Power Quality Improvement using DSTATCOM

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Abstract – *Now a day's power quality issue becomes a major challenge for the utility and the consumers. Good power quality is defined as reliable power supply. If power quality issues such as poor power factor, harmonics, load imbalance, voltage fluctuations are not properly resolved then it will lead into high electricity bill, high running cost in industries, malfunctioning of equipment. In this paper, a distributed static synchronous compensator (DSTATCOM) is modelled and simulated in MATLAB/Simulink environment to improve the power quality of the grid supply by injecting the reactive and harmonic components to meet the load demand. Simulated results show that DSTATCOM mitigates the voltage profile, maintains the unity power factor and also reduces harmonic distortion of the waveforms.*

Key Words: Power Quality, DSTATCOM, Reactive Power, Harmonic Compensation, Unity Power factor etc

1. Introduction

In distribution network, the power supplied to the consumers from its nominal value is decreases drastically due to power quality problems. Voltage sag, harmonic, transient, overvoltage and under voltage are major impacts to a distribution system. The utility and the users are responsible in polluting the supply network due to operating of large linear and nonlinear loads. Power quality problems have been encouraged to associate with the security, stability, profitable and reliable operation of the entire power system and equipment. Voltage sag is one of the dominant problems related to power quality. This phenomenon happens continuously in sub-transmission and distribution systems. During a voltage sag event, amplitude of the effective load voltage decreases from the nominal load voltage in very short time (less than one minute). Various methods have been applied to reduce or mitigate voltage sags. The reported methods are by using capacitor banks, introduction of new parallel feeders and by installing uninterruptible power supplies (UPS). However, the power quality problems are not solved completely due to uncontrollable reactive power compensation and high costs of new feeders and UPS. The DSTATCOM 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 DSTATCOM has additional capability to sustain reactive current at low voltage, reduce land use and can be developed as a voltage and frequency support by replacing capacitors with batteries as energy storage.

1.1 Power Quality

The term electric power quality broadly refers to maintaining a near sinusoidal power distribution bus voltage at rated magnitude and frequency. In addition, the energy supplied to a customer must be uninterrupted from the reliability point of view.

The cause of power quality can be divided in two categories.

- The first category contains natural causes such as faults or lighting strikes on transmission lines or distribution feeders. Falling of trees or branches on distribution feeders during stormy conditions. Equipment failure.
- The second category contains the man-made causes that may be due to load or feeder/transmission line operation. Some of these causes are transformer energization, capacitor or feeder switching. Power electronic loads such as uninterrupted power supply (UPS), adjustable speed drives (ASD), converters etc. Arc furnaces and induction heating systems. Switching on or off of large loads.

1.2 Power Quality Problems

Some of the major problems for both customers and utility are

- Poor load power factor
- Harmonic contents in loads
- Notching in load voltages
- DC offset in load voltages
- Unbalanced loads
- Supply voltage distortion
- Voltage sag/swell
- Voltage flicker

2. STATCOM

A simplified single line diagram for STATCOM is shown in Fig.1. DSTATCOM unit employs an inverter (VSC) to convert the DC link voltage Vdc of the capacitor link to a voltage source of adjustable magnitude and phase. Therefore, the DSTATCOM can be treated as a voltage-controlled source. The DSTATCOM can also be seen as a current-controlled source by connecting a series inductor.

A DSTATCOM unit is modelled with DC link capacitor, a three-phase PWM inverter having six IGBT switches, interfacing inductor and, an L–C output filter, connected to the grid shown in Fig. 1 for compensation of harmonic and to maintain the unity power factor.

Selection of components like IGBTs, inductor, DC link capacitor and the ripple filter are made according to design requirement.

Selection of DC Capacitor Voltage

The minimum dc bus voltage of VSC should be greater than and equal to twice the peak of the phase voltage of the system, which is calculated by equation.

$$V_{DC} \geq \frac{2\sqrt{2}\, V_{LL}}{\sqrt{3}m}$$

Where m is the modulation index and is considered as 0.9 and VLL is the ac line output voltage of VSC.

Design of Interfacing Inductor for VSC of DSTATCOM

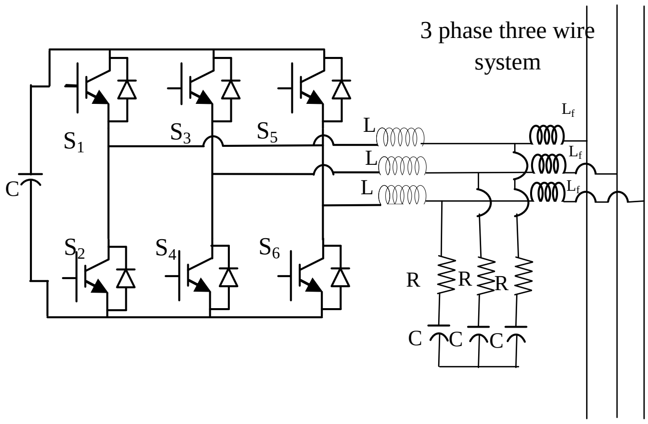

Fig. 1 DSTATCOM Circuit Model.

The selection of the interfacing inductance (*Lf*) of VSC depends on the current ripple *Δi*, switching frequency *fs* , dc bus voltage (Vdc), and Lf is given as,

$$L_f = \frac{\sqrt{3}mV_{dc}}{12hf_s\Delta i}$$

Where,

m = modulation index,
h = overload factor,
Δi = ripple current,
fs = switching frequency of VSC, and
Vdc = DC link Voltage.

Design of ripple filter

The ripple filter is designed based on the switching frequency (fs). Usually cut-off frequency (fc) is below 70% of switching frequency. The reactance given by the capacitor and inductor at cutoff frequency is

$$X_{Cr} = \frac{1}{(2 * \pi * f_c * C_r)}$$

$$X_{Lr} = (2 * \pi * f_c * L_r)$$

By considering any value of X_{Cr} and X_{Lr} according to load, the values of ripple filter elements can be calculated with the help of above formulas.

The controller of each D-STATCOM unit is used to operate the VSC 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 VARs at the point of connection.

3. STATCOM OPERATION

Reactive power compensation (Unity Power factor operation) and harmonic compensation

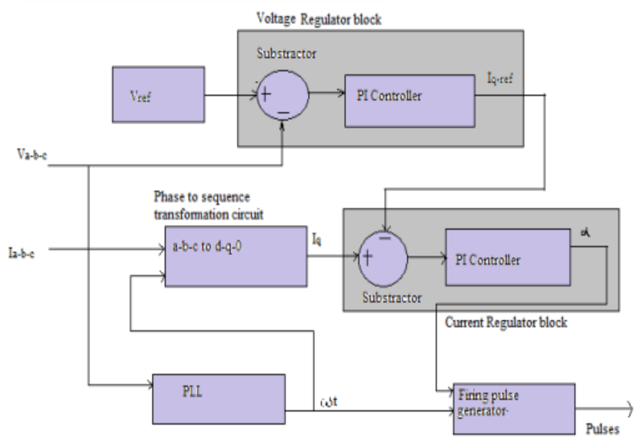

Fig. 2 DSTATCOM Control

In this block diagram, PLL synchronizes the GTO or IGBT pulses to the system voltage and generates a reference angle. *a-b-c* to *d-q-0* transformation is used for calculation of *q*-component for the DSTATCOM current using reference angle. Difference between reference voltage and measured bus voltage is calculated by voltage regulator block and the output is passed through a PI controller to generate the reactive current reference I_{qref}. The angle α is generated by passing I_{qref} through a current regulator block. This current regulator block also consists of a PI controller to keep the angle α close to zero. The output of the PLL and regulator block is used by the firing pulse generator block to generate square pulse for inverter. If the bus voltage reduces to some extent due to the application of a pulse load, the voltage regulator changes the I_{qref} , this results in the increase in angle α by the current regulator so that more active power flows from the DC- bus to the DSTATCOM and energizes the capacitor. So, the DC voltage increases and therefore the AC output of the inverter also increases and the necessary reactive power flows from DSTATCOM to the load point.

Similar to the reactive power compensation, in case of harmonics compensation same control technique is used. Here, instead of reactive component, I_q of source current, harmonic component, I_h of source is used. This I_h is compared with zero and then passed through a PI controller to generate the reference signal for the DSTATCOM to mitigate the harmonic demand of the load.

System Parameters

S. No	Parameter	System voltage
1	Grid Voltage	3-Phase, 400V, 50Hz
2	3 phase breakers	Breaker resistance=0.001ohm, snubber resistance=$1e^6$ohm
3	SPWM	Trianguler wave generator frequency=$20e^3$Hz
5	Inverter Parameter	DC Link Voltage=800V
		DC Link Capacitor=$1000e^{-6}$F
6	IGBT Rating	Internal resistance=$1e^{-3}$, snubber resistance=$1e^5$
7	Power	Sampling time=$5e^{-0.06}$s
8	Load Parameter	Lagging reactive load=400V, 50Hz, 5000W, 3000VAR Harmonic load L=0.1H, C=$500e^{-6}$, R=20ohm

4. Simulation Results

In the simulation results, it is shown that DSTATCOM is injecting reactive power and harmonics components to meet the load demand after t=0.15 sec. The supply voltage and current waveforms show that after the switching of DSTATCOM at t=0.15 sec, the grid supply quality gets improved and grid is suppling pure sinusoidal voltage and current at unity power factor.

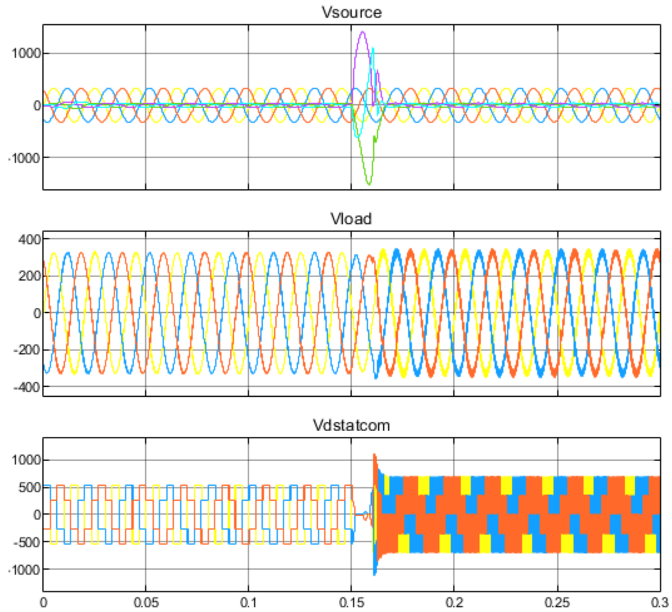

Fig. 3 Voltage Waveforms

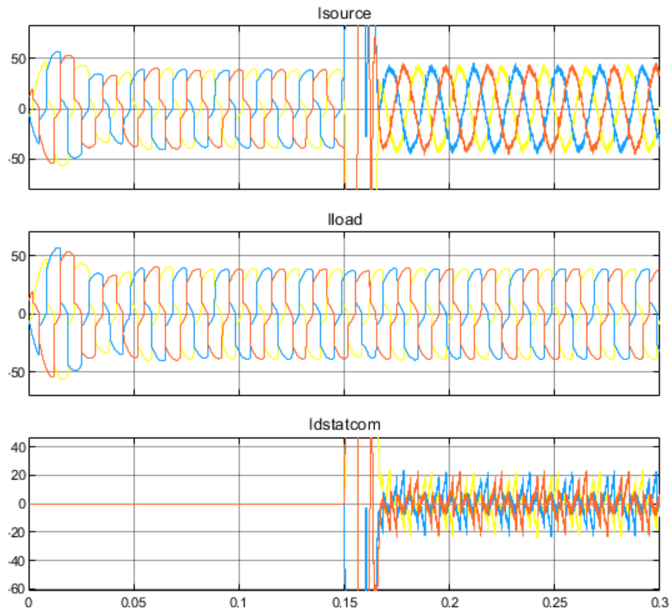

Fig. 4 Current Waveforms

5. Conclusion

In this paper, a direct current compensation technique is used for DSTATCOM to mitigate the reactive and harmonic demand of the load. The DSTATCOM model is build and simulated in MATLAB/Simulink environment to verify its performance under reactive and non-linear load.

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