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Technical Review of Static Compensator in Modern Distribution System

1st Jiteshkumarsahu , 2nd Dr. Devendrasharma
Dept. of Electrical and Electronics Engineering,
Technocrats Institute of Technology & Science Bhopal (M.P.)

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ABSTRACT; Modern Power System is tassel of versatile load comprises of high frequency power electronic devices and distributed generation connected using power electronic converters. All these devices draw Non-Linear Current (NLC) form the system. The NLC distort the source profile and injects harmonic in voltage and current waveforms. Due to the harmonics, waveforms deviate from sinusoidal shape to non-sinusoidal one. This phenomenon degrades the Power Quality (PQ) of the system.One of the promising technology which is extensively used in MDS is Static Compensator (STATCOM). STATCOM is shunt compensator connected in MDS to provide reactive power particularly to regulate output voltage and to mitigate harmonics generated due to NLC. This paper presents a comprehensive review on the application of STATCOM in MDS to improve PQ.

Key Words: NLC, MDS, PSS, PSSC, PQ, DSTATCOM, DVR, SRF.

I. INTRODUCTION

The commercial application of high rating Power semiconductor Switches (PSS) begin in 1970's. PSS were used a compensator (PSSC) as switched capacitor, controlled reactor or a combination therefrom with passive filters. PSSC can eliminate dominant harmonics generated from Non-Linear Current(NLC) [1,2].

As the technology paces with the era, a paradigm shift has been witnessed in the power electronics leading to the concept of multi-functionality.Hingorani [3] has introduced the concept of FACTS controller which were basically a VAR impedance-type controllers, controlled by varying the firing angle.PSSCs are network of power/semiconductor switches which provide power conditioning with high efficiency and reliability [4]. In Modern Distribution System (MDS) various PSSC based power conditioning devices namely; distribution static compensator (DSTATCOM), dynamic voltage restorer (DVR), and unified power quality conditioner (UPQC) are available which are installed both at load-end and source-end to improve PQ of the system [5-7]. One of the commonly used PSSC is VSC which is a self-commutating DC-to-AC converter and is known as the backbone of the compensating devices [8,9]. As it can be employed to regulate reactive current by generation and absorption of controllable reactive power. The major attributes of STATCOM are quick response time, less space requirement, optimum voltage platform, higher operational flexibility and excellent dynamic characteristics under various operating conditions. These controllers are also known as Distribution compensator (DSTATCOM) [10,11], advanced static VAR compensator (ASVC), advanced static VAR generator (ASVG), STATicCONdenser (STATCON), static var generator (SVG), synchronous solid-state VAR compensator (S^2VC) [12-15].The VSC-based STATCOM (VSTATCOM) has arose as a qualitatively superior technology relative to other members of its family which provide shunt compensation.VSTATCOMis commercially available with high power capacitywith simple converter control and robust design. In this paper comprehensive review of DSTATCOM technology with its numerous topologies is presented along with its application in MDS to improve PQ. The author includes four sections viz. (i) Brief introduction (ii) working principle of DSTATCOM, (iii) topologies and configurations and (iv) Application in MDS to improve PQ.

II. WORKING PRINCIPLE OF DSTATCOM

The DSTATCOM is a PSSC which provides reactive power compensation. It is shunt-connected at a point of application in the MDS. The main building block of the configuration of DSTATCOM is three-phase VSI [16-19]. VSI consist of three arms for three phase having 6 switches as shown in Fig. 1. Upstream is connected toward the substation and is modelled as three-phase source while downstream is connected across non-linear and unbalance load [20]. This will generate harmonic currents to represent the aggregate behavior of load also PV with three-phase inverter and other harmonics producing loads such as personal computers, television sets, energy efficient lamps (fluorescent and LED). The DSTATCOM is shunt-connected and injects current to mitigate harmonic and to make current drawn from the source (I_S) sinusoidal and in phase with the voltage.

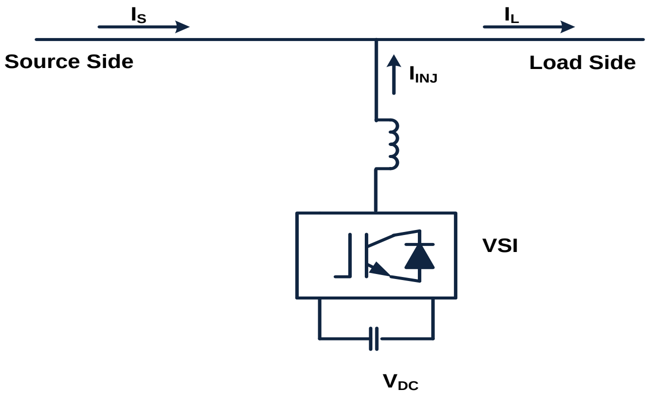

Figure 1 Schematic diagram of DSTATCOM

The performance of theDSTATCOM depends primarily on the control strategy adopted for VSI and the reference current detection technique used [21-23]. In this paper, for reference current detection, synchronous rotating reference frame (SRF) method has been adopted. The control for switching of power electronic switches of VSI is presented in Fig. 2. For gird SRF draws the three-phase reference signal of voltages and currents. [24]. Three phase to two phase i.e., abc-dq0 transformation is carried out to obtain direct axis component equivalent in order to simplify the control design as presented Eq. (1). Phase Lock Loop (PLL) is used to calculate the phase angle of the reference signal [25,26]. A Low Pass Filter (LPF), removes the harmonics from direct axis current component Id, PI controller calculates the magnitude of the pulses generated and fed to the dq0-abc transform to obtain the equivalent three phase output [27]. The synchronized three phase voltages obtained from PI controller is fed to the PWM generator to obtain the gate pulses for universal bridge.

$$\begin{bmatrix} Id \\ Iq \\ I0 \end{bmatrix} = \frac{\sqrt{2}}{3} \begin{bmatrix} \cos\theta & \cos(\theta - 120°) & \cos(\theta + 120°) \\ -\mathrm{Sin}\theta & -\sin(\theta - 120°) & -\sin(\theta + 120°) \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \end{bmatrix} \begin{bmatrix} Ia \\ Ib \\ Ic \end{bmatrix} \quad (1)$$

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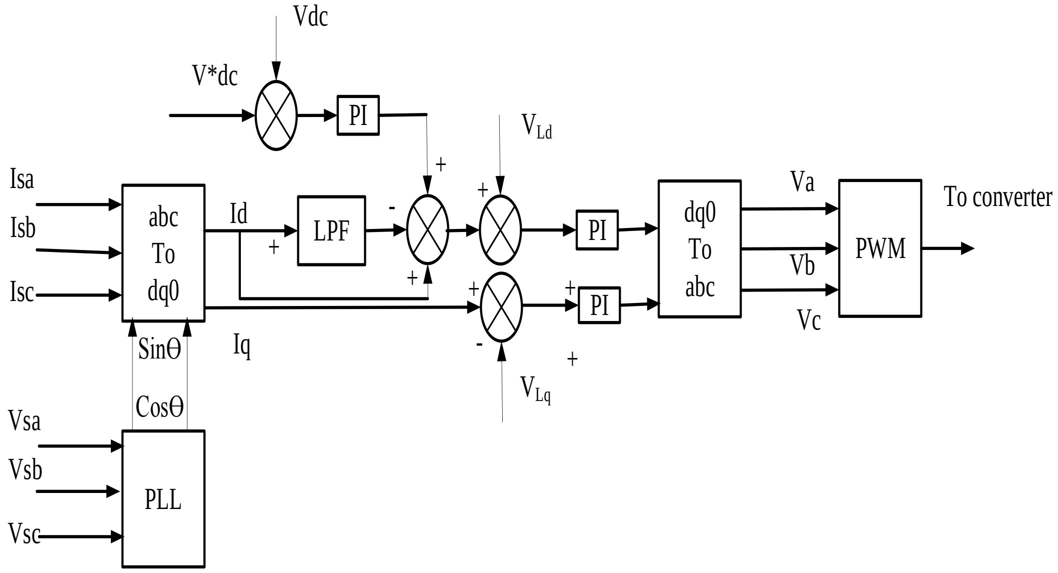

Figure 2. Schematic diagram for the control of converters

III. TOPOLOGIES OF DSTATCOM

The DSTATCOM is a very mature technology and has umpteen topologies as per its application. It can be easily designed as per the system requirement and consumer demand. Hence its classification is versatile which is presented in fig. 3. STATCOM has been broadly classified as per its connection in distribution system; three-phase three-wire (3P3W) and three-phase four-wire (3P4W). Further its bifurcation is done base on isolation transformer. The transformer topologies which are used as an coupling/injection transformer may be of following type;

1. Star/delta
2. Zig-zag
3. T-connected
4. Star-hexagon.

3P3W DSTATCOM are used for reactive power compensation, elimination of harmonic, load balancing and PQ issues mitigation [28]. The most commonly used topology for 3P3W DSTATCOMs is VSC-based DSTATCOM which is shown in Fig.4.

3P4W DSTATCOM is used to filter NLC and to meet out the specifications for the utility connection [29]. This can be used to cancel the effect of poor load power factor (PF) such that source current has near unity PF, provide compensation for unbalanced so as to regulate the source voltage, cancel dc offset in loads and for PQ improvement. The commonly used topology for 3P4W is three-leg VSC based DSTATCOM topology as shown in fig. 5.

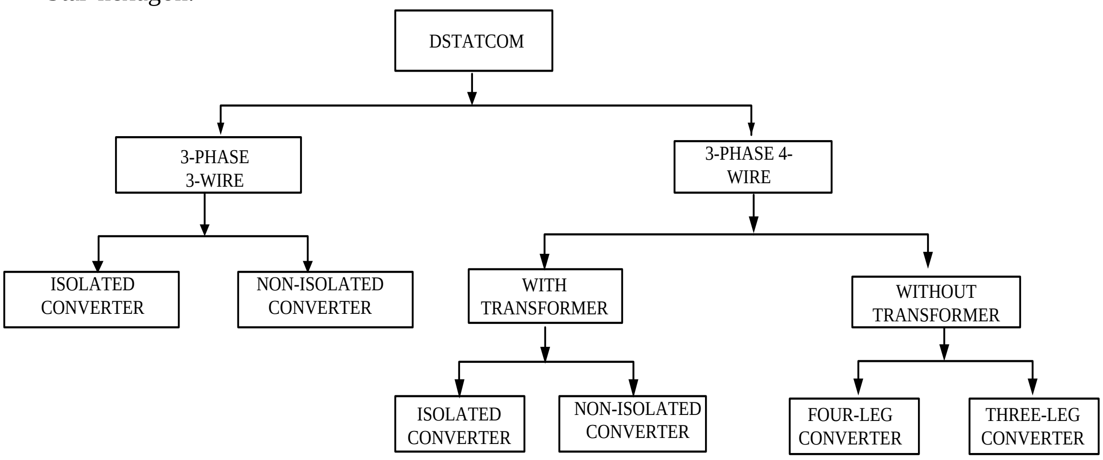

Figure 3 Classification of DSTATCOM

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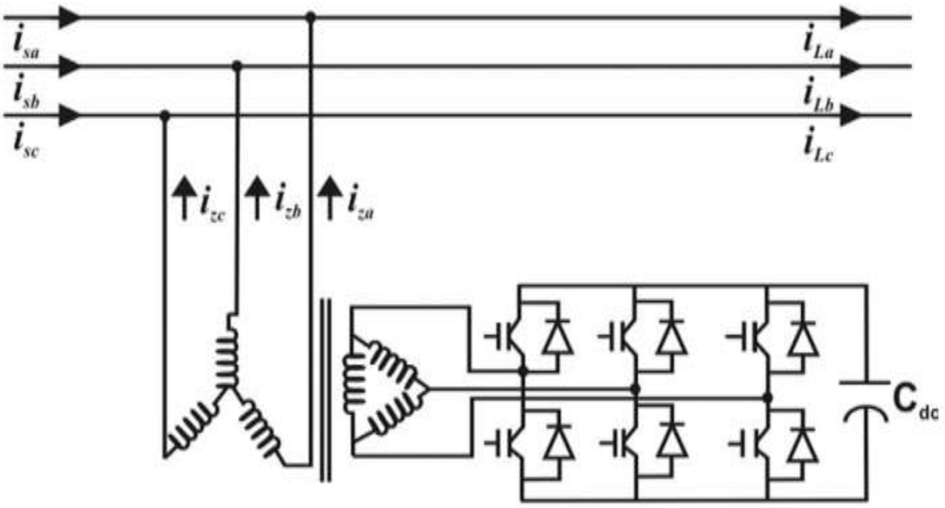

Figure 4. VSC-based 3P3W DSTATCOM

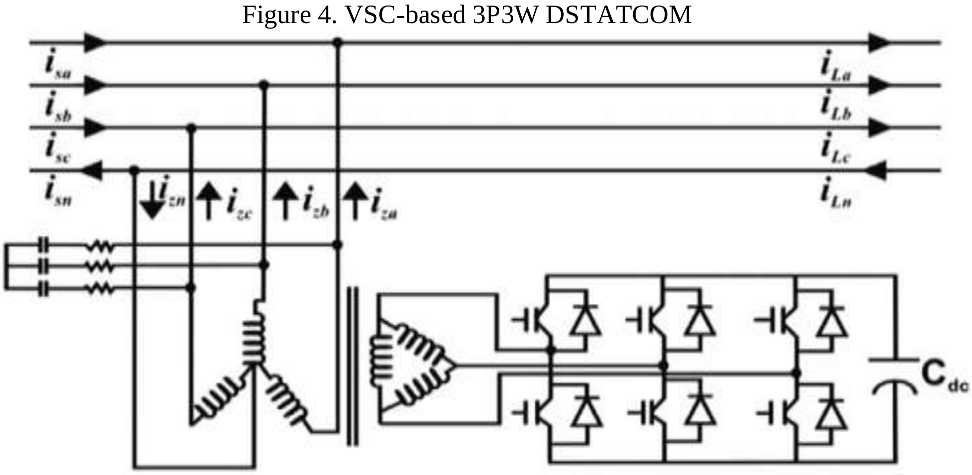

Figure 5. VSC-based 3P4W DSTATCOM

IV. APPLICATION OF STATCOM

The distribution system suffers dual problem of PQ, one is due to the Distribute Generation (DG) like solar, wind, geothermal, etc. and another is non-linear loads. STATCOM has the capability to deal with both the problems.It can provide reactive power control, power swings/oscillations damping [30], voltage regulation [31], resonance damping [32], enhancement in transmission line capacity, steady state and dynamic stability improvement, transient stability [35, 36], and for application to interconnected operation of DG [33,34]. It is also used as hybrid controllers in combination with passive elements [35]. STATCOM has many interesting features such as high speed of response (sub-cycle), versatile controlling and operational characteristics, ability to implement controllers of low/medium/high MVA ratings, low-space requirement, higher stability margins and so on. It is rapidly replacing the conventional forced-commutating reactive power controllers, SVC and other slow-acting controllers in power system. In the field of distribution system, the acronym of this controller is D-STATCOM [36].

A concept of utilizing PV in conjunction with STATCOM during nighttime for providing different grid support is presented in [37]. Research work is also available for PV-inverters implanted with smart inverter control which can be used to improve the PQ. But this diminishes inverter reliability and adds additional complexity and cost [38]. A capacitor-less topology for PV-DSTATCOM is presented in [39] to reduce the cost and complexity of the system.In combination with an energy storage system (battery or magnetic storage device), STATCOM are being widely utilized [40] for power-quality improvements and also for uninterruptible power supply and real power exchange during emergency.

V. CONCLUSION

The DSTATCOM is very suitable for eliminating both voltage and current related PQ problems such as NLC elimination, load balancing, voltage regulation, PF correction in MDS. The MDS is heavily burdened with PE based loads such as stabilizer based refrigerator and air-conditioner, variable speed motors, solid state LEDs, sensitive hospital equipments etc. DSTATCOM is on high use in the system to mitigate PQ issues generated due to these loads. Therefore, it is highly desirable to carry out extensive research to reduce the cost of DSTATCOM without affecting the efficiency and effectiveness. DG penetration into the electric utility grid is increasing day by day and intermittent nature of these resources affects the quality of supplied power. The weather conditions such as wind speed and solar insolation affect its performance. The DSTATCOM may be an effective solution for these problems, hence possibilities of implementation of DSTATCOM in DG based MDS is explored.

This paper presents a comprehensive literature review on the available topologies of DSTATCOM to improve PQ of the MDS. A brief review on its various application is also presented.

REFERENCES

[1]. LARSEN E., MILLER N., NILSON S., LINDGREN S., 'Benefits of GTObased compensation systems for electric utility applications', IEEE Trans. Power Deliv., 1992, 7, (4), pp. 2056– 2064.

[2]. GALANOS G.D., HATZIADONIU C.I., CHENG X.-J., MARATUKULAM D.: 'Advanced static compensator for flexible AC transmission', IEEE Trans. Power Syst., 1993, 8, (1), pp. 113–121.

[3]. HINGORANI N.G.: 'FACTS Technology – state of the art, current challenges and the future prospects'. IEEE PES GM, 2007, pp. 1– 4.

[4]. EDWARDS C.W., NANNERY P.R., MATTERN K.E., GUBERNICK J., 'Advanced static VAR generator employing GTO thyristors', IEEE Trans. Power Deliv., 1988, 3, (4), pp. 1622– 1627.

[5]. Shu Z, Guo Y, Lian J.,'Steady-state and dynamic study of active power filter with efficient FPGA-based control algorithm'.IEEE Trans. Ind. Electron. Apr. 2008; 55(4): pp. 1527–1536.

[6]. Sen K. K, Keri A J F.,'Comparison of field results and digital simulation results of Voltage-Sourced Converter-based FACTS controllers.' IEEE Trans. Power Delivery. January 2003;18(1): pp. 300-306.

[7]. Padiyar K R.,'FACTS controllers in power transmission and distribution'. India: New age international publishers; 2007.

[8]. LIU X., LIU W.-H., JIANG Q.-R., WANG Z.-H.: 'Development of a voltage source inverter based static VAR generator'. IEEE Energy Conversion Engineering Conf., IECEC Proc., 1996, vol. 1, pp. 611– 616.

[9]. SEKI N., UCHINO H.: 'Converter configurations and switching frequency for a GTO reactive power compensator', IEEE Trans. Ind. Appl., 1997, 33, (4), pp. 1011–1018.

[10]. GYUGYI L.: 'Converter-based FACTS controllers'. Flexible AC Transmission Systems – The FACTS, IEE Colloquium, 23 November 1998, p. 1/1–1/11.

[11]. TAN Y.L.: 'Analysis of line compensation by shuntconnected FACTS controllers: a comparison between SVC and STATCOM', IEEE Power Eng. Rev., 1999, 19, (8), pp. 57–58.

[12]. EL-MOURSI M.S., SHARAF A.M.: 'Novel controllers for the 48- pulse VSC STATCOM and SSSC for voltage regulation and reactive power compensation', IEEE Trans. Power Syst., 2005, 1, (4), pp. 1985–1997.

[13]. HAN B.-M., BAEK S.-T., KO J.-S.: 'New configuration of 36- pulse voltage source converter for STATCOM application'. 32nd IEEE Annual Conf. Industrial Electronics Society, IECON, 2005, p. 6.

[14]. LIU Y.H., ARRILLAGA J., WATSON N.R.: 'STATCOM performance of a multi-level voltage reinjection converter'. IEEE/PES Transmission and Distribution Conf. Exhibition, Asia and Pacific, 2005, pp. 1– 6.

[15]. LIU Y.H., WATSON N.R., ARRILLAGA J., PERERA L.B.: 'Multi-level current reinjection CSC for STATCOM application'. IEEE Int. Conf. Power System Technology, Powercon, 2006, pp. 1–5 [71] SINGH B., SAHA R.: 'Modeling of 18-pulse STATCOM for power system applications', J. Power Electron., 2006, 7, pp. 146– 158.

[16]. PAN W., ZHANG J., CHEN H., CHANG Y., WANG C.: 'Novel configuration of 60-pulse voltage source converter'. IEEE PES GM, 2007, pp. 1– 6.

[17]. Naderi E, Hagh M, Zare K.,'Determination of the performance of the distribution static

compensator (d-statcom) in distribution network'. In: 22nd International conference and exhibition on electricity distribution (CIRED 2013); 2013. p. 1–4.
[18]. Iyer S, Ghosh A, Joshi A.,'Inverter topologies for {DSTATCOM} applications—a simulation study'. Electr Power Syst Res 2005;75(23):161–70.
[19]. Eldery M, El-Saadany E, Salama M.,'Dstatcom effect on the adjustable speed drive stability boundaries'. IEEE Trans Power Delivry 2007;22(2):1202–9.
[20]. L. Qian, P. Li, K. Yong, T. Shiying, W. Deliang, Q. Yu,.'A novel design and optimization method of an LCL filter for a shunt active power filter'. IEEE Trans. Ind. Electron. 61 (8) (2014) 4000-4010. Aug.
[21]. M. El-Habrouk, M.K. Darwish, P. Mehta, 'Active power filters: a review', IEE Proc. Electr. Power Appl. 147 (5) (2000) 403-413.
[22]. R.N. Beres, X. Wang, M. Liserre, F. Blaabjerg, C.L. Bak, A review of passive power filters for three-phase grid-connected voltage-source converters, IEEE J. Emerg. Select. Top. Power Electron. 4 (1) (2016) 54-69.
[23]. R.S. Rani, C.S. Rao, M.V. Kumar, 'Analysis of active power filter for harmonic mitigation in distribution system,' in: Presented at the 2016 International Conference on Electrical, Electronics, and Optimization Techniques (ICEEOT), 2016, 3-5 March.
[24]. D. Schwanz, M. Bollen, A. Larsson, Ł.H. Kocewiak, 'Harmonic mitigation in wind power plants: active filter solutions'. in: Presented at the 2016 17th International Conference on Harmonics and Quality of Power (ICHQP), 2016, 16-19 Oct.
[25]. T. Demirdelen, M. Inci, K.C. Bayindir, M. Tumay, 'Review of hybrid active power filter topologies and controllers'. in: Presented at the Fourth International Conference on Power Engineering, Energy and Electrical Drives (POWERENG), 2013, 13-17 May.
[26]. B. Singh, K. Al-Haddad, A. Chandra, 'A new control approach to three-phase active filter for harmonics and reactive power compensation'. IEEE Trans. Power Syst. 13 (1) (1998) 133-138.
[27]. Singh B, Arya S, Jain C.,'Simple peak detection control algorithm of distribution static compensator for power quality improvement'. IET Power Electron 2014;7(7):1736–46.
[28]. Kulkarni O, Mishra M.,'Power quality improvement using zig-zag transformer and dstatcom in three phase power distribution system'. In: 2013 Annual IEEE India conference (INDICON); 2013.
[29]. Singh B, Kumar S.,'Modified power balance theory for control of dstatcom'. In: 2010 Joint international conference on power electronics, drives and energy systems (PEDES), 2010 Power India; 2010. p. 1–8.
[30]. Sharma S, Singh B.,'An enhanced phase locked loop technique for voltage and frequency control of stand-alone wind energy conversion system'. In: 2010 India international conference on power electronics (IICPE); 2011. p. 1–6.
[31]. Efkarpidis N, Wijnhoven T, Gonzalez C, De Rybel T, Driesen J.,'Coordinated voltage control scheme for distribution grids utilizing oltc transformers and d-statcom's'. In: 12th IET international conference on developments in power system protection (DPSP 2014); 2014. p. 1–6.
[32]. LIU F., MEI S., LU Q., NI Y., WU F.F., YOKOYAMA A.: 'The nonlinear internal control of STATCOM: theory and application', Int. J. Electr. Power Energy Syst., 2003, 25, (6), pp. 421–430.
[33]. CAN˜ IZARES C.A., POZZI M., CORSI S., UZUNOVIC E.: 'STATCOM modeling for voltage and angle stability studies', Int. J. Electr. Power Energy Syst., 2003, 25, (6), pp. 431– 441.
[34]. KESHAVAN B.K., PRABHU N.: 'Damping of subsynchronous oscillations using STATCOM – a FACTS controller'. Int. Conf. Power System Technology, PowerCon, 2004, vol. 1, pp. 12– 16.
[35]. SOTO D., PENA R.: 'Nonlinear control strategies for cascaded multilevel STATCOMs', IEEE Trans. Power Deliv., 2004, 19, (4), pp. 1919– 1927.
[36]. JOSH K., BEHALF A., JAIN A.K., MOHAN N.: 'A comparative study of control strategies for fast voltage regulation with STATCOMs'. 30th IEEE Annual Conf. Industrial Electronics Society, IECON, 2004, vol. 1, pp. 187– 192.
[37]. PONNALURI S., STEINKE J.K., STEIMER P., REICHERT S., BUCHMANN B.: 'Design comparison and control of medium voltage STATCOM with novel twin converter topology'. 35th IEEE Annual Power Electronics Specialists Conf., PESC, vol. 4, 2004, pp. 2546– 2552.

[38]. VORAPHONPIPUT N., CHATRATANA S.: 'STATCOM analysis and controller design for power system voltage regulation'. IEEE/PES Transmission and Distribution Conf. Exhibition: Asia and Pacific, 2005, pp. 1– 6.
[39]. Varma, Rajiv K., and Ehsan M. Siavashi. 'PV-STATCOM: A new smart inverter for voltage control in distribution systems.' IEEE Transactions on Sustainable Energy 9.4 (2018): 1681-1691.
[40]. Rohouma, Wesam, et al. 'D-STATCOM for harmonic mitigation in low voltage distribution network with high penetration of nonlinear loads.' Renewable Energy 145 (2020): 1449-1464.