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# A Novel Voltage Sag/Swell Compensation using DVR with Distributed Generation Scheme

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**Abstract:** To facilitate more extensive adoption of renewable distributed electric generation. The study addressed the technical and analytical challenges that must be addressed to enable high penetration levels of distributed renewable energy technologies. In order to meet the required load demand, it is better to integrate the renewable energy sources with the DG system. The PV generator is connected to the boost DC-DC converter, PV array to generate the maximum power to the grid with change weather conditions. Now a day, the problem of voltage sags and swells create a severe impact on sensitive loads in industries supported by active compensation scheme with DG Application. Due to which load shedding and over voltages might occur achieve the grid synchronization. This paper deals with the PI controller fed DVR which achieve the desired frequency with respective magnitude and time domain specifications simultaneously. Voltage sag and swell is big problem in power system. Sensitive load has a severe impact on itself due to voltage sag and swell. Dynamic Voltage Restorer (DVR) is a power custom device used in power distribution network. The Dynamic Voltage Restorer (DVR) is fast, flexible and efficient solution to voltage sag problem. The DVR is designed for protecting the whole plant with loads in the range of some MVA. The DVR can restore the load voltage within few milliseconds. This paper discussed abc to dq0 base new control algorithm to generate the pulse. The simulation results are obtained through MATLAB/SIMULINK software.

**Keywords:** Power Quality, Voltage Sags /Swells, DVR, Matlab/Simulink.

## I. INTRODUCTION

In today circumstances, rapid development of power network cause the fault current of the system increased greatly. The levels of fault current in many places have often exceeded the withstand capacity of existing power system equipment. As implication to this matter; security, stability and reliability of power system will be negatively affected with effective DG system with renewable energy system. As Conventional sources of energy are rapidly depleting and the cost of energy is rising, photovoltaic energy becomes a promising alternative source. Among its advantages are that it is: 1) abundant; 2) pollution free; 3) distributed throughout the earth; and 4) clean and noise-free source of electricity. The main drawbacks are that the initial installation cost is considerably high and the energy conversion efficiency is relatively low. To overcome these problems, the following two essential ways can be used: 1) increase the efficiency of conversion for the solar array and 2) maximize the output power from the solar array. The PV generation is gaining increased importance as a renewable source. It is used today in many applications e.g. battery charging; water pumping, home power supply, swimming-pool heating systems, satellite power system. The PV systems have the advantage of being maintenance and pollution-free but their installation cost is high and, in most applications; they require a power conditioner (DC/DC or DC/AC converter) for load interface. Since PV modules still have relatively low conversion efficiency.

The overall system cost can be reduced using high efficiency power conditioners which, in addition, are designed to extract the maximum possible power from the PV module. The various power quality problems are due to the increasing use of non linear and power electronic loads. Harmonics and voltage distortion occur due to these loads. The power quality problems can cause malfunctioning of sensitive equipments, protection and relay system [1]. Distribution system is mainly affected by voltage sag and swell power quality issue. Short circuits, lightning strokes, faults and inrush currents are the causes of voltage sags. Start/stop of heavy loads, badly dimensioned power sources, badly regulated transformers, single line to ground fault on the system lead to voltage swells. To improve power quality, custom power devices are used. 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 (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.

One of the power electronic solutions to the voltage regulation is the use of a Dynamic Voltage Restorer (DVR). 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 voltage sags/swells. The DVR applications are mainly for sensitive loads that may be drastically affected by fluctuations in system voltage. Power Quality problems encompass a wide range of disturbances such as voltage sags/swells, flicker, harmonics distortion, impulse transient, and interruptions. This paper presents the voltage sag/swell compensation scheme using dynamic voltage restorer to regulate the voltage at PCC level to improve power quality features and the proposed connected scheme is interfaced to grid connected/load by using energy scheme. The simulation analysis is carried out in Matlab/Simulink environment.

## II. SYSTEM DISCRIPTION

Dynamic Voltage Restorer is one of custom power device specially used to maintain the load voltage constant in the distribution system. DVR has two operating modes. In normal operation mode it is in standby mode in which voltage injection by DVR is zero. The primary function of DVR is to compensate voltage sags and swells but it can also perform the tasks such as: harmonic compensation, reduction of transient in voltage and fault current limitation. The main parts of DVR are injection transformer, harmonic filter, a voltage source converter, energy storage device and control & protection system [7-8]. As soon as control circuit detects the any voltage disturbance, reference voltage is generated for required magnitude, duration and phase and is injected through injection transformer. This mode of DVR is known as injecting mode [1]. This injection should satisfy the equation (1)[6]

$$V_L = V_S + V_{inj} \tag{1}$$

Where $V_S$ is the source voltage, $V_{inj}$ is the injected voltage by DVR and VL is the load voltage.

Fig.1 shows the basic configuration and operation of DVR which consist of an injection transformer, Voltage Source Converter (VSC), harmonic filter, storage device and control system.

### A. Injection Transformer

Injection transformer is used to connect the DVR to the distribution network via High Voltage winding and injects the compensating voltage generated by VSC after the detection of any disturbance in supply voltage by control circuit. Another main task of injection transformer is that it will limit the coupling of noise and isolate VSC and control circuit from the system [9].

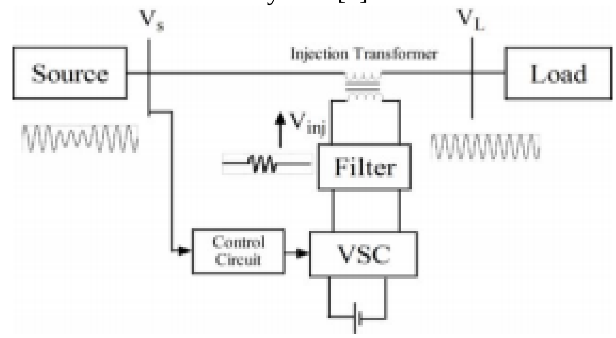


**Fig.1. Structure of DVR.**

### B. Voltage Source Converter (VSC)

VSC is a power electronic device consists of storage device and switching devices used to generate the compensating sinusoidal voltage of required magnitude, duration, in phase as that of system and instantaneously. In DVR voltage source converter provides the missing voltage during voltage sag [10].

### C. Harmonic Filter

Output of VSC contains large content of harmonics. Harmonic filter is used to keep this harmonic content in permissible limit [9].

### D. Storage Device

It is basically used to supply the necessary energy to VSC to generate the compensating voltage [9], [10].

### E. Control Circuit

Control circuit continuously monitors the supply voltage. The function of control system is to detect the disturbance in the supply voltage, compare it with the set reference value and then generate the switching pulses to the VSC to generate the DVR output voltages which will compensate the voltage sag/swell [9], [10].

## III. DESIGN OF DVR

The aim of the control scheme is to maintain constant voltage magnitude at the sensitive load under voltage disturbance condition. The proposed control scheme based on comparison of actual supply voltage and desired load voltage. The error is determined dynamically based on difference between desired and measured value. In the control scheme the actual voltage is measured and also the desired voltage. These voltages are converted in dq0 with the Parks transformation [6].

$$f_{qd0} = K_s f_{abc} \tag{2}$$

Where

$$\left(f_{qd0}\right)^T = \left(f_q \; f_d \; f_0\right) \tag{3}$$

$$\left(f_{abc}\right)^T = \left(f_a \; f_b \; f_c\right) \tag{4}$$

$$K_s = \frac{2}{3}\begin{bmatrix} \cos\theta & \cos\left(\theta - \frac{2\pi}{3}\right) & \cos\left(\theta + \frac{2\pi}{3}\right) \\ \sin\theta & \sin\left(\theta - \frac{2\pi}{3}\right) & \sin\left(\theta + \frac{2\pi}{3}\right) \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \end{bmatrix} \quad (5)$$

$$\omega = \frac{d\theta}{dt} \quad (6)$$

It can be shown that for the inverse transformation we have

$$(K_s)^{-1} = \begin{bmatrix} \cos\theta & \sin\theta & 1 \\ \cos\left(\theta - \frac{2\pi}{3}\right) & \sin\left(\theta - \frac{2\pi}{3}\right) & 1 \\ \cos\left(\theta + \frac{2\pi}{3}\right) & \sin\left(\theta + \frac{2\pi}{3}\right) & 1 \end{bmatrix} \quad (7)$$

The angular velocity $\omega$ and displacement $\theta$ are related by

$$\theta = \int \omega\, dt \quad (8)$$

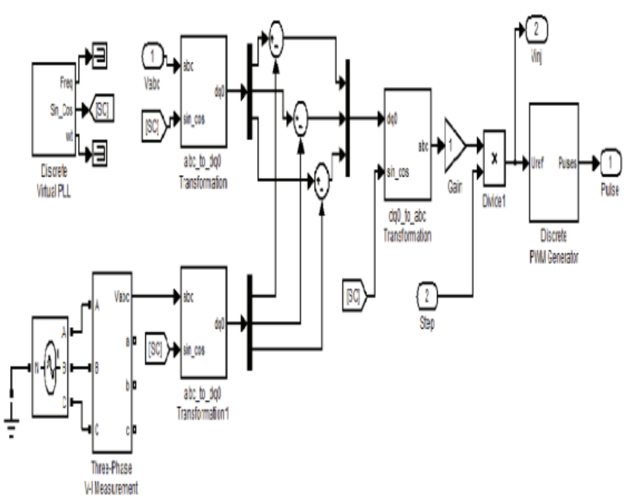


**Fig. 2. Control block diagram for DVR.**

The control system employs abc to dqo transformation to dq0 voltages. During normal condition and symmetrical condition, the voltage will be constant and d-voltage is unity in p.u. and q-voltage is zero in p.u. but during the abnormal conditions it varies. After comparison d-voltage and q voltage with the desired voltage error d and error q is generated. These error components are converted into abc component using dq0 to abc transformation. Phase Locked Loop (PLL) is used to generate unit sinusoidal wave in phase with main voltage. This abc components are given to generate three phase Pulses using Pulse Width Modulation (PWM) technique. Proposed control technique block is shown in Fig 2.

## IV. CONTROL ALGORITHM

The basic functions of a controller in a DVR are the detection of voltage sag/swell 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/swells. The dqo transformation or Park's transformation [8-10] is used to control of DVR. The dqo method gives the sag depth and phase shift information with start and end times. The quantities are expressed as the instantaneous space vectors. Firstly convert the voltage from abc reference frame to d-q-o reference. For simplicity zero phase sequence components is ignored. Fig.3 illustrates a flow chart of the feed forward dqo transformation for voltage sags/swells detection. The detection is carried out in each of the three phases.

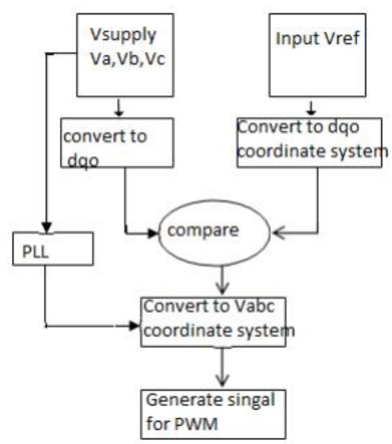


**Fig.3. Flow chart of feed forward control technique for DVR based on dqo transformation.**

The control scheme for the proposed system is based on the comparison of a voltage reference and the measured terminal voltage ($V_a$, $V_b$, $V_c$).The voltage sags is detected when the supply drops below 90% of the reference value whereas voltage swells is detected when supply voltage increases up to 25% of the reference value. The error signal is used as a modulation signal that allows generating 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 block diagram of the phase locked loop (PLL) is illustrated in Fig 3. The PLL circuit generates a unit sinusoidal wave in phase with mains voltage. Equation (9) defines the transformation from three phase system a, b, c to dqo stationary frame. In this transformation, phase A is aligned to the d axis that is in quadrature with the q-axis. The theta (θ) is defined by the angle between phase A to the d-axis.

$$\begin{pmatrix} V_d \\ V_q \\ V_o \end{pmatrix} = \begin{pmatrix} \cos(\theta) & \cos\left(\theta - \frac{2\pi}{3}\right) & 1 \\ -\sin(\theta) & -\sin\left(\theta - \frac{2\pi}{3}\right) & 1 \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \end{pmatrix} \begin{pmatrix} V_a \\ V_b \\ V_c \end{pmatrix} \quad (9)$$

## V. MATLAB MODELING AND SIMULATION RESULTS

Here simulation is performed under different cases

- Mitigation of Voltage Sag/Swell using VSI Based DVR.
- Mitigation of Voltage Sag/Swell using ZSI Based DVR (Z-Source DVR).

**Case 1:** Mitigation of Voltage Sag/Swell using VSI Based DVR.

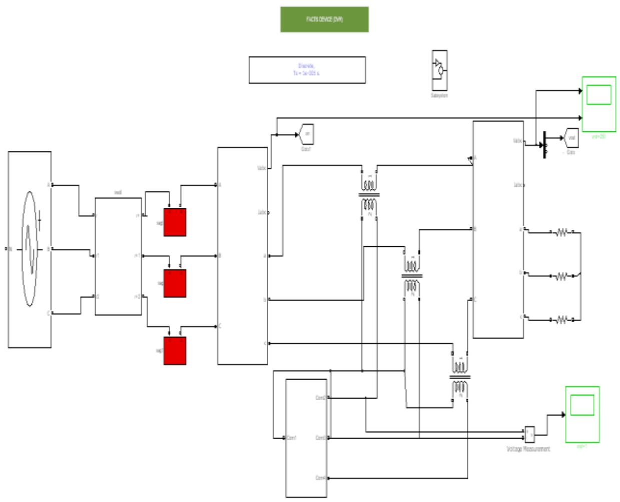

**Fig.4. MATLAB/Simulink model of three phase VSI based DVR.**

Fig.4 shows the Matlab/Simulink model of three phases VSI based DVR using Matlab/Simulink Platform.

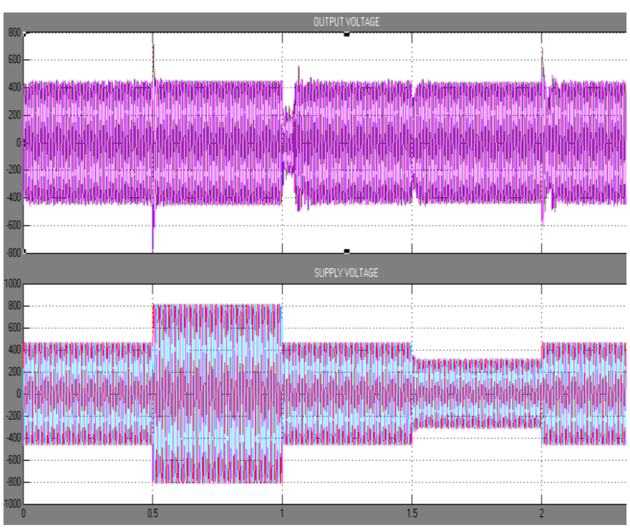


**Fig.5. Source voltage and Load voltage during Voltage Swell and Sag.**

Fig.5 shows simulation results for voltage swell and sag compensation. From the simulation result it is clear that even through there is swell and sag in the supply voltage, output voltage is almost constant.

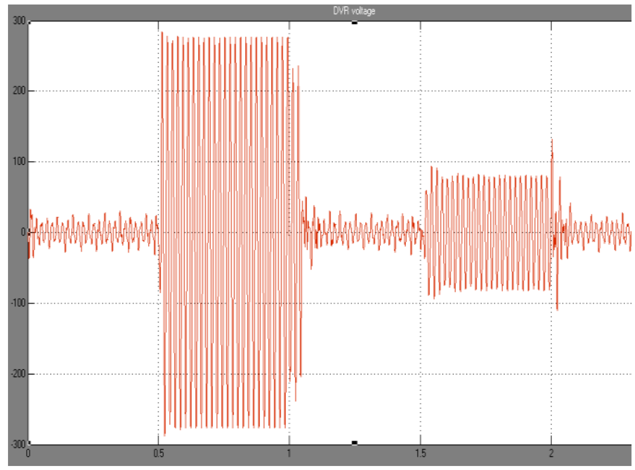


**Fig.6. Inverter output voltage during voltage swell and sag mitigation.**

Fig.6 shows the voltage source converter/inverter output voltage. It is clear that under normal condition voltage source converter/inverter output voltage is zero, but during swell voltage source converter/inverter is producing equal and opposite voltage to swell and sag.

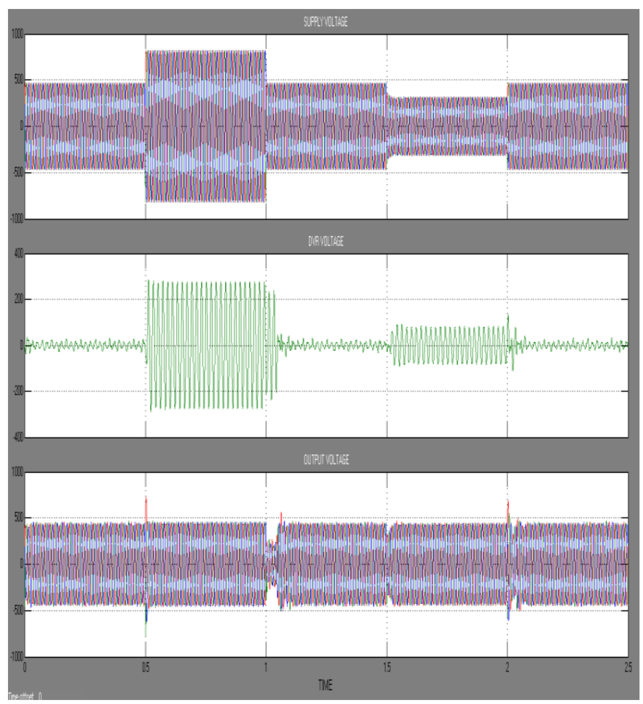


**Fig.7 Overall Compensation.**

Fig.7 shows the overall compensation of voltage swell and sag occurs in the input supply voltage that time inverter buck the voltage in the swell condition and boost the voltage in the sag condition but the output voltage maintain constant.

**Case 2:** Mitigation of Voltage Sag/Swell using PV Energy Source.

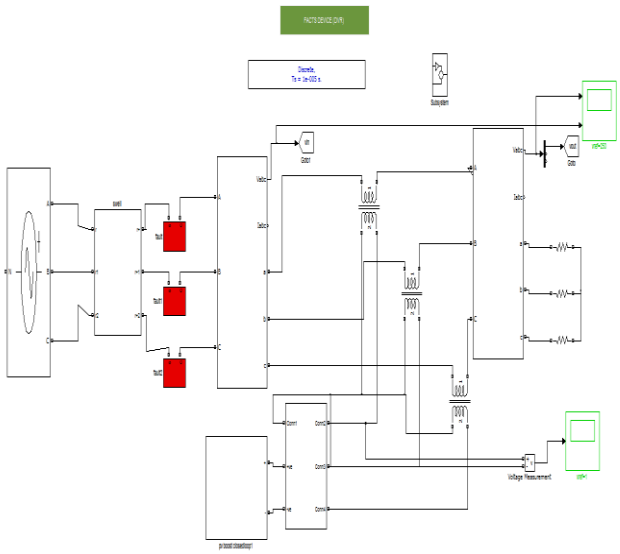

**Fig.8. MATLAB/Simulink model of three phase VSI based DVR with PV Energy Source.**

Fig.8 shows the Matlab/Simulink model of three phases VSI based DVR with PV Energy Source using Matlab/Simulink Platform.

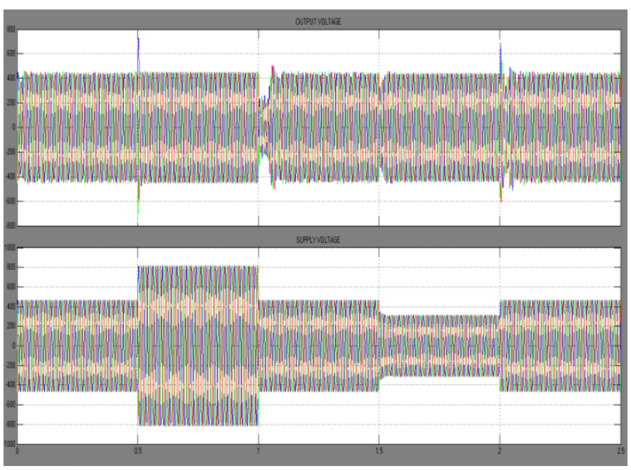

**Fig.9. Supply Voltage & Output Voltage.**

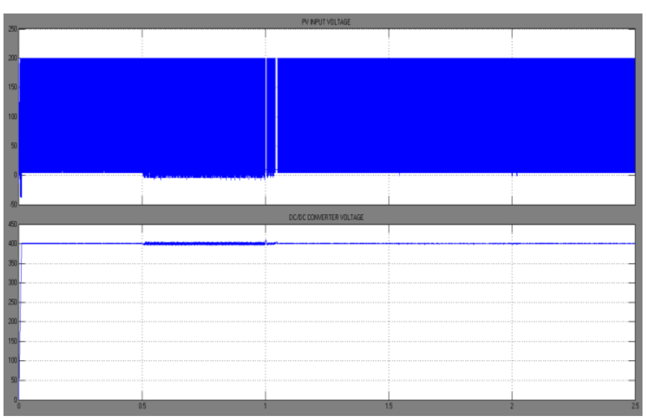

**Fig.10 PV Input & Output Voltages.**

Fig.9 shows the Supply Voltage & Output Voltage of with DVR Fed PV energy source with PI Controller, both voltage sag & swell problem compensates by using series compensator and output voltage maintains constant with low DC input voltage based on the operation of DC/DC converter.

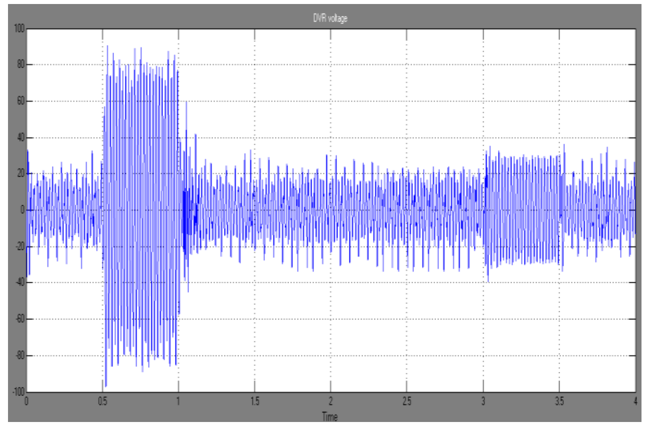

**Fig.11. DVR Injected Voltage.**

Fig.10 and 11 shows the DVR Injected Voltage of Proposed Three Phase DVR with PI Controller using PV energy source.

## VI. CONCLUSION

Energy storage technologies are essential for modern power systems. Distributed Generation is also termed as decentralized generation because the energy generated and distributed using small scale technologies closer to its end. This paper describes a better solution for power quality problems, because the power quality problems can have a straight financial impact on various industrialized customers. Many industries consist of large number of power electronics devices and energy resourceful apparatus these are more susceptible to the unbalance in the input supply voltage. Now a day these issues of power quality are very important for customer and utility also. So for this custom power device, dynamic voltage restorer as it plays an important role in mitigation of voltage sag, voltage swell, harmonics etc. by using this PV energy source to eliminate the short-circuit currents from the VSI topology and boost the DC link voltage with respect to low value of DC voltage. Simulation result show the DVR mitigates voltage sag /swell very fast and satisfactory in terms of voltage regulation too. The DVR has effectively handled injection of proper voltage component. It can also compensate long duration voltage sag/swell.

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