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Mitigation of Voltage SAG and Voltage Swells By Controlling the DSTATCOM

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Abstract: **In this paper an overview of DSTATCOM is presented. The power quality problems such as voltage sags and swells and its severe impact on nonlinear loads or sensitive loads. The DSTATCOM is an effective custom power device for voltage sags and swells mitigation. This paper describes the mitigation of voltage sags and swells. The design procedure for various components of DSTATCOM is presented. The control of the Voltage Source Converter (VSC) is done with the help of SPWM. The proposed D-STATCOM is modeled and simulated using MATLAB/SIMULINK software. The simulation results show clearly the performance of a DSTATCOM in mitigating voltage sags and swells and also it has a fast dynamic response**

Index terms: **DSTATCOM, Power Quality Problems, Sinusoidal Pulse Width Modulation, Voltage Source Converter.**

I. INTRODUCTION

An increasing demand for high quality, reliable electrical power and increasing number of distorting loads may leads toan increased awareness of power quality both by customersand utilities. The most common power quality problems todayare voltage sags, harmonic distortion and low power factor.

Power Electronics and Advanced Control technologies have made it possible to mitigate power quality problems and maintain the operation of sensitive loads. Among power system disturbances, voltage sags, swells and harmonics are some of the severe problems to the sensitive loads. The series compensation method is best suited to protect such loads against those disturbances. The use of a series compensator (SC) to improve power quality is an isolated power system is investigated. The role of the compensator is not only to mitigate the effects of voltage sag, but also to reduce the harmonic distortion due to the presence of non linear loads in the network. In this paper, a Distribution STATCOM (DSTATCOM) is proposed and a method of harmonic compensation is described and a method to mitigate voltage sag is investigated.

In This paper presents the systematic procedure of the modeling and simulation of a Distribution STATCOM (DSTATCOM) for power quality problems, voltage sag and swell based on Sinusoidal Pulse Width Modulation (SPWM) technique. Power quality is an occurrence manifested as a nonstandard voltage, current or frequency that results in a failure of end use equipments. The major problems dealt here is the voltage sag and swell. To solve this problem, custom power devices are used. One of those devices is the Distribution STATCOM (D-STATCOM), which is the most efficient and effective modern custom power device used in power distribution networks. D-STATCOM injects a current in to the system to correct the voltage sag and swell. The control of the Voltage Source Converter (VSC) is done with the help of SPWM. The proposed D-STATCOM is modeled and simulated using MATLAB/SIMULINK software.

II. POWER QUALITY PROBLEMS

The power disturbances occur on all electrical systems and electronic devices make. In distribution systems and for some sensitive devices, Power quality problems create a wide range of disturbances such as voltage sags, swells, flickers, harmonic distortion, impulse transients, and interruptions.

Power quality-

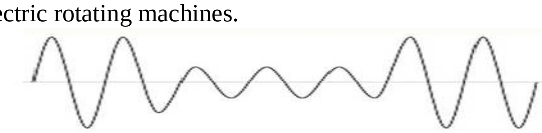
Power quality is a term that mean different to different people. Institute of Electrical and electrical engineers (IEEE) standard IEEE 1100 defines power quality "as the concept of powering and grounding sensitive electronic equipment in a manner suitable for the equipment".

Types of power quality problems

1. Voltage sag (or dip): It is a dip of .1 to .9 p.u. in rms voltage or current at the power frequency, for interval of 0,5 cycle to 1 minute.

Causes: Whenever a load end draws a heavy current suddenly. That's why it is associated with faults on the transmission or distribution network, faults in consumer's installation, sudden connection of heavy loads and start-up of large motors.

Consequences: Malfunction of microprocessor-based control systems (PCs, PLCs, ASDs, etc), that may cause false tripping of contactors and electromechanical relays. Mal-operation of electric rotating machines.



2. Voltage swells: Momentary increase of the voltage, at the power frequency, outside the normal tolerances, with duration of more than one cycle and typically less than a few seconds.

Causes: Start/stop of heavy loads, badly dimensioned power sources, badly regulated transformers (mainly during off-peak hours).

Consequences: Data loss, flickering of light and screens, stoppage or damage of sensitive equipment, if the voltage values are too high.

III. DISTRIBUTION STATIC COMPENSATOR (D-STATCOM)

D-STATCOM consists of a two-level VSC, a dc energy storage device, controller and a coupling transformer connected in shunt to the distribution network. Figure 1. Shows the schematic diagram of D-STATCOM.

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

$$I_{out} < \gamma = I_L < (-\theta) - \frac{V_{th}}{Z_{th}} < (\delta - \beta) + \frac{V_L}{Z_{th}} < (-\beta) \quad (2)$$

Referring to the equation (2), output current, will correct the voltage sags by adjusting the voltage drop across the system impedance, ($Z_{th} = R + jX$). It may be mention that the effectiveness of D-STATCOM in correcting voltage sags depends on:

a) The value of Impedance, $Z_{th} = R + jX$
b) The fault level of the load bus

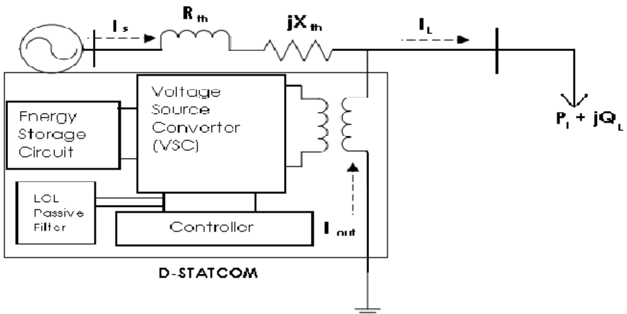


Fig 1: Schematic diagram of a D-STATCOM

IV. 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

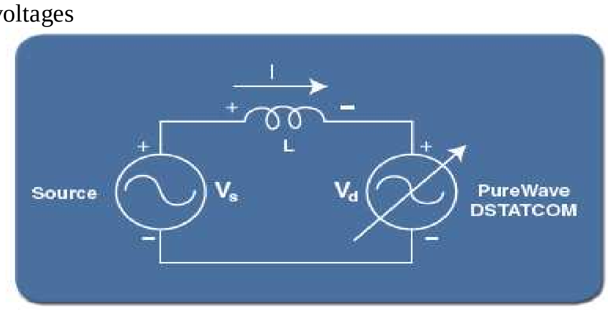


Fig 2: Voltage Source Converter

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.

V. SINUSOIDAL PULSE WIDTH MODULATION BASED CONTROL

The aim of the control scheme is to maintain constant voltage magnitude at the point where a sensitive load is connected, under system disturbance. The control system only measures the rms voltage at the load point i.e., no reactive power measurements are required [9]. The VSC switching strategy is based on sinusoidal PWM technique which offers simplicity and good response.

The PI controller process identifies the error signal and generates the required angle δ to drive the error to zero, i.e., the load rms voltage is brought back to the reference voltage. In the PWM generator, the sinusoidal signal V_{comrol} is compared against a triangular signal (carrier) in order to generate the switching signals for the VSC valves [1], [2]. The main parameters of the sinusoidal PWM scheme are the amplitude modulation index M_a of signal $v_{control}$ and the frequency modulation index M_f of the triangular signal. The amplitude index Ma is kept fixed at 1 pu.

$$M_{a=} V_{comrol/Vin}$$

Where Vcomrol is the Peak amplitude of the signal. Vin is the peak amplitude of the Triangular signal.

In order to obtain the highest fundamental voltage component at the controller output [10], the switching frequency is set at 450 Hz. The frequency of modulation index is given by,

Mf =fs/ff=450/50=9

Where M f is the frequency of modulation index, fs is the switching frequency, ff is the fundamental frequency.

In this paper, balanced network and operating conditions are assumed. The modulation angle δ is applied to the PWM generator in phase A. The angle for phases B and C are shifted by 240° and 120°, respectively.

VI. METHODOLOGY AND SIMULINK MODEL FOR THE PROPOSED SYSTEM

To enhance the performance of distribution system, D-STATCOM was connected to the distribution system. The performance of the distribution system in terms of power quality problems is analysed by connecting the D-STATCOM. Distribution STATCOM was designed using MATLAB simulink software. The simulink model for the proposed system is as shown in fig 3. 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

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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 75 μF capacitor on the dc side provides the DSTATCOM energy storage capabilities. Circuit Breaker is used to control the period of operation of the D-STATCOM.

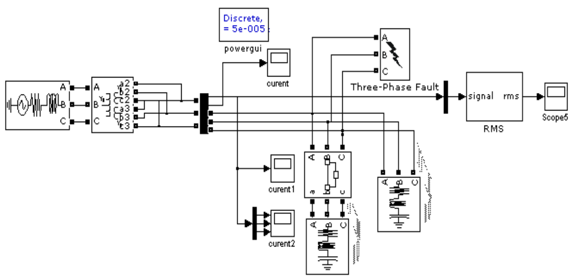

Fig. 3a. Simulation diagram without DSTATCOM

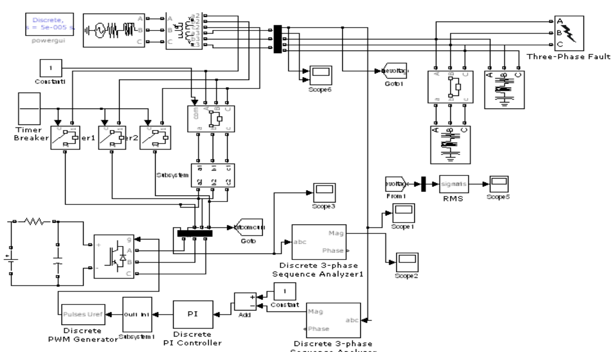

Fig 3b. Simulation diagram with DSTATCOM

a. D-STATCOM Simulations and Results for Voltage Sag

Fig 4a. The simulation results without D-STATCOM and for a three-phase short-circuit fault is applied at load point with a fault resistance of 0.2, during the period 300-600 ms. The voltage sag at the load point is 36% with respect to the reference voltage.

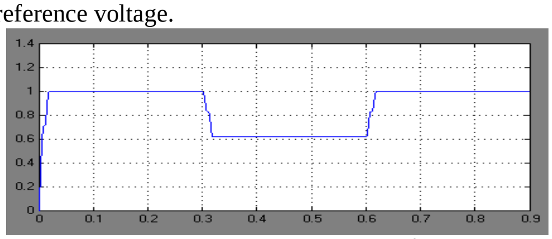

Fig. 4a.1. Voltage V: ms at load point, with three-phase fault: (a) Without DSTATCOM .

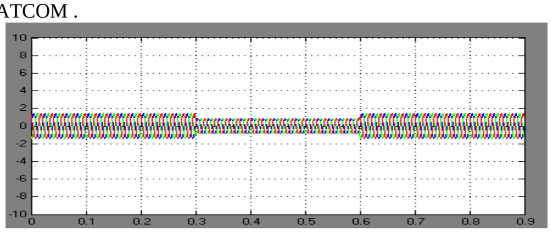

Fig 4a.2. Voltage sag in three-phase voltage.

Fig 4a.With three-phase fault: (a) Without DSTATCOM.

Fig 4b. The second simulation is carried out using the same scenario as above, but now D-STATCOM is connected to the system, then the voltage sag is mitigated almost completely, and the rms voltage at the sensitive load point is maintained at 99% as shown in Fig. 4(b).

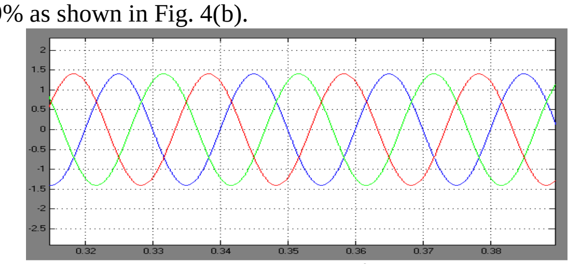

Fig 4b.1. three-phase voltage, with three-phase fault: with DSTATCOM

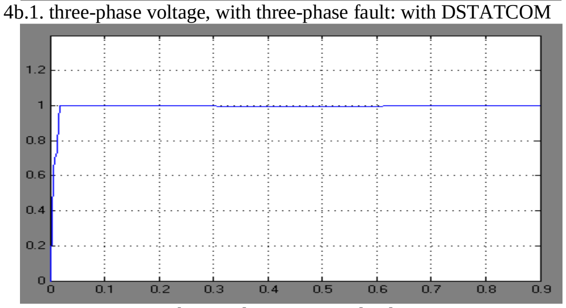

Fig. 4b. 2. Voltage V:.ms at load point,

Fig.4b.With three-phase fault: With D-STATCOM.

Simulations Results for Voltage Sag (for the fault resistance of 0.4 ohms)

The simulation results for same test system with a fault resistance of 0.4 ohms, during the period 300-600 ms, without DSTATCOM as shown in fig 5a. The voltage sag at the load point is 30% with respect to the reference voltage.

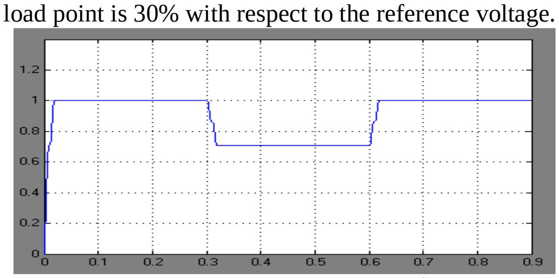

Fig. 5a.1. Voltage V: ms at load point, with three-phase fault: (a) Without DSTATCOM .

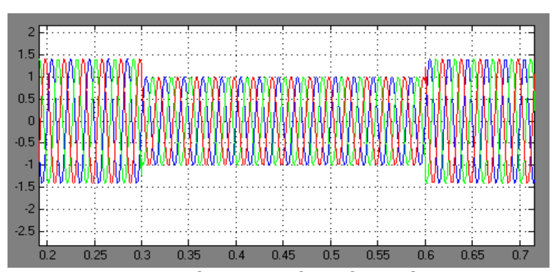

Fig 5a.2. Voltage sag in three-phase voltage.

Fig 5b. shows the compensated voltage sag for same test system for the fault resistance as mentioned above in fig 5a,with D-STATCOM is connected to the system, then the

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voltage sag is mitigated almost completely, and the rms voltage at the sensitive load point is maintained at 99% as shown in Fig. 5(b).

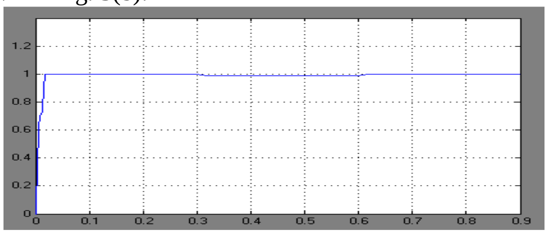

Fig. 5b.1. Voltage V:r ms at load point, With DSTATCOM .

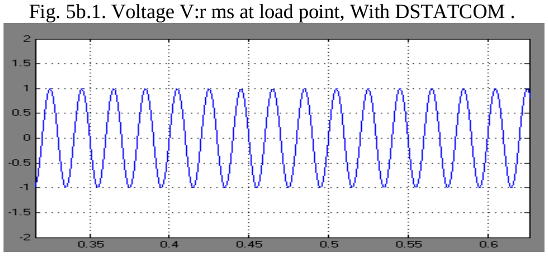

Fig 5b.2. DSTATCOM injected current into the system

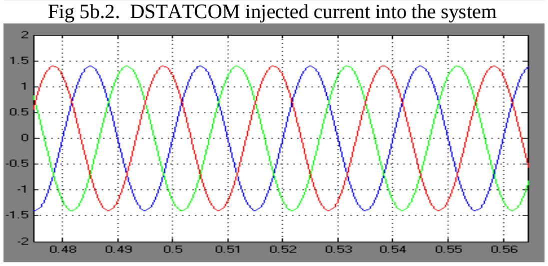

Fig 5b.3. Voltage sag in three-phase voltage.

b. DSTATCOM Simulations and results for voltage swell

Fig. 3 shows the test system used to carry out the DSTATCOM simulations and results for voltage swell.

The first simulation contains no DSTATCOM and a three-phase fault is applied at point A, during the period 300-600 ms. The voltage swell at the load point is 20% with respect to the reference voltage, as shown in Fig. 6a.

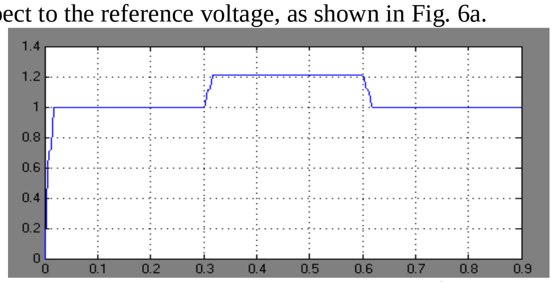

Fig. 6a.1. Voltage V: rms at load point, with three-phase fault: (a) Without DSTATCOM .

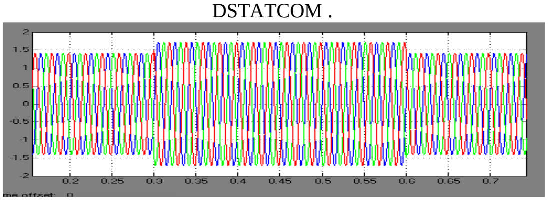

Fig 6a.2. Voltage swell in three-phase voltage.
Fig 6a.With three-phase fault: (a) Without DSTATCOM.

The second simulation is carried out using the same scenario as above, but now D-STATCOM is connected to the system, then the voltage swell is mitigated almost completely, and the rms voltage at the sensitive load point is maintained at 98% as shown in Fig.6b.

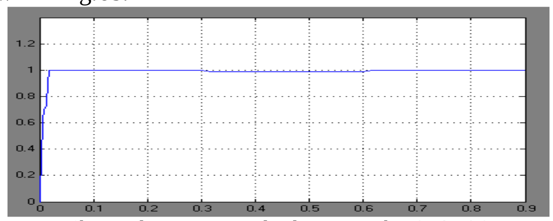

Fig. 6b.1. Voltage V:r ms at load point, With DSTATCOM .

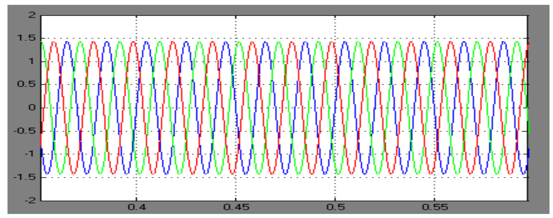

Fig 6b.2. Compensated three-phase voltage .
Fig 6b.With three-phase fault With DSTATCOM.

VII. CONCLUSION

This paper describes the problem of voltage sags and swells and its severe impact on nonlinear loads or sensitive loads. The design procedure for various components of DSTATCOM is presented. The control of the Voltage Source Converter (VSC) is done with the help of SPWM. The proposed D-STATCOM is modeled and simulated using MATLAB/SIMULINK software. The simulation results show clearly the performance of a DSTATCOM in mitigating voltage sags and swells and also it has a fast dynamic response. The further work focuses on the study of DSTATCOM by using multilevel inverter instead of VSC.

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BIOGRAPHIES

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