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Reactive Power Control using DSTATCOM of Distribution System

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Abstract: Reactive power is produced when the current waveform is out of phase angle with the voltage waveform due to inductance or capacitance load. Current lags voltage with an inductive load, and leads voltage with a capacitive load. Only the component of current in phase with voltage produces real or active power. Major industrial loads for example transformers, furnaces, induction motors etc… needs reactive power for sustaining magnetic field. The main reason for reactive power compensation is- the voltage regulation, increased system stability, better utilization of machines connected to the systems, reducing system losses associated with the system.

The DSTATCOM (Distribution Static Compensator) is a device used to control the flow of reactive power in distribution systems. A DSTATCOM is a fast response device that provides flexible voltage control at the point connection to the distribution feeder for reactive power compensation. The performance of the DSTATCOM depends on the control algorithm. So, for this, there are various control algorithms are used. This paper presents study of the reference current generation technique through decoupled current control i.e, p-q theory by using voltage source converter based DSTATCOM for reactive power compensation.

Reference currents generated by control technique have been tracked by the compensator in a hysteresis band control scheme. The models of DSTATCOM with HCC (hysteresis current controller) are developed and simulated in MATLAB using Simulink. It is observed that DSTATCOM is effective in compensating reactive power.

Index Terms:
DSTATCOM, Voltage Source Converter, Reactive Power Compensation, Distribution system, Decoupled current control (p-q theory), Hysteresis current controller (HCC).

I. INTRODUCTION

In present day distribution systems, major power consumption has been in reactive loads, such as fans, pumps etc. These loads draw lagging power factor currents and therefore give rise to reactive power burden in the distribution system. Excessive reactive power demand increases feeder losses and reduces active power flow capability of the distribution system, whereas unbalancing affect the operation of transformers and generators. For reactive power compensation, DSTATCOM provides reactive power as needed by the load and therefore the source current remains at unity power factor (UPF). The reference source current used to decide the switching of the DSTATCOM has real fundamental frequency component of the load current which is extracted by these techniques.

A STATCOM at the real fundamental frequency component of the load current which is extracted by these techniques. A STATCOM at the transmission level handles only fundamental reactive power and provides voltage support while as a DSTATCOM is employed at the distribution level or at the load end for power factor improvement and voltage regulation. A DSTATCOM can also behave as a shunt active filter, to eliminate unbalance or distortions in the source current or the supply voltage. Since a DSTATCOM is such a multifunctional device, the main objective of any control algorithm should be to make it flexible and easy to implement.

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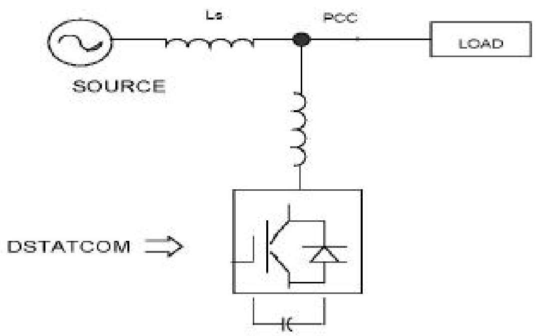
The main objective of any compensation scheme is that it should have a fast response, flexible and easy to implement. Reactive power cannot be transmitted across large power angle even with substantial voltage magnitude gradient. We can make several reason to minimize reactive power transfers.

1. It is inefficient during high real power m transfer and require substantial voltage magnitude.
2. It causes high real and reactive power losses.
3. It can lead to damaging temporary overvoltage's following load rejections.
4. It requires larger equipment size for transformer and cables.

II. BASIC PRINCIPLE OF DSTATCOM



A DSTATCOM (Distribution Static Compensator), which is shown in Fig.1, consists of a two-level Voltage Source Converter (VSC), a dc energy storage device, a coupling transformer connected in shunt to the distribution network through an interfacing inductor. The VSC converts the dc voltage across the storage device into a set of three-phase ac output voltages. 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 DSTATCOM output voltages allows effective control of active and reactive power exchanges between the DSTATCOM and the ac system. Such configuration allows the device to absorb or generate controllable active and reactive power. The AC terminals of the VSC are connected to the Point of Common Coupling (PCC) through an inductance, which could be a filter inductance or the leakage inductance of the coupling transformer, as shown in Fig.1. The DC side of the converter is connected to a DC capacitor, which carries the input ripple current of the converter and is the main reactive energy storage element. This capacitor could be charged by a battery source, or could be pre charged by the converter itself. If the output voltage of the VSC is equal to the AC terminal voltage, no reactive power is delivered to the system. If the output voltage is greater than the AC terminal voltage, the DSTATCOM is in the capacitive mode of operation and vice versa.

III. CONTROL ALGORITHM

The main objective of any compensation scheme is that it should have a fast response, flexible and easy to implement. The control algorithms of a DSTATCOM are mainly implemented in the following steps:

* Measurements of system voltages and current and signal conditioning.
* Calculation of compensating signals.
* Generation of firing angles of switching devices.

Generation of proper PWM firing is the most important part of DSTATCOM control and has a great impact on the compensation objectives, transient as well as steady state performance. Since a DSTATCOM shares many concepts to that of a STATCOM at transmission level, a few control algorithms have been directly implemented to a DSTATCOM. This paper presents the p-q theory with the hysteresis current controller scheme of a DSTATCOM for reactive power compensation.

IV. p-q THEORY

In p-q theory, Clarke's transformation changes the three phase system into a two-phase system using

$$v_{\alpha\beta} = v_\alpha + jv_\beta = v_a + av_b + a^2 v_c ,$$

$$i_{\alpha\beta} = i_\alpha + ji_\beta = i_a + ai_b + a^2 i_c$$

where $a = \exp(j\,2\pi/3)$

$$\begin{bmatrix} x_\alpha \\ x_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} x_a \\ x_b \\ x_c \end{bmatrix}$$

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where $x = v$ or i.
In terms of Clarke's components, the instantaneous apparent power-

$$\begin{bmatrix} p_{\alpha\beta} \\ q_{\alpha\beta} \end{bmatrix} = \begin{bmatrix} v_\alpha & v_\beta \\ -v_\beta & v_\alpha \end{bmatrix} \begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix}$$

The compensator currents are to be provided by the compensator at PCC voltages. Hence, the average real power component is filtered and the inverse transformation results in reference currents of the compensator. The complete flow chart of p-q theory is

$$\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} = \begin{bmatrix} 1/|v_{\alpha\beta}|\cos(\omega t) & -1/|v_{\alpha\beta}|\sin(\omega t) \\ 1/|v_{\alpha\beta}|\sin(\omega t) & 1/|v_{\alpha\beta}|\cos(\omega t) \end{bmatrix} \begin{bmatrix} p_{oscl} \\ q_{\alpha\beta} \end{bmatrix}$$

The p-q theory control algorithm for reference current generation is as shown in Fig 2.

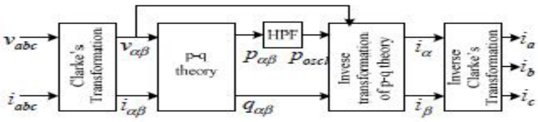

Fig 2: p-q theory control algorithm

V. HYSTERESIS CURRENT CONTROLLER

Under hysteresis control, rapid switching of each switch according to the continuous measurement of the difference between the DSTATCOM supply current and reference sinusoidal current. The basic principle of current hysteresis control technique is that the switching signals are derived from the comparison of the current error signal with a fixed width hysteresis band. Whenever the phase current exceeds the upper band, the upper switch of that leg will be turned ON while the lower switch will be turned OFF. If phase current falls below the lower band, the upper switch will be turned OFF whereas the lower switch will be turned ON. Fig 3 shows the principle of hysteresis band current controller.

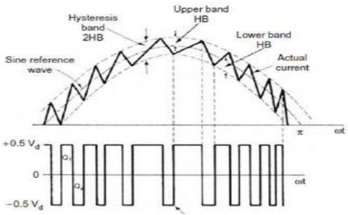

Fig 3: Principle of hysteresis band current Controller

Model of the DSTATCOM and its controller is developed in MATLAB environment with Simulink and Power System Block-sets (PSB) toolboxes. Fig.4 and 5 shows the simulation models. In fig. 6 the first window shows the waveform of active power, second window shows the waveform of reactive power, third & fourth window the actual active & reactive power respectively. In fig.7 the first window shows the waveform of posc, third & fourth window shows the waveform of pulses & current respectively. Fig. 8 shows the simulation model of hysteresis current controller and fig. 9 shows the output of with and without DSTATCOM. The pink waveform shows the output with DSTATCOM and blue waveform shows the output without DSTATCOM

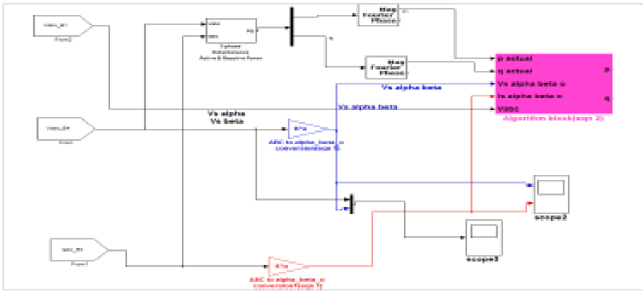

Fig:4 Simulation model.

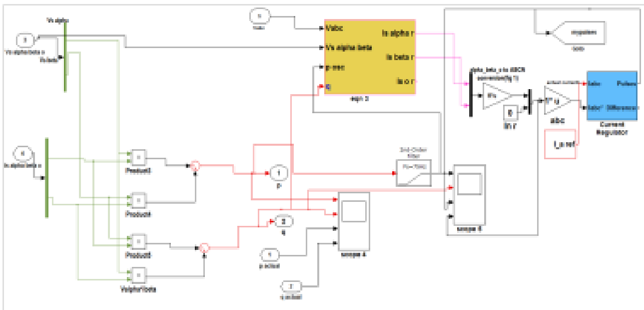

Fig.5: Simulation model.

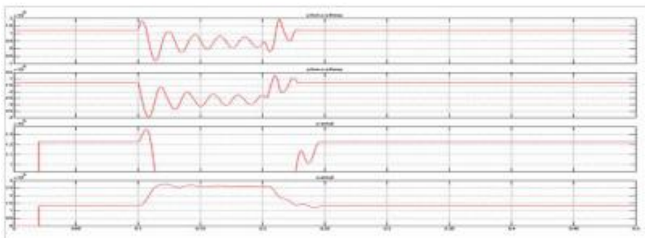

Fig 6.

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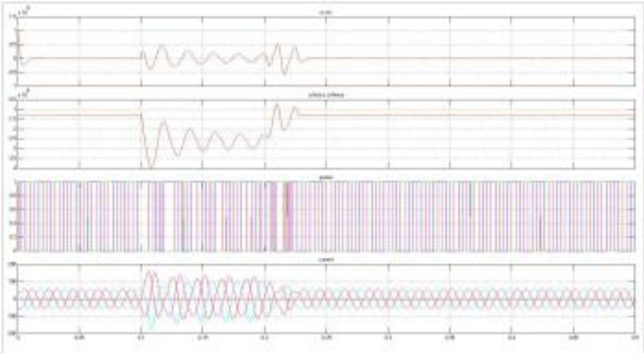

Fig 7

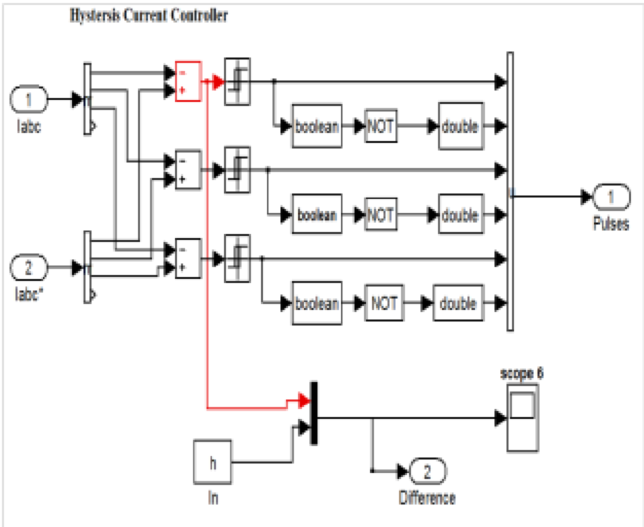

Fig 8

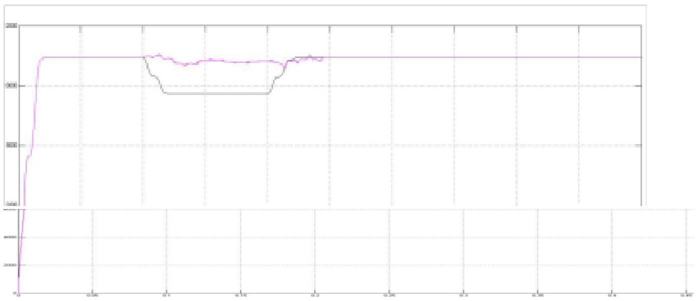

Fig 9

CONCLUSION

This paper presents the study of DSTATCOM, p-q theory and hysteresis current controller for control of DSTATCOM. The proposed control algorithm of the DSTATCOM has been found suitable for compensation of balanced load. Thus, the proposed control algorithm is found suitable for compensation technique. Thus it can be concluded that DSTATCOM compensate the reactive power in the system.

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