Unit Vector Template Control Analogy Control Algorithm for DSTATCOM to Improvement of Power Factor

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Received 18.11.2025 **received in revised form** 13.12.2025, **accepted** 14.12.2025
DO1: 10.47904/IJSKIT.15.2.2025.58-62

Abstract- The sources and power system equipment's performance is impacted by the load neutral current. Consequently, compensating the current will help to enhance the power system equipment performance. The design for test system and execution of DSTATCOM for improve the power quality with a T-Connected transformer for load output neutral current for compensation in the existence of a 3-ϕ unbalanced non-linear load connected. The proposed DSTATCOM was managed utilizing a control methodology derived from the unit vector template approach. These analogies used for increase the power quality and mitigate the harmonic distortion and unity power factor. The SIMULINK/MATLAB environment has been used design test system and simulate for mitigate harmonics and uncertain disturbance in system. The outcomes of the simulations demonstrate how successful the suggested algorithm is valid.

Keywords–power quality, Distribution static compensator, T-Connected transformer, neutral current compensation, unit vector template method.

1. INTRODUCTION

Low voltage Distribution (DB) systems experience significant PQ issues and clean current and voltage, including excessive neutral current, load imbalances, elevated reactive power and harmonic current burdens, and inadequate voltage regulation. Furthermore, the source voltages within distribution systems manifest flicker, sag, swell, harmonics, imbalance, and other PQ-related issues [1]. Additionally, the source voltage in the distribution systems exhibits flicker, sag, swell, harmonics, imbalance, and other PQ problems [1]. Neutral current is another significant power quality issue that affects the source's functionality. Therefore, compensating devices must be used to regulate it suitably. The literature has discussed power quality and neutral current correction. Power quality issues and abnormalities that disrupt lower power quality, sinusoidal waveforms and network reliability include harmonics; capacitor switching, voltage sag, and voltage swell [2].

Use a DVR to protect against voltage drops and surges, balance voltage, and fix voltage harmonic distortion. Many power enhancement devices were deliberate and develop for well applied to compensate for several clean PQ issues in a DB system and mitigate the disturbance and improve the power quality [3]. These anomalies affect both the equipment and the user. DSTACOM addresses power quality issues, including voltage fluctuations, unbalanced loads, and distribution system harmonics. UPQC is used for compensation, power factor correction reduces load current harmonic, maintain the dc link voltage and improve current and voltage quality.

The novel topology for low voltage power system quality enhancement by using of distribution STATCOM was described and how to improve reactive power (inductive and capacitive) for voltage control and UPF (Pf) correction using balancing inductive load and input and output flow neutral current compensation with remove harmonics distortion at DC link [4]-[5]. By using of a T-Connected transformer associate DSTACOM to improve the power quality with clean voltage and current. T-Connected transformer associate for interfacing low voltage up to 11kv distribution system, thereby reducing the required voltage and current rating of the VSC [6]-[7]. By using simulation, the transformer's power kVA rating was verified, and it was revealed to be effective in remove for fundamental and harmonic distortion currents of zero sequence. The transformer must be almost half of load rating and (inductive and capacitive) reactive power requiring fine-tuning for the improve power quality, reactive power control, reduce harmonics distortion and dc link voltage maintain constant within a distribution system, intelligent controller like neural-network (NN), fuzzy control based controlled DSTATCOM [8] was design and developed utilizing a dSPACE processor. For reactive power control, an improved zigzag transformer is used to achieve for load balancing and voltage regulation at dc link and harmonic distortion current reduce up to 5% as IEEE std., for both input and output neutral current compensation at DC link coupling. A new design for a 3-ϕ, 4-wire distribution system includes an H-bridge voltage source converter (VSC) and a T-Connected transformer to improve power quality. [10]– [11].

A three-leg VSC for DC voltage convert to 3 phase AC voltage is associated with a star/hexagon transformer to control additional unwanted apparent power tuning for voltage regulation and unity power factor (Pf) correction and also control load to be balance and compensation input and output neutral current and improve clean current for eliminated system harmonics. [12]-[15].

This research works an introduction is provided in Section I, followed by design and simulation proposed test system in Section II. The control algorithm and topology are pronounced in Section III. After that the simulation results and related explanations and outcomes discussion are explain in Section IV followed by conclusions.

2. PROPOSED TEST SYSTEM

The distribution systems giving input power to 3-ϕ, 4-wire inductive loads are associated with power quality improve controller STATCOM which is shown in Figure 1. The DSTATCOM used to improve power quality of distribution system which is low voltage system. The T-Connected transformer has provided I_{ln} to stable system. The DSTATCOM part of voltage source converter (VSC) which is convert dc voltage to 3 phase ac voltage and comprises six IGBT switches for control and also connected anti-parallel diodes with DC capacitor which is also called DC link. Ripple current control through the continuously charging and discharging process of the DC link capacitors which is maintain the dc voltage. To mitigate the harmonic distortion in current ripples connected VSC to the supply input of system with help of interacting inductors. At PCC voltage reduces switching ripples by using RC filter, which impact is a result of the DSTATCOM's rapid switching. The DSTATCOM controls and compensates maintain voltage regulation for the load's reactive and load current harmonic distortion when sudden change load and faulty condition and uncertain disturbance in system. [17-23]

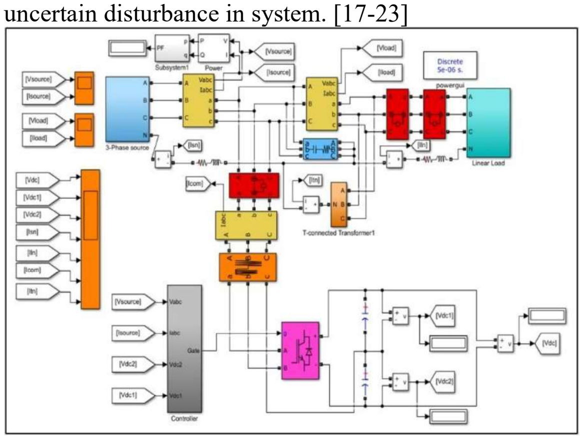


Figure 1: Basic circuit diagram of the DSTATCOM based model

Zero phase shifts with respect to the PCC voltages are established by supply currents in the power factor (pf) correction mode. In zero voltage regulation modes, currents are injected by the D-STATCOM. Dependent on the load's power factor and the reference PCC clean voltage, the supply currents in this scenario could be either leading or lagging.

The system's data are supplying voltage is 415 V at 50 Hz and its impedance (z) equal to 0.01+j0.0628. DC link capacitor operates rating 1400 V and 2500μF. The inductor is 6 mH with 10 kHz switching frequency. The ripple filter has a capacitance 6 μF and its resistance 3 **Ω**. The T-Connected transformer which rating 2.5 KVA, 240V/120V/120V.

3. PROPOSED CONTROL ALGORITHM

Figure 2 displays the suggested test model which is design and simulate in matlab software, schematic SLD diagram. The VSC's IGBTs use for design D-STATCOM device for design low voltage compensator a fixed frequency carrier-based sinusoidal PWM to generate its switching pulses. The PI controller is easy to use and easily design controller and given better response. The unit vector template approach is the generate clean refence current and easily synchronize with input system voltage foundation of this algorithm. In this test system for control the system use two PI controllers. The DC link voltage is regulated and maintain by one PI controller, and other has work regulated AC terminal voltage. Figure 2 show flowchart the entire input and output utilized to control DSTATCOM in system, along with the parameters. [19]-[20]

4. RESULTS AND DISCUSSION

The test model findings for system primary and I_{ln} compensation using D-STATCOM and with or without T-Connected transformer are associated. The next subsections provide specifics on the outcomes and mitigate neutral current and harmonics distortion with and without compensation and also connected with and without associate T-Connected transformer for improve PQ.

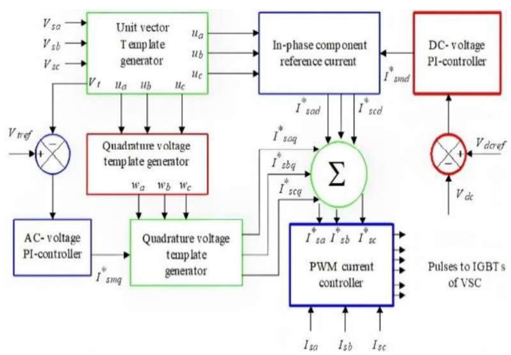
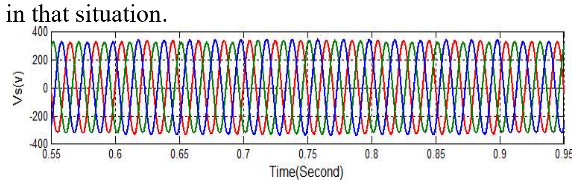


Figure 2: Controller Algorithm

4.1 Healthy Stable System

The analyzed test system depicted in Figure 1 is replicated under ideal circumstances and no anyone fault and disturbance in this system. In this test system uses a 3-ϕ four-wire balanced non-linear load. Plot 3 displays the load voltage and current at PCC with LG fault which its occurrence of wind plant generation because of in wind generation the many factors depend and system not stable by uncertain speed of wind. The source current's waveform is identical to that of the load current. Figure 3 waveform indicate that there is no trouble in the load currents or voltage mean no neutral current flow in system in that situation.



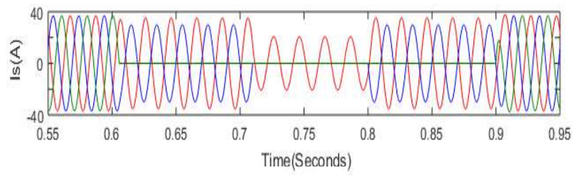


Figure 3: V-I Graph without series compensation with LG fault.

4.2 Unstable System Without Compensation

In this case study, the DSTATCOM compensation for low voltage distribution system and not utilized in system Figure 5 displays the neutral currents on the input and output. Phases B and C are activated at the eleventh cycle to recreate the system imbalance. At the twentieth cycle, they are switched off, restoring the system to its starting point. Figure 4 displays the voltage and current waveforms. The neutral currents flow in unbalanced condition on the primary and load are shown in Figure 5 and Neutral current is shown to flow during unbalanced condition the length of time that the network is out of balance. There is no current flowing through the system's neutral during the balanced time. High distribution system efficiency requires compensating for this neutral current under imbalanced conditions.

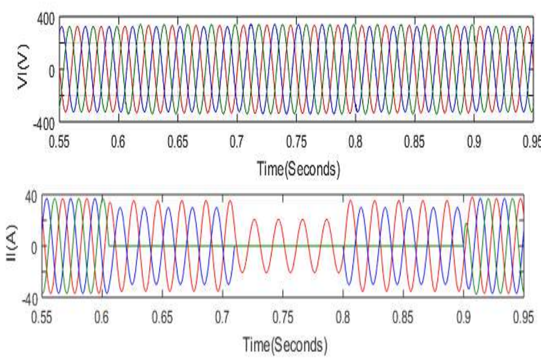


Figure 4: V-I Plot for unstable system with fault without compensation.

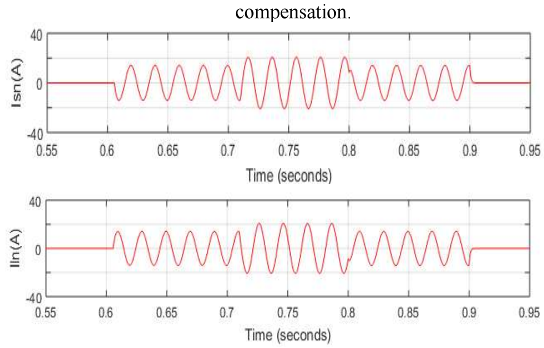


Figure 5: In an unbalanced system without compensation, neutral current flows on both the source and load sides.

4.3 Disturbed System with Neutral Current Compensation

As illustrated in Figure 1, the DSTATCOM is linked to the PCC in order to correct for the neutral current in the event of an unbalanced 3-ϕ load. Figure 6 shows how to use the DSTATCOM to modify the source voltage and current while maintaining neutral current. Both with and without the T-Connected transformer, these voltage and current values are measured. It has been shown that the T-Connected transformer has no effect on these numbers. By opening phases B and C on load, imbalanced conditions that have been simulated result in a decrease in the source side current. The unbalancing has no effect on the voltages of any of the three phases.

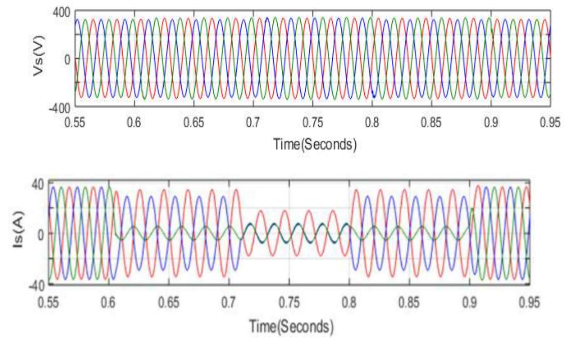


Figure 6: Source V-I Plot with neutral current correction

Figure 7 shows the outcomes results of compensating DC Link utilizing the D-STATCOM without a star-delta transformer for comparision for effect for transformer. In This plot 7 shown the DC link capacitor's voltage (Vdc), input sourse (Isn) and load (Iln) neutral current, DSTATCOM current (Icom) and current passing through the primary neutral current of transformer (Izn) and output results analysed. When a T-Connected transformer is not associate with STATCOM device then source neutral input current rises too high. During the unbalancing load conditions, the DSTATCOM injects less current. DC link capacitor voltage has also been shown in figure to exhibit the small magnitude transient current. When unbalancing or disturbance occurs then voltage rises a little before returning to stable condition its initial value.

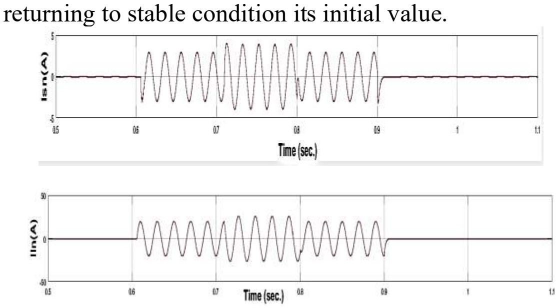


Figure 7 : I_{sn} and I_{ln} Without Controller and T-connected Transformer

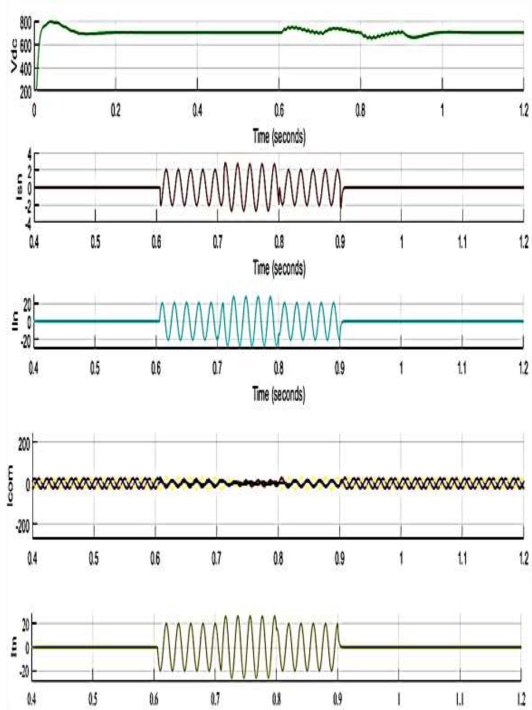


Figure 8: DC Link Voltage, Source and Load Neutral Current with T-Connected Transformer

The compensatory outcomes achieved by using a DSTATCOM for lower power system in associate with T-Connected transformer shown in Figure 8. The DC link capacitor's voltage (Vdc), I_{ln}, Isn, DB STATCOM current (Icom), and current passing through the primary-side neutral of the x-mer (Izn) are all shown in the figure. It was found that the source neutral current is much decreased when a T-Connected transformer is used. During the unbalancing conditions like sudden change load and faulty condition, the DSTATCOM injects less current mean the system power quality improved. Therefore, for improve the current quality the source or input neutral current is decreased when a T-Connected transformer is used with the D-STATCOM. The capacitor maintains the dc link voltage and also maintains and it's shown to exhibit the small magnitude transient. When unbalancing condition occurs, this voltage rises a little before returning to its initial value once the system has returned to its stable condition.

5. CONCLUSION

In this study, for distribution system improve the current and voltage power quality and mitigate harmonic distortion used static compensator with a T-Connected transformer to compensate and improve quality for source neutrality. For the neutral current compensation and for low voltage up to 11 kv power quality improve the DSTATCOM's unit vector template control has better than other power quality device. It has been noted that when a T-Connected transformer is used, the source neutral current is decreased as the load neutral current flows through the transformer's winding than source neutral current has been mitigate and compensation harmonics distortion and improve the current and voltage quality is accomplished. The MATLAB/Simulink environment has been used to design model analyses outcomes for better system. The presented work can be extended on 3 and 4 leg VSC with T-connected Transformer; a model of 3 phase 4 wire framework can be created in the lab to confirm the simulation result of the proposed plan in near future work.

6. APPENDIX

AC line voltage: 415V, 50Hz, Rs = 0.01, Ls = 6mH,
Linear load: 20KVA, 0.08pf, $R_f = 3\Omega$; $C_f = 6\mu F$,
DC bus Capacitance: 2500μF, Vdc = 1400V.
PWM Switching frequency: 10 KHz.
T-Connected transformer: 2.5 KVA, 240V/120V/120V.

REFERENCES

[1]. Bhim Singh, P. Jayaprakash, T. R. Somayajulu, and D. P. Kothari, "Reduced rating VSC with a Zig-Zag transformer for current compensation in a three-phase four-wire distribution system," IEEE Transactions on Power Delivery, vol. 24, no. 1, pp. 249–259, January (2009).

[2]. Mahmoud Zadehbagheri, Naziha Ahmad Azli, Askar Bagherinasab, and Shahrin bin Md Ayob, "Performance evaluation of custom power devices in power distribution networks for power quality improvement: a review," International Journal of Scientific & Engineering Research, vol. 4, no. 5, May (2013).

[3]. B. Singh, G. Bhuvaneswari, and S. R. Arya, "Review on power quality solution technology," Asian Power Electronics Journal, vol. 6, no. 2, December (2012).

[4]. Bhim Singh, P. Jayaprakash, and D. P. Kothari, "Magnetics for neutral current compensation in three-phase four-wire distribution system," IEEE International Conference, (2010).

[5]. Bhim Singh, P. Jayaprakash, and D. P. Kothari, "Three-leg VSC and a transformer based three-phase four-wire DSTATCOM for distribution systems," Fifteenth National Power Systems Conference (NPSC), IIT Bombay, India, December (2008).

[6]. G. Sahu and K. Mahapatra, "FPGA based all-on-chip DSTATCOM control for power quality improvement," 2015 IEEE Power, Communication and Information Technology Conference (PCITC), Bhubaneswar, India, (2015), pp. 54–59.

[7].

[8]. C. Jain and B. Singh, "An offset reduction second order generalized integrator based control algorithm for single-phase S-DSTATCOM," 2015 39th National Systems Conference (NSC), Greater Noida, India, (2015), pp. 1–6.

[9]. A.J. Rana, I. N. Trivedi, C. K. Vasoya, M. H. Pandya, S. N. Gohil, and P. M. Saradva, "Application of D-STATCOM for power quality improvement in distribution line," 2016 International Conference on Computation of Power, Energy, Information and Communication (ICCPEIC), Melmaruvathur, India, (2016), pp. 719–725.

[10]. G. Sahu and K. Mahapatra, "Model predictive control of DSTATCOM for power quality improvement: Modeling, simulation and analysis – Part I," 2015 IEEE Power, Communication and Information Technology Conference (PCITC), Bhubaneswar, India, (2015), pp. 1–6.

[11]. B. Geethalakshmi and C. Sharmiladevy, "An improvement in the performance of unified power quality conditioner using dc-link voltage control," IEEE International Conference on Advances in Engineering, Science and Management (ICAESM-2012), Nagapattinam, India, (2012), pp. 534–539.

[12]. A Kumar and P. Kumar, "Power quality improvement for grid-connected PV system based on distribution static compensator with fuzzy logic controller and UVT/ADALINE-based least mean square controller," Journal of Modern Power Systems and Clean Energy, vol. 9, no. 6, pp. 1289–1299, November (2021).

[13]. V. Nagamalleswari, S. R. Arya, S. Mallikharjun, and G. Sridhar, "Improvement in power quality for distribution system using momentum algorithm," 2022 IEEE 2nd International Conference on Sustainable Energy and Future Electric Transportation (SeFeT), Hyderabad, India, (2022), pp. 1–5.

[14]. Bhim Singh, P. Jayaprakash, Sunil Kumar, and D. P. Kothari, "Implementation of neural-network-controlled three-leg VSC and a transformer as three-phase four-wire DSTATCOM," IEEE Transactions on Industry Applications, vol. 47, no. 4, July/August (2011).

[15]. Hurng-Liahng Jou, Kuen-Der Wu, Jinn-Chang Wu, and Wen-Jung Chiang, "A three-phase four-wire power filter comprising a three-phase three-wire active power filter and a Zig–Zag transformer," IEEE Transactions on Power Electronics, vol. 23, no. 1, January (2008).

[16]. Bhim Singh, P. Jayaprakash, and D. P. Kothari, "Isolated H-bridge VSC based three-phase four-wire DSTATCOM for power quality improvement," 2008 IEEE International Conference on Sustainable Energy Technology, Singapore, (2008), pp. 366–377.

[17]. Bhim Singh, P. Jayaprakash, and D. P. Kothari, "Three-leg voltage source converter integrated with T-connected transformer as three-phase four-wire distribution static compensator for power quality improvement," Electric Power Components and Systems, pp. 817–831, (2010).

[18]. D. Sreenivasarao, Pramod Agarwal, and Biswarup Das, "Neutral current compensation in three-phase, four-wire systems: A review," Electric Power Systems Research, vol. 86, pp. 170–180, (2008).

[19]. A. Jain and M. Jain, "Comparison of Star/Delta and Zig/Zag transformer based DSTATCOM for power quality improvement," 2016 IEEE Students' Conference on Electrical, Electronics and Computer Science (SCEECS), Bhopal, India, (2016), pp. 1–6.

[20]. Rai, S. K. Dalai, S. K. Prince, S. Affijulla, and G. Panda, "Power quality improvement in distribution network using DSTATCOM," 2024 6th International Conference on Energy, Power and Environment (ICEPE), Shillong, India, (2024), pp. 1–5.

[21]. M. Mangaraj, T. Penthia, and A. K. Panda, "Implementation of sparse LMS control algorithm in DSTATCOM," 2016 National Power Systems Conference (NPSC), Bhubaneswar, India, (2016), pp. 1–6.

[22]. R. Jayabarathi, "Voltage regulation and stability enhancement in renewable energy microgrids with E-STATCOM under unbalanced loads," Renewable Energy, (2025), Article 124716.

[23]. Diab, Ahmed A. Zaki, et al., "Voltage stability enhancement in electrical transmission networks using STATCOM with two different controllers: Case study in Middle Egypt electricity zone," Journal of Advanced Engineering Trends, vol. 44, no. 1, pp. 315–343, (2025).

[24]. Govil, Vinamra Kumar, Kuldeep Sahay, and S. M. Tripathi, "Enhancing power quality through DSTATCOM: A comprehensive review and real-time simulation insights," Electrical Engineering, vol. 106, no. 6, pp. 7257–7286, (2024).