D-STATCOM FOR VOLTAGE SAG, VOLTAGE SWELL MITIGATION USING MATLAB SIMULINK

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ABSTRACT

This paper deals with control strategies for DSTATCOM (Distribution Static Compensator) for power quality improvement for a three-phase, three-wire distribution system. A three-leg voltage source inverter (VSI) configuration with a dc bus capacitor is employed as DSTATCOM. The PWM current controllers are designed analyzed and compare for PI controller. The capability of the DSTATCOM is demonstrated through results obtained using Simulink MATLAB. The performance of the DSTATCOM acting as a shunt compensator is found satisfactory under varied load perturbations.

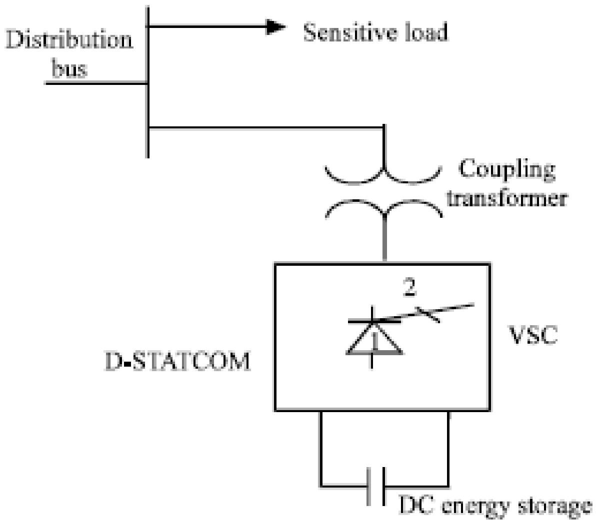
Keywords: FACTS, Shunt Compensation, Static Synchronous Compensator (STATCOM), Voltage dip, VSC.

I INTRODUCTION

Power system is a complex network & it's made of thousands of buses and hundreds of generators. Available power generation does not situated near a growing of load center, to meet the demand, utilities have an interest in better utilization of available power system capacities, existing generation and existing power transmission network, instead of building new transmission lines and expanding substations. On the other hand, power flows in some of the transmission lines are overloaded, which has as an overall effect of deteriorating voltage profiles and decreasing system stability and security. Series capacitor, shunt capacitor, and phase shifter are different approaches to increase the power system transmission lines load ability, all these devices were controlled and switched mechanically and therefore, relatively slow. The best equipment to solve this problem at distribution systems at minimum cost is by using Custom Power family of D-STATCOM [1].

II CONFIGURATION OF D-STATCOM

The basic electronic block of the D-STATCOM is the voltage source inverter that converts an input dc voltage into a three-phase output voltage at fundamental frequency. 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 D-STATCOM output voltages allows effective control of active and reactive power exchanges between the DSTATCOM and the ac system. Fig 1 shows the schematic of D-STATCOM. The D-STACOM employs an inverter to convert the DC link voltage *Vdc* on the capacitor to a voltage source of adjustable magnitude and phase. Therefore the DSTATCOM can be treated as a voltage-controlled source. Fig.2 shows a single phase equivalent of the Statcom[2]. A voltage source inverter produces a set of three phase voltages, Vi, that are in phase with the system voltage, Vs. small reactance, Xc, is used to link the compensator voltage to the power system. When. Vi>Vs, a reactive current, ic, is produced that leads Vs and when Vi<Vs, the current lags Vs.



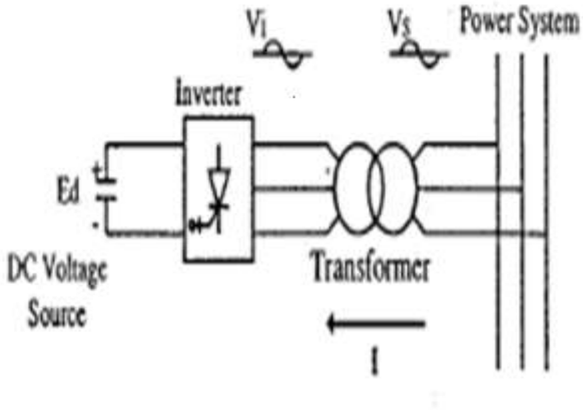
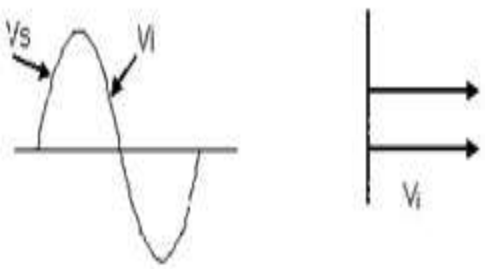
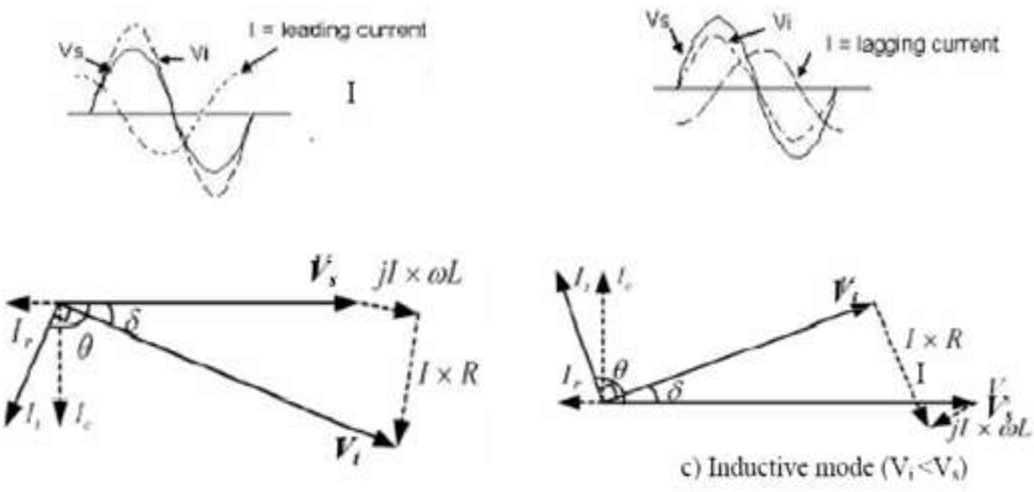


Fig. 1 STATCOM based on voltage-sourced converter. Fig. 2. Single line equivalent model of dstatcom

Fig. 2 shows the inductance *L* and resistance *R* which represent the equivalent circuit elements of the step-down transformer and the inverter will is the main component of the D-STATCOM. The voltage *Vi* is the effective output voltage of the D-STATCOM and δ is the power angle. The reactive power output of the D-STATCOM inductive or capacitive depending can be either on the operation mode of the D-STATCOM. Referring to figure 1, the controller of the D-STATCOM 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 D-STATCOM generates or absorbs the desired VAR at the point of connection. The phase of the output voltage of the thyristor-based inverter, Vi, is controlled in the same way as the distribution system voltage, Vs. Figure 3 shows the three basic operation modes of the DSTATCOM output current, I, which varies depending upon Vi. If Vi is equal to Vs, the reactive power is zero and the D-STATCOM does not generate or absorb reactive power. When Vi is greater than Vs, the DSTATCOM shows an inductive reactance connected at its terminal. The current, I, flows through the transformer reactance from the D-STATCOM to the ac system, and the device generates capacitive reactive power. If Vs is greater than Vi, the D-STATCOM shows the system as a capacitive reactance. Then the current flows from the ac system to the D-STATCOM, resulting in the device absorbing inductive reactive power[3].



(a)



(b)

Fig.3 Operation mode of DSTATCOM a) No Load, b) Capacitive mode, c) Inductive mode

III OPERATING PRINCIPLE OF THE DSTATCOM

The DSTATCOM system is comprised of three main parts: a VSC, a set of coupling reactors and a controller. The basic principle of a DSTATCOM installed in a power system is the generation of a controllable ac voltage source by a voltage source inverter (VSI) connected to a dc capacitor (energy storage device). The ac voltage source, in general, appears behind a transformer leakage reactance. The active and reactive power transfer between the power system and the DSTATCOM is caused by the voltage difference across this reactance. The DSTATCOM is connected to the power networks at a PCC, where the voltage-quality problem is a concern[4]. All required voltages and currents are measured and are fed into the controller to be compared with the commands. The controller then performs feedback control and outputs a set of switching signals to drive the main semiconductor switches MOSFET’s, which are used at the distribution level) of the power converter accordingly. The basic diagram of the DSTATCOM is illustrated in Fig.4.

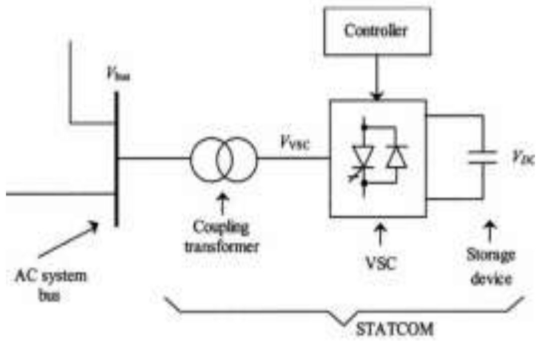


Fig.4 Block Diagram of the voltage source converter based DSTATCOM.

The ac voltage control is achieved by firing angle control. Ideally the output voltage of the VSI is in phase with the bus (where the DSTATCOM is connected) voltage. In steady state, the dc side capacitance is maintained at a fixed voltage and there is no real power exchange, except for losses[5]. The DSTATCOM differs from other reactive power generating devices (such as shunt Capacitors, Static VAR Compensators etc.) in the sense that the ability for energy storage is not a rigid necessity but is only required for system unbalance or harmonic absorption. There are two control objectives implemented in the DSTATCOM. One is the ac voltage regulation of the power system at the bus where the DSTATCOM is connected and the other is dc voltage control across the capacitor inside the DSTATCOM[6]. It is widely known that shunt reactive power injection can be used to control the bus voltage. In conventional control scheme, there are two voltage regulators designed for these purposes: ac voltage regulator for bus voltage control and dc voltage regulator for capacitor voltage control. In the simplest strategy, both the regulators are proportional integral (PI) type controller[7]s. Thus, the shunt current is split into d-axis and q-axis components. The reference values for these currents are obtained by separate PI regulators from dc voltage and ac-bus voltage errors, respectively. Then, subsequently, these reference currents are regulated by another set of PI regulators whose outputs are the d-axis and q-axis control voltages for the DSTATCOM [8].

IV 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 rms 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 rms 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 rms voltage is brought back to the reference voltage.

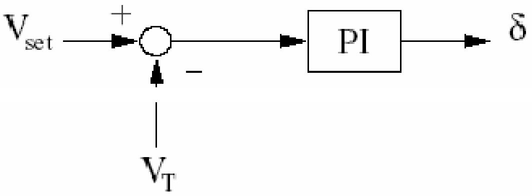


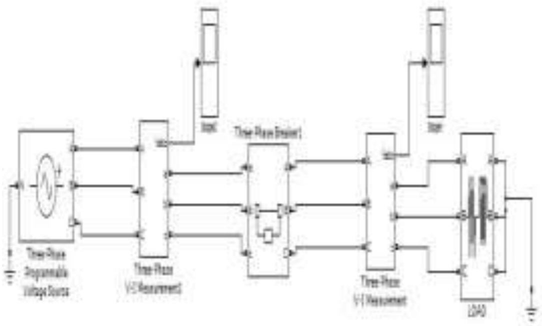
Fig.5 PI controller

V METHODOLOGY

To enhance the performance of distribution system, D-STATCOM was connected to the distribution system. D-STATCOM was designed using MATLAB simulink version R2012.

VI SIMULINK MODEL FOR THE TEST SYSTEM

6.1 Short Circuit Fault



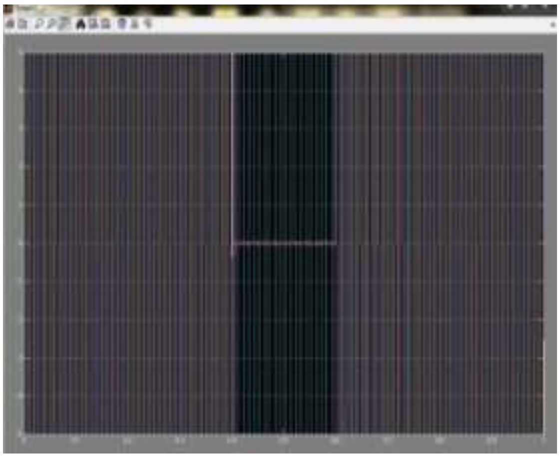
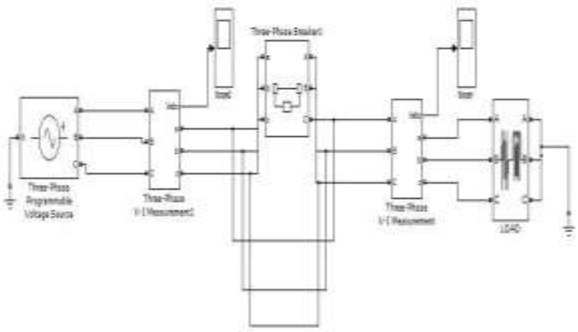


Fig.6 short circuit fault without D-Statcom **Fig.7 Waveforms of Short Circuit Fault without D-Statcom**

6.2 Swell Fault



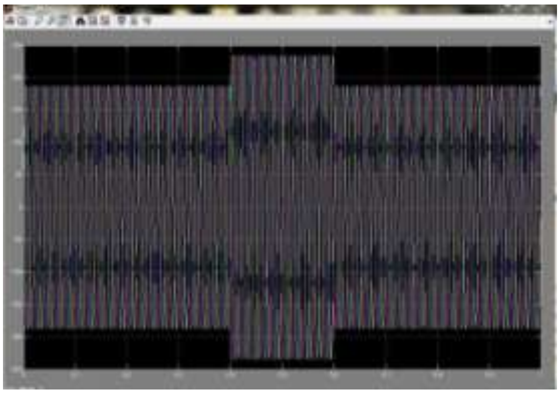
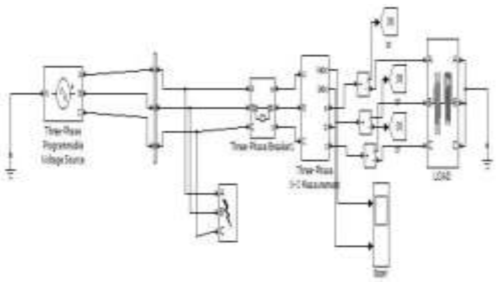


Fig.8 Circuit without D-Statcom **Fig.9 Waveforms of Swell Fault without D-Statcom**

6.3 Sag Fault



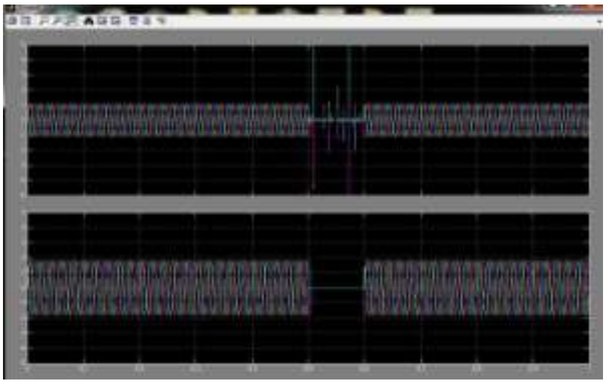
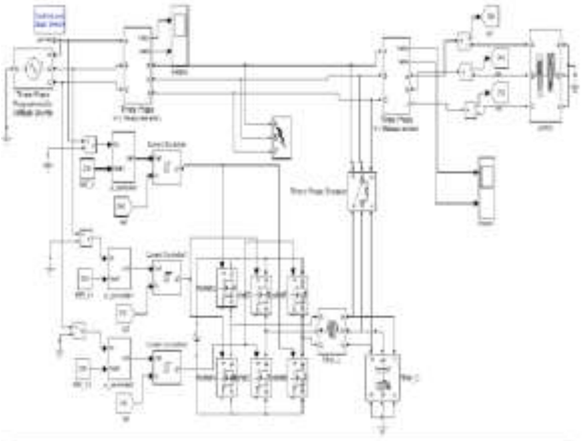


Fig.10 Circuit without D-Statcom **Fig.11 Waveforms of Sag Fault without D-Statcom**

6.4 Simulink Model for the Test System



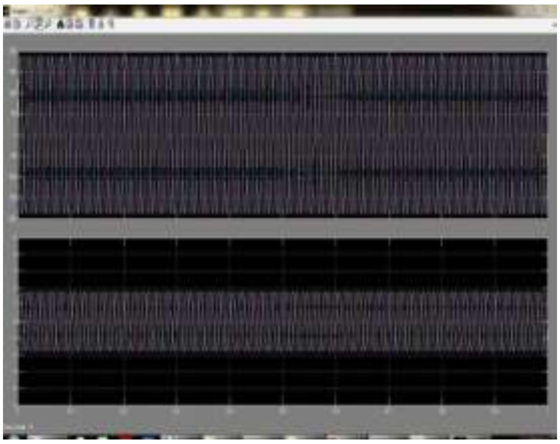


Fig.12 Wave forms of Controlled Output using D-Statcom

VII CONCLUSION

The power quality problems such as voltage dips, swells and interruptions, consequences, and mitigation techniques of custom power electronic devices D-STATCOM. The design and applications of D-STATCOM for voltage sags, interruptions and swells, and comprehensive results are presented. The simulations carried out showed that the DSTATCOM provides relatively better voltage regulation capabilities. It was also observed that the capacity for power compensation and voltage regulation of DSTATCOM depends on the rating of the dc storage device.

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