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Power Quality Improvement Using Closed Loop PI &FLC Controlled VSI Based STATCOM

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ABSTRACT: STATCOM is a popular device to improve voltage of weak buses in two bus systems. This work deals with modeling and simulation of closed loop controlled Three Phase voltage source inverter based STATCOM in eight bus system. Closed loop PI & FLC controlled STATCOM systems are investigated and their results are compared. The comparison is done in term of time domain response parameters like steady state error & settling time. The STATCOM with FLC is observed to be faster than PI controlled system.

KEYWORDS: Flexible Alternating Current Transmission System (FACTS); Static synchronous Compensator (STATCOM); Static VAR Compensator (SVC); PI –Proportional integral; FLC-Fuzzy logic controller; Total Harmonic Distortion (THD);

I. INTRODUCTION

FLEXIBLE AC transmission systems (FACTS) are being used extensively in power system to enhance the system utilization, power deportation quantity as well as the power quality of ac system interconnections [1], [2]. As a typical shunt FACTS device, static synchronous compensator (STATCOM) is employed at the point of common connection (PCC) to absorb or inject the appropriate reactive power, through which the voltage quality of PCC is improved [3]. In recent years, many topologies have been enforced to the STATCOM. Amid these various types of topology, H-bridge cascaded STATCOM has been extensively acknowledged in high-power applications for the following abilities: quick response speed, small volume, high efficiency, minimal synergy with the supply grid and its individual phase control ability [4]–[7]. Compared with other types of converter three phase VSI based STATCOM can obtain a high number of levels more easily and connected to the grid directly without using the bulky transformer. This empowers us to minimize cost and maximize the use of Three phase VSI based STATCOM [8].

There are two technological difficulties which are there in Three phase VSI based STATCOM up to date. First, the curb approach for the current loop is an significant factor influencing the compensation performance. Yet, different non-ideal factors, such as the small bandwidth of the output current loop, the time delay lured by the signal disclosure circuit, and the reference command current generation process, will deteriorate the compensation effect. Second, Three phase VSI based STATCOM is a perplexing system with many VSI based inverter in each phase, so the voltage imbalance issue caused by different active power losses among the cells, various switching patterns for different cells, parameter variations of active and passive components inside cells will influence the reliability of the system and even lead to the breakdown of the system. Hence, lots of researches have focused on seeking the solutions to these problems.

In terms of current loop control, recently used methodology involves linear control method, in which the non-linear equations of the STATCOM model are linearized with a specific equilibrium. The most widely used linear control schemes are PI controllers [9], [10]. In [9], to regulate reactive power, only a simple PI controller is carried out. In [10], through a decoupled lured strategy, the PI controller is employed in a synchronous d–q frame. However, it is hard to find the suitable parameters for designing the PI controller and the performance of the PI controller might degrade with the external disturbance. Thus, a number of intelligent methods have been proposed to modify the PI controller efficiency such as particle swarm optimization [11], neural networks [12], and artificial immunity [13]. In literature [14], [15], adaptive control and linear robust control have been reported for their anti-external disturbance ability. In literature [16], [17], a popular dead-beat current controller is used. This control method has the maximum bandwidth and the speedy current tracking reference. The steady-state performance of Three phase VSI based STATCOM is improved, but the dynamic performance is not improved. In [18], a DC injection elimination method called IDCF is proposed to build an additional closed loop for the DC component of the output current. It can improve the output current quality of STATCOM. However, the circuit configuration of the cascaded STATCOM is the delta configuration, but not the star configuration. Moreover, an adaptive theory-based improved linear sinusoidal tracer control method is proposed in [19] and a leaky least mean square-based lured methodology is expected in [20]. But these methods are not for STATCOM with the VSI structure. By using the traditional linear control method, the controller is characterized by its simple control structure and parameter design convenience, but poor dynamic control stability.

Other control approaches apply nonlinear control which directly compensates for the system nonlinearities without requiring a linear approximation. In [21], a transfer function linearization controller is designed. By adding a damping term, the oscillation amplitude of the internal dynamics can be effectively decreased. However, the stability cannot be guaranteed [22]. Then, many new modified damping controllers are designed to enhance the stability and performance of the internal dynamics [23]–[26]. However, the implementation of these controllers is very complex. To enhance robustness and simplify the controller layout, a passivity-based controller (PBC) based on fault dynamics is proposed for STATCOM [27]–[30]. Furthermore, the exponential cohesion of system equilibrium point is guaranteed. Nevertheless, these methods are not designed on the basis of STATCOM with the three phase VSI based arrangement and no literature is verified experimentally.

In terms of DC voltage balancing control in capacitor, there are three major issues: overall voltage stabilization clustered stabilizing control, and specific balancing control. In literature [31], under the assumption of all DC capacitors being equally charged and balanced, they can only eliminate the imbalances caused by the inconsistent drive pulses without detecting all DC capacitor voltages. In [32]–[34], additional hardware circuits are required in the methods based on AC bus energy exchange and DC bus energy exchange, which will maximize the cost and the complexity of the system. In [35], a method based on zero-sequence volt-age interjection is enhanced and it will increase the DC capacitor voltage endurance capacity. On the confliction, the methodology using negative-sequence current in [36] do not require the maximum mar-gin of DC capacitor voltage, but the action of STATCOM is minimized. In [8], the individual phase with active power cluster is lured independently. In [37] and [38], it is super imposing the cosine component of the system voltage with clustered output voltage, but it can be easily affected by an inaccurate phase-locked loop (PLL). In [39], the active voltage vector superposition method is enhanced. The selective harmonic elimination modulation method is used in [40] and [41], in which DC voltage balancing control and low-frequency modulation are achieved. Compared with the method in [40] and [41], a methodology shifting phase angle for DC voltage stabilization control is proposed in [42] and [43], through which the desirable effect can be easily achieved, whereas it is limited by the capacity of STATCOM. In [44], the DC voltage and reactive power are lured. yet, it cannot be extensively used due to fact that many non-ideal factors are neglected. In [45] and [46], the proposed method assumes that all cells are distributed with equal reactive power and it uses the cosine value of the current phase angle. It could lead to system instability, when using the zero-crossing point of the cosine value. In [47] and [48], the results of experiments are obtained in the downscaled laboratory system. Thus, they are not very persuasive in this condition.

In this paper, VSI system using STATCOM is modeled and simulated. Comparison of result shows that PI controller offers better performance. VSI reduces THD content in the output of STATCOM .Scheme of the STATCOM in a simple two-bus System is illustrated in Fig.1.1

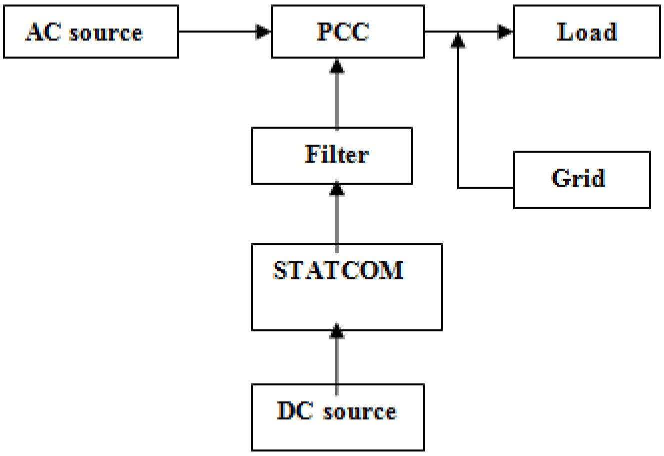

Fig.1.1 Block diagram of MLI based grid connected STATCOM

As the shunt converters of the STATCOM are single-phase, it gives an opportunity to STATCOM to control current in each bus dependently, which implies that both negative and zero sequence unbalanced voltage can be compensated. Additional controllers are supplemented to the existing STATCOM controller. Their control principle is to monitor the negative and zero sequences current through the transmission line and to force them to zero.

The above literature does not deal with comparison of PI and FLC controlled STATCOM systems used. The objective of this paper is to study the improvement in reactive power and reduction in THD using VSI.

II. PRINCIPLE OF THE STATCOM

A) Control Principle of STATCOM

The STATCOM system consists of MLI based converters, and each of PWM pulse technique control scheme. The block diagram of the STATCOM and its control is shown in Fig (2). The shunt converter is controlled to inject a constant odd harmonic current into the transmission line, which is intended to supply reactive power for the shunt converters.

The shunt converter extracts some reactive power from the grid at the fundamental frequency to maintain its DC voltage. The DC voltage of the shunt converter is controlled by the *d* component of the current at the fundamental frequency, and the *q* component is utilized for reactive power compensation. The power flow control function is realized by an outer control loop, the power flow control block. This block gets its reference signals from the system operator, and the control signals for STATCOM shunt converters are sent remotely via wireless or PLC communication method.

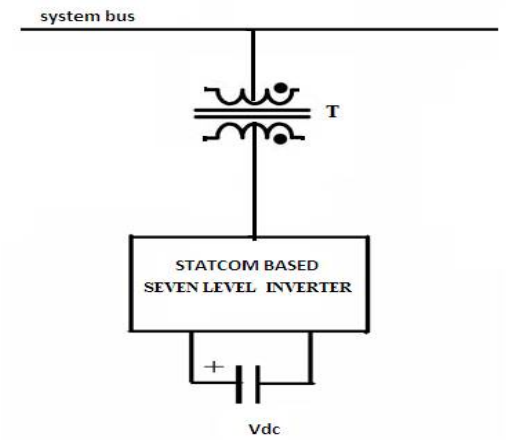

Fig.2. Block diagram of the bus radial STATCOM

The functions of each control block shown in Fig (2) are described here:

●**Power flow control:** It receives the set point for power flow from the system operator, and calculates the fundamental frequency voltage that should be injected by the shunt converters.

●**AC voltage control:** gives the set points to shunt converter for reactive power compensation at the fundamental frequency.

●**Shunt converter control:** generates odd harmonic current, the reactive power at the fundamental frequency and stabilizes the DC voltage.

III. SIMULATION RESULTS

Three Phase VSI based STATCOM systems are considered for simulation studies. The closed loop system with PI controller is shown in Figure 3.1.The output voltage is shown in Figure 3.2.Receiving end voltage THD is shown in Figure 3.3**.**Receiving end current is shown in Figure 3.4 Receiving end current THD is shown in Figure 3.5.and it has value of 500 volts The closed loop system with FLC controller is shown in Figure 4.0.The output voltage is shown in Figure 4.1.Receiving end voltage THD is shown in Figure 4.2**.**Receiving end current is shown in Figure 4.3 Receiving end current THD is shown in Figure 4.4. The real & reactive powers are shown in Figure 3.4and Figure 4.4 for PI and PID system resp. Real power value is 600 W and reactive power value is 1300w.The comparison of responses with PI and FLC controllers is given in Table 2.The comparison indicates that settling time and steady state error in FLC system are 25% less than that of PI controlled system. Peak time is reduced from 0.35 to 0.26 seconds. Settling time is reduced from 0.43 to 0.30 seconds and steady state error is reduced from 5.6 to 1.3 Volts using FLC controller.

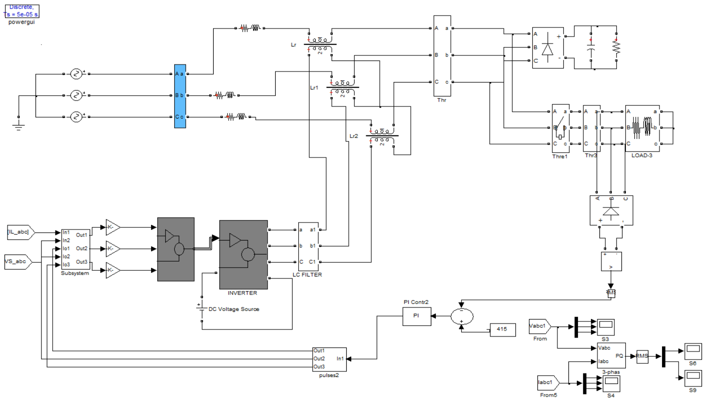

Figure 3.1.Closed loop system with PI controller

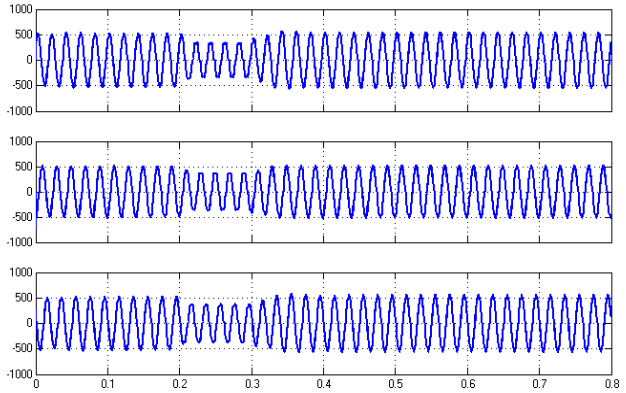

Figure 3.2.Receiving end voltage

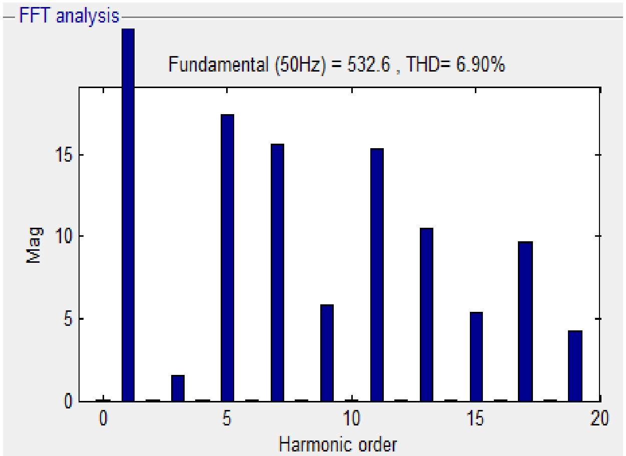

Figure 3.3.Receiving end voltage THD

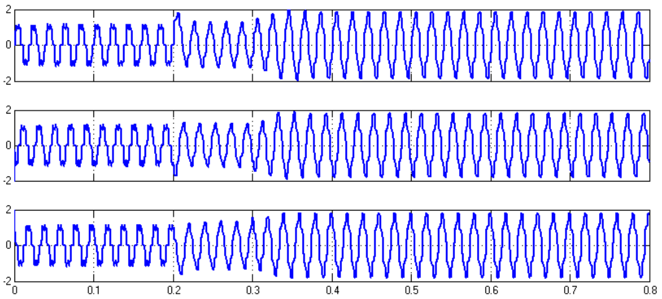

Figure 3.4.Receiving end current

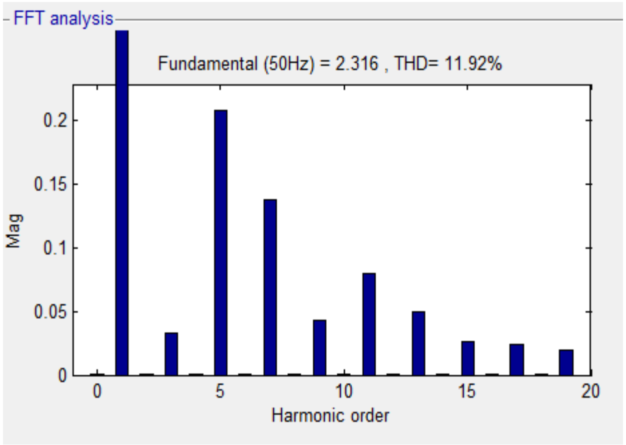

Figure 3.5.Receiving end current THD

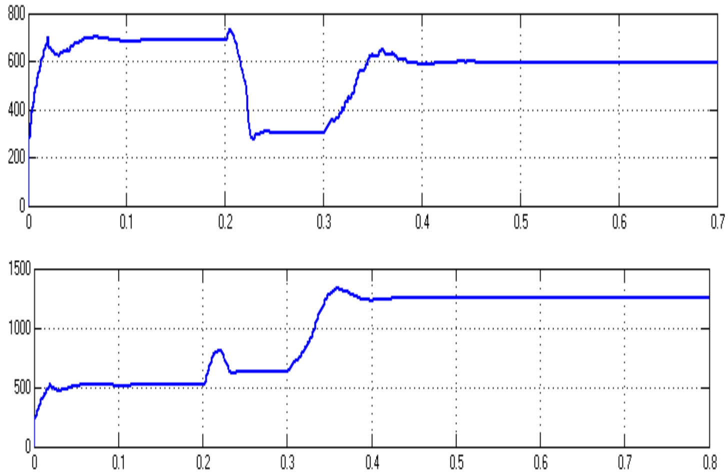

Figure 3.6.Real & reactive powers

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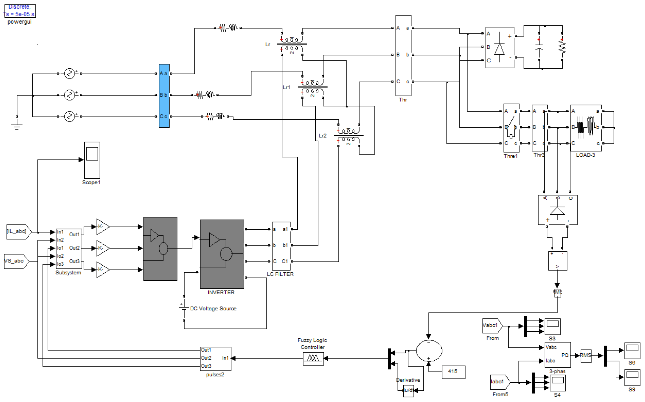

Figure 4.0.Closed loop system with FLC controller

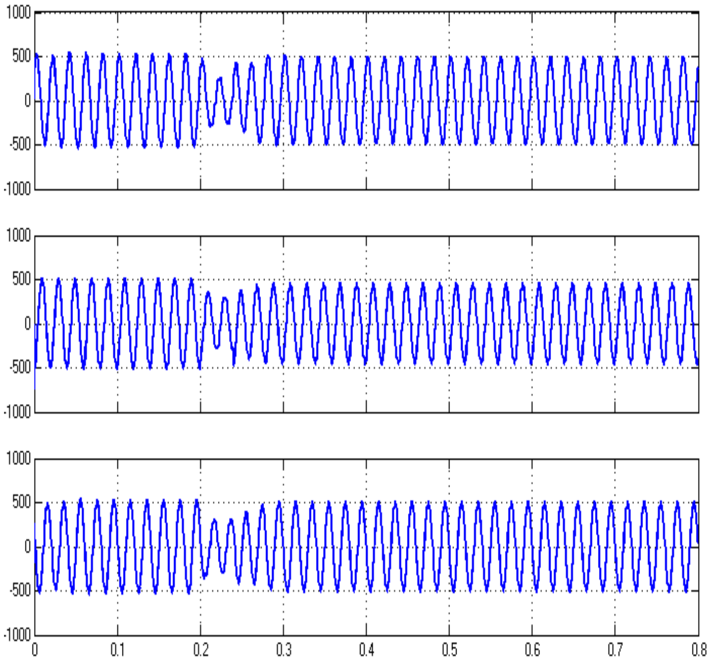

Figure 4.1.Receiving End Voltage

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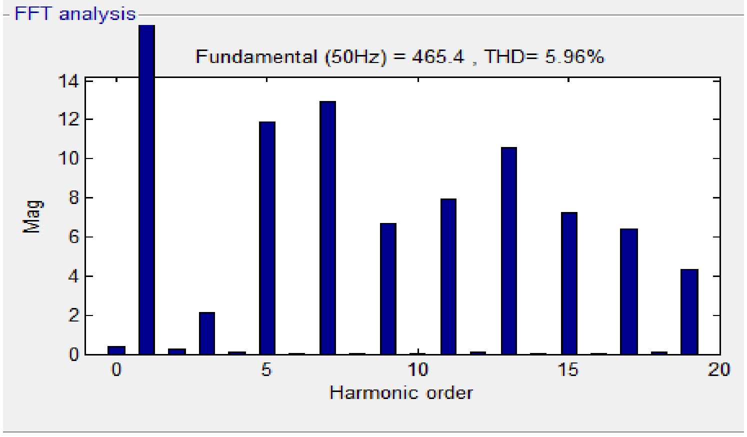

Figure 4.2.Receiving End Voltage

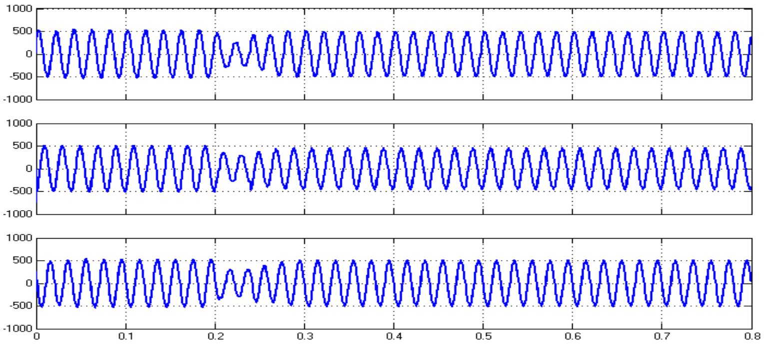

Figure 4.3.Receiving current

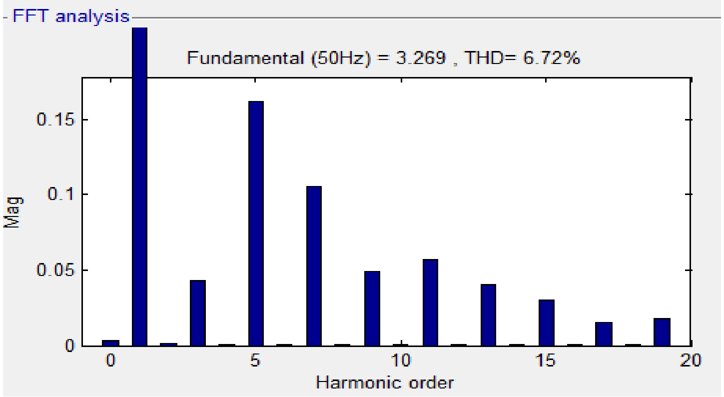

Figure 4.4.Receiving current THD

Table-1
Comparison of Time domain parameters

STATCOM	Tr	Ts	Tp	Ess
PI controller	0.32	0.43	0.35	5.6
FLC controller	0.25	0.30	0.26	1.3

Table-2
Comparison of voltage & current THD

STATCOM	Voltage THD	Current THD
PI controller	6.90%	11.92%
FLC controller	5.96%	6.72%

IV. CONCLUSION

The Closed loop PI and FLC controlled VSI based STATCOM systems are modeled and simulated successfully. Their results are compared which shows that FLC controlled system gives superior performance to PI controlled system. The proposed VSI based STATCOM system has advantages like low THD, Reduced losses and heating .The only disadvantage of VSI based STATCOM system is that it requires six switches.

The scope of present work is to compare PI and FLC controlled system. The response of above systems will be compared with fuzzy logic controlled system in future. And fabricate single phase prototype hardware module.

REFERENCES

[1] Gultekin and M. Ermis, "Cascaded multilevel converter-based transmission STATCOM: System design methodology and development of a 12 kV ±12 MVAr power stage," *IEEE Trans. Power Electron.*, vol. 28, no. 11, pp. 4930–4950, Nov. 2013.

[2] B. Gultekin, C. O. Gerc¸ek, T. Atalik, M. Deniz, N. Bic¸er, M. Ermis, K. Kose, C. Ermis, E. Koc¸, I. C¸ adirci, A. Ac¸ik, Y. Akkaya, H. Toygar, and S. Bideci, "Design and implementation of a 154-kV±50-Mvar transmission STATCOM based on 21-level cascaded multilevel converter," *IEEETrans. Ind. Appl.*, vol. 48, no. 3, pp. 1030–1045, May/Jun. 2012.

[3] S. Kouro, M. Malinowski, K. Gopakumar, L. G. Franquelo, J. Pou, J. Rodriguez, B.Wu,M. A. Perez, and J. I. Leon, "Recent advances and industrial applications of multilevel converters," *IEEE Trans. Ind. Electron.*, vol. 57, no. 8, pp. 2553–2580, Aug. 2010.

[4] F. Z. Peng, J.-S. Lai, J. W. McKeever, and J. VanCoevering, "A multilevel voltage-source inverter with separateDCsources for static var generation," *IEEE Trans. Ind. Appl.*, vol. 32, no. 5, pp. 1130–1138, Sep./Oct. 1996.

[5] Y. S. Lai and F. S. Shyu, "Topology for hybrid multilevel inverter," *Proc. Inst. Elect. Eng.—Elect. Power Appl.*, vol. 149, no. 6, pp. 449–458, Nov.2002.

[6] D. Soto and T. C. Green, “A comparison of high-power converter topologies for the implementation of FACTS controllers,” *IEEE Trans. Ind.Electron.*, vol. 49, no. 5, pp. 1072 1080, Oct. 2002.

[7] C. K. Lee, J. S. K. Leung, S. Y. R. Hui, and H. S.-H. Chung, “Circuit-level comparison of STATCOM technologies,” *IEEE Trans. Power Electron.*, vol. 18, no. 4, pp. 1084–1092, Jul. 2003.

[8] H. Akagi, S. Inoue, and T. Yoshii, “Control and performance of a transformerlesscascade PWM STATCOM with star configuration,” *IEEETrans. Ind. Appl.*, vol. 43, no. 4, pp. 1041–1049, Jul./Aug. 2007.

[9] A. H. Norouzi and A. M. Sharaf, “Two control scheme to enhance the dynamic performance of the STATCOM and SSSC,” *IEEE Trans. PowerDel.*, vol. 20, no. 1, pp. 435–442, Jan. 2005.

[10] C. Schauder, M. Gernhardt, E. Stacey, T.Lemak, L. Gyugyi, T. W. Cease, and A. Edris, “Operation of ±100 MVAr TVA STATCOM,” *IEEE Trans.Power Del.*, vol. 12, no. 4, pp. 1805–1822, Oct. 1997.

[11] C. H. Liu and Y. Y. Hsu, “Design of a self-tuning PI controller for a STATCOM using particle swarm optimization,” *IEEE Trans. Ind. Electron.*, vol. 57, no. 2, pp. 702–715, Feb. 2010.

[12] S. Mohagheghi, Y. Del Valle, G. K. Venayagamoorthy, and R. G. Harley, “A proportional-integrator type adaptive critic design-based neurocontrollerfor a static compensator in a multimachine power system,” *IEEETrans. Ind. Electron.*, vol. 54, no. 1, pp. 86–96, Feb. 2007.

[13] H. F. Wang, H. Li, and H. Chen, “Application of cell immune responsemodelling to power system voltage control by STATCOM,” *Proc. Inst.Elect.Eng. Gener.Transm.Distrib.*, vol. 149, no. 1, pp. 102–107, Jan. 2002.

[14] A. Jain, K. Joshi, A. Behal, and N. Mohan, “Voltage regulation with STATCOMs: Modeling, control and results,” *IEEE Trans. Power Del.*, vol. 21, no. 2, pp. 726–735, Apr. 2006.

[15] V. Spitsa, A. Alexandrovitz, and E. Zeheb, “Design of a robust state feedback controller for a STATCOM using a zero set concept,” *IEEETrans. Power Del.*, vol. 25, no. 1, pp. 456–467, Jan. 2010.

[16] C. D. Townsend, T. J. Summers, and R. E. Betz, “Multigoal heuristic model predictive control technique applied to a cascaded H-bridge STATCOM,” *IEEE Trans. Power Electron.*, vol. 27, no. 3, pp. 1191–1200, Mar. 2012.

[17] C. D. Townsend, T. J. Summers, J. Vodden, A. J. Watson, R. E. Betz, and J. C. Clare, “Optimization of switching losses and capacitor voltage ripple using model predictive control of a cascaded H-bridge multilevel STATCOM,” *IEEE Trans. Power Electron.*, vol. 28, no. 7, pp. 3077–3087, Jul. 2013.

[18] Y. Shi, B. Liu, and S. Duan, “Eliminating DC current injection in currenttransformer- sensed STATCOMs,” *IEEE Trans. Power Electron.*, vol. 28, no. 8, pp. 3760–3767, Aug. 2013.

[19] B. Singh and S. R. Arya, “Adaptive theory-based improved linear sinusoidal tracer control algorithm for DSTATCOM,” *IEEE Trans. PowerElectron.*, vol. 28, no. 8, pp. 3768–3778, Aug. 2013.

[20] S. R. Arya and B. Singh, “Performance of DSTATCOM using leaky LMS control algorithm,” *IEEE J. Emerging Select. Topics Power Electron.*,vol. 1, no. 2, pp. 104–113, Jun. 2013.

[21] P. Petitclair, S. Bacha, and J.-P.Fe rrieux, “Optimized linearization via feedback control law for a STATCOM,” in *Proc. IEEE Ind. Appl. Soc.Annu. Meeting*, 1997, pp. 880–885.

[22] H. Khalil, *Nonlinear Systems*, 3rd ed. Englewood Cliffs, NJ, USA: Prentice-Hall, 2002.

[23] Y. Han, Y. O. Lee, and C. C. Chung, “Modified non-linear damping of internal dynamics via feedback linearisation for static synchronous compensator,” *IET Gener. Transm.Distrib.*, vol. 5, no. 9, pp. 930–940, 2011.

[24] Y. O. Lee, Y. Han, and C. C. Chung, “Output tracking control with enhanced damping of internal dynamics and its output boundedness for STATCOM system,” *IET Control Theory Appl.*, vol. 6, no. 10, pp. 1445– 1455, 2012.

[25] Y. O. Lee, Y. Han, and C. C. Chung, “Output tracking control with enhanced damping of internal dynamics and its output boundedness,” in *Proc. IEEE Conf. Decision Control*, 2010, pp. 3964–3971.

[26] Y. Han, Y. O. Lee, and C. C. Chung, “A modified nonlinear damping of zero-dynamics via feedback control for a STATCOM,” in *Proc. IEEEPowerTech*, 2009, pp. 880–885.

[27] G. E. Valderrama, P. Mattavelli, and A. M. Stankovic, “Reactive power and imbalance compensation using STATCOM with dissipativity-based control,” *IEEE Trans. Control Syst. Technol.*, vol. 9, no. 5, pp. 718–727, Sep. 2001.

[28] H. Tsai, C. Chu, and S. Lee, “Passivity-based nonlinear STATCOM controller design for improving transient stability of power systems,” presented at the IEEE/PES Transmission and Distribution Conference &Exhibition: Asia and Pacific, Dalian, China, 2005.

[29] Y. Gui, Y. O. Lee, H. J. Kang, Y. Han, and C. C. Chung, “Novel passivitybaseDController design for STATCOM,” in presented at the 2011 11thInternationalConference on Control, Automation and Systems, Gyeonggido, Korea, Oct. 26–29, 2011, pp. 556–560.