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COMPARATIVE STUDY OF DIFFERENT CONTROL STRATEGIES FOR DSTATCOM

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Abstract: DSTATCOM (Distribution Static Compensator) is an important device for correcting power factor, to maintaining constant distribution voltage and to mitigate harmonics in a distribution network. There are many industrial applications where a DSTATCOM offers very fast response to reactive power demand. Therefore it can be used for power factor correction and voltage regulation. In this paper three different control strategies are discussed for DSTATCOM and these are implemented in MATLAB/SIMULINK using PS SIM toolbox and the results are compared with each other.

Keywords*:* DSTATCOM, Decoupled current control, Phase Shift control, Hysterisis control.

I. INTRODUCTION

With the proliferation of nonlinear loads, high harmonic content and poor power factor at the distribution end, reactive power control using DSTATCOM is gaining immense popularity. This important shunt compensator has immersive potential to solve many power quality problems faced by distribution systems [9].The performance of the DSTATCOM depends on the control algorithm i.e. the extraction of current components. Various control algorithms have been proposed for the Control of DSTATCOM such as phase shift control [1, 2], Decoupled current control (p-q theory) [1, 2, 3], hysterisis control [1,2]. The first two schemes have been successfully implemented for STATCOM control at the transmission level, for reactive power compensation, and voltage support and recently are being incorporated to control a DSTATCOM.

The paper presents a comparative study of control Algorithms for the control of DSTATCOM. The comparison is done on the basis of- signals conditions, performance under balanced/unbalanced and nonlinear load, total harmonic distortion and multi functionality. The paper briefly describes the salient features of each algorithm with their merits and demerits A dynamic model of a DSTATCOM has been

Developed using various control algorithms MATLAB/SIMULINK Environment to observe their performances and Comparison.

II. BASIC PRINCIPLE OF DSTATCOM

A DSTATCOM is a controlled reactive source which includes a Voltage Source Converter (VSC) and a DC link capacitor connected in shunt, capable of generating and /or absorbing reactive power. It is analogous to an ideal synchronous machine, which generates a balanced set of three sinusoidal voltages at the fundamental frequency with controllable amplitude and phase angle. This ideal machine has no inertia, gives an instantaneous response, does not alter the system impedances, and can internally generate reactive (both capacitive and inductive reactive power). Fig.1 shows the basic structure of a DSTATCOM 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. The quantity of reactive power flow is proportional to the difference in the two voltages.

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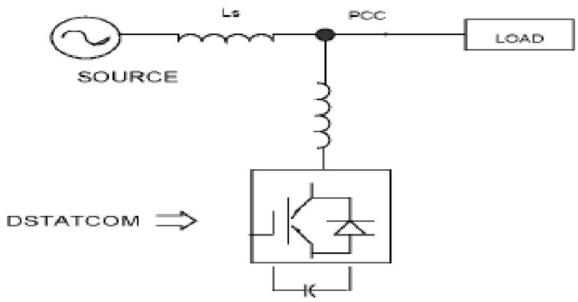


FIG.1 Basic Structure of DSTATCOM

It is to be noted that voltage regulation at Point of Common Coupling (PCC) and power factor correction cannot be achieved simultaneously [8]. For a DSTATCOM used for voltage regulation at PCC the compensation should be such that the supply currents should lead the supply voltages and for power factor correction the supply current should be in phase with the supply voltages. The control algorithms studied in this paper are applied with a view to study the performance of a DSTATCOM for reactive power compensation and power factor correction.

III. CONTROL STRATEGIES

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 were incorporating Pulse Width Modulation (PWM) switching, rather than Fundamental Frequency switching (FFS) methods. This paper is an attempt to compare the following schemes of a DSTATCOM for reactive power compensation and power factor correction based on:

1. Phase Shift Control
2. Decoupled Current Control (p-q theory)
3. Hysterisis control

The performance of DSTATCOM with different control Schemes have been tested through digital simulations

A. Phase Shift Control

In this control algorithm the voltage regulation is achieved in a DSTATCOM by the measurement of the rms voltage at the load point and no reactive power measurements are required [1,2]. Fig.2 shows the block diagram of the Implemented scheme.

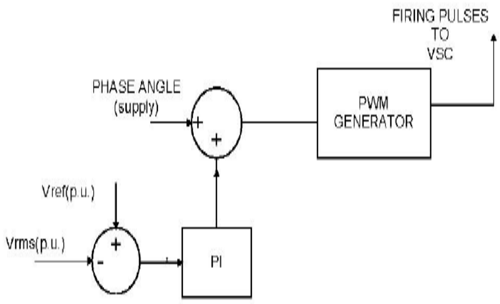
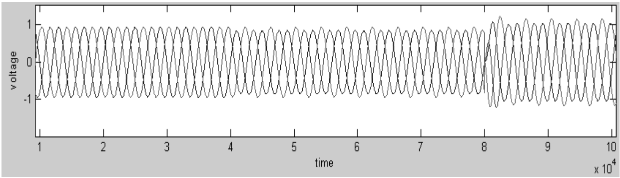
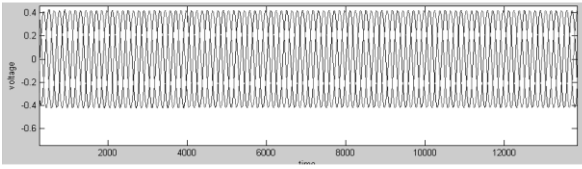


Fig 2 Shows the block diagram of phase shift Control

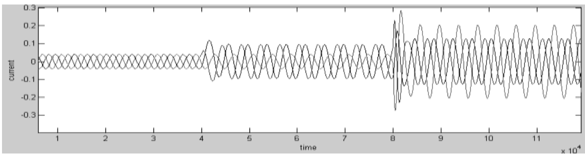
Sinusoidal PWM technique is used which is simple and gives a good response. The error signal obtained by comparing the measured system rms voltage and the reference voltage, is fed to a PI controller which generates the angle which decides the necessary phase shift between the output voltages of the VSC and the AC terminal voltage. This angle is summed with the phase angle of the balanced supply voltages, assumed to be equally spaced at 120 degrees, to produce the desired synchronizing signal required to operate the PWM Generator. In this algorithm the D.C. voltage is Maintained constant using a separate dc source.



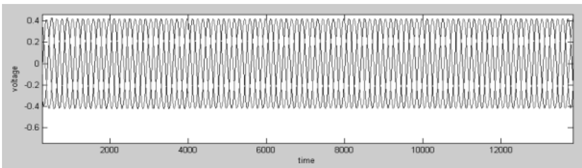
(a) Source voltage without phase shift control



(b) Source voltage with phase shift control



(c) Source current without phase shift control



(d) Source current with phase shift control

Fig 3 Shows the response using phase shift control for Linear load

The source current and the source voltage are in phase, Correcting the power factor of the system in case of a balanced fluctuating load, but in case of nonlinear load complete compensation is not achieved, the source current is lagging and the THD of the source current is also very high.

This algorithm is easy to implement and is robust, but is accompanied with the following major disadvantages:

- Assumes balanced source supply as Vrms and the supply phase angle are calculated over the fundamental only.
- A high switching frequency is required for Harmonic suppression.
- No harmonic suppression achieved in case of Nonlinear loads.

B. Decoupled Current Control (p-q theory)

This algorithm requires the measurement of instantaneous values of three phase voltage and current. Fig.4 shows the block diagram representation of the control scheme. The compensation is achieved by the control of id and iq [1,2,3].Using the definition of the instantaneous reactive power theory for a balanced three phase three wire system, the quadrature component of

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the voltage is always zero, the real (p) and the reactive power (q) injected into the system by the DSTATCOM can be expressed under the dq reference frame

$$p = v_d\, i_d + v_q\, i_q$$
$$q = v_q\, i_d - v_d\, i_q$$

Since vq=0, id and iq completely describe the instantaneous value of real and reactive powers produced by the DSTATCOM when the system voltage remains constant. Therefore the instantaneous three phase current measured is transformed by abc to_dqo transformation. The decoupled d axis component id and q axis component iq are regulated by two separate PI regulators. The instantaneous id reference and the instantaneous iq reference are obtained by the control of the dc voltage and the ac terminal voltage measured. Thus, instantaneous current tracking control is achieved using four PI regulators. A Phase Locked Loop (PLL) is used to synchronize the control loop to the ac supply so as to operate in the abc_to_dqo reference frame.

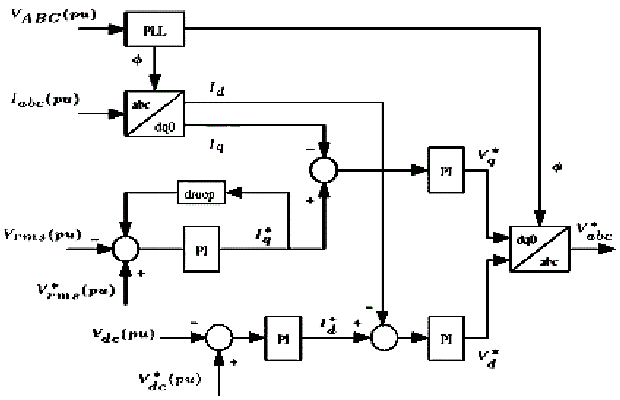
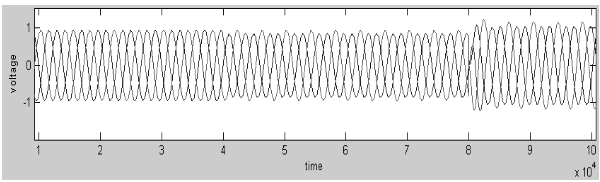


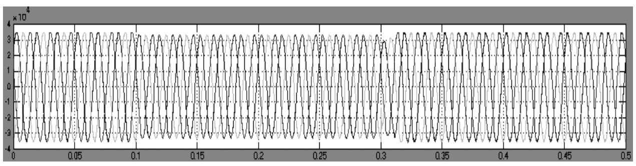
Fig 4. Block Diagram using Decoupled Current Control

Fig.5 shows the simulated results, reactive power compensation and power factor correction for balanced linear load and nonlinear load. It is observed from the figure that the transient current reaches a very high value before reaching steady state. Though complete reactive power compensation and power factor correction is achieved the THD in case of nonlinear load is still as high as 21%. The main advantage of this scheme is that it incorporates a self supporting dc bus. The disadvantages of this scheme are:

- The response time is slow as four PI controllers are used.
- Phase Locked Loop gives erroneous results in case of distorted mains and is applicable for only three phase systems.
- It is not applicable for single phase systems and three phase systems with neutral.
- Complete harmonic suppression is not achieved in case of nonlinear loads.
- During transient condition the supply current shoots to a very high value.
- A larger filter inductance is required to filter the harmonics in the output converter current, but it reduces the var generating capability of the compensator.



(a) Source voltage without Decoupled current control



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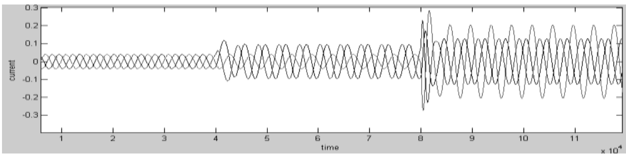
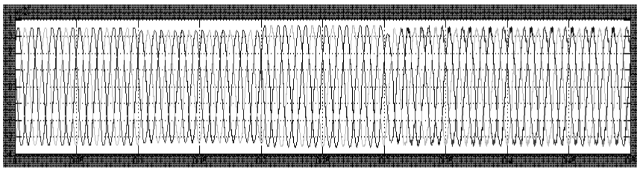
(b) Source voltage with Decoupled current control



(c) Source current without Decoupled current control



(d) Source current with Decoupled current control

Fig 5 shows the response of Decoupled Current control
with linear loads

C.HYSTERISIS CONTROL

This compensation scheme is multifunctional and can be effectively used for load balancing and harmonic suppression in addition to power factor correction and dynamic voltage regulation. Three phase ac supply voltages and DC link voltage is sensed and fed to two PI controller , the outputs of which decide the amplitude of the reference reactive and active current to be generated by the DSTATCOM. Fig.6 shows the block diagram of the implemented scheme.

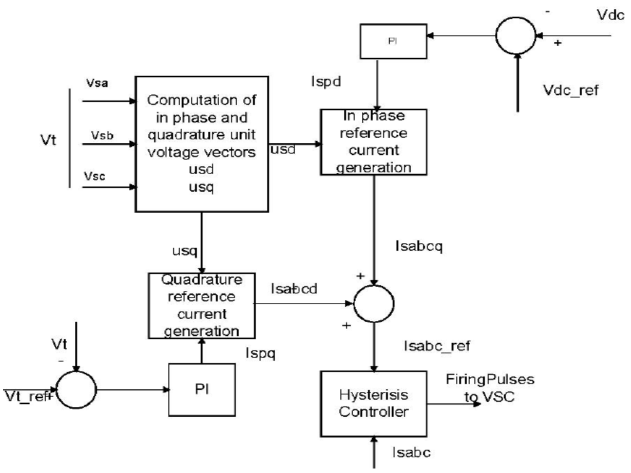


Fig.6 shows the block Diagram of Hysterisis Control

Multiplication of these amplitudes with the in phase and quadrature voltage unit vectors yields the respective component of reference currents. When applying the algorithm for power factor correction and harmonic elimination the quadrature component of the reference current is made zero. The summed direct and quadrature axis reference currents and the sensed line currents are fed to carrier less hysterisis controller which is used for tracking control. The converter switching actions are generated from a hysterisis controller which adds a hysterisis band +/-h around the calculated reference current. The pulses are generated for the lower leg switches when, Isabc >= Isabc_ref+h and for the upper leg switches when, Isabc <= Isabc_ref-h. The tracking becomes better if hysterisis band is narrower, but then the switching frequency is increased which results in increased switching losses. Therefore the choice of hysterisis band should be a compromise between tracking error and inverter losses. This method of tracking current controls is simple robust and exhibits an automatic current limiting characteristic.

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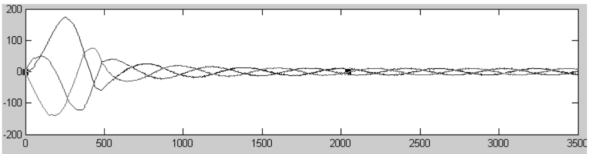
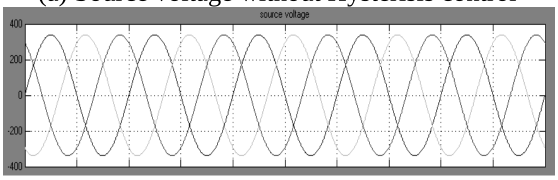
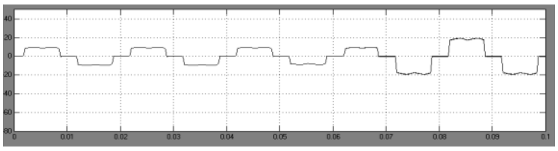
The simulated results of the above control scheme are shown in Fig. 7(a) and (b). The transient period is very short and complete reactive power compensation and power factor correction is achieved in case of any type of load. In case of nonlinear load the THD of the source Current is 1.13%, well below the IEEE-519 standard for Harmonic suppression.

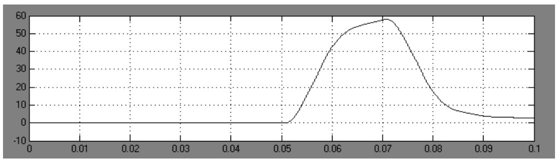


(a) Source voltage without Hysterisis control



(b) Source voltage with Hysterisis control


(c) Load current with Hysterisis control



(d) Voltage across capacitor

Fig 7 shows the response using Hysterisis control
With Non Linear load

The advantages of this scheme are:

- The derivation of switching signals is using a hysterisis controller which is robust simple.
- The algorithm is flexible and can be easily modified for voltage regulation, harmonic suppression and load balancing.
- The THD in case of nonlinear loads is well below the IEEE-519 standards limits.
- Reactive power compensation and power factor correction is achieved for both linear &non linear loads.

IV.CONCLUSION

The paper presents the comparative study of three control strategies used for the control of DSTATCOM with their relative merits and demerits. Various control algorithms are described with the help of simulation results under linear and nonlinear loads. A comparison of three control algorithms is tabulated in table 2. It can also be concluded that a DSTATCOM though is conceptually similar to a STATCOM at the transmission level, its control scheme should be such that in addition to complete reactive power compensation, power factor correction and voltage regulation the harmonics are also checked, for achieving improved power quality levels at the distribution end.

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TABLE 1.
COMPARISON OF CONTROL ALGORITHMS

ALGORITHM PARAMETERS	DECOUPLED CURRENT CONTROL	PHASE SHIFT CONTROL	HYSTERISIS CONTROL
REACTIVE POWER COMPENSATION	Complete	Satisfactory in case of linear loads	No
PERFORMACE UNDER BALANCED AND NON LINEAR LOADS	Partial	Contains undesired harmonics in case of non linear loads	Yes
APPLICABLE FOR SINGLE PHASE SYSTEMS	Complete	Satisfactory in case of linear and non linear loads	Yes
THD	15%	21%	1.13%

REFERENCES

[1] Deepika Masand, Shailendra Jain and Gayatri Agnihotri, “Control Algorithms for Distribution Static Compensator” Dept.Of Electrical Engineering, National Institute of Technology, Bhopal (MP), India, IEEE ISIE, July 9-12, 2006.
[2] Bhim Singh & Jitendra Solanki, “A comparative study of Control Algorithms for DSTATCOM for load compensation”, Department Of Electrical Engineering, Indian Institute of Technology, New Delhi IEEE, 2006
[3] Jovitha Jerome & R.Subha, “Power Quality Enhancement in Distribution System, IIT Madras, Dec 27-30.
[4] Bhim Singh “Power Quality Enhancement with DSTATCOM for Small Isolated Alternator feeding Distribution System”, Department of Electrical Engineering, Indian Institute of Technology, New Delhi.
[5] Mahesh K. Mishra Student Member, IEEE, Arindam Ghosh, Senior Member, IEEE, and Avinash Joshi “Operation of a DSTATCOM in Voltage Control Mode” IEEE Transactions on Power Delivery, Vol. 18, No. 1, January 2003.
[6] Dinesh Kumar, Rajesh, “Modelling, Analysis and Performance of a DSTATCOM for Unbalanced and Non-Linear Load” IEEE/PES Transmission and Distribution Conference & Exhibition:Asia and Pacific Dalian, China,2005.
[8] N. G. Hingorani, L. Gyugyi “Understanding FACTS; Concepts And Technology of Flexible AC Transmission Systems. IEEE Press, Standard Publishers Distributors.