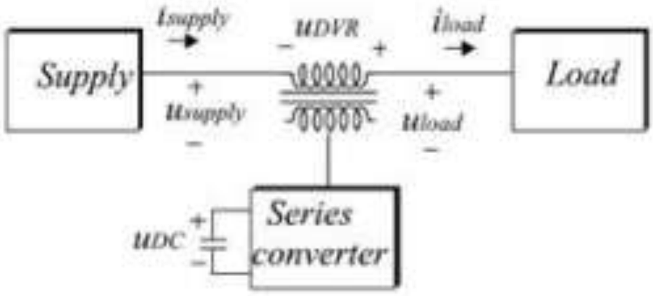

Fig.3 DVR with Variable DC Link Voltage

III. DVR POWER CIRCUIT

In the previous section, a response of DVR in different PQ problems with the developed control algorithm assuming

DVR realized by ideal voltage sources is demonstrated. In this section, the power circuit of DVR is discussed. Practically, the DVR is realized by three single-phase H-bridge VSCs along with a common dc capacitor (Cdc)as shown in Fig. 4. The three H-bridge VSCs are connected to each phase of the distribution feeder through the improved structure ripple filter (Lr, Cr, Rr) and an injection transformer. The injection transformer not only reduces the voltage requirement of the converter but also provides isolation between the converter and the distribution feeder. The shunt capacitor filter Cf is used to provide a low impedance path to higher order harmonics of load currents when the load current is nonlinear. The operation of practical DVR with nonlinear load current is discussed in the next section.

To track the reference compensating voltages, an improved filter structure constant switching frequency hysteresis band controller is used in this work. The main advantages of the band controller are unconditional stability, faster response and easy implementation compared to other controllers like carrier-based controllers, dead-beat control state feedback control, combined feed forward and feedback control, etc., which are based on complex mathematical computations and need much information about system parameters. Despite these advantages, the main disadvantage of the band controller compared to carrier-based controllers is variable switching frequency which may cause stress in the switches of the VSC, resulting in the deterioration of its life. The band controller has other drawbacks also like poor controllability, heavy filter currents, parabolic band voltage response, and frequent band violations due to the use of a conventional LC filter which has a second-order characteristic equation.

The constant switching frequency hysteresis band controller with improved filter structure discussed preserves all the advantages of the band controller and also overcomes its drawbacks by improved filter structure and adaptive hysteresis band which gives constant switching frequency.

The single-phase equivalent circuit of the DVR-connected system in Fig. 4 is shown in Fig. 5 to explain the basic principle of the hysteresis band controller. The reference compensating voltage for the DVR is calculated using the proposed algorithm. To inject this voltage in series with the distribution feeder, appropriate switching pulses for VSC are generated using the hysteresis band controller with hysteresis bandh. The VSC output voltage is made to track the reference voltages within upper and lower boundaries vref C +h and vref C −h, respectively.

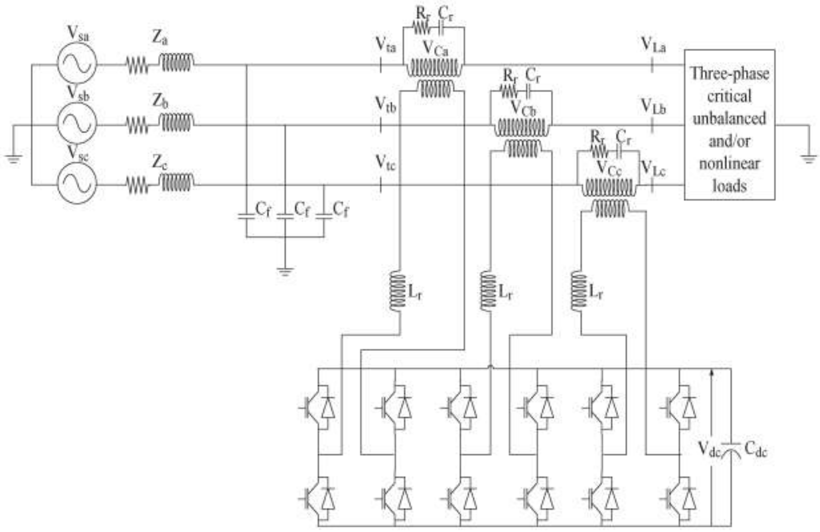

Fig.4. DVR Power Circuit

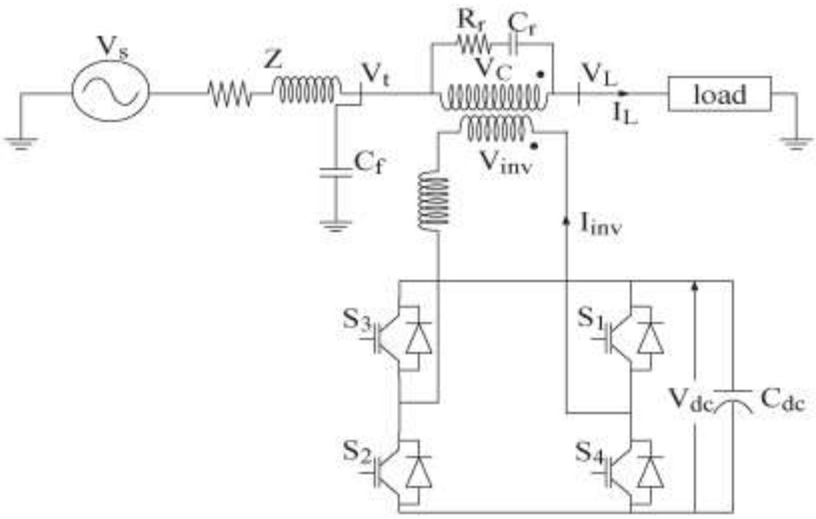

Fig.5. Single-Phase Equivalent Circuit of DVR-Connected System

TABLE I

SWITCHINGLOGIC OFVSC WITHHYSTERESISBANDCONTROLLER

If	S_1	S_2	S_3	S_4
$V_C < v_c^{ref} - h$	on	on	off	off
$V_C > v_c^{ref} + h$	off	off	on	on

When the DVR voltage VC goes below the lower boundary, the positive dc voltage is applied across the ac filter combination (Cr, Rr) by turning switches S1 and S2 on. If DVR voltage VC goes above the upper boundary, the negative dc voltage is applied by turning switchesS3andS4on. The switching logic thus can be stated as given in Table I. In order to improve the performance of the controller, an extra resistance Rr is connected in series with ac filter capacitor Cr as shown in Fig. 5. This resistance dominates the capacitive reactance at switching frequency. At switching frequency, the resistance Rr and combined inductive reactance of the Lr and transformer are very large compared to the capacitive reactance of Cr. Thus, at switching frequency, this improved structure filter circuit behaves as an R−L circuit and gives a linear voltage variation within the band compared to the parabolic voltage variation given by the conventional L−C filter circuit. Because of the linear response, this filter has less band violations and, hence, better controllability compared to the conventional filter. Details of the design of filter components can be found.

IV. MATLAB/SIMULINK RESULTS

Case1: Without SRF

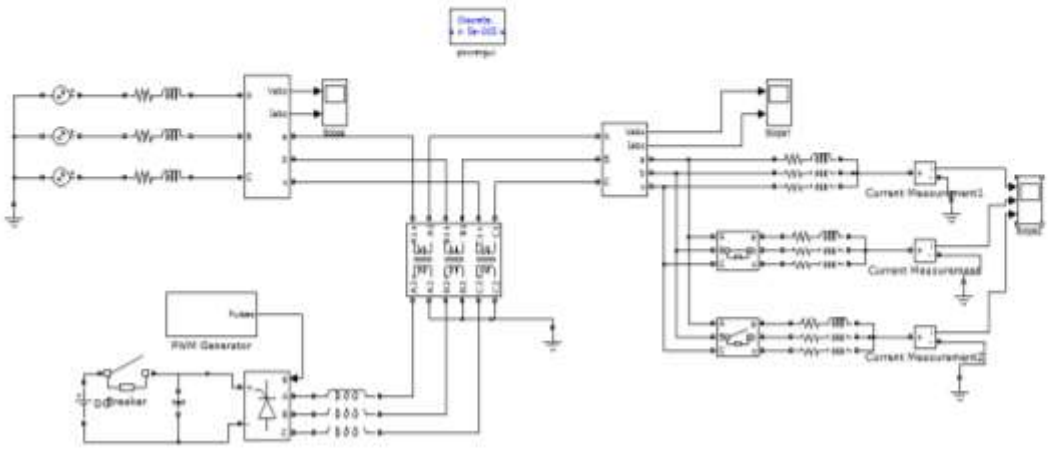

Figure6: Matlab/Simulink Model Of Without Synchronous Reference Frame (SRF)

Figure6 shows the Matlab/Simulink model of without synchronous reference Frame (SRF).

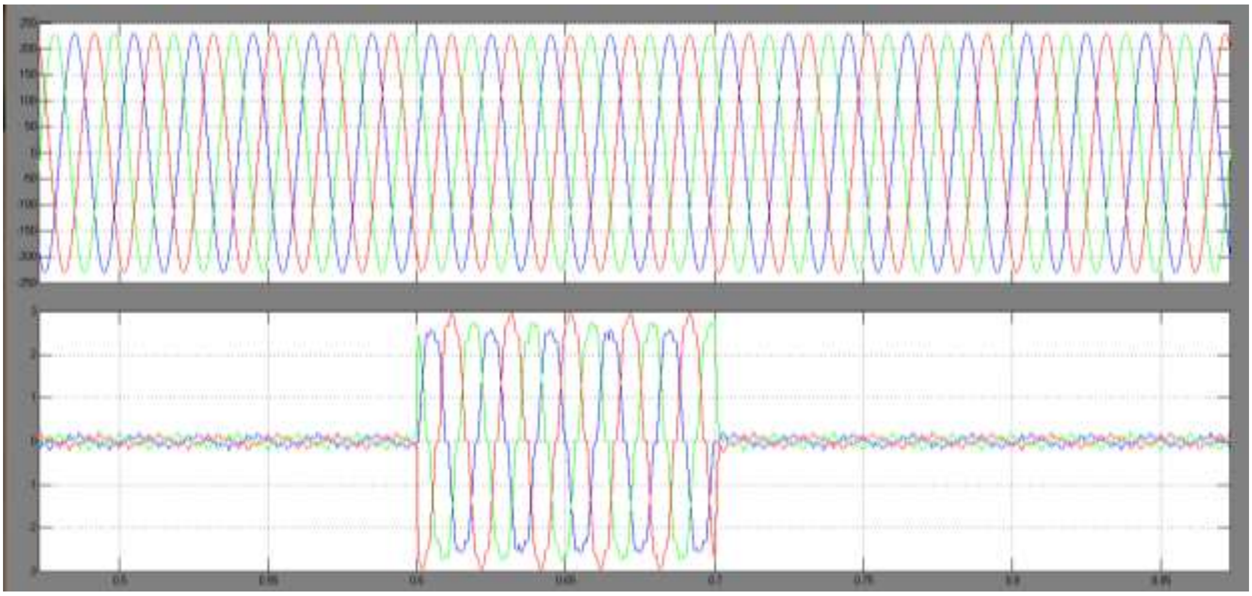

Figure: 7 Source Side Voltage And Current Wave Form of the Without Synchronous Reference Frame (SRF)

Figure7 shows the source voltage and current wave form of the without synchronous reference Frame (SRF).

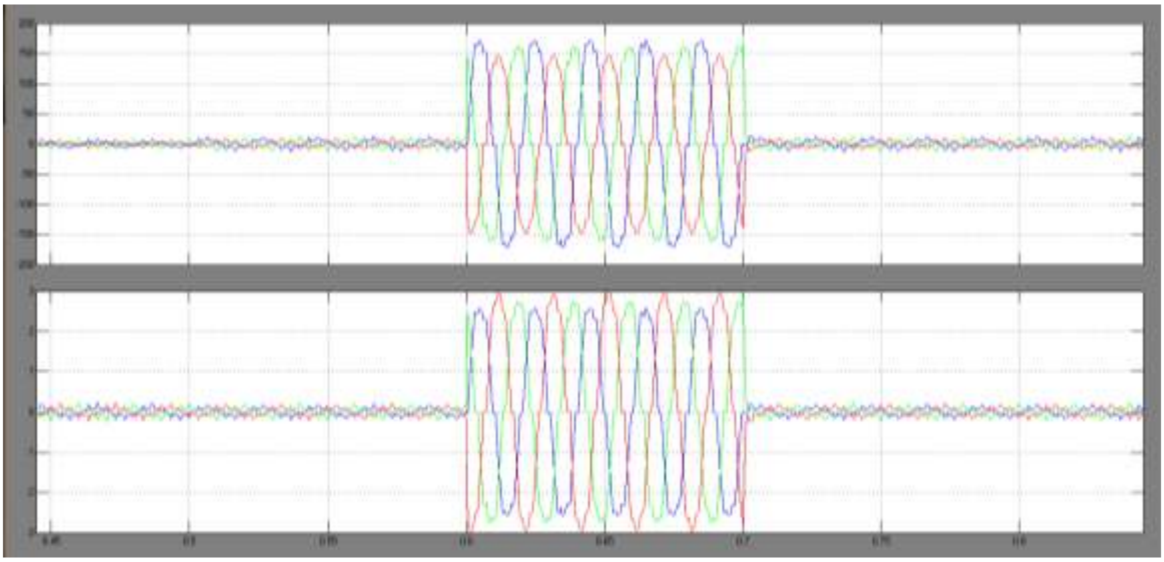

Figure: 8 Load Side Voltage And Current Wave Form of the Without Synchronous Reference Frame (SRF)

Figure8 shows the Load side voltage and current wave form of the without synchronous reference Frame (SRF).

Case2: With SRF

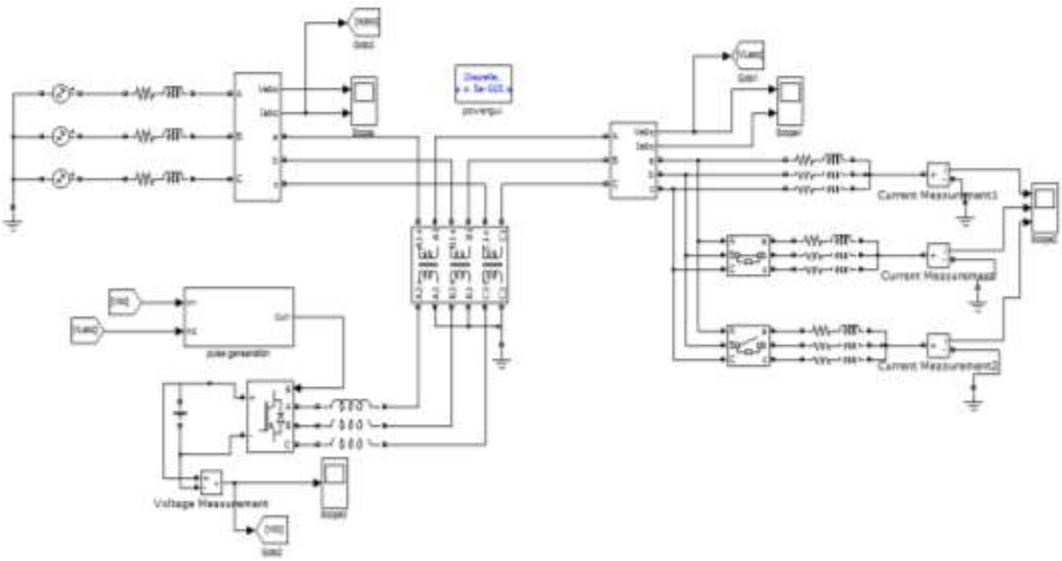

Figure: 9Matlab/Simulink Model of With Synchronous Reference Frame (SRF)

Figure9 shows the Matlab/Simulink model of with synchronous reference Frame (SRF).

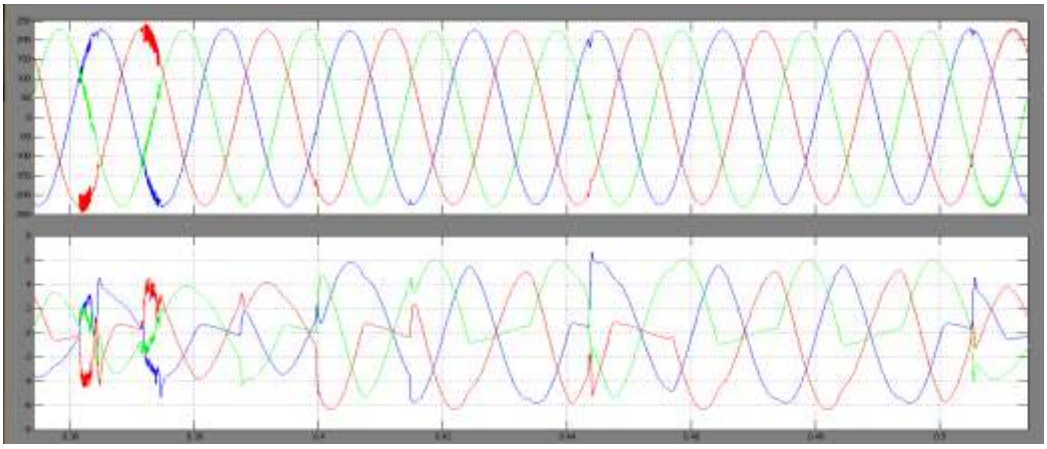

Figure: 10 Source Side Voltage and Current Wave Form of the With Synchronous Reference Frame (SRF)

Figure10 shows the source side voltage and current wave form of the with synchronous reference Frame (SRF).

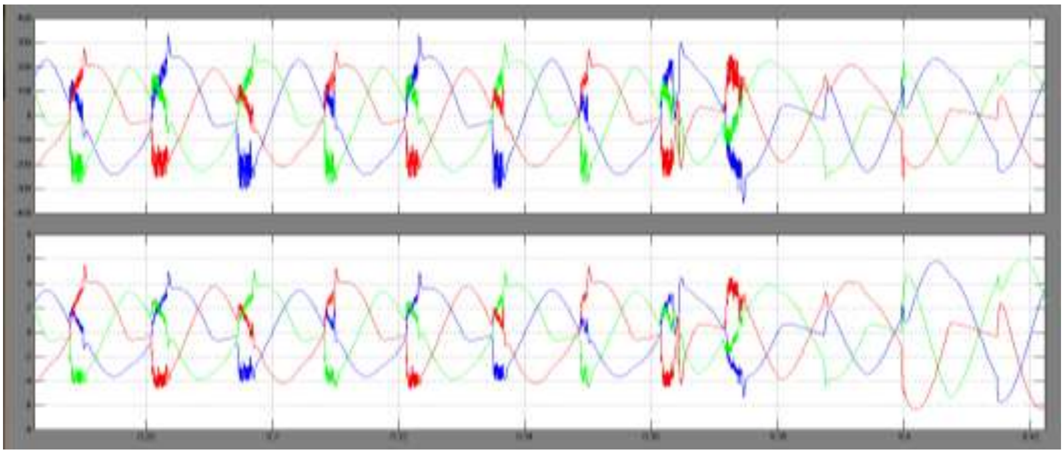

Figure: 11 Load Side Voltage and Current Wave Form of the With Synchronous Reference Frame (SRF)

Figure 11shows the Load side voltage and current wave form of the with synchronous reference Frame (SRF).

Case3: Voltage Sags and Swells

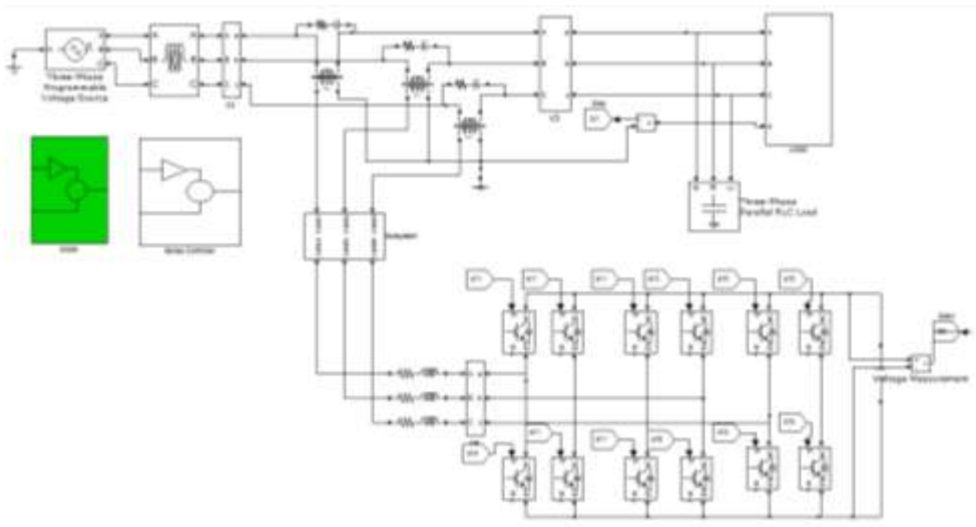

Figure: 12Matlab/Simulink Model of DVR during Voltage Sag

Figure12 shows the Matlab/Simulink model of DVR during voltage sag.

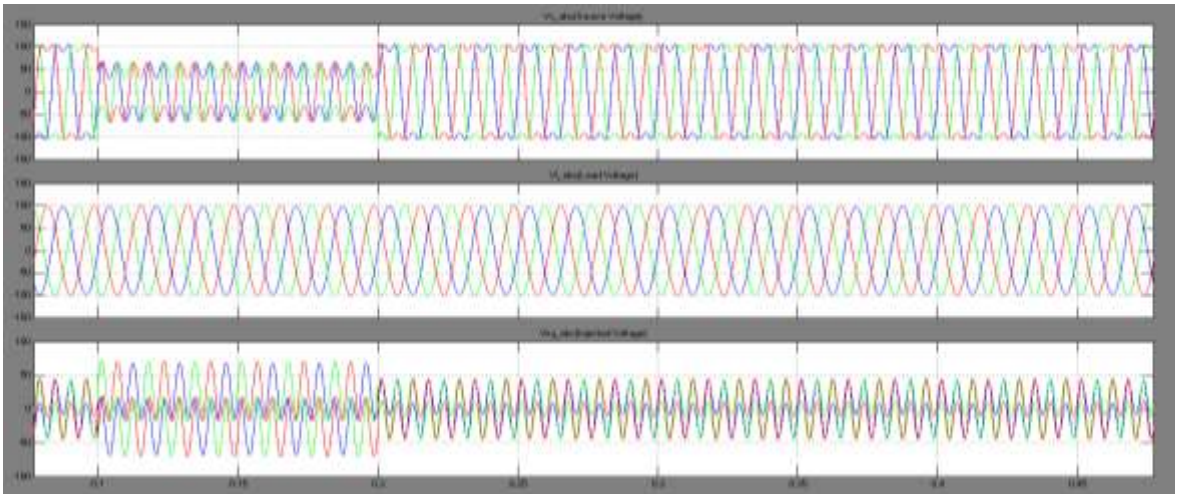

Fig.13 Response of DVR during Voltage Sag

Figure13 shows the Response of DVR during voltage sag.

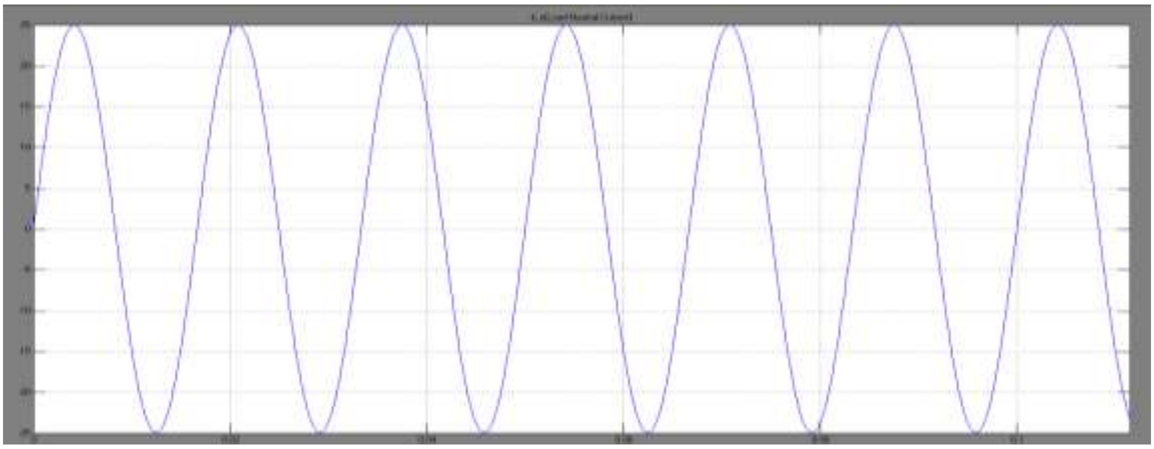

Figure: 14 Load Natural Current

Figure14 shows the load natural current.

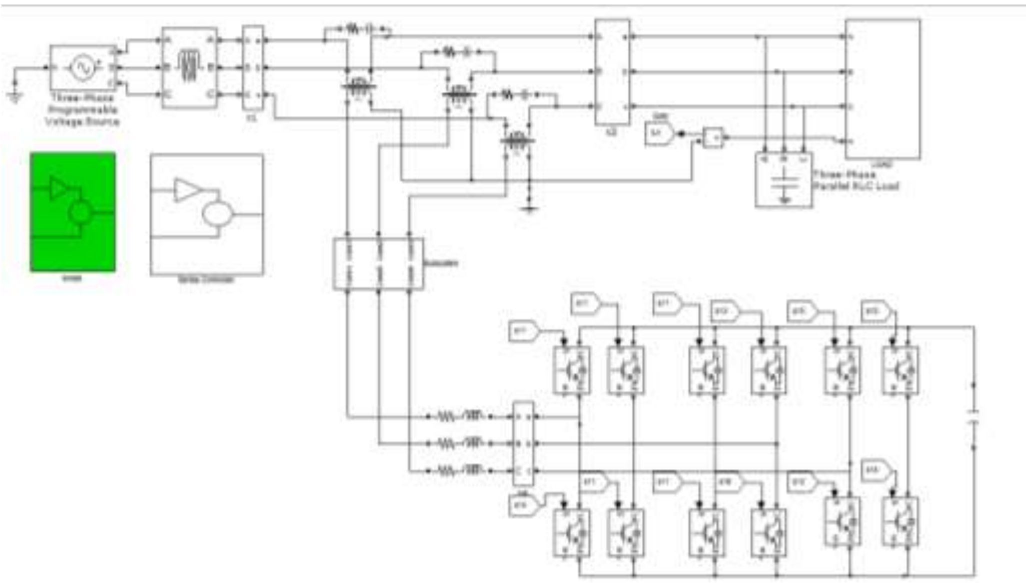

Figure: 15Matlab/Simulink Model of DVR during Voltage Swell

Figure15 shows the Matlab/Simulink model of DVR during voltage swell.

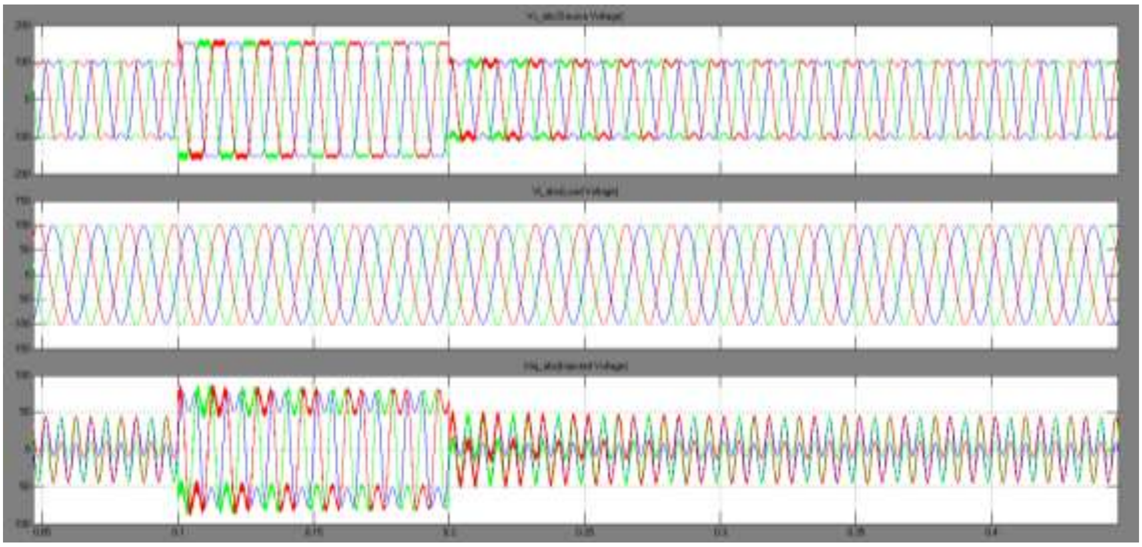

Fig. 16 Response of DVR during Voltage Swells

Figure16 shows the Response of DVR during voltage swell.

V.CONCLUSION

A simple generalized algorithm has been developed for the generation of instantaneous reference compensating voltages for controlling self-supported DVR based on basic SRFT to protect unbalanced and nonlinear loads. A fundamental positive-sequence extractor has been proposed, which extracts three fundamental positive-sequence phase voltages by sensing only two unbalanced and/or distorted line voltages. The performance of DVR with the proposed control algorithm has been evaluated for both the harmonic current source and the harmonic voltage source type of nonlinear loads with different supply voltage quality problems. This research work presents comprehensive results for the design and application of DVR for voltage sag. A controller utilizes the error signal which is actually the difference between the reference signal and the actual signal. Voltage source convertor (VSC) was implemented with the help of pulse width modulation. Modeling and Simulation of DVR is done through MATLAB/SIMULINK computer software. The simulation carried out here shows that DVR provide better voltage regulation capabilities. Based on analysis of test system, it is suggested that percentage sag and operating voltage are major factors in estimating the requirement of DC storage capacity.

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