International Journal of Engineering Research-Online
A Peer Reviewed International Journal
Articles available online http://www.ijoer.in

Vol.3., Issue.3, 2015

RESEARCH ARTICLE

ISSN: 2321-7758

MITIGATION OF VOLTAGE SAG\SWELL IN DISTRIBUTION NETWORK

GAGANDEEP SINGH DUA[1],RAMINDER KAUR[2]

[1]PG Student, [2]Assistant Professor

Electrical Engineering Department

PEC University Of Technology Chandigarh

Article Received:10/06/2015

Article Revised on:18/06/2015

Article Accepted on:21/06/2015

ABSTRACT

There are various Power Quality Problems that are found in the literature. These problems have become one of the major concern, especially, with the use of power electronics devices which are sensitive to the variation of power supply. Among these problems Voltage Sag & Swell are identified as major concern to the electrical consumers. Voltage Sag is one of the most occurring power quality problems that cause severe problems and losses to industry. With the power systems restructuring and shifting trend towards distributed and dispersed generation, the concern of power quality has taken newer dimensions. In developing countries like India, where the variation of power frequency and many such other problems related to power quality are themselves a serious question, it is very vital to take positive steps in this direction. This paper presents modeling and simulation of a Dynamic Voltage Restorer (DVR) and DSTATCOM (Distribution STATCOM) a common Custom Power Devices using MATLAB for compensating Sag and Swell and comparing their performance. These devices are modeled using PI controller and Discrete PWM pulse generator. The simulations were performed using MATLAB/SIMULINK using SIMPOWER SYSTEM.

Keywords: DSTATCOM (Distribution Static Compensator), Power Quality, DVR (Dynamic Voltage Restorer), Sag, VSC(Voltage Source Converter), PWM

I. INTRODUCTION

Voltage sag, voltage swell and momentary power loss are seen as vital issues from the last decade due to the widespread use of sophisticated power electronic equipment. Due to this the loads are becoming more sensitive and less tolerant to short term voltage disturbances in the form of voltage sag and voltage swell. A great effort has been made to enhance the power quality either from customer side or utility side. Voltage sag is a momentary decrease in the r.m.s voltage magnitude lasting between half a cycle and several seconds [1]. A voltage dip or Voltage sag is a short time (10 ms to 1 minute) event during which a reduction in r.m.s voltage magnitude occurs. The voltage sag magnitude is ranged from 10% to 90% of nominal voltage and with duration from half a cycle to 1 min. Voltage sag is caused by a fault in the utility system, a fault within the customer's facility or a large increase of the load current, like starting a motor or transformer energizing. Typical faults are single-phase or multiple-phase short circuits, which leads to high currents. At the fault location the voltage in the faulted phases drops close to zero, whereas in the non-faulted phases it remains more or less unchanged. And the increase of voltage magnitude between 1.2 and 1.8 p.u. is called voltage swell. The most accepted duration of a swell is from 0.5 cycles to 1 minute. Voltage Swell appear on the switching off of a large load; energizing a capacitor bank or voltage increase of the unfaulted phases during a single line to ground fault. The possible effects of voltage swell are stress on computer components and they shorten their life. Also swell can upset electronic control and electric motor drives.

Voltage sag are much concern for an industry as they cause severe problems and economical losses. If the economical losses due to voltage sag are significant, their mitigation actions can be profitable for the customer and even in some cases for the utility. Utilities often focus on disturbances from end-user equipment as the main power quality problems. This is true for many disturbances like flicker, harmonics, etc., but voltage dips mainly have their origin in the higher voltage levels. Faults due to lightning, is one of the most common causes to voltage dips on overhead lines. Since there is no standard solution which will work for every site, each mitigation action must be carefully planned and evaluated. There are different ways to mitigate voltage dips, swell and interruptions in transmission and distribution systems. At present, a wide range of very flexible controllers, which capitalize on newly available power electronics components, are emerging for custom power applications [3, 4]. Among these, the distribution static compensator and the dynamic voltage restorer are most effective devices, both of them based on the VSC principle.

II. DSTATCOM

A D-STATCOM (Distribution Static Compensator), as depicted in figure-, consists of a two-level Voltage Source Converter (VSC), a dc energy storage device, a coupling transformer connected in shunt to the distribution network through a coupling transformer. The VSC converts the dc voltage across the storage device into a set of three-phase ac output voltages. These voltages are coupled with the ac system through the reactance of the coupling transformer. The exchange of active and reactive power between the D-STATCOM and the ac system is done with suitable adjustment of the phase and magnitude of the D-STATCOM output voltages. Such configuration allows the device to absorb or generate controllable active and reactive power.

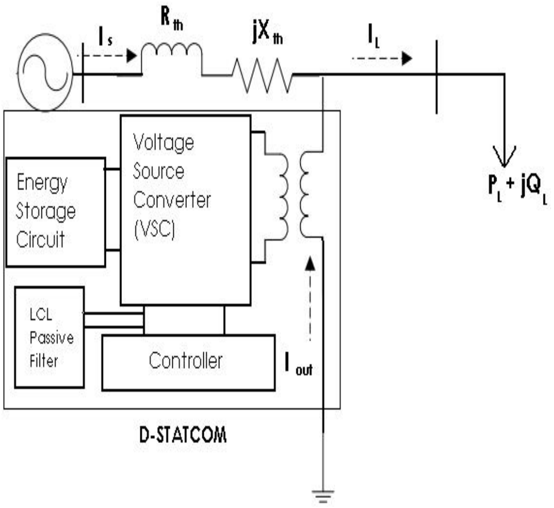

Fig.1. Schematic diagram of DSTATCOM

The value of Ish can be controlled by adjusting the output voltage of the converter. The shunt injected current Ish can be written as,

$$I_{sh} = I_L - I_S = I_L - \frac{V_{th} - V_L}{Z_{th}} \quad (1)$$

$$I_{sh}\angle\eta = I_L\angle -\theta - \frac{V_{th}}{Z_{th}}\angle(\delta - \beta) + \frac{V_L}{Z_{th}}\angle -\beta \quad (2)$$

I_{out} = I_{sh} output current, I_L = load current, I_S = source current, V_{th} = Thevenin voltage, V_L = load voltage, Z_{th} = impedence.

According to the equation 5.2, output current, will correct the voltage sags by adjusting the voltage drop across the system impedance $Z_{th.}$

III. SERIES VOLTAGE CONTROLLER

The series voltage controller or Dynamic Voltage Restorer (DVR) as shown in fig… is a controller that is connected in series with line distribution system using injecting transformer. The DVR consists of solid state power electronics switching device either GTO or IGBT, energy storage device and injection transformers. It can maintain load voltage by injecting three phase output voltages whose phase, magnitude and frequency can be controlled [2]. The converter generates the reactive power needed while the taking active power from the energy storage. The energy storage can be different depending on the needs of compensating. The DVR often has limitations on the depth and duration of the voltage sag that it can compensate. The DVR expected time response is about 25millisecond and which is less than some of the traditional methods of voltage correction such as tap-changing transformer.

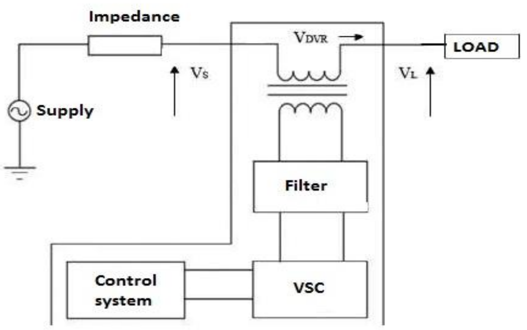

Fig.2. Schematic diagram of DVR

Energy storage device becomes one of the constraint factors in the distribution compensation process, especially for sag and long duration fault due to its capacity. The load impedance Zth depends on the fault level of the load bus. When the system voltage (Vth) drops, the DVR injects a series voltage V_{DVR} 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:

$$V_{DVR} = V_L + Z_{th} I_L - V_{th} \qquad (3)$$

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.

The complex power injection of the DVR can be written as,

$$S_{DVR} = V_{DVR} \cdot I_L^{*} \qquad (4)$$

When the injected voltage V_{DVR} is kept in quadrature with I_L, no active power injection by the DVR is required to correct the voltage. It requires the injection of only reactive power and the DVR itself is capable of generating the reactive power. The DVR voltage can be kept in quadrature with I_L only up to a certain value of voltage sag and beyond which the quadrature relationship cannot be maintained to correct the voltage sag. For such a case, injection of active power into the system is essential. The injected active power must be provided by the energy storage system of the DVR.

IV. CONTROLLER AND TEST SYSTEM

The aim of the control scheme for DVR & DSTATCOM is to maintain constant voltage magnitude at the point of common coupling (PCC) where a sensitive load is connected. The control system measures the r.m.s voltage at the PCC. The VSC switching strategy is based on a sinusoidal PWM technique which offers simplicity and good response.

The controller input is an error signal obtained from the reference voltage i.e. 1p.u and the value rms of the terminal voltage measured. Such error is processed by a PI controller generating the required angle to drive the error to zero, i.e., the load rms voltage is brought back to the reference voltage. The sinusoidal signal $V_{control}$ is phase-modulated by means of the angle δ and is further provided to the PWM signal generator. This technique is called as indirectly controlled converter and there is active and reactive power exchange with the network simultaneously. This combination in the control circuit is much more efficient by injecting the minimum amount of active power thus reducing its VA rating to a great extent while compensating voltage sags, swell.

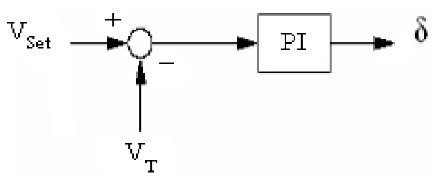

Fig.3. PI Controller

To enhance the performance of distribution system, DVR and D-STATCOM was connected to the distribution system. Modeling is done using MATLAB SIMULINK SIMPOWER SYSTEM. The test system comprises a 230kV, 50Hz transmission system, represented by a Thevenin equivalent, feeding into the primary side of a 3-winding transformer connected in D/Y, 230/11 kV. A varying load is connected to the 11 kV, secondary side of the transformer.

SIMULINK MODEL OF DVR & DSTATCOM

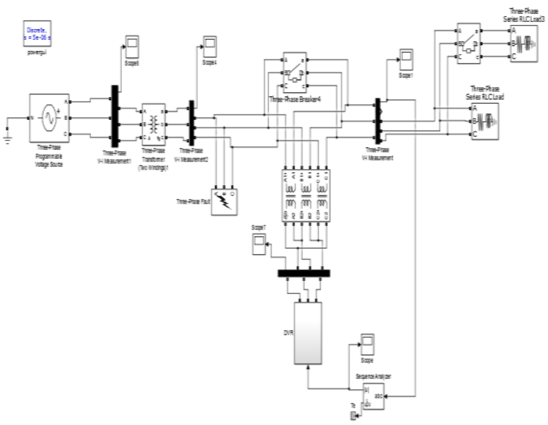

Fig.4. Simulation of DVR

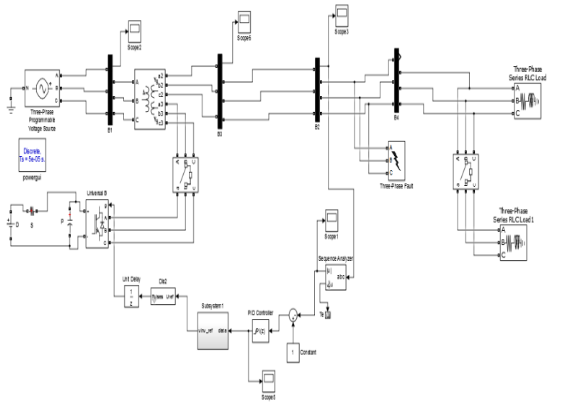

Fig.5. Simulation DSTATCOM

Table I: System Parameters

System Quantities	Standards
Source	230KV, 50Hz 100MVA
3-Phase fault	Rf=0.2
Load on bus1	P=90kW, Q= 47kVAR(inductive)
Load on bus2	P=385KW Q=50kVAR(highly inductive)
Injection transformer	3MVA, 50Hz,Y/Y 11/11KV
Inverter parameters	IGBT based, 3 arms, 6 pulse, carrier Frequency=10000Hz
PI Controller	Kp= 1, Ki= 70

V. RESULTS

A. *Simulation Result of DVR*

Case I: Voltage Sag due to 3-phase Short Circuit fault at PCC

Applying 3-phase Short Circuit fault at PCC, via a resistance of 0.2 Ω to create sag of 0.71 p.u for duration of 100 - 400 msec. The voltage sag is mitigated with energy storage of capacity 8.8 kV, when the DVR is connected to the system with the help of circuit breaker for duration 200 – 400 msec.

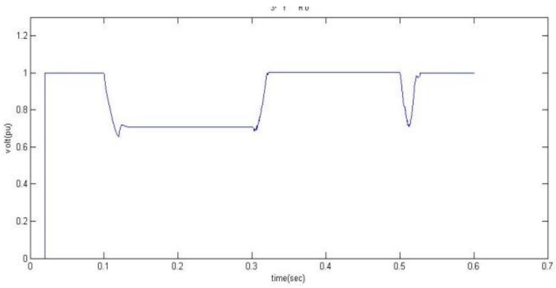

Fig.6. Voltage waveform at PCC showing Voltage Sag due to 3-phase Short Circuit

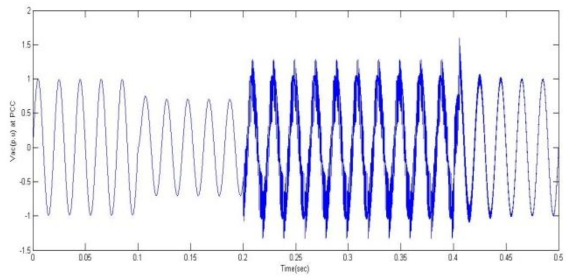

Fig.7. Phase waveform at PCC compensating Voltage Sag due to 3-phase Short Circuit

CASE II: Voltage Sag due to highly inductive Load

Switch on highly inductive load for duration of 100 - 400 msec create sag 0.985 p.u. The voltage sag is mitigated with energy storage of capacity 8.8 kV, when the DVR is connected to the system with the help of circuit breaker for duration 200 – 400 msec.

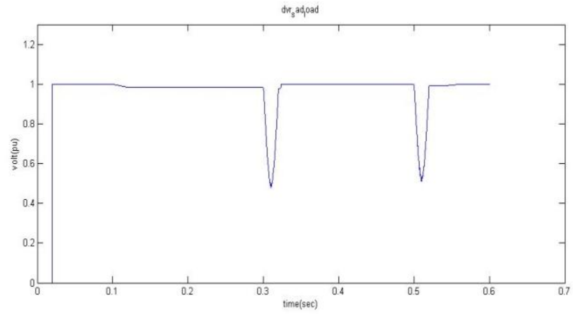

Fig.8. Voltage waveform at PCC Compensating Voltage Sag due to Load

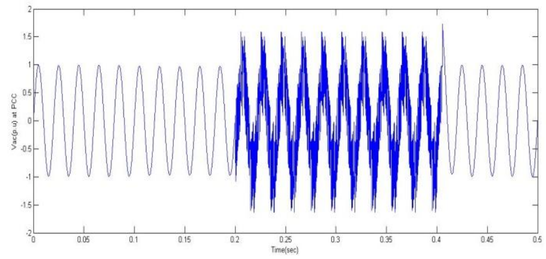

Fig.9. Phase waveform at PCC showing Voltage Sag

CASE II: Voltage Sag due to Programmable Voltage Source (PVS)

Programming the source to create voltage sag 0.9 p.u for duration of 100 - 400 msec. The voltage sag is mitigated with energy storage of capacity 16.8 kV, when the DVR is connected to the system with the help of circuit breaker for duration 200 – 400 msec.

International Journal of Engineering Research-Online
A Peer Reviewed International Journal
Articles available online http://www.ijoer.in
Vol.3., Issue.3, 2015

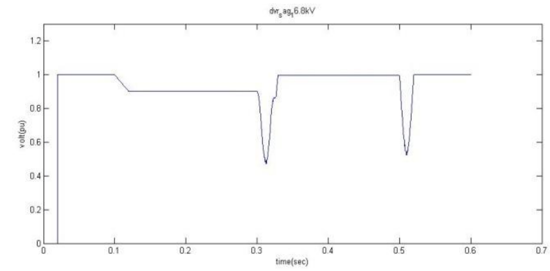

Fig.10. Voltage waveform at PCC Compensating Voltage Sag due to PVS

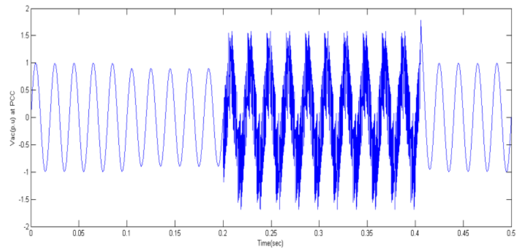

Fig.11. Phase waveform at PCC compensating Voltage Sag due to PVS

CASE III: Voltage Swell due to Programmable Voltage Source (PVS)

Programming the source to create swell 1.09 p.u for duration of 100 - 400 msec. The voltage swell is mitigated with energy storage of capacity 18.4 kV, when the DVR is connected to the system with the help of circuit breaker for duration 200 – 400 msec.

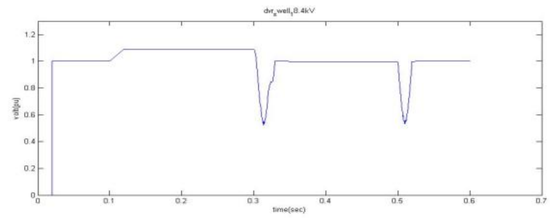

Fig.12. Voltage waveform at PCC compensating Voltage Swell due to PVS

B. Simulation Result of DSTATCOM

CASE I: Voltage Sag compensation due to 3-phase Short Circuit fault at PCC

Applying 3-phase Short Circuit fault at PCC, via a resistance of 0.2 Ω to create sag of 0.71 p.u for duration of 100 - 400 msec. The voltage sag is mitigated with energy storage of capacity 28.7 kV, when the DSTATCOM is connected to the system with the help of circuit breaker for duration 200 – 400 msec.

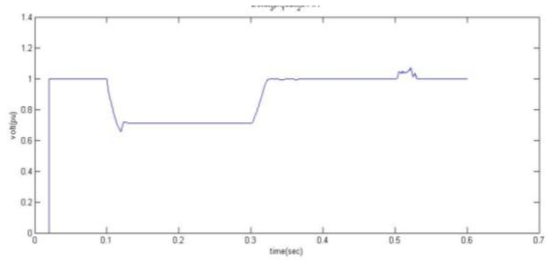

Fig.13. Voltage waveform at PCC showing Voltage Sag due to 3-phase Short Circuit

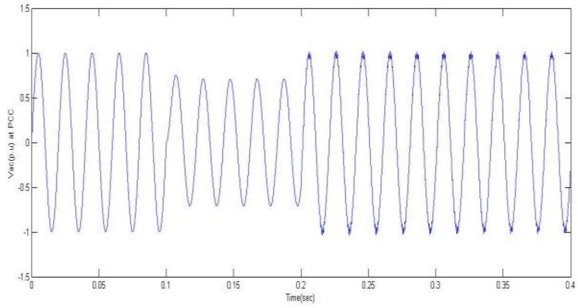

Fig.14. Phase-Phase Voltage waveform at PCC compensating Voltage Sag due to 3-phase Short Circuit

CASE II: Voltage Sag due highly inductive load

Switch on of highly inductive load for duration of 100 - 400 msec create sag 0.985 p.u. The voltage sag is mitigated with energy storage of capacity 19.2 kV, when the DSTATCOM is connected to the system with the help of circuit breaker for duration 200 – 400 msec.

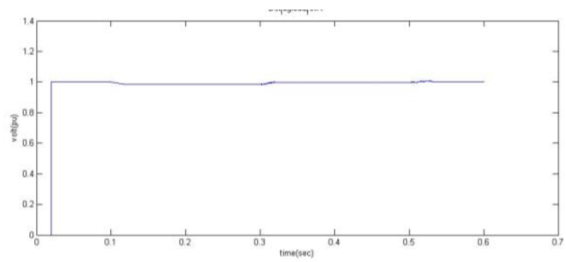

Fig.15. Voltage waveform at PCC showing Voltage Sag due to Highly Inductive Load

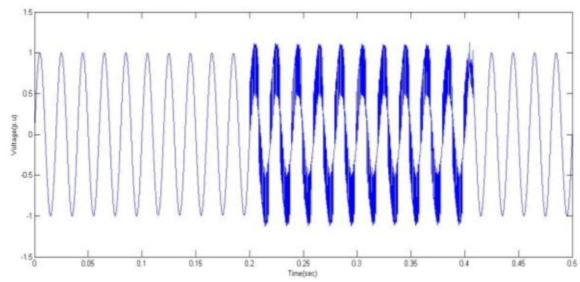

Fig.16. Phase- Phase Voltage waveform at PCC compensating Voltage Sag due to load

CASE III: Voltage Sag due to Programmable Voltage Source (PVS)

Programming the Voltage source to create sag of 0.9 p.u for duration of 100 - 400 msec. The voltage sag is mitigated with energy storage of capacity 21.4 kV, when the DSTATCOM is connected to the system with the help of circuit breaker for duration 200 – 400 msec.

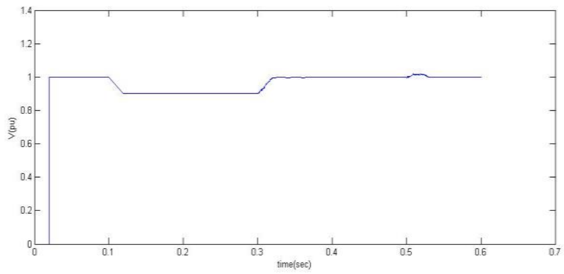

Fig.17. Voltage waveform at PCC showing Voltage Sag due to PVS

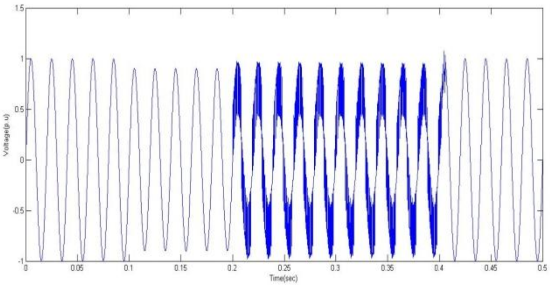

Fig.18. Phase-Phase Voltage waveform at PCC compensating Voltage Sag due to PVS

CASE III: Voltage Swell due to Programmable Voltage Source (PVS)

Programming the Voltage source to create sag of 1.09 p.u for duration of 100 - 400 msec. The voltage sag is mitigated with energy storage of capacity 18 kV, when the DSTATCOM is connected to the system with the help of circuit breaker for duration 200 – 400 msec.

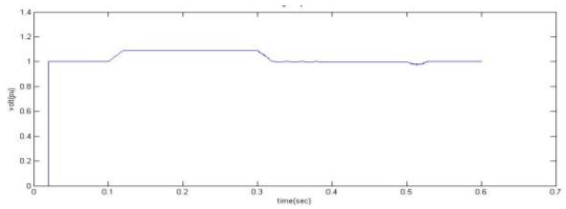

Fig.19. Voltage waveform at PCC showing Voltage Sag

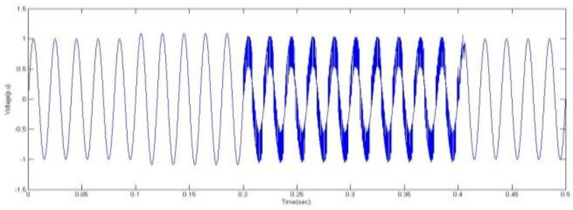

Fig.20. Phase-Phase Voltage waveform at PCC compensating Voltage Swell

C. Comparing the performance of DVR and DSTATCOM

Table2: Performance of DVR and DSTATCOM for 3-phase short circuit fault

For 3-phase fault

Rf=0.2 Voltage Sag=0.71

DSTATCOM DVR

Vdc(kV)	Vac (p.u)	Vdc(kV)	Vac (p.u)
21	0.84	5	0.84
28.7	0.9999	8.5	0.97
28.8	1.0001	8.8	0.999
28.9	1.002	8.9	1.002
29	1.014	9	1.01

Table 3: Performance of DVR and DSTATCOM for load

Highly inductive load switched on

Voltage Sag=0.985

DSTATCOM DVR

Vdc(kV)	Vac (p.u)	Vdc(kV)	Vac (p.u)
19	0.998	16	0.89
19.1	0.999	17.5	0.93
19.5	1.01	18.4	0.985
20	1.02	18.5	0.9999
20.9	1.05	20	1.03

Table 4: Performance of DVR and DSTATCOM for Sag by PVS

Sag=0.9

DSTATCOM DVR

Vdc(kV)	Vac (p.u)	Vdc(kV)	Vac (p.u)
19.5	0.974	15	0.85
20	0.986	16.5	0.93
21.4	0.9996	16.8	0.999
21.5	1.001	17.2	1.03

Table 5: Performance of DVR and DSTATCOM for Swell by PVS

Voltage Swell=1.09

DSTATCOM DVR

Vdc(kV)	Vac (p.u)	Vdc(kV)	Vac (p.u)
16.8	0.93	18	0.975
16.9	0.935	18.4	0.999
17.8	0.99	18.5	1.005
18	1.02	18.8	1.03

CONCLUSION

This paper has presented the one of the most occurring power quality problem voltage dips or sags & swells, their consequences, and mitigation techniques by use of custom power electronic devices DVR and D-STATCOM. The design and applications of DVR and D-STATCOM for voltage sags, interruptions and swells, and desired results were obtained.

A PWM-based control scheme has been implemented to control the electronic valves in the two-level VSC used in the D-STATCOM and DVR. This PWM control scheme works by voltage measurements only. This characteristic makes it ideally suitable for low-voltage custom power applications. The simulations results showed that the DVR provides relatively better voltage regulation capabilities in comparison to DSTATCOM and the same is cleared from above tables. It was also observed that the voltage regulation capacity of DVR and D-STATCOM depends on the rating of the dc storage device.

REFERENCES

[1]. M. Bollen, Understanding power quality problem, voltage sags and interruption. Piscataway, NJ: IEEE Press, USA, 1999.

[2]. Francisco Jurado "*Neural Network Control For Dynamic Voltage Restore"* IEEE Transaction on Industrial Electronic. Vol 51,No.3, June 2004.

[3]. Haque, M.H., "Compensation Of Distribution Systems Voltage sags by DVR and D-STATCOM",Power Tech Proceedings, 2001 IEEE Porto, Volume 1, PP.10-13, September 2001.

[4]. Anaya-Lara O, Acha E., "Modeling and Analysis Of Custom Power Systems by PSCAD/EMTDC", IEEE Transactions on Power Delivery, Volume 17, Issue: 2002, Pages: 266-272.

[5]. Muhammad Taha Ali, Zhang Jianhua, S. Furqan Rafique, Design of an Efficient Dynamic Voltage Restorer for Compensating Voltage Sags, Swells, and Phase Jumps, 16th International Power Electronics and Motion Control Conference and Exposition Antalya, Turkey 21-24 Sept 2014,IEEE-2014.

[6]. Mario Fabiano Alves, Tatiana Nesralla Ribeiro "Voltage Sag : An Overview of IEC and IEEE Standards and Application Criteria", 1999 IEEE.

[7]. Akil Ahemad, Sayyad Naimuddin, "Simulation Of D-Statcom In Power System**",** International Conference on Advances in Engineering & Technology – 2014 (ICAET-2014), IOSR Journal of Electrical and Electronics Engineering.

[8]. Deepa Francis, Tomson Thomas, "International Conference on Magnetics, Machines & Drives" (AICERA-2014 iCMMD) 978-1-4799-5202-1/14/$31.00 ©2014 IEEE Mitigation of Voltage Sag and Swell Using Dynamic Voltage Restorer.

[9]. S. P. Gawande & S.Khan, and M. R. Ramteke, Voltage Sag Mitigation Using Multilevel Inverter based Distribution Static Compensator (DSTATCOM) in Low Voltage Distribution System, 978-1-4673-0934-9/12/$31.00 ©2012 IEEE

[10]. N.Srinivasa Rao, "Modeling and Simulation of DSTATCOM for Power Quality Enhancement in Distribution System", International Journal of Engineering Research & Technology (IJERT) Vol. 1 Issue 5, July – 2012,ISSN: 2278-0181