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COMPARATIVE ANALYSIS OF DVR AND D-STATCOM FOR VOLTAGE DIPS MITIGATION

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ABSTRACT: Nowadays, the fast developments in power electronics increases use of sensitive and nonlinear load in power system. The fast developments in power electronic technology have made it possible to mitigate voltage disturbances in power system. Power Quality problem in a system leads to various disturbances such as voltage fluctuations, transients and waveform distortions those results in a mis operation or a failure of end user equipment. In this paper design and implementation of Modulation index based Multi-level inverter based Dynamic Voltage Restorer (DVR) static synchronous compensator (DSTATCOM) has been carried out. DSTATCOM and DVR both of them based on VSI principle. A DVR is a series compensation device which injects a voltage in series with system and a DSTATCOM is a shunt compensation device which injects a current into the system to correct the power quality problems. This paper presents a power system operation with PI controller approach. Total Harmonics Distortion (THD) is also calculated for the system with and without compensation. Results are presented to assess the performance of devices as a potential custom power solution. Improve dynamic voltage control and thus increase system load ability. This paper presents modeling and simulation of DVR & DSTATCOM in MATLAB/Simulink.

I. INTRODUCTION

The Generally we can define power quality as any power problem manifested in voltage, current, or frequency deviations that results in failure or disoperation of customer equipment [1]. Presently, most of the industries use power electronics conversion and switching for manufacturing and processing. One of the major concerns in electricity industry today is power quality problems to sensitive loads. This is due to the advent of a large numbers of sophisticated electrical and electronic equipment, such as computers, programmable logic controllers, variable speed drives, and so forth. Power distribution systems, ideally, should provide their customers with an uninterrupted flow of energy at smooth sinusoidal voltage at the ideal magnitude level and frequency. Good quality of electric power is necessary for right functioning of industrial processes as well as protection to the industrial machines and its long usage

Among various power quality problem voltage sag and swell are most significant short duration variation problem. Voltage sag and swell [1] can cause sensitive equipment to fail, shutdown and create a large current unbalance.A sag is a decrease to between 0.1 and 0.9 pu in rms voltage or current at the power frequency for durations from 0.5 cycle to 1 min [2]. Faults on electrical power system like short circuit due to insulation breakdown at heavy load conditions can cause voltage sag. Voltage swell, in contrast can be defined an increase to between 1.1 and 1.8 pu in RMS voltage or current at the power frequency for durations from 0.5 cycle to 1 min [2]. Switching off of large loads, Energization of capacitor banks etc. can be considered as the common causes of voltage swell. Among various custom power devices to mitigate voltage sag and swell series connected device called DVR is commonly used.

In this paper, the performance of the DVR used for the load bus voltage control have been analysed and compared when Voltage sag & swell occur in the distribution system across the load bus. In this paper, Synchronous reference frame theory is used for generating reference voltages and Space Vector Pulse Width Modulation technique is used to generate the switching pulses for Voltage source Inverter. Simulation studies have been performed to check the results in a three-phase distribution system.

II. DYNAMIC VOLTAGE RESTORER(DVR)

DVR is a 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 critical load feeder as shown in Figure-1. Usually the connection is made via a transformer, but configurations like DVR with no storage and supply-side-connected shunt converter also exist. The resulting voltage at the load bus bar equals to the sum of the grid voltage and the injected voltage from the DVR.

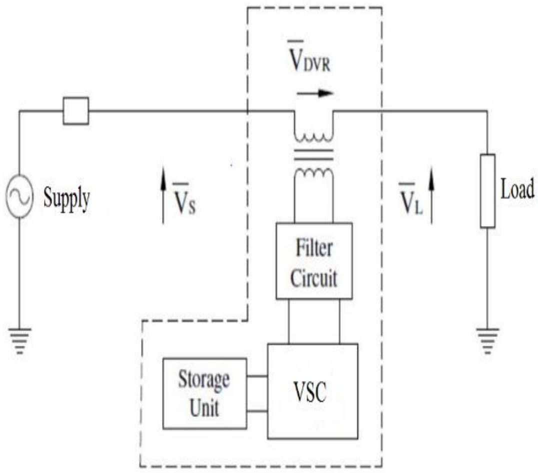

Figure 1. DVR Configuration

The converter generates the reactive power needed while the active power is taken from the energy storage. The compensation for voltage sags and Swells using a DVR can be performed by injecting/absorbing reactive power or real Power.

Fundamental Components of DVR

- Series Injection Transformer
- Voltage Source Converter (VSC)
- Filter
- Control System
- DC Energy Storage Device

Control Strategy

In Figure-2 shows the control block diagram of the DVR in which the synchronous reference frame (SRF) theory is used for the control of self-supported DVR [4]. The voltages at PCC (Vt) are converted to the rotating reference frame using the abc-dqo conversion.

The harmonics and the oscillatory components of voltages are eliminated using low pass filters.

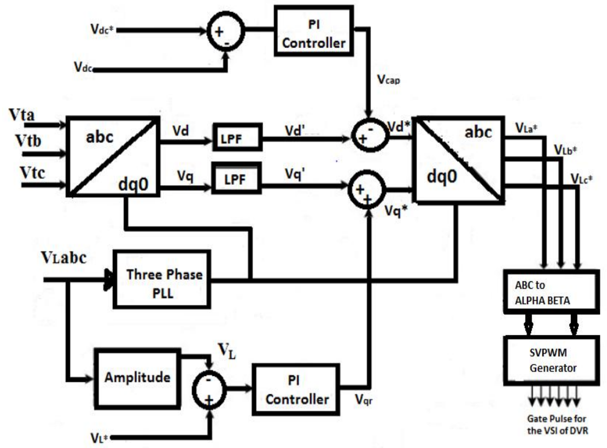

Figure-2Block Diagram of DVR control strategy with SRF theory

Three-phase reference supply voltages (VLa*,VLb*,VLc*) are derived using the sensed load voltages, terminal voltages and dc bus voltage of the DVR as feedback signals. The SRF theory based method is used to obtain the direct axis (Vd) and quadrature axis (Vq) components of the load voltage. The load voltages are converted into the d-q-0 frame using the Park's transformation [4]. The resultant voltages (Vd*, Vq*, Vo) are again converted into the reference supply Voltages using the reverse Park's transformation. Reference supply voltages (VLa*,VLb*,VLc*) are then converted into alpha beta component with the help of alpha beta conversion. Then the SVPWM generator generates required gating pulses for switches of VSI.

III. DISTRIBUTION STATCOM (D-STATCOM)

The purpose of the D-STATCOM is to cancel load harmonics fed to the supply. The coupling of D-STATCOM is three phase, in parallel to network and load as shown in figure 5.1. It work as current sources, connected in parallel with the nonlinear load, generating the harmonic currents the load requires also balance them in addition to providing reactive power. In order to compensate undesirable components of the load current DSTATCOM injects currents into the point of common coupling. With an appropriated control strategy, it is also possible to correct power factor and unbalanced loads. This principle is applicable to any type of load considered a harmonic source. Its advantage is that it of carries only the compensation current plus a small amount of active fundamental current supplied to compensate for system losses. Shunt Active Power Filter in current control mode is also called as DSTATCOM.

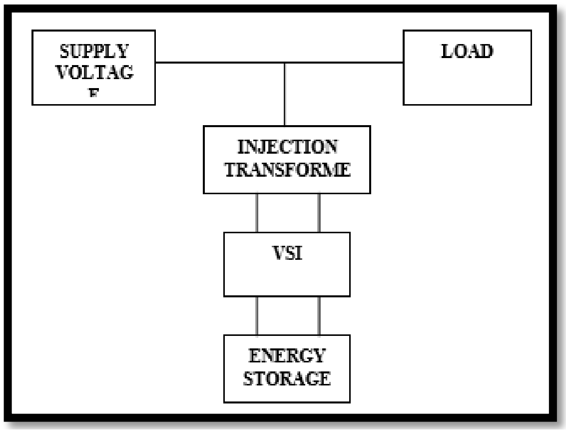

Fig 3: Distribution-STATCOM [7]

A Distribution-STATCOM consists of a two-level VSI, a dc energy storage device, a coupling transformer connected in shunt to the distribution network through a coupling transformer as shown in Figure-3. The VSI converts the dc voltage across the storage device into a set of three-phase ac output voltages. These voltages are in phase and coupled with the ac system through the reactance of the coupling transformer. Suitable adjustment of the phase and magnitude of the DSTATCOM output voltages allows effective control of active and reactive power exchanges between the DSTATCOM and the ac system. Such configuration allows the device to absorb or generate controllable active and reactive power.

The system scheme of DSTATCOM is shown in Figure 4. These are briefly described as follows:

A. Isolation transformer: It connects the DSTATCOM to the distribution network and its main purpose is to maintain isolation between the DSTATCOM circuit and the distribution network.

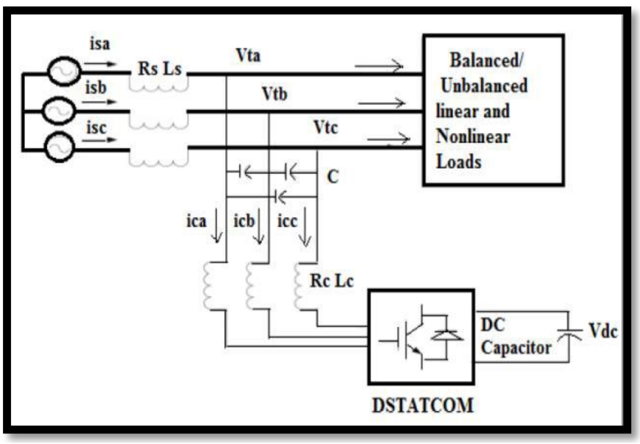

Fig-4: Schematic Diagram of DSTATCOM [1]

B. Voltage source converter:A voltage source converter consists of a storage device and devices of switching, generating a sinusoidal voltage at any required frequency, magnitude and phase angle. In the DSTATCOM application, this temporarily replaces the supply voltage or generates the part of the supply voltage which is absent and injects the compensating current into the distribution network depending upon the amount of unbalance or distortion. In this work, an IGBT is used as the switching device.

C. DC charging unit:This unit charges the energy source after a compensation event and also maintains the dc link voltage at the nominal value.

D. Harmonic filters:The main function of harmonic filter is to filter out the unwanted harmonics generated by the VSC and hence, keep the harmonic level within the permissible limit.

E. Energy storage unit: Energy storage units like flywheels, batteries, superconducting magnetic energy Storage (SMES) and super capacitors store energy. It serves as the real power requirements of the system when D-STATCOM is used for compensation [3]. In case, no energy source is connected to the DC bus, then the average power exchanged by the D-STATCOM is zero assuming the switches, reactors, and capacitors to be ideal. Figure 4 represents the schematic scheme of D-STATCOM in which the shunt injected current ISh corrects the voltage sag by adjusting the voltage drop across the system impedance ZTh and value of ISh can be controlled by altering the output voltage of the converter.

IV. SIMULATION AND RESULTS

Matlab Simulation of Voltage Sag mitigation with DVR

Now the DVR Control Strategy is also applying with the multi-level inverter for voltage sag condition mitigation in the system. The Multilevel inverter-based topology of DVR control Strategy is shown in the fig below with their simulation results: -

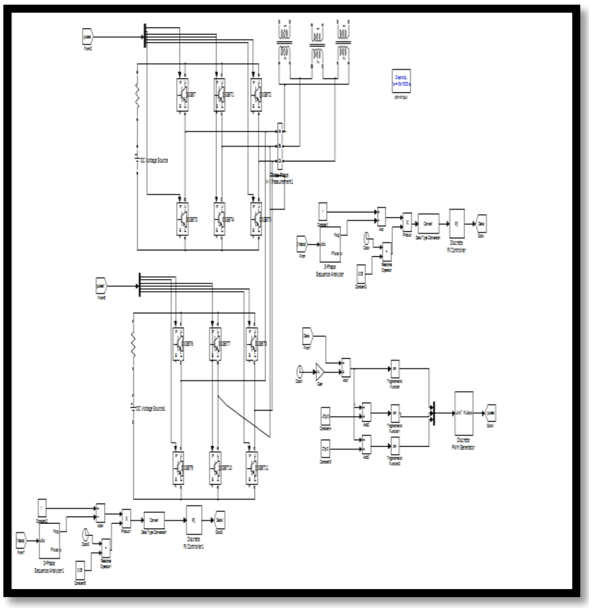

Fig.5- Multilevel Inverter based DVR MATLAB model

After the connection of multilevel inverter-based DVR in the system the voltage sag condition at input side and point of common coupling is shown in the fig below. There is also the voltage mitigation at load side using multilevel inverter is shown in the fig below:

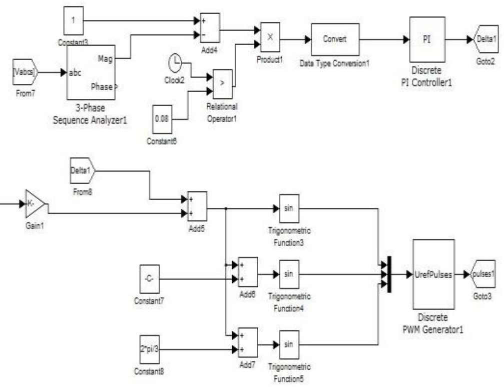

Fig 6- Matlab Simulation of DVR controlling system

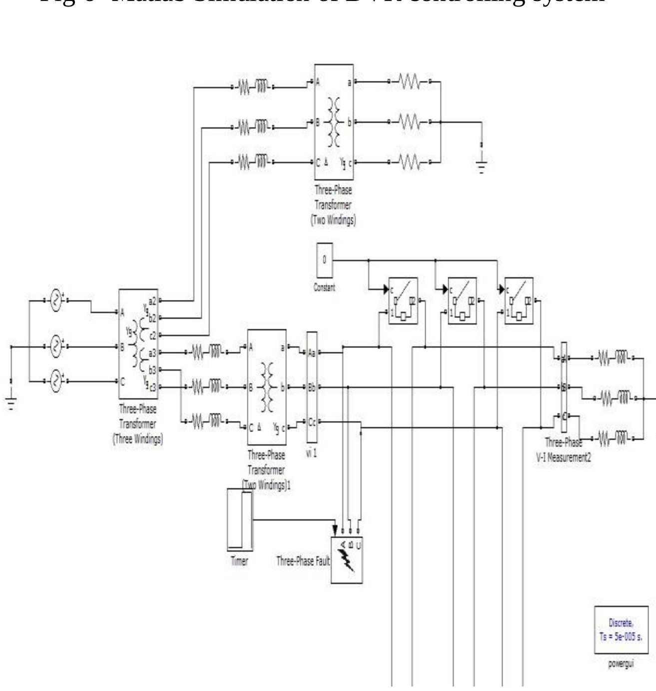

Fig 7- Main Supply System for voltage sag condition

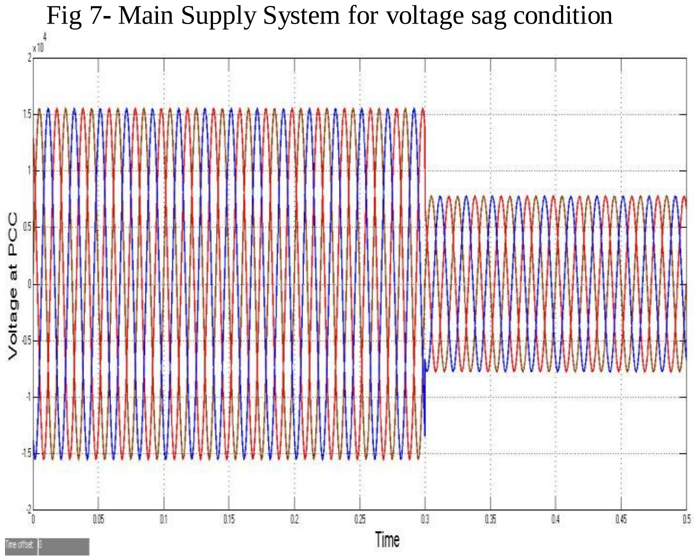

Fig 8- Voltage sag condition at PCC without DVR

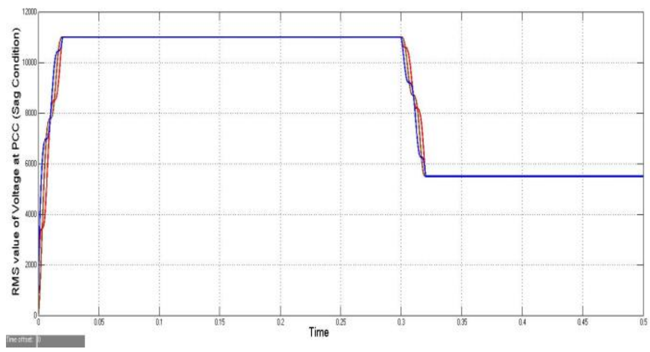

Fig 9- RMS value of voltage sag condition at PCC without DVR

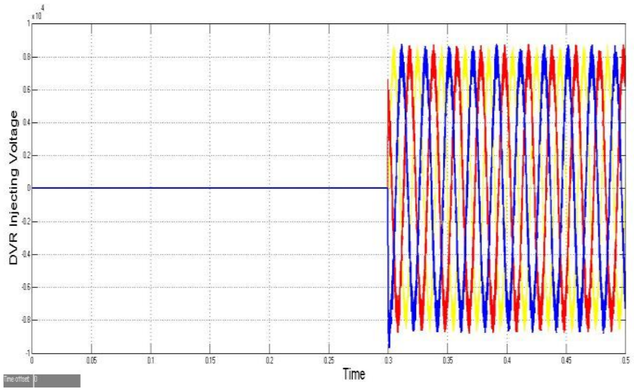

Fig 10- DVR injecting voltage for control

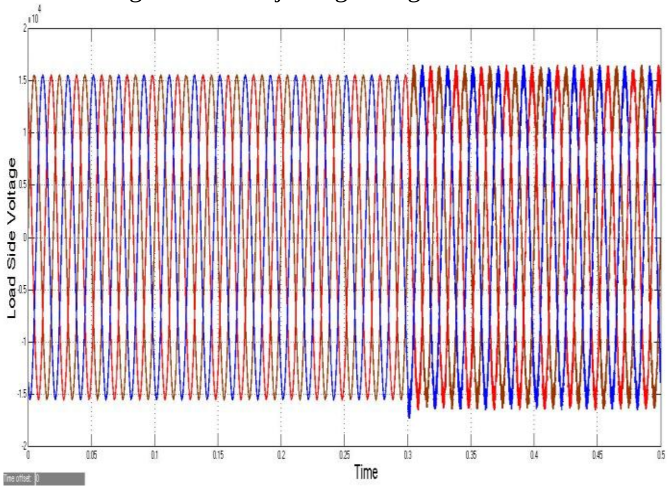

Fig 11- Load Side voltage using DVR

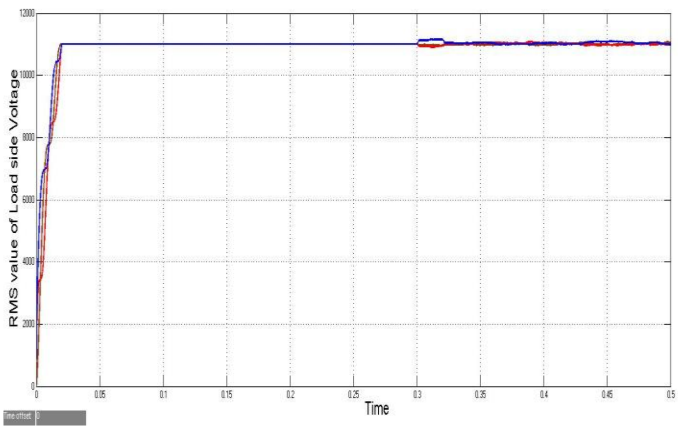

Fig 12- RMS value of Load side voltage using DVR control

Matlab Simulation of Voltage Sag mitigation with D-STATCOM

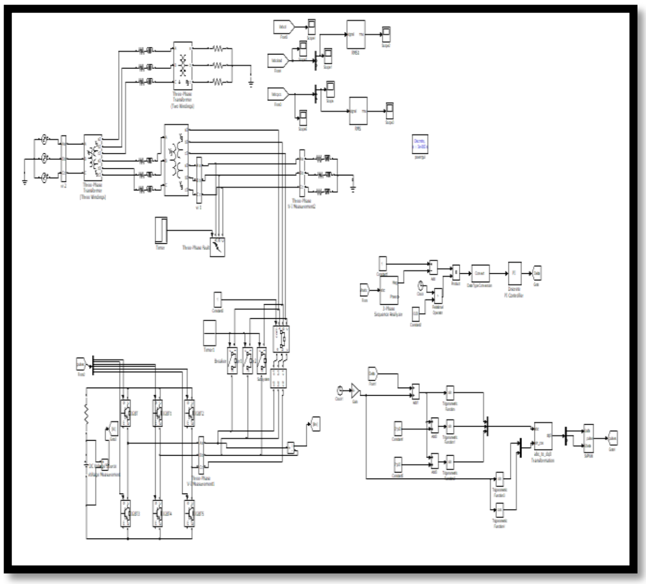

Fig 13 Matlab Simulation of voltage sag mitigation using DSTATCOM

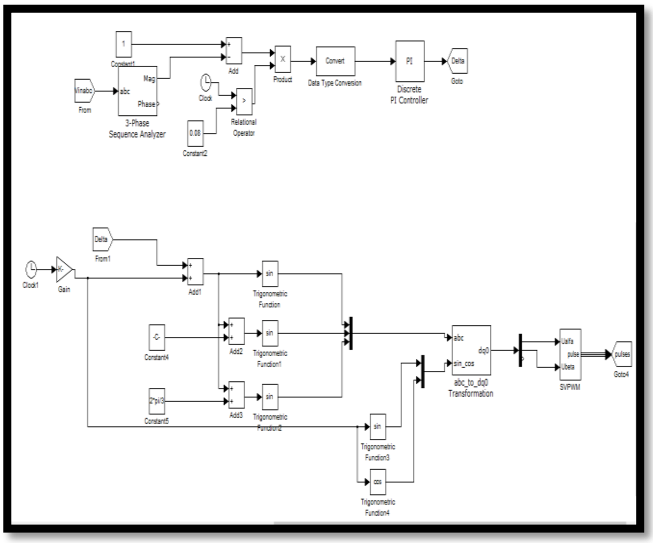

Fig 14- DSTATCOM controlling subsystem

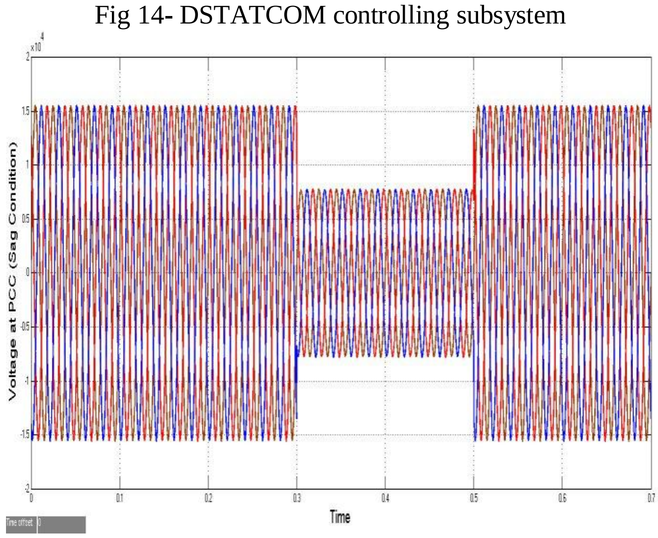

Fig 15-Voltage sag condition at PCC without D-STATCOM

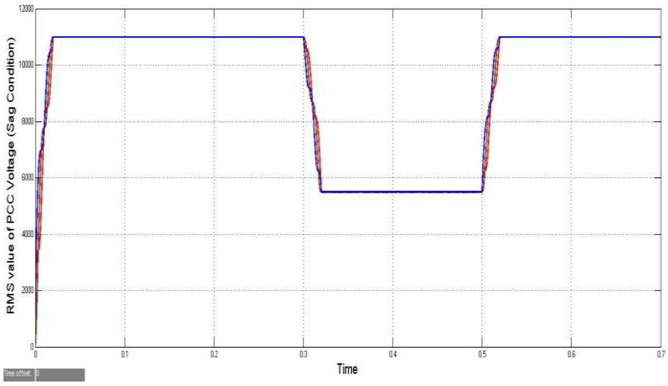

Fig 16- RMS value of Voltage sag condition at PCC without D-STATCOM

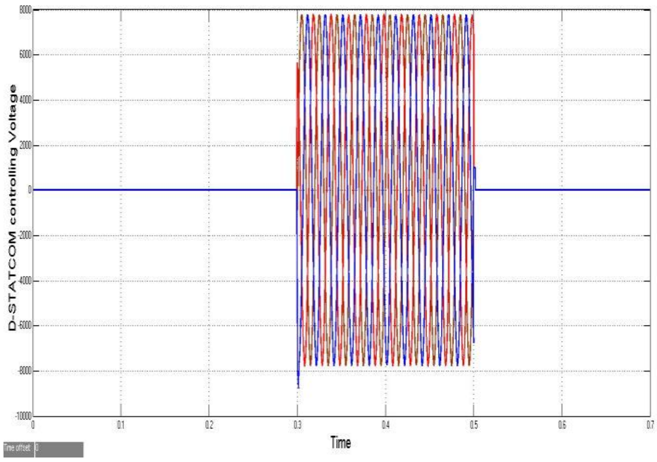

Fig 17- D-STATCOM controlling voltage

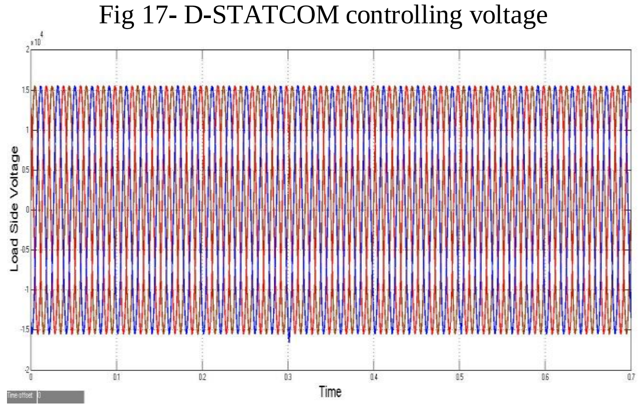

Fig 18- Load side voltage using D-STATCOM controlling

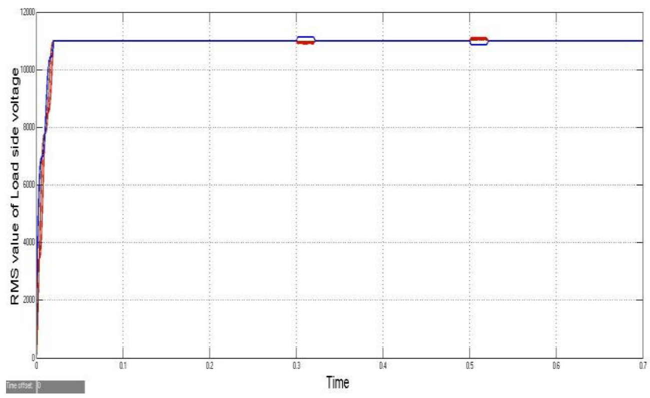

Fig 19- RMS value of Load side voltage using D-STATCOM

Matlab Simulation of Voltage Swell mitigation with DVR

Now the DVR Control Strategy is also applying with the multi-level inverter for voltage Swell condition mitigation in the system. The Multilevel inverter-based topology of DVR control Strategy is shown in the fig below with their simulation results: -

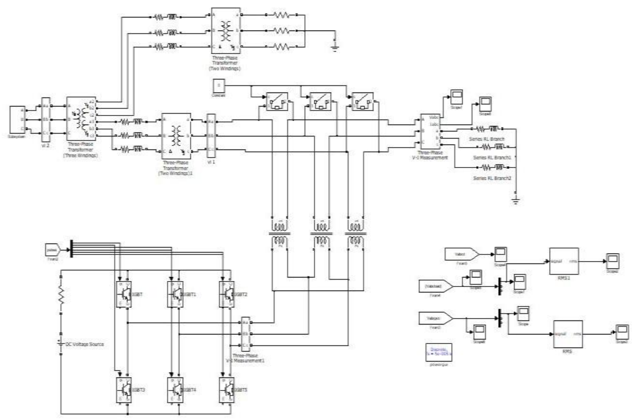

Fig 20 DVR MATLAB model for voltage swell mitigation

After the connection of multilevel inverter-based DVR in the system the voltage Swell condition at PCC occurs -input side and point of common coupling is shown in the fig below. There is also the voltage mitigation at load side using multilevel inverter is shown in the fig below:

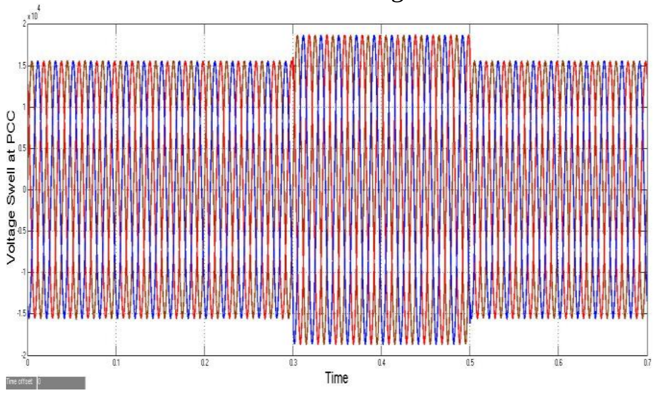

Fig 21- Voltage swell at PCC without DVR

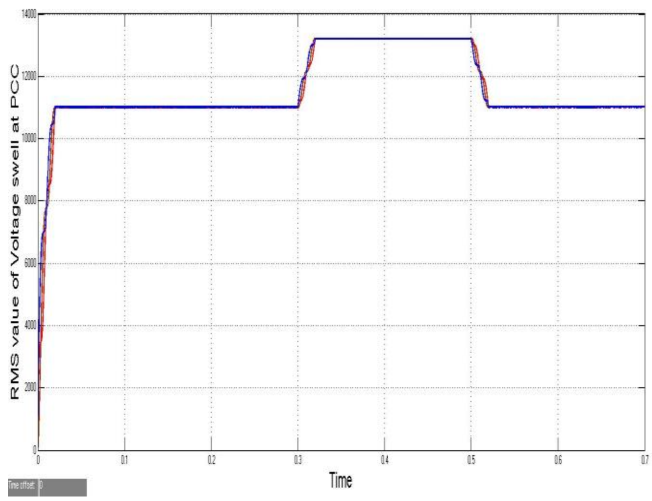

Fig 22- RMS value of voltage swell condition without DVR

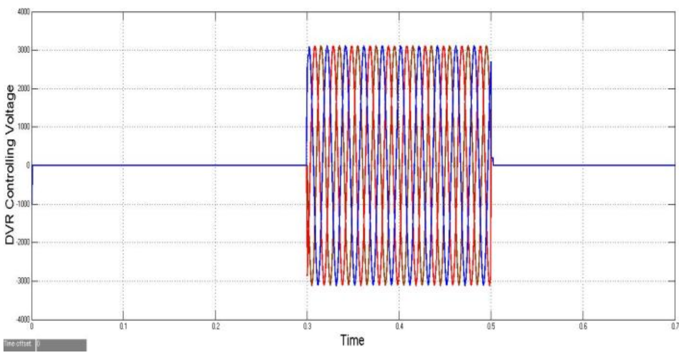

Fig 23- DVR controlling voltage

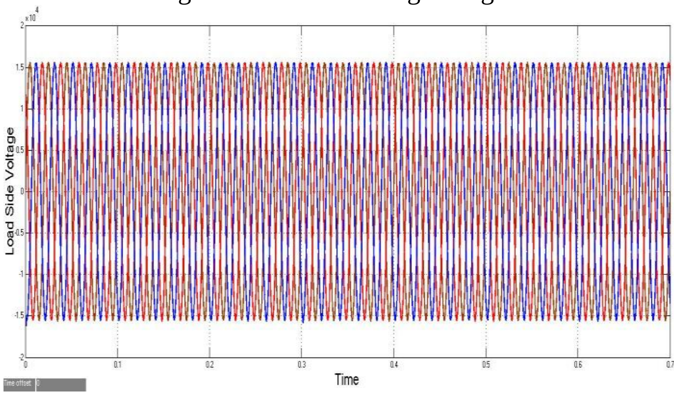

Fig 24- Load side voltage using DVR control

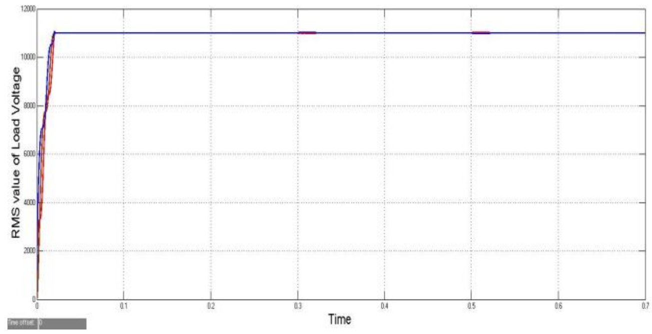

Fig 25- RMS value of load side voltage using DVR control

Voltage Swell Mitigation using D-STATCOM

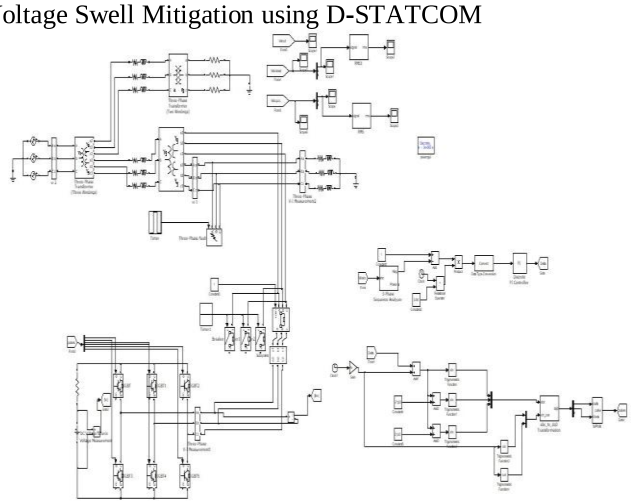

Fig 26- Three phase voltage swell mitigation system using D-STATCOM

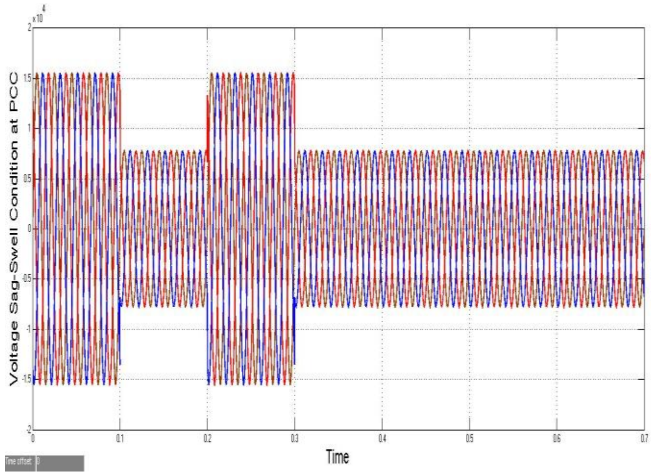

Fig 27- Voltage swell effect at PCC without D-STATCOM

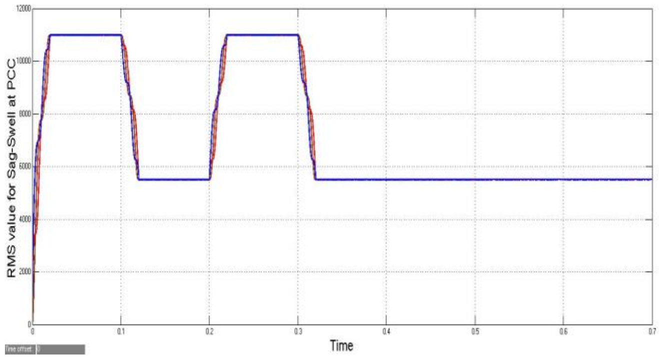

Fig.28- RMS value of Voltage swell effect at PCC without D-STATCOM

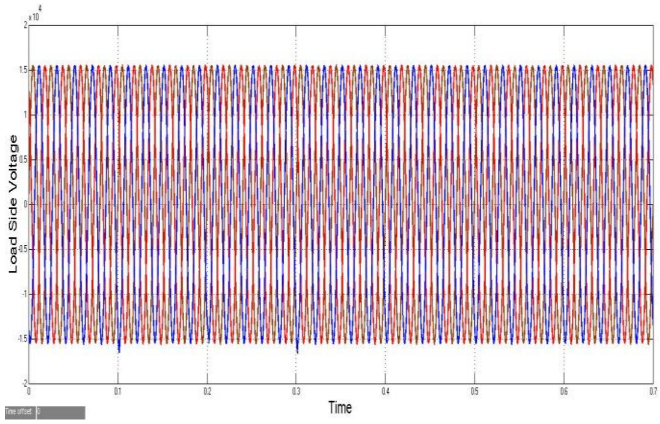

Fig 29- Load side voltage using D-STATCOM control

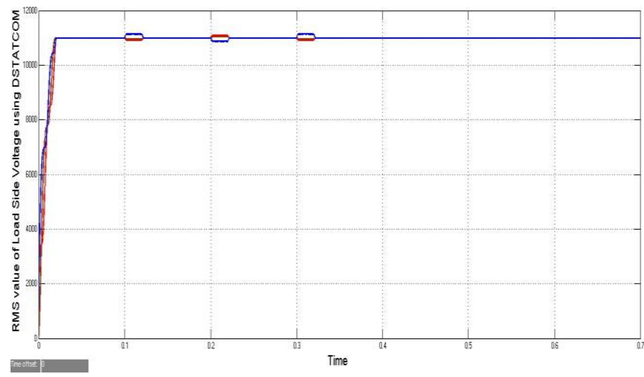

Fig 30-RMS value of Load side voltage using D-STATCOM control

THD Analysis

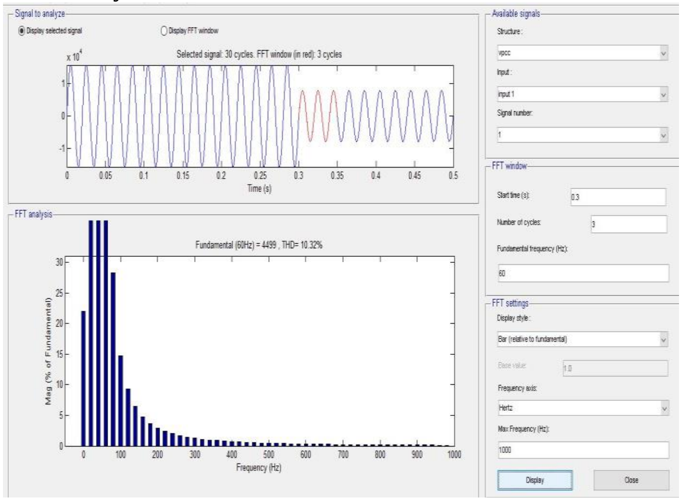

Fig 31- Voltage Sag THD %

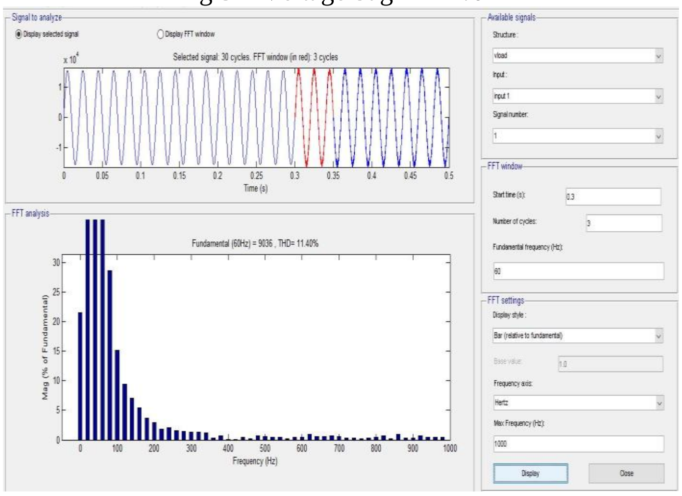

Fig 32- Load Voltage using DVR THD%

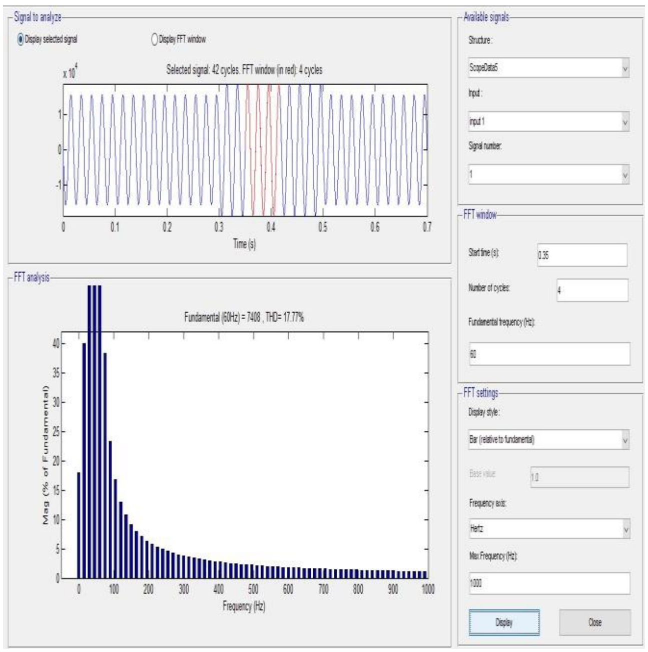

Fig 33- Voltage Swell THD %

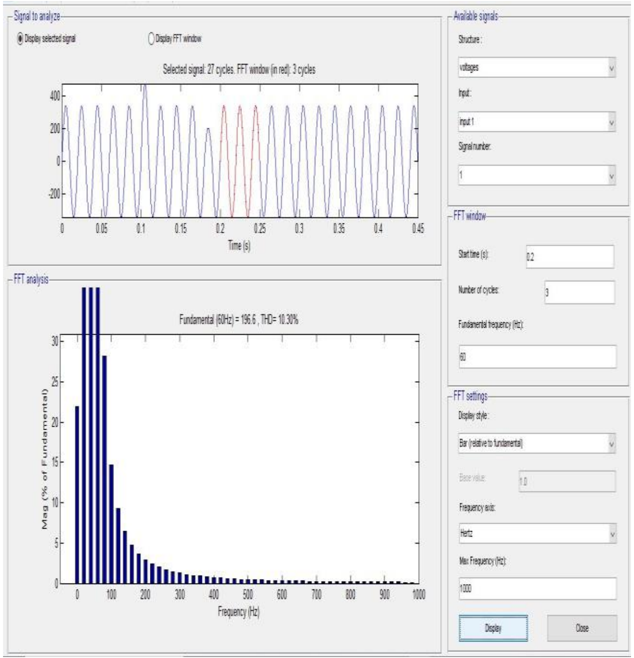

Fig 34- Load Voltage using DVR THD%

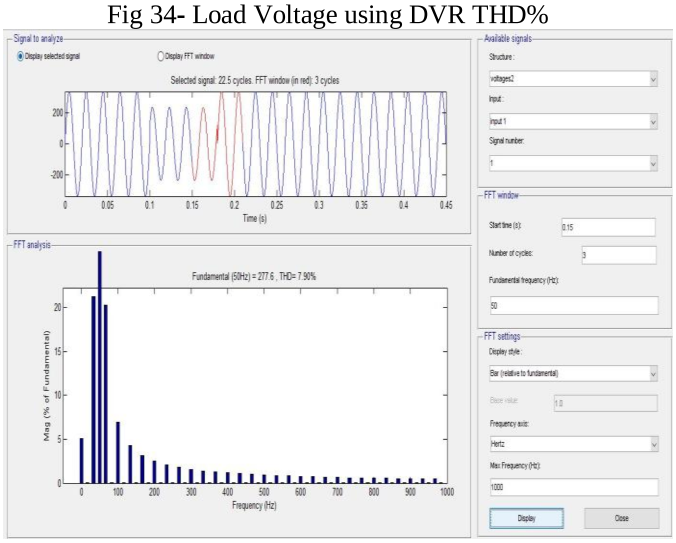

Fig 35- Voltage Sag THD % with D-STATCOM

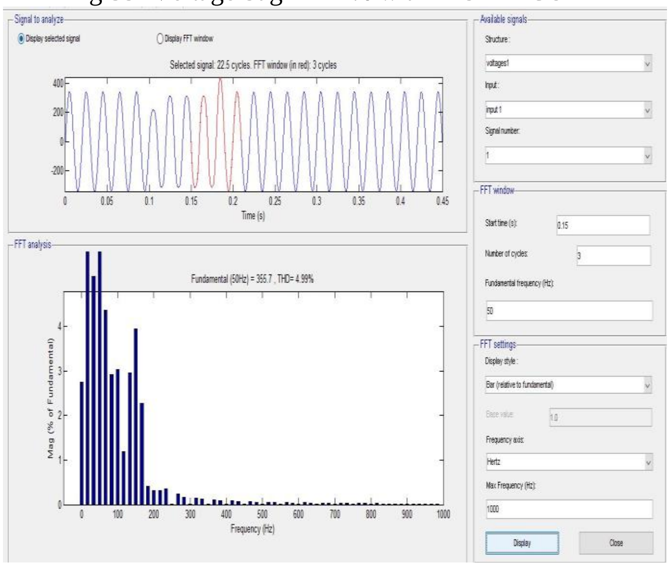

Fig 36- Load Voltage using DSTATCOM THD%

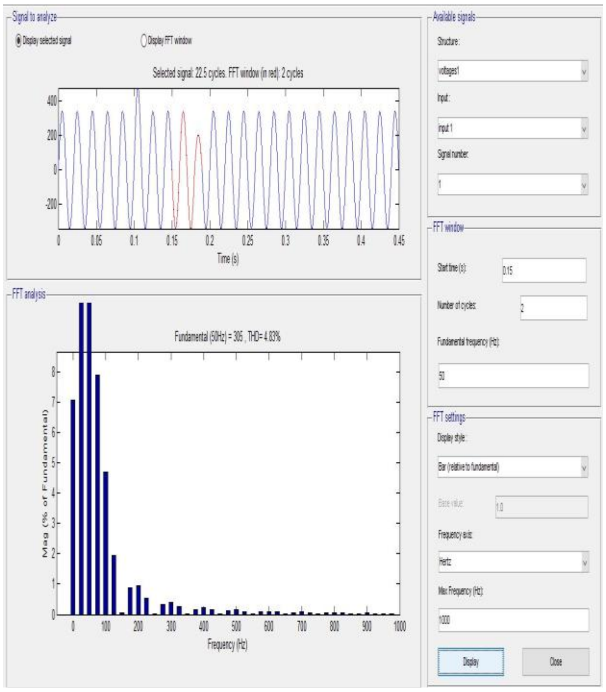

Fig 37- Voltage Swell THD % with D-STATCOM

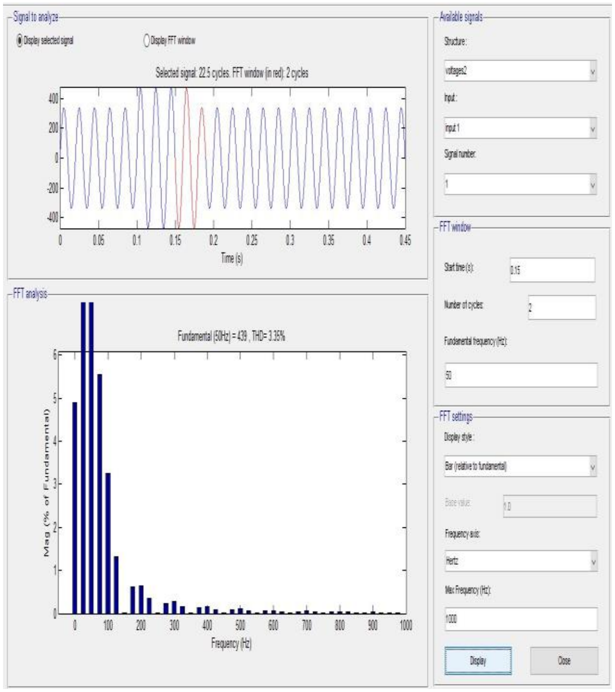

Fig 38- Load Voltage using DSTATCOM THD%

THD Comparative Analysis

Parameters	Using DVR THD %	Using D-STATCOM THD %
Voltage Sag	10.32 %	7.90 %
Load Voltage (Sag Mitigation)	11.40 %	4.99 %
Voltage Swell	17.77 %	4.83 %
Load Voltage (Swell Mitigation)	10.30 %	3.35 %

V. CONCLUSION

The modelling and simulation of DVR using MATLAB/Simulink has presented in this paper for short duration voltage variation power quality problem like sag and swell. The voltage sag & swell is analysed by implementing three phase fault and a three-phase external signal directed from the source. Simulation results in this proposed scheme is represent the voltage sag & swell mitigation using DVR effectively. The proposed MLI has control phase shifting and using PI controller had the DVR had succefully done the voltage sag and swell problem mitigation. The proposed controlling mitigates the voltage sag condition using DSTATCOM as shown in the simulation results. As a result, the modified control scheme can regulate voltage deviation using D-STATCOM. The Matlab simulation of DVR and D-STATCOM for voltage sag and swell mitigation is succefully done.

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