Compensation of Balanced and Unbalanced voltage disturbance using SRF controlled DVR

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Abstract - *The growth of power electronic technology in the field of electric power sector has caused a greater awareness on the power quality of distribution systems. With the re-structuring of power systems and with shifting trend towards distributed and dispersed generation, the issue of power quality is going to take newer dimensions. The present research is to identify the prominent concerns in this area and hence the measures that can enhance the quality of power. The research work is going to be investigates the problems of voltage sag, swell and its severe impact on nonlinear loads, sensitive loads. Protection of the sensitive unbalanced nonlinear loads from sag/swell, distortion, and unbalance in supply voltage is achieved economically using the dynamic voltage restorer (DVR).DVR is installed between supply and load which will inject voltage and active power to the distribution system during balanced/unbalanced voltage sag and swell disturbances. The control technique used to operate the DVR is SRF Theory with Proportional Integral (PI) controller. The performance of DVR based Synchronous reference frame theory (SRF) for the mitigation of voltage sag, swell for balanced and unbalanced voltages is going to be tested and Simulation results are going to be carried out by MATLAB with its Simu-link to analyze the proposed method .*

Key Words: **SRF (synchronous reference frame theory), DVR (dynamic voltage restorer), balanced and unbalanced voltage.**

1. INTRODUCTION

In power distribution systems the advent of a large numbers of sophisticated electrical and electronic equipment such as computers, programmable logic Controllers and variable speed drives causes various power quality problems like voltage sag, voltage swell and harmonics. These are the major concern of the industrial and commercial electrical consumers due to enormous loss in terms of time and money, in which voltage sag and swell are major power quality problems.

Voltage sags and swells are the most common power quality problems in electrical distribution systems. Voltage sag is defined as decrease in the rms value of voltage magnitude. Voltage swell is defined as increment in the rms value of voltage magnitude. There are two types of voltage sag and swell which can occur on any transmission lines; balanced and unbalanced voltage sag and swell which are also known as symmetrical and asymmetrical voltage sag and swell respectively. Most of these faults that occur on power systems are not the balanced three-phase faults, but the unbalanced faults. In the analysis of power system under fault conditions, it is necessary to make a distinction between the types of fault to ensure the best results possible in the analysis. In balanced voltage sag & swell, voltage decreases and increase in all three phases simultaneously. In unbalanced voltage sag & swell voltage decrease and increases in only one phase or two phases at a time.

1.1 Overview

Custom power devices are used to compensate these power quality problems in the systems. There are different types of Custom power devices used in electrical network to improve power quality problems. Each of the devices has its own benefits and limitations. A few of these reasons are as follows. The SVC (Static Var Compensator) pre-dates the DVR, but the DVR is still preferred because the SVC has no ability to control active power flow. Another reason include that the DVR has a higher energy capacity compared to the SMES (Super Conducting Magnetic Energy Storage) and UPS devices. Furthermore, the DVR is smaller in size and cost is less compared to the DSTATCOM (Distributed Static Compensator) and other custom power devices. Based on these reasons, it is no surprise that the DVR is widely considered as an effective custom power device in mitigating voltage sags. In addition to voltage sags and swells compensation, DVR can also add other features such as harmonics and power factor correction. Compared to the other devices, the DVR is clearly considered to be one of the best economic solutions for its size and capabilities .Dynamic Voltage Restorer is located between grid and sensitive load. It injects controlled voltage to keep dc link voltage constant at load-side.

The proposed DVR is connected to the system through the three single phase injection transformers. DVR is designed according to the voltage needed in the secondary side of transformer. The DVR consists of three single phase VSI units. Each unit is connected to system through the injection transformer. It provides the isolation to the converter. The performance of DVR depends up on control strategy used. In this paper SRF Theory with Proportional Integral (PI) controller technique is used for compensation of balanced/unbalanced voltage sag and swell.

The generation of Vd ,Vq and Vo SRF Controlled DVR For Compensation of Balanced and Unbalanced Voltage Disturbances reference signal involves the conversion from three-phase to two-phase and vice versa. Moreover low pass filters are essential part of this algorithm which has slow dynamic response of the compensator. The paper is organized as follows. In section 2, the configuration part of the DVR is described, the Control technique and the voltage injection capabilities of the DVR is discussed in section 3, and the detailed description of MATLAB Simulation model along with its performance in electrical network is discussed in section 4.

2. PROBLEM DEFINATION AND OBJECTIVES

Power quality is very important issue recently due to the impact on electricity suppliers, equipment manufacture and customers. Power quality is described as the variation of voltage, current and frequency in a power system. It refers to a wide variety of electromagnetic phenomena that characterize the voltage and current at a given time and at a given location in the power system. Nowadays, there are so many industries using high technology for manufacturing and process unit. This technology requires high quality and high reliability of power supply. The industries like semiconductor, computer, and the equipments of manufacturing unit are very sensitive to the changes of quality in power supply. Power Quality problems encompass a wide range of disturbances such as voltage sags/swells, flicker, harmonics distortion, impulse transient, and interruptions. Voltage sags/swells can occurs more frequently than other Power quality phenomenon. These sags/swells are the most important power quality problems in the power distribution system.

One of the best solutions to improve power quality is the dynamic voltage restorer (DVR). DVR is a kind of custom power devices that can inject active/reactive power to the power grids. This can protect loads from disturbances such as sag and swell. Usually DVR installed between sensitive loads feeder and source in distribution system. Its features include lower cost, smaller size, and its fast dynamic response to the disturbance. In this project SRF technique is used for conversion of voltage from rotating vectors to the stationary frame. SRF technique is also referred as park's transformation. In this the reference load voltage is estimated using the unit vectors.

3. PROJECT IMPLEMENTATION

The system contains a block named 'Three-phase programmable source with sag/swell generation'. This block generates the ac supply for the system, along with the sags or swells, if any. The main supply has a peak amplitude of 15 kV per phase. It is connected or disconnected from the system using a switch which is initially closed, and opens and disconnects this main supply whenever a sag or swell is to be created. The switch opens at 0.05 s when the sag is created and closes again at 0.15 s to resume normal supply. It again opens at 0.2 s to permit the creation of a swell, and recloses again at 0.35 s to resume the normal supply. There is a phase shift of 120 degrees between each of the phases. Another supply is introduced in each of the three phases to create a sag in the system. The system voltage under sag condition is set at 7 kV per phase (peak value). The sag is created in the system from 0.05 s to 0.15 s through the switch connected in series. A similar system exists for the creation of a swell from 0.2 to 0.35 s. The system voltage under swell is set at 23 kV per phase (peak value).

The above described block is followed by a 'Three-phase series RLC branch' having a resistance of 1 ohm and inductance of 10 mH. This block represents a transmission line.This block is followed by a VI measurement block, which measures the three phase voltages with respect to ground. The measured voltage can be viewed outside using a 'From' block with label Vabc1.The VI measurement block is followed by the DVR, another VI measurement block to measure the load voltage (signal label VabcL) and the load.

The DVR is connected in series with the system through three single phase transformers. Each transformer is rated at 250 kVA and has a voltage ratio of 10:1 (20e3:2e3).The DVR uses a separate H-bridge cell for each phase. The input dc supply to each H-bridge is 1000 V. Each H-bridge is capable of providing three voltages at its output side, namely E, -E and 0 (where E=1000 V). For example, for phase A, when switches S1 and S2 are on, the output voltage VAA' is E. When switches S3 and S4 are on, the output voltage is –E. When either S1S3 are on, or S2S4 are on, the output voltage is zero.

The control scheme for controlling the output of the inverter utilizes the SRF theory. For this, the system voltage Vabc1 (measured earlier) is taken. Note that Vabc1 are the phase to ground voltages, having peak amplitude of 15 kV under normal conditions. Hence, Vabc1 is divided by 15 kV to convert it into per unit. This per unit value of the system voltages is then converted into the dq0 reference frame using the abc to dqo transformation block. The per unit Vabc1 is also given to a PLL block to generate the 'sin-cos' required by the abc to dq0 transformation block.

The per unit dq0 voltages thus obtained are then separated using a de-mux. These actual values are then compared with the reference values (1 for Vd and 0 for Vq and V0). The error voltages thus obtained are processed through a low pass filter so as to remove any harmonics. The cut off frequency of the low pass filter is 500 Hz .The outputs of each of the filter are again combined to give Vdq0 and these are then given to the dq0 to abc transformation block. The output of this block is the reference voltage for sinusoidal PWM.

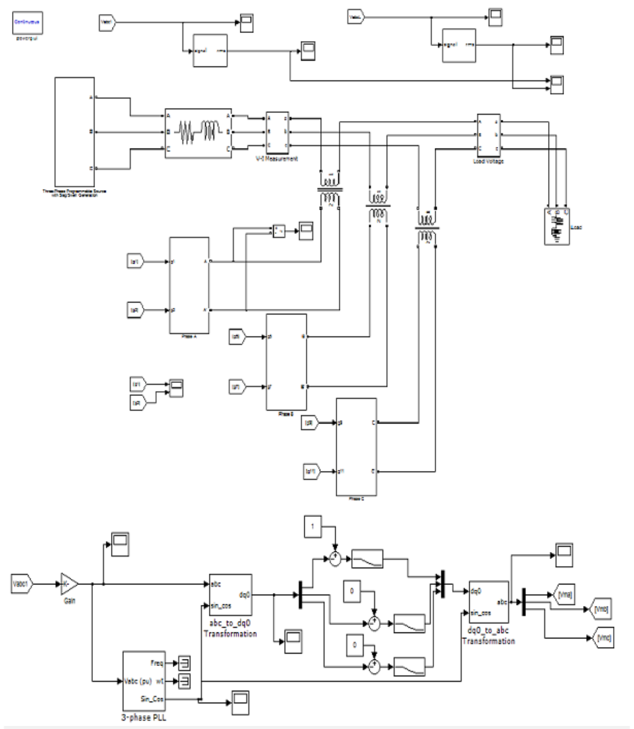

Fig 3 .1SRF Control DVR implementation.

The following figure shows the Control Block Diagram of the DVR .In this control, Source Voltage is sensed and is given as an input to the abc/dq transformation block .The same source voltage is given as an input to the PLL block , this PLL block gives the information of sin, cos .This is given as an input to the abc/dq block, with these two inputs this transformation block gives Vd, Vq, and Vo information .

This information is compared with Vdact, Vqact and Voact which are the actual parameters .The quadrature and Vo axis is compared with 0 p.u .The error generated is given as an input to the pi controller ,the pi controller output is again given as an input to dq/abc block , and PLL information is also given as an input to dq/abc block. This block gives us the pulse information which is given as an input to pwm generator and from that gate pulses are generated, those gate pulses are for inverter. As shown in fig 3.2.

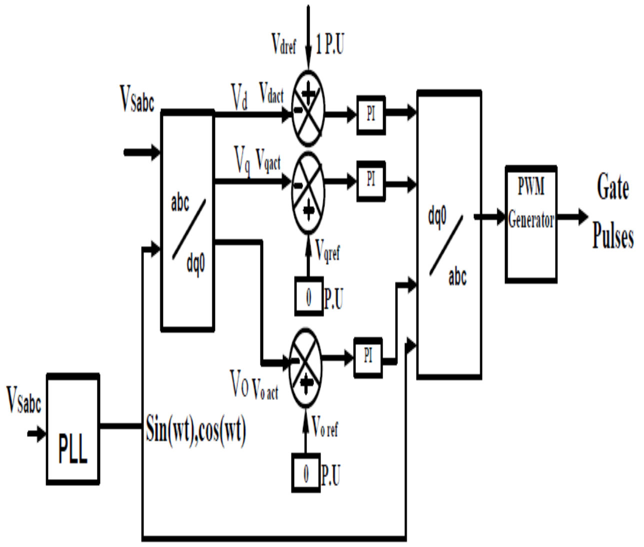

Fig 3.2 Block diagram of DVR controlled Synchronous reference frame.

4. SIMULATION RESULT

The performance of the DVR is demonstrated for different supply voltage disturbances such as balanced and unbalanced sag and swells at terminal voltages. The DVR is modeled and simulated using the MATLAB and its Simulink.

Case 1: Balanced Sag Condition

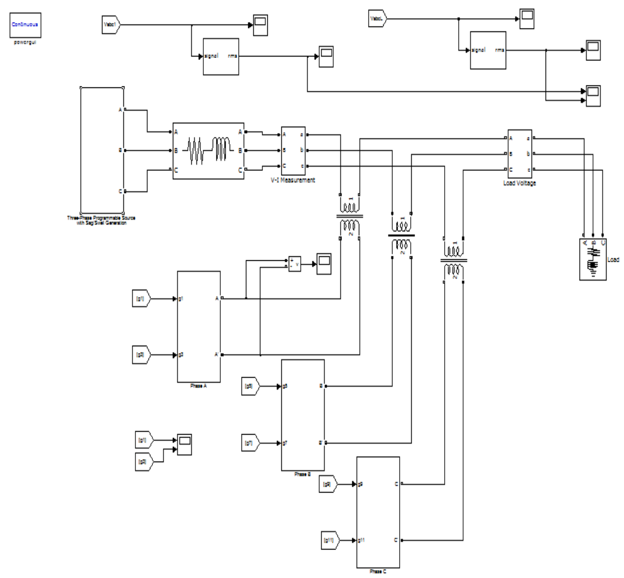

Fig 4.1 Matlab/Simulink model with DVR for Balanced Sag Condition

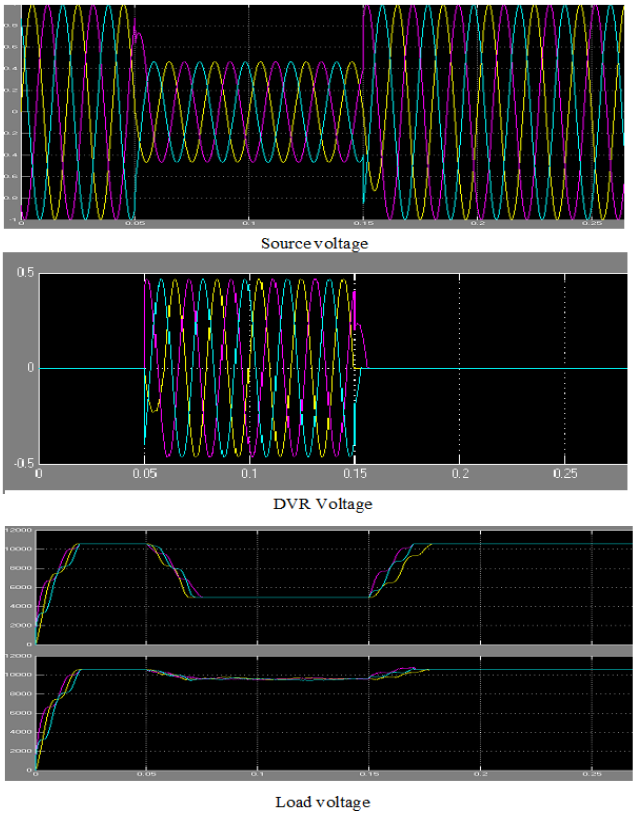

Fig 4.1.2DVR Final Sag (a) Source Voltage (b) DVR Voltage (c) Load voltage

Fig.4.1.2 Shows the Balanced Sag condition of a DVR .In Supply Voltage Sag occurs at period 0.1 and continues up to 0.2.In this period i.e. from 0.1 to 0.2 DVR injects the Compensation Voltage and load side voltage is maintained constant.

Case: 2 Balanced Swell Conditions

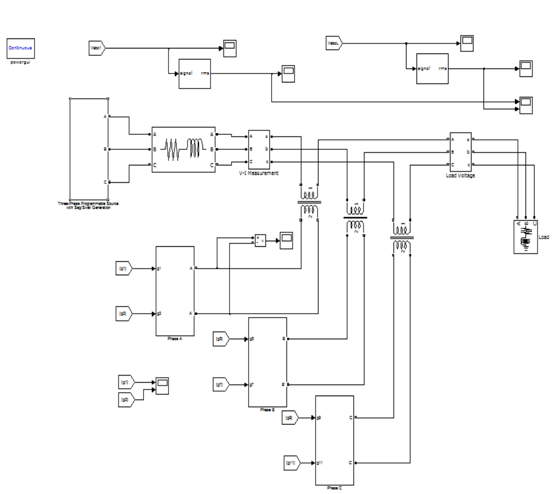

Fig 4.2. Matlab/Simulink model with DVR for Balanced Swell condition

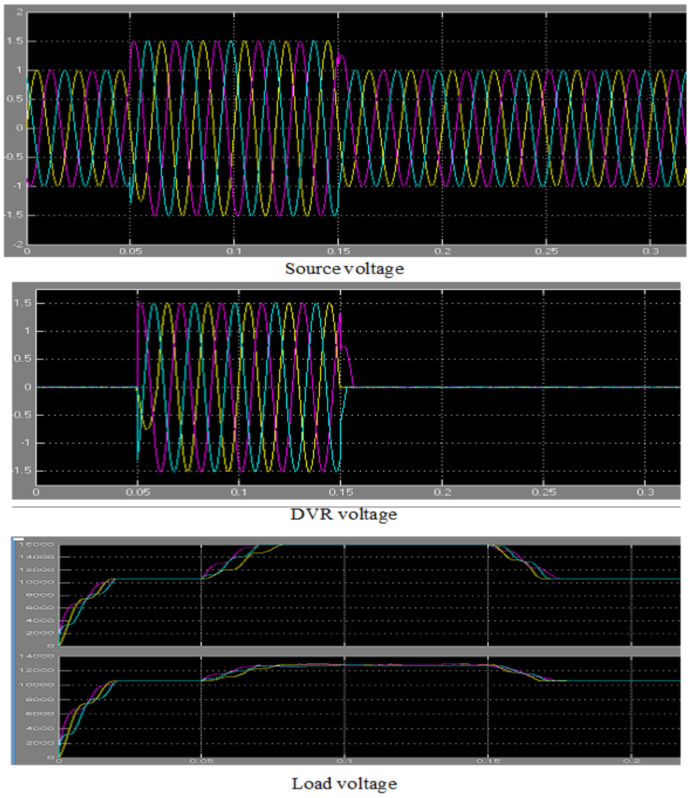

Fig 4.2.2 DVR Final Swell (a) Source Voltage (b) DVR Voltage (c) Load voltage.

Fig.4.2.2 Shows the Balanced Swell condition of a DVR .In Supply Voltage Swell occurs at period 0.1 and continues up to 0.2.In this period i.e. from 0.1 to 0.2 DVR injects the Compensation Voltage and load side voltage is maintained constant.

Case 3: Balanced Multiple Sag Condition

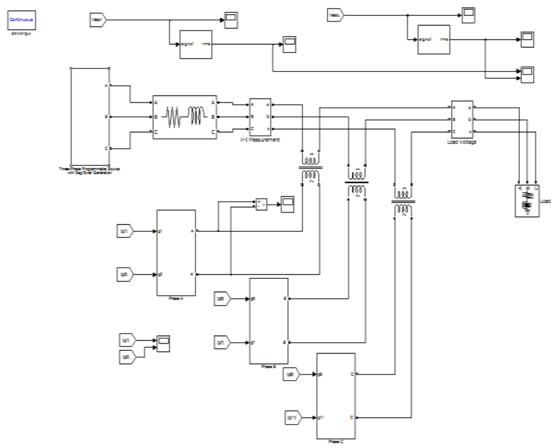

Fig 4.3 Matlab/Simulink model with DVR for Balanced Multiple Sag Condition

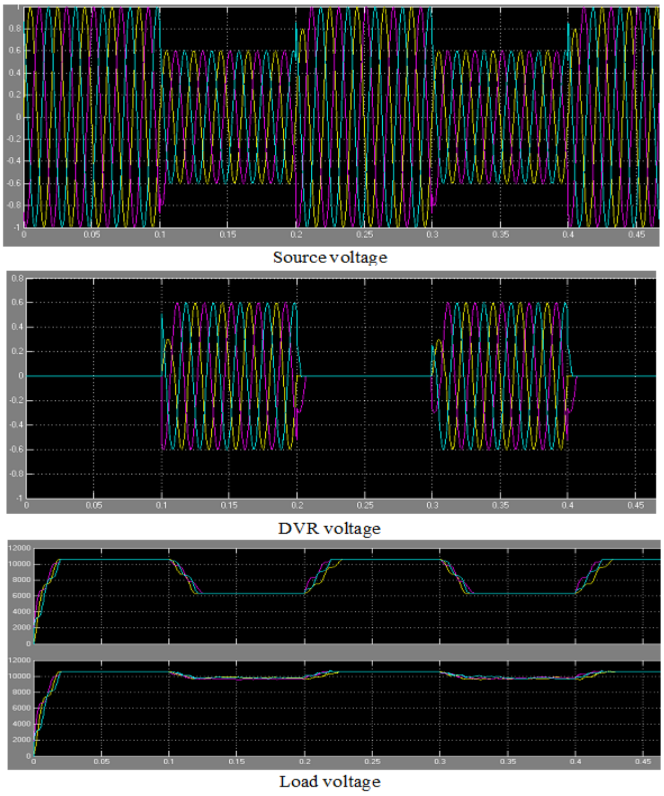

Fig 4.3.2 DVR Final Multiple Sag (a) Source Voltage (b) DVR VOltage (c) Load voltage

Fig.4.3.2 Shows the Balanced Multiple Sag condition of a DVR .In Supply Voltage Sag occurs at period 0.1 and continues up to 0.2 and 0.3 to 0.4 .In this period i.e. from 0.1 to 0.2 and 0.3 to 0.4 DVR injects the Compensation Voltage and load side voltage is maintained constant.

Case 4: Balanced Multiple Swell Condition

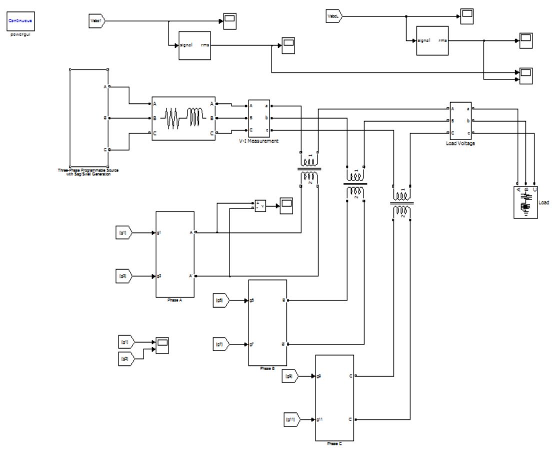

Fig 4.4 Matlab/Simulink model with DVR for Balanced Multiple Swell Condition

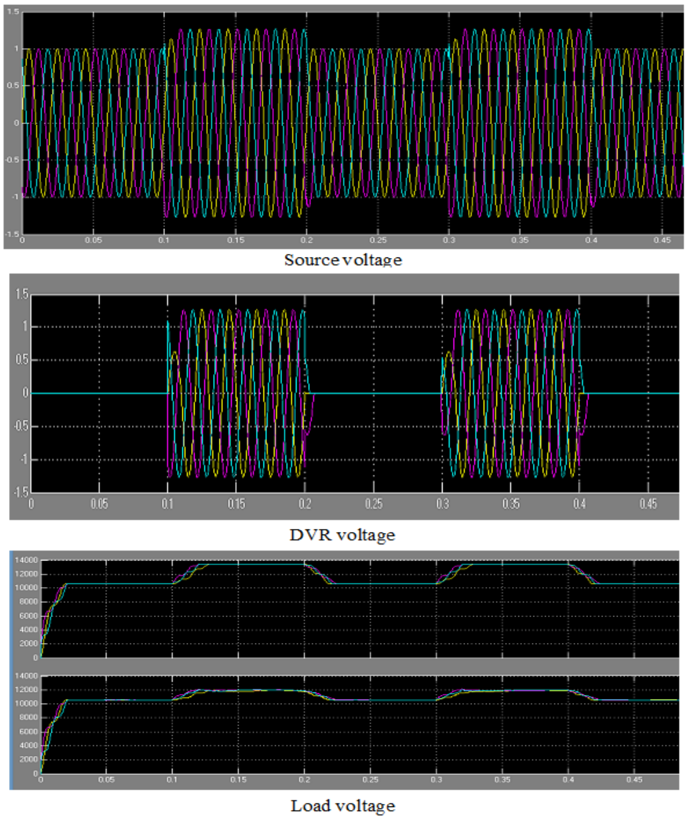

Fig 4.4.2 DVR Final Multiple Swell case (a) Source Voltage (b) DVR Voltage (c) Load Voltage

Fig.4.4.2 Shows the Balanced Multiple Swell condition of a DVR .In Supply Voltage Swell occurs at period 0.1 and continues up to 0.2 and 0.3 to 0.4. In this period i.e. from 0.1 to 0.2 and 0.3 to 0.4 DVR injects the Compensation Voltage and load side voltage is maintained constant.

Case 5: Balanced Sag and Swell Condition

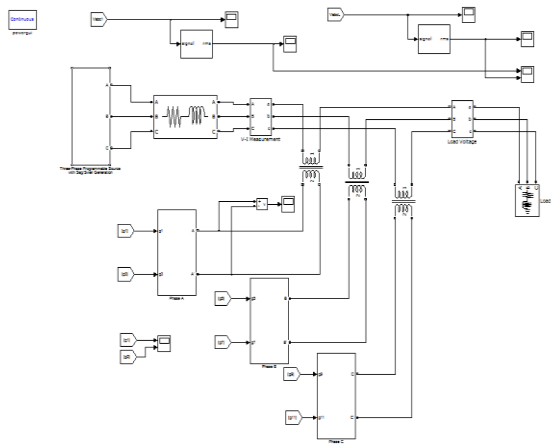

Fig 4.5Matlab/Simulink model with DVR for Balanced Sag and Swell Condition

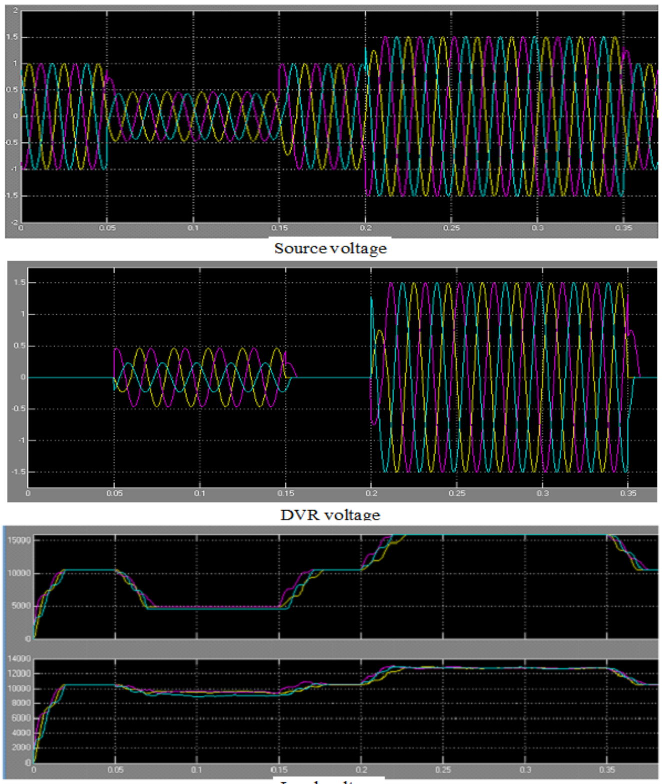

Fig 4.5.2 DVR Final Multiple Swell (a) Source Voltage (b) DVR Voltage (c) Load voltage

Fig. 4.5.2 shows the Balanced Sag and Swell condition of a DVR .In Supply Voltage Sag occurs at period 0.05 and continues up to 0.15 and Swell occurs at 0.2 to 0.35. In this period i.e. from 0.05 to 0.15 and 0.2 to 0.35 DVR injects the Compensation Voltage and load side voltage is maintained constant.

Case 6: Unbalanced Sag Condition

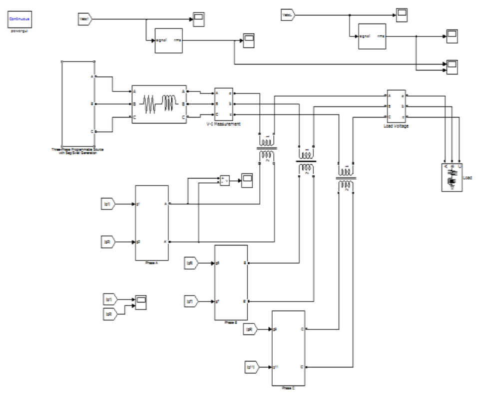

Fig 4.6Matlab/Simulink model with DVR for Unbalanced Sag Condition

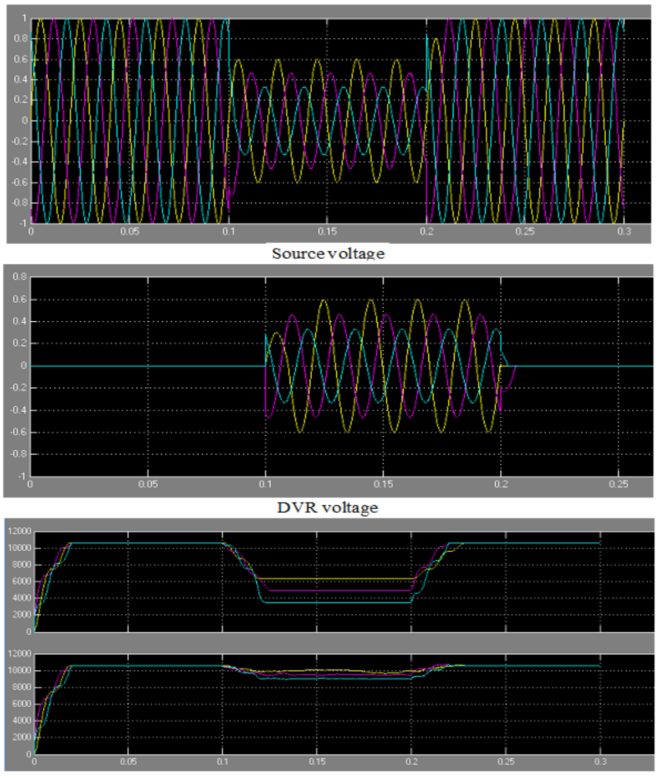

Fig 4.6.2 DVR Final Unbalanced Sag (a) Source Voltage (b) DVR Voltage (c) Load voltage

Fig. 4.6.2 shows the Unbalanced Sag condition of a DVR .In Supply Voltage Sag occurs at period 0.1 and continues upto 0.2 in a Two Phase. In this period i.e. from 0.1 to 0.2 DVR injects the Compensation Voltage and load side voltage is maintained constant.

Case 7: Unbalanced Swell Condition

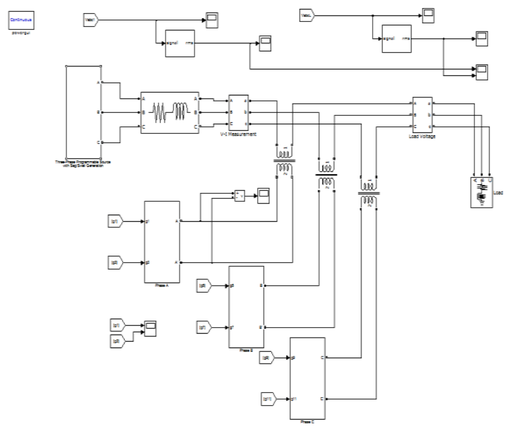

Fig 4.7Matlab/Simulink model with DVR for Unbalanced Swell Condition

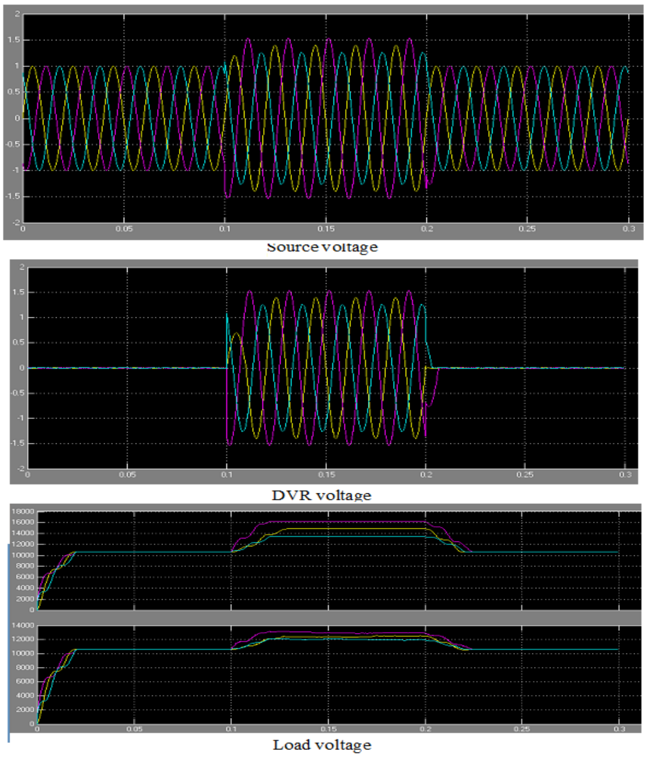

Fig 4.7.2 DVR Final Unbalanced Swell (a) Source Voltage (b) DVR Voltage (c) Load voltage

Fig.4.7.2 Shows the Unbalanced Swell condition of a DVR .In Supply Voltage Swell occurs at period 0.1 and continues upto 0.2.In this period i.e from 0.1 to 0.2 DVR injects the Compensation Voltage and load side voltage is maintained constant.

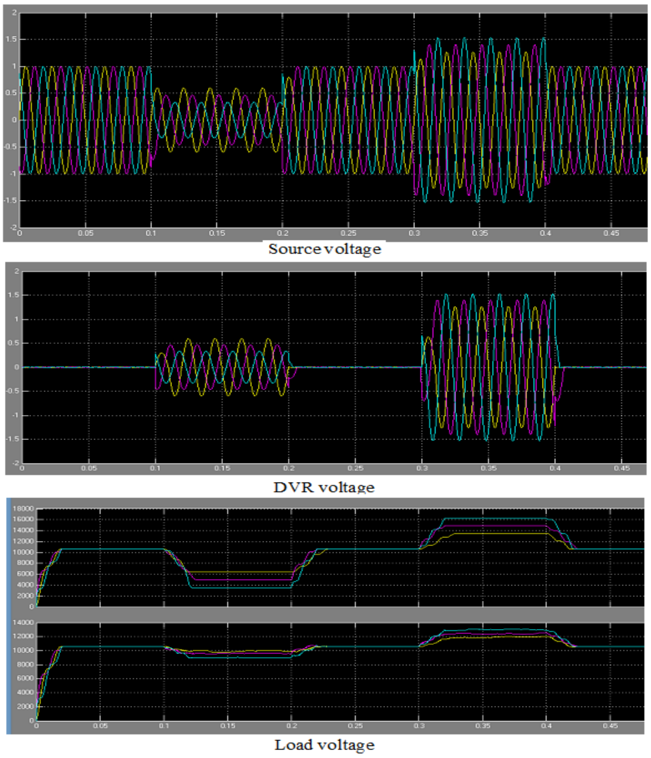

Fig 4.8.2 DVR Final Unbalanced Sag & Swell (a) Source Voltage (b) DVR Voltage (c) Load voltage

Fig.4.8.2 Shows the Unbalanced Sag and Swell condition of a DVR .In Supply Voltage Sag occurs at period 0.1 and continues up to 0.2, and Swell occurs at 0.3 to 0.4. In this period i.e. from 0.1 to 0.2 and 0.3 to 0.4 DVR injects the Compensation Voltage and load side voltage is maintained constant.

Case 8: Unbalanced Sag & Swell Condition

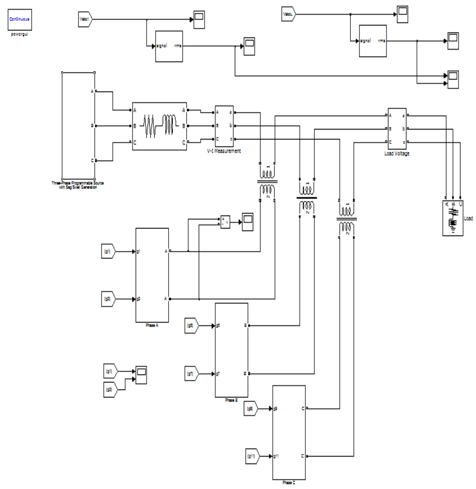

Fig 4.8Matlab/Simulink model with DVR for Unbalanced Sag & Swell Condition

Case 9: Unbalanced Multiple Sag Condition

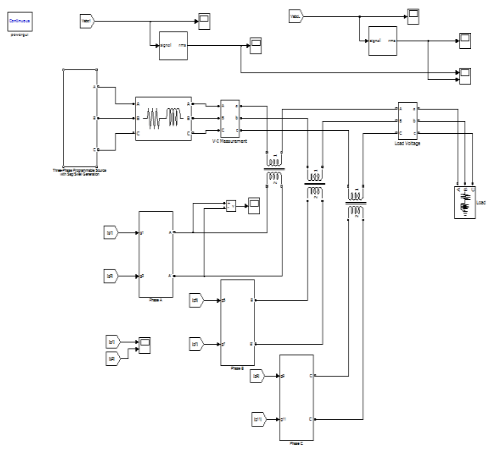

Fig 4.9Matlab/Simulink model with DVR for Unbalanced Multiple Sag Condition

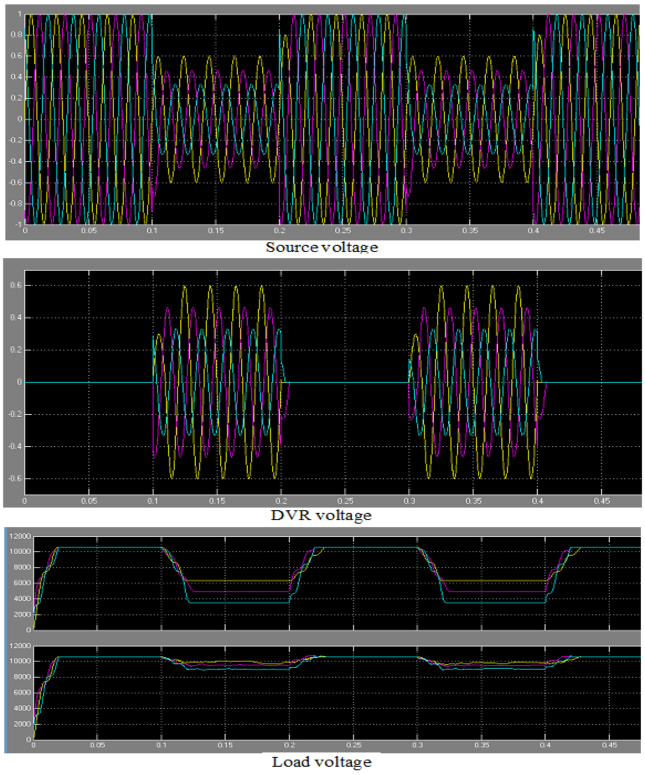

Fig 4.9.2 DVR Final Unbalanced Multiple Sag (a) Source Voltage (b) DVR Voltage (c) Load voltage

Fig.4.9.2 Shows the Unbalanced Multiple Sag condition of a DVR .In Supply Voltage Sag occurs at period 0.1 and continues upto 0.2, and 0.3 to 0.4 .In this period i.e from 0.1 to 0.2 and 0.3 to 0.4 DVR injects the Compensation Voltage and load side voltage is maintained constant.

Case 10: Unbalanced Multiple Swell Condition

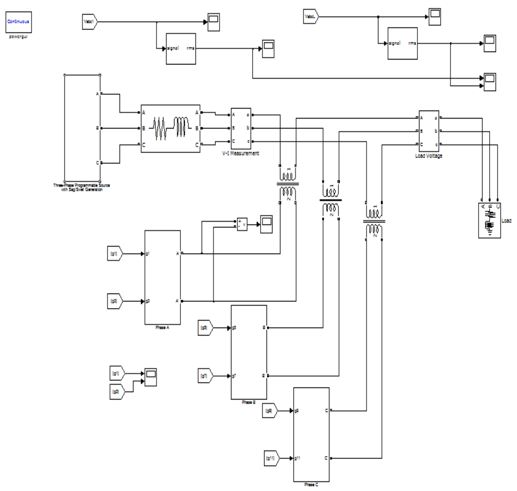

Fig 4.10Matlab/Simulink model with DVR for Unbalanced Multiple Swell Condition

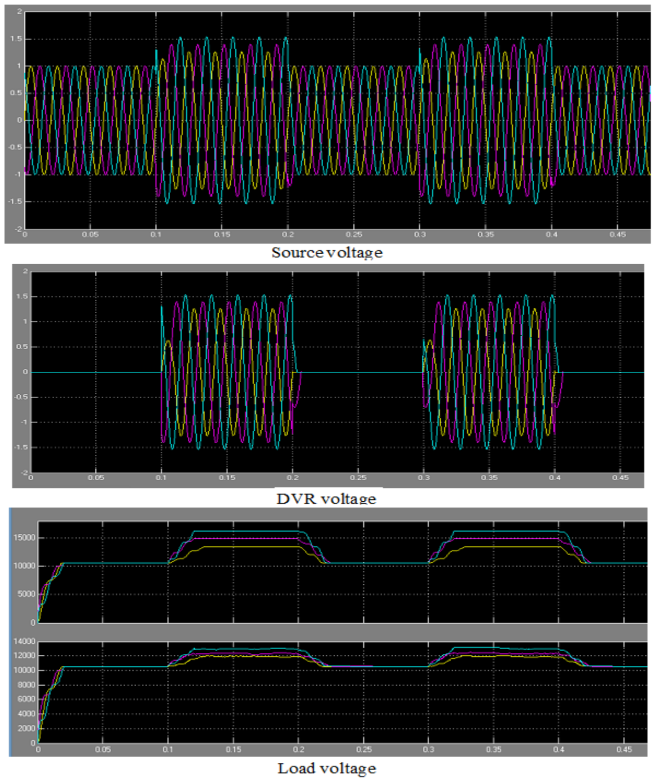

Fig 4.10.2 DVR Final Unbalanced Multiple Swell (a) Source Voltage (b) DVR Voltage (c) Load voltage

Fig.4.10.2 Shows the Unbalanced Multiple Swell condition of a DVR .In Supply Voltage Swell occurs at period 0.1 and continues upto 0.2, and 0.3 to 0.4 .In this period i.e from 0.1 to 0.2 and 0.3 to 0.4 DVR injects the Compensation Voltage and load side voltage is maintained constant.

5. CONCLUSIONS

DVR is capable of compensating the various voltage disturbances like single phase and two phase sag and swell in unbalanced condition as well as sag and swell in unbalanced condition in three phases. Various conditions are tested for the performance capability of DVR through extensive simulation and results are verified.DVR is tested for balanced sag, swell, multiple sag and multiple swell and sag and swell cases, and in unbalanced condition sag and swell in single and two phases as well as unbalanced three phase condition.

In this research work we are going to improve the compensation of device by implementing the hardware model using facts device and PROTEUS -Simulation result using DVR based SRF controlled. The DVR is the best solution for mitigating the various voltage disturbances in a distribution system.

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