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Voltage Sag Mitigation with D-STATCOM In Distribution Systems

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Abstract: This paper presents the application of Distribution Static Compensator (DSTATCOM) on power distribution systems for mitigation of voltage sag at critical loads. DSTATCOM is one of the compensating types of custom power devices. The DSTATCOM, which is based on forced-commutated voltage source converter (VSC) has been proved suitable for the task of compensating voltage sags/swells. Simulation results are presented to illustrate and understand the performances of DSTATCOM in supporting load voltages under voltage sags/swells conditions.

Key words: power quality, voltage sags, voltage swells, Distribution Static Compensator (DSTATCOM).

INTRODUCTION

Both electric utilities and end users of electrical power are becoming increasingly concerned about the quality of electric power. The term power quality has become one of the most prolific buzzword in the power industry since the late 1980s . The issue in electricity power sector delivery is not confined to only energy efficiency and environment but more importantly on quality and continuity of supply or power quality and supply quality. Electrical Power quality is the degree of any deviation from the nominal values of the voltage magnitude and frequency. Power quality may also be defined as the degree to which both the utilization and delivery of electric power affects the performance of electrical equipment .From a customer perspective, a power quality problem is defined as any power problem manifested in voltage, current, or frequency deviations that result in power failure or disoperation of customer of equipment. Power quality problems concerning frequency deviation are the presence of harmonics and other departures from the intended frequency of the alternating supply voltage. On the other hand, power quality problems concerning voltage magnitude deviations can be in the form of voltage fluctuations, especially those causing flicker. Other voltage problems are the voltage sags, short interruptions and transient over voltages. Some common reason for voltage sags are lightning strikes in power lines, equipment failures, accidental contact power lines, and electrical machine starts. Despite being a short duration between 10 milliseconds to 1 second event during which a reduction in the RMS voltage magnitude takes place, a small reduction in the system voltage can cause serious consequences.

Distribution Static Compensator (DSTATCOM):

In its most basic function, the DSTATCOM configuration consist of a two level voltage source converter (VSC), a dc energy storage device, a coupling transformer Connected in shunt with the ac system, and associated control circuit as shown in Figure 1. 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.

The VSC connected in shunt with the ac system provides a multifunctional topology which can be used for up to three quite distinct purposes , Voltage regulation and compensation of reactive power, Correction of power factor; and Elimination of current harmonics. The design approach of the control system determines the priorities and functions developed in each case. In this case the control is based on sinusoidal PWM and only requires the measurement of the rms voltage at the load point.

Sinusoidal PWM-Based Control Scheme.

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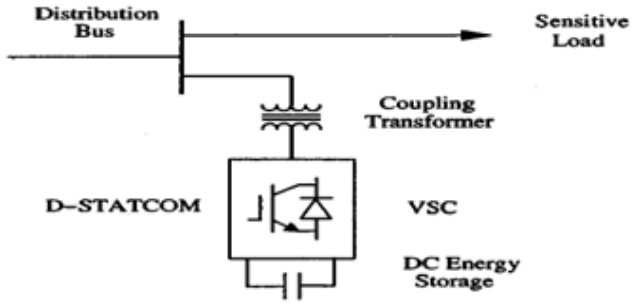

Fig. 1: Schematic diagram of the DSTATCOM as a custom power controller.

A sinusoidal PWM-based control scheme is implemented, with reference to the DSTATCOM is shown in Fig.2.

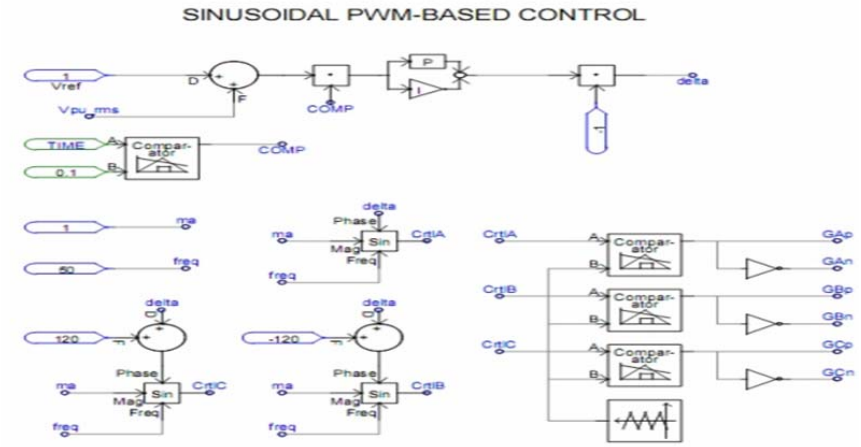

Fig. 2: Control scheme for the test system implemented in PSCAD/EMTDC to carry out the D-STATCOM simulations.

The aim of the control scheme is to maintain a constant voltage magnitude at the point where sensitive load is connected, under the system disturbance. The VSC switching strategy is based on a sinusoidal PWM technique which offers simplicity and good response. Besides, high switching frequencies can be used to improve the efficiency of the converter, without incurring significant switching losses. The DSTATCOM control system exerts voltage angle control as follows: an error signal is obtained by comparing the reference voltage with the rms voltage measured at the load point. The PI controller processes the error signal and generates the required angle δ to drive the error to zero, in example, the load rms voltage is brought back to the reference voltage.

The main parameters of the sinusoidal PWM scheme are the amplitude modulation index, ma, of signal vcontrol, and the frequency modulation index, mf, of the triangular signal. The switching frequency mf is set at 450 Hz, mf = 9. The vcontrol in the .2 are nominated as CtrlA, CtrlB and CtrlC. It should be noted that, an assumption of balanced network and operating conditions are made. A two-level DSTATCOM 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 DSTATCOM energy storage capabilities. Figure 3 shows the build of the DSTATCOM in PSCAD/EMTDC which is the two-level voltage source converter and the realization of the test system being employed shown in Figure 5 .

Basic Configuration and Function of DSTATCOM:

The DSTATCOM is a three phase and shunt connected power electronics based device. It is connected near the load at thedistribution systems. The major components of the DSTATCOM are shown in Fig.4. It consists of a dc capacitor, three phase inverter module such as IGBT or thyristor, ac filter, coupling transformer and a control strategy. The basic electronic block of the DSTATCOM is the voltage sourced converter that converts an input dc voltage into three phase output voltage at fundamental frequency.

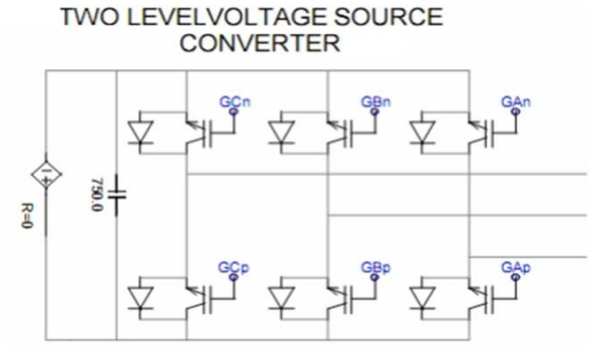

Fig. 3: One line diagram of the DSTATCOM test system.

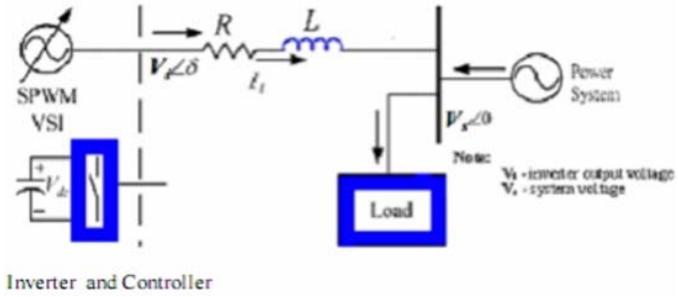

Fig. 4: Building blocks of D-STATCOM.

Referring to Figure 4.4, the controller of the DSTATCOM is used to operate the inverter in such a way that the phase angle between the inverter voltage and the line voltage is dynamically adjusted so that the DSTATCOM generates or absorbs the desired VAR at the point of connection. The phase of the output voltage of the thyristor based converter, Vi, is controlled in the same way as the distribution system voltage, Vs. For instance, if Vi is equal to Vs, the reactive power is zero and the DSTATCOM does not generate or absorb reactive power. When Vi is greater than Vs, the DSTATCOM 'sees' an inductive reactance connected at its terminal. Hence, the system 'sees' the DSTATCOM as a capacitive reactance. The current, I, flows through the transformer reactance from the DSTATCOM to the ac system, and the device generates capacitive reactive power.

Simulation Model and Parameters:

Test system as three phase laoy out is shown in Fig.5.

Table I: Description of Outout Parameters

Description	Result Name
The Voltage of Line to Line	Voltage (pu)
The Refrence Voltage in Voltage Loop Control	Vref
Error Voltage in Voltage Loop Control	Error(pu):
:Output Angle of Voltage Lopp Control	Angle(deg)
Output Active Power from STATCOM	: Active Power (Pm)
Voltage DC in STATCOM	Dc voltage (kv)
Output Reactive Power from STATCOM	Reactive power(Qm)
he Voltage of LoadT	VL
The Current of Load	IL

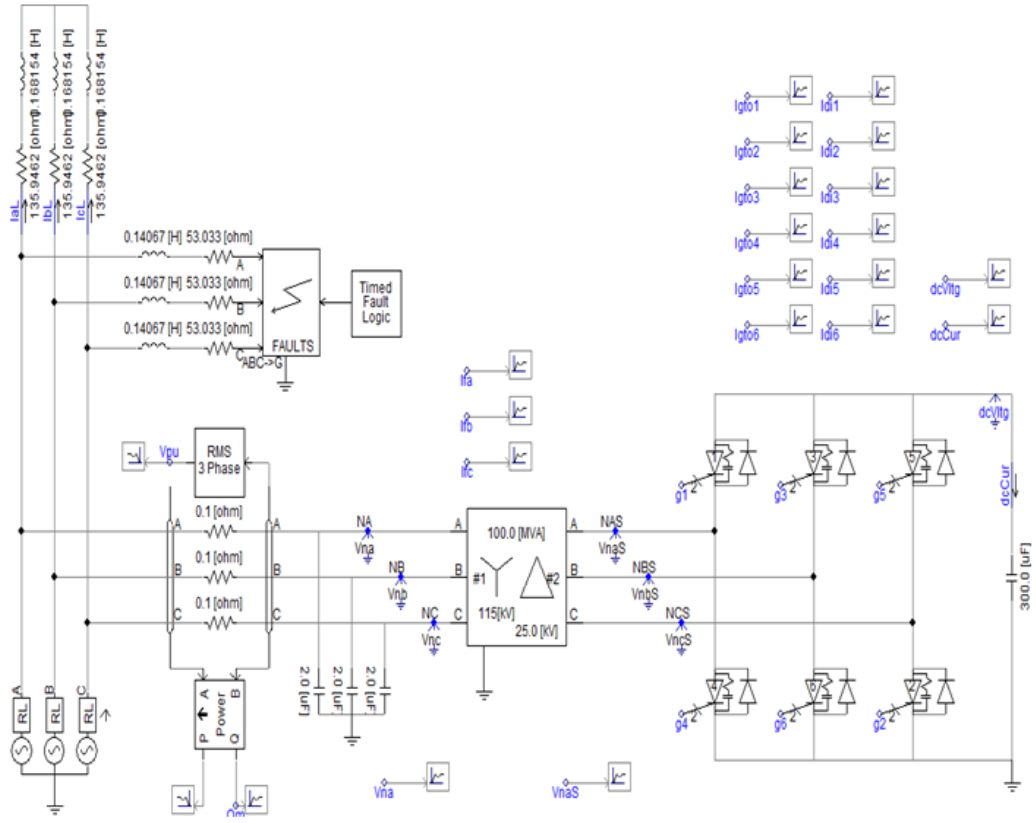

Fig. 5: Schematic diagram of the test system with D-STATCOM connected to the system.

Table II: Simulation Parameters

AC System	Voltage - Short circuit	115kV -500MVA
Without voltage control device the voltage level is:	Normal conditions Fault conditions	0.78 pu 0.61 pu
LOAD	Power - Power Factor	88MVA 0.906
FAULT	Type Fault Impedance X/R ratio Occurring Time Time Duration	3 phase to ground through 75ohms equal to 1 at 1.5 sec 0.75 sec

RESULTS AND DISCUSSION

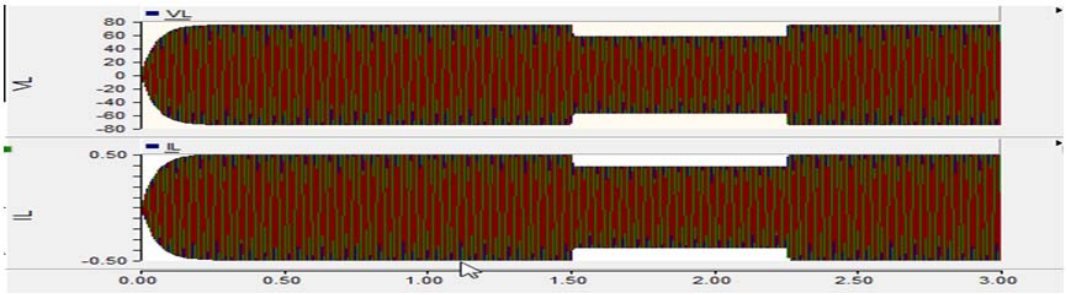

Fig. 6: The result of voltage and current of load without D-STATCOM.

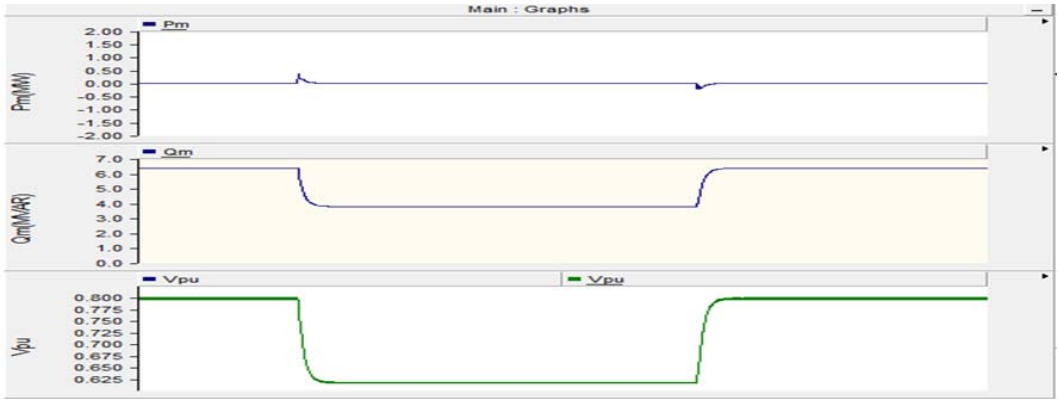

Fig. 7: The result of Pm,Qm and V without D-STATCOM

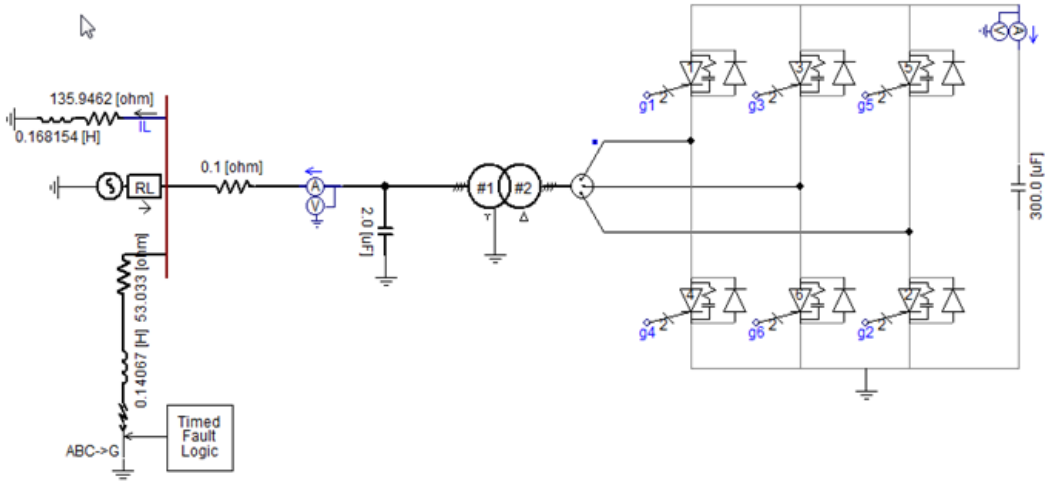

Fig. 8: Single line diagram of test system with D-STATCOM.

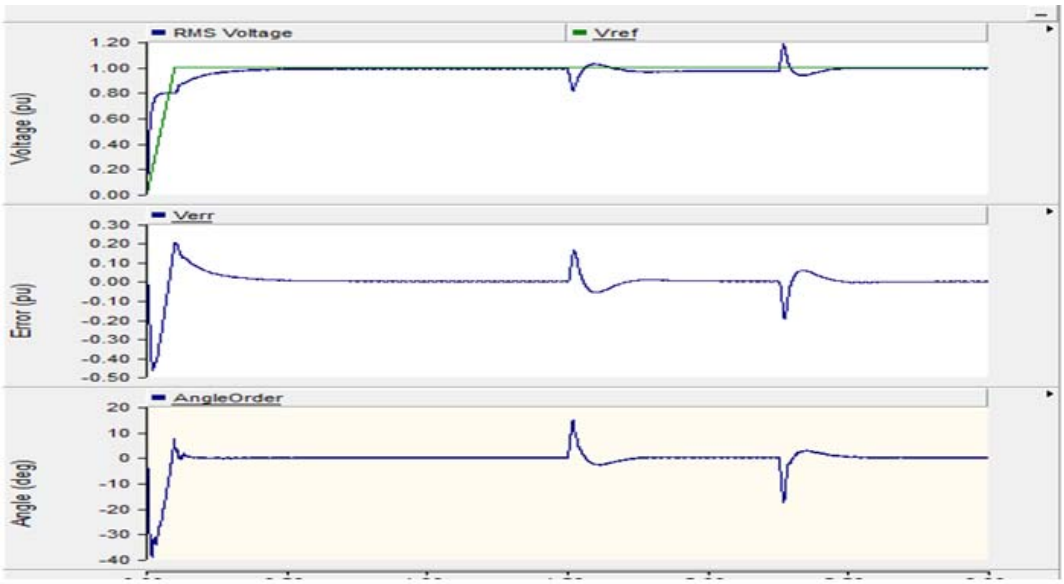

Fig. 9: The Result of Voltage Line to Line and Error and Angle of Voltage Control Loop With D-STATCOM.

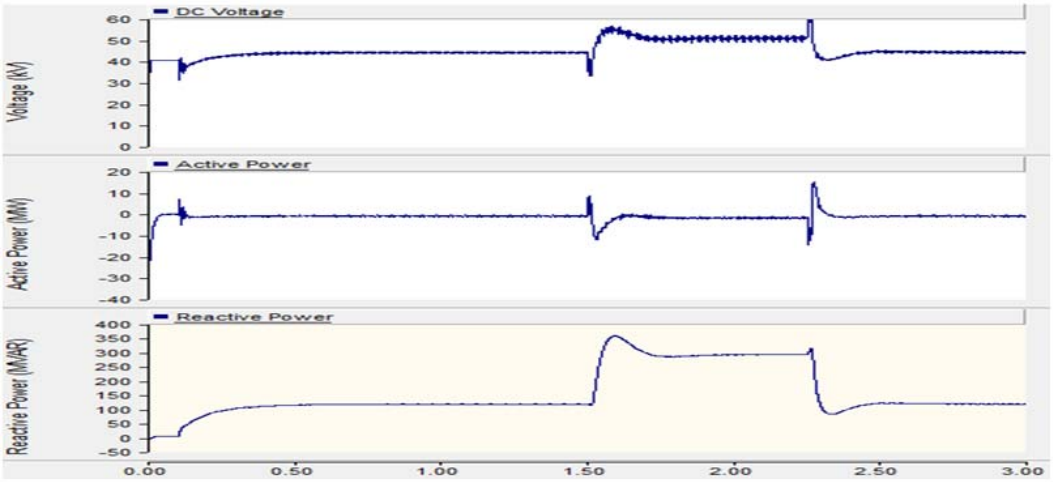

Fig. 10: The Result of Pm, Qm and V With D-STATCOM.

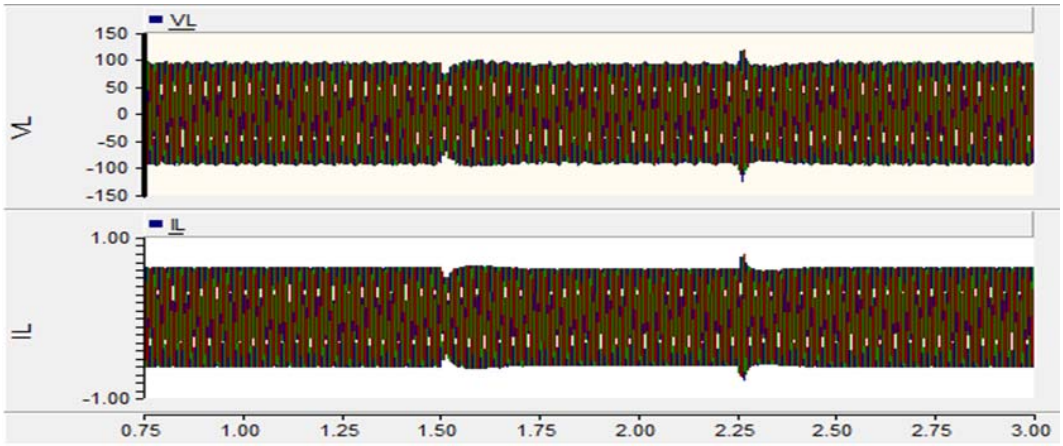

Fig. 11: The result of voltage and current of load with D-STATCOM.

Conclusion:

Nowadays, reliability and quality of electric power is one of the most discuss topics in power industry. There are numerous types of power quality issues and power problems and each of them might have varying and diverse causes. The types of power quality problems that a customer may encounter classified depending on how the voltage waveform is being distorted. There are transients, short duration variations (sags, swells, and interruption), long duration variations (sustained interruptions, under voltages, over voltages), voltage imbalance, waveform distortion (dc offset, harmonics, inter harmonics, notching, and noise), voltage fluctuations and power frequency variations. Among them, two power quality problems have been identified to be of major concern to the customers are voltage sags and harmonics, but this project is focusing on voltage sags.

Voltage sags are huge problems for many industries, and it is probably the most pressing power quality problem today. Voltage sags may cause tripping and large torque peaks in electrical machines. Generally, voltage sags are short duration reductions in rms voltage caused by faults in the electric supply system and the starting of large loads, such as motors. Voltage sags are also generally created on the electric system when faults occur due to lightning, which are accidental shorting of the phases by trees, animals, birds, human error such as digging underground lines or automobiles hitting electric poles, and failure of electrical equipment. Sags also may be produced when large motor loads are started, or due to operation of certain types of electrical equipment such as welders, arc furnaces, smelters, etc.

The distribution static compensator (DSTATCOM) offers an alternative to conventional series shunt compensation. In the traditional power transmission system, controllable devices are restricted to the slow mechanisms such as transformer tap changers and switched capacitor. In the late 1980's, thanks to the major developments in the semiconductor technology, it became possible to apply power electronics in the control

of DSTATCOM. Based on the simulation, there's a room for improvement. DSTATCOM is a device that promises a prominent feature in power system in mitigating power quality related problems in the future.

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