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A Novel Control Strategy for Distribution Static Compensator Under Power Quality Problems



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ABSTRACT:

The proposed scheme exhibitsseveral advantages compared to traditional voltage-controlledDSTATCOM where the reference voltage is arbitrarily. Power quality is an occurrencemanifested as a nonstandard voltage, current or frequencythat results in a failure of end use equipment's. In order to maintain the power system quality the DSTATCOM will absorb and providereactive power to mitigate voltage sag, swell, interruption and improve powerfactor in various conditions. The compensatorinjects lower currents and, therefore, reduces losses in thefeeder and voltage-source inverter. This scheme allows DSTATCOM totackle power-quality issues by providing power factor correction,harmonic elimination, load balancing, and voltage regulationbased on the load requirement. Its performance is simulated in the MATLAB environment using SIMULINK and Sim Power System (SPS) toolboxes. The performance of DSTATCOM is found satisfactory under time varying and unbalanced loads.

Keywords:

DSTATCOM, Power factor correction,voltage-source inverter, dead beat voltage control.

INTRODUCTION:

Power quality in distribution systems affects all the connected electrical and electronics equipment's. It is a measure of deviations in voltage, current, frequency of a particular system and associated components. In recent years, use of power converters in adjustable speed drives, power supplies etc. is continuously increasing. This equipment drawsharmonics currents from AC mains and increases the supply demands. These loads can be grouped as linear (lagging power factor loads), nonlinear (current or voltage source type of harmonic generating loads), unbalanced and mixed types of loads. Some of power quality problems associated with these loads include harmonics, high reactive power burden, load unbalancing, voltage variation etc. A survey on power quality problems is discussed for classification, suitable corrective and preventive actions to identify these problems. A variety of custom power devices are developed and successfully implemented to compensate various power quality problems in a distribution system. These custom power devices are classified as the DSTATCOM (Distribution Static Compensator), DVR (Dynamic Voltage Restorer) and UPQC (Unified Power Quality Conditioner).

The DSTATCOM is a shunt-connected device, which can mitigate the current related power quality problems. The power quality at the PCC is governed by standards such as IEEE-519-1992, IEEE-1531-2003 and IEC- 61000, IECSC77A etc. The effectiveness of DSTATCOM depends upon the used control algorithm for generating the switching signals for the voltage source converter and value of interfacing inductors. For the control of DSTATCOM, many control algorithms are reported in the literature based on the instantaneous reactive power theory, deadbeat or predictive control, instantaneous symmetrical component, nonlinear control technique, modified power balance theory, enhanced phase locked loop technique, Adeline control technique, synchronous reference frame control technique, ANN and fuzzy based controller, SVM based controller, correlation and cross-correlation coefficients based control algorithm, Other techniques applied in active filters are based on Hilbert transform, soft phase locked loop and novel hysteresis current controller etc.

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The control algorithm based on cross correlation function approach has been reported for single phase AC system. In this paper, this control algorithm based on the correlation and cross correlation function approach is used in a three phase distribution system for compensation of reactive current, harmonics current and load balancing in PFC and ZVR modes of operation of DSTATCOM.

Design of DSTATCOM:

A DSTATCOM is a device which is used in an AC distribution system where, harmonic current mitigation, reactive currentcompensation and load balancing are necessary. The building block of a DSTATCOM is a voltage source converter (VSC)consisting of self-commutating semiconductor valves and a capacitor on the DC bus (Singh et al, 2008). The device is shuntconnected to the power distribution network through a coupling inductance that is usually realized by the transformer leakagereactance. In general, the DSTATCOM can provide power factor correction, harmonics compensation and load balancing.

Themajor advantages of DSTATCOM compared with a conventional static VAR compensator (SVC) include the ability to generatethe rated current at virtually any network voltage, better dynamic response and the use of a relatively small capacitor on the DCbus. The size of the capacitor does not play an important role in steady-state reactive power generation, which results in asignificant reduction of the overall compensator size and cost (Ghosh et al, 2002; Padiyar, 2008).Fig. 1 shows the schematic diagram of a DSTATCOM connected to a three phase AC mains feeding three phase loads. Threephase loads may be a lagging power factor load or an unbalanced load or nonlinear loads or mixed of these loads. For reducingripple in compensating currents, interfacing inductors (Lf) are used at AC side of the voltage source converter (VSC).

A smallseries connected capacitor (Cf) and resistor (Rf) represent the ripple filter installed at PCC in parallel with the loads and thecompensator to filter the high frequency switching noise of the voltage at PCC. The harmonics/ reactive currents (iCabc) are injectedby the DSTATCOM to cancel the harmonics /reactive power component of the load currents so that the source currents areharmonic free (reduction in harmonics) and load reactive power is also compensated. The rating of the switches is based on thevoltage and current rating of the required compensation. For considered load of 35kVA, compensator data are given in Appendix, the rating of the VSC for reactive power compensation/harmonics elimination is found to be 25kVA (15% more reactive currentfrom rated value). The selection of the DC bus voltage, DC bus capacitor, AC inductors and the ripple filter of DSTATCOM aregiven as,

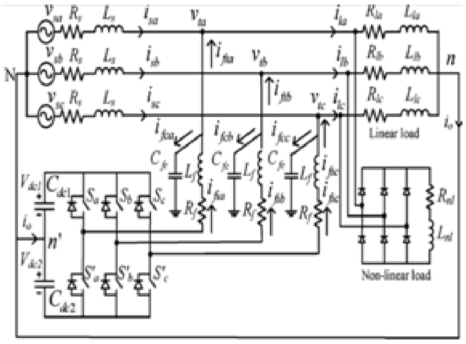

Fig 1: Circuit diagram of the DSTATCOM

CONTROL STRATEGY:

Generationof Reference Terminal Voltages:

Reference terminal voltages are generated such that, at nominalload, all advantages of CCM operation are achieved whileDSTATCOM is operating in VCM. Hence, the DSTATCOMwill inject reactive and harmonic components of load current.To achieve this, first the fundamental positive-sequence componentof load currents is computed. Then, it is assumed thatthese currents come fromthe source and considered as referencesource currents at nominal load.With these source currents andfor UPF at the PCC, the magnitude of the PCC voltage is calculated.Let three-phase load currentsila(t),ilb(t), andilc(t) berepresented by the following equations:

$$i_{lj}(t) = \sum_{n=1}^{m} \sqrt{2}\, I_{lj\,n} \sin\left(n\,\omega t + \phi_{lj\,n}\right)$$

Wherej = a, b, c represent three phases, n is the harmonicnumber, and m is the maximum harmonic order.ϕlan Representsthe phase angle of the nth harmonic with respect to referencein phase- and is similar to other phases. Using instantaneoussymmetrical component theory, instantaneous zero-sequenceilao(t), positive-sequence ila+(t), and negative-sequenceila-(t)current components are calculated as follows:

$$\begin{bmatrix} i^0_{la}(t) \\ i^+_{la}(t) \\ i^-_{la}(t) \end{bmatrix} = \frac{1}{3}\begin{bmatrix} 1 & 1 & 1 \\ 1 & \alpha & \alpha^2 \\ 1 & \alpha^2 & \alpha \end{bmatrix}\begin{bmatrix} i_{la}(t) \\ i_{lb}(t) \\ i_{lc}(t) \end{bmatrix}$$

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Whereα is a complex operator.

The fundamental positive-sequence component of load current I+la1, calculated by finding the complex Fourier coefficient,is expressed as follows

$$\bar{I}^{+}_{la1} = \frac{\sqrt{2}}{T}\int_{0}^{T} i^{+}_{la}(t)\, e^{-j(\omega t - 90^{\circ})}\, dt$$

$I^{+}_{la1}$is a complex quantity, contains magnitude and phase angleinformation.

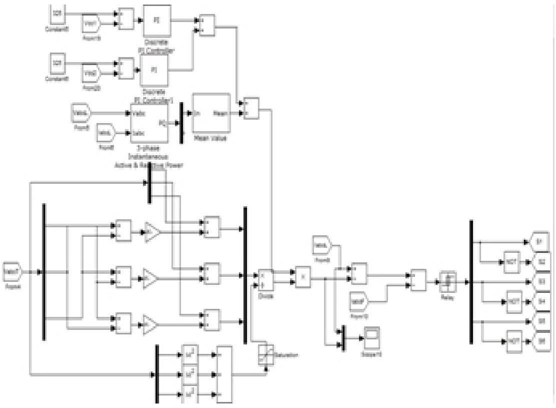

Fig 2: simulation circuit of control strategy

The fundamental positive-sequence component of load currentsmust be supplied by the source at nominal load. Hence, it willbe treated as reference source currents. For UPF at nominal operation,the nominal load angle is used. By knowing,fundamental positive-sequence currents in phases and can beeasily computed by providing a phase displacement of -2π/3 and 2π/3, respectively, and are given as

$$i^{*}_{sa} = i^{+}_{la1}(t) = \sqrt{2}\,\left|\bar{I}^{+}_{la1}\right| \sin(\omega t - \delta_0)$$
$$i^{*}_{sb} = i^{+}_{lb1}(t) = \sqrt{2}\,\left|\bar{I}^{+}_{la1}\right| \sin\left(\omega t - \frac{2\pi}{3} - \delta_0\right)$$
$$i^{*}_{sc} = i^{+}_{lc1}(t) = \sqrt{2}\,\left|\bar{I}^{+}_{la1}\right| \sin\left(\omega t + \frac{2\pi}{3} - \delta_0\right)$$

When reference source currents derived are supplied bythe source, three-phase terminal voltages can be computed usingthe following equations:

$$v_{tj}(t) = v_{sj}(t) - L_s \frac{di^{*}_{sj}}{dt} - R_s i^{*}_{sj}$$

Let the rms value of reference terminal and source voltagesbe V*tand V, respectively. For UPF, the source current and terminalvoltage will be in phase. However, to obtain the expressionof V* independent of δo, we assume the PCC voltage as areference phasor for the time-being. Hence, phase-a quantities,by considering UPF at the PCC, will be

$$v_{ta}(t) = \sqrt{2}\, V^{*}_{t}\ \sin \omega t$$
$$i^{*}_{sa} = \sqrt{2}\, \left|\bar{I}^{+}_{la1}\right| \sin \omega t$$
$$v_{sa}(t) = \sqrt{2}\, V\ \sin(\omega t + \delta_0)$$

The phasor equation will be

$$V^{*}_{t}\angle 0 = V\angle \delta_0 - (R_s + jX_s)\left|\bar{I}^{+}_{la1}\right| \angle 0$$

Simplifying the above equation

$$V^{*}_{t} = V\cos\delta_0 + jV\sin\delta_0 - \left|\bar{I}^{+}_{la1}\right| R_s - j\left|\bar{I}^{+}_{la1}\right| X_s$$

The expression for reference load voltagemagnitude will be

$$v^{*}_{ta}(t) = \sqrt{2}\, V^{*}_{t}\ \sin(\omega t - \delta)$$
$$v^{*}_{tb}(t) = \sqrt{2}\, V^{*}_{t}\ \sin\left(\omega t - \frac{2\pi}{3} - \delta\right)$$
$$v^{*}_{tc}(t) = \sqrt{2}\, V^{*}_{t}\ \sin\left(\omega t + \frac{2\pi}{3} - \delta\right)$$

SIMULATION RESULTS:

The control scheme is implemented using PSCAD software.Distorted and unbalanced source currents flowing through thefeeder make terminal voltages unbalanced and distorted. Threeconditions, namely, nominal operation, operation during sag,and operation during load change are compared between the traditional and proposed method.

Conventional operation:

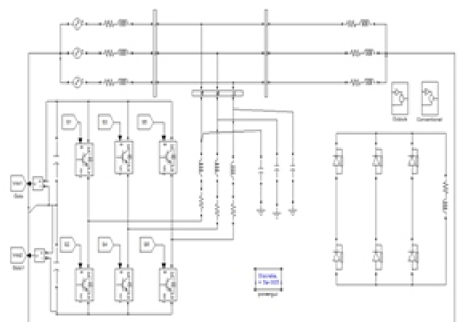

Fig 3: simulation circuit conventional dstatcom

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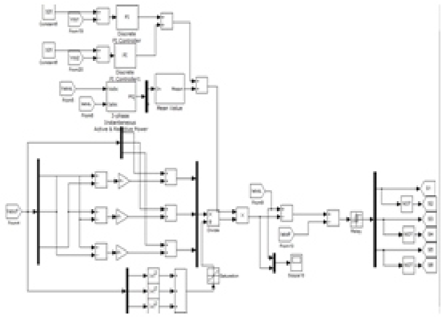


Fig 4: control strategy

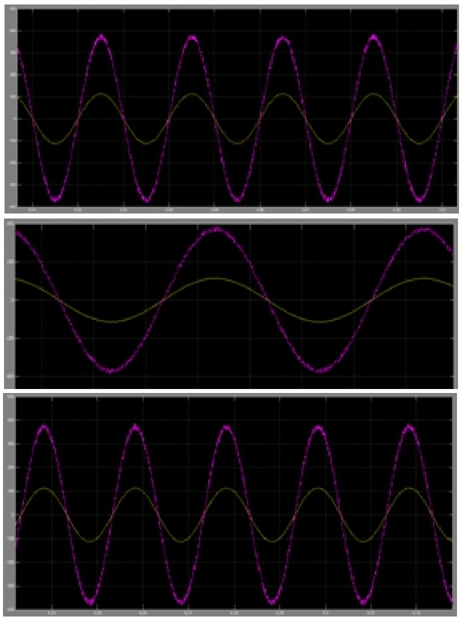


Fig 5: Terminal voltages and source currents using the traditional method. (a) Phase-a. (b) Phase-b. (c) Phase-c.

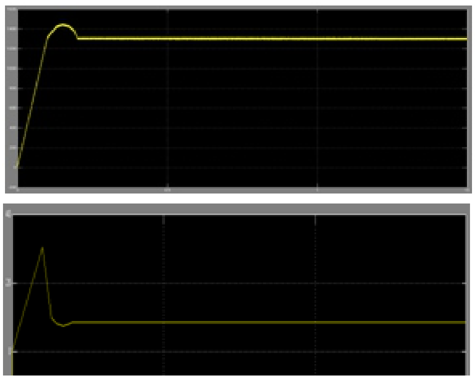


Fig 6: (a) Voltage at the dc bus. (b) Load angle.

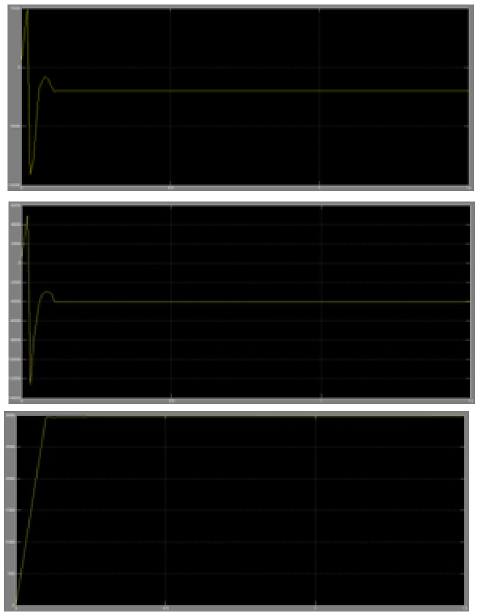


Fig 7: Load reactive power, compensator reactive power, and reactive power at PCC. (a) Traditional method.

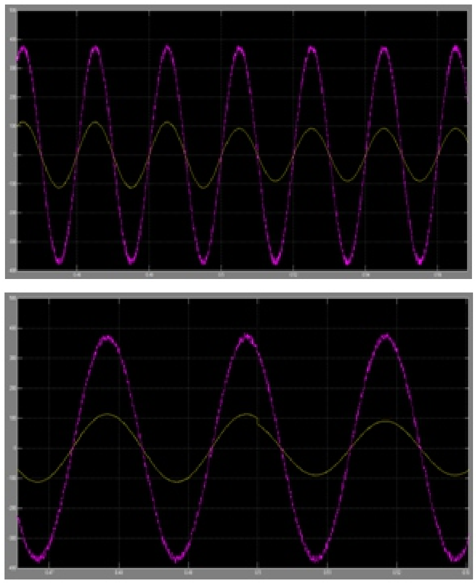
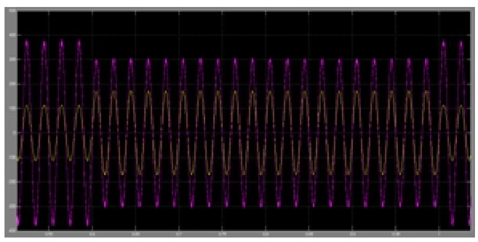


Fig 8: Terminal voltages and source currents using the traditional method during load change.



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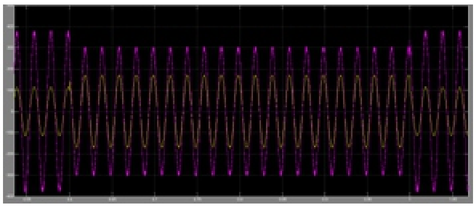


Fig 9: Terminal voltages and source currents using the traditional method during sag.

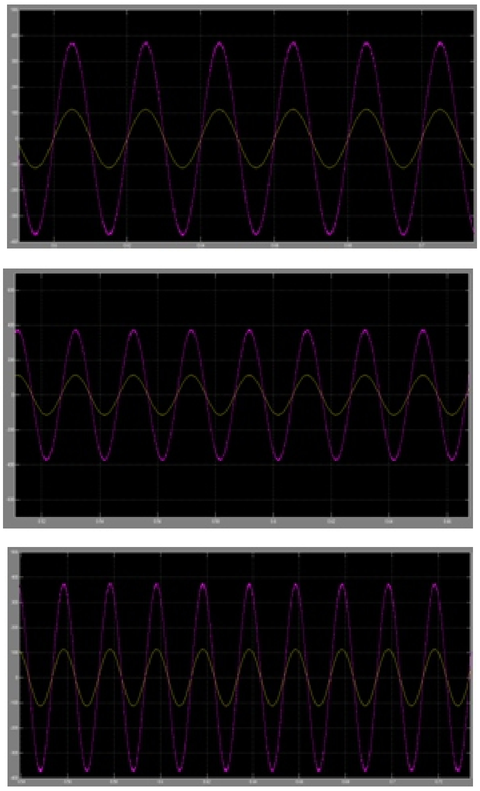


Fig 10: Terminal voltages and source currents using the proposed method. (a) Phase-A. (b) Phase-B. (c) Phase-C.

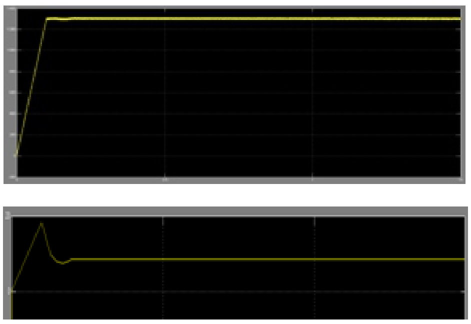


Fig 11: (a) Voltage at the dc bus. (b) Load angle for proposed method.

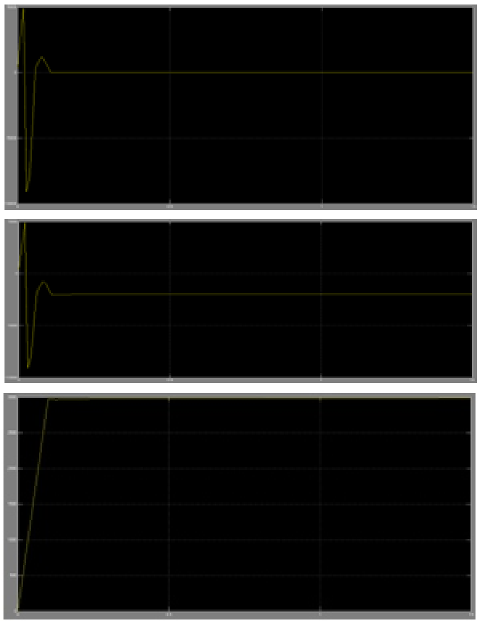


Fig 12: Load reactive power, compensator reactive power, and reactive power at PCC for proposed method.

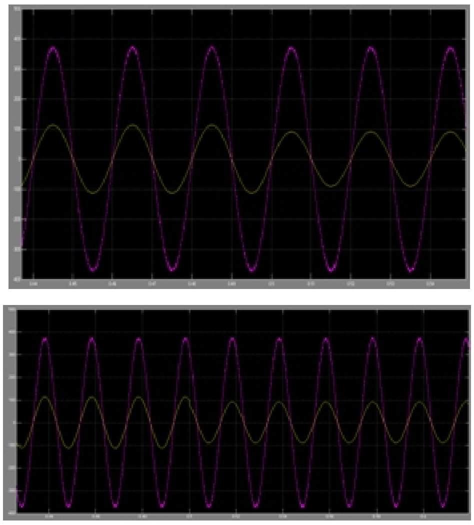
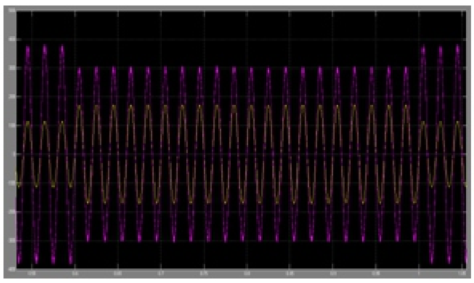


Fig 13: Terminal voltages and source currents using the proposed method during load change.



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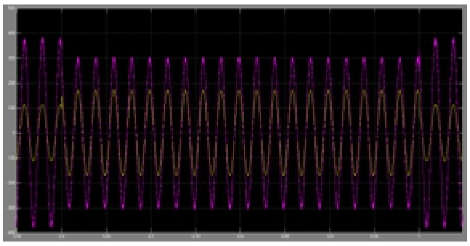

Fig 14: Terminal voltages and source currents using the proposed method during sag.

CONCLUSION:

The performance of the proposed scheme is comparedwith the traditional voltage-controlled DSTATCOM.Theproposed method provides the following advantages: 1) at nominalload, the compensator injects reactive and harmonic componentsof load currents, resulting in UPF; 2) nearly UPF ismaintained for a load change; 3) fast voltage regulation has beenachieved during voltage disturbances; and 4) losses in the VSIand feeder are reduced considerably. DSTATCOM control algorithm isflexible and it has been observed to be capable of correctingpower factor to unity, eliminate harmonics in supplycurrents and provide load balancing.

REFERENCES:

[1] M. Bollen, Understanding Power Quality Problems. Piscataway, NJ,USA: IEEE, 2000, ch. 1, pp. 1–35.

[2] H. Fujita and H. Akagi, "Voltage-regulation performance of a shuntactive filter intended for installation on a power distribution system,"IEEE Trans. Power Electron., vol. 22, no. 3, pp. 1046–1053, May 2007.

[3] A. Ghosh and G. Ledwich, "Load compensating DSTATCOM in weakac systems," IEEE Trans. Power Del., vol. 18, no. 4, pp. 1302–1309,Oct. 2003.

[4] A. Elnady and M. Salama, "Unified approach for mitigating voltagesag and voltage flicker using the DSTATCOM," IEEE Trans. PowerDel., vol. 20, no. 2, pt. 1, pp. 992–1000, Apr. 2005.

[5] S. Rahmani, A. Hamadi, and K. Al-Haddad, "A Lyapunov-functionbasedcontrol for a three-phase shunt hybrid active filter," IEEE Trans.Ind. Electron., vol. 59, no. 3, pp. 1418–1429, Mar. 2012.

[6] M. K. Mishra and K. Karthikeyan, "A fast-acting dc-link voltage controllerfor three-phase DSTATCOM to compensate ac and dc loads,"IEEE Trans. Power Del., vol. 24, no. 4, pp. 2291–2299, Oct. 2009.

[7] M. K. Mishra, A. Ghosh, A. Joshi, and H. M. Suryawanshi, "A novelmethod of load compensation under unbalanced and distorted voltages,"IEEE Trans. Power Del., vol. 22, no. 1, pp. 288–295, Jan. 2007.

[8] M. K.Mishra, A. Ghosh, and A. Joshi, "Operation of a DSTATCOMin voltage control mode," IEEE Trans. Power Del., vol. 18, no. 1, pp.258–264, Jan. 2003.

[9] A. Jain, K. Joshi, A. Behal, and N. Mohan, "Voltage regulation withSTATCOMs:Modeling, control and results," IEEE Trans. Power Del.,vol. 21, no. 2, pp. 726–735, Apr. 2006.