International Journal of Engineering Inventions
ISSN: 2278-7461, www.ijeijournal.com
Volume 1, Issue 4 (September2012) PP: 80-90

A Modern Approach of a Three Phase Four Wire Dstatcom for Power Quality Improvement Using T Connected Transformer

A.Dheepanchakkravarthy.M.E.[1], Prof.Jebasalma.M.E.[2],
[1]*Department Of EEE, M.I.E.T Engineering College, Trichy – 07*
[2] *Department Of EEE, A.C. College Of Engineering And Technology, Karaikudi-04*

Abstract*—Three-phase four-wire distribution systems are facing severe power quality problems such as poor voltage regulation, high reactive power and harmonics current burden, load unbalancing, excessive neutral current, etc., due to various reasons such as single phase loads, nonlinear loads etc. A new topology of DSTATCOM [Distribution Static Compensator] is proposed in this paper in which a three phase three leg VSC [Voltage Source Converter] is Integrated with T connected transformer for nonlinear loads and is able to perform all the compensation required for three phase four wire system. The T-connected transformer connection mitigates the neutral current and the three-leg VSC compensates harmonic current, reactive power, and balances the load. Two single-phase transformers are connected in T-configuration for interfacing to a three-phase four-wire power distribution system and the required rating of the VSC is reduced. The DSTATCOM is tested for power factor correction and voltage regulation along with neutral current compensation, harmonic reduction, and balancing of nonlinear loads. The performance of the three-phase four-wire DSTATCOM is validated using MATLAB software with its Simulink and power system block set toolboxes.

***Keywords*—Power quality improvement, DSTATCOM, voltage source converter, T connected transformer, neutral current compensation**

I. INTRODUCTION

Three-phase four-wire distribution systems are used in commercial buildings, office buildings, hospitals, etc. Most of the loads in these locations are nonlinear loads and are mostly unbalanced loads in the distribution system. This creates 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 unplanned expansion and the installation of different types of loads in the existing distribution system. The power quality at the distribution system is governed by various standards such as IEEE-519 standard [1]. The remedies to power quality problems are reported in the literature and are known by the generic name of custom power devices (CPD) [2]. These custom power devices include the DSTATCOM (distribution static compensator), DVR (dynamic voltage restorer) and UPQC (unified power quality conditioner). 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.

Some of the topologies of DSTATCOM for three-phase four-wire system for the mitigation of neutral current along with power quality compensation in the source current are four-leg voltage source converter (VSC), three single-phase VSCs, three-leg VSC with split capacitors [5], three-leg VSC with zigzag transformer [9],[10], and three-leg VSC with neutral terminal at the positive or negative of dc bus [11]. The voltage regulation in the distribution feeder is improved by installing a shunt compensator [12]. 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. [13], [14]. The synchronous reference frame theory [14] is used for the control of the proposed DSTATCOM.

The T-connected transformer is used in the three-phase distribution system for different applications [6]–[8].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. BLOCK DIAGRAM REPRESENTATION

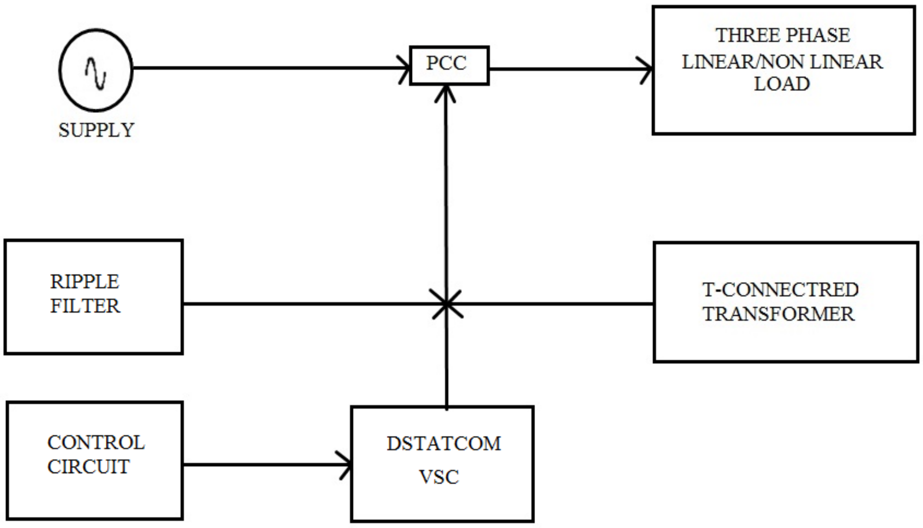


Fig. 2.1: Block Diagram Representation

The block diagram representation of the proposed Three-Phase Four-Wire DSTATCOM and T-connected Transformer based distribution System is as shown in fig 2.1. It consists of three phase linear/nonlinear load block, ripple filter block, control circuit block and shunt active filter block. The T-connected Transformer block is used for neutral current compensation and it reduces the rating of three leg voltage source converter. The control circuit consists of DSATATCOM with Three leg Voltage Source Converter. This block is used to compensate the harmonic current and reactive power and load balancing. Also The DSTATCOM is tested for power factor correction and voltage regulation. The three leg VSC is used as an active shunt compensator along with a T-connected transformer. The ripple filter block is used to reduce the high frequency ripple voltage in the voltage at **Point of Common Coupling (PCC)**. High frequency ripple is due to switching current of the VSC of the DSTATCOM. All the blocks should be connected at PCC.

III. SYSTEM CONFIGURATION AND DESIGN

Fig.3.1 (a) shows the single-line diagram of the shunt-connected DSTATCOM-based distribution system. The dc capacitor connected at the dc bus of the converter acts as an energy buffer and establishes a dc voltage for the normal operation of the DSTATCOM system. The DSTATCOM can be operated for reactive power compensation for power factor correction or voltage regulation. Fig.3. (b) shows the phasor diagram for the unity power factor operation. The reactive current (I_c) injected by the DSTATCOM has to cancel the reactive power component of the load current, so that the source current is reduced to active power component of current only (I_S). The voltage regulation operation of DSTATCOM is depicted in the phasor diagram of Fig. 3.1 (c). The DSTATCOM injects a current I_c such that the voltage at the load (V_L) is equal to the source voltage (V_S). The DSTATCOM current are adjusted dynamically under varying load condition.

The proposed DSTATCOM consisting of a three-leg VSC and a T-connected transformer is shown in Fig.3.2, where the T-connected transformer is responsible for neutral current compensation. The windings of the T-connected transformer are designed such that the mmf is balanced properly in the transformer. A three-leg VSC is used as an active shunt compensator along with a T-connected transformer, as shown in Fig. 3.2, and this topology has six IGBTs, and one dc capacitor. The required compensation to be provided by the DSTATCOM decides the rating of the VSC components. The data of DSTATCOM system considered for analysis is shown in the Appendix 1. The VSC is designed for compensating a reactive power of 12 KVAR, as decided from the load details. The ripple filter block is used to reduce the high frequency ripple voltage in the voltage at Point of Common Coupling (PCC). High frequency ripple is due to switching current of the VSC of the DSTATCOM. All the blocks are connected at PCC. The selection of dc capacitor and the ripple filter are given in the following sections.

3.1. DC CAPACITOR VOLTAGE

The minimum dc bus voltage of VSC of DSTATCOM should be greater than twice the peak of the phase voltage of the system [17]. The dc bus voltage is calculated as

$$V_{dc} = 2\sqrt{2}V_{LL} / \sqrt{3}\, m \qquad (1)$$

Where m is the modulation index and is considered as 1 and V_{LL} is the ac line output voltage of DSTATCOM. Thus, V_{dc} is obtained as 677.69V for V_{LL} of 415 V and is selected as 700V.

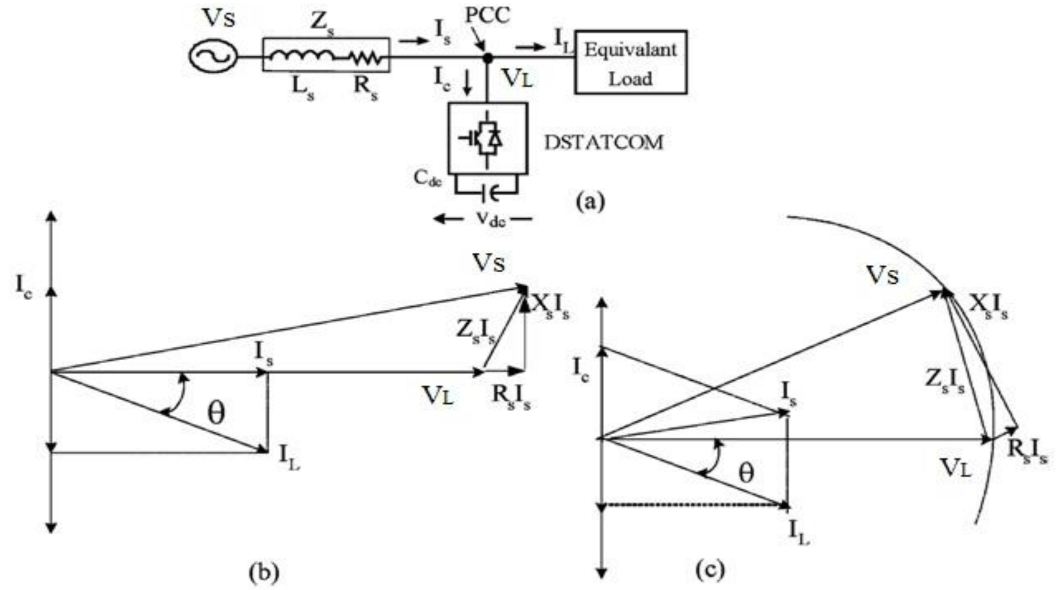


Fig.3.1. (a) Single-line diagram of DSTATCOM system. (b) Phasor diagram for UPF operation. (c) ZVR operation

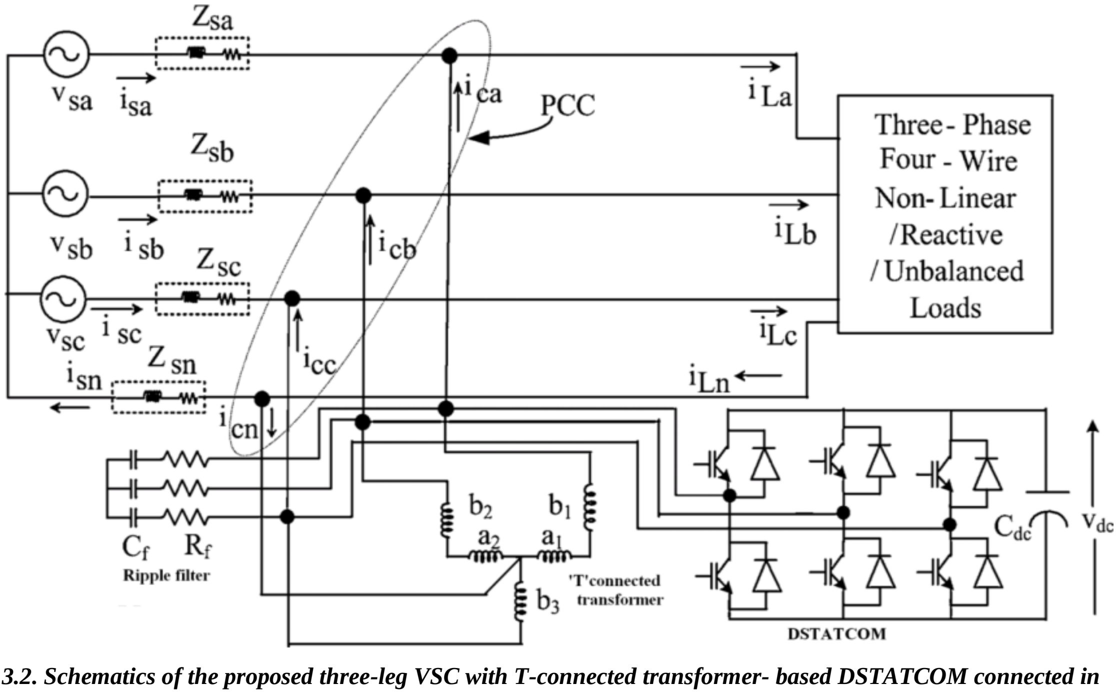


Fig.3.2. Schematics of the proposed three-leg VSC with T-connected transformer- based DSTATCOM connected in distribution system

3.2. DC BUS CAPACITOR

The value of dc capacitor (C_{dc}) of VSC of DSTATCOM depends on the instantaneous energy available to the DSTATCOM during transients [17]. The principle of energy conservation is applied as

$$(1/2)\ C_{dc}\,[(V_{dc})^2 - (V_{dc1})^2] = 3V(a\ I)\ t \qquad (2)$$

Where V_{dc} is the reference dc voltage and V_{dc1} is the minimum voltage level of dc bus, a is the overloading factor, V is the phase voltage, I is the phase current, and t is the time by which the dc bus voltage is to be recovered. Considering, a 1.5 %(10 V) reduction in DC bus voltage during transients, V_{dc1} = 690 V, V_{dc} = 700 V, V = 239.60 V, I = 28.76 A, t = 350 μs, a = 1.2, the calculated value of C_{dc} is 2600 μF and is selected as 3000 μF.

3.3. RIPPLE FILTER

A low-pass first-order filter tuned at half the switching frequency is used to filter the high-frequency noise from the voltage at the PCC. Considering a low impedance of 8.1 Ω for the harmonic voltage at a frequency of 5 kHz, the ripple filter capacitor is designed as C_f = 5 μF. A series resistance (R_f) of 5 Ω is included in series with the capacitor (C_f). The impedance is found to be 637 Ω at fundamental frequency, which is sufficiently large, and hence, the ripple filter draws negligible fundamental current.

IV. DESIGN OF THE T-CONNECTED TRANSFORMER

Fig. 4.1 (a) shows the connection of two single-phase transformers 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 as shown shortly.

The phasor diagram shown in Fig. 4.1 (b) gives the following relations to find the turn's ratio of windings. If V_{a1} and V_{b1} are the voltages across each winding and V_a is the resultant voltage,
Then

$$V_{a1} = K_1 V_a \qquad (3)$$

$$V_{b1} = K_2 V_a \qquad (4)$$

Where K_1 and K_2 are the fractions of winding in the phases.
Considering

$$|V_a| = |V_b| = V \text{ and}$$

From phasor diagram,

$$\cos 30^\circ = V_{a1} / V_a$$

$$V_{a1} = V_a \cos 30^\circ$$

and

$$\sin 30^\circ = V_{b1} / V_a$$

$$V_{b1} = V_a \sin 30^\circ$$

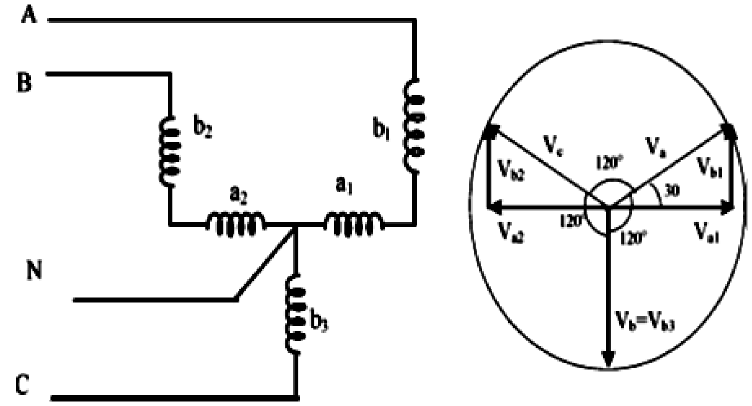


Fig. 4.1 (a) Design of T-connected transformer (b) Phasor diagram

Then from (4) and (5), one gets, $K_1 = 0.866$ and $K_2 = 0.5$. The line voltage is

$$V_{ca} = 415 \text{ V}$$

$$V_a = V_b = V_c = 415\ \sqrt{3} = 239.60 \text{ V} \qquad (5)$$

$$V_{a1} = 207.49 \text{ V},\ Vb1 = 119.80 \text{ V} \qquad (6)$$

Hence, two single-phase transformers of ratings 5kVA, 240 V/120V/120 V and 5kVA, 208 V/208 V are selected.

V. 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) based, instantaneous symmetrical components based, etc. [13], [14]. The SRFT is used in this investigation for the control of the DSTATCOM. A block diagram of the control scheme is shown in Fig. 5.1. The load currents (i_{La}, i_{Lb}, i_{Lc}), the PCC voltages (V_{Sa}, V_{Sb}, V_{Sc}), and dc bus voltage (V_{dc}) 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

$$\begin{pmatrix} i_{Ld} \\ i_{Lq} \\ i_{L0} \end{pmatrix} = \frac{2}{3} \begin{pmatrix} \cos\theta & -\sin\theta & \left(\frac{1}{2}\right) \\ \cos(\theta - 120) & -\sin(\theta - 120) & \left(\frac{1}{2}\right) \\ \cos(\theta + 120) & \sin(\theta + 120) & \left(\frac{1}{2}\right) \end{pmatrix} \begin{pmatrix} i_{La} \\ i_{Lb} \\ i_{Lc} \end{pmatrix} \qquad (7)$$

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

$$i_{Ld} = i_{d\,dc} + i_{q\,ac} \qquad (8)$$
$$i_{Lq} = i_{q\,dc} + I_{q\,ac} \qquad (9)$$

5.1. Unity Power Factor (UPF) operation of DSTATCOM

The control strategy for reactive power compensation for UPF operation considers that the source must deliver the mean value of the direct-axis component of the load current along with the active power, component current for maintaining the dc bus and meeting the losses (i_{loss}) in DSTATCOM. The output of the proportional-integral (PI) controller at the dc bus voltage of DSTATCOM is considered as the current (i_{loss}) for meeting its losses

$$i_{loss\,(n)} = i_{loss\,(n-1)} + K_{pd}\,(V_{de\,(n)} - V_{de\,(n-1)}) + K_{id}V_{de(n)} \qquad (10)$$

where $V_{de(n)} = V^{*}_{dc}-V_{dc(n)}$ is the error between the reference (V^{*}_{dc})and sensed (V_{dc}) dc voltages at the nth sampling instant. K_{pd} and K_{id} are the proportional and integral gains of the dc bus voltage PI controller The reference source current is therefore

$$I^{*}_{d} = i_{d\,dc} + i_{loss} \qquad (11)$$

The reference source current must be in phase with the voltage at the PCC but with no zero-sequence component. It is therefore obtained by the following inverse Park's transformation with i^{*}_{d} as in and i^{*}_{q} and i^{*}_{0} as zero.

$$\begin{pmatrix} i^{*}_{a} \\ i^{*}_{b} \\ i^{*}_{c} \end{pmatrix} = \begin{pmatrix} \cos\theta & \sin\theta & 1 \\ \cos(\theta-120) & \sin(\theta-120) & 1 \\ \cos(\theta+120) & \sin(\theta+120) & 1 \end{pmatrix} \begin{pmatrix} i^{*}_{d} \\ i^{*}_{q} \\ i^{*}_{0} \end{pmatrix} \qquad (12)$$

5.2. 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 ($i_{q\,dc}$) and the component obtained from the PI controller (i_{qr}) used for regulating the voltage at PCC. The amplitude of ac terminal voltage (V_S) 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 (i_{qr}) for zero-voltage regulation of ac voltage at PCC. The amplitude of ac voltage (V_S) at PCC is calculated from the ac voltages (v_{sa}, v_{sb}, v_{sc}) as

$$V_S = (2/3)^{1/2}\,(v^{2}_{sa} + v^{2}_{sb} + v^{2}_{sc})^{½} \qquad (13)$$

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

$$i_{qr\,(n)} = i_{qr\,(n-1)} + K_{pq}\,(V_{te\,(n)} - V_{te\,(n-1))} + K_{iq}\,V_{te\,(n)} \qquad (14)$$

Where $V_{te\,(n)} = V^{*}_{S} - V_{S(n)}$ denotes the error between reference (V^{*}_{S}) and actual ($V_{S(n)}$) terminal voltage amplitudes at the nth sampling instant. K_{pq} and K_{iq} are the proportional and integral gains of the dc bus voltage PI controller. The reference source quadrature-axis current is

$$I^{*}_{q} = i_{q\,dc} + i_{qr} \qquad (15)$$

The reference source current is obtained by inverse Park's transformation using (12) with i^{*}_{d} as in (11) and i^{*}_{q} as in (15) and i^{*}_{0} as zero.

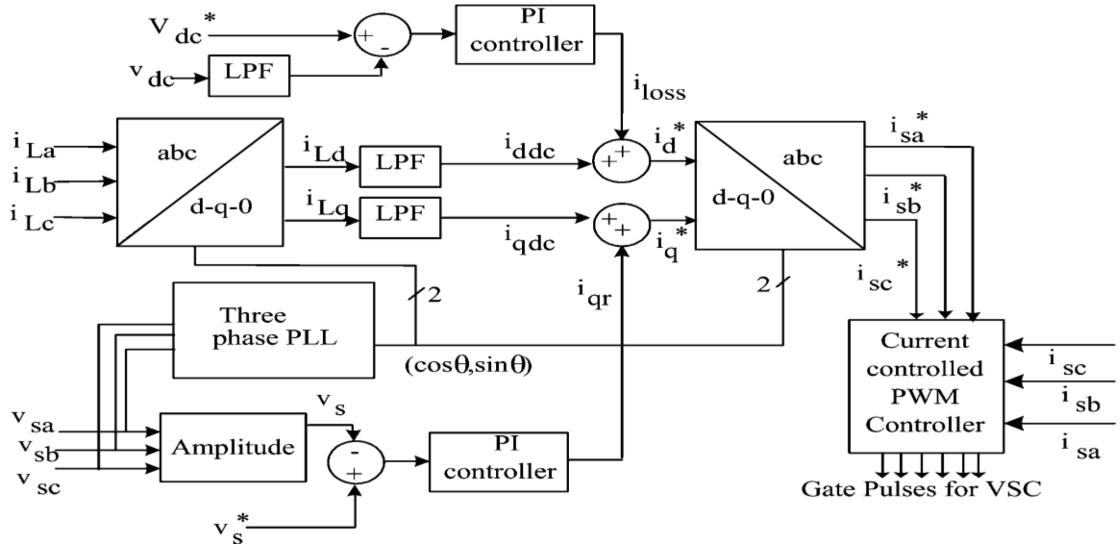


Fig.5.1 Control algorithm for the three-leg-VSC-based DSTATCOM in a three phase four-wire system.

5.3. Current controlled PWM generator:

In a current controller, the sensed source currents (isa, isb, isc) and reference source currents (i_{sa}^*, i_{sb}^*, i_{sc}^*) 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.

VI. MODELING AND SIMULATION

The three-leg VSC and the T-connected-transformer-based DSTATCOM connected to a three-phase four-wire system is modeled and simulated 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.6.2. 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. 6.2. The available model of linear transformers, which includes losses, is used for modeling the T-connected transformer. The control algorithm for the DSTATCOM is also modeled in MATLAB. The reference source currents are derived from the sensed PCC voltages (v_{sa}, v_{sb}, v_{sc}), load currents (i_{La}, i_{Lb}, i_{Lc}), and the dc bus voltage of DSTATCOM (v_{dc}). 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 DSTATCOM.

6.1 Simulation diagram of Three-Phase Four-Wire Distribution System without Controller Circuits

It consists of two three phase circuit breakers and Active Reactive power block, Power factor calculation Block and Display. The circuit Breakers are used to simulate the unbalanced condition. The Source voltage (V_s), Source current (I_s), Load current (I_L), Load neutral current (I_{Ln}), Source neutral current (I_{Sn}) are measured from the corresponding scopes as in shown fig.6.1

6.2. Simulation diagram of the T-connected Transformer and Three leg VSC based DSTATCOM for power quality improvement

It consists of Three Three-phase Circuit Breakers, Nonlinear load, DSTATCOM block, T-connected transformer, controller block, Power factor correction, ripple filter and the measurement scopes as shown in fig.6.2. Initially the three-phase four-wire distribution system is in stable condition (CB1 and CB2 are open), and the controller circuit is not connected to the balanced three-phase four-wire distribution system. When Circuit breaker1 gets closed at 0.2sec, one phase of the load is disconnected resulting load become unbalanced. At this junction the circuit breaker3 gets closed thereby connecting the controller circuit to the three-phase four-wire distribution system. The circuit breaker1 remain closed from 0.2sec to 0.5 sec. Further at 0.3sec the circuit breaker2 gets closed disconnecting another phase. The circuit breaker 2 remains closed till 0.4sec. During unbalanced condition as a result of fault is rectified by the controller action.

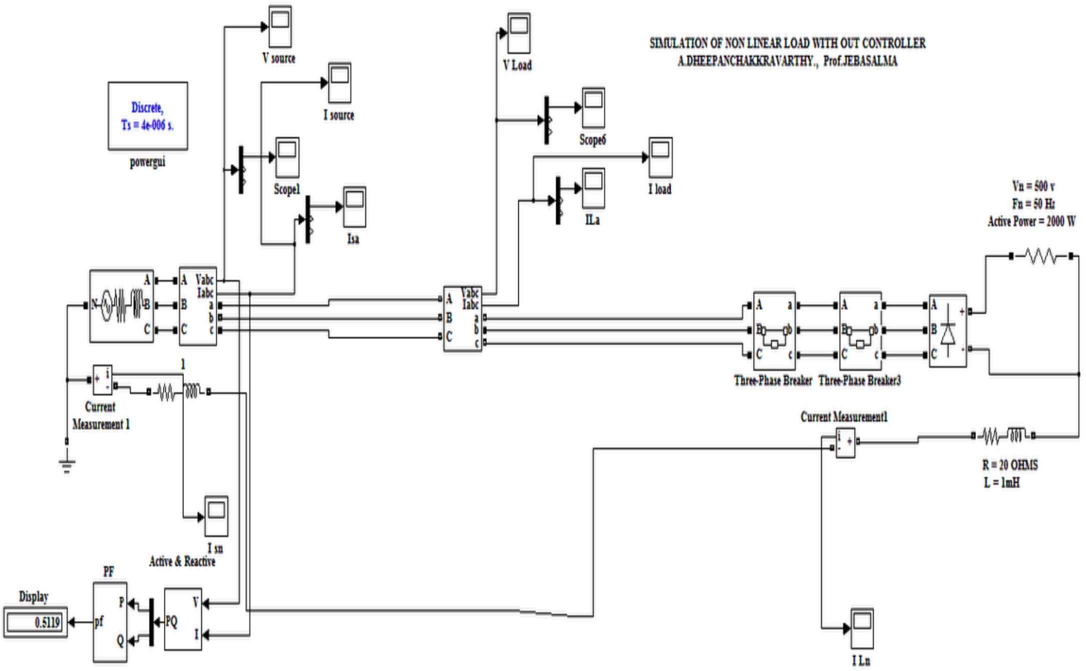


Fig.6.1. Simulation diagram of three-phase four-wire System without controller circuits

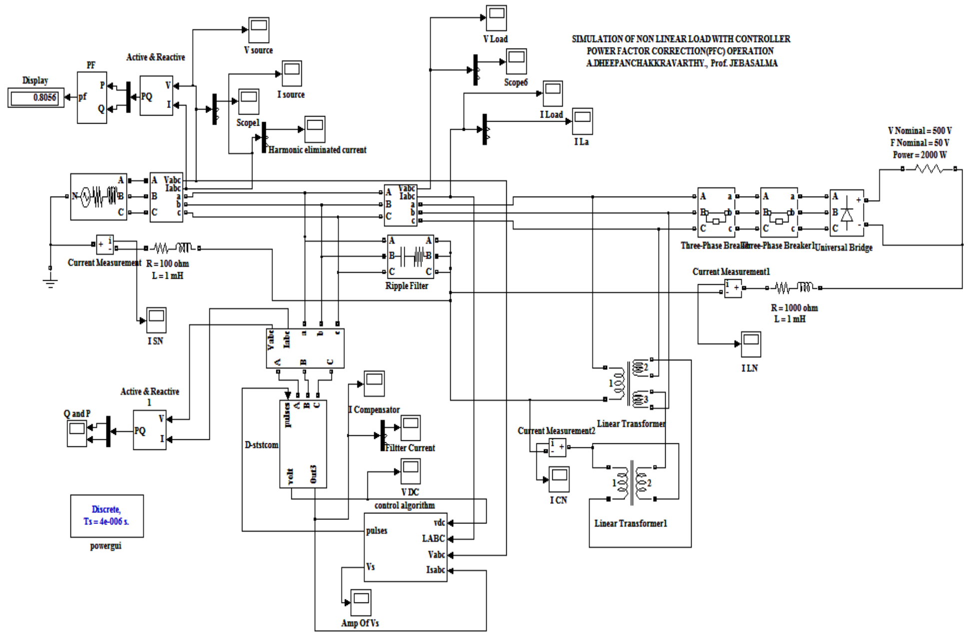


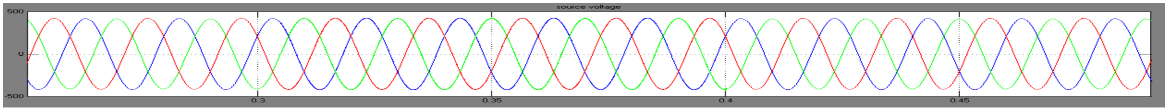
Fig.6.2. Simulation diagram of the proposed three-phase four-wire DSTATCOM-connected system for Non-linear Load

VII. RESULTS

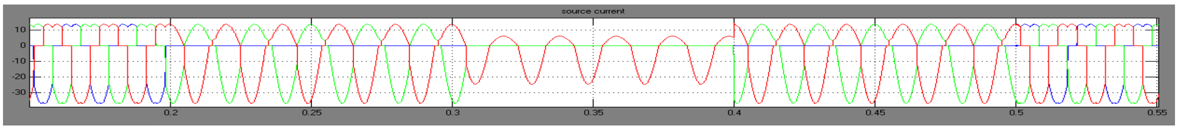
7.1. Performance of three phases four wire distribution system for linear load without controller circuits:

The source voltage (V_s), source current (I_s), load current (I_L), load neutral current (I_{Ln}), source neutral current (I_{Sn}) are measured from the corresponding scopes of fig.6.1. and shown in Fig.7.1. The power factor measured in this condition is 0.5119 as shown in fig. 6.1. The source current (Is) and load current (I_L) both contain harmonics. The THD measured is 37.85% with help of FFT analysis. The Source current and harmonic spectrums without controller circuit are also shown in fig. 7.1.

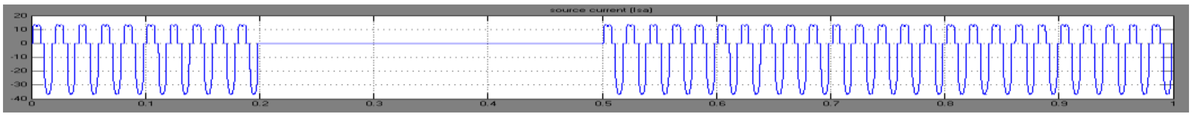
Source Voltage (Vs)



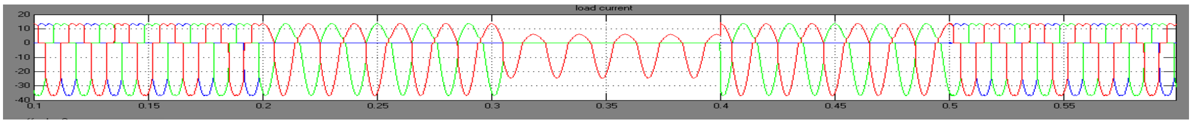
Source Current (Is)



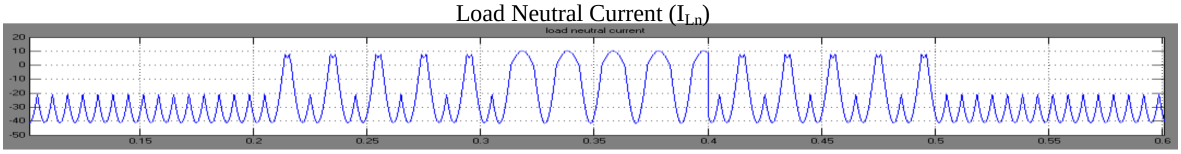
Source Current (Isa)



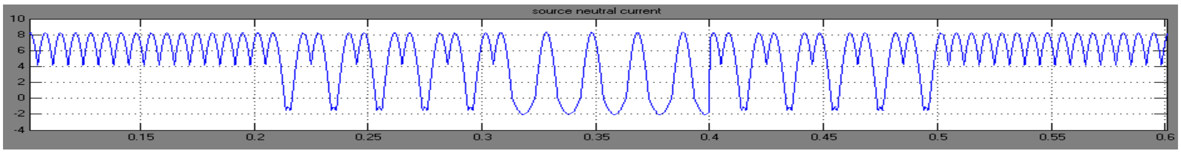
Load Current (I_L)



Load Neutral Current (I_{Ln})



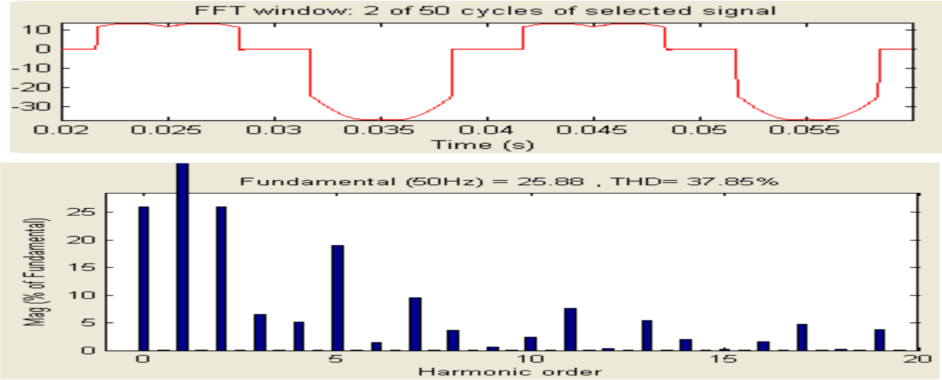
Source Neutral Current (I_{Sn})



Source current and Harmonic Spectrum

Fig.7.1. Performance of three phases four wire distribution system for nonlinear load without controller circuits

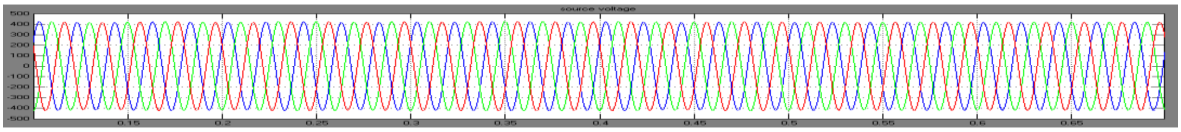
7.2. Performance of three phases four wire DSTATCOM with Non-Linear load for Harmonic compensation, Load



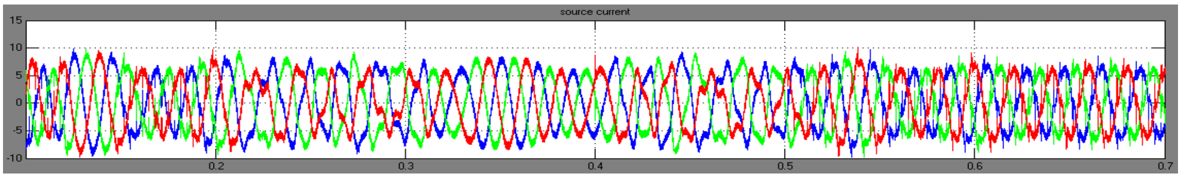
The dynamic performance during Non-linear, unbalanced load condition is shown in fig.6.2. At 0.2 sec, the load is changed to two phase load and single phase load at 0.3 sec. These loads are applied again at 0.4 sec and 0.5 sec respectively. The PCC voltage (VS), source current (IS), load current (IL), compensator current (IC), source neutral current (I_{Sn}), load neutral current (I_{Ln}),and compensator neutral current (I_{Cn}), DC bus Voltage of DSTATCOM (VDC), amplitude of voltage (VAmp) at PCC, reactive Power (Q), active power (P), harmonic spectrum of source current and Filter current are shown in Fig 7.2.

The source currents are observed as balanced and sinusoidal under all these condition. The harmonic currents are added with the filter currents so we can get the pure sinusoidal source current with help of DSTATCOM and VSC. The total Harmonic Distortion (THD) of the source current was improved from 37.85% to 5.52% and this shows the satisfactory performance of DSTATCOM for harmonic compensation as stipulated by IEEE 519 – standard. The load current and the compensator current are observed as balanced under all these condition with help of DSTATCOM. The T - connected transformer is responsible for neutral current compensation. By adding the load neutral current (ILn) with Compensator neutral current (ICn) as a result source neutral current is equal to zero (ISn = ILn + ICn = 0) and this is used to verify the proper compensation.

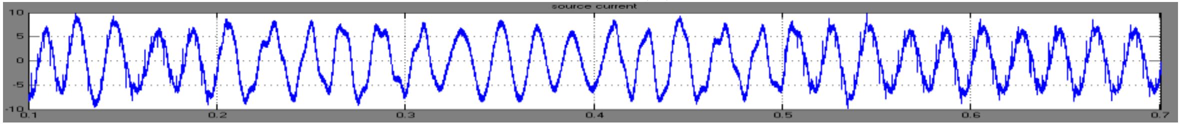
The Reactive power (Q) is compensated for power factor correction with help of DSTATCOM. From the waveform we can measure the reactive power (Q = 0) value is equal to zero. Here power factor value nearly one (cosΦ = 1). Here the power factor value was improved from 0.5119 to 0.8040.



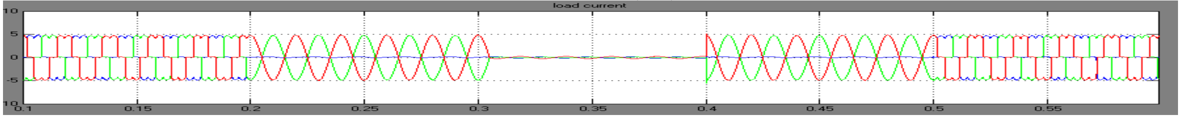
Source Voltage (Vs)



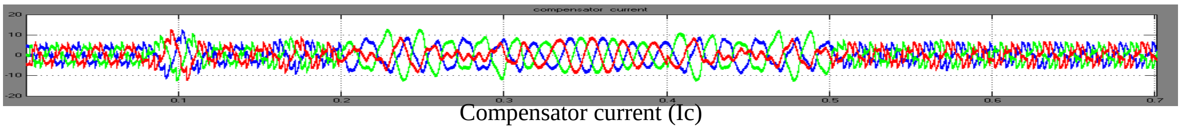
Source Current (Is)



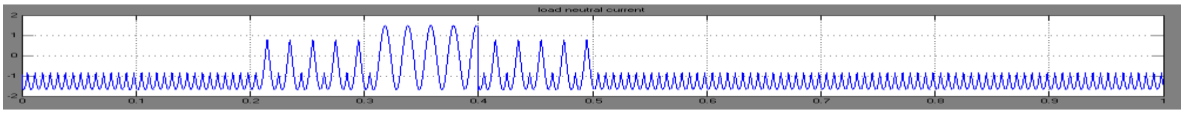
Source current (ISa)



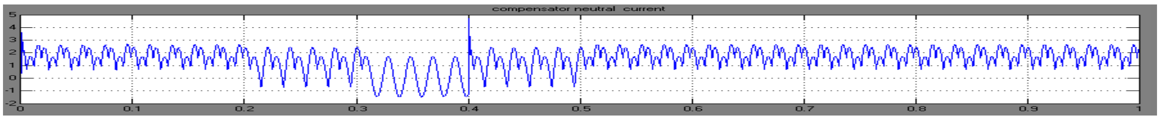
Load current (IL)



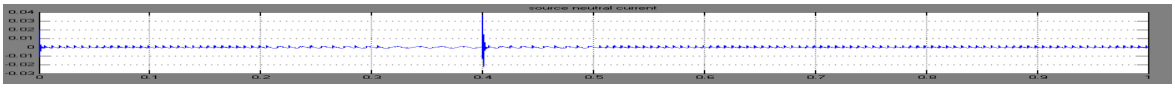
Compensator current (Ic)



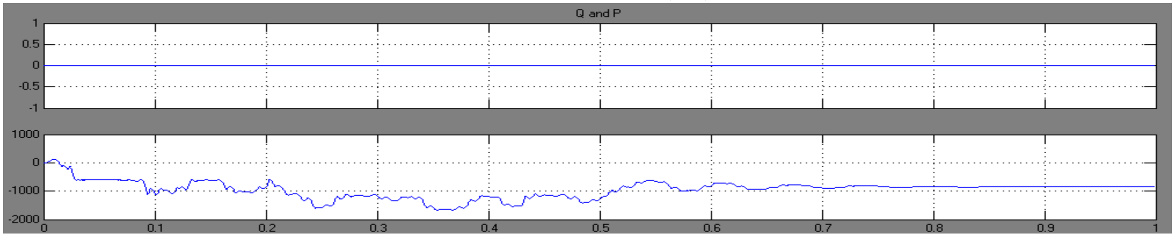
Load neutral Current (ILn)



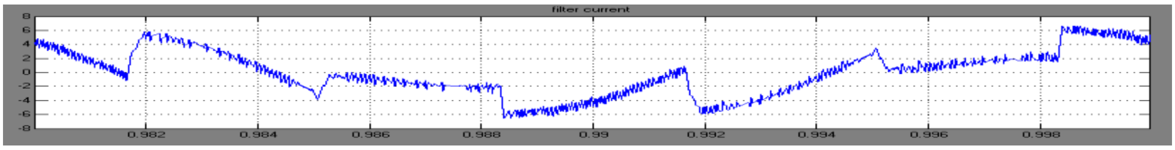
Compensator neutral Current (ICn)



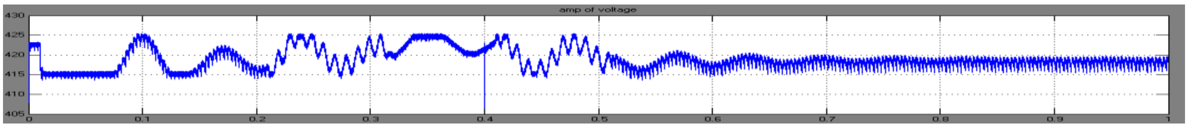
Source neutral Current (ISn)



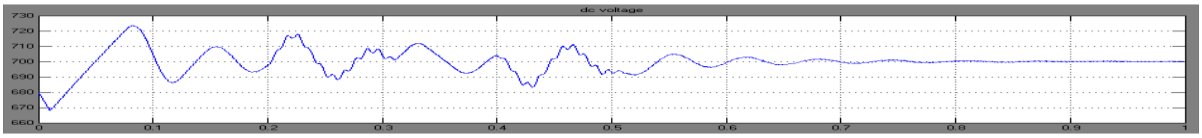
Reactive power (Q) and Active power (P)



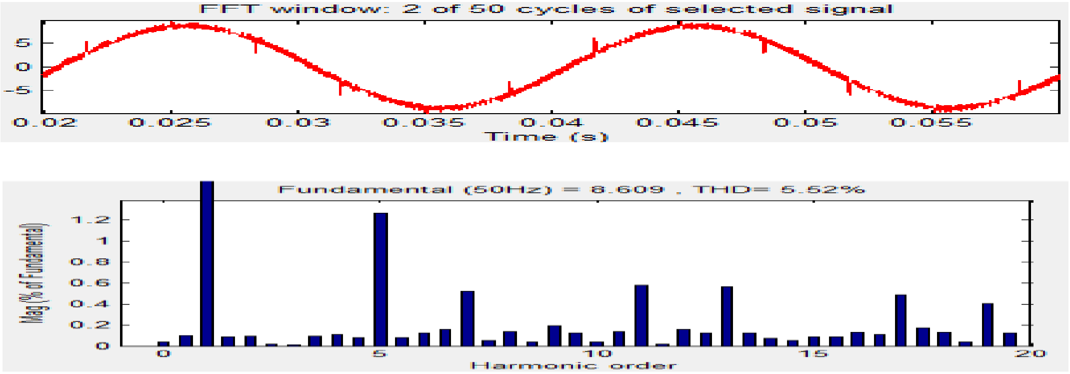
Filter current (If)



Amplitude of PCC Voltage (VAmp)



DC bus voltage (VDC)



Source current and Harmonic Spectrum

Fig.7.2. Performance of three phases four wire DSTATCOM for Nonlinear load with controller circuits

7.3. Comparison with other techniques

A three-leg single-phase-VSC-based DSTATCOM [5] requires a total of 12 semiconductor devices, and hence, is not attractive, and the three-leg VSC with split capacitors [5] has the disadvantage of difficulty in maintaining equal dc voltage at two series-connected capacitors. The four-leg-VSC-based DSTATCOM [3] is considered as superior considering the number of switches, complexity, cost, etc. A three-leg VSC with T connected transformer [10] is reported recently and has shown improved performance. The three-leg VSC with T-connected transformer has the advantage of using a passive device for neutral current compensation, reduced number of switches, use of readily available three-leg VSC, etc. The proposed three-phase four-wire DSTATCOM is based on a three-leg VSC and a T-connected transformer. The T connected transformer requires two single-phase transformers. A star/delta transformer is also reported [19] for neutral current compensation and the kVA rating required is higher compared to T-connected transformer. Table I shows the rating comparison of the two transformer techniques for a given neutral current of 10 A. It is observed that the kVA rating of the T-connected transformer is much less compared to a star/delta transformer. Similarly, comparison with the four-leg converter shows that the numbers of switches are reduced in the proposed configuration, thus reducing the complexity and cost of the system.

Transformer	Winding voltage (V)	Winding current(A)	KVA	Number of Transformer	Total KVA
Star/Delta	240/240	10	2.4	3 Nos	7.2
T-Connected	240/120/120 208/208	10	2.4 2.08	1 Nos 1 Nos	4.48

Table.7.1. Comparison with other technique.

VIII. CONCLUSION

A new three phase four wire DSTATCOM using T-connected transformer has been proposed for Three-Phase Four-wire DSTATCOM system to improve the power quality. The performance of distribution system has been demonstrated for neutral current compensation along with reactive power compensation, harmonic reduction and load balancing for non-linear load.The performance of three-phase four-wire distribution system with and without controller circuits for Non-linear load was discussed in the above section and following observation is obtained.From the performance of the distribution system without controller source current of each phase is reduced to zero during the fault period (I_{SA}=0:I_{SB}=0;I_{SC}=6A from 0.2sec to 0.5sec as shown fig.7.1). This is compensated by using the DSTATCOM circuits and also the load current of the each phase is compensated as shown fig.7.2. The THD of the system without controller is 37.85% this is reduced to 5.57% with help of DSTATCOM. The reactive power Q was compensated and the power factor was improved from 0.5119 to 0.8040 by using DSTATCOM. The VDC was regulated to reference value (700V) under all load disturbances. The voltage regulation and power factor correction mode of operation of the DSTATCOM has been observed as the expected ones.Two single phase transformers are used for the T-configuration of the transformer to interface with a three-phase four-wire system. The total kilovolt amperes rating of the T-connected transformer is lower than a star/delta transformer for a given neutral current compensation. From the above discussion, the proposed technique **"A MODERN APPROACH OF THREE-PHASE FOUR-WIRE DSTATCOM FOR POWER QUALITY IMPROVEMENT USING T-CONNECTED TRANSFORMER"** is very efficient one for power quality improvement of Three-phase Four-wire distribution system compared to other techniques(Using star-delta and star-hexagon transformer).

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: 700 V
DC bus capacitance of DSTATCOM: 3000 μF
AC inductor: 2.5 mH
DC voltage PI controller: Kpd = 0.19, Kid = 6.25
PCC voltage PI controller: Kpq = 0.9, Kiq = 7.5
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. IEEE Recommended Practices and Requirements for Harmonics Control in a Electric Power Systems, IEEE Std. 519, 1992.
2. A.Ghosh and G. Ledwich, Power Quality Enhancement using Custom Power devices, Kluwer Academic Publishers, London, 2002.
3. Bhim Singh, Jayaprakash Pychadathil, and Dwarkadas Pralhaddas Kothari "Three-Leg VSC and a Transformer Based Three-Phase Four-Wire Dstatcom for Distribution Systems" Fifteenth National Power Systems Conference (NPSC), IIT Bombay, December 2008.

4. Bhim Singh, Jayaprakash Pychadathil, and Dwarkadas Pralhaddas Kothari."Star/Hexagon Transformer Based Three-Phase Four-Wire DSTATCOM for Power Quality Improvement" International Journal of Emerging Electric Power Systems Volume 9, Issue 6 2008 Article 1

5. H. Akagi, E H Watanabe and M Aredes, Instantaneous power theory and applications to power conditioning, John Wiley & Sons, New Jersey, USA, 2007.

6. B. A. Cogbill and J. A. Hetrick, "Analysis of T–T connections of two single phase transformers," IEEE Trans. Power App. Syst., vol. PAS-87, no. 2, pp. 388–394, Feb. 1968.

7. B. Singh, V. Garg, and G. Bhuvaneswari, "A novel T-connected auto transformer based 18-pulse AC–DC converter for harmonic mitigation in adjustable-speed induction-motor drives," IEEE Trans. Ind. Electron., vol54, no. 5, pp. 2500–2511, Oct. 2007.

8. IEEE Guide for Applications of Transformer Connections in Three-Phase Distribution Systems, IEEE C57.105-1978 (R2008).

9. H.-L. Jou, J.-C. Wu, K.-D. Wu, W.-J. Chiang, and Y.-H. Chen, "Analysis of zig-zag transformer applying in the three-phase four-wire distribution power system," IEEE Trans. Power Del., vol. 20, no. 2, pp. 1168–1173, Apr. 2005.

10. H.-L. Jou, K.-D.Wu, J.-C.Wu, andW.-J.Chiang, "A three-phase four-wire power filter comprising a three-phase three-wire active filter and a zig-zag transformer," IEEE Trans. Power Electron., vol. 23, no. 1, pp. 252–259, Jan. 2008.

11. H. L. Jou, K. D. Wu, J. C. Wu, C. H. Li, and M. S. Huang, "Novel powerconverter topology for three-phase four-wire hybrid power filter," IET Power Electron., vol. 1, no. 1, pp. 164–173, 2008.

12. H. Fugita and H. Akagi, "Voltage-regulation performance of a shunt active filter intended for installation on a power distribution system," IEEE Trans. Power Electron., vol. 22, no. 1, pp. 1046–1053, May 2007.

13. M. I. Milan´es, E. R. Cadaval, and F. B. Gonz´alez, "Comparison of control strategies for shunt active power filters in three-phase four-wire systems," IEEE Trans. Power Electron., vol. 22, no. 1, pp. 229–236, Jan. 2007.

14. M. C. Benhabib and S. Saadate, "New control approach for four-wire active power filter based on the use of synchronous reference frame," Electr. Power Syst. Res., vol. 73, no. 3, pp. 353–362, Mar. 2005.

15. "A TEXT BOOK OF ELECTRICAL TECHNOLOGY" B.L.Theraja, A.K.Theraja. Volume III. First multicolor edition, 2005. S.Chand and company Ltd.,

16. "THYRISTOR-BASED FACTS CONTROLLERS FOR ELECTRICAL TRANSMISSION SYSTEMS" R. Mohan Mathur ,Rajiv K. Varma, "a john wiley & sons, inc. Publication"2002.

17. B.N.Singh, P.Rastgoufard, B.Singh, A.Chandra and K.Al.Haddad, "Design, simulation and implementation of three pole/ four pole topologies for active filters," IEE Eletr. Power Appl., vol. 151, no. 4, pp. 467-476, July 2004.

18. S. Bhattacharya and D. Diwan, "Synchronous frame based controller implementation for a hybrid series active filter system," in Proc. IEEE Ind. Appl. Soc. Meeting 1995, pp. 2531–2540.

19. P. Enjeti,W. Shireen, P. Packebush, and I. Pitel, "Analysis and design of a
New active power filter to cancel neutral current harmonics in three-phase
Four-wire electric distribution systems," IEEE Trans. Ind. Appl., vol. 30,
no.6, pp. 1565–1572, Nov./Dec. 1994.

20. Wei-Neng Chang and Kuan-Dih Yeh" Design And Implementation Of Dstatcom For Fast Load Compensation Of Unbalanced Loas" *Journal of Marine Science and Technology, Vol. 17, No. 4, pp. 257-263 (2009)* 257

21. Mahesh K. Mishra, Arindam Ghosh, Avinash Joshi, and Hiralal M.Suryawanshi," A Novel Method of Load Compensation Under Unbalanced and Distorted Voltages" IEEE transactions on power delivery, vol. 22, no. 1, january 2007.

22. Fabiana Pottker and Ivo Barbi "Power Factor Correction of Non-Linear Loads Employing a Single Phase Active Power Filter: Control Strategy, Design Methodology and Experimentation" IEEE Transaction.

23. Hendri Masdi, Norman Mariun, S.M.Bashi, A. Mohamed, Sallehhudin Yusuf "DESIGN OF A PROTOTYPE D-STATCOM FOR VOLTAGE SAG" IEEE Transaction on Power delivery.

24. Pierre Giroux, Gilbert Sybille and Hoang Le-Hye "modeling and Simulation of a DSTATCOM using Simulinh's power System Blockset" The 27th annual conference on The IEEE Electronics Society.

25. H. Nasiraghdam, and A. Jalilian "Balanced and Unbalanced Voltage Sag Mitigation Using DSTATCOM with Linear and Nonlinear Loads" World Academy of Science, Engineering and Technology 28 2007.

26. Oscar Armando Maldonado Astorga, José Luz Silveira, Julio Carlos Damato "The Influence of Harmonics from Non-Linear Loads In The Measuring Transformers Of Electrical Substations" Laboratory of High Voltage and Electric Power Quality.

27. Arindam Dutta, Tirtharaj Sen, S. Sengupta "Reduction in Total Harmonic Distortion in a Non-Linear Load with Harmonic Injection Method" International Journal of Recent Trends in Engineering, Vol 1, No. 4, May 2009.

28. www.feg.unesp.br/gose

29. www.ieee.org

30. The Berkely Electronic Press

31. www.google.com