International Journal of Scientific Engineering and Technology (ISSN : 2277-1581)
Volume 2 Issue 5, pp : 317-321 1 May 2013

A New Proposal for Mitigation of Power Quality Problems Using D-STATCOM

M. Anuj Gargeya

Department of Electrical and Electronic Engineering, GITAM University, Hyderabad.
[1]anuj.gargeya@gmail.com

Abstract: DSTATCOM (Distribution Static Compensator) is Used for Mitigation of Power Quality Problems under unbalance caused by various loads in distribution system. This paper addresses the modeling and analysis of custom power controllers, power electronic-based equipment aimed at enhancing the reliability and quality of power flows in low voltage distribution networks using DSTATCOM. A new PWM- based control scheme has been proposed that only requires voltage measurements the operation of the proposed control method is presented for D-STATCOM. Simulations and analysis are carried out in MATLAB/SIMULINK with this control method for two proposed systems.

Keyword: D-STATCOM, VSC, FACTS Controller, PCC.

I. INRODUCTION

In recent years, the custom power technology, the low-voltage counterpart of the more widely known flexible ac transmission system (FACTS) technology, aimed at high-voltage power transmission applications, has emerged as a credible solution to solve many of the problems relating to continuity of supply at the end-user level. Both the FACTS and custom power concepts are directly credited to EPRI [1], [2]. 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, the distribution static compensator (D-STATCOM) based on the VSC principle [3]-[5] has been used to perform the Modelling and analysis of such controllers for a wide range of operating conditions based PWM control reported in this seminar for the D-STATCOM. It relies only on voltage measurements for its operation, i.e., it does not require reactive power measurements [6]. A sensitivity analysis is carried out to determine the impact of the dc capacitor size on D-STATCOM performance.

When used in low-voltage distribution systems the STATCOM is normally identified as Distribution STATCOM (D-STATCOM). It operates in a similar manner as the STATCOM (FACTS controller), with the active power flow controlled by the angle between the AC system and VSC voltages and the reactive power flow controlled by the difference between the magnitudes of these voltages. As with the STATCOM, the capacitor acts as the energy storage device and its size is chosen based on power ratings, control and harmonics considerations. The D-STATCOM controller continuously monitors the load voltages and currents and determines the amount of compensation required by the AC system for a variety of disturbances.

A D-STATCOM (Distribution Static Compensator), which is schematically depicted in Fig.1consists 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 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 VSC connected in shunt with the ac system provides a multifunctional topology which can be used for up to three quite distinct purposes [7]:

1. Voltage regulation and compensation of reactive power
2. Correction of power factor
3. Elimination of current harmonics

Here, such device is employed to provide continuous voltage regulation using an indirectly controlled converter.

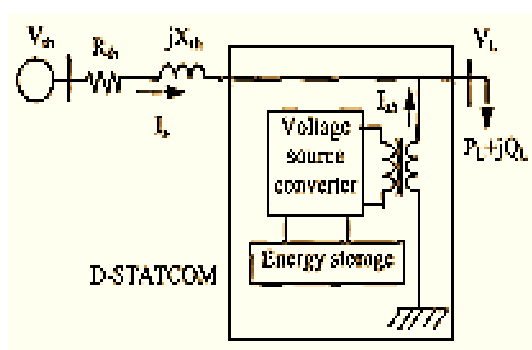


Fig. 1. Single line diagram of D-STATCOM connected distribution system

International Journal of Scientific Engineering and Technology (ISSN : 2277-1581)
Volume 2 Issue 5, pp : 317-321 1 May 2013

II. System Representation

DISTRIBUTION STATIC COMPENSATOR (DSTATCOM)

A D-STATCOM (Distribution Static Compensator), which is schematically 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 in phase and coupled with the ac system through the reactance of the coupling transformer. Suitable adjustment of the phase and magnitude of the D-STATCOM output voltages allows effective control of active and reactive power exchanges between the D-STATCOM and the ac system. Such configuration allows the device to absorb or generate controllable active and reactive power.
The VSC connected in shunt with the ac system provides a multifunctional topology which can be used for up to three quite distinct purposes:

1. Voltage regulation and compensation of reactive power;
2. Correction of power factor; and
3. Elimination of current harmonics.

Here, such device is employed to provide continuous voltage regulation using an indirectly controlled converter.
Figure.1- the shunt injected current Ish corrects the voltage sag by adjusting the voltage drop across the system impedance Zth. The value of Ish can be controlled by adjusting the output voltage of the converter.

The shunt injected current Ish can be written as,

$$I_{sh} = I_L - I_s = I_L - \frac{V_{Th} - V_L}{Z_{Th}}$$

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

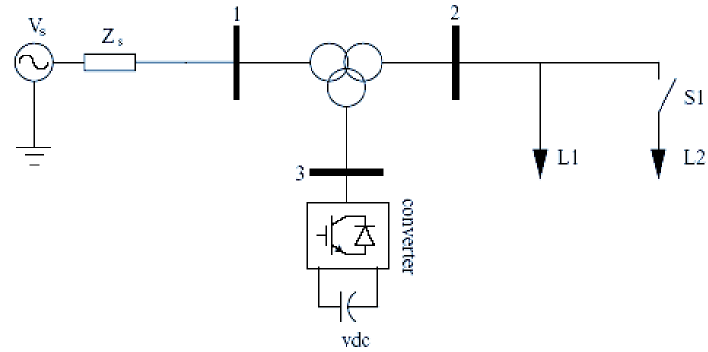
The complex power injection of the D-STATCOM can be expressed as,

$$S_{sh} = V_L I_{sh}^*$$

It may be mentioned that the effectiveness of the D-STATCOM in correcting voltage sag depends on the value of Zth or fault level of the load bus. When the shunt injected current Ish is kept in quadrature with VL, the desired voltage correction can be achieved without injecting any active power into the system. On the other hand, when the value of Ish is minimized, the same voltage correction can be achieved with minimum apparent power injection into the system. The control scheme for the D-STATCOM follows the same principle as for DVR. The switching frequency is set at 475 Hz.

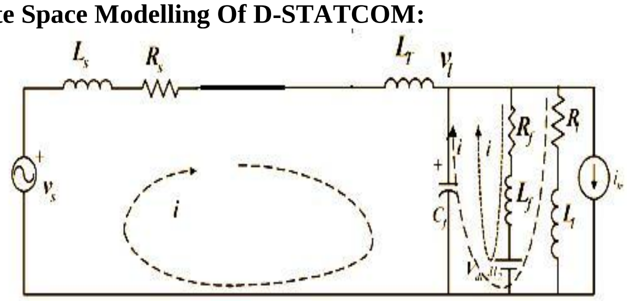
TEST SYSTEM

Figure shows the test system used to carry out the various D-STATCOM simulations.



Single line diagram of the test system for D-STATCOM.

State Space Modelling Of D-STATCOM:



III. Control Strategy

The aim of the control scheme is to maintain constant voltage magnitude at the point where a sensitive load is connected, under system disturbances. The control system only measures the rms voltage at the load point, i.e., no reactive power measurements are required. The VSC switching strategy is based on a sinusoidal PWM technique which offers simplicity and good response. Since custom power is a relatively low-power application, PWM methods offer a more flexible option than the Fundamental Frequency Switching (FFS) methods favored in FACTS applications. Besides, high switching frequencies can be used to improve on the efficiency of the converter, without incurring significant switching losses.
In fig .2 shows that the controller input is an error signal obtained from the reference voltage and the value rms of the terminal voltage measured. Such error is processed by a PI controller and the output is the angle d, which is provided to the PWM signal generator. It is important to note that in this case, indirectly controlled converter, there is active and reactive power exchange with the network simultaneously: an error signal is obtained by comparing the reference voltage with the rms voltage measured at the load point. The PI controller process the

error signal and generates the required angle to drive the error to zero, i.e., the load rms voltage is brought back to the reference voltage.

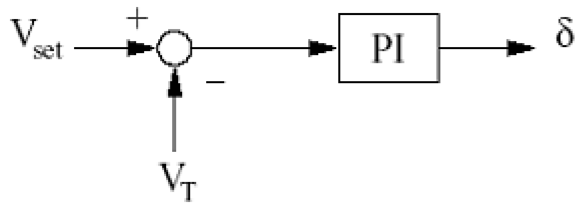


Fig. 2. Indirect Controller

The sinusoidal signal $V_{CONTROL}$ is phase-modulated by means of the angle δ.

i.e.

$$V_A = \sin(\omega t + \delta)$$

$$V_B = \sin(\omega t + \delta - 120°)$$

$$V_C = \sin(\omega t + \delta + 120°) \quad (5)$$

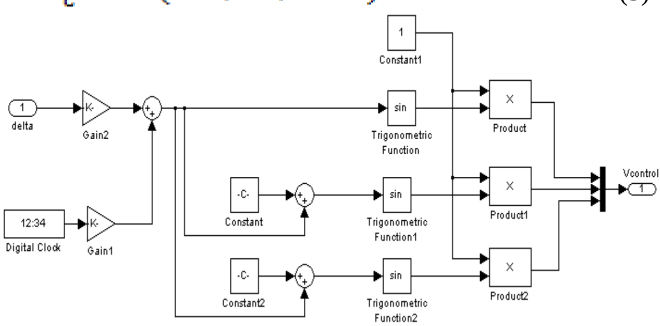
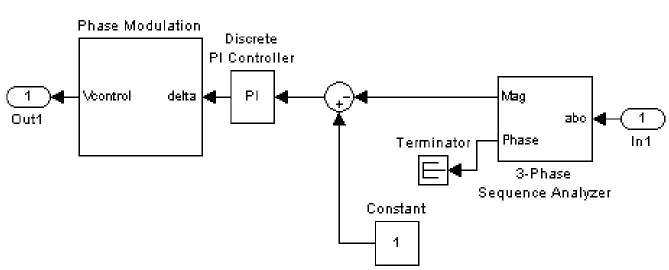


Fig. 3. The sinusoidal signal $V_{CONTROL}$

The modulated signal $V_{CONTROL}$ is compared against a triangular signal (carrier) in order to generate the switching signals for the VSC 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 amplitude index is kept fixed at 1 p.u, in order to obtain the highest fundamental voltage component at the controller output.



Where $V_{CONTROL}$ is the peak amplitude of the control signal

V_{Tri} is the peak amplitude of the triangular signal the switching frequency is set at 450 Hz. The frequency modulation index is given by;

$$M_a = \frac{V_{CONTROL}}{V_{TRI}} = 1 \text{ p.u}$$

$$M_f = \frac{f_x}{f_1} = 9 \quad (6)$$

Where f_1 is fundamental frequency

The modulating angle is applied to the PWM generators in phase A. The angles for phases B and C are shifted by 240° and 120° respectively. It can be seen in that the control implementation is kept very simple by using only voltage measurements as the feedback variable in the control scheme. The speed of response and robustness of the control scheme are clearly shown in the simulation results. The Simulink block diagram of SPWM generator is as shown in fig.6

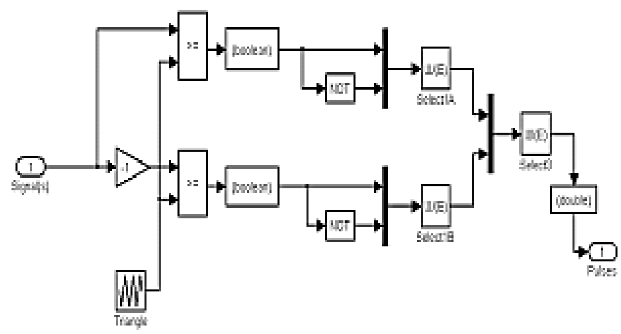


Fig.4.The Simulink block diagram of SPWM generator

IV. SYSTEM MODELLING

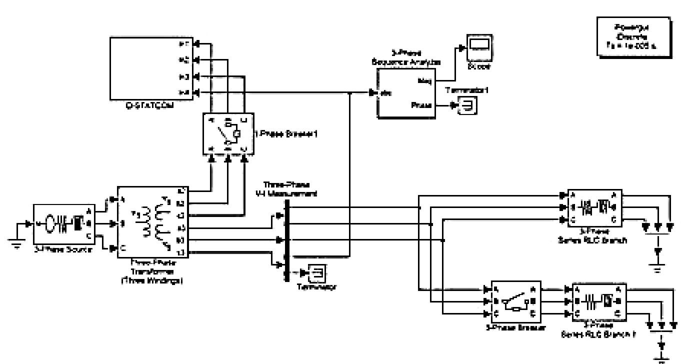


Fig.5.Simulink model of D-STATCOM test system.

TABLE I

System Parameters	Values
System frequency (f)	50HZ
Rated voltage	230KV
Voltage source v_{S1}	230KV,Phase angle 0^0
Voltage source v_{S2}	230KV,Phase angle 0^0
Feeder-1	1+j0.8Ω
Load-1	A three-phase diode bridge rectifier with an resistor (500) Ω

D-STATCOM PARAMETERS

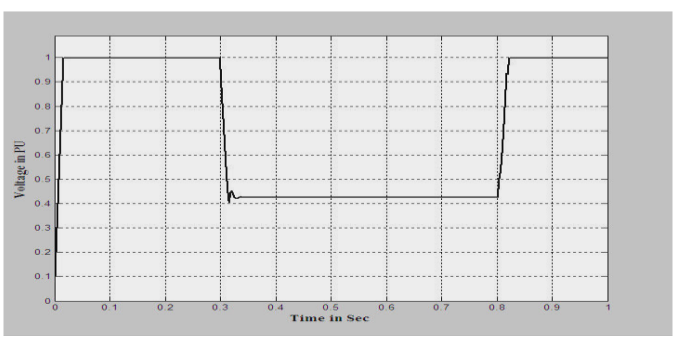
System Parameters	Values
System frequency (f)	50HZ
VSC-1 single-phase transformers ($T1$)	100MVA,230KV/11KV, 2% resistance and 8% leakage Reactance
VSC-2 single-phase transformers ($T2$)	100MVA,230KV/11KV, 2% resistance and 8% leakage Reactance

The test system shown in figure 5 comprises a 230kV, 50Hz transmission system, represented by a Thevenin equivalent, feeding into the primary side of a 3-winding transformer connected in Y/Y/Y, 230/11/11 kV. A varying load is connected to the 11 kV, secondary side of the transformer. A two-level D-STATCOM is connected to the 11 kV tertiary winding to provide instantaneous voltage support at the load point. A 750 μF capacitor on the dc side provides the D-STATCOM energy storage capabilities. Breaker 1 is used to control the period of operation of the D-STATCOM and breaker 2 is used to control the connection of load 1 to the system.

Case-1

Simulated Results of Sag modeled system with and without D-STATCOM:

The circuit shown is Fig. 5, is nothing but a sag generating circuit without the D-STATCOM connected to it is simulated and the magnitude of voltage is as shown in the Fig 6.1.



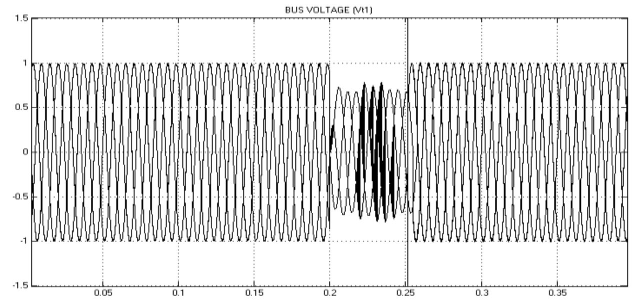
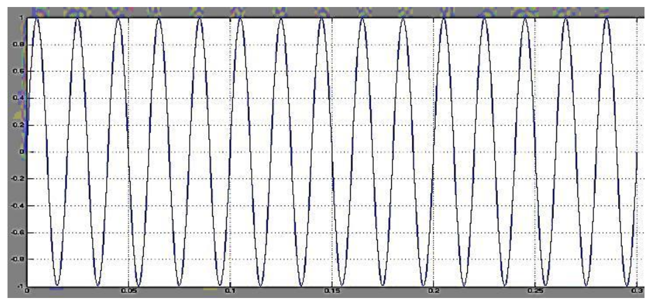
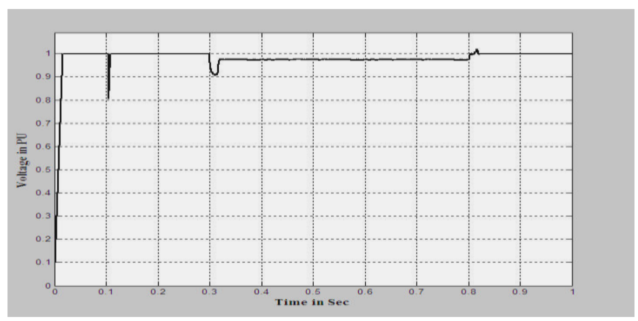


Fig 6.1 VRMS Voltage at the Load Point of the Sag System without D-STATCOM.

The circuit shown is Fig. 5, is nothing but a sag eliminating circuit with the D-STATCOM connected to it is simulated and the magnitude of voltage is as shown in the Fig 6.2.





As shown in fig.6.2, a very effective voltage regulation which is provided by the D-STATCOM can be clearly appreciated. The D-STATCOM supplies reactive power to the system to eliminate the voltage sag. In spite of sudden load variations, the regulated RMS voltage shows a reasonably smooth profile, where the transient overshoots is almost non-existent.

Case-2

Simulated Results of Swell modeled system with and without D-STATCOM:

The circuit shown is Fig. 5, is nothing but a swell generating circuit without the D-STATCOM connected to it is simulated and the magnitude of voltage is as shown in the Fig 6.3.

International Journal of Scientific Engineering and Technology (ISSN : 2277-1581)
Volume 2 Issue 5, pp : 317-321 1 May 2013

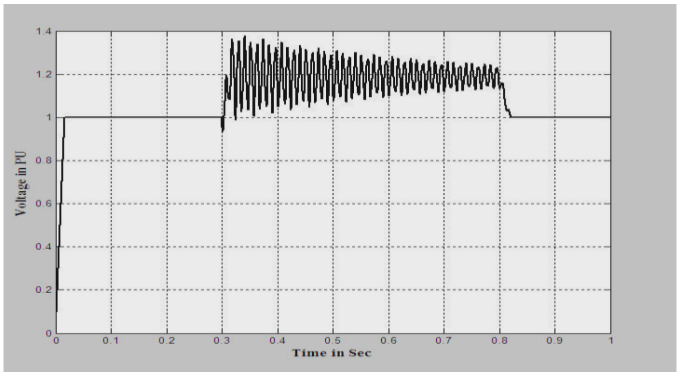
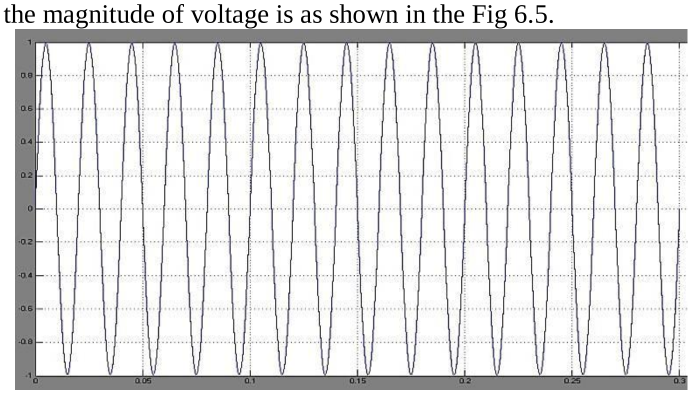


Fig 6.3 VRMS Voltage at the Load Point of the Swell System without D-STATCOM.

The circuit shown is Fig. 6.4, is nothing but a swell eliminating circuit with the D-STATCOM connected to it is simulated and the magnitude of voltage is as shown in the Fig 6.5.



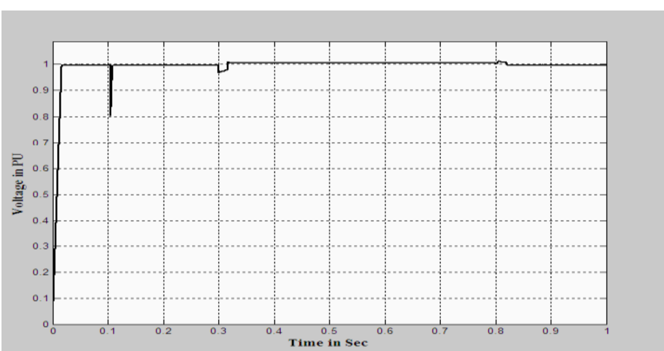


Fig 6.5 VRMS Voltage at the Load Point of the Swell System with D-STATCOM.

As shown in fig.6.5, a very effective voltage regulation which is provided by the D-STATCOM can be clearly appreciated. The D-STATCOM eliminates the voltage swell. In spite of sudden load variations, the regulated RMS voltage shows a reasonably smooth profile, where the transient overshoots is almost non-existent.

V. CONCLUSION

The paper presents voltage regulation in parallel distribution feeders by using multi converter dynamic voltage restorer (MC-DVR). The MC-DVR is connected in shunt between two parallel feeders coming from different substations. Two non-linear loads L-1 and L-2 are supplied by the two feeders. The phase angles of the PCC bus voltages are obtained such that the voltage across the dc link remains constant. The performance of the MC-DVR has been evaluated under the disturbance conditions such as voltage sags in either feeder. It has been demonstrated that bi-directional power flow between the two feeders is possible. This can be accomplished by supplying power from one feeder in case of deep voltage sag in the other feeder and vice versa.

REFERENCES

[1] N.G. Hingorani "Introducing custom power," *IEEE spectrum*, vol.32, June 1995, pp. 41-48.

[2] Ray Arnold "Solutions to Power Quality Problems" power engineering Journal, Volume 15; Issue: 2 April 2001, pp: 65-73.

[3] John Stones and Alan Collision "Introduction to Power Quality" power engineering journal, Volume 15; Issue 2, April 2001, pp: 58-64.

[4] Anaya-Lara, O.; Acha, E." Modeling and analysis of custom power systems by PSCAD/EMTDC", *IEEE Transactions on Power Delivery*, Volume: 17, Issue: 1, Jan. 2002 pp: 266 – 272.

[5] Po-Tai Cheng; Chian-Chung Huang; Chun-Chiang Pan; Bhattacharya, S.;" Design and implementation of a series voltage sag compensator Under practical utility conditions" *IEEE Transactions on Industry Applications*, Volume: 39 , Issue: 3 , May-June 2003

[6] Soo-Young Jung; Tae-Hyun Kim; Seung-Il Moon; Byung-Moon Han;" Analysis and control of DSTATCOM for a line voltage regulation "Power Engineering Society Winter Meeting, 2002. IEEE, Volume: 2, 27-31 Jan. 2002, pp: 729 - 734

[7] Bollen, M.H.J.," Voltage sags in three-phase systems" *Power Engineering Review, IEEE,* Volume: 21, Issue: 9, Sept. 2001, pp: 8 -11, 15.

[8] Hague, M.H." Compensation of distribution system voltage sag by DVR and D-STATCOM", *IEEE Porto Power Tech Conference*, Volume: 1, 10th-13th Sept. 2001.

[9] L. Gyugyi, K. K. Sen and C. D. Schauder, "The interline power flow controller concept: a new approach to power flow management in transmission system," *IEEE Trans. Power Deliv.*, Vol. 14, No. 3, pp. 1115- 1123, 1999.

[10] A. Ghosh and G. Ledwich, *Power Quality Enhancement Using Custom Power Devices*, Norwell, MA: Kluwer, 2002.