Improvement of Power Quality by Enhancing the Voltage Stability by VSC based DSTATCOM

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Abstract – This paper investigates the working of a shunt connected Distribution Static Compensator (DSTATCOM) for power quality improvement in the distribution system. The proposed DSTATCOM is employed for the control of voltage stability at the point of common coupling. The performance of DSTATCOM is validated by detailed simulations using MATLAB Software with the Simulink and power system toolboxes. The performance of DSTATCOM is found to be satisfactory under time varying and nonlinear loads. The result for voltage compensation validates the effectiveness of DSTATCOM for improving Power Quality.

Index Terms **– Distribution Static Compensator (DSTATCOM), Power Quality (PQ), Reactive Power Compensation, Voltage Stability.**

1. INTRODUCTION

Distribution Systems are currently undergoing through lots of problems related to Power Quality (PQ).Now a day's lots of emphasis is given on the quality of power supplied to the end user. The term Power Quality (PQ) includes all possible situations in which the waveform of the supply voltage (Voltage Quality) or Load Current (Current Quality) deviates from the sinusoidal waveform for all the three phases. The source voltages in distribution system are also encountering PQ problems, such as flicker, voltage sag, voltage swell, unbalance, etc [1-4].In order to limit these problems many standards are proposed such as IEEE 519-1992,IEEE Std.141-1993, etc [9-11].At the distribution level ,power electronic controllers also called as custom power devices have been proposed many of which have a Voltage Sourced Converter(VSC) connected to the grid. The solutions to the PQ problems are investigated and discussed in the literature[5-10].The DSTATCOM is proposed for compensating PQ problems in current. DSTATCOM is a custom power used for mitigating voltage sag and swell, improving power factor and balancing the load. There are many techniques proposed and some have been patented also for elimination of harmonics from source current and for compensation [5-8]

The DSTATCOM is a custom power device and it consists of a current source (VSC) which injects current into the system at the PCC through the interface reactor. The operation of VSC is supported by a dc storage capacitor. The DSTATCOM has a very significant transient response while providing compensation to the system. Basically a DSTATCOM is a device which is used in ac distribution system where harmonic current mitigation, reactive current compensation and load balancing are necessary.

The main benefit of DSTATCOM is that it has very fine and advanced power electronics control [3-6] which can bus. efficiently regulate the current injection into the distribution bus. In a distribution system, there may be several different compensating devices. However, in a radial distribution system, the voltage of a particular bus can be distorted or unbalanced if the loads in any part of the system are nonlinear.

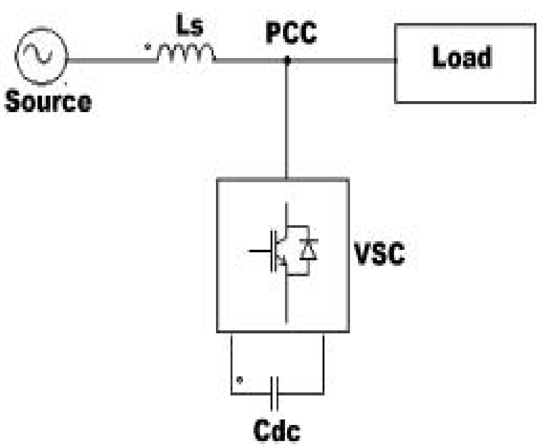

Fig 1.Basic structure of DSTATCOM

2. RELATED WORK

Sub topic 1

Mahesh K. Mishra,, Arindam Ghosh,and Avinash Joshi, IEEE TRANSACTIONS ON POWER DELIVERY, VOL. 18, NO. 1, JANUARY 2003. Operation of a DSTATCOM in Voltage Control Mode. The paper presents the operating principles of a distribution static compensator (DSTATCOM) that is used to maintain the voltage of a distribution bus. A three-phase, four-wire distribution system is assumed in this study. A three-phase bridge inverter circuit that is supplied by two neutral-clamped dc storage capacitors realizes the DSTATCOM. Three filter capacitors, one for each phase, are connected in parallel with the DSTATCOM to eliminate high-frequency switching components. The voltage across the filter capacitor is controlled by a dead-beat controller to maintain the ac bus voltage. The magnitude of the bus voltage is chosen as nominal value, i.e., 1.0 p.u., while its phase angle is obtained through a feedback loop that maintains the voltage across the dc storage capacitors. Through detailed simulation and experimental results, it has been shown that the DSTATCOM can maintain the voltage against any unbalance and distortion in either the load or supply side.

Sub topic 2

Chandan Kumar, and Mahesh K. Mishra, IEEE TRANSACTIONS ON POWER DELIVERY, VOL. 29, NO. 3, JUNE 2014

A Voltage-Controlled DSTATCOM for Power-Quality Improvement. This paper proposes a new algorithm to generate reference voltage for a distribution static compensator (DSTATCOM) operating in voltage-control mode. The proposed scheme exhibits several advantages compared to traditional voltage-controlled DSTATCOM where the reference voltage is arbitrarily taken as 1.0 p.u. The proposed scheme ensures that unity power factor

(UPF) is achieved at the load terminal during nominal operation, which is not possible in the traditional method.

Further, a saving in the ratingof DSTATCOM is achieved which increases its capacity to,mitigatevoltage sag. Nearly UPF is maintained, while regulating voltageat the load terminal, during load change. The state-space model of DSTATCOM is incorporated with the deadbeat predictive controller for fast load voltage regulation during voltage disturbances.With these features, this scheme allows DSTATCOM to tackle power-quality issues by providing power factor correction,harmonic elimination, load balancing, and voltage regulation based on the load requirement. Simulation and experimental results are presented to demonstrate the efficacy of the proposed algorithm.

Sub topic 3

In this paper, DSTATCOM is used for Grid Connected Power System, for Voltage Fluctuation for wind power quality smoothening and hydrogen generation. Relevant solutions which are used to improve power quality of electric network are discussed. Simulation is done using MATLAB / Simulink to validate the proposed system.

3. PROPOSED MODELLING

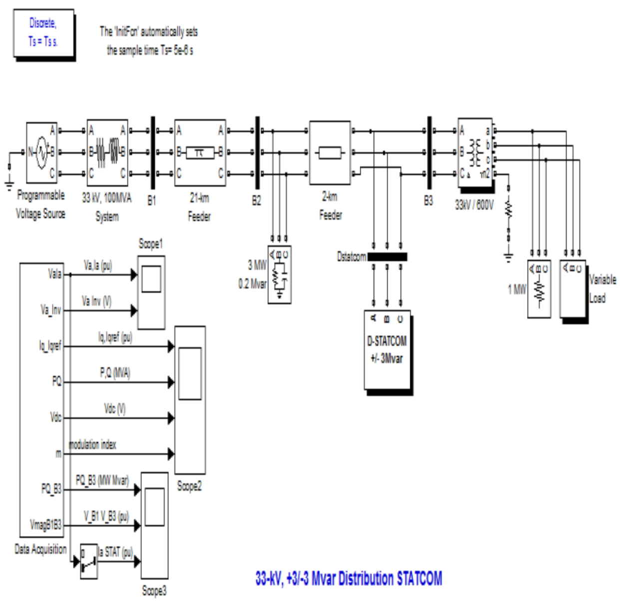

Fig. 2 Proposed Scheme in MATLAB / Simulink

A Distribution Static Synchronous Compensator (D-STATCOM) is used to regulate voltage on a 33-kV distribution network. Two feeders transmit power to loads connected at buses B2 and B3. A shunt capacitor is used for power factor correction at bus B2. The 600-V load connected to bus B3 through a 33kV/600V transformer represents a load that has continuously changing currents producing voltage flicker. The proposed model shows the ability of the D-STATCOM to reduce voltage flicker.

The D-STATCOM regulates bus B3 voltage by absorbing or generating reactive power. This reactive power transfer is done through the leakage reactance of the coupling transformer by generating a secondary voltage in phase with the primary voltage (network side). This voltage is provided by a voltage -sourced PWM inverter. When the secondary voltage is lower than the bus voltage, the D-STATCOM acts like an inductance absorbing reactive power. When the secondary voltage is higher than the bus voltage, the D-STATCOM acts like a capacitor generating reactive power.

The D-STATCOM consists of the following components:

i) a 33 kV/1.25kV transformer ensures coupling between the inverter and the network. a voltage-sourced PWM inverter consisting of two IGBT bridges.

ii)LC damped filters connected at the inverter output.

iii) A capacitor acting as a DC voltage source for the inverter a voltage regulator that controls voltage at bus B3

Source voltage	33 kv
Source Power	100MVA
Total Line Length	23 km
Coupling transformer	33 / 1.25kv
DC link voltage	2400 V

Table 1 :- System Parameters

4. RESULTS AND DISCUSSIONS

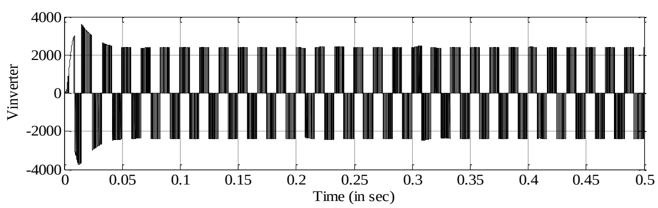

Fig 3. Inverter Output Voltage

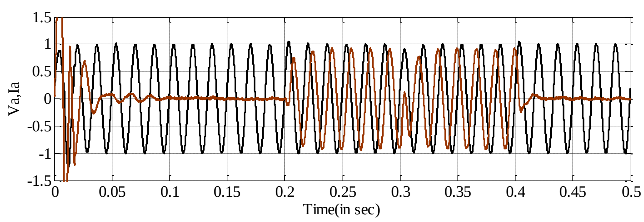

Fig.4 Voltage and Current of Phase a

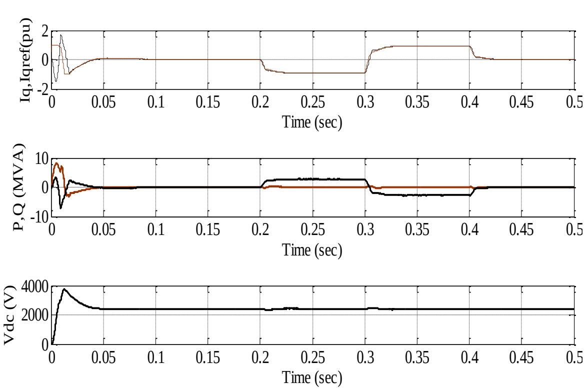

Fig.5.Reactive Current, Reactive Power and Voltage across dc capacitor

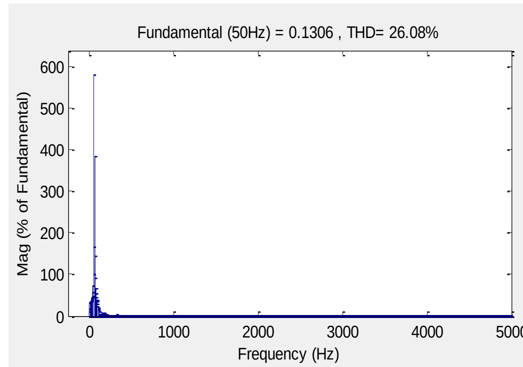

Fig 6.FFT Analysis of THD for voltage flicker

During this test, the variable load will be kept constant and you will observe the dynamic response of a D-STATCOM to step changes in source voltage. Check that the modulation of the Variable Load is not in service (Modulation Timing [Ton Toff]= [0.15 1]*100 > Simulation Stop time). The Programmable Voltage Source block is used to modulate the internal voltage of the 25-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 (1.077 pu).Start the simulation. Observe on Scope1 the phase A voltage and current waveforms of the D-STATCOM as well as controller signals on Scope2. 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=+2.7 Mvar on trace 2 of Scope2). 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 +2.7 MVAR to -2.8 MVAR). Note that when the D-STATCOM changes from inductive to capacitive operation, the modulation index of the PWM inverter is increased from 0.56 to 0.9 (trace 4 of Scope2) 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 (magenta signal on trace 1 of Scope1).

Without DSTATCOM	With DSTATCOM
V_{B1}=1.064 p.u	V_{B1}=1.02 p.u
V_{B3}=0.936 p.u	V_{B3}=0.96 p.u

Table 2 Voltage Flicker Mitigation using DSTATCOM

5. CONCLUSION

The modeling and simulation of DSTATCOM in MATLAB SIMULINK toolbox and its detailed simulation analysis indicates DSTATCOM as a effective option for overall compensation. The DSTATCOM can be hence used to address problems related to the Power Quality; this has been validated by extensive computer simulation. The performance of DSTATCOM is found to be satisfactory under nonlinear loads.

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