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Voltage Quality Improvement Using DVR Based on Synchronous Reference Frame Theory

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ABSTRACT: Voltage sags and swells in the medium and low voltage distribution grid are considered to be the most frequent type of power quality problems based on recent power quality studies. Their impact on sensitive loads is severe. For sensitive loads, even voltage sags of short duration can cause serious problems in the entire system. Normally, a voltage interruption triggers a protection device, which causes shutdown of the entire system. Different solutions have been developed to protect sensitive loads against such disturbances but the DVR is considered to be the most efficient and effective solution.The control strategy for extracting the compensation voltages in DVR is based on synchronous reference frame theory (SRF) along with PI controller. The control strategy is verified through extensive simulation studies using MATLAB & SIMULINK to demonstrate the improved performance of DVR.

KEYWORDS: Voltage Sag and Swell, Synchronous Reference Frame Theory, DVR.

I.INTRODUCTION

In the early days of power transmission voltage deviation during load changes, power transfer limitation was observed due to reactive power unbalances. Modern power systems are complex networks, where hundreds of generating stations and thousands of load centers are interconnected through long power transmission and distribution networks. The main concern of customer is the quality and reliability of power supply at various load centers. Even though power generation in most well-developed countries is fairly reliable, the quality of supply is not. Power distribution system should ideally provide their customers an uninterrupted flow of energy with smooth sinusoidal voltage at the contracted magnitude and frequency. However, in practice power system especially the distribution system, have numerous nonlinear loads, which significantly affect the quality of power supply [1].
A power distribution system is a very complex system. It is important to remove any system faults or abnormalities so that the rest of the power distribution network is not interrupted or damaged. Power Quality has serious economic implications for customers, utilities and electrical equipment manufacturers. Modern industrial equipments are more sensitive to power quality problems such as voltage sag, swell, interruption, harmonic flickers and impulse transients. Failures due to such disturbances create impact on production cost. So now-a-days, high quality has become basic need of highly automated industries. Power electronics and advanced control technologies have made it possible to mitigate the power quality problems and maintain the operation of sensitive loads. When a fault or an abnormality event occurs somewhere in a power distribution network, the voltage is affected throughout the power system. Among various power quality problems, the majority of events are associated with either voltage sag or a voltage swell, and they often cause serious power interruptions, if proper care will not be taken in time [2].

The thought of custom power (CP) identifies with the utilization of electronic controllers for power system network. There are number of custom power units which are given below, Distribution Statcom (DSTATCOM), Dynamic Voltage Restorer (DVR), Unified Power Quality Conditioner (UPQC), Active Power Filters, Battery Systems (BESS), Distribution Series Capacitors (DSC), Surge Arresters (SA), Un-interruptible Power Supplies (UPS), Solid State Fault Current Limiter (SSFCL), Solid-State Transfer Switches (SSTS), and Static Electronic Tap Changers (SETC)[3]. Dynamic Voltage Restoration (DVR) is a method and apparatus used to sustain, or restore, an operational electric load during sags, or spikes, in voltage supply. DVRs are a class of custom power devices for providing reliable distribution power quality. They employ a series of voltage boost technology using solid state switches for compensating sags/swells.

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Dynamic Voltage Restorer (DVR) [4] is a very effective series compensation device for mitigating voltage sag/swell. Dynamic Voltage Restorer (DVR) is a voltage source inverter (VSI) which is inserted in series between the supply and a critical load. The basic operating principle of the DVR is to inject appropriate voltage in series with the supply through an injection transformer to mitigate the power qulaity problems [5]. The voltage injection schemes and design of the self-supported DVR and the different control strategies for the controllers of the DVR have been discussed in [6]-[7]. E.g, adaline based fundamental extraction have been implemented in [8]. Instantaneous symmetrical component theory [9], space vector modulation, synchronous reference frame theory (SRFT) [10]-[12] based control techniques for a DVR are reported in this literature. In this paper, a new control algorithm is suggested based on SRF theory which includes P-I Controller.

II.DYNAMIC VOLTAGE RESTORER (DVR) CONFIGURATION

DVR is a Custom Power Device used to eliminate supply side voltage disturbances. DVR also known as Static Series Compensator which maintains the load voltage at a desired magnitude and phase by compensating the voltage sags/swells and voltage unbalances presented at the point of common coupling.The power circuit of the DVR is shown in Fig. 1.

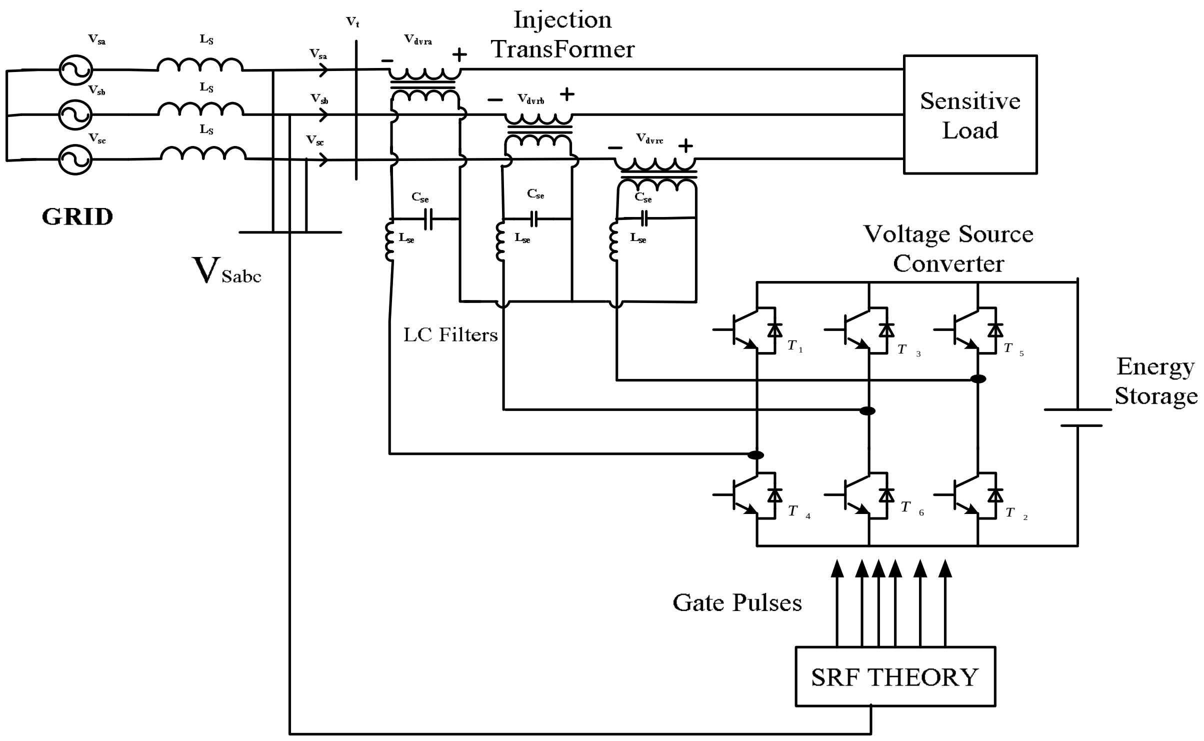

Fig.1 DVR Block Diagram

The DVR consists of the following major parts:-

A. Voltage Source Inverter (VSI)

PWM inverter using IGBT switches is used in the model. IGBT switches are commonly used in series connected circuits. The insulated gate bipolar transistor or IGBT is a three-terminal power semiconductor device, noted for high efficiency and fast switching. Pulse-width modulation (PWM) is a very efficient way of providing intermediate amounts of electrical power between fully on and fully off. The voltage source converter is used to convert the DC to AC and then supply the voltage to distribution feeder through an injection transformer.

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B. Injection Transformers

The injection transformers connect the DVR to the distribution network via the high voltage windings. They transform and couple the injected compensating voltages generated by the VSI to the incoming supply voltage. Basically injection transformers used in the model presented in this paper are three single phase transformers. The high voltage side of the injection transformer is connected in series to the distribution line, while the low voltage side is connected to the DVR power circuit. For a three-phase DVR, three single-phase or three-phase voltage injection transformers can be connected to the distribution line, and for single phase DVR one single-phase transformer is connected. The transformers not only reduce the voltage requirement of the inverters, but also provide isolation between the inverters.

C. Passive Filters

Passive filters are placed at the high voltage side of the DVR to filter the harmonics. These filters are placed at the high voltage side, as placing the filters at the inverter side introduces phase angle shift which can disrupt the control algorithm.

D .Energy storage

The energy storage unit supplies the required power for compensation of load voltage during voltage sag. A dc battery is used for this purpose. Batteries, flywheels or SMEs can be used to provide real power for compensation. Compensation using real power is essential when large voltage sag occurs.

III.DVR CONTROLLING BASED ON SYNCHRONOUS REFERENCE FRAME THEORY

The basic functions of a controller in a DVR are the detection of voltage sag/swell events inthe system; computation of the correcting voltage, generation of trigger pulses to the PWM based DC-AC inverter, correction of any abnormalities in the series voltage injection and termination of the trigger pulses when the event has passed. The compensation for voltage sags using a DVR can be performed by injecting/absorbing reactive power or real power. The control technique adopted should consider the limitations such as the voltage injection capability (inverter and transformer rating) and optimization of the size of energy storage.

The following figure shows the Control Block Diagram of the DVR .In this control, Source Voltage is sensed and gives as an input to the abc/dq transformation block and same source voltage is given as an input to the PLL block .The 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 the information of V_d, V_q i. This information is compared with V_{dact},V_{qact} which are the actual parameters .The quadrature 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.

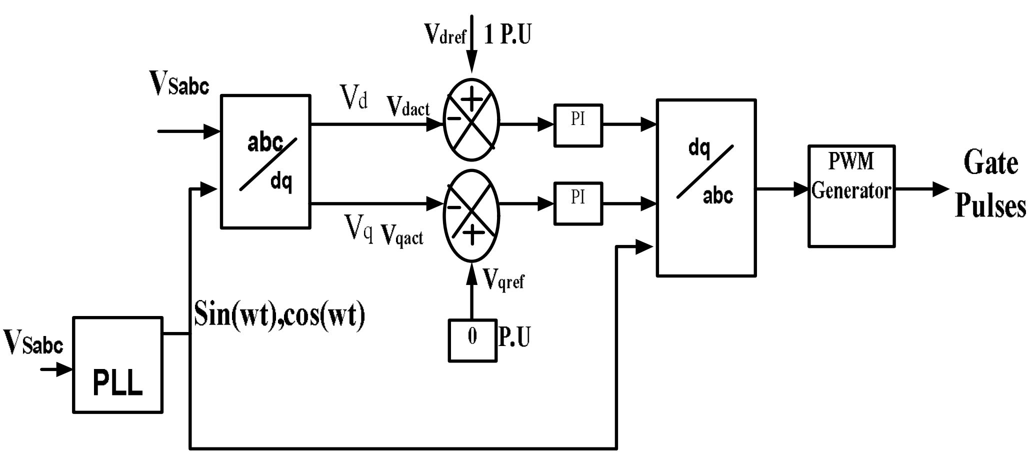

Fig.2 DVR Control Block Diagram based on SRF Theory

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IV. MATLAB/SIMULATION RESULTS AND DISCUSSION

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

The Specification and parameters of the system were listed in the below Table I.

Table I.

PARAMETERS OF THE SYSTEM SPECIFICATIONS

SYSTEM PARAMETERS	VALUES
1. AC Line Voltage	440 V, 50Hz
2. Load	10 KVA
3. DC Voltage	550 V
4. PI Controller	KP=10 Ki =0.1

Case 1: Sag Condition

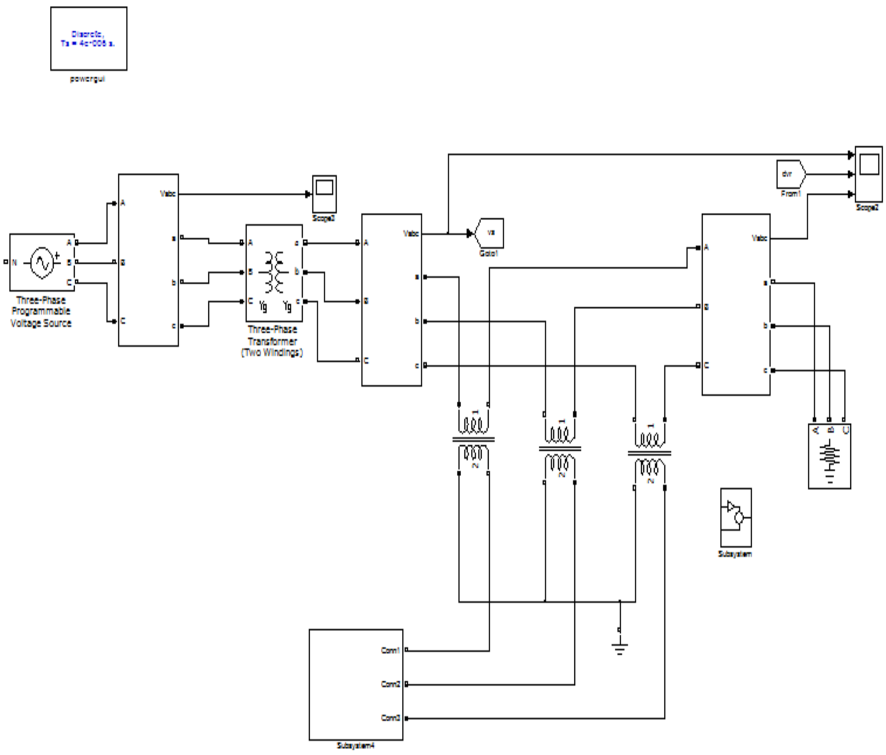

Fig.3 Matlab/Simulink model with DVR for Sag Condition

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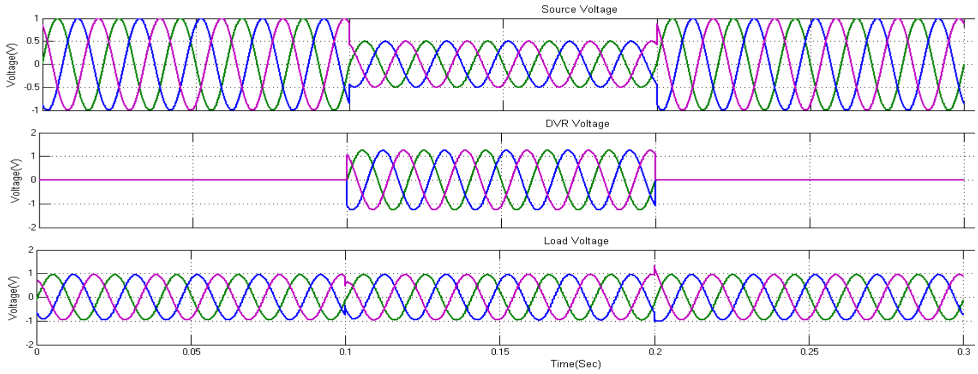

Fig.4 DVR Final Sag Case (a) Source Voltage (b) DVR Voltage

(c)Load Voltage

Fig.4 Shows the Sag condition of a DVR .In Supply Voltage Sag 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.

Case:2 Swell Condition

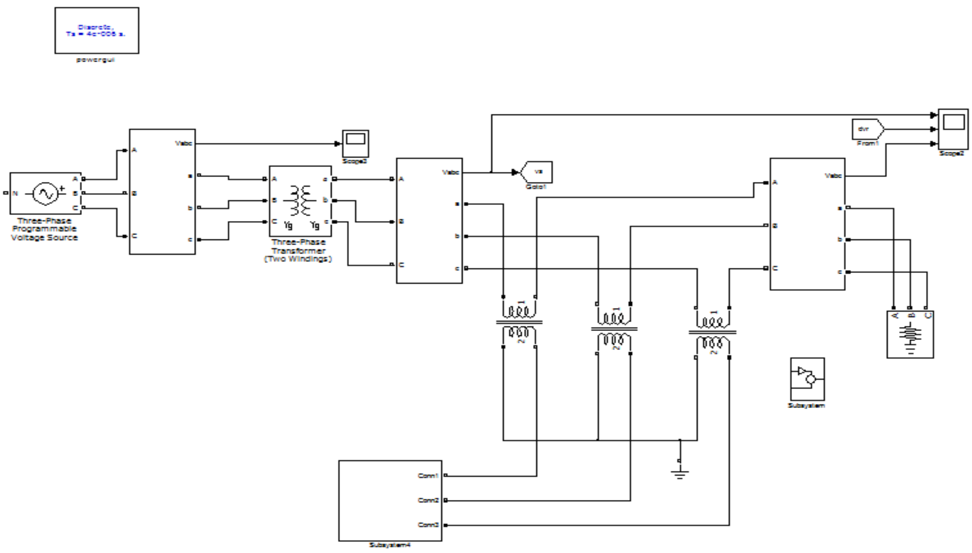

Fig.5 Matlab/Simulink model with DVR for Swell condition

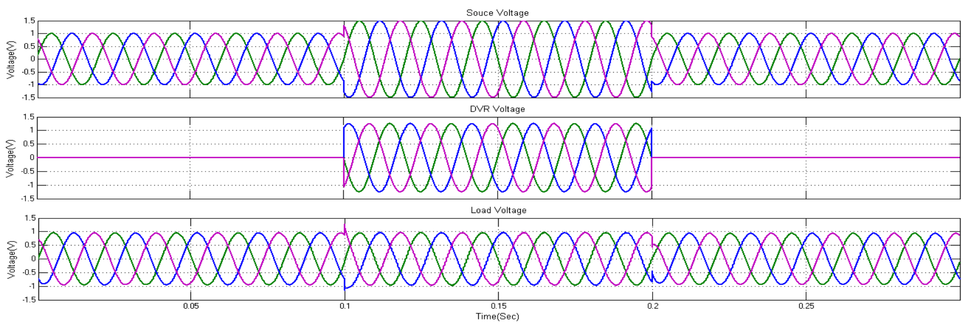

Fig.6 DVR Final Swell case (a) Source Voltage (b) DVR Voltage (c) Load Voltage

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Fig.6 Shows the 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: Multiple Sag Condition

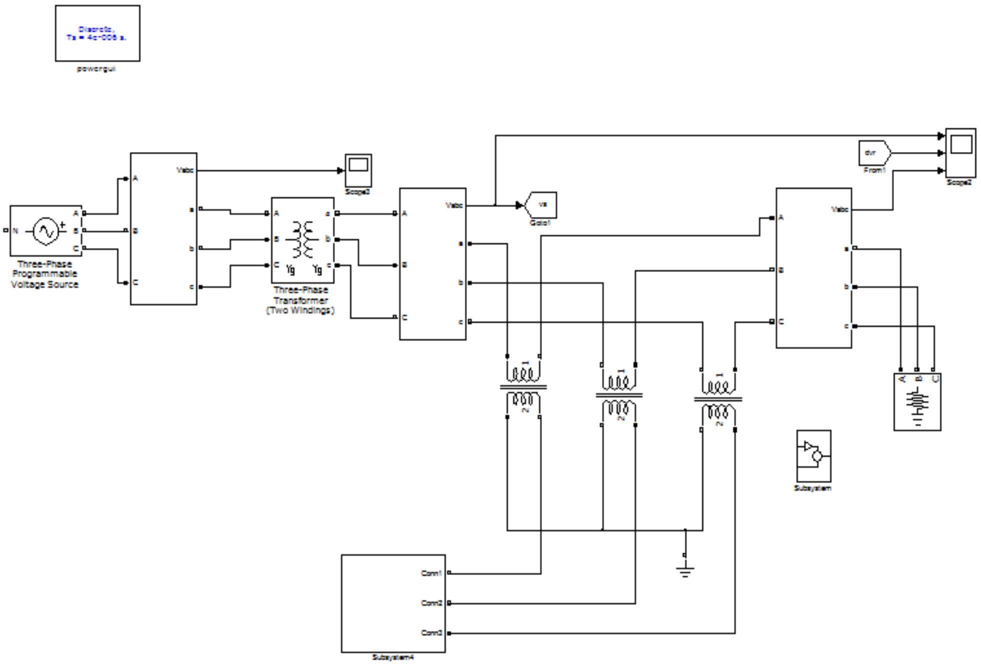

Fig.7 Matlab/Simulink model with DVR for Multiple Sag Condition

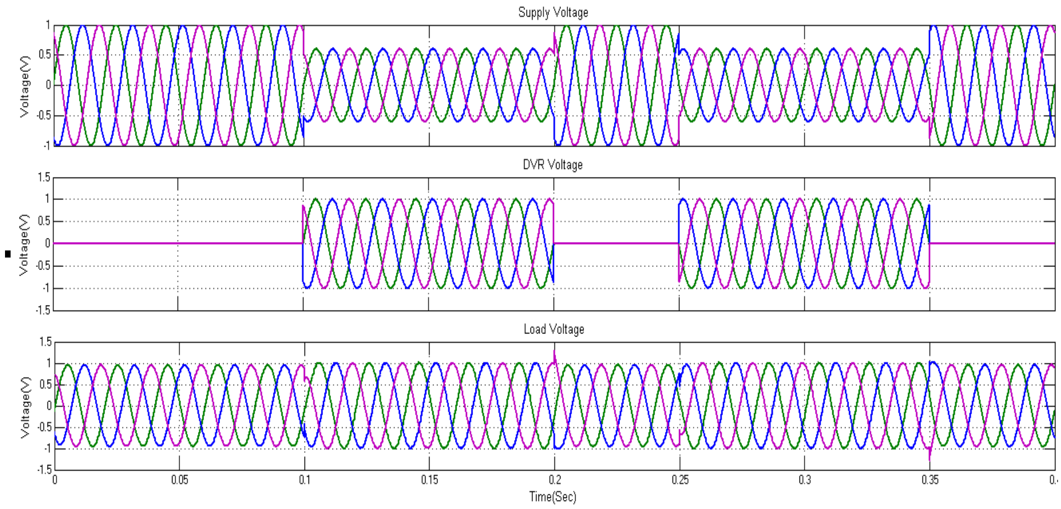

Fig.8 DVR Final Multiple Sag case (a) Source Voltage (b) DVR Voltage (c) Load Voltage

Fig.8 Shows the Multiple Sag condition of a DVR .In Supply Voltage Sag occurs at period 0.1 and continues upto 0.2, and 0.25 to 0.35 .In this period i.e from 0.1 to 0.2 and 0.25 to 0.35 DVR injects the Compensation Voltage and load side voltage is maintained constant.

Case 4: Multiple Swell Condition

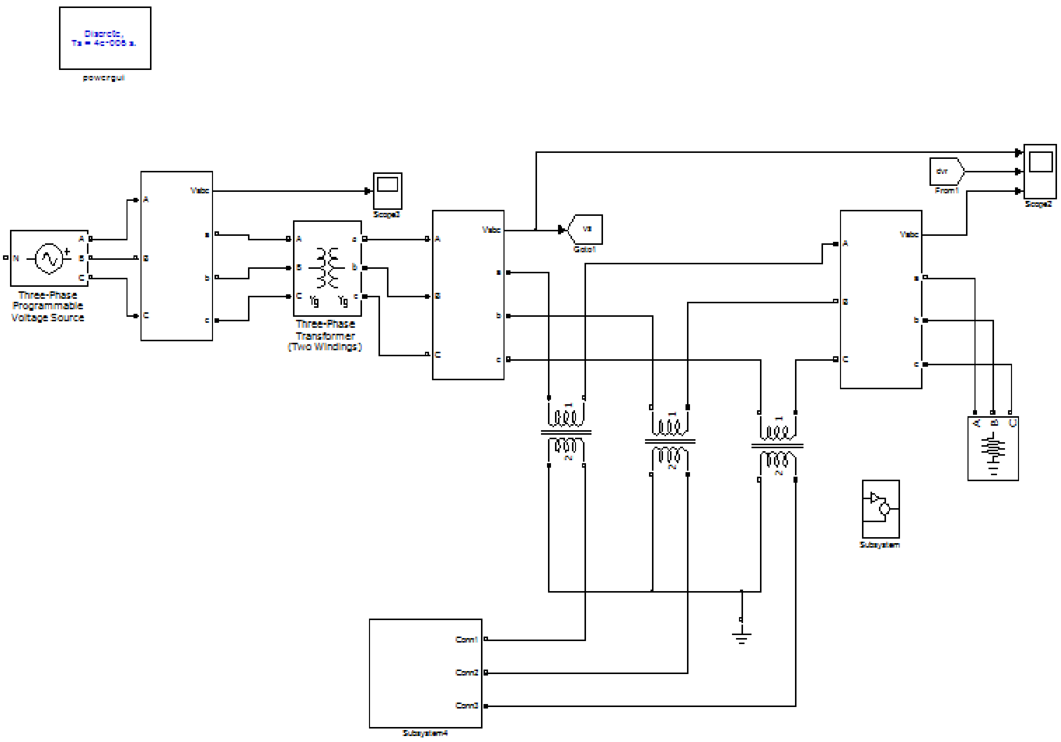

Fig.9 Matlab/Simulink model with DVR for Multiple Swell Condition

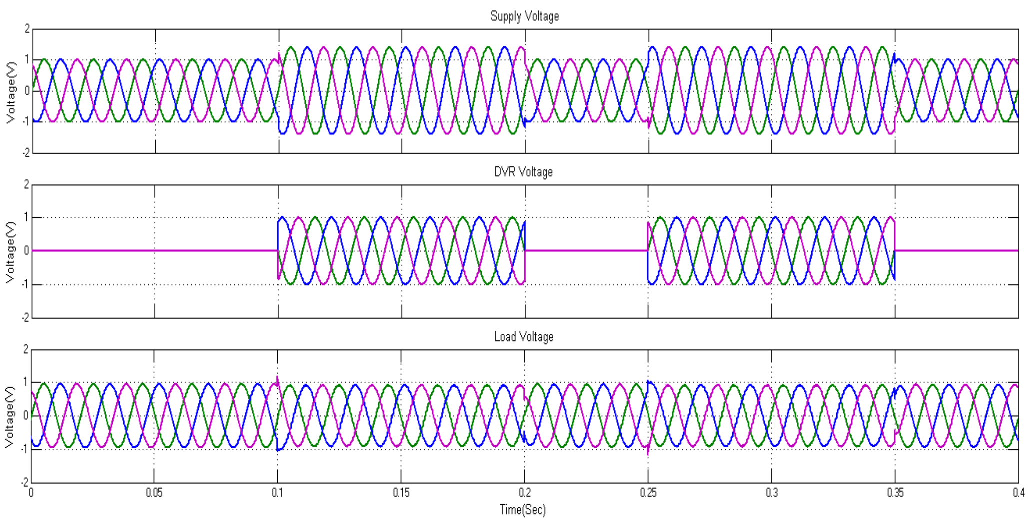

Fig.10 DVR Final Multiple Swell case (a) Source Voltage (b) DVR Voltage (c) Load Voltage

Fig.10 Shows the Multiple Swell condition of a DVR .In Supply Voltage Swell occurs at period 0.1 and continues up to 0.2, and 0.25 to 0.35 .In this period i.e from 0.1 to 0.2 and 0.25 to 0.35 DVR injects the Compensation Voltage and load side voltage is maintained constant.

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Case 5: Sag and Swell Condition

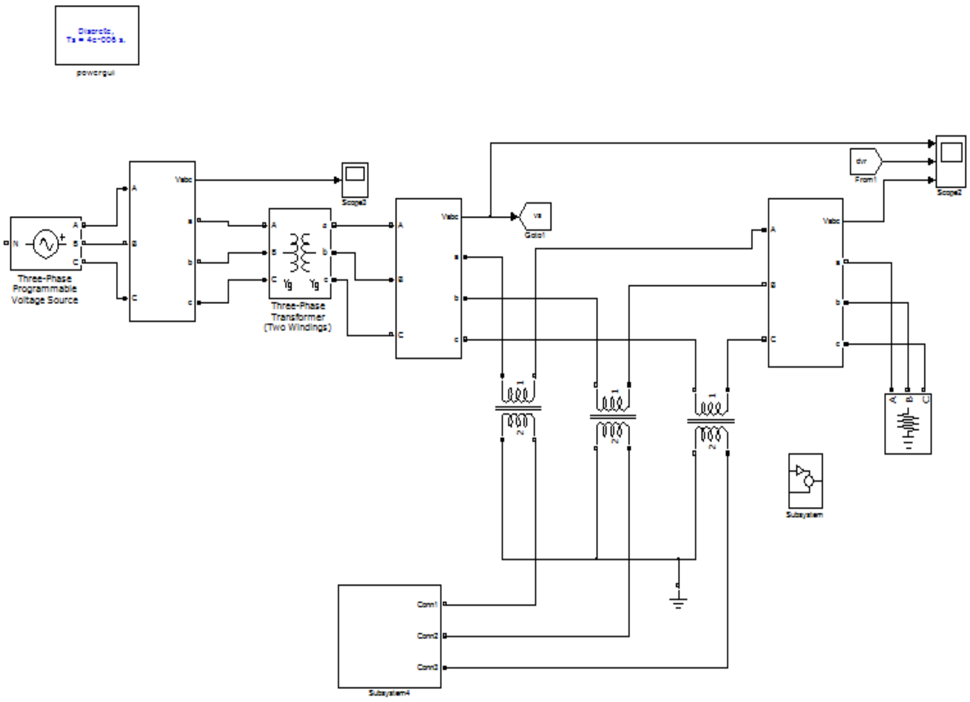

Fig.11 Matlab/Simulink model with DVR for Sag and Swell Condition

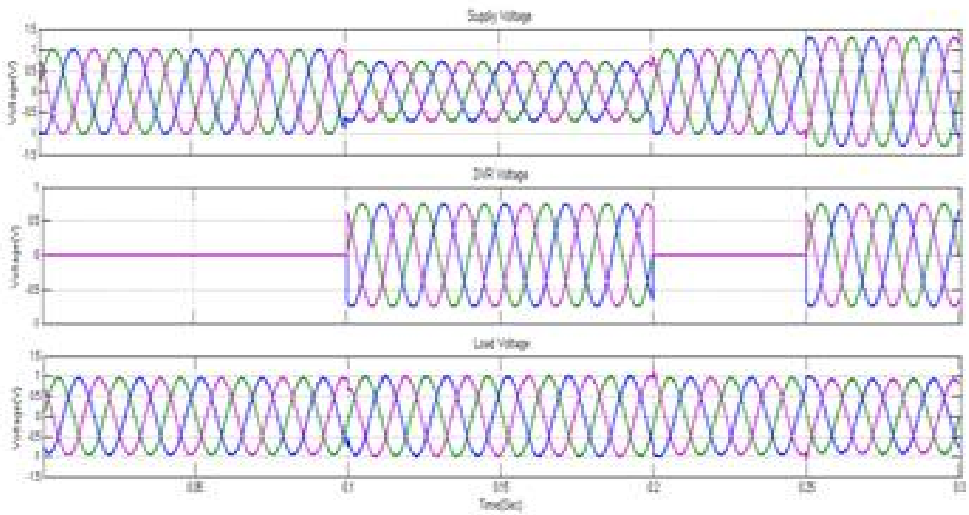

Fig.12 DVR Final Multiple Swell case (a) Source Voltage (b) DVR Voltage (c) Load Voltage

Fig.12 Shows the 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 0.25 to 0.3 .In this period i.e from 0.1 to 0.2 and 0.25 to 0.3 DVR injects the Compensation Voltage and load side voltage is maintained constant.

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V.CONCLUSION

The modeling and simulation of a DVR using MATLAB/SIMULINK has been presented. And simulation analysis is presented for the voltage disturbances like voltage Sag, voltage Swell, multiple Sags and multiple Swells and the voltage Sag and Swell conditions .From the Simulation analysis, the DVR based on Synchronous Reference Frame theory (SRF) is able to detect different types of power quality problems without an error and injects the appropriate voltage component to correct immediately any abnormality in the terminal voltage to keep the load voltage balanced and constant at the nominal value. Simulation results show that, the proposed DVR successfully protects the most critical load against balanced and unbalanced voltage sags and swell.

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