POWER QUALITY IMPROVEMENT USING DVR (DYNAMIC VOLTAGE RESTORER) UNDER VARIOUS FAULT CONDITIONS

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Abstract - *Power quality improvement has become a very serious concern in present days due to increase in modern sensitive and sophisticated loads connected to the Distribution System. Because non-standard voltage, current or frequency causes a failure of the loads connected to the system. Power electronics and advanced control technologies have made it possible to improve the quality of power and operate the sensitive loads satisfactorily. One of the major problems dealt in this paper is the voltage quality which is very severe for the industrial customers as it can cause mal-functioning of several sensitive electronic equipment. Dynamic Voltage Restorer (DVR) is a solution to improve voltage quality, which is connected in series with the network. This paper presents modeling, analysis, and simulation of DVR in MATLAB/SIMULINK, which includes PI controller and discrete PWM generator for control purpose of DVR. Simulation results of performance of DVR under different fault conditions such as single line to ground fault, double line to ground fault, double line fault, three phase fault etc. are presented in this paper. The results exhibit clearly the performance of the DVR in voltage quality improvement.*

KEY WORDS: DVR, POWER QUALITY, FACTS, PI CONTROLLER, PWM

1. INTRODUCTION:

Electric Power Utilities and end users of electric power are becoming increasingly more serious about the electric power quality. The term “Power Quality” has become most popular word in the power industry since the late 1980s. There are following reasons for the increased concern towards power quality. Newer generation load equipment, with microprocessor-based controls and power electronic devices, is more sensitive to power quality variations than was the equipment used before the late 1980s. Increasing emphasis on overall power system efficiency has resulted in continuous growth in the application of devices such as high-efficiency, adjustable-speed motor drives and shunt capacitors for The purpose of power factor improvement so that losses can be reduced. This is resulting in increasing harmonic levels on power systems and has many people concerned about the future impact on the system capabilities. End users have an increased awareness of power quality issues. Utility customers are becoming better informed about such issues as interruptions, sags and switching transients and are challenging the utilities to improve the quality of power delivered. Many devices are now interconnected in a network. Integrated processes mean that the failure of any component has much more important consequences. Load equipment. Interestingly, the equipment installed to increase the productivity is also often the equipment that suffers the most from common power disruptions and the equipment is sometimes the source of additional power quality problems. When entire processes are automated, the efficient operation of machines and their controls becomes increasingly dependent on quality of the power. Power quality can be defined as those properties of the power supply which allows the electrical apparatus to function properly. But in actual sense power quality is ultimately a customer driven issue, and the end user’s point of reference takes preference [1]. So any power problems manifested in voltage, current, or frequency deviations that result in failure or mal-operation of the customer equipment can be categorized into power quality problem. To deliver clean and pure power ie. pure sinusoidal voltage waveform, FACTS (Flexible Alternating Current Transmission System) devices are used. There are many FACTS devices which are being used in the modern electrical network, some of them are Static Synchronous Compensator(STATCOM), Static Synchronous Series Compensator(SSSC), Interline Power Flow Controller (IPFC), Unified Power Flow Controller(UPFC), etc. . In actual practice FACTS devices were designed for the transmission system and these are modified to be used in distribution system and named as “Custom Power Devices”. Some of the widely used custom power devices are Distribution Static Synchronous Compensator (DSTATCOM), Dynamic Voltage Restorer (DVR), Active Filter (AF), Unified Power Quality Conditioner (UPQC). With the help of these devices the quality problems are reduced to great extents. DVR is one of the most efficient and effective custom power devices due to its fast response lower cost and smaller size [2]. There are many power quality problems in distribution system such as sag, swell, harmonics, transients etc., but voltage sag is the most severe disturbance which is generally caused by the faults. Voltage Sag and swell can be instantaneous, momentary or temporary. If voltage sag occurs for 0.5 to 30 cycles and voltage magnitude remains between 0.10 to 0.9 pu then it comes under the category of instantaneous voltage sag. If it occurs for 30cycles to 3 seconds and voltage magnitude remains between 0.10to 0.9 pu known as momentary voltage sag and in the temporary voltage sag it occurs for 3 seconds to 1 minute & voltage magnitude remains in between 0.10to 0.9 pu. Similarly voltage swell are also of three types: Instantaneous, Momentary and Temporary. If voltage swell exists for 0.5 to 30 cycles and its magnitude lies in between 1.1 to 1.8 pu, it is a case of instantaneous voltage swell. In momentary, it occurs for 30 cycles to 3 seconds and magnitude remains in between 1.1 to 1.4pu. In temporary voltage swell, it lasts for 3 seconds to 1 minute and its magnitude remains in between 1.1 pu to 1.2 pu. In order to mitigate voltage sag and swell in distribution system DVR is one of the efficient and effective custom power devices[9]. DVR is connected in series with the line and injects or absorbs voltage in order to compensate the voltage sag or swell in the load side and remains the flat voltage profile at the load end.

2. CONFIGURATION AND WORKING PRINCIPLE OF DVR:

Dynamic Voltage Restorer is a power electronic switching device which major parts are: Storage Unit, DC link, Filter Circuit, Control Unit, Series Injection Transformer and Voltage Source Inverter as shown in the fig.1. DVR is connected in series with the line between the supply and load as shown in the fig 1.

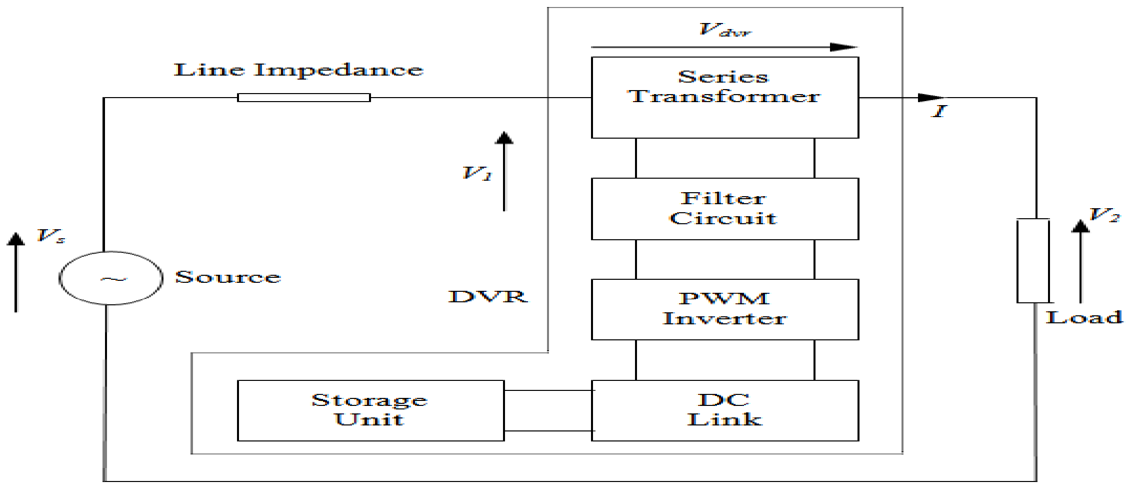

Fig. (1) A Simplified Block Diagram of Dynamic Voltage Restorer (DVR)

The main function of the DVR is to boost up the voltage at the load side so that equipment connected at the load end is free from any power disruption. In addition to voltage sag compensation DVR also carry out other functions such as line voltage harmonic compensation, reduction of transient voltage and fault current. The various building blocks of DVR circuit are described below.

Storage Unit: The function of the storage unit is to supply the necessary energy to the voltage Source Inverter which will be converted to alternating quantity and fed to the series injection transformer. Batteries of suitable ratings are commonly used as storage unit. The capacity of the battery is determined by the amount of the voltage which should be compensated by the DVR.

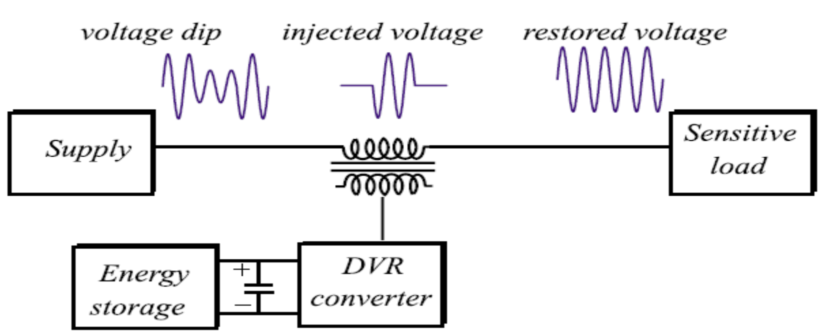

Fig2. Operating Principle of DVR

Voltage Source Inverter (VSI): A VSI is a power electronic device consisting of switching device and a storage unit such as a battery. VSI is used to generate three phase voltage of any required magnitude, phase and frequency to compensate the load voltage of the required value. MOSFET is suitable as a high frequency switching device but its improved version is now available as IGBT which is used to design VSI for DVR operation.

Series Injection Transformer: It is used to couple the VSI to the distribution line. The high voltage side normally connected in series with the distribution network while the power circuit of the DVR is connected to the low voltage side [3]. The DVR inject the voltage which is required for the compensation from DC side of the inverter to the distribution network through the series injection transformer. In this paper three single phase transformers are connected instead of a single three phase injection transformer and each transformer is connected in series with each phase of the distribution line to couple the VSI (at voltage level) to the higher distribution level. The transformer also helps in isolating the line from the DVR system.

Control unit: A controller is used for proper operation of DVR, which detect the presence of voltage disturbance and operate VSI to mitigate the voltage sag/swell. Pulse Width Modulation (PWM) control technique is applied for inverter switching so as to generate a three phase sinusoidal voltage. The magnitude of load voltage is compared with reference voltage and if any difference is there error signal will be generated, which is an actuating signal. This error signal drives the PI controller and the final output signal which is obtained controls the pulse for inverter. PI controller is a feedback controller which controls the system depending on the error signal. In PI controller technique the proportional response can be obtained by multiplying the error with constant Kp (proportional gain) and the integral response is proportional to both the magnitude of error and duration (Fig3) [4] [5].

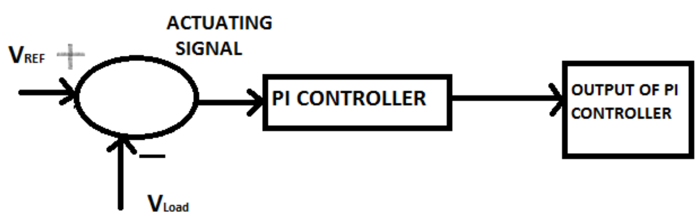

Fig3. Operation of PI controller

3. SIMULATION & RESULT OF DYNAMIC VOLTAGE RESTORER:

In order to show the performance of the DVR in voltage sags and swells mitigation, a simple distribution network was simulated using MATLAB R2014a (Fig.4). A DVR was connected to the system through a series transformer with a capability to insert a maximum of 50% of the phase to ground system nominal voltage [6],[7]. In this simulation in-phase compensation method is used ie. voltage required to mitigate the sag in voltage will be in phase with the load voltage. The components required for constructing DVR test Model is shown in Fig(a) and Table-1.

Table 1 : System Parametrs

Sr. No.	Parametrs	Standards
1	Source	3 phase, 13kv, 50 Hz
2	Inverter Parametrs	IGBT based, 3arms,6 pulse, carrier frequency=1080Hz, Sample time=50 μs, Vdc= 5KV Amplitude, Rs=10Ω, Cs=750μF
3	PI controller	Kp=20, Ki=154, Sample Time=150μs
4	RL Load	R=0.1ohm, L=0.1926H
5	Two Winding Transformer	250MVA, 50Hz, 11KV/9KV

Fault Analysis: A case of various faults was simulated. The simulation diagram is shown in fig.(4a).

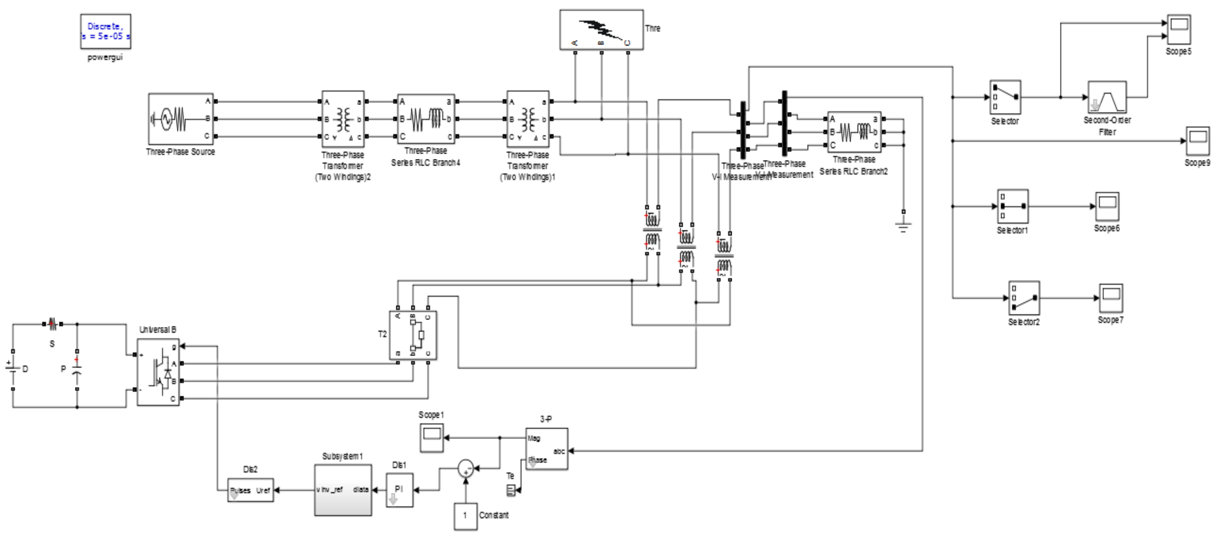

Fig.4(a) : A Simulation model of DYNAMIC VOLTAGE RESTORER for voltage sag/swell mitigation

As shown in the simulation diagram a PI controller is used for controlling the IGBT based universal bridge[8]. The output of the PI controller is given to discrete PWM generator(mask) in order to send the controlling pulses to the DVR. A three phase fault has created between the instant 0.4 sec to 0.6 sec using external fault block as shown in the Simulink model. The three-phase voltage during the fault is shown in the fig.(4b). It can be obserbed from the figure that during the three phase fault the line voltage was reduced below 0.4 pu. After the operation of the DVR the load voltage were recovered to its nominal value till the fault cleared. Thus it is quite sure that dynamic voltage restorer is suitable for voltage sag mitigation during the fault on the distribution line. The similar result is also true for the other type of faults like single phase to ground fault, double line to ground fault etc.

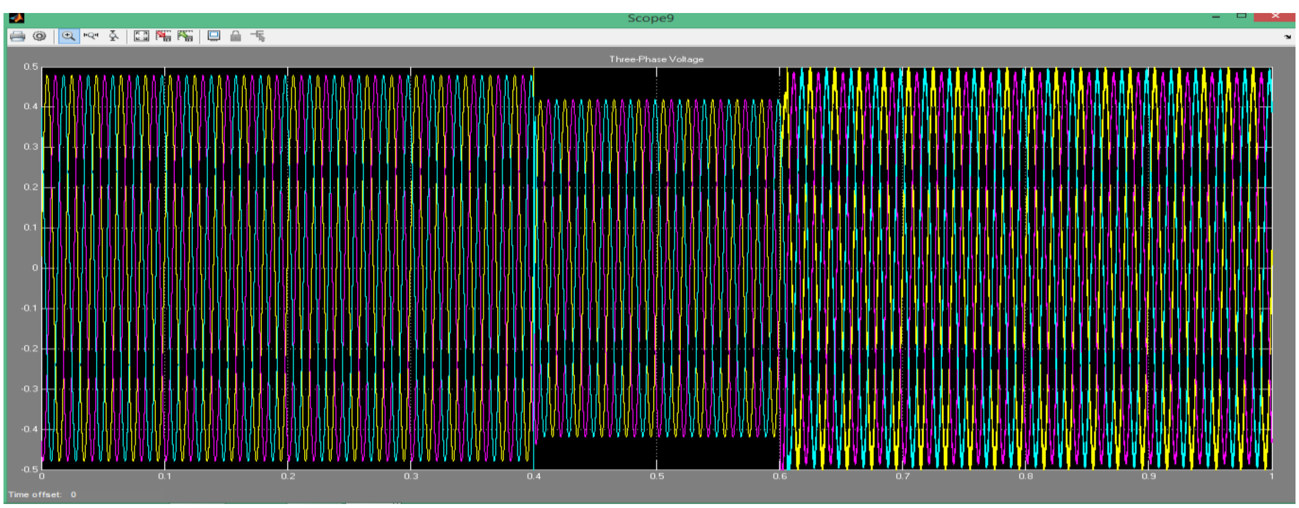

Fig.(4b): Load voltage during three-phase fault

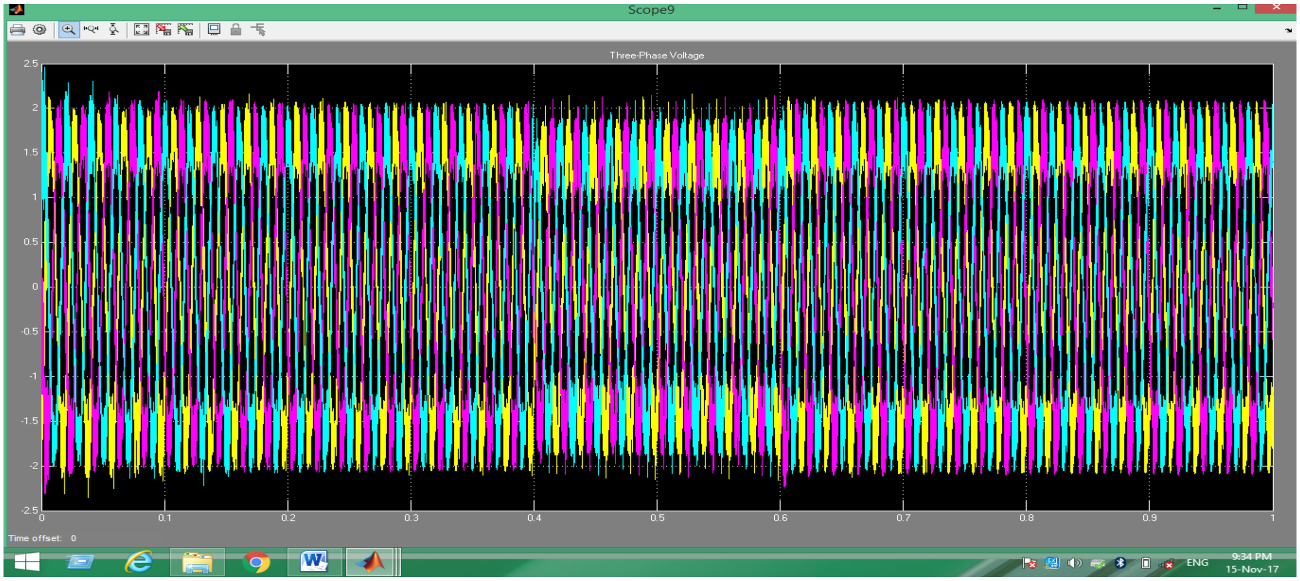

Fig.(4c): Load voltage after the DVR operation on three-phase fault

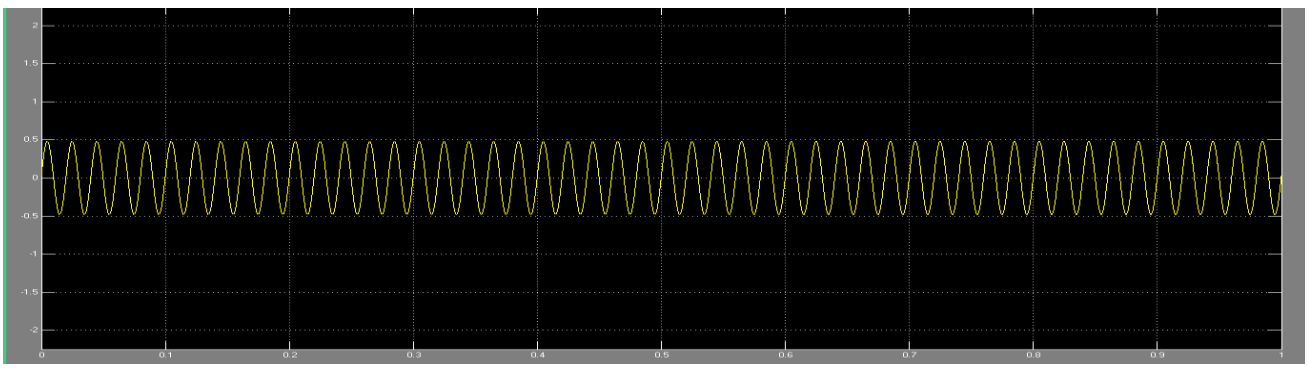

Fig.(4d): Load voltage of phase-A during single-phase fault

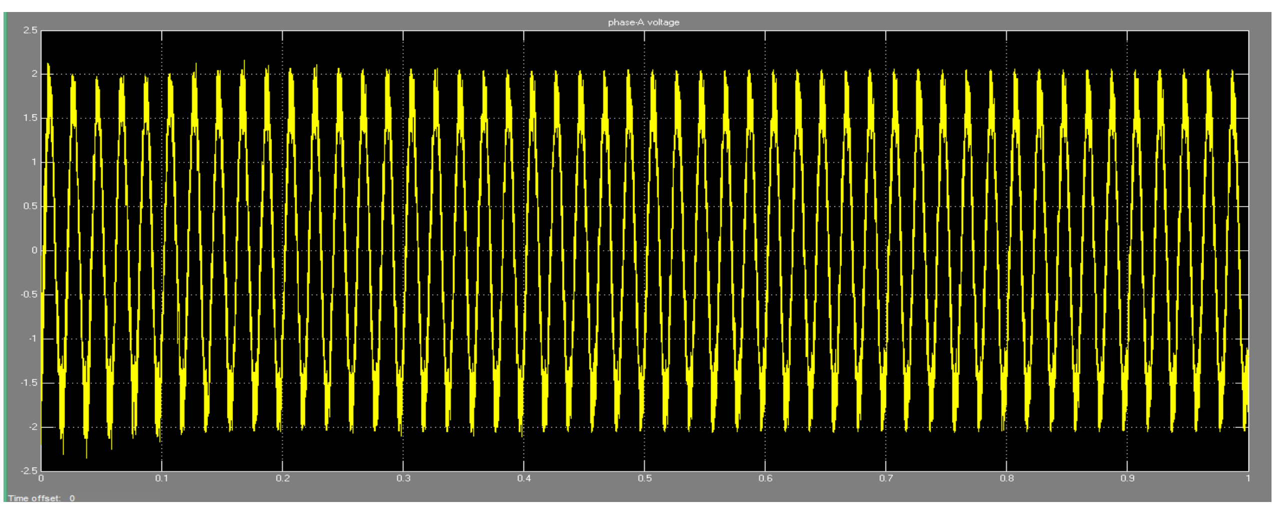

Fig.(4 e): Load voltage of phase-A after the DVR operation on single-phase fault

From fig.(4d) & (4e) it can be observed that during line to ground fault, the voltage on phase is reduced to 0.5 pu and after the application of DVR, it is recovered back to its nominal value until the fault clearance. It is observed from the above figures that due to the fault the load voltage reduce to a very low value. If we compare the waveforms of load voltage with and without DVR, we observed that when the DVR is in operation the voltage dip is compensated almost completely and the r.m.s voltage at the sensitive load is maintained at desired value ie. near about the nominal value. The DVR is designed to supply or absorb difference in voltage under different fault conditions ie. until the fault is cleared from the distribution system.

4. CONCLUSION:

For the distribution networks with static linear and non-linear loads , PI controller is used with the device to improve its performance. Test system is analyzed and results are presented in the simulation section. The results exhibit the satisfactory performance of DVR in the distribution networks under different fault conditions and it can be concluded that DVR improves more effectively the power quality in distribution networks as compared to the other custom power devices.

5. REFERENCES:

[1] Roger C. Dugan/Mark F. Mc Granaghan/Surya Santoso/H. Wayne Beaty, Electrical Power Systems,Quality, Second edition, Mc Graw Hill Publication.

[2] N.G Hingorani, Flexible AC Transmission, IEEE Spectrum, vol. 30, pp. 40-44,1993.

[3] N.G Hingorani, " Introducing Custom Power", IEEE Spectrum, vol. 32, pp. 41-48,1995 Distribution Custom Power Task Force, 2003

[4] K.R Padiyar, FACTS controllers in power transmission and distribution, new age international publicaions

[5] Smriti Dey, Performance of DVR under various fault conditions in Electrical Distribution Systems, IOSR Journal of Electrical and Electronics engineering, vol-8,Issue 1,pp-03-12, dec-2013

[6] C. Benachiba and B. Ferdi, Power Quality Improvement using DVR, American Journal of Applied Sciences 6(3): 396-400, 2009 ISSN 146-9239

[7] Samrat Shende and Nilesh Chamat, D- Statcom & DVR in power quality enhancement in distribution Network under various fault conditions, International Jouranal of Innovative Research in Science, Engineering and Technology, ISSN : 2319-8753

[8] M.H Rashid Power Electronics : circuits, devices and applicatins, prentice hall NJ, vol.2-1998.

[9] H.P. Tiwari and Sunil kumar Gupta " Dynamic Voltage Restorer against Volage sag" International Journal of Innovation, Management and Technology vol.1 no.3, pp. 232-237, 2010

[10] Math Works, (2012) : Power System Toolbox: Users Guide (R2012a)

[11] https://www.mathworks.com/

[12] https://ieeeexplore.ieee.org