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SIMULATION OF VOLTAGE STABILIZATON & POWER QUALITY IMPROVEMENT IN DISTRIBUTION SYSYTEM THROUGH D-STATCOM

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Abstract- P*ower quality is a major issue in the distribution system. Voltage flicker is a major power quality concern for both power companies and customers. The dynamic performance of a Distribution Static Synchronous Compensator (D-STATCOM) with ESS for mitigation of voltage flicker is discussed. Voltage-sourced converter (VSC) with Pulse-width modulation (PWM) provides a faster control that is required for flicker mitigation purpose. The voltage regulation in the distribution feeder is improved by installing a shunt compensator. The proposed DSTATCOM is modeled and its performance is simulated and verified for power factor correction and voltage regulation .The D-STATCOM is intended to replace the widely used static var compensator (SVC). This protects the utility transmission or distribution system from voltage sag and flicker caused by rapidly varying reactive current demand. It can regulate bus voltage by absorbing or generating reactive power. The simulation is carried out using MATLAB/SIMULINK and the simulation results illustrate the performance of D-STATCOM in mitigation of voltage flicker.*

Keywords: D-STATCOM, Voltage Sag/Flicker Mitigation, Voltage Stabilization, Power Quality Improvement.

1. INTRODUCTION

In present day's power distribution systems is suffering from severe power quality problems such as voltage sags, harmonics, voltage swell, power interruptions and voltage flicker, reactive power burden, harmonics currents, load unbalance, excessive neutral current etc. But a new generation electric grid should be free from these disturbances [1]. The D-STATCOM (Distribution Static Synchronous Compensator) is a three phase and shunt connected power electronics based reactive power compensation equipment, which generates and /or absorbs the reactive power whose output can be varied so as to maintain control of specific parameters of the electric power system. The most basic configuration of D-STATCOM consists of two-level Voltage Source Converter (VSC) with a DC energy storage device, a coupling transformer connected in shunt with the AC system and the associated control circuits. The D-STATCOM has emerged as a promising device to provide not only for voltage sag mitigation but a host of other power quality solutions such as voltage stabilization, flicker suppression, power factor correction and harmonic control. The D-STATCOM has additional capability to sustain reactive current at low voltage and to reduce land use. In general, the D-STATCOM can be utilized for providing voltage regulation, power factor correction, harmonics compensation and load leveling [3]. Proposed voltage sourced converter (VSC) based D-STATCOM with Pulse-width modulation (PWM) provides a faster control that is required for flicker mitigation purpose. The proposed control scheme for the integrated DSTATCOM is based on concepts of instantaneous power on the synchronous-rotating dq reference Frame [2].

2. BASIC PRINCIPLE OF D-STACOM

The operating principles of a DSTATCOM are based on the exact equivalence of the conventional rotating synchronous compensator. The AC terminals of the VSC are connected to the Point of Common Coupling (PCC) through an inductance, which could be a filter inductance or the leakage inductance of the coupling transformer, as shown in Fig. 1

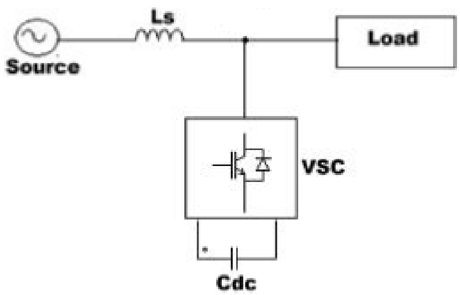

Fig. 1 Basic structure of DSTATCOM

The DC side of the converter is connected to a DC capacitor, which carries the input ripple current of the converter and is the main reactive energy storage element. This capacitor could be charged by a battery source, or could be recharged by the converter itself. If the output voltage of the VSC is equal to the AC terminal voltage, no reactive power is delivered to the system. If the output voltage is greater than the AC terminal voltage, the DSTATCOM is in the capacitive mode of operation and vice versa. The quantity of reactive power flow is proportional to the difference in the two voltages. For a DSTATCOM used for voltage regulation at the PCC, the compensation should be such that the supply currents should lead the supply voltages; whereas, for power factor Correction, the supply current should be in phase with the supply voltages. The control strategies studied in this paper are applied with a view to studying the performance of DSTATCOM [5].

2.1 Methods of Controllable VAR Generation

The aim of Static var generators is to produce variable reactive shunt impedance that can be adjusted to meet the compensation requirements of the transmission network. The basic principle of reactive power generation by a voltage-sourced converter is similar to that of the conventional rotating synchronous machine. For purely reactive power flow, the three-phase induced electromotive forces (EMFs), E_a, E_b, and E_c of the synchronous rotating machine are in phase with the system voltages, Va, Vb, and Vc.

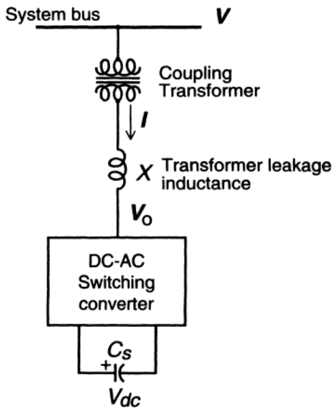

Fig. 2 Reactive power generation by rotating a voltage-sourced switching converter

The reactive current I drawn by the synchronous compensator is determined by the magnitude of the system voltage *V,* that of the internal voltage *E,* and the total circuit reactance *X:*

$$I = \left(\frac{V - V_0}{X} \right) \tag{1}$$

The corresponding reactive power Q exchanged can be expressed as follows:

$$f(x) = \left(\frac{1 - \frac{V_0}{V}}{X} \right) \times V^2 \tag{2}$$

By controlling the excitation of the machine, and hence the amplitude V_0 of its internal voltage related to the amplitude V of the system voltage, the reactive power flow can be controlled. Increasing V_0 above V, results in a leading current, that is, the machine is "seen" as a capacitor by the ac system. Decreasing V_0 below V, produces a lagging current, that is, the machine is "seen" as a reactor (inductor) by the ac system. Under either operating condition a small amount of real power of course flows from the ac system to the machine to supply its mechanical and electrical losses. By varying the amplitude of the output voltages produced, the reactive power exchange between the converter and the ac system can be controlled in a manner similar to that of the rotating synchronous machine. That is, if the amplitude of the output voltage is increased above that of the ac system voltage, then the current flows through reactance from converter to the ac system, and the converter generates reactive (capacitive) power for the ac system. If the amplitude of the output voltage is decreased below that of the ac system, then the reactive current flows from the ac system to the converter, and the converter absorbs reactive (inductive) power. If the amplitude of the output voltage is equal to that of the ac system voltage, the reactive power exchange is zero [4].

2.2 Controller circuit

The main function of the internal control is to operate the converter power switches so as to produce a synchronous output voltage waveform that forces the reactive (and real) power exchange required for compensation [6]. The internal control achieves this by computing the magnitude and phase angle of the required output voltage from IQ_{ref} and IP_{ref} provided by the external control and generating a set of coordinated timing which determines the on and off periods of each switch in the converter corresponding to the wanted output voltage. These timing waveforms have a defined phase relationship between them, determined by the converter pulse number, the method used for constructing the output voltage waveform, and the required angular phase relationship between the three outputs.

3. SIMULATION

A D-STATCOM is used to regulate voltage on a 11kV distribution network. Two feeders (8 km and 2 km) transmit power to loads connected at buses B2 and B3. A shunt capacitor is used for power factor correction at bus B2. The 415V load connected to bus B3 through a 11kV/415V transformer represents a plant absorbing continuously changing currents, similar to an arc furnace, thus producing voltage flicker. The variable load current magnitude is modulated at a frequency of 5 Hz so that its apparent power varies approximately between 1 MVA and 5.2 MVA, while keeping a 0.9 lagging power factor. This load variation will allow you to observe the ability of the D-STATCOM to mitigate voltage flicker. The D-STATCOM consists of the following components: (1). A 11kV/550V coupling transformer, (2). A voltage-sourced PWM inverter, (3). LC damped filters, (4). A 10000-microfarad capacitor, (5). Two voltage regulator, (6). A PWM pulse generator using a modulation frequency of 1.68 kHz, (7). Anti-aliasing filters, (8). A Phase Locked Loop, (9). Two measurements systems, (10). Inner current regulation loop, (11). Outer voltage regulation loop [7].

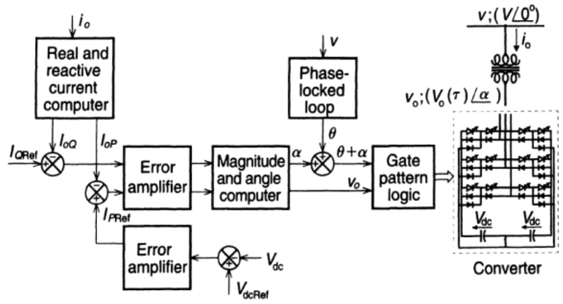

Fig. 3 Internal pattern of the controller

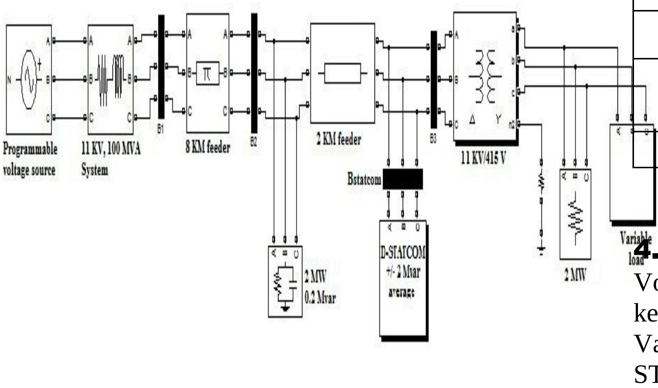

Fig. 4 Simulation model of distribution system with DSTATCOM

4. SIMULATION RESULT

4.1 Dynamic Response

The variable load will be kept constant and observed the dynamic response of DSTATCOM to step changes in source voltage. The Programmable Voltage Source block is used to modulate the internal voltage of the 11-kV equivalent. The voltage is first programmed at 1.077 pu in order to keep the D-STATCOM initially floating (B3 voltage=1 pu and reference voltage Vref=1 pu). Three steps are programmed at 0.2 s, 0.3 s, and 0.4 s to successively increase the source voltage by 6%, decrease it by 6% and bring it back to its initial value. Start the simulation. Observe on figure the phase voltage waveform of the D-STATCOM as well as Output voltage of voltage source inverter on fig. 6. After a transient lasting approximately 0.15 sec., the steady state is reached. Initially, the source voltage is such that the D-STATCOM is inactive. It does not absorb nor provide reactive power to the network. At t = 0.2 s, the source voltage is increased by 6%. The D-STATCOM compensates for this voltage increase by absorbing reactive power from the network (Q = +1.7 Mvar on Fig. 9). At t = 0.3 s, the source voltage is decreased by 6% from the value corresponding to Q = 0. The D-STATCOM must generate reactive power to maintain a 1 pu voltage (Q changes from +1.7 MVAR to -1.85 MVAR). When the D-STATCOM changes from inductive to capacitive operation, the modulation index of the PWM inverter is increased from 0.265 to 0.40 (fig. 7) which corresponds to a proportional increase in inverter voltage. Reversing of reactive power is very fast, about one cycle, as observed on D-STATCOM current (fig. 8).

Table 1 Simulation Values of the system.

Parameter	Values
Source voltage	11kv/50Hz
Source power	100MVA
Total line length	10km
Distribution transformer	11kv/415v
Coupling transformer	11kv/550v
Modulation frequency	1.68kHz
DC link voltage	2.4kv

4.2 Mitigation of Voltage Flicker

Voltage of the programmable voltage source will be kept constant and one enable modulation of the Variable Load so that you can observe how the D-STATCOM can mitigate voltage flicker. In the Variable Load block menu, set the Modulation Timing parameter to [T_{on} T_{off}]=[0.15 1]. Finally, in the D-STATCOM Controller, change the "Mode of operation" parameter to "Q regulation" and make sure that the reactive power reference value Qref is set to zero. In this mode, the D-STATCOM is floating and performs no voltage correction. Run the simulation and observe on variations of P and Q at bus B3 as well as voltages at buses B1 and B3 figure 07. The D-STATCOM Controller, change the "Mode of operation" parameter back to "Voltage regulation" and restart simulation. Observe on figure 07 that voltage fluctuation at bus B3 is now reduced to +/-

0.7 %. The DSTATCOM compensates voltage by injecting a reactive current modulated at 5 Hz and varying between 0.6 pu capacitive when voltage is low and 0.6 pu inductive when voltage is high.

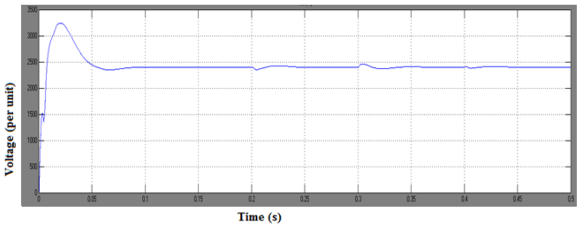

Fig. 5 Fixed dc voltage

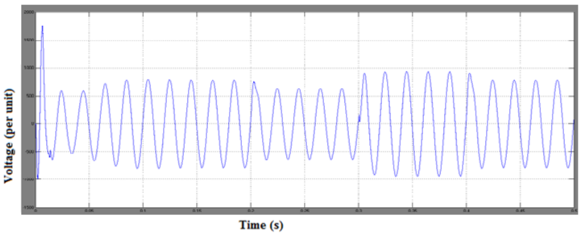

Fig. 6 Inverted voltage

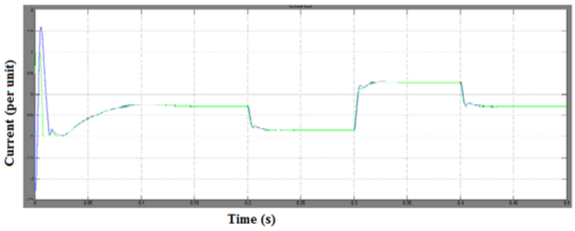

Fig. 7 Iq and Iqref

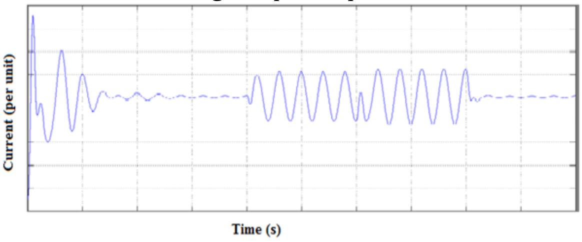

Fig. 8 DSTATCOM current

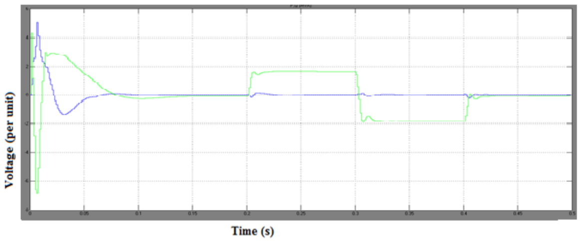

Fig. 9 Real and reactive power in D-STATCOM

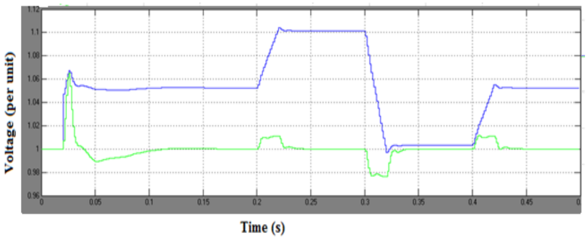

Fig. 10 Sending (blue colour) and receiving (green colour) end voltage

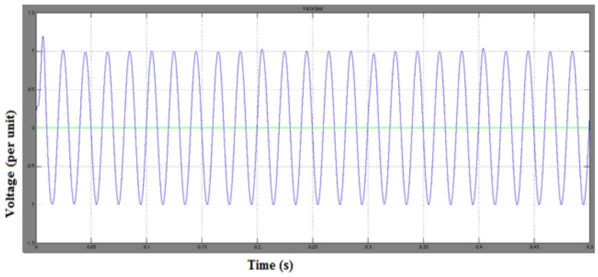

Fig. 11 Stabilized voltage at load side

5. CONCLUSION

The proposed DSTATCOM is modeled and its performance is simulated and verified for power factor correction and voltage regulation along with harmonic elimination and load balancing with linear loads and non-linear loads. The expected simulation results show that the voltage regulation at the point of common coupling is much better with a D-STATCOM. The proposed technique could identify the disturbance and capable of mitigating the disturbance by maintaining the load voltage at desired magnitude within limits as well as improved power quality. The proposed technique is simple and only one IGBT switch per phase is required. Hence the system is more simple and economical compared to commonly used DVR.

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8. NOMENCLATURE:

symbol	meaning	unit
D-STATCOM	Distribution Static Synchronous compensator	Dimension less
ESS	Electric Source Supply	,,
PWM	Pulse Width Modulation	,,
SVC	Static Var Compensator	,,
VSC	Voltage Source Converter	,,
PCC	Point of common coupling	,,