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POWER QUALITY AND RELIABILITY ENHANCEMENT BY DSTATCOM

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ABSTRACT

Over the recent period of time, power quality problems have been marked as a buzzing issue with regards to promote delicate or miniature power electronic devices where Voltage sag problem is the most frequently occurring as well as detrimental power quality problems. Thus, the purpose of this study is to assuage voltage sag problem using proposed Distribution Static Synchronous Compensator (D-STATCOM). 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. In developing countries such as India, where the power frequency and many such other determinants of power quality are themselves a serious question. The DSTATCOM is a most effective device which is based on the VSC principle. In this paper DSTATCOM, under different faults is analyzed. The modeling and simulation of the proposed shunt compensator was implemented in MATLAB Simulink environment. Simulation results showed that the proposed shunt compensator was efficient in mitigating voltage sags power system.

Keywords: Power Quality, Distribution Static Synchronous Compensator (DSTATCOM), Voltage Source Converter (VSC), MATLAB.

I. INTRODUCTION

Due to the increasing demand for high quality, reliable electrical power and increasing number of distorting loads may leads tons of increased awareness of power quality both by the customers and utilities[1]. The most common power quality problems today exist in power system are voltage sags, harmonic distortion and low power factor. Among power system disturbance-voltage sags, swells and harmonics are some of the severe problems to the sensitive loads [2]. The role of the compensator is not only to mitigate the effects of voltage sag/swell, but also to reduce the harmonic distortion due to the presence non linear loads in the network. In this paper, a Distribution STATCOM (DSTATCOM) is proposed, for the mitigation voltage sag is investigated. This paper deals with the systematic procedure of the modeling and simulation of a DSTATCOM for power quality problems, voltage sag and swell based on Sinusoidal Pulse Width Modulation (SPWM) technique [4]. The major problems dealt here is the voltage sag and swell. To solve such problems, custom power devices are used. One among those devices is the DSTATCOM (Distribution STATCOM), which is the most efficient and effective modern custom power device used in power distribution networks. The control of the Voltage Source Converter (VSC) is done with the help of SPWM technique. The proposed system is modeled and simulated through MATLAB /SIMULINK.

II. OVERVIEW OF POWER QUALITY PROBLEMS

The power disturbances eventuate on all electrical systems and electronic devices. In distribution systems and for some of the sensitive devices i.e. personal systems, adjustable speed drives contractors and relays [4]. Power quality problems create a wide range of disturbances such as voltage sags (or dip), swells, flickers, harmonic distortion, impulse transients, long and short interruptions, Voltage spikes and noise [5].

Power quality as per IEEE standard defined as “the concept of powering and grounding sensitive electronic equipment in a manner suitable for the equipment” [2].

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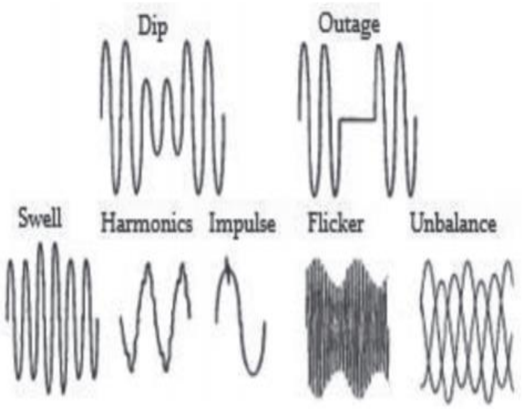

Fig. 1(a) Various Types of power Quality Problem

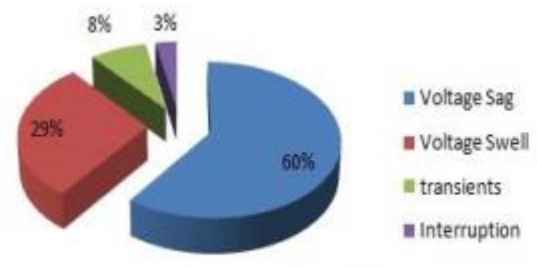

Fig. 1(b) Classification of power quality problems

III. METHODOLOGY

A. DISTRIBUTED STATIC COMPENSATOR (DSTATCOM)

D-STATCOM is the most important controller for distribution networks. It has been widely used to regulate system voltage along with improve voltage profile, reduce voltage harmonics, reduce transient voltage disturbances and load compensation [5]. The DSTATCOM uses a power electronics converter is controlled using pulse width modulation. It consists of a two level self-commutated Voltage source converter (VSC), a dc energy storage device, a coupling transformer connected in shunt (parallel) with the distribution network through a coupling transformer[6]. Such configuration allows the device to absorb or generate controllable active and reactive power. The DSTATCOM has been utilized mainly for the regulation of voltage, power factor correction and elimination of current harmonics[8]. Such a device is employed to provide the continuous voltage regulation using an indirectly controlled converter. The D-STATCOM is used to regulate the voltage at the point of connection. The control is based on sinusoidal PWM control and requires the measurement of the value of RMS voltage at the load point. The Distribution Static Compensator (DSTATCOM) is a voltage source inverter based static compensator that is used for the correction of bus voltage sags. It may be mention that the effectiveness of D-STATCOM in correcting voltage sags depends upon the following:

a)The value of Impedance of the line and,
b)The fault level of the load bus

The major components of a D-STATCOM are shown in Fig.2 It consists of a source, DC link capacitor, one or more inverter modules, an ac filter, a transformer to match the inverter output to the line voltage [8].

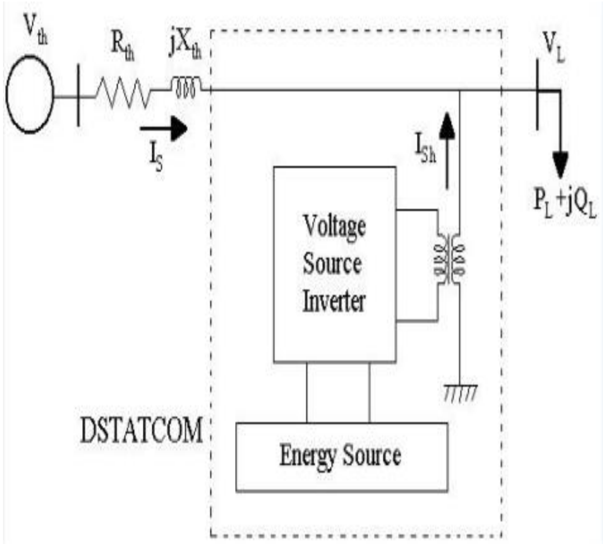

Fig.. 2 Structure of DSTATCOM

B. MATHMATICAL MODELLING OF DSTATCOM

The shunt injected current I_{sh} corrects the voltage sag by adjusting the voltage drop across the system impedance Z_{th} and the value of I_{sh} can be controlled by adjusting the output voltage of the converter in the system. The injected current I_{sh} can be written as,

$$I_{sh} = I_L - I_S$$

Here source current is

$$I_s = \frac{V_{th} - V_L}{Z_{th}}$$

The injected shunt current is

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

In Polar form

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

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

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

Where, I_{out} = Output current,
I_L = Load current,
I_s= Source current,
V_L = Load voltage,
V_{th}= Thevenin voltage,
Z_{th}= Impedance (Z_{th}=R+jX)

It shows that the effectiveness of the DSTATCOM in correcting voltage sag depends on the value of Z_{th} or fault level of the load bus. The shunt injected current I_{sh} is kept in quadrature along with the V_L, the desired voltage correction can be accomplished without injecting any active power into the power system. On the other hand, when the value of I_{sh} is minimized, the same voltage correction can also be achieved with the minimum apparent power injection into the power system.

Three Phase Voltage Source Converter (VSC) & Controller

VSC is the heart of most new FACTS power equipments used in power electronics. Voltage source converters (VSC) are commonly used to transfer the power between a dc and an ac system or in back to back connection for ac systems with different frequencies. VSC is a power electronic device, which can generate a three-phase ac output voltage, which is controllable in phase and magnitude [1].

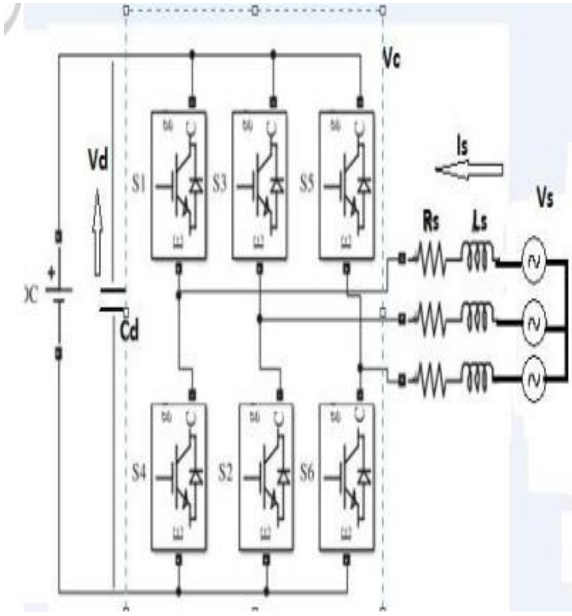

Fig.3 Voltage source converter

These voltages are injected into ac distribution network in order to keep the load voltage at the desired voltage reference. VSCs are widely used in not only for adjustable speed drives, but can also be used to mitigate the voltage sags/swells in the system. VSC is used either to completely replace the voltage or to inject the 'missing voltage'. The 'missing voltage' can be defined as the difference between the nominal voltage and the actual voltage. The converter is generally based on some kind of energy storage, which will supply the converter with a dc voltage. A basic VSC structure is shown in Fig. 3 where Rs and Ls represents the resistance and inductance between the converter ac voltages V and the ac system voltage Vs and I_s is the current injected into the grid. A dc capacitor is connected on the dc side in parallel with the energy storage device to produce a smooth dc voltage. IGBTs are connected in antiparallel with diodes for commutation purposes in the system and for charging of the DC capacitor [9]. The main aim of the control scheme is to provide constant voltage at the point where a sensitive load is connected, under system disturbance. The control system measures only the RMS voltage at the load point i.e., no reactive power measurements are required in the system [10]. The VSC switching [4][5] strategy is based on the sinusoidal PWM technique which offers simplicity and a good response. The PI controller identifies the error signal and generates the required angle (α) to drive the error to 0, i.e., the load RMS voltage is brought back to reference voltage. As in the PWM generator, the sinusoidal signal $V_{control}$ is compared with a triangular signal (carrier) in order to generate the switching signals for the VSC valves [11].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 and the amplitude index

$$M_a = V_{control}/V_{in}$$

where, $V_{control}$ - Peak amplitude of the signal.

V_{in} -peak amplitude of the Triangular signal. In order to have the highest fundamental voltage component at the controller output [10], the switching frequency is set at the 450 Hz. The frequency of the modulation index M_f is given by,

$$M_f=f_s/f_f=450/50=9$$

Where M_f - the frequency of modulation index, f_s -the frequency, f_f - the fundamental frequency. The modulation angle δ is applied to the PWM generator in phase A and the angle for the phases B and C are shifted by 240° and 120°, respectively.

SIMULINK MODEL FOR THE DSTATCOM

In order to enhance the performance of the distribution network, DSTATCOM is connected in shunt with the distribution system. The performance of the distribution system in terms of power quality problems is analyzed by the DSTATCOM. DSTATCOM was designed using MATLAB Simulink software.

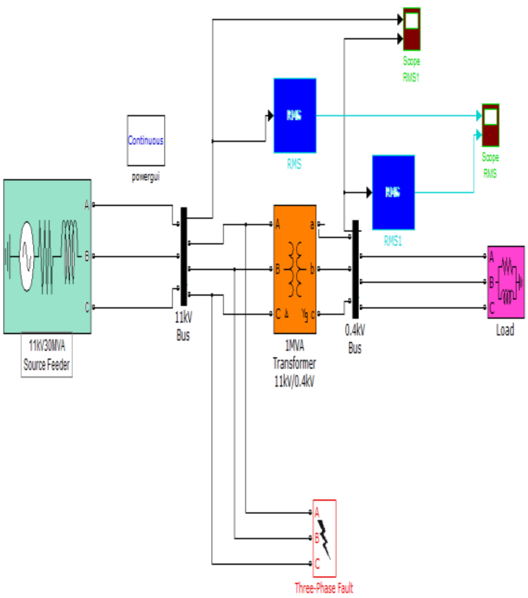

Fig.4 simulation without DSTATCOM

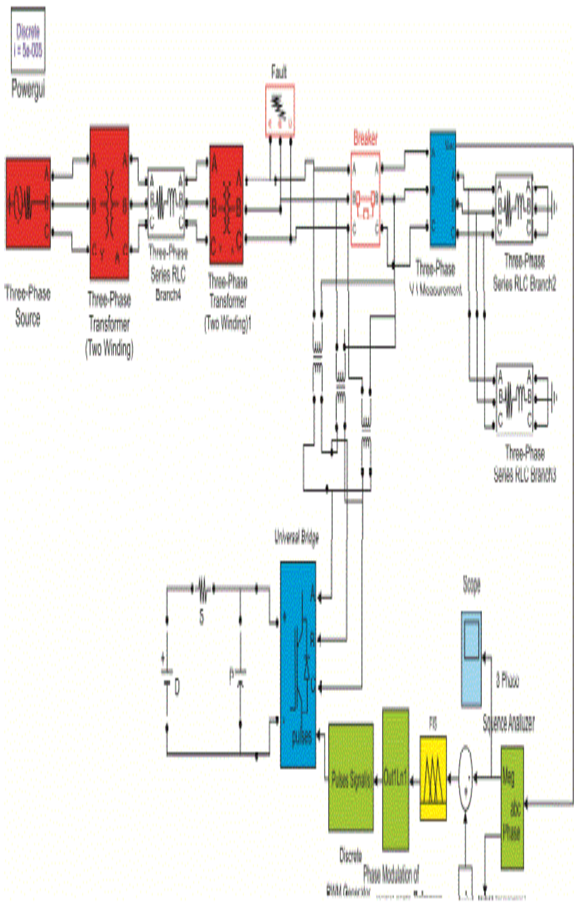

Fig.5 simulation with DSTATCOM

In Fig.4 Simulation of DSTATCOM is shown for the proposed system Comprises a 230kV, 50Hz transmission system and represented by a Thevenin equivalent, feeding into the primary side of a 3-phase winding transformer connected in Y/Y/Y, 230/11/11 kV. A varying load is connected at the 11 kV, secondary side of transformer. A two-level DSTATCOM is connected to the 11 kV tertiary winding to provide instantaneous voltage support at the load point in the system. A 75 µF capacitor on the dc side provides the DSTATCOM energy storage capabilities. A Circuit Breaker is used for providing to control the period of operation of the DSTATCOM.

Results for Voltage Sag for three phase Faults

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

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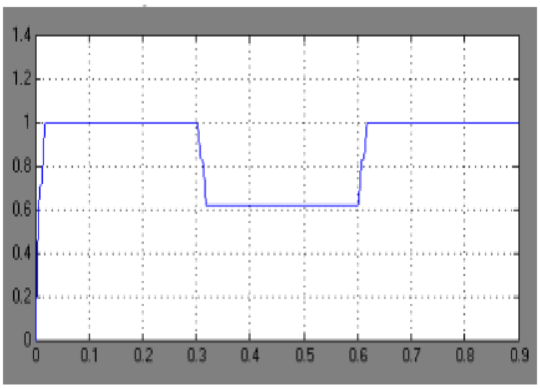

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g. 4a.1 Voltage V: rms at load point, with three- phase fault: Without DSTATCOM

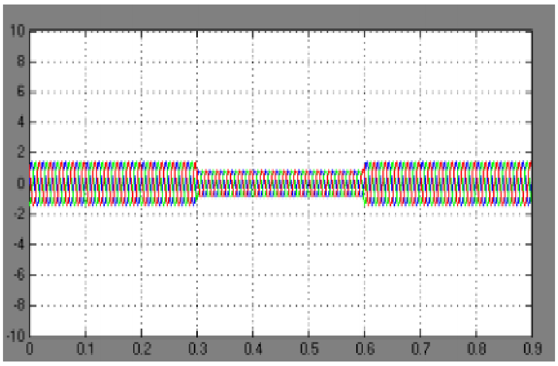


Fig. 4a.2. Voltage sag in three-phase

Fig. 4.2.With three-phase fault: (a) Without DSTATCOM

In Fig. 5a., the second simulation is carried out by using the same scenario as above, but now DSTATCOM 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. 5(b).

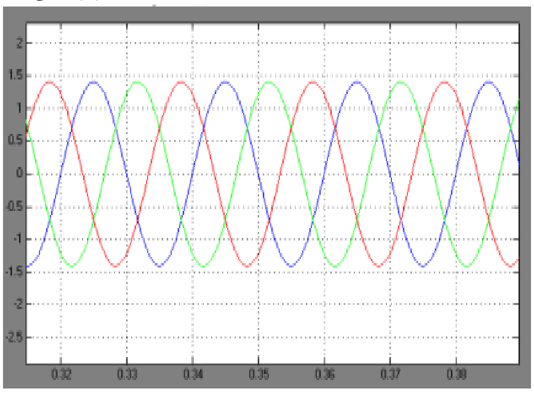


Fig. 5a.1: three-phase voltage, with three-phase fault: with DSTATCOM

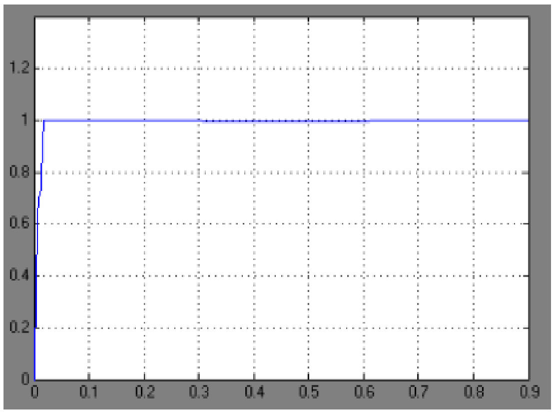


Fig.5a.2: Voltage V:.ms at load point

Fig. 5a: With three-phase fault: With D-STATCOM.

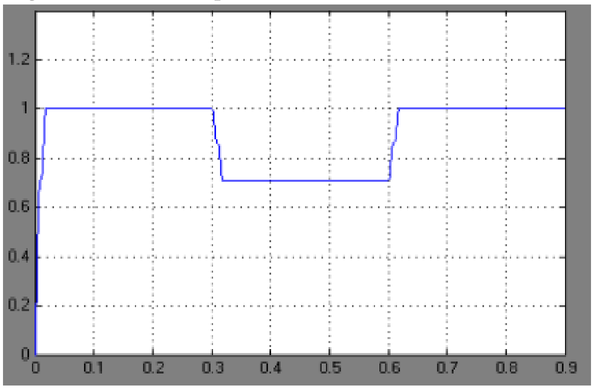
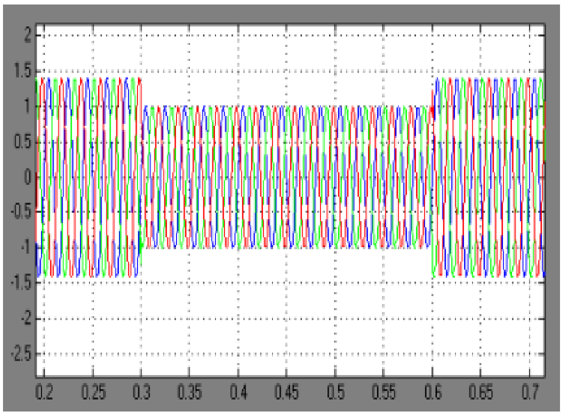


Fig. 5b.1: Voltage V: ms at load point, with three- phase fault : (a)Without DSTATCOM



. Fig. 5b.2: Voltage sag in three-phase voltage.

Fig. 5c. shows the compensated voltage sag for same test system for the fault resistance as mentioned in the above Fig. 5a,with 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. 5(c).

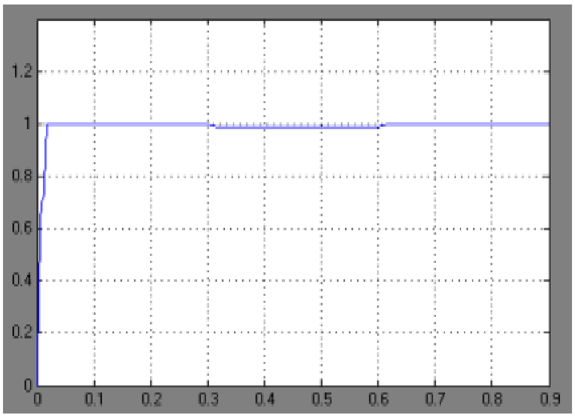


Fig. 5c.1: Voltage V:rms at load point, With DSTATCOM

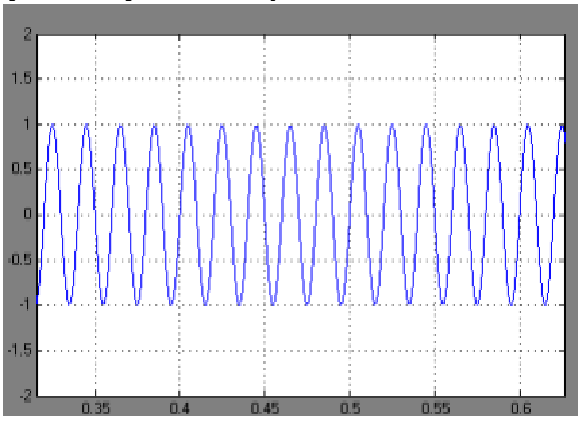


Fig. 5c.2. DSTATCOM injected current into the system

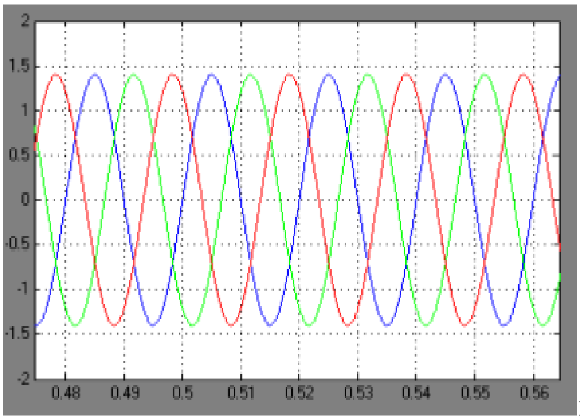


Fig. 5c.3. Voltage sags in three-phase voltage.

CONCLUSION

This paper presents the problem of voltage sags and its severe impact on nonlinear loads and on sensitive loads. The design procedure for the various components of DSTATCOM is presented. The control of the Voltage Source Converter (VSC) is done with the help of SPWM. The proposed DSTATCOM is modeled and simulated using MATLAB/SIMULINK software. The simulation results show clearly the performance of a DSTATCOM in mitigating voltage sags 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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