Simulation of D-STATCOM to study Voltage Stability in Distribution system

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Abstract— This paper presents the simulation of D-statcom to understand the improvement of voltage stability [1] of distribution system. The power circuits of the D-STATCOM and distribution networks are made up of simpower system blocks, while the control circuits made with the simulink blocks The STATCOM is applied to regulate transmission voltage to allow greater power flow in a voltage limited transmission network, in the same manner as a static var compensator (SVC), the STATCOM has further potential by giving an inherently faster response and greater output to a system with depressed voltage and offers improved quality of supply. The main applications of the STATCOM are; Distribution STATCOM (D-STATCOM) exhibits high speed control of reactive power to provide voltage stabilization and other type of system control. The DSTATCOM protects the utility transmission or distribution system from voltage sag and /or flicker caused by rapidly varying reactive current demand. During the transient conditions the D-STATCOM provides leading or lagging reactive power to active system stability, power factor correction and load balancing.

Keywords: FACTS, D-STATCOM, VSC, PWM, PCC, Inverter.

I. INTRODUCTION

One of the most common power quality problems today is voltage dips [2]. A voltage dip is a short time (10 ms to 1 minute) event during which a reduction in r.m.s. voltage magnitude occurs. It is often set only by two parameters, depth/magnitude and duration. The voltage dip magnitude is ranged from 10% to 90% of nominal voltage (which corresponds to 90% to 10% remaining voltage) and with a duration from half a cycle to 1 min. In a three-phase system a voltage dip is by nature a three-phase phenomenon, which affects both the phase-to-ground and phase-to-phase voltages. A voltage dip is caused by a fault in the utility system, a fault within the customer's facility or a large increase of the load current, like starting a motor or transformer energizing. Typical faults are single-phase or multiple-phase short circuits, which leads to high currents [3]. The high current results in a voltage drop over the network impedance. At the fault location the voltage in the faulted phases drops close to zero, whereas in the non-faulted phases it remains more or less unchanged.

Electric power distribution network becomes more increasingly important and plays an essential role in power system planning. This type of power systems has a major function to serve distributed customer loads along a feeder line; therefore under competitive environment of electricity market eservice of electric energy transfer must not be interrupted and at the same time there must provide reliable, stable and high quality of electric power [4]. To complete this challenge, it requires careful design for power network Planning. There exist many different ways to do so. However, one might consider an additional device to be installed somewhere in the network. Such devices are one of capacitor bank, shunt reactor, series reactors, and automatic voltage regulators and/or recently developed dynamic voltage restorers, distribution STATCOM or combination of them [5].

II. STRUCTURE OF STATCOM

Basically, STATCOM is comprised of three main parts, (1) voltage source inverter (VSI), (2) step-up coupling transformer, and (3) controller. In a very-high-voltage system, the leakage inductances of the step-up power transformers can function as coupling reactors. The main purpose of the coupling inductors is to filter out the current harmonic components that are generated mainly by the pulsating output voltage of the power converters.

A. Voltage Source Converter (VSC)

A voltage-source converter is a power electronic device, which can generate a sinusoidal voltage with any required magnitude, frequency and phase angle. Voltage source converters are widely used in adjustable speed drives, but can also be used to mitigate voltage dips. The VSC is 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. The converter is normally based on some kind of the energy storage, which will supply the converter with a DC voltage. The solid-state electronics in the converter is then switched to get the desired output voltage. Normally the VSC is not only used for voltage dip mitigation, but also for other power quality issues, e.g. flicker and harmonics.

B. A Controller

The aim of the control scheme is to maintain constant voltage magnitude at the point where a sensitive load is connected, under system disturbances. The control system only measures the r.m.s. voltage at the load point, i.e., no reactive power measurements are required. The VSC switching strategy is based on a sinusoidal PWM technique which offers simplicity and good response. Since custom power is a relatively low-power application, PWM methods offer a more flexible option than the Fundamental Frequency Switching (FFS) methods favored in FACTS applications. Besides, high switching frequencies can be used to improve on the efficiency of the converter, without incurring significant switching losses. The controller input is an error signal obtained from the reference voltage and the value r.m.s. of the terminal voltage measured. Such error is processed by a PI controller the output is the angle δ, which is provided to the PWM signal generator. It is important to note that in this case, indirectly controlled converter, there is active and reactive power exchange with the network simultaneously: an error signal is obtained by comparing the reference voltage with the r.m.s. voltage measured at the load point. The PI controller process the error signal generates the required angle to drive the error to zero, i.e., the load r.m.s. voltage is brought back to the references.

The control circuit consists of the following [6];

A phase-locked loop (PLL) which synchronizes on the positive-sequence component of the three phase primary voltage V1. The output of the PLL (angle θ=ωt) is used to compute the direct-axis and quadrature-axis components of the AC three-phase voltage and currents (labeled as V_d, V_q or I_d, I_q on the diagram).

Measurement systems measuring the d and q components of AC positive-sequence voltage and currents to be controlled as well as the DC voltage V_{dc}.

An outer regulation loop consisting of an AC voltage regulator and a DC voltage regulator [7]. The output of the AC voltage regulator is the reference current I_{qref} for the current regulator (I_q = current in quadrature with voltage which controls reactive power flow). The output of the DC voltage regulator is the reference current I_{dref} for the current regulator (Id = current in phase with voltage which controls active power flow).

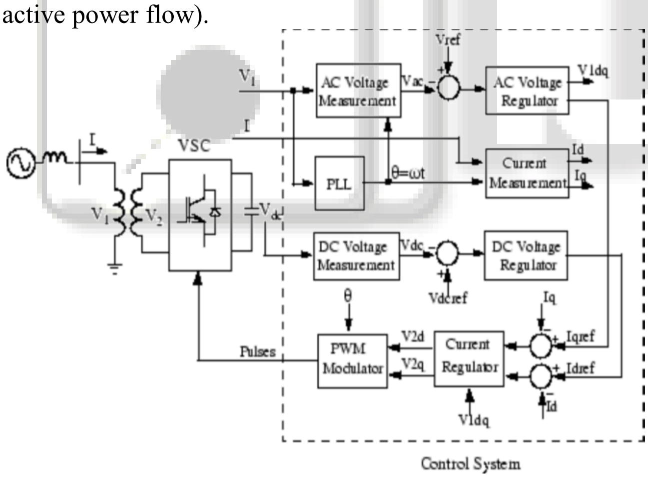

Fig. 1: control circuit of STATCOM

An inner current regulation loop consisting of a current regulator. The current regulator controls the magnitude and phase of the voltage generated by the PWM converter (V2d V2q) from the Idref and Iqref reference currents produced respectively by the DC voltage regulator and the AC voltage regulator (in voltage control mode). The current regulator is assisted by a feed forward type regulator which predicts the V2 voltage output (V2d V2q) from the V1 measurement (V1d V1q) and the transformer leakage reactance.

III. BASIC CONCEPT OF VSC BASED STATCOM

Basically a voltage-sourced converter based STATCOM generates ac voltage from a dc voltage. With a voltage sourced converter, the magnitude, the phase angle and the frequency of the output voltage can be controlled.

The basic principle of reactive power generation by a voltage-sourced converter is akin to that of the conventional rotating synchronous machine. The basic voltage-sourced converter scheme for reactive compensation is shown schematically in Figure 1.From a dc input voltage source, provided by the charged capacitor Cs, the converter produces a set of controllable three-phase output voltages with the system frequency of the ac power system.

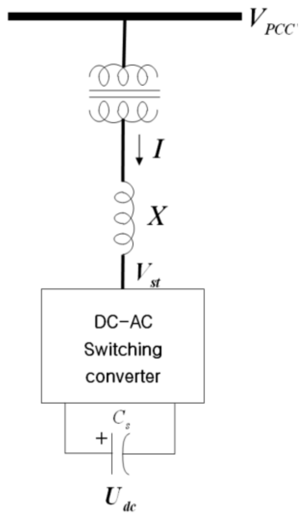

Fig. 2: Basic principal of STATCOM

A phase shift between the two voltages, δ, allows real power to flow and thus can be used to regulate the dc bus voltage (Udc), In addition, the reactive current or power can be controlled by adjusting the relative voltage of the converter output voltage (Vst),

$$P(\delta)=\frac{V_{PCC}V_{st}}{X}\sin\delta$$

$$Q(V_{st})=\frac{V_{PCC}^{2}-V_{PCC}V_{st}\cos\delta}{X}$$

Where Vst is the fundamental component of the converter output voltage, Vpcc is the voltage at the PCC (Point of common coupling), and X is the leakage inductance of the coupling transformer. δ corresponds to the power angle between the two voltages. Then, assuming the angle, δ is small allows us to re-write (1) and (2) as follows

$$P(\delta)=\frac{V_{PCC}V_{st}}{X}\delta$$

$$Q(V_{st})=\frac{V_{PCC}(V_{PCC}-V_{st})}{X}$$

IV. SIMULATION BLOCK DIAGRAM OF D-STATCOM

The simulink diagram described has been used to simulate the operation of the D STATCOM under different conditions[8] to illustrate its static and dynamic performance the simulation was done using a discrete step time (Ts=5.8μs).

The PSB prog.source block is used to modulate the internal voltage of the 25-kv source [6].

At starting, the source voltage is such that the D STATCOM is inactive. It does not absorb not provide reactive power to the network. At t =0.2s, the source voltage is increased by 6% The D STATCOM compensates for this voltage increased by absorbing reactive power from the network (Q = ± 2.7Mvar).At t=0.3s, the source voltage is decreased by 6% from the value corresponding to Q = 0.Then the D STATCOM must generate reactive power to maintain 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 inverter modulation index in is increased from 0.52 to 0.87 which corresponds to a proportional increase in inverter voltage. Reversing of reactive power flow is very fast (about one cycle).

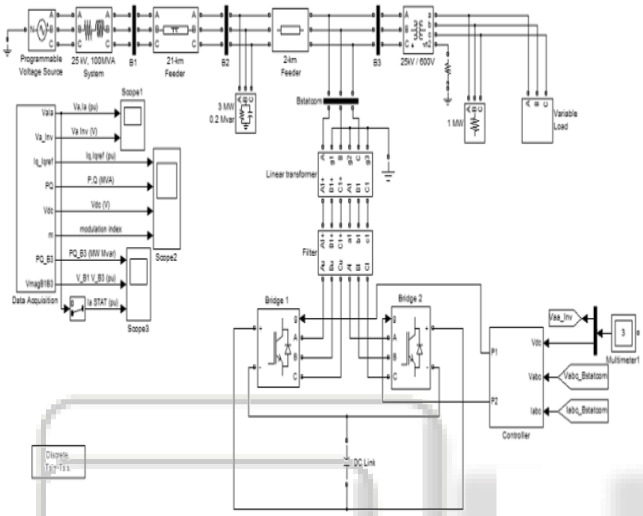

Fig. 3: Simulation of D-Statcom

V. SIMULATION RESULTS

A. Without D-Statcom

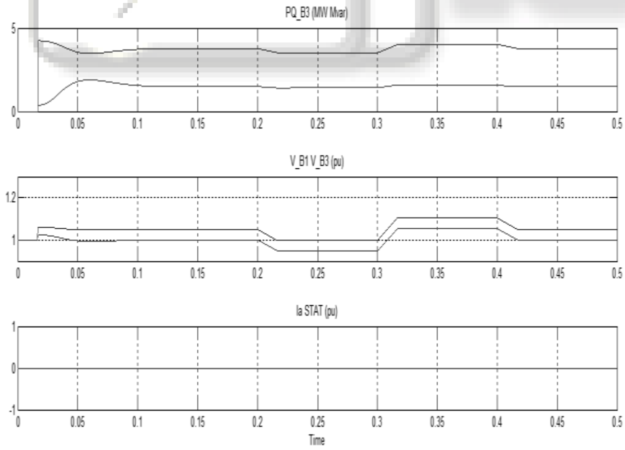

Fig. 4: Simulation Results without D Statcom

Here initially the D-STATCOM was not connected to the system and the load of three phase RLC load of 3MW, 0.2 MVAR is applied on the system in the time interval of 0.1sec to 0.5 sec. the voltage got dipped from 1.05 p.u to 0.98p.u for voltage across B1 and 1.02 p.u to 0.93 p.u for voltage across B3.

B. With D-Statcom

Here the D-STATCOM was connected to the system and the load of three phase RLC load of 3MW, 0.2 MVAR is applied on the system in the time interval of 0.1sec to 0.5 sec. the voltage got dipped from 1.05 p.u to 1.02 p.u for voltage across B1 and 1.02 p.u to 1.0 p.u for voltage across B3.

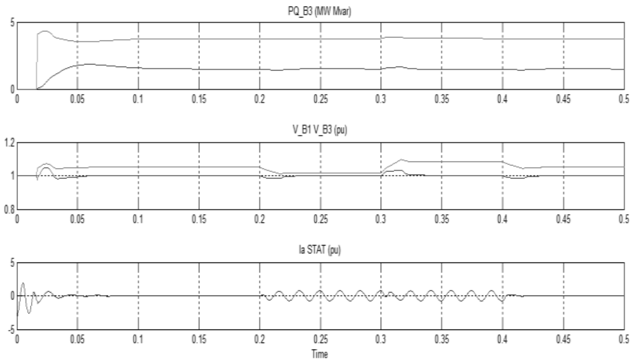

Fig. 5: Simulation Results with D- Statcom

VI. CONCLUSION

Voltage dip and voltage flickering are the two major power quality problems which are frequently seen in the distribution systems. These power quality problems in 25KV, 100 MVA distribution systems are investigated in this paper. The analysis and simulation of a DSTATCOM application for the mitigation of power quality problems are presented and discussed. The Matlab Power System Block set simulation results shows that the mitigation of the power quality problems (voltage dip and the voltage flickering) done effectively with D-STATCOM. The voltage got dipped to 0.93 in case of without D-Statcom. This instability of voltage can be mitigating with the help of D-Statcom and the voltage becomes 1.0 p.u at the bus 3.

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