ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 2.114

IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

Performance of Capacitor Supported SRF based DSTATCOM in Three-Phase Four-Wire Distribution System under Linear and Non-Linear Load Condition

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Abstract

In this paper, the four-leg voltage source converter (VSC) with capacitor in its parallel, was functioned as a distribution static compensator (DSTATCOM). In three-phase four-wire distribution system, DSTATCOM was proposed for obtaining load balancing, harmonic current reduction and voltage regulation. The proposed technology was based on synchronous reference frame (SRF Theory). This theory was used for generating a reference current or gate pulse for VSC of DSTATCOM. Performance analysis of DSTATCOM under linear non linear loads was carried out and the Simulink results were shown. The analysis was carried out in MATLAB environment using Simulink and SimPowerSystem toolbox. The proposed SRF based DSTATCOM model was seen to be very effective to enhance the power quality of a three phase four wire distribution system.

Keywords: capacitor supported DSTATCOM, four-leg voltage source converter, Hysteresis controller, PI controller, power quality, synchronous reference frame theory..

Introduction

The term power quality means maintaining a near sinusoidal power distribution bus voltage at rated magnitude and frequency. The common power quality problems in three-phase four-wire distribution system are load unbalance, low power factor, increase in neutral current, harmonic distortion, voltage imbalance, etc.[1-6]

Some of the FACTS devices are Static Voltage Controller (SVC), Static Compensator (STATCOM), Distribution Static Compensator (DSTATCOM), Dynamic Voltage (DVR) and Unified Power Quality Conditioner (UPQC). These devices are custom power devices used for maintaining and improving quality of power.

The DSTATCOM is shunt connected, custom power device, for compensating the power quality problems in current. Similarly the other custom power device i.e. DVR which is series connected device, is used for compensating the power quality problems in supply voltage. The UPQC, the combination of both DSTATCOM and DVR, is also used to provide solution for power quality problem in both voltage and current [5].

There are various topologies such as a three single-phase Voltage Source Converter (VSC), three-leg VSC with Zig-zag transformer, three-leg VSC with spilt capacitor, four-leg VSC [8-10]. After searching the topologies of DSTATCOM proposed for neutral current compensation in three- phase four-wire distribution system, three-leg VSC with capacitor in parallel was selected.

The three-leg VSC with parallel connected capacitor is used as a DSTATCOM for neutral current compensation and improving the performance of the system. The different control techniques available for generating reference control signals for VSC of DSTATCOM are: power balance theory, synchronous reference frame theory (SRF theory), instantaneous reference frame theory (p-q theory) [11-13]

In this paper, the control approach is based on SRF theory which is used for generation of control signal for VSC of DSTATCOM in three-phase four-wire distribution system. The advantages of DSTATCOM are-

(a) Perform under non-sinusoidal supply condition.
(b) Load balancing

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(c) Neutral current compensation
(d) Indirect current compensation.
(e) Capacitor supported operation of DSTATCOM

Principle of dstatcom

Fig 1(a) shows the single line diagram of DSTATCOM system, which represents complete distribution system. The two-leg VSC with capacitor is connected to load through line inductor (L_s) and resistor (R_s), where the capacitor C_f and resistor R_f represents the ripple filter capacitance and resistance respectively is used for high frequency filtering purpose of voltages at PCC. The DSTATCOM is connected at the end bus of the distribution line [5].The phasor diagram of the DSTATCOM system for unity power factor operation (UPF) and Zero voltage Regulation operation (ZVR) are Shown below in fig. 1(b) and fig. 1(c) respectively.

In UPF operation, the reactive current (I_c) injected by the DSTATCOM cancels the reactive component of the load current so that source current is reduced to real current component (I_s) only. These currents are adjusted dynamically to maintain unity power factor. In ZVR mode, the DSTATCOM injects a current I_c, such that the load voltage, V_s and source voltage, V_m is on the locus of some cycle

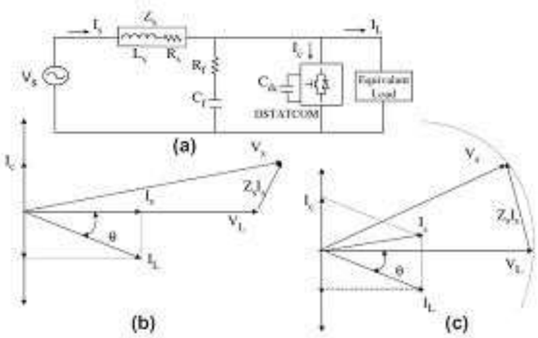

Fig.1: (a) Single line diagram of DSTATCOM system. (b) Phasor diagram for UPF operation. (c) ZVR operation

Simulaton and modelling of dstatcom

The control algorithm for the operation of four–leg VSC based capacitor supported DSTATCOM in a three- phase four-wire system is shown in fig. 5. There are various control techniques available for generating reference source current for VSC of DSTATCOM.

In this paper, the SRF theory is used for control of four-leg DSTATCOM. Fig. 5 shows the load currents (iLa, iLb, iLc), the PCC voltage (Vsa,Vsb,Vsc) and dc bus voltage (Vdc) of DSTATCOM are sensed as feedback signals. The load current in three-phases are converted into the d-q-0 frame using Park's transformation. A three-phase phase locked loop (PLL) is used to synchronise the signals with voltage at Point of Common

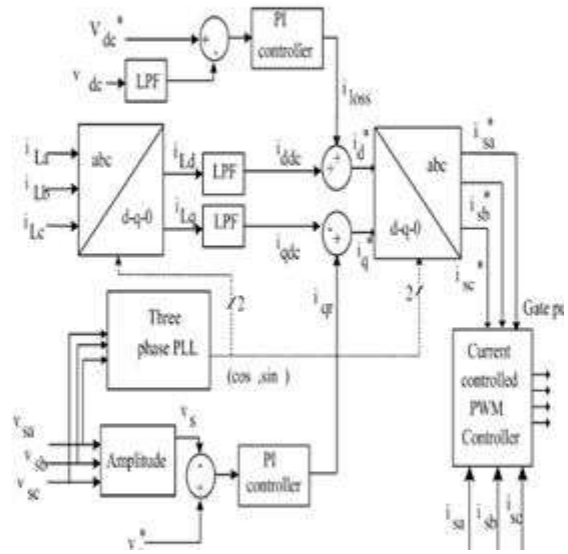

Fig. 2 Control algorithm for the operation of DSTATCOM in three-phase four-wire system

Coupling (PCC). Two PI controllers are added for the purpose of dc voltage control in Fig.2 The control algorithm for operation of four-leg VSC with capacitor based of DSTATCOM in three phase four wire system.

The overall system of SRF based DSTATCOM with balanced liner load was shown in fig.3. In this diagram the three-phase linear R-L load are connected in distribution side, V_{abc} are the three-phase terminal voltage I_{abc} are the three-phase terminal current injected by the device into the system and V_{dc} is the dc voltage measured in the capacitor and superscripts * shows the reference value.

Fig.4 shows the Matlab based model of the three-phase four-wire balanced non-linear load. In this diagram the three-phase non-linear load is connected.

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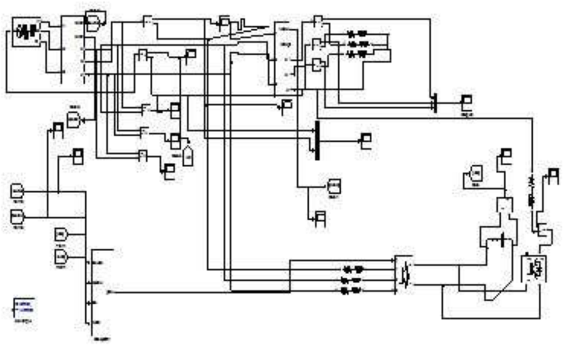

Fig.3 Matlab based model of three–phase four-wire SRF based DSTATCOM system with balance linear load

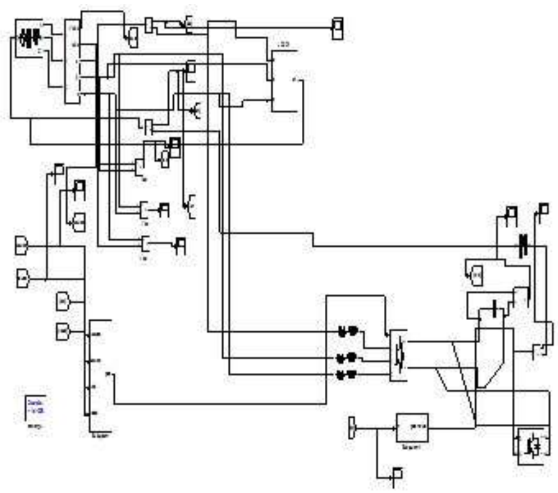

***Fig.4 Matlab based model of three–phase four-wire SRF based DSTATCOM* system with unbalance linear load**

Fig.5 Shows the Matlab based model of the control scheme for the three-phase four-wire DSTACOM.

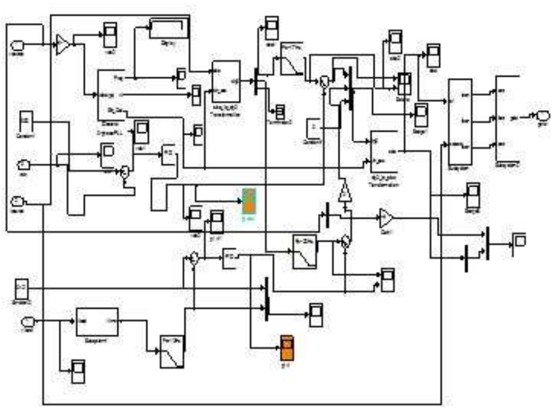

Fig.5 Matlab based model of the control scheme for three-phase four-wire DSTATCOM system

Results and tables

The dynamic performance of SRF based DSTATCOM under linear and non-linear balanced load conditions, and various results are discussed briefly in below.

(a). Performance of SRF based DSTATCOM with balance linear load for harmonic compensation, load balancing

Fig.6 shows the three-phase (Vabc) source voltage with linear balance load. Fig.7 shows the source voltage in one phase and source current waveform with balanced linear load. It is observed that the at t=0 to t=0.5 sec the controller is off the source current is out of phase with source voltage and at t=0.5sec the controller is on the source current is settled down at t=0.6 sec and in phase with the source voltage. Fig.8 shows the dc link voltage Vdc as draw by DSTATCOM, the dc link voltage is settled to reference value 698V

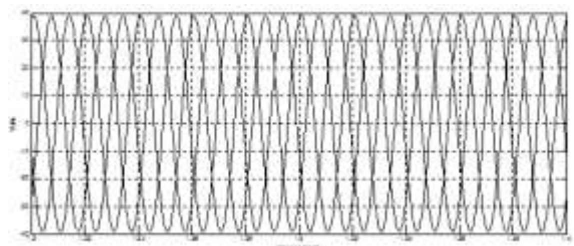

Fig. 6 Source voltage (V_{abc})

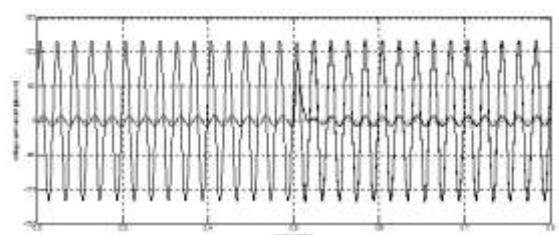

Fig.7 Source Voltage (V_{ab}) and Uncompensated & Compensated Source Current

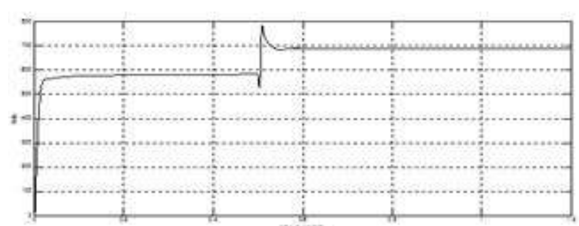

Fig.8 V_{dc} voltage

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Scientific Journal Impact Factor: 3.449
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(b).Performance of SRF based DSTATCOM with unbalance linear load for load balancing and neutral current compensation

Fig. 9 shows the source voltage and uncompensated source current waveform. This figure shows that at t=0 to t=0.5sec when the controller was off the source voltage and current are out of phase.

Fig.10 shows the source voltage and compensated source current waveform. This figure shows that at t=0.5sec when the controller was on the source current settled down in phase with.

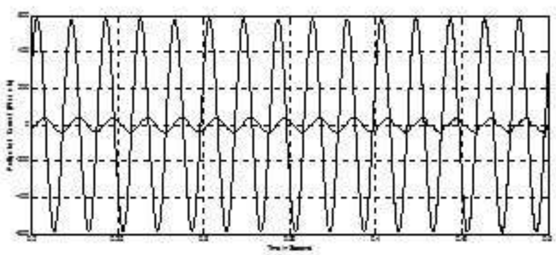

Fig.9 Voltage and Current Source waveform without Controller

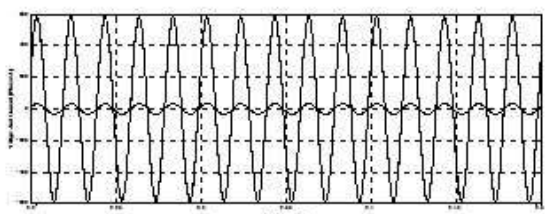

Fig.10 Voltage and Current Source waveform with Controller

(c).Performance of SRF based DSTATCOM with non- linear load for harmonic compensation, load balancing

The dynamic performance of SRF based DSTATCOM under non-linear balanced load conditions, and various results are discussed briefly in below.

Fig.11 shows the non-linear source current. In duration t=0.2s to t=0.5s the controller is off so that the uncompensated source current waveform was shown in the figure. After 0.5 s, the DSTATCOM was switched on and the compensated waveform settled at t= 0.6 sec.

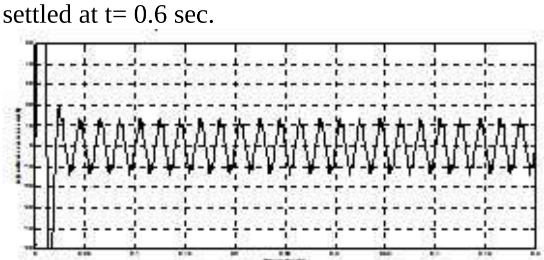

Fig.11 Non-linear source current waveform (isa) without controller

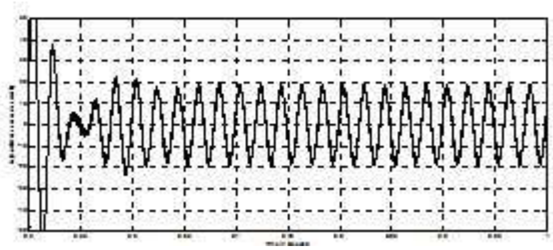

Fig.12 Non-linear source current waveform (isa) with controller

Fig.13 shows the non-linear voltage and current waveforms. It is observed that the harmonic current is compensated and the supply currents are balanced, sinusoidal and in-phase with the supply phase voltage (UPF). From t=0.2s to t=0.5s, the DSTATCOM was switched off, then the voltage and current waveforms were out of phase. After DSTATCOM was switched on at t=0.5s, the compensated current and voltage waveforms were found to be in phase.

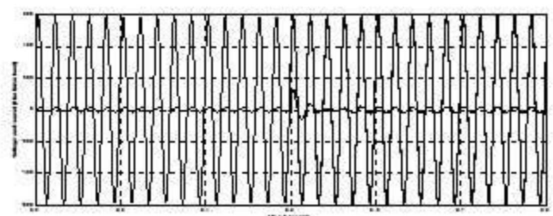

Fig.13 Nonlinear source voltage and current wave form (isa) without and with Controller

Fig.14 shows the harmonic spectrum analysis of supply current before compensation. The THD was 17.51% which is intolerable

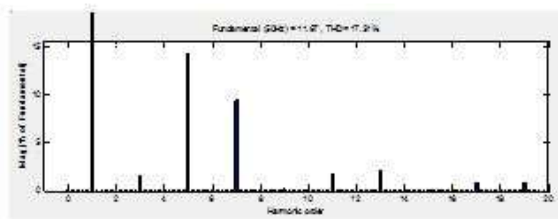

Fig14.Frequency spectrum of uncompensated source current

Fig.15 shows the harmonic spectrum analysis of supply current after compensation. The THD was 3.50%.

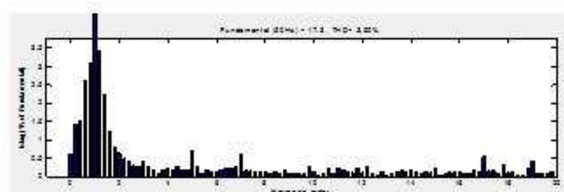

Fig 15: Frequency spectrum of compensated source current

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(d).Performance of SRF based DSTATCOM for voltage regulation with linear load

The performance of the DSTATCOM during the distorted supply voltage condition is shown in Fig.16 when the linear load changes the voltage are increases and decreases shown in figure and When the DSTATCOM is on at 0.8 sec. DSTATCOM is able to achieve the supply side power factor to unity and settled down to 1

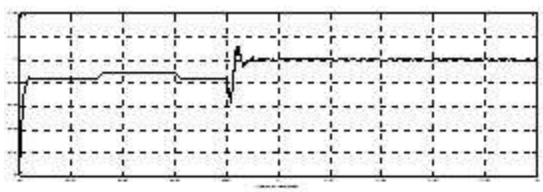

Fig.16 Performance of DSTATCOM for voltage regulation with linear load

Conclusion

A new control scheme based on synchronous reference frame (SRF) theory had been used for the four-leg DSTATCOM for three-phase four-wire distribution system to improve the performance under non-linear load condition.

The model was developed using Simulink and SimPowerSystem toolbox. The analysis was performed for non-linear loads. It was seen that before the compensation was provided, the current and the voltage waveforms were out of phase. After the SRF based DSTATCOM was connected in the system, the current compensation was provided, making the current and voltage waveforms in phase.

The following objectives have been successfully achieved.

- Load balancing.
- Harmonics Current Compensation
- Voltage Regulation

Acknowledgment

I sincerely thank MS. Deepika Masand (Guide), for supporting and contributing there valuable points in my Paper.

References

1. Acha E, Agelids VG, Anaya-Lara O, Miller TJE. Power electronic control in electric systems, newness power engineering series. 1st ed. Oxford; 2002.
2. Ghosh A, Ledwich G. Power quality enhancement using custom power devices. London: Kluwer Academic Publishers; 2002.
3. Akagi H, Watanabe EH. M Aredes. Instantaneous power theory and Applications to power conditioning. New Jersey, USA: John Wiley & Sons; 2007.
4. IEEE recommended practices and requirements for harmonics control in Electric power systems, IEEE Std. 519; 1992.
5. Fugita H, Akagi H. Voltage-regulation performance of a shunt active filter Intended for installation on a power distribution system. In: IEEE trans on Power electronics, vol. 22, no. 1; May 2007. p. 1046–53.
6. Tavakoli Bina M, Eskandari MD, Panahlou M. Design and installation of a ±250 kV Ar D-STATCOM for a distribution substation. Electr Power Syst Res 2005;73(3):383–91.IEEE Std. 802.11, 1997.
7. Akagi H, Watanabe EH, Aredes M. Instantaneous power theory and applications to power conditioning. New Jersey, USA: John Wiley & Sons; 2007.] Fuchs Ewald F, Mausoum Mohammad AS. Power quality in power systems and electrical machines. London, UK: Elsevier Academic Press; 2008.
8. Hurng- Liahng Jou, Jinn- Chang Wu, Kuen-Der Wu, Wen- Jung Chiang and Yi- Hsun Chen, "Analysis of zig-zag Transformer applying in the three-phase Four- Wire Distribution Power System,"*IEEE Trans. Power Delivery*, vol. 20, no. 2, pp. 1168-1173, April2005.
9. Hurng-Liahng, Kuen- Der Wu, Jinn- Chang Wu and Wen- Jung Chiang, "A three-phase four- wire power filter comprising a three phase three-wire active filter and a zig-zag transformer," *IEEE Trans. Of Power Electronics.* vol. 23, No. 1, pp. 252- 259, Jan. 2008.
10. H.L.Jou, K. D. Wu, J. C. Wu, C. H. Li and M. S. Huang, "Novel power converter topology for three-phase four-wire hybrid power filter", *IET Power Electron*., vol.1, No.1, pp. 164-173, 2008.
11. R. C. Dugan, M. F. McGranaghan and H. W. Beaty, *Electric Power Systems Quality*. 2ed Edition, McGraw Hill, New York, 2006.[12] H. Akagi, E H Watanabe and M Aredes, *Instantaneous power theory and applications to power conditioning*, John Wiley & Sons, New Jersey, USA, 2007.
12. K.R. Padiyar, *FACTS Controllers in Transmission and Distribution*, New Age International, New Delhi, 2007.

ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 2.114

13. B.N.Singh, P.Rastgoufard, B.Singh, A.Chandra and K.Al.Haddad,"Design, simulation and implementation of three pole/ four pole Topologies for active filters," *IEE Proc. of Eletr. Power Appl.*, vol 151, no. 4, pp. 467-476, July 2004.
14. Bhim Singh, Vishal Verma and Jitendra Solanki, "Neural network based Selective compensation current quality problems in distribution system," *IEEE Trans. on Industrial electron*ics, vol. 54, no. 1, pp. 53 – 60, Feb. 2007.
15. B. Singh, J. Solanki, **"**An Implementation of an Adaptive Control Algorithm for a Three-Phase Shunt Active Filter," *IEEE Trans. On Industrial Electronics*, vol.56, no. 5, May 2009.
16. Bhim Singh Sunil Kumar (2009) "Modified Power Balanced theory for control of DSTATCOM.
17. Singh, B. and Verma, "Selective Compensation of Power-Quality Problems through Active Power Filter by Current Decomposition," IEEE. Trans. Power Delivery, Vol. 23, No. 2, April, (2008), pp. 792–799.
18. Bhim Singh, Vishal Verma and Jitendra Solanki, "Neural network based selective compensation current quality problems in distribution system," IEEE Trans. on Industrial electronics, vol.54, no. 1, pp. 53 – 60, Feb. 2007.
19. M.C. Benhabib and S. Saadate, "New control approach for four-wire active power filter based on the use of synchronous reference frame," Electric Power Systems Research, vol. 73,no. 3, pp. 353-362, Mar 2005.