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Design of DSTATCOM for Real and Reactive Power Compensation in Power System

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Abstract: In Voltage sag and reactive power are the important power quality problems faced by utilities and many industries. Mostly reactive power is consumed by industrial inductive loads. This causes lower power factor. Consequently it limits the active power flow in the line. DSTATCOM (Distribution static compensator) is a shunt connected FACTS device, used for reactive power compensation especially in distribution system. DSTATCOM in multi bus system is capable of reducing the losses and hence improving the voltage regulation. This paper deals with voltage source converter based DSTATCOM, for compensation of active and reactive power in distribution system. The voltage source converter (of DSTATCOM) is controlled by controlling the dc link voltage. Implementation of DSTATCOM in distribution system is carried out in a MATLAB environment.

I.INTRODUCTION

The recent development of technology results in plenty of nonlinear loads in utilities, mainly power electronic devices. Such a load causes distortion of voltage and current in the distribution network. Hence distribution system accounts for the maximum portion of power loss as compared to generation and transmission. To overcome these losses reactive power compensation is needed [11]. As reactive power cannot be transmitted over long distance, hence it should be generated near to the point of consumption [4]. Conventionally series voltage regulator and shunt capacitors are used for maintaining voltages of distribution system at a desired level. But series voltage regulators have

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slow response therefore they cannot generate sufficient reactive power. Also, shunt capacitors cannot generate continuously variable reactive power [3].

FACTS devices overcome the said problems of series voltage regulator and shunt capacitors. FACTS devices are based on power electronic which maintains the power flow and controls the dynamic stability of the system by varying voltage, phase angle, and impedance etc. For low voltage distribution system custom power devices are used. Construction and operation of custom power devices are identical as FACTS devices [2]. Most widely used custom power devices are DSTATCOM, DVR and UPQC. Among them DSTATCOM is eminent because it provides both active and reactive power compensation at low cost compare to other devices [1].DSTATCOM is a shunt connected voltage source inverter fed power electronic device used for mitigation of harmonic and other problems in power quality. Operation of DSTATCOM is mainly governed by different control algorithms which provide gate pulses to voltage source inverter, also define reference current [5]. DSTATCOM is nothing but STATCOM used in distribution system.

II. PRINCIPLES OF DSTATCOM

A. Basic Structure of DSTATCOM

Basically Distribution Static Compensator (DSTATCOM) is a power electronic device connected in shunt with distribution line near to the load [1,2,4]. The schematic diagram of DSTATCOM is shown in Fig.1, and Fig.2 shows 3-phase connection of DSTATCOM with Distribution line [2]. Basically DSTATCOM consist of dc energy storage device, thyristors based voltage source converter, which convert a DC input voltage from storage device into AC output voltage so as to compensate both active and reactive power, and coupling transformer [6].

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The shunt connected voltage source converter provides three different functions:

- Reactive power compensation and voltage regulation.
- Power factor correction.
- Current harmonic [1,9].

In the DSTATCOM a 1000 micro Farad capacitor is used dc as a voltage at inverter input side. Voltage of capacitor is proportional to energy stored in the capacitor, which control the inverter voltage

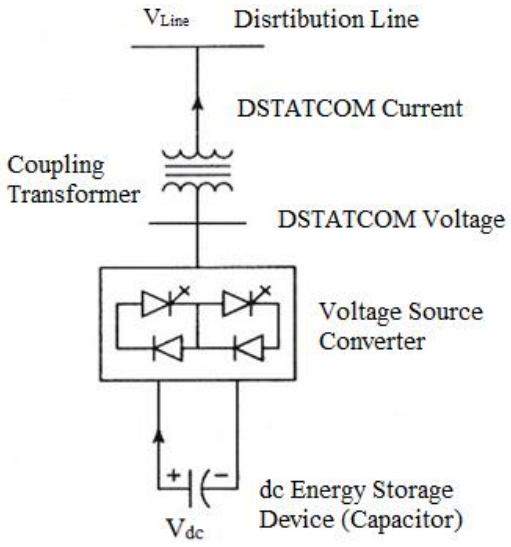

Figure1. Structure of DSTATCOM

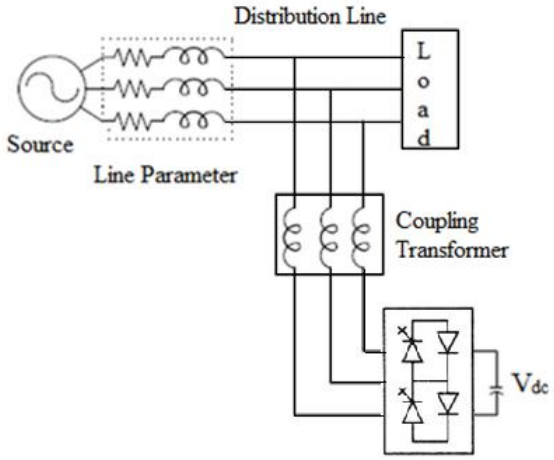

Figure2. Connection of DSTATCOM in 3-ph Distribution Line

In the DSTATCOM a 1000 micro Farad capacitor is used dc as a voltage at inverter input side. Voltage of capacitor is proportional to energy stored in the capacitor, which control the inverter voltage.

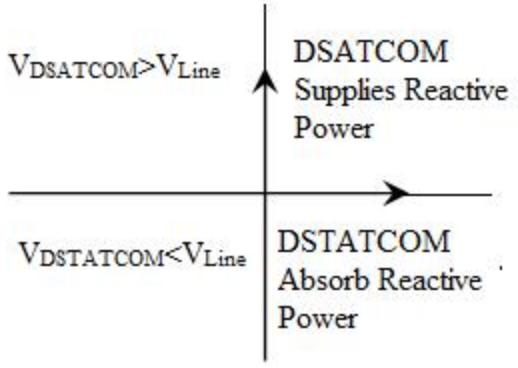

Figure3. Generation and absorption of Reactive Power by DSTATCOM

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1. Under Excited: If the magnitude of distribution line voltage is greater than DSTATCOM voltage, DSTATCOM works as an inductor and absorb reactive power and hence known as inductive mode of operation.

2. Over Excited: If the magnitude of distribution line voltage is less than DSTATCOM, DSTATCOM works as a capacitor and generate reactive power and hence known as capacitive mode of operation.

3. Normally Excited: When distribution line voltage is same as DSTATCOM voltage, then DSTATCOM does nothing, and hence DSTATCOM work in floating mode.

DSTATCOM with energy storage device can supply real power also. This can be accomplished by adjusting phase angle of distribution line and DSTATCOM. Leading the phase angle of voltage source converter by phase angle of distribution line, DSTATCOM absorbs real power from distribution line, on the other hand when phase angle of voltage source converter leads the phase angle of distribution line, DSTATCOM supplies real power to distribution line [6,15].

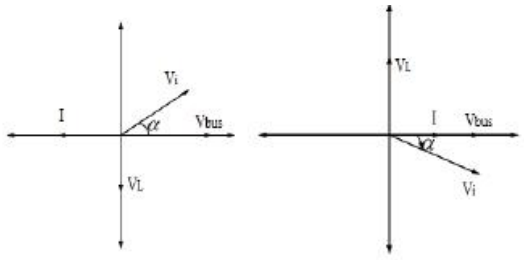

Figure4. Generation and absorption of Real Power by DSTATCOM

C. Controller for Reactive Power Compensation

The main function of controller is to provide stable voltage near to the non linear loads which causes the disturbance. The controller measures only rms voltage because there is no need of measurement of reactive power. The voltage source converter switching scheme is based on Pulse Width Modulation (PWM) techniques which gives simple operation and good results. Since DSTATCOM is a somewhat low power

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application, PWM switching method provides more flexible option compared to conventional switching method employed in FACTS application. Efficiency of the converter can be improved by using high switching frequency, with negligible switching losses [17].

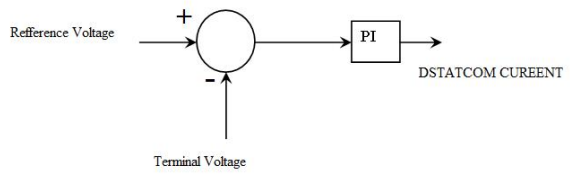

Figure5. PI control for reactive power compensation

The reference voltage and rms terminal voltage provide error signal and is given to the input of PI controller. The PI controller processed on error signal and output, i.e, angle δ is given to PWM for signal generator. Here it should be noted that in the case of indirectly controlled converter, real and reactive power exchange with the network exist simultaneously.

III. SIMULATION AND RESULTS

The model of DSTATCOM and its controller is implemented in distribution system network in MATLAB environment with Simulink and PSB toll boxes.

A. Simulation Modeling

Figure 6 shows the comprehensive system implemented in MATLAB environment to carry out the simulation of DSTATCOM in distribution network. For simulation, testing model contain three phase RLC load, 400V rms voltage source, three phase PI section and three phase circuit breaker. The load and source side voltages and currents are measured with the three phase VI measurement. Initially circuit breaker is opened and closed after 0.5s, DSTATCOM get connected in distribution line. Detailed model of DSTATCOM is shown in figure 7

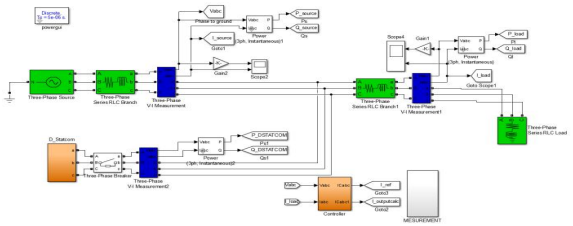

Figure6. Simulink model of Distribution System with DSTATCOM

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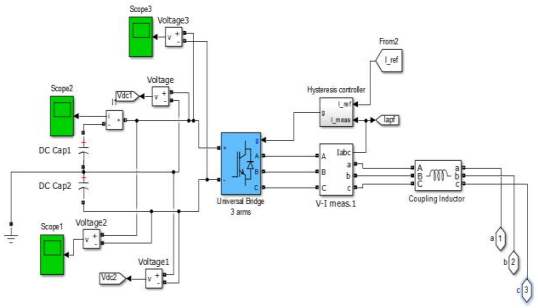

Figure7. DSTATCOM

Figure 8 shows the controller model of DSTATCOM for compensation, developed in MATLAB environment. The modelling of whole controller is done in two subsystems. One port of modelling consists of generation of reference current while second port is modelled for pulse generation.

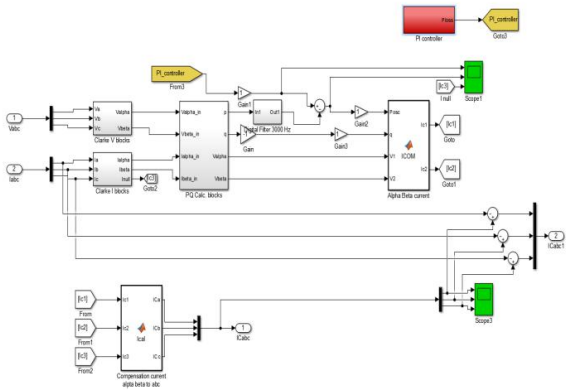

Figure8. Controller for DSTATCOM

B. Simulation Results

Each component is modelled separately and combined together in order to form complete system. For distinct and better results, simulation is carried out with complete system in MATLAB platform at different condition.

Without DSTATCOM

At the initial stage of simulation, it is a known fact that we are distribution system with RLC load and DSTATCOM is not in action. After time delay of 0.5s circuit breaker closes and loads get connected to the line. Source provides 4.9kW of active power and 2.41kVAR of reactive power. The simulation results are shown in figures. Figure 9 shows source side active and reactive power and figure 10 shows load side real and reactive power

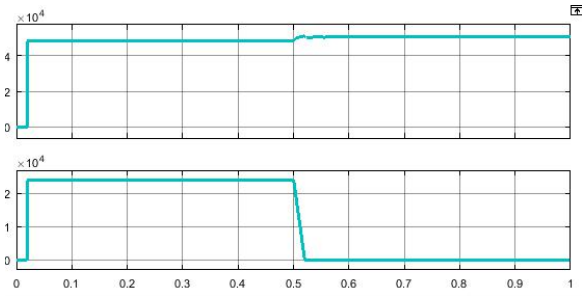

Figure9. Source side Active and Reactive Power

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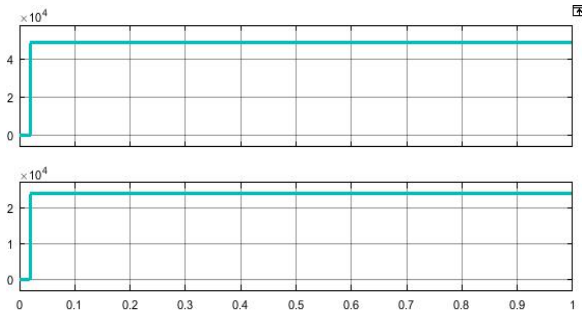

Figuure10. Load side Active and Reactive Power

With DSTATCOM Compensation

In this case DSTATCOM is get connected in distribution line through circuit breaker, which closes after 0.5s. When DSTATCOM is connected to the system active power transferred by source rises to 50KW, and active power reduced to 100VAR. the power received by load is unchanged and completely satisfied. Also DSTATCOM injects 25kvar reactive power in the system to satisfy load. Active and reactive power of DSTATCOM is shown in figure11

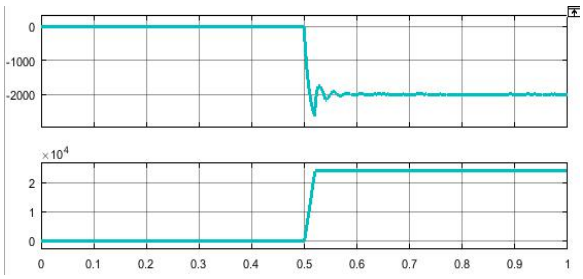

Figure11. Active and reactive power of DSTATCOM

IV. CONCLUSION

By the outcome of the simulation of non linear load in the distribution line, the conclusion cam be drawn that compensation is needed in the distribution line in order to provide reliable and stable operation. Conventional compensating device like series voltage regulator and shunt capacitors have many restrictions and hence in this paper DSTATCOM is projected to provide both active and reactive power compensation in distribution line. On the basis of different case studies, it is clear that non linear loads force the system to supply reactive power, and when DSTATCOM is connected in distribution line, the source does not required supplying reactive power because DSTATCOM supplies almost all reactive power needed. Also from simulation results it is proved that DSTATCOM not only compensate reactive

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power but also other system parameter and hence overall performance of the distribution system gets improved.

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