RESEARCH ARTICLE OPEN ACCESS

Based DSTATCOM For Neutral Current Compensation with Linear and Non Linear Load in Combination of T-Connected Transformer and SRF

Naga Sowjanya Palety[1],
[1]*(Assistant Professor, E.E.E. Department,Sir.C.R.Reddy College of Engineering , A.P.)*

ABSTRACT
In this paper, a SRF based DSTATCOM with a T- connected transformer is proposed for power quality improvement in three-phase four-wire distribution systems. The proposed DSTATCOM is employed for the of reactive power compensation or power factor correction along with elimination of harmonic currents, load balancing and neutral current compensation at the point of common coupling (PCC).The VSC is able to compensate the power quality problems in the current and the dc bus voltage is regulated to the reference value. The winding of T-connected transformer provides a path to the zero sequence fundamental as well as harmonics currents. As compared to the conventional star/delta transformer and zig-zag transformer, the T- connected transformer requires only two single phase transformers. The performance of the proposed DSTATCOM system is validated through simulations using MATLAB software with its Simulink and Power System Blockset (PSB) toolboxes.
Keywords: power quality improvement, DSTATCOM, voltage source converter, T-connected transformer, neutral current compensation.

Date of Submission: 25 -09-2017 Date of acceptance: 10-10-2017

I. INTRODUCTION

Three-phase four-wire distribution systems are facing various power quality problems. Three-phase four-wire distribution systems are used in commercial buildings, office buildings, etc. Most of the loads in these locations are nonlinear loads in the distribution system. This generates excessive neutral current both of fundamental and harmonic frequency and the neutral conductor gets overloaded. The voltage regulation is also poor in the distribution system due to the installation of different types of loads in the existing distribution system. The remedies to power quality problems are reported in the literature and are known by the generic name of custom power devices (CPD). These custom power devices include the DSTATCOM, DVR and UPQC. The DSTATCOM is a shunt connected device, which takes care of the power quality problems in the currents, whereas the DVR is connected in series with the supply and can mitigate the power quality problems in the voltage and the UPQC can compensate power quality problems both in the current and voltage. The voltage regulation in the distribution feeder is improved by installing a shunt compensator. There are many control schemes reported in the literature for control of shunt active compensators such as instantaneous reactive power theory, power balance theory, synchronous reference frame theory, symmetrical components based, etc. In this investigation the synchronous reference frame theory is used for the control of the proposed DSTATCOM and T- connected transformer is used in the three-phase distribution system for different applications. But the application of T- connected transformer for neutral current compensation is demonstrated for the first time. Moreover, the T-connected transformer is suitably designed for magneto motive force (MMF) balance. The T-connected transformer mitigates the neutral current and the three-leg VSC compensates the harmonic current and reactive power, and balances the load. The IGBT based VSC is self-supported with a dc bus capacitor and is controlled for the required compensation of the load current. The DSTATCOM is designed and simulated using MATLAB software with its Simulink and power system block set (PSB) toolboxes for power factor correction and voltage regulation along with neutral current compensation, harmonic reduction, and load balancing with nonlinear loads.

II. DSTATCOM

Fig. 1(a) shows the power circuit of proposed VSC based DSTATCOM along with a T-connected transformer connected in the three-phase four-wire distribution system. The linear and non-linear, balanced and unbalanced loads are connected at the PCC. The DSTATCOM consists of a voltage-source converter (VSC) using four insulated-gate bipolar transistors (IGBTs), two interface inductors, and two dc capacitors. The T-connected Transformer connected at the load terminal provides a circulating path for zero sequence harmonic and fundamental currents. The DSTATCOM provides neutral current compensation, harmonics elimination and load balancing along with power factor correction or line voltage regulation. The unity power factor (UPF) operation using the DSTATCOM is shown in Fig. 1(b). The compensator current is to compensate the reactive power component of the load current. Fig. 1(c) shows the Phasor diagram for zero voltage regulation (ZVR) operation. The DSTATCOM injects a current Ic, such that the load voltage, VS and source voltage, VM are in the locus of same circle. The design of the T-connected transformer, design and control of the H-bridge VSC are depicted in the following section.

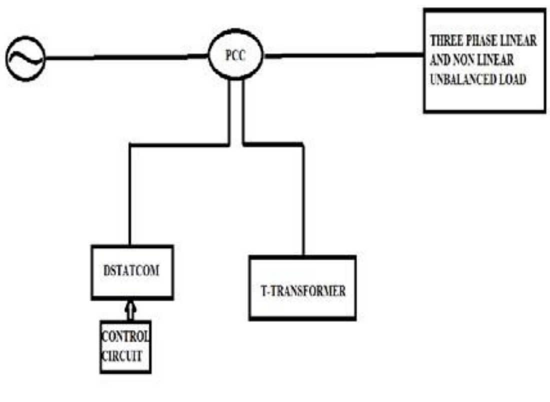


Fig.1.1Block Diagram Representation

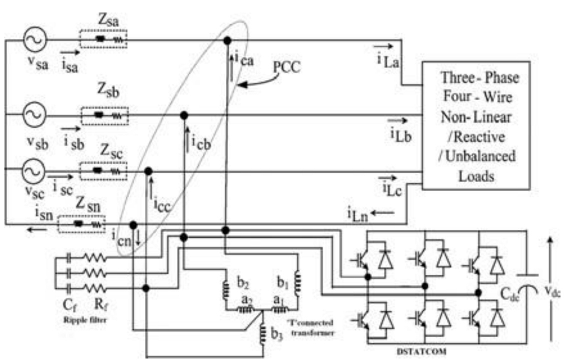


Fig.1.2 Three-leg VSC with T-connected-transformer based DSTATCOM connected in distribution system.

III. T-TRANSFORMER

The connection of two single-phase Transformer in T- configuration for interfacing with a three-phase four-wire system. The T-connected windings of the transformer not only provide a path for the zero-sequence fundamental current and harmonic currents but also offer a path for the neutral current when connected in shunt at point of common coupling (PCC). Under unbalanced load, the zero-sequence load-neutral current divides equally into three currents and takes a path through the T-connected windings of the transformer. The current rating of the windings is decided by the required neutral current compensation. The voltages across each winding are designed using the phasor diagram shown in Fig. 1.4 gives the following relations to find the turn's ratio of windings.

If Va1 and Vb1 are the voltages across each winding and Va is the resultant voltage, then

Va1 = K1Va----------- (1)

Va2 = K2Va ---------------(2)

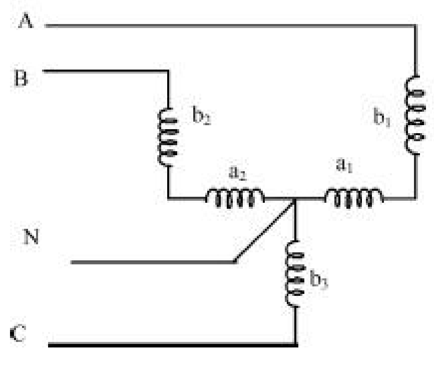


Fig.1.3 T-connected transformer

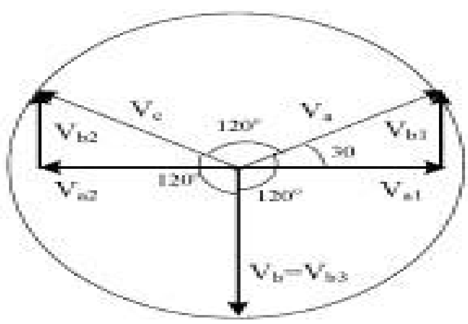


Fig.1.4 Phasor Diagram

IV. CONTROL OF DSTATCOM

The control approaches available for the generation of reference source currents for the control of VSC of DSTATCOM for three-phase four-wire system are instantaneous reactive power theory (IRPT), synchronous reference frame theory (SRFT), unity power factor(UPF) etc. The SRF theory is used in this investigation for the control of DSTATCOM. The block diagram of control

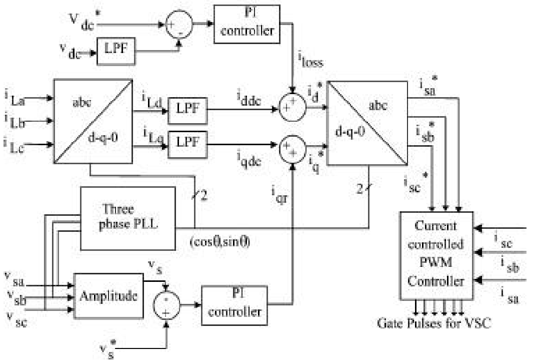


Fig.1.5 Control algorithm for the operation of SRF based DSTATCOM in a three phase 4-wire system.

The load currents (iLa, iLb, iLc), the PCC voltages (VSa, VSb, VSc), and dc bus voltage (Vdc) of DSTATCOM are sensed as feedback signals. The load currents from the a–b–c frame are converted to the d–q–o frame using Park's Transformation

$$\begin{bmatrix} i_{Ld} \\ i_{Lq} \\ i_{L0} \end{bmatrix} = \frac{2}{3}\begin{bmatrix} \cos\theta & \sin\theta & \frac{1}{2} \\ \cos(\theta-120) & -\sin(\theta-120) & \frac{1}{2} \\ \cos(\theta+120) & \sin(\theta+120) & \frac{1}{2} \end{bmatrix}\begin{bmatrix} i_{La} \\ i_{Lb} \\ i_{Lc} \end{bmatrix}$$

Where cos θ and sin θ are obtained using a three-phase phase locked loop (PLL). A PLL signal is obtained from terminal voltages for generation of fundamental unit vectors [18] for conversion of sensed currents to the d–q–o reference frame. The SRF controller extracts dc quantities by a low-pass filter, and hence, the non-dc quantities (harmonics) are separated from the reference signal. The d-axis and q-axis currents consist of fundamental and harmonic components as

$$i_{Ld} = i_{d\,dc} + i_{q\,ac}$$

$$i_{Lq} = i_{q\,dc} + i_{d\,ac}$$

Zero-Voltage Regulation (ZVR) operation of DSTATCOM:

The compensating strategy for ZVR operation considers that the source must deliver the same direct-axis component i*d, as mentioned in along with the sum of quadrature-axis current (iq dc) and the component obtained from the PI controller (iqr) used for regulating the voltage at PCC. The amplitude of ac terminal voltage (VS) at the PCC is controlled to its reference voltage (V*S) using the PI controller. The output of PI controller is considered as the reactive component of current (iqr) for zero-voltage regulation of ac voltage at PCC. The amplitude of ac voltage (VS) at PCC is calculated from the ac voltages (vsa, vsb, vsc) as

$$V \quad 2 \quad v^2sa \quad v^2sb \quad v^2sc)^2 \quad -$$

Then, a PI controller is used to regulate this voltage to a reference value as

iqr (n) = iqr (n−1)+Kpq(Vte (n) − Vt (n−1))+ KiqVte (n)

Where Vte (n) = V*S – VS(n) denotes the error between reference (V*S) and actual (VS(n)) terminal voltage amplitudes at the nth sampling instant. Kpq and Kiq are the proportional and integral gains of the dc bus voltage PI controller. The reference source quadrature-axis current isisc) and reference source currents (isa*, isb*, isc*) are compared and a proportional controller is used for amplifying current error in each phase. Then, the amplified current error is compared with a triangular carrier signal of switching frequency to generate the gating signals for six IGBT switches of VSC of DSTATCOM. The gate signals are PWM controlled so that sensed source currents follows the reference source currents precisely

V. MODELING AND SIMULATION

The T-connected-transformer and SRF based DSTATCOM connected to a three-phase four-wire system is model and simulate using the MATLAB with its Simulink and PSBs. The ripple filter is connected to the DSTATCOM for filtering the ripple in the PCC voltage. The system data are given in the Appendix I. The MATLAB-based model of the three-phase four-wire DSTATCOM is shown in Fig. The T connected transformer in parallel to the load, the three-phase source, and the shunt-connected three-leg VSC are connected as shown in Fig.1.4. The available model of linear transformers, which includes losses, is used for modelling the T-connected transformer. The control algorithm for the DSTATCOM is also model in MATLAB. The reference source currents are derived from the sensed PCC voltages (vsa, vsb, vsc), load currents (iLa, iLb, iLc), and the dc bus voltage of DSTATCOM (vdc). A PWM current controller is used over the reference and sensed source currents to generate the gating signals for the IGBTs of the VSC of the

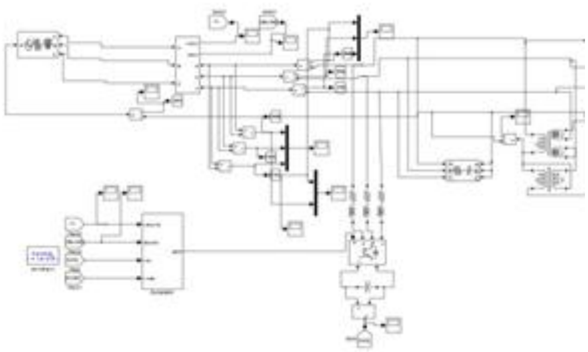


Fig.1.6 MATLAB model of the T-connected transformer and the three-leg-VSC-based DSTATCOM connected system

VI. RESULTS AND DISCUSSION

The performance of the T-connected transformer and three- leg VSC based three-phase four-wire DSTATCOM is demonstrated for power factor correction and voltage regulation along with harmonic reduction, load balancing, and neutral current compensation. The developed model is analyzed under varying loads and the results are discussed below.

VII. Performance of DSTATCOM with Linear Load for Neutral Current Compensation, Load Balancing, and ZVR Operation

The dynamic performance of the DSTATCOM under linear lagging power factor unbalanced load condition is shown in fig.5. The PCC voltages (Vs), source currents (is), load currents (iL), compensator currents (iC), source neutral current (iSn), load-neutral current (iLn), compensator neutral current (iCn), dc bus voltage (Vdc), and amplitude of voltage (Vs) at PCC are also shown. The source neutral current is observed as nearly zero, and this verifies the proper compensation. It is also observed that the dc bus voltage of DSTATCOM is able to maintain close to the reference value

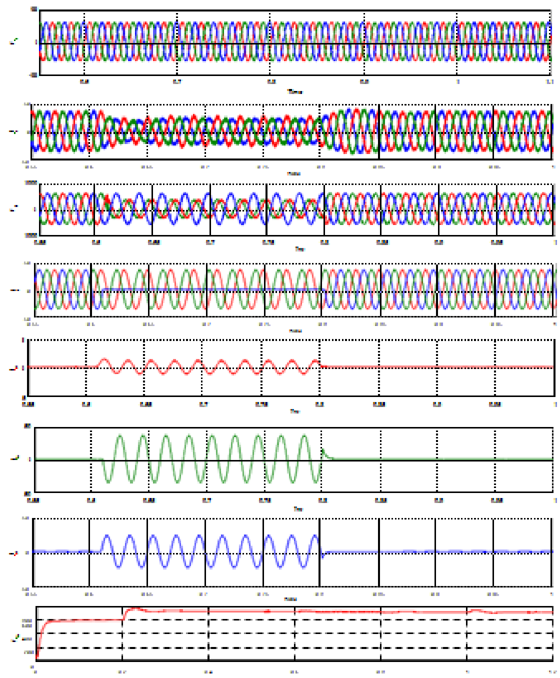
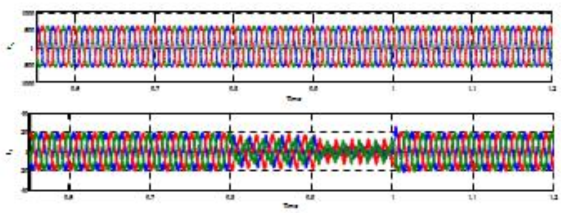


Fig1.7 Performance of a SRF based DSTATCOM and T- connected ransformer for current compensation, load balancing and voltage regulation for linear load.

VIII. Performance of DSTATCOM with Non-Linear Load for Harmonic compensation, Load Balancing, and ZVR Operation

The dynamic performance of the DSTATCOM with nonlinear and unbalanced load is shown in fig 1.7. It is observed that the harmonic current is compensated and the source currents are balanced and sinusoidal. The source currents are still balanced and sinusoidal even when the load current in a phase is zero. The dc bus voltage of DSTATCOM is maintained at nearly its reference value under all load disturbances. The amplitude of PCC voltage is maintained at the reference value under various load disturbances, which shows the ZVR mode of operation of DSTATCOM.



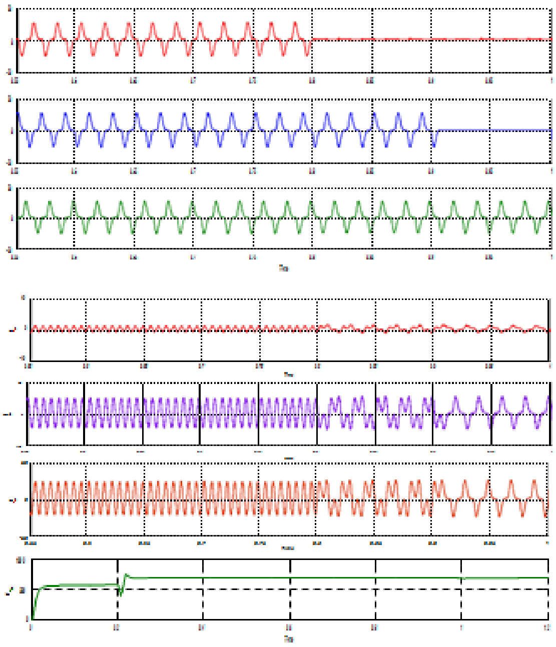


Fig.1.8 Performance of a SRF based DSTATCOM and T- connected transformer for current compensation, load balancing and voltage regulation for linear load.

under all disturbances. The amplitude of PCC voltage is maintained at the reference value under various load disturbances, which shows the ZVR mode of operation of DSTATCOM.

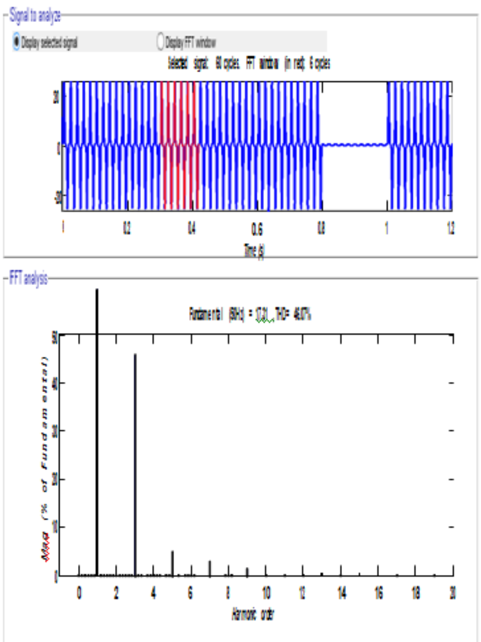


Fig.1.9 load current and harmonic spectrum under unbalanced load.

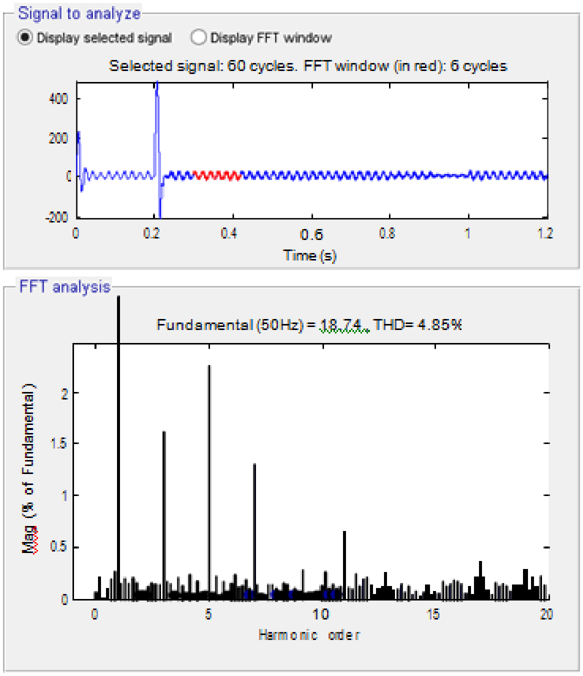


Fig.1.10 load current and harmonic spectrum under balanced load.

APPENDIX-I

Line impedance: Rs = 0.01 Ω, Ls = 2 mH For linear Loads: 20 KVA, 0.80 pF lag
For Nonlinear: Three single-phase bridge rectifiers with R = 25 Ω and C = 470 μF
Ripple filter: Rf = 5 Ω, Cf = 5 μF
DC bus voltage of DSTATCOM: 680 V
DC bus capacitance of DSTATCOM: 4700 μF AC inductor: 2 mH
DC voltage PI controller: Kpd = 3.57, Kid = 0.5
PCC voltage PI controller: Kpq = 0.5, Kiq = 1 AC line voltage: 415 V, 50 Hz
PWM switching frequency: 10 kHz
Hence, two single-phase transformers of rating are

Rating of Transformer1: 5 kVA, 240 V/120 V/120 V and Rating of Transformer2: 5 kVA, 208 V/208 V are selected.

REFERENCES

[1] Bhim singh and D.P. Kothari “T-connected transformer and Three-leg VSC based Dstatcom for power quality improvement” IEEE Tractions On power electronics, VOL.23,NO.6.
[2] Sreenivasarao D, Pramod Agarwal, Biswarup Das. “A T- connected transformer based hybrid D-STATCOM for three phase, four-wire systems” . Electr Power Syst Res(2013);44:964–970.
[3] Arrillaga J, Watson NR. Power system harmonics. 2nd ed. John Wiley & Sons

Ltd.; 2003.
[4] Dugan RC, McGranaghan MF, Beaty HW. Electric power systems quality. 2nd ed. New York: McGraw-Hill; 2006.
[5] Sreenivasarao D, Pramod Agarwal, Biswarup Das. Neutral current compensation in three-phase, four-wire systems: a review. Electr Power Syst Res 2012;86:170–80.
[6] Gruzs TM. A survey of neutral currents in three-phase computer power systems. IEEE Trans Ind Appl 1990;26(4):719–25.
[7] IEEE Recommended Practices and Requirements for Harmonics Control in Electric Power Systems, IEEE Std. 519; 1992.
[8] Khadkikar V, Chandra A, Singh B. Digital signal processor implementation and performance evaluation of split capacitor, four-leg and three H-bridge-based three-phase four-wire shunt active filters. IET Power Electron 2011;4(4):463–70.
[9] Quinn CA, Mohan N. Active filtering of harmonic currents in three-phase, four wire systems with three-phase and single- phase nonlinear loads. Proc IEEE APEC 1992:829–35.
[10] Quinn CA, Mohan N, Mehta H. A four-wire, current- controlled converter provides harmonic neutralization in three- phase, four-wire systems. Proc IEEE APEC 1993:841–6.
[11] Khera PP. Application of Zig-Zag transformers for reducing harmonics in the neutral conductor of low voltage distribution system. Proc IEEE/IAS 1990;2:1092–6.
[12] A.Ghosh and G. ledwitch power quality Enhancement using custom power devices. “London, U.K.; kluwer,2002.”
[13] Bhim singh,P.jayaprakash, D.P.Kothari,”New control approach for capacitor supported DSTATCOM in three-phase, four wire distribution systems under non-ideal supply voltage conditionbased on synchronous reference frame theory” Electr Power Syst Res(2011);33:1109–1117.

International Journal of Engineering Research and Applications (IJERA) is **UGC approved** Journal with Sl. No. 4525, Journal no. 47088. Indexed in Cross Ref, Index Copernicus (ICV 80.82), NASA, Ads, Researcher Id Thomson Reuters, DOAJ.

Naga Sowjanya Palety. “Based DSTATCOM For Neutral Current Compensation with Linear and Non Linear Load in Combination of T-Connected Transformer and SRF.” International Journal of Engineering Research and Applications (IJERA) , vol. 7, no. 10, 2017, pp. 20–25.