International Journal on Recent and Innovation Trends in Computing and Communication
Volume: 3 Issue: 2

ISSN: 2321-8169
083– 089

Performance of DVR & Distribution STATCOM in Power Systems

Akil Ahemad[1]
Electrical Department
Anjuman College Of Engg & Tech.
Nagpur,India
akil_135@rediffmail.com

Prof. Pramod Gadge[2]
Electrical Department
Anjuman College of Engg.& Tech.
Nagpur,India
gadgepm@rediffmail.com

Mohammad Safique[3]
Electrical Department
Anjuman College of Engg.& Tech.
Nagpur,India
safikm8@gmail.com

Abstract-This paper investigates the effects of D-Statcom & Dynamic voltage Restorer (DVR) on voltage stability of a power system. This paper will discuss and demonstrate how both the devices succtssfully been applied to power system for effectively regulating system voltage. One of the major reasons for installing a & D-Statcom is to improve dynamic voltage control and thus increase system load ability. This paper describes the techniques of correcting the supply voltage sag, swell and interruption in a distributed system. At present, a wide range of very flexible controllers, which capitalize on newly available power electronics components, are emerging for custom power applications. Among these, both the devices are most effective, based on the VSC principle. A DVR injects a voltage in series with the system and D-Statcom inject the current with the system to correct the voltage sag, swell and interruption.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 modelling and simulation of DVR & D-Statcom in MATLAB/Simulink

Keywords-. *Custom power, distribution static compensator (D-STATCOM), dynamic voltage restorer (DVR), PWM, voltage source converter.*

*****

I. INTRODUCTION

The electrical power system is considered to be consisting three functional blocks like generation, transmission and distribution. For reliable power system, the generation unit must produce adequate power to meet customer's demand, transmission systems should transport bulk power over long distance without overloading or maintain system stability and distribution system must deliver electric power to each customer's premises from bulk power systems. Distribution system locates the end of power system and is connected to the customer directly, so the power quality mainly depends on distribution system.[4]

One of the most common power quality problems today is voltage sag and swells. Voltage sag is a short time event during which a reduction in r.m.s voltage magnitude occurs similarly swell is event during which rise in r.m.s voltage magnitude. Initially for the improvement of power quality or reliability of the system FACTS devices like static synchronous compensator (STATCOM), static synchronous series compensator (SSSC), interline power flow controller (IPFC) and unified power flow controller(UPFC) etc are introduce. These FACTS devices are designed for the transmission system. But now a day more attention is on the distribution system for the improvement of power quality, these devices are modified and known as custom power devices. The main custom power devices which used in distribution system for power quality improvement are distribution static synchronous compensator (D-STATCOM), dynamic voltage Restorer (DVR), active filter (AF), unified power quality conditioner (UPQC) etc. In this paper from the above custom power devices, D-STATCOM and DVR are used with PI controller for the power quality improvement in the distribution system. Here, different loads are considered with different fault condition and analyze the operation of D-STATCOM and DVR in distribution system.[1]

II DYNAMIC VOLTAGE RESTORER (DVR)

The DVR is a solid state dc to ac switching power converter that injects a set of three single phase ac output voltages in series with the distribution feeder and in synchronism with the voltages of the distribution system. By injecting voltages of controllable amplitude, phase angle and frequency (harmonic) into the distribution feeder in instantaneous real time via a series injection transformer, the DVR can restore the quality of voltage at its load side terminals when the quality of the source side terminal voltage is significantly out of specification for sensitive load equipment. [3]

The reactive power exchanged between the DVR and distribution system is internally generated by the DVR without any ac passive reactive components, i.e. reactors and capacitors. For large variations in the source voltage, the DVR supplies partial power to the load from a rechargeable energy source attached to the DVR dc terminal. The DVR, with its three single phase independent control and inverter design is able to restore line voltage to critical loads during sags caused by unsymmetrical as well as symmetrical three phase faults on adjacent feeders or disturbances that may originate many miles away on the higher voltage interconnected transmission system. Connection to the distribution network is via three single-phase series transformers there by allowing the DVR to be applied to all classes of distribution voltages. At the point of connection the DVR will, within the limits of its inverter, provide a highly regulated clean output voltage.[4]

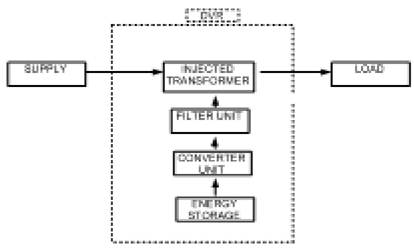


Fig.1 block diagram of DVR

III.DISTRIBTION STATIC COMPENSTOR (D-STATCOM)

This presents the operating principles of D-STATCOM. The D-STATCOM is basically one of the custom power devices. It is nothing but a STATCOM but used at the Distribution level. The key component of the DSTATCOM is a power VSC that is based on high power electronics technologies.

The Distribution STATCOM is a versatile device for providing reactive compensation in ac networks. The control of reactive power is achieved via the regulation of a controlled voltage source behind the leakage impedance of a transformer, in much the same way as a conventional synchronous compensator. However, unlike the conventional synchronous compensator, which is essentially a synchronous generator where the field current is used to adjust the regulated voltage, the D-STATCOM uses an electronic voltage sourced converter (VSC), to achieve the same regulation task. The fast control of the VSC permits the STATCOM to have a rapid rate of response. [5]

The DSTATCOM is the solid-state based power converter version of the SVC. Operating as a shunt connected SVC, its capacitive or inductive output currents can be controlled independently from PWM technique. Because of the fast-switching characteristic of power converters, the D-STATCOM provides much faster response. D-STATCOM is a shunt connected, reactive compensation equipment, which is capable of generating and or absorbing reactive power whose output can be varied so as to maintain control of specific parameters of the electric power system. D-STATCOM employ solid state power switching devices, hence, it provides rapid controllability of the three phase voltages, both in magnitude and phase angle. [3]

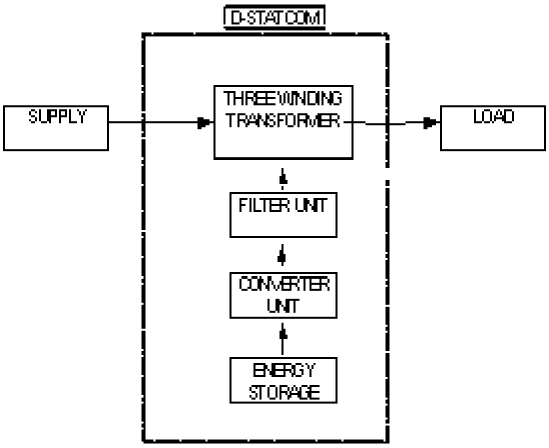
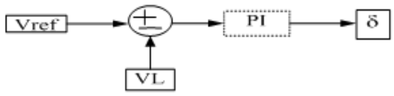


Fig.2 block diagram of D-statcom

IV CONTROLLER

A controller is required to control or to operate both D-Statcom and DVR during the fault condition only. Load voltage is sensed and passed through a sequence analyzer. The magnitude of the actual voltage is compared with reference voltage i.e Vref. Pulse width modulated(PWM) control system is applied for inverter switching so as to generate a three phase 50Hz sinusoidal voltage at the load terminals. Switching frequency in the range of few KHz. The IGBT Inverter is controlled with PI controller in order to maintain 1p.u voltage at the load side. An advantage of proportional pulse integral controller is an actuating signal which is the difference between the reference voltage and feedback load voltage. Output of the controller is in the form of an angle δ, which introduces additional phase-lag/lead in the three-phase voltage. The output of error detector is the missing voltage. The controller output when compared at PWM signal generator hence, the result in the desired firing sequence.[3]



schematic of PI controller

The sinusoidal signal $V_{control\ phase}$ modulated by means of the angle δ is,

V_A=Sin (ωt + δ) V_B=sin (ωt + δ -2π/3) V_C =sin (ωt + δ+2π/3)

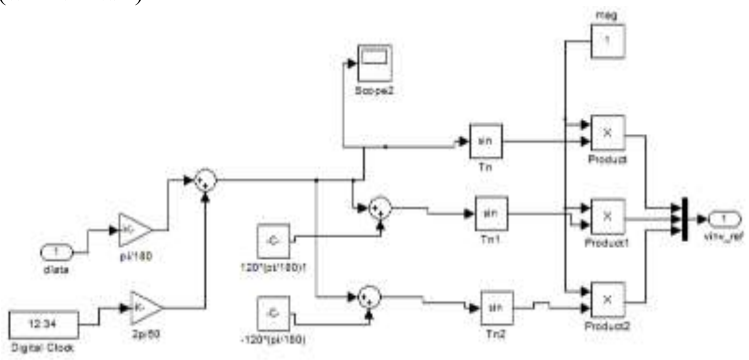


Fig. 3 phase modulation of the control angle δ.

This modulated signal is compaired with triangular signal and generates the switching signals for the converter valves. The main parameters of the sinusoidal PWM scheme are the amplitude modulation index of signal, and the frequency modulation index of the triangular signal. The modulating angle is applied to the PWM generator in phase A. the angles for Phase B and phase C are shifted by 120º and 240º lagging respectively. [6]

V PARAMETERS OF DVR TEST SYSTEM

The test system consists of 13KV, 50Hz generation system (considered to be source). This source, feeding two transmission lines through a three winding transformer connected in Y/Δ/Δ 13/115/115 KV. Such transmission lines feed two distribution network through two transformer connected in Δ/Y, 115/11KV. [3]

Table.1 System parameters.

Sr. No.	System Quantities	Standards
1	Source	13KV,50Hz 100MVA
2	Three winding transformer	100MVA,Y/Δ/Δ 13/115/115 KV
3	Impedance of	R1=0.05Ω/Km, L1=0.4806

ISSN: 2321-8169
018– 021

	transmission line1	H/Km
4	Impedance of transmission line2	R2=1mΩ/Km, L2=5mH/KM
5	Two winding transformer	100MVA,50Hz, Δ/Y 115/11 KV
6	Injection transformer	100MVA, 50Hz,Δ/Y 11/11KV
7	Load on bus1	P=6.05MW(resisitive load)
8	Load on bus2	P=3.4922KW Q=2MVAR(highly inductive)
9	Inverter parameters	IGBT based, 3 arms, 6 pulse, carrier Frequency=1080Hz
10	PI controller	Kp=0.5, Ki=50, Sample time=50μs
11	Filter unit	L= 7mH C=15 μF
12	Rating of DVR	5MVA

VI SINGLE LINE DIAGRAM OF THE DVR TEST SYSTEM

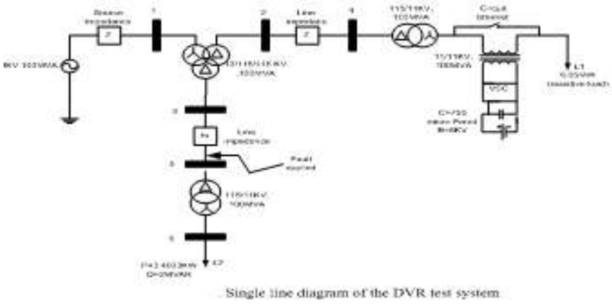


fig. 4 single line diagram of DVR

In the above test system we have a generating unit of 13KV, 50Hz which is considered as source of 100MVA. The test system is constructed with concerning the DVR actuation. The output from the source is fed to the primary of tertiary winding transformer. Now, further two parallel feeders of 11KV each are drawn with the help of two winding transformer. In one of the feeder (L2) DVR is connected in series and on other line fault is applied to create sag.

VII SIMULINK MODEL OF TEST SYSTEM AND RESULTS

A Simulation of test system without fault and without DVR

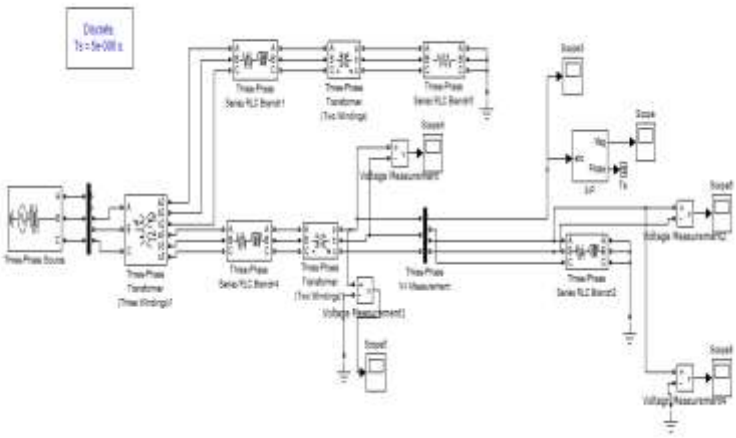
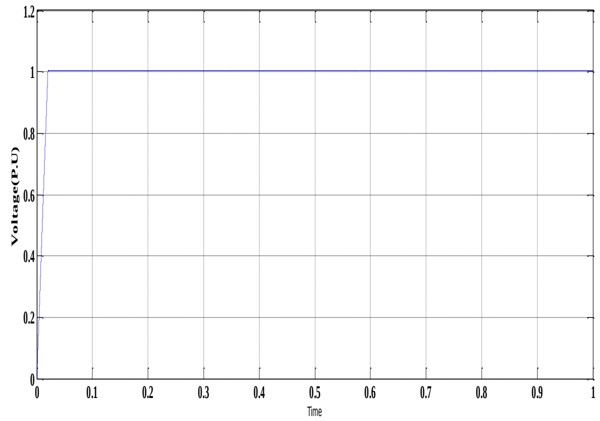
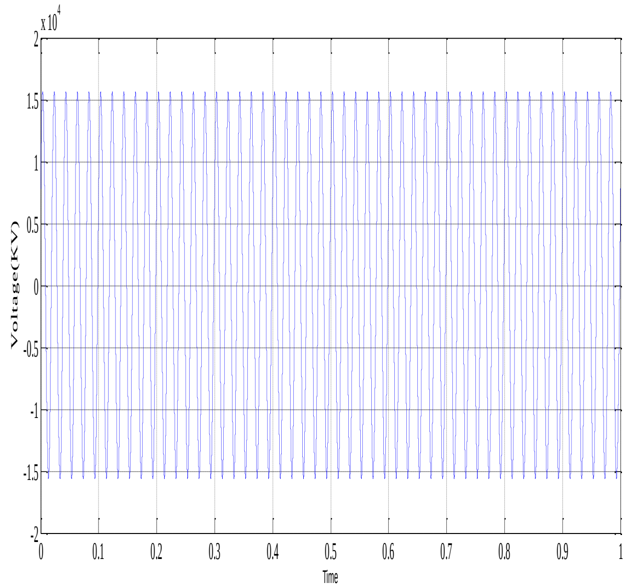


Fig.5 Simulation of test system without fault and without DVR

The following result shows the system when considering no fault and no connection of DVR.



Voltage Vrms(p.u) at load side.



line to line voltage (KV) at load side

B Simulink model of test system with fault but without DVR

In this simulink model we have system which fed the two buses or feeders through two winding transformer as shown. On the upper bus we are applying the 3phase Line to ground fault(3LG) , here we are not considering the presence

 ISSN: 2321-8169
018– 021

of DVR and have to observe the effect on voltages on the lower bus(second bus or second feeder).

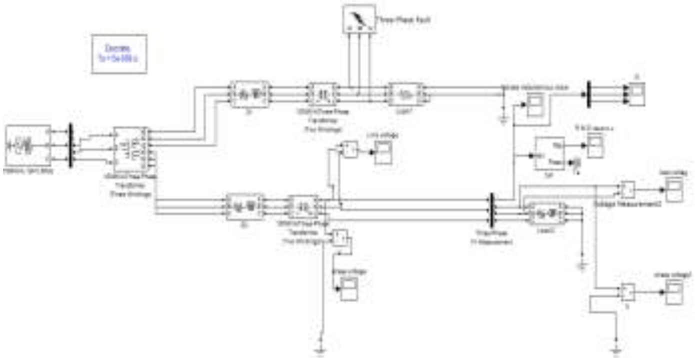
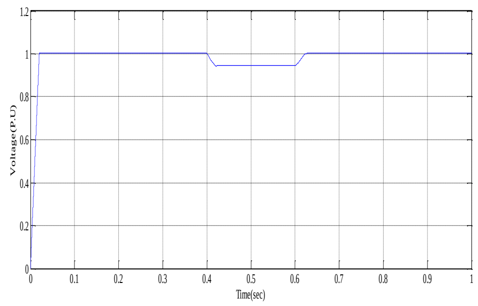


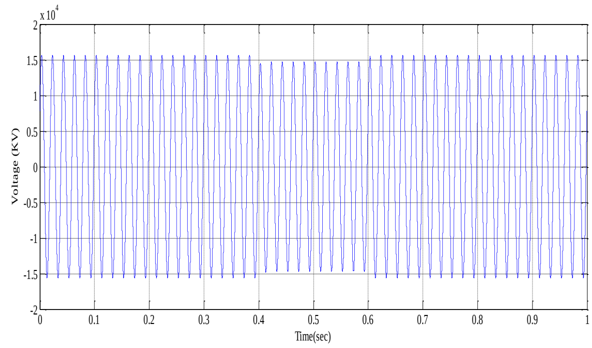
Fig. 6 Simulink model with fault without DVR.

C Simulation Result of test system with fault and without DVR

From the following results it is observed that during the fault time i.e 0.4-0.6 sec, the voltage sag to some finite value. Since the fault is on upper bus, hence sag may be 70-80% . The sag on the lower bus at the load side is nearly 10-15% , and measured the line to line voltage value during fault time is 10.1KV.



Voltage Vrms(p.u) at load side.



line to line voltage (KV) at load side

D Simulink model of test system with fault and with DVR

In this simulink model we have system which fed the two buses or feeders through two winding transformer as shown. On the upper bus we are applying the three phase Line to ground fault (3LG). And on the lower bus we have connected the DVR because in this bus sag is low and custom device can compensate easily. The system is shown in following fig.

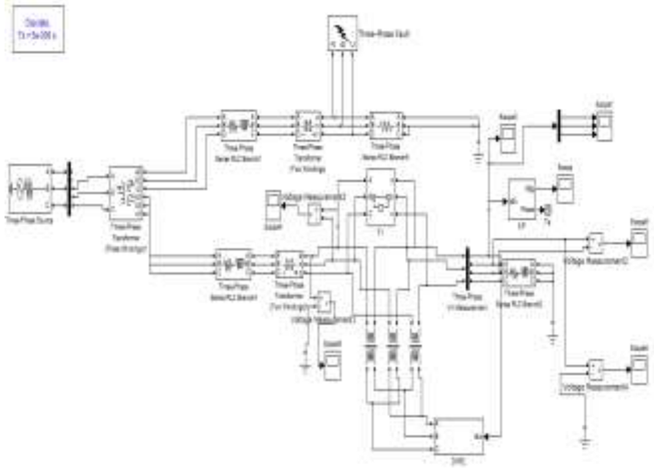
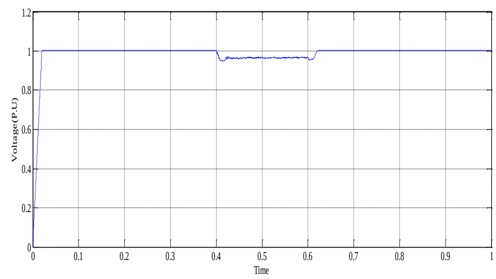


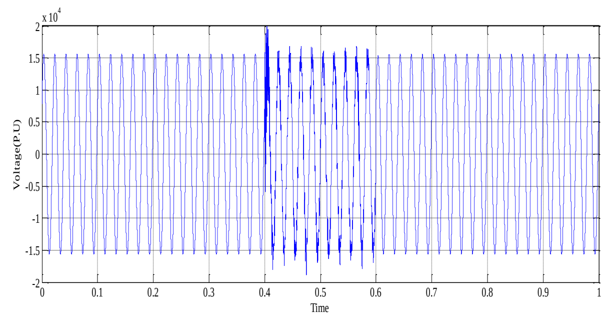
Fig.7simulation test system with DVR

E Simulation Results with fault and with DVR

From the following results it is clear that the DVR compensate the voltage sag during the fault time 0.4-0.6 sec. the compensated results of sag with respective rms value of voltage, instantaneous value, line to line voltage injected by the DVR which is nearly 0.5KV.



Voltage Vrms(p.u) at load side.



line to line voltage (KV) at load side

VIII PARAMETERS OF D-STATCOM TEST SYSTEM

The test system consists of 230KV, 50Hz transmission line (considered to be source). This source, feeding two distribution network through a three winding transformer connected in Y/Δ/Δ 230/11/11 KV. [3]

Table-2 system parameters

Sr. No.	System Quantities	Standards
1	Source	230KV, 50Hz 100MVA

ISSN: 2321-8169
018– 021

2	Three winding transformer	100MVA,Y/Y/Y 230/11/11 KV
3	Load on bus1	P=1.776MW, Q=65.26MVAR(highly inductive)
4	Load on bus2	P=385.124KW Q=2MVAR(highly inductive)
5	Injection transformer	100MVA, 50Hz,Δ/Y 11/11KV
6	Inverter parameters	IGBT based, 3 arms, 6 pulse, carrier Frequency=1080Hz
7	Rating of D-STATCOM	5 MVAR

IX SINGLE LINE DIAGRAM OF THE DVR TEST SYSTEM

In the above test system we have a transmission line of 230KV, 50Hz which is considered as source of 100MVA. The test system is constructed with concerning the D-Statcom actuation. The source is fed to the primary of tertiary winding transformer. Now, further two parallel feeders of 11KV each are drawn from secondary winding the transformer. In one of the feeder D-STATCOM is connected in shunt and on other line two parallels loads are connected. The fault is applied at load side to create sag.

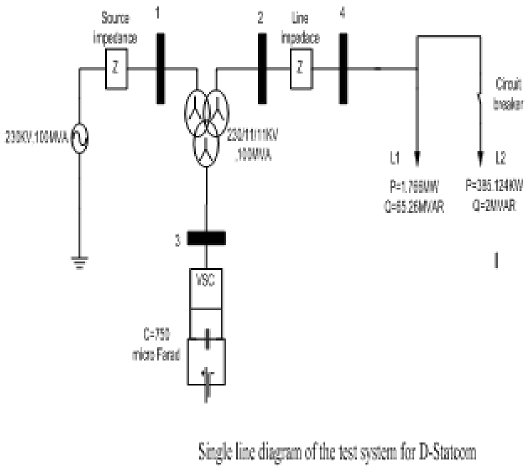


Fig.8 single line diagram of D-Statcom

X Simulation of test system without fault and without D-STATCOM.

This simulink model presents the test system without any fault and no connecting custom device like D-Statcom.

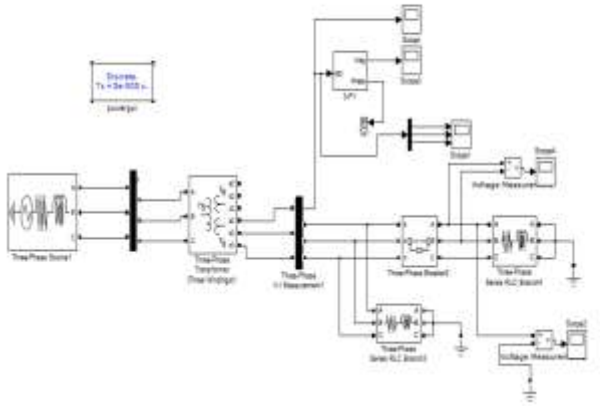
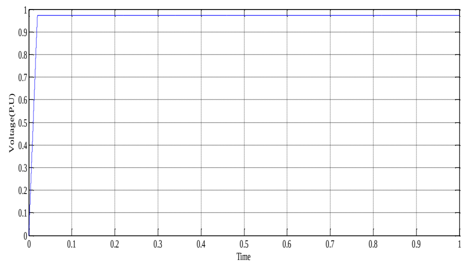


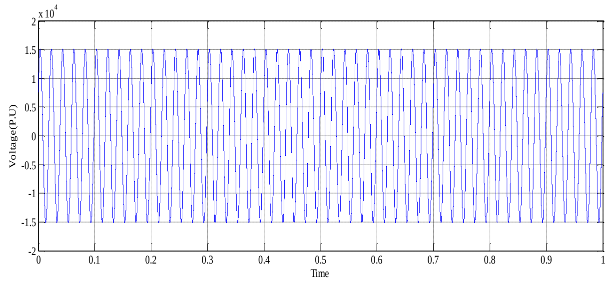
fig.9 simulink model without fault and without D-STATCOM.

A Simulation Results without fault and without D-STATCOM

The following results shows the system when considering no fault and no connection of D-STATCOM rms value of Voltage in p.u, instantaneous voltages, line to line voltage. The line to line voltage nearly11KV is measured.



Voltage Vrms(p.u) at load side.



line to line voltage (KV) at load side.

B Simulation of test system with fault but without D-STATCOM

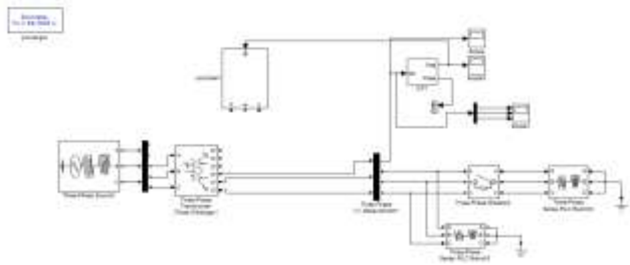


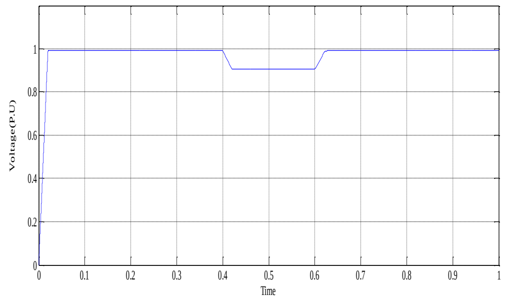
Fig. 10 Simulation test system without D-STATCOM

C Simulation Results with fault but without D-STATCOM

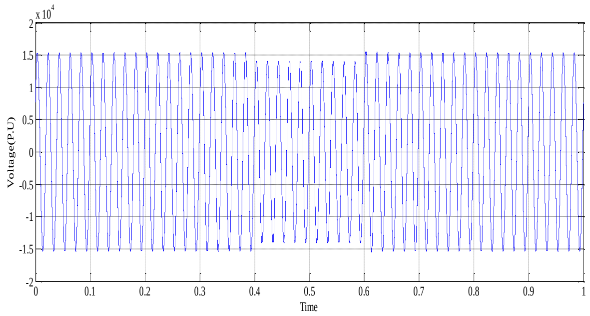
From the following results it is observed that during the fault time i.e 0.4-0.6 sec, the voltage sag to some finite

ISSN: 2321-8169
018– 021

value.The sag during the fault at the load side is nearly 10-15% , and measured the line to line voltage value during fault time is 10.25KV.



Voltage Vrms(p.u) at load side.



line to line voltage (KV) at load side.

D Simulation of test system with D-STATCOM

In this simulink model we have system which fed the load through secondary winding of tertiary transformer as shown. Out of two parallel loads, sag is created by providing the switching on one of load. The D-STATCOM is connected to one of the secondary winding of tertiary transformer .The system is shown in following.

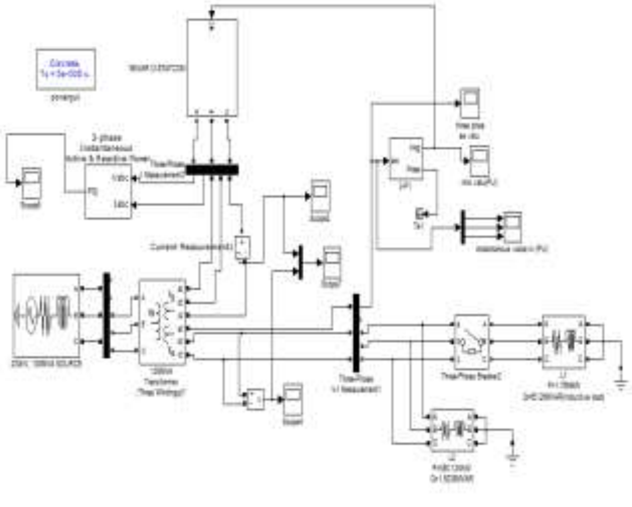
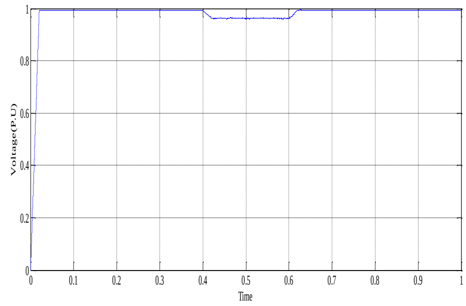


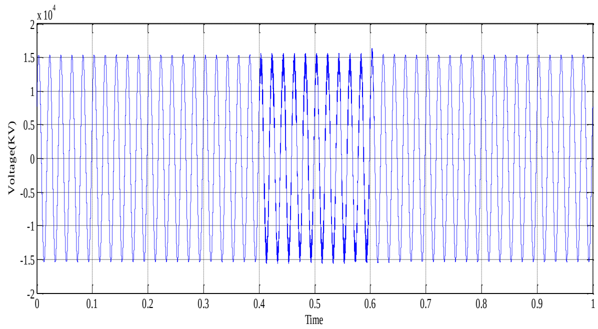
Fig.11 Simulation test system with D-STATCOM

E Simulation Results with fault and with D-STATCOM

From the following results it is clear that the D-STATCOM compensate the voltage sag during the fault time 0.4-0.6 sec. the compensated results of sag with respective rms value of voltage, line to line voltage.



Voltage Vrms(p.u) at load side.



line to line voltage (KV) at load side with fault but without D-STATCOM

XI CONCLUSION

The paper presented the study and simulation model of custom power equipment, namely D-STATCOM and DVR, and applied them for power quality problem such as voltage sag. The highly develop graphic facilities available in MATLAB is used to conduct all the aspect of model implementation and to carry out extensive simulation studies. A controller which is based on closed loop technique is used which generate error signals and this signals are used to trigger the switches of inverter using pulse width modulation (PWM) scheme in the D-STATCOM and DVR, this PWM control scheme only requires voltage measurements. The simulations are carried out for both sag on 11KV feeder using both D-Statcom and DVR as custom power devices and it has been found that DVR provide excellent voltage regulation capabilities. It is also observed that the DVR capacity for power compensation and voltage regulation depends mainly on two factors that is, the rating of the dc storage device and the coupling transformer. [6]

REFERENCES

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

[2] N.G.Hingorani, "Introducing Custom Power", IEEE Spectrum, vol. 32 pp.41-48,1995.

[3] Anaya-Lara O, Acha E., "Modeling and analysis of custom power system by PSCAD/EMTDC", IEEE Transactions on Power Delivery, Vol.17, and Issue: 1, Jan. 2002. Pp.266-272.

[4] M.J.H.Bollen, "Voltage sags in three-phase system" Power Engineering Review, IEEE, Vol.21 Issue:9, Sept.2001.pp.8-11.

[5] Haque. M.H, "Compensation of distribution system voltage sag by DVR and D-STATCOM". Power Tech. proceeding. 2001IEEE Porto, vol.11, Issue: Sept. 2001 pp.10-13

[6] S.V Ravi Kumar "SIMULATION OF D-STATCOM AND DVR IN POWER SYSTEMS" ARPN Journal of Engineering and Applied Sciences .VOL. 2, NO. 3, JUNE 2007

[7] Arindam Ghosh, “Copensation of Distribution System Voltage Using DVR”. IEEE Transaction on power delivery, vol.17, No.4, Oct. 2002. pp.1030-1036
[8] H.P Tiwari and Sunil Kumar Gupta “Dynamic Voltage Restorer against Voltage Sag” International of Innovation, Management and Technology vol.03, pp. 232-237,2010.
[9] C.S Chang, Y.S Ho, “The Influence of Motor Load on the Voltage Restoration Capability of Dynamic Voltage Restorer”. Power System Technology, Proceedings, Power Con, International Conference, vol.2,pp. 637-642,2000.
[10] M.H. Rashid, “Power Electronics” 2nd edition, Elsevier, Inc, Publication, Californial, U.S.A 2007.
[11] Rakosh Das Begamudre, “Extra High Voltage AC Transmission Engineering”, 2nd Edition, New Age International Limited, New Delhi 1990.
[12] Majid Moradlou and Hamid R. Karshenas, “Design Strategy for Optimum Rating Selection of Interline DVR”IEEE, VOL. 26, NO. 1, Jan, 2011