Enhancement of Power Quality Problem by Using Dynamic Voltage Restorer

Mr.Shinde Abhijeet G.
Electrical Engg. Department
MSS's CET Jalna
Dr. BAMU University Aurangabd.

Mr.Pramod Kumar S.
Asst. Prof. Electrical Engg.Department
MSS's CET Jalna
Dr. BAMU University Aurangabd.

Abstract— ***Dynamic voltage restorers (DVRs) are used to protect sensitive loads from the effects of voltage sags on the distribution feeder. This paper presents and verifies a novel voltage sag detection technique for use in conjunction with the main control system of a DVR. In all cases it is necessary for the DVR control system to not only detect the start and end of a voltage sag but also to determine the sag depth and any associated phase shift. The DVR, which is placed in series with a sensitive load, must be able to respond quickly to a voltage sag if end users of sensitive equipment are to experience no voltage sag. The DVR can restore the load voltage within few milliseconds. A control technique based on a proportional–integral (PI) controller and a selective controller is used. The controller is designed in a synchronously-rotating reference frame. In fact, three independent controllers have been used to tackle balanced and unbalanced voltage supplies. Simulation results using 'MATLAB SIMULINK' Sim Power System Toolbox is presented to illustrate the principle and performance of a DVR operation in load voltage compensation.***

Keywords— *Dynamic Voltage Restorer (DVR), MATLAB SIMULINK, sensitive load, voltage sags, voltage swells.*

I. INTRODUCTION

Nowadays, modern industrial devices are mostly based on electronic devices such as programmable logic controllers and electronic drives. The electronic devices are very sensitive to disturbances and become less tolerant to power quality problems such as voltage sags, swells and harmonics. Voltage dips are considered to be one of the most severe disturbances to the industrial equipments.

Voltage support at a load can be achieved by reactive power injection at the load point of common coupling. The common method for this is to install mechanically switched shunt capacitors in the primary terminal of the distribution transformer. The mechanical switching may be on a schedule, via signals from a supervisory control and data acquisition (SCADA) system, with some timing schedule, or with no switching at all. The disadvantage is that, high speed transients cannot be compensated. Some sags are not corrected within the limited time frame of mechanical switching devices. Transformer taps may be used, but tap changing under load is costly.

Another power electronic solution 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 [1].

II. POWER QUALITY PROBLEMS

Power distribution systems, ideally, should provide their customers with an uninterrupted flow of energy at smooth sinusoidal voltage at the contracted magnitude level and frequency. However, in practice, power systems, especially the distribution systems, have numerous nonlinear loads, which significantly affect the quality of power supplies. As a result of the nonlinear loads, the purity of the waveform of supplies is lost. This ends up producing many power quality problems. While power disturbances occur on all electrical systems, the sensitivity of today's sophisticated electronic devices makes them more susceptible to the quality of power supply. For some sensitive devices, a momentary disturbance can cause scrambled data, interrupted communications, a frozen mouse, system crashes and equipment failure etc. A power voltage spike can damage valuable components. Power Quality problems encompass a wide range of disturbances such as voltage sags/swells, flicker, harmonics distortion, impulse transient, and interruptions [2-3].

III. SOLUTIONS TO POWER QUALITY PROBLEMS

There are two approaches to the mitigation of power quality problems. The solution to the power quality can be done from customer side or from utility side First approach is called load conditioning, which ensures that the equipment is less sensitive to power disturbances, allowing the operation even under significant voltage distortion. The other solution is to install line conditioning systems that suppress or counteracts the power system disturbances. Dynamic Voltage Restorer is suitable device for voltage sag reduction [4].

IV. DYNAMIC VOLTAGE RESTORER

Among the power quality problems (sags, swells, harmonics…) voltage sags are the most severe disturbances. In order to overcome these problems the concept of custom power devices is introduced recently. One of those devices is

International Journal of Innovative Research in Advanced Engineering (IJIRAE) ISSN: 2349-2163
Volume 1 Issue 6 (July 2014) http://ijirae.com

the Dynamic Voltage Restorer (DVR), which is the most efficient and effective modern custom power device used in power distribution networks. DVR is a recently proposed 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 the critical load feeder at the point of common coupling (PCC). Other than voltage sags and swells compensation, DVR can also added other features like: line voltage harmonics compensation, reduction of transients in voltage and fault current limitations[5].

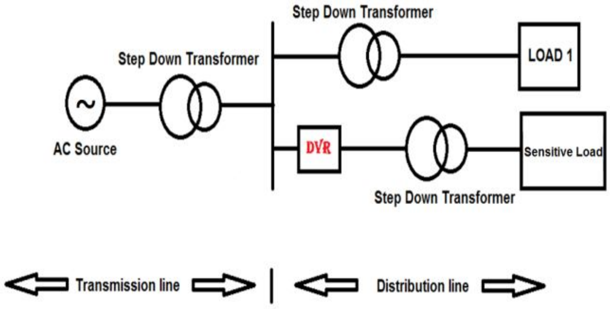

FIGURE 1: Location of DVR

A. Equations Related to DVR

The system impedance Zth depends on the fault level of the load bus. When the system voltage (VTH) drops, the DVR injects a series voltage VDVR through the injection transformer so that the desired load voltage magnitude VL can be maintained. The series injected voltage of the DVR can be written as

$$V_{DVR} = V_L + Z_{TH} I_L - V_{TH}$$

Where

V_L: The desired load voltage magnitude
Z_{TH}: The load impedance.
I_L: The load current
V_{TH}: The system voltage during fault condition

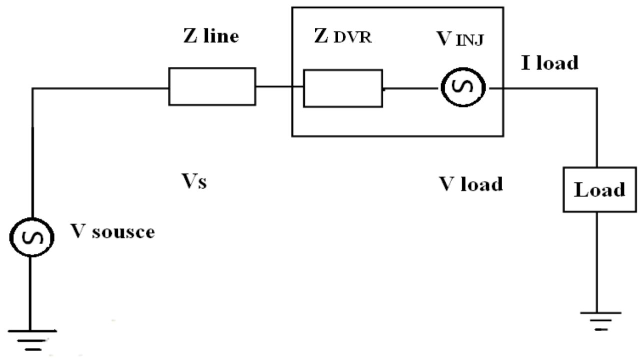

FIGURE 2: Equivalent circuit diagram of DVR

B. Operating Modes of DVR

The basic function of the DVR is to inject a dynamically controlled voltage VDVR generated by a forced commutated converter in series to the bus voltage by means of a booster transformer. The momentary amplitudes of the three injected phase voltages are controlled such as to eliminate any detrimental effects of a bus fault to the load voltage VL. This means that any differential voltages caused by transient disturbances in the ac feeder will be compensated by an equivalent voltage generated by the converter and injected on the medium voltage level through the booster transformer [6].

The DVR has three modes of operation which are: protection mode, standby mode, injection/boost mode.

1. Protection mode:

If the over current on the load side exceeds a permissible limit due to short circuit on the load or large inrush current, the DVR will be isolated from the systems by using the bypass switches (S2 and S3 will open) and supplying another path for current (S1 will be closed).

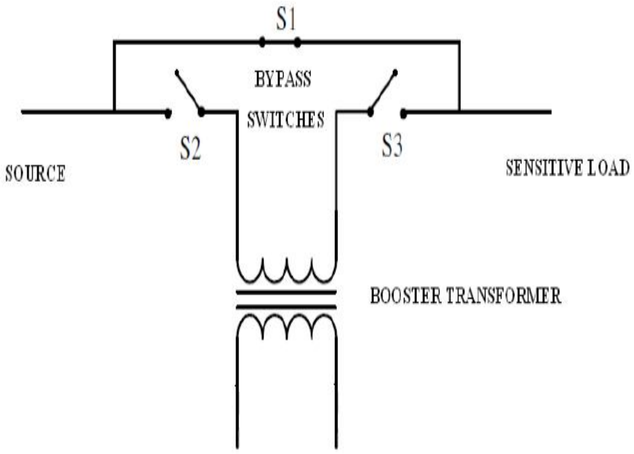

FIGURE 3: Protection Mode (creating another path for current)

2. **Standby Mode: (VDVR= 0)**

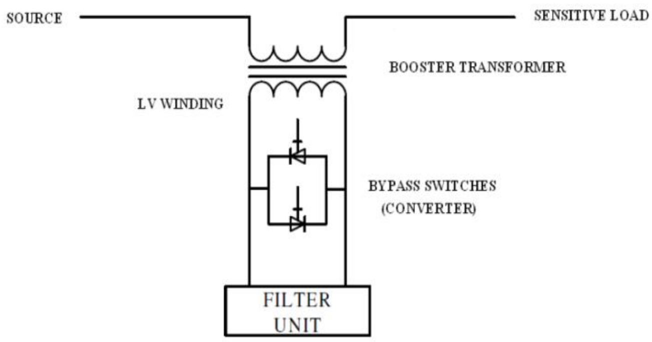

FIGURE 4: Standby Mode of DVR

In the standby mode the booster transformer's low voltage winding is shorted through the converter. No switching of semiconductors occurs in this mode of operation and the full load current will pass through the primary.

3. **Injection/Boost Mode: (VDVR>0)**

In the Injection/Boost mode the DVR is injecting a compensating voltage through the booster transformer due to the detection of a disturbance in the supply voltage.

C. Discrete PWM-Based Control Scheme

In order to mitigate the simulated voltage sags in the test system of each compensation technique, also to compensate voltage sags in practical application, a discrete PWM-based control scheme is implemented, with reference to DVR. The aim of the control scheme is to maintain a constant voltage magnitude at the sensitive load point, under the system disturbance. The control system only measures the rms voltage at load point, for example, no reactive power measurement is required. Figure 4.1 shows the DVR controller scheme implemented in MATLAB/SIMULINK. The DVR control system exerts a voltage angle control as follows: an error signal is obtained by comparing the reference voltage with the rms voltage measured at the load point[7-8]. The PI controller processes the error signal and generates the required angle δ to drive the error to zero, for example; the load rms voltage is brought back to the reference voltage.

It should be noted that, an assumption of balanced network and operating conditions are made. The modulating angle δ or delta is applied to the PWM generators in phase A, whereas the angles for phase B and C are shifted by 240° or -120° and 120° respectively[9].

$$VA = \sin(\omega t + \delta)$$
$$VB = \sin(\omega t + \delta - 2\pi/3)$$
$$VC = \sin(\omega t + \delta + 2\pi/3$$

V. SIMULATION AND RESULTS

Digital simulation is done using the blocks of Matlab simulink and the results are presented here. The first simulation was done with no DVR and no three phase fault is applied to the system. This system shows the normal operating power system without DVR and three phase fault.

Figure 5 shows the SIMULINK model for Normal Operating Power System. Figure 6 and Figure 7 shows the output waveform for figure 5. The FFT analysis for this model shows total harmonic distortion is 0%, which means the system, is in healthy condition figure 8 shows the FFT analysis for Normal Operating Power System.

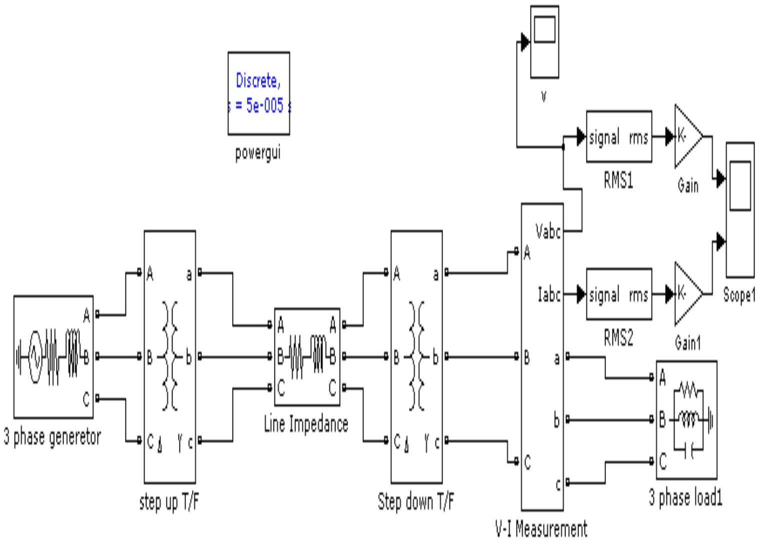

FIGURE 5: Normal Operating Power System

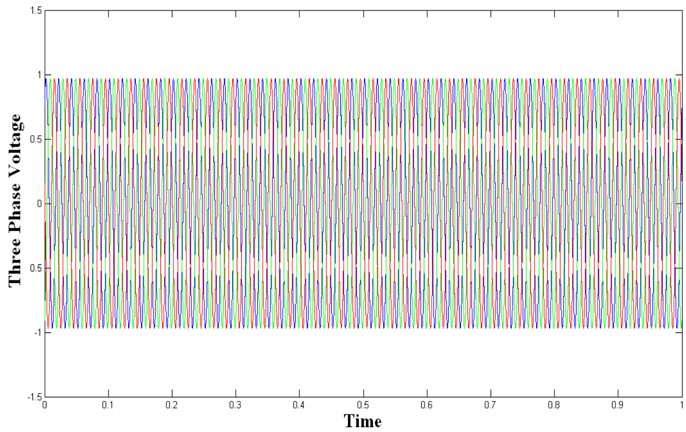

FIGURE 6: 3-Ø Voltage at Load Point, Without DVR

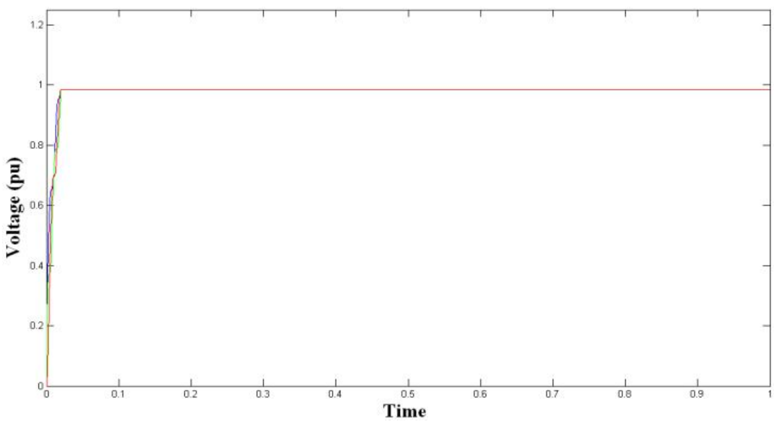

FIGURE 7: P.U Voltage at Load Point Without DVR

The second simulation was done (figure 9) with no DVR and a three phase fault is applied to the system at point with fault resistance of 0.66 U for a time duration of 200 ms. The third simulation is carried out (figure 10) at the same scenario as above but a DVR is now introduced at the load side to compensate the voltage sag occurred due to the three phase fault applied.

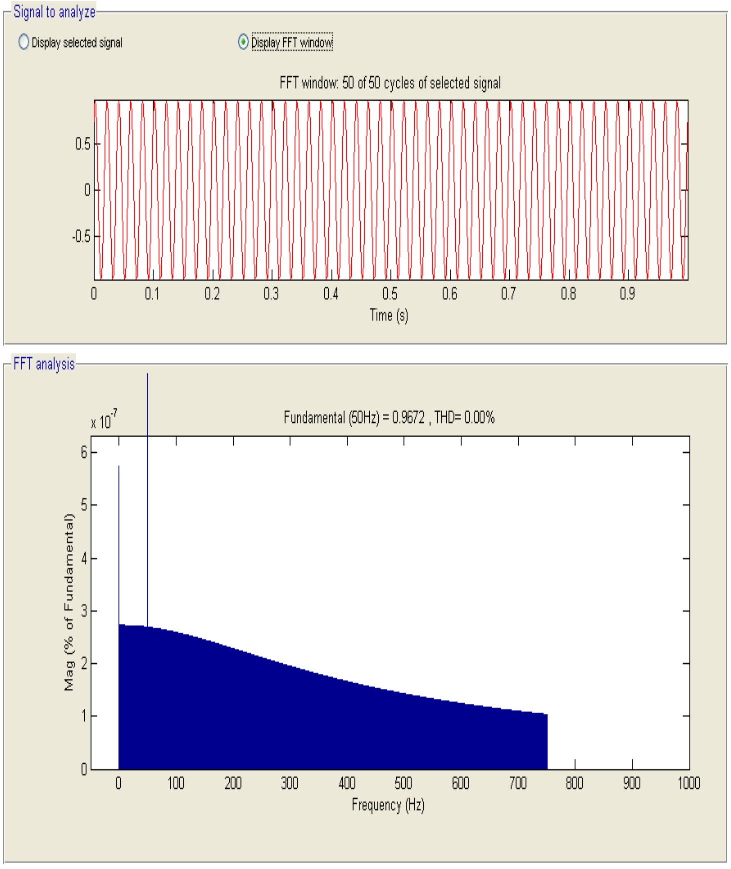

FIGURE 8: FFT Analysis for Normal Operating Power System

Figure 11 shows the pu voltage at load point when the system operates with no DVR and a three phase fault is applied to the system.

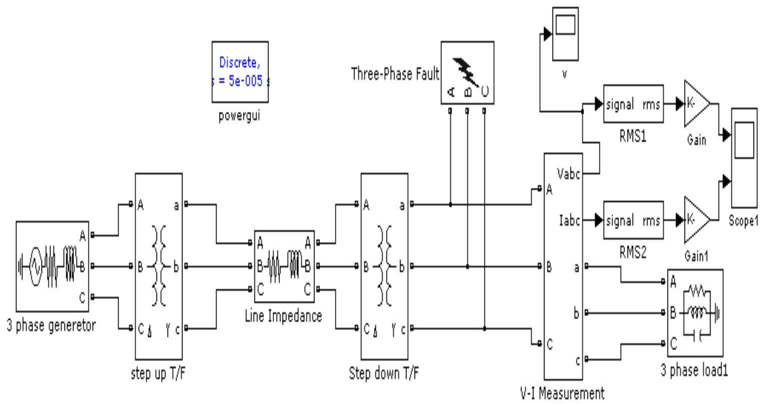

FIGURE 9: SIMULINK for Fault on Power System

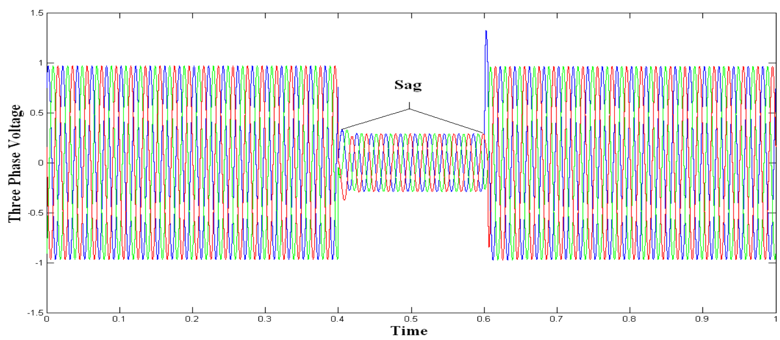

FIGURE 10:3-Ø Voltage at Load Point, with 3-Ø fault, without DVR

International Journal of Innovative Research in Advanced Engineering (IJIRAE) ISSN: 2349-2163
Volume 1 Issue 6 (July 2014) http://ijirae.com

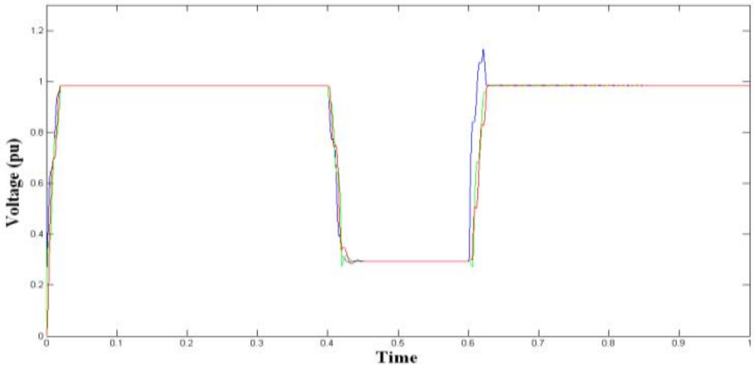

FIGURE 11: P.U Voltage at Load Point, with 3-Ø fault, without DVR

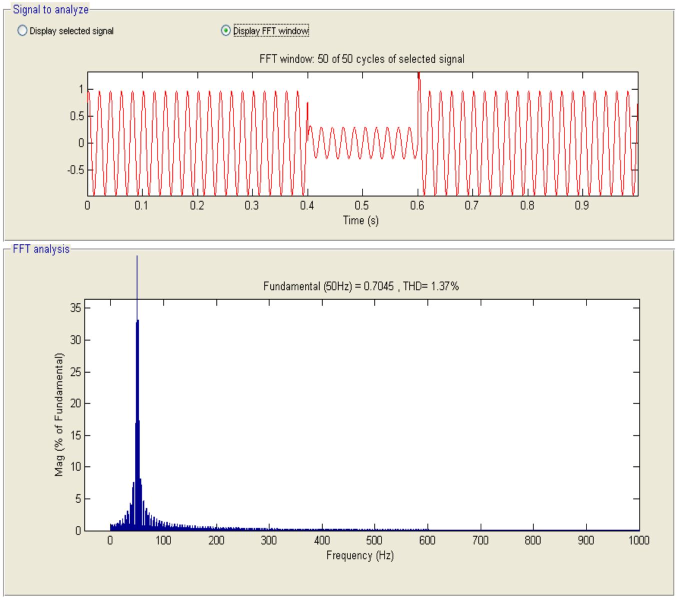

FIGURE 12: FFT analysis for fault on Power system

Figure 12 shows the FFT analysis of power system during fault.

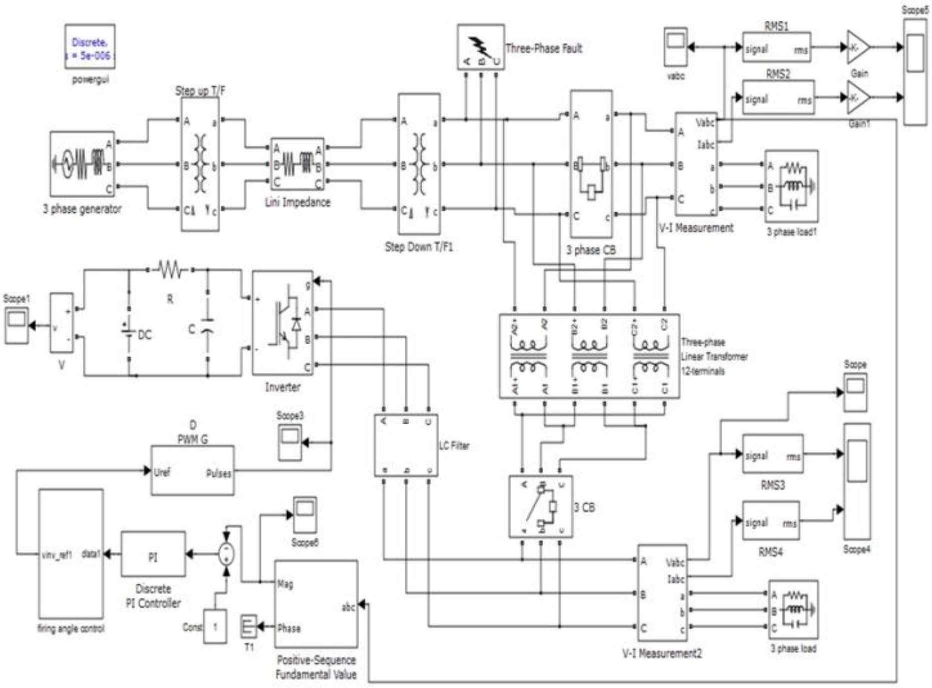

FIGURE 13: SIMULINK Model of DVR In Power System

When the DVR is in operation (Figure13) the voltage interruption is compensated almost completely and the rms voltage at the sensitive load point is maintained at normal condition. Injected voltage and the voltage across load is shown in Figure14 & Figure15. FFT analysis for the output voltage is shown in Figure16. THD reduces to 0.39%. Thus the harmonics are reduced from 1.37% to 0.39%.

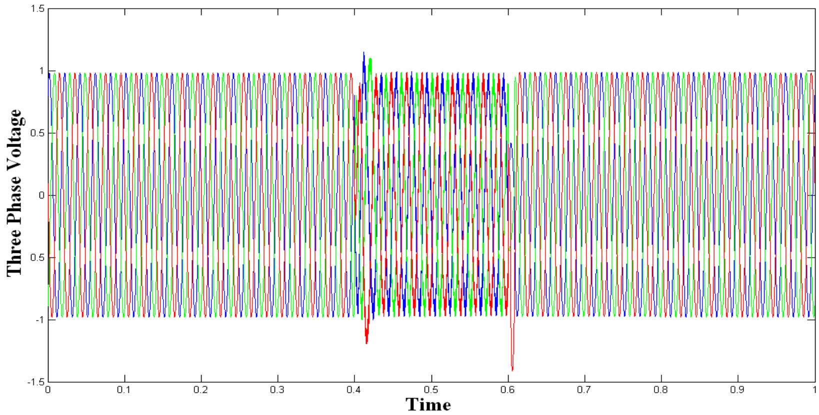

FIGURE14: 3-Ø Voltage at Load Point, with 3-Ø fault, with DVR

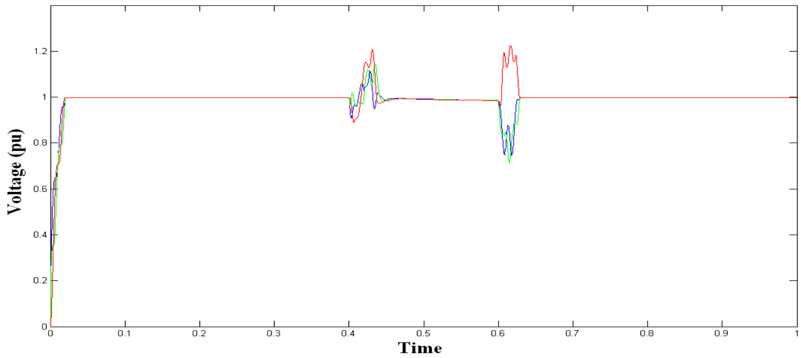

FIGURE15: P.U Voltage at Load Point, with 3-Ø fault, with DVR

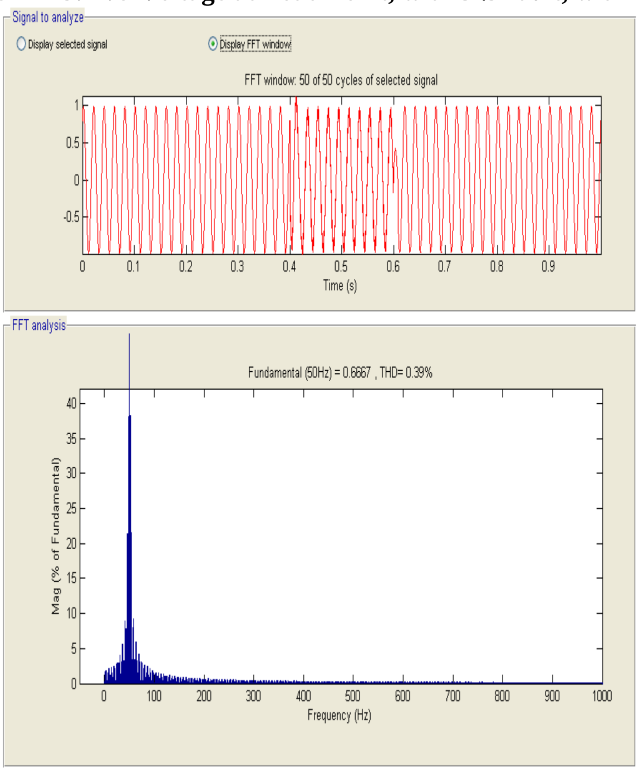

FIGURE16: FFT Analysis for Power System with DVR

V. CONCLUSION

We are presented here power quality problems such as voltage sag and harmonics. By using the custom power electronic device (DVR) we have solved the problem of voltage sag and harmonics. The design and applications of DVR for voltage sags and comprehensive results were presented. The effectiveness of a DVR system mainly depends upon the rating of DC storage rating and the loads. In the test system it is observed that after a particular amount of load increases on 11 kV feeders, the voltage levels at the load terminal decreases. The simulation shows that the DVR performance is satisfactory in mitigating voltage sags. From simulation results also show that the DVR compensates the sags/swells quickly and provides excellent voltage regulation. The DVR handles both balanced and unbalanced situations without any difficulties and injects the appropriate voltage component to correct rapidly any anomaly in the supply voltage to keep the load voltage balanced and constant at the nominal value. A PWM-based control scheme was implemented. As opposed to fundamental frequency switching schemes already available in the MATLAB/ SIMULINK, this PWM control scheme only requires voltage measurements. This characteristic makes it ideally suitable for low-voltage custom power applications.

Acknowledgment

I Mr. Shinde Abhijeet acknowledges that the above study achieved by myself with the aid of MATLAB/SIMULINK. All the simulation results are performed by the mentioned software.

REFERENCES

[1] A. Kara, P. Dahler, D. Amhof, and H. Gruning, Power supply quality improvement with a dynamic voltage restorer (DVR), in Proc. IEEE APEC'98, vol. 2, Feb. 15–19, 1998, pp. 986–993.

[2] M. H. J. Bollen, Understanding Power Quality Problems: Voltage Sags and Interruptions. New York: IEEE Press, 1999.

[3] M. F. McGranaghan, D. R. Mueller, and M. J. Samotyj, Voltage sags in industrial systems, IEEE Trans. Ind. Applicat., vol. 29, pp. 397– 403, Mar./Apr. 1993.

[4] Chris Fitzer, Mike Barnes, Voltage Sag Detection Technique for a Dynamic Voltage Restorer, IEEE Transactions on Industry Applications, vol. 40, no. 1, pp.203 January/February 2004.

[5] N.G. Hingorani, Introducing Custom Power in IEEE Spectrum, 32p, pp. 4l-48, 1995. IEEE Std. 1159 – 1995, Recommended Practice for Monitoring Electric Power Quality.

[6] P. Boonchiam and N. Mithulananthan, Understanding of Dynamic Voltage Restorers through MATLAB Simulation, Thammasat Int. J. Sc. Tech., Vol. 11, No. 3, July-Sept 2006.

[7] R. Buxton, Protection from voltage dips with the dynamic voltage restorer, in IEE Half Day Colloquium on Dynamic Voltage Restorers – Replacing Those Missing Cycles, 1998, pp. 3/1- 3/6.

[8] C. Zhan, V. K. Ramachandaramurthy, A. Arulampalam, C. Fitzer, S. Kromlidis, M. Barnes, and N. Jenkins, Dynamic voltage restorer Based on voltage space vector PWM control, IEEE Trans. Ind. Applicat., vol. 37, pp. 1855–1863, Nov./Dec. 2001.

[9] R. Buxton, Protection from voltage dips with the dynamic voltage restorer, in Dynamic Voltage Restorers—Replacing Those Missing Cycles, IEE Half Day Colloq., Feb. 11, 1998, pp. 3/1–3/6.

