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Power Quality Enhancement in Power System Network using DSTACOM

Dr. P. Chandra Sekhar
Associate Professor, Department of Electrical and Electronics Engineering,
MGIT, Hyderabad, (A.P), India.

Abstract: *A problem in Power system network is an occurrence characterized by a nonstandard voltage, current or frequency that results in a failure or a mis-operation of end user equipments. Utility distribution networks, sensitive industrial loads and critical commercial operations suffer from various types of outages and service interruptions which can cost significant financial losses. With the restructuring of power systems and with shifting trend towards distributed and dispersed generation, the issue of power quality is going to take newer dimensions. In developing countries like India, where the variation of power frequency and many such other determinants of power quality are themselves a serious question, it is very vital to take positive steps in this direction .The present work is to identify the prominent concerns in this area and hence the measures that can enhance the quality of the power are recommended. This paper presents the enhancement of voltage sags using Distribution Static Compensator (DSTATCOM) in distribution system. The model is based on the Voltage Source Converter (VSC) principle. The D-STATCOM injects a current into the system to mitigate the voltage sags. The simulations were performed using MATLAB SIMULINK version R2007b.Voltage sags are mitigated.*
Keywords: *D-STATCOM, Voltage Sags, Voltage Source Converter (VSC).*

I. INTRODUCTION

One of the most common power quality problems today is voltage dips. A voltage dip is a short time (10 ms to 1 minute) event during which a reduction in r.m.s voltage magnitude occurs. It is often set only by two parameters, depth/magnitude and duration. The voltage dip magnitude is ranged from 10% to 90% of nominal voltage (which corresponds to 90% to 10% remaining voltage) and with a duration from half a cycle to 1 min. In a three-phase system a voltage dip is by nature a three-phase phenomenon, which affects both the phase-to-ground and phase-to-phase voltages. A voltage dip 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. The high current results in a voltage drop over the network impedance. 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 [1, 2].

Voltage dips are one of the most occurring power quality problems. Off course, for an industry an outage is worse, than a voltage dip, but voltage dips occur more often and cause severe problems and economical losses. Utilities often focus on disturbances from end-user equipment as the main power quality problems. This is correct for many disturbances, 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. If the economical losses due to voltage dips are significant, mitigation actions can be profitable for the customer and even in some cases for the utility. 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.

STATCOM is often used in transmission system. When it is used in distribution system, it is called D-STATCOM（STATCOM in Distribution system). D-STATCOM is a key FACTS controller and it utilizes power electronics to solve many power quality problems commonly faced by distribution systems. Potential applications of D-STATCOM include power factor correction, voltage regulation, load balancing and harmonic reduction. Comparing with the SVC, the D-STATCOM has quicker response time and compact structure. It is expected that the D-STATCOM will replace the roles of SVC in nearly future D-STATCOM and STATCOM are different in both structure and function, while the choice of control strategy is related to the main-circuit structure and main function of compensators [3], so D-STATCOM and STATCOM adopt different control strategy. At present, the use of STATCOM is wide and its strategy is mature, while the introduction of D-STATCOM is seldom reported. Refer to the strategies for STATCOM, in this paper; a compound control strategy used in D-STATCOM is presented to achieve the purpose of rapid-response compensation. A PWM-based control scheme has been implemented to control the electronic valves in the two-level VSC used in the D-STATCOM [5, 10].

II. DISTRIBUTION STATIC COMPENSATOR (D-STATCOM)

A D-STATCOM consists of a two-level VSC, a dc energystorage device, controller and a coupling transformer\ connected in shunt to the distribution network. Figure 2.1 shows the schematic diagram of D-STATCOM.

$$I_{out} = I_L - I_S = I_L - \frac{V_{th} - V_L}{Z_{th}} \quad (2.1)$$

$$I_{out} < \gamma = I_L < (-\theta) - \frac{V_{th}}{Z_{th}} < (\delta - \beta) + \frac{V_L}{Z_{th}} < (-\beta) \quad (2.2)$$

$I_{out} = output\ current$ $\quad I_L = load\ current$
$I_S = source\ current$ $\quad V_{th} = Thevenin\ Voltage$
$V_L = load\ voltage$ $\quad Z_{th} = impedance$

Referring to the equation 2.2, output current, Iout will correct the voltage sags by adjusting the voltage drop across the system impedance, (Zth=***R+jX***). It may be mention that the effectiveness of D-STATCOM in correcting voltage sags depends on:

a) The value of Impedance, Zth= ***R+jX***
b) The fault level of the load bus

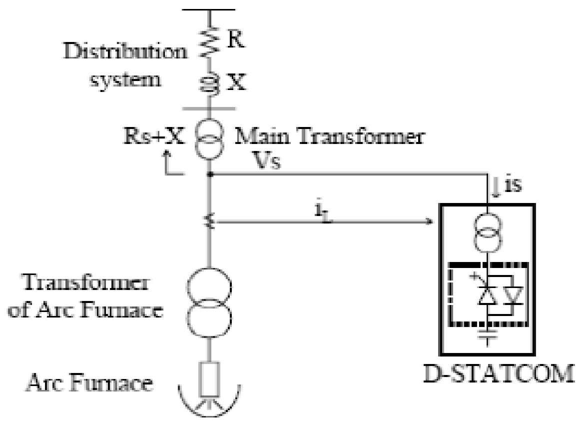

Figure2.1. Schematic diagram of a D-STATCOM

A. Voltage Source Converter (VSC)

A voltage-source converter is a power electronic device that connected in shunt or parallel to the system. It can generate a sinusoidal voltage with any required magnitude, frequency and phase angle. The VSC used to either completely replace the voltage or to inject the 'missing voltage'. The 'missing voltage' is the difference between the nominal voltage and the actual. It also converts the DC voltage across storage devices into a set of three phase AC output voltages [8, 9]. In addition, D-STATCOM is also capable to generate or absorbs reactive power. If the output voltage of the VSC is greater than AC bus terminal voltages, D-STATCOM is said to be in capacitive mode. So, it will compensate the reactive power through AC system and regulates missing voltages. These voltages are in phase and coupled with the AC system through the reactance of coupling transformers. Suitable adjustment of the phase and magnitude of the DSTATCOM output voltages allows effectives control of active and reactive power exchanges between D-STATCOM and AC system. In addition, the converter is normally based on some kind of energy storage, which will supply the converter with a DC voltage [10].

B. Controller

Figure 2.2 shows the block diagram of Controller system. The controller system is partially part of distribution system. Proportional-integral controller (PI Controller) is a feedback controller which drives the system to be controlled with a weighted sum of the error signal (difference between the output and desired set point) and the integral of that value. In this case, PI controller will process the error signal to zero. The load r.m.s voltage is brought back to the reference voltage by comparing the reference voltage with the r.m.s voltages that had been measured at the load point. It also is used to control the flow of reactive power from the DC capacitor storage circuit. PWM generator is the device that generates the Sinusoidal PWM waveform or signal.

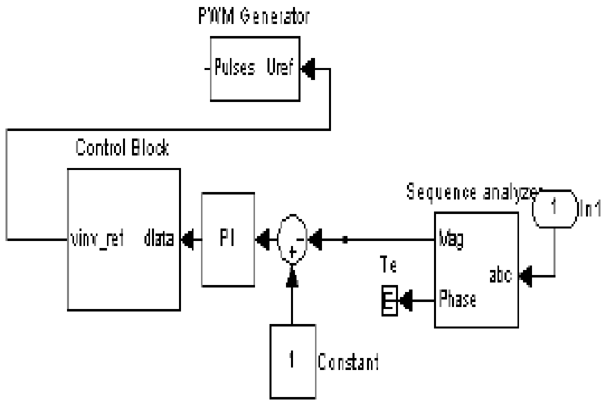

Figure 2.2.Block Diagram of Controller System

To operate PWM generator, the angle is summed with the phase angle of the balance supply voltages equally at 120 degrees. Therefore, it can produce the desired synchronizing signal that required. PWM generator also received the error signal angle from PI controller. The modulated signal is compared against a triangle signal in order to generate the switching signals for VSC valves.

C. Instantaneous Current Component (id-iq) Theory

The Modified Synchronous Frame method is presented in [7]. It is called the instantaneous current component (id-iq) method. This is similar to the SRF frame method. The transformation angle is now obtained with the voltages of the ac network. The major difference is that, due to voltage harmonics and imbalance, the speed of the reference frame is no longer constant. It varies instantaneously depending of the waveform of the three phase voltage system. In this method the compensating currents are obtained from the instantaneous active and reactive current components and of the nonlinear load. In the same way, the mains voltages V(a,b,c) and the polluted currents il(a,b,c) in α-β components must be calculated as given by (2), where C is Clarke Transformation Matrix. However, the load current components are derived from a synchronous reference frame based on the Park transformation, where represents the instantaneous voltage vector angle (3).

$$\begin{bmatrix} \mathrm{il}_\alpha \\ \mathrm{il}_\beta \end{bmatrix} = [C] \begin{bmatrix} I_{la} \\ I_{lb} \\ I_{lc} \end{bmatrix}$$

$$\begin{bmatrix} \mathrm{il}_d \\ \mathrm{il}_q \end{bmatrix} = \begin{bmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} \mathrm{il}_\alpha \\ \mathrm{il}_\beta \end{bmatrix} , \theta = \tan^{-1}\frac{v_\beta}{v_\alpha}$$

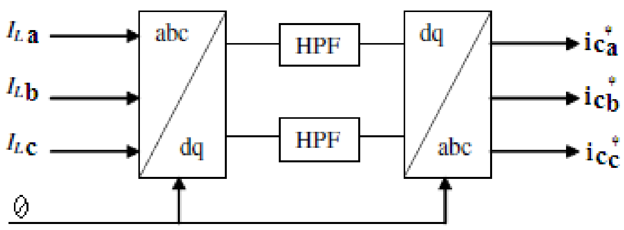

Figure.2.3 Principal of the synchronous reference frame method

Fig. 2.3 shows the block diagram SRF method. Under balanced and sinusoidal mains voltage conditions angle θ is a uniformly increasing function of time. This transformation angle is sensitive to voltage harmonics and unbalance; therefore dθ/dt may not be constant over a mains period. With transformation (2) and (3) the direct voltage component is

$$\begin{bmatrix} il_d \\ il_q \end{bmatrix} = \frac{1}{\sqrt{V_\alpha{}^2 + V_\beta{}^2}} \begin{bmatrix} V_\alpha & V_\beta \\ -V_\beta & V_\alpha \end{bmatrix} \begin{bmatrix} il_\alpha \\ il_\beta \end{bmatrix}$$

$$\begin{bmatrix} ic_\alpha \\ ic_\beta \end{bmatrix} = \frac{1}{\sqrt{V_\alpha{}^2 + V_\beta{}^2}} \begin{bmatrix} V_\alpha & -V_\beta \\ V_\beta & V_\alpha \end{bmatrix} \begin{bmatrix} ic_d \\ ic_q \end{bmatrix}$$

$$\begin{bmatrix} I_{comp,a} \\ I_{comp,b} \\ I_{comp,c} \end{bmatrix} = [C]^T \begin{bmatrix} ic_\alpha \\ ic_\beta \end{bmatrix}$$

III. MATLAB/SIMULINK MODELING AND SIMULATION RESULTS

Fig. 4 shows the Matlab/Simulink model of distribution system with DSTATCOM. Fig.5 shows the internal view of DSTATCOM. In this paper simulation is carried out in two cases. In case one we have considered load disturbance means sudden change of reactive load without DSTATCOM and with DSTATCOM. In case two we have considered line disturbance like single line to ground fault (SLG), without DSTATCOM and with DSTATCOM.

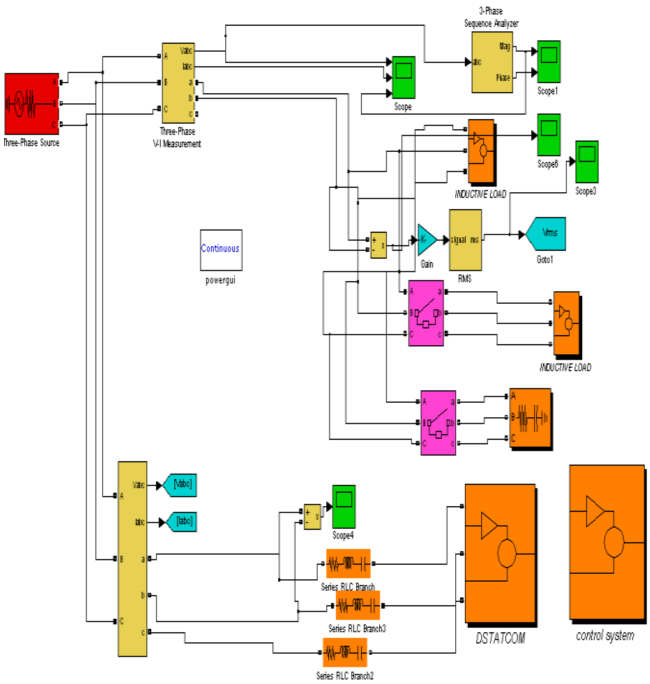

Figure. 3 Matlab/Simulink Model of DSTATCOM

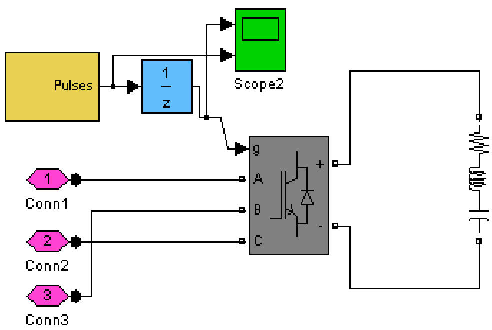

Figure. 4 DSTATCOM Internal view

A Case One

Fig. 5 shows the three phase voltage and three phase currents and RMS value of one line voltage. Here at t=0.2 sec a inductive load is switched ON the line voltage fall from1 P.U to 0.8 P.U

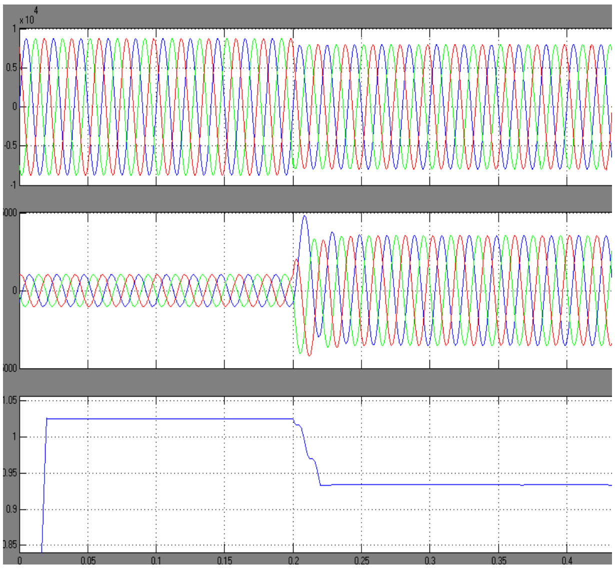

Figure. 5 Simulation results without DSTATCOM

Fig. 6 shows the RMS value of one line voltage with DSTATCOM. Here at t=0.2 sec a inductive load is switched ON the line voltage fall from1 P.U to 0.98 P.U

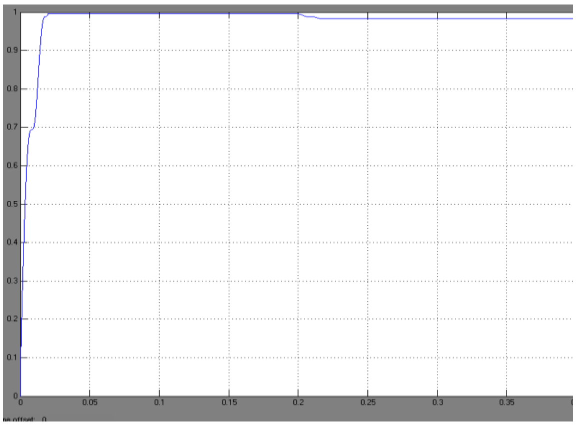

Figure. 6 Simulation results with DSTATCOM

B Case two

Fig. 7 shows RMS value of line voltage. Here at t=0.2 sec a SLG fault is created the line voltage fall from1 P.U to 0.78 P.U.

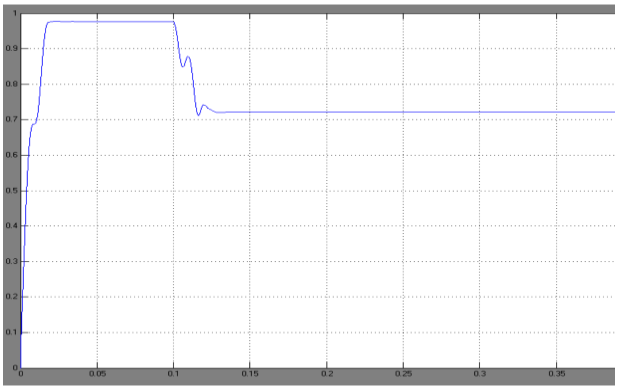

Figure. 7 Simulation results without DSTATCOM

Fig. 8 shows the RMS value of line voltage with DSTATCOM. Here at t=0.2 sec a SLG fault is created the line voltage fall from1 P.U to 0.98 P.U

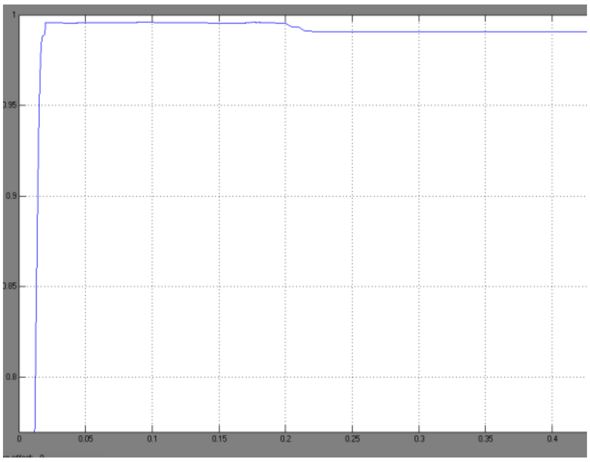

Figure. 8 Simulation results with DSTATCOM

IV. CONCLUSION

DSTATCOM system is an efficient mean for mitigation of PQ disturbances introduced to the grid by DERs. DSTATCOM compensator is a flexible device which can operate in current control mode for compensating voltage variation, unbalance and reactive power and in voltage control mode as a voltage stabilizer. The latter feature enables its application for compensation of dips coming from the supplying network. The simulation results show that the voltage sags can be mitigate by inserting D-STATCOM to the distribution system. The same analysis can be carried out for Double Line to Ground (DLG) fault and Three Line to Ground (TLG) fault also.

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