ISSN XXXX XXXX © 2017 IJESC

Research Article Volume 7 Issue No.10

Power Quality Issues Mitigated By Using D-STATCOM

Shivangi Gupta[1], Manjaree Pandit[2], Deepika Masand[3]
ME Scholar[1], Dean Academics & Professor[2], Associate Professor[3]
Madhav Institute of Technology & Science, Gwalior, India[1, 2]
Vellore Institute of Technology, Bhopal, India[3]

Abstract:
Today's world faces several quality issues in electrical power system like voltage distortion, excessive neutral current due to harmonics, load unbalancing. In this paper, a hybrid DSTATCOM with T connected transformer and a single phase APF is used to remove harmonics and to compensate the current in neutral. SRF based control algorithm used to control the D-STATCOM. The complete model is designed using MATLAB Simulink environment and the results shown further.

Keywords: SVC, D-Statcom, T-connected Transformer, (APF) Active Power Filter and Neutral Current Compensation, Simulink, Matlab.

I. INTRODUCTION

Earliar days in power transmission due to the reactive power, unbalance load, the problems like voltage deviation during load changes and power transfer limitation were observed. Most of AC load consume reactive power because of presence of reactance. Power quality getting poor due to heavy consumption of reactive power. Development of fast and reliable semiconductors devices like GTO and IGBT allowed new power electronic configurations to be introduced to the tasks of power Transmission and load flow control. Over the transmission parameters, the FACTS devices offer a fast and reliable control. Most widely known custom power devices are SVC, STATCOM, IPC, DVR, UPFC, TCSC, TCPST and DSTATCOM. Among them DSTATCOM is very well known and can provide cost effective solution for the compensation of reactive power and unbalance loading in distribution system. DSTATCOM is capable to inject a current into the system to correct the power factor and reactive power compensation and harmonics reduction. In this paper the test model of DSTATCOM is showed in simulation to observe how DSTATCOM works. The DSTATCOM applications are mainly for sensitive loads that may be drastically affected by fluctuations in the system voltage.

II. CONFIGURATION OF HYBRID SYSTEM

Fig. 1. Shows a 3 phase 4 wire distribution system is connected to a non-linear load, a T-connected transformer along with 3 phase 3 wire D-STATCOM is connected in shunt with the non-linear load and a single phase active power filter is connected between the neutral of T-connected transformer and the neutral conductor of load. The inverter of the single-phase APF is energized from a separate single phase transformer through a diode bridge rectifier of a very low VA rating. However, with uncompromising voltage unbalance/distortions, voltage across the single phase APF increases to a large value. Therefore, under these conditions single phase APF is protected by switch (S). Where the switch is realized by protective devise (MOVs) Metal Oxide Varistors and it operates under sustained unbalanced/distorted utility voltage conditions or fault condition. The T-connected transformer is realized by using 2 single phase two winding transformers as shown in Fig. 2.

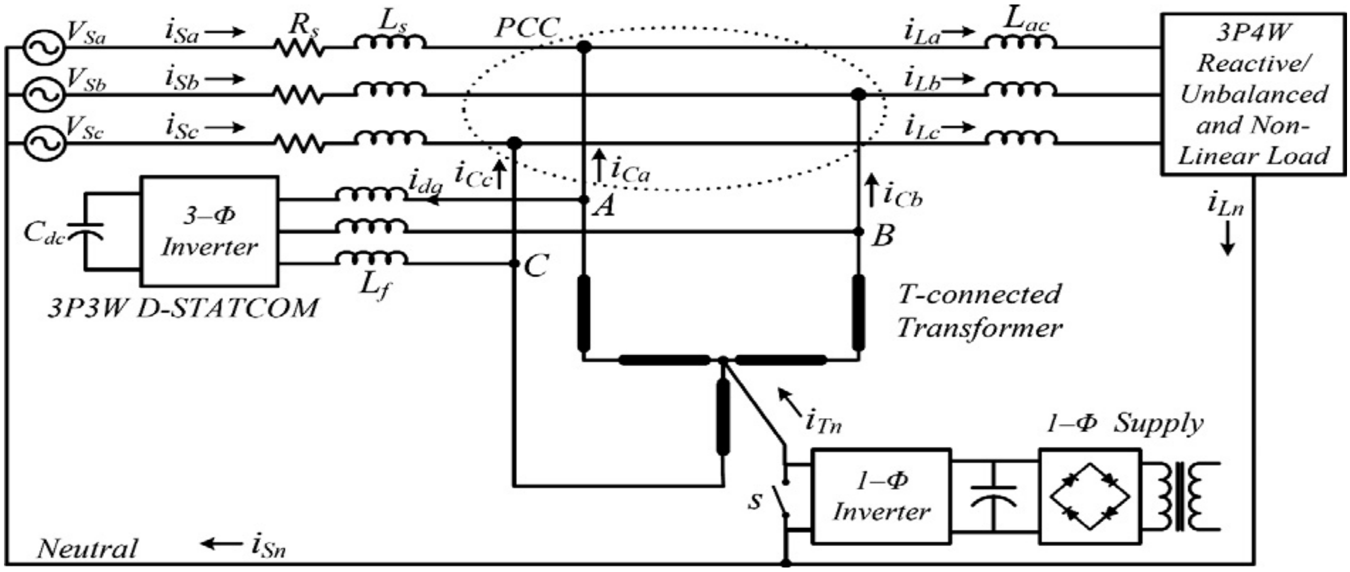

FIGURE 1
A 3P3W HYBRID D-STATCOM FOR 3P4W DISTRIBUTION SYSTEM USING T-CONNECTED AND 1-Φ ACTIVE POWER FILTER

CONFIGURATION OF D-STATCOM

The power electronic based three phase reactive power compensation equipment is the D-STATCOM, which generates and /or absorbs the reactive power whose output can be varied so as to maintain control of specific parameters of the electric power system. The D-STATCOM basically consists of a coupling transformer with a leakage reactance, a three phase GTO/IGBT voltage source inverter (VSI), and a DC capacitor. A Voltage Source Converter (VSC) is a power electronic device; this voltage source converter can generate a sinusoidal voltage with any required phase angle, frequency and also for magnitude. Voltage source converters are most widely used in variable-speed drives and also be used to decrease the voltage drops. For completely replace the voltage, the VSC is used to inject the 'missing voltage'. The 'missing voltage' is the difference between the transient wave and the actual sine wave.

CONFIGURATION OF T-CONNECTED TRANSFORMER

T-connected transformer is realized by using 2 single phase transformer: consequently, the cores are economical to build and also easy to assemble. And therefore the transformer is small is the floor space, low height and weight with comparison to any other types of transformer available [10]. The realization is shown in Fig. 2.

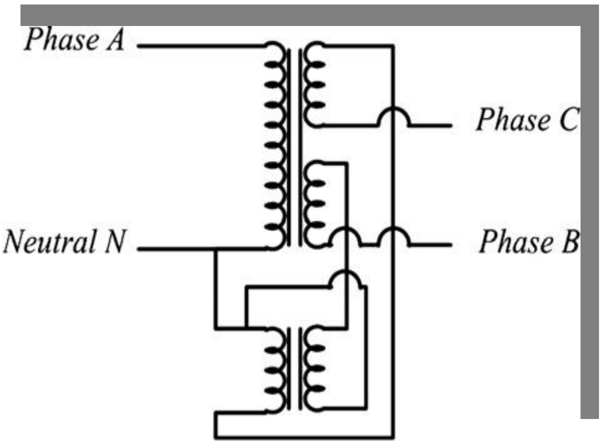

FIGURE 2
REALIZATION OF T-CONNECTED TRANSFORMER

III. OPERATION AND CONTROL STRATEGY OF HYBRID SYSTEM

When T-connected transformer only acts as compensator (S closed) then transformer provides low impedance path for zero sequence currents to flow between load and T-connected transformer. However, the effectiveness of compensation strongly depends on the location of the compensator, impedance offered by T-connected transformer and the system [7].

When (S open) single phase APF operates and produce the desired current for compensation of source neutral current and injects the same through neutral of T-connected transformer. This current split equally and flow through each T-connected winding of transformer. Such that APF circulate neutral current to the load via T-connected transformer. Therefore effectiveness does not depends on the zero sequence impedance of T-connected transformer and its location. Hence, special design for T-connected transformer for low zero sequence impedance is not requiring.

When the switch S is closed then the active power filter is bypassed and only T-connected transformer along with D-STATCOM acts as the compensating device the T-connected transformer make available the low impedance path for the zero sequence current to flow between T-connected transformer and the nonlinear load [6]. T-connected transformer and D-STATCOM takes care of the compensation of sequence currents while the compensation characteristics depends on their locations, impedances of the transformers and utility voltage conditions [7]. The capacitor connected on the DC side of VSC is charged by the real power taken from distribution system.

When switch S in open then the active power filter is connected into the circuit and the single phase active power filter is supplied by the separate single phase source. The APF takes care of the harmonics in the system and reduces the neutral current to very less value which results improving power factor.

Control Strategy of D-STATCOM

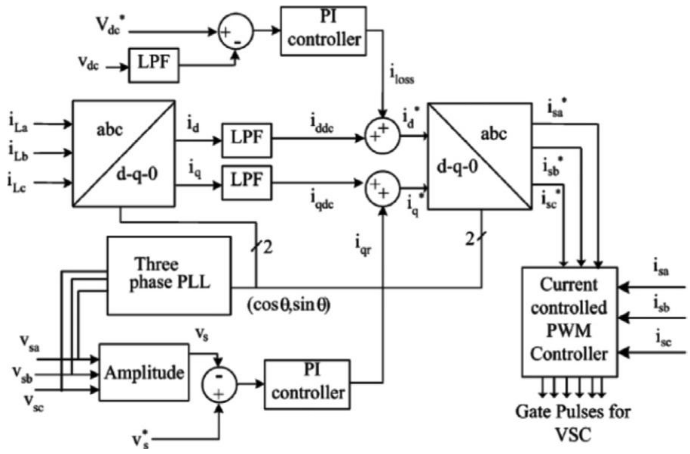

FIGURE 3
CONTROL STRATEGY OF D-STATCOM

The various issues are present in the control of Distribution Static Compensator are as follows:

1. Measurement of voltage and current signals
2. Control of dc link terminal voltage
3. Generation of switching signal commands for semiconductor switches.
4. Extraction of reference compensator currents

The proposed work is based on Synchronous Reference Frame Theory (SRF THEORY). A block diagram of the control scheme equipped with the function of voltage regulation is shown in Fig. 9.2. We use two proportional integral (PI) controller for controlling dc bus voltage of DSTATCOM and ac voltage at PCC. The compensation current should lead or lag by 90^o form the voltage. The compensating current produces a voltage drop and then, the line-voltage amplitude is kept at its reference value. In the case, when the load is an inductive, the DSTATCOM operates as a capacitor. Along with reactive current control, the control of DSTATCOM consists of the following control functions: harmonic elimination, load balancing and neutral current compensation.

Above figure shows the control algorithm of DSTATCOM with two PI controllers. The controller's functions were discussed above. The in-phase component of current is responsible for power factor correction of load whereas to regulate AC system voltage at PCC, quadrature component of SRF based DSTATCOM is responsible. The output of PI controller over the DC bus voltage (I_{spdr}) is measured as quadrature component of supply reference currents. The instantaneous reference currents (i_{sar}, i_{sbr} and i_{scr}) are obtained with adding the in-phase supply reference currents (i_{sadr}, i_{sbdr} and i_{scdr}) and quadrature supply reference currents (i_{saqr}, i_{sbqr} and i_{scqr}). When reference supply currents generated in the circuit, a hysteresis current controller controls the sensed supply currents (i_{sa}, i_{sb} and i_{sc}) and instantaneous reference currents (i_{sar}, i_{sbr} and i_{scr}) for generating gating pulses for ICBT'S of DSTATCOM. The function of controller is to control the DSTATCOM currents within a band around the desired reference currents values. The hysteresis controller generates suitable switching pulses for six IGBT'S of the VSI working as DSTATCOM.

Control Strategy of Single Phase APF

The block diagram of the closed-loop control system for single-phase APF is shows in Fig. 4. The current reference for the single-phase APF is derived by summing up the load currents flowing in each phase.

The current reference generated is compared with the actual T-connected transformer neutral current (I_{Tn}) and the difference of these two quantities is passed through a PI controller. The output of the PI controller is compared with the triangular carrier wave to obtain the required gate patterns for the single-phase inverter.

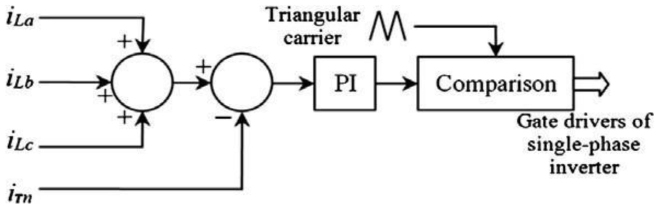

FIGURE 4:
CONTROL SCHEME FOR SINGLE-PHASE APF.

IV. Simulation Result and Discussion

The Simulink study of the entire system has been carried out in MATLAB/Simulink environment and the Simulink model of the entire system is shown in Fig. 5. Control blocks for the 3P3W D-STATCOM and APFs are also modeled in MATLAB/Simulink power system blocksets. The parameters used in the simulation are shown in Table 1.

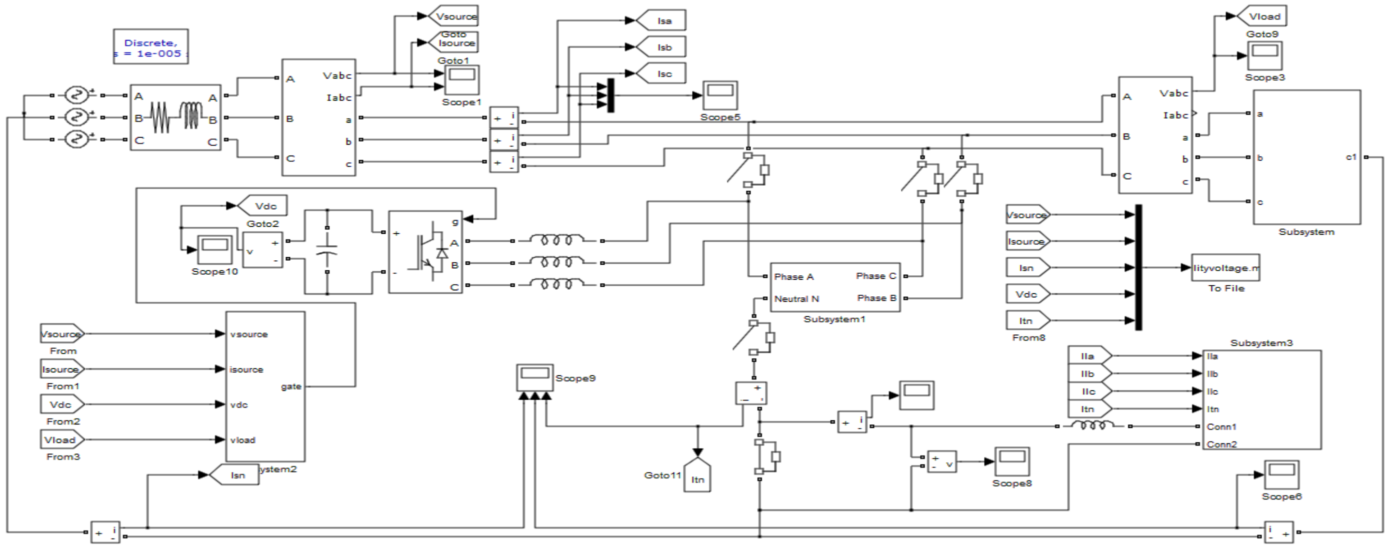

FIGURE 5: SIMULINK MODEL OF COMPLETE SYSTEM

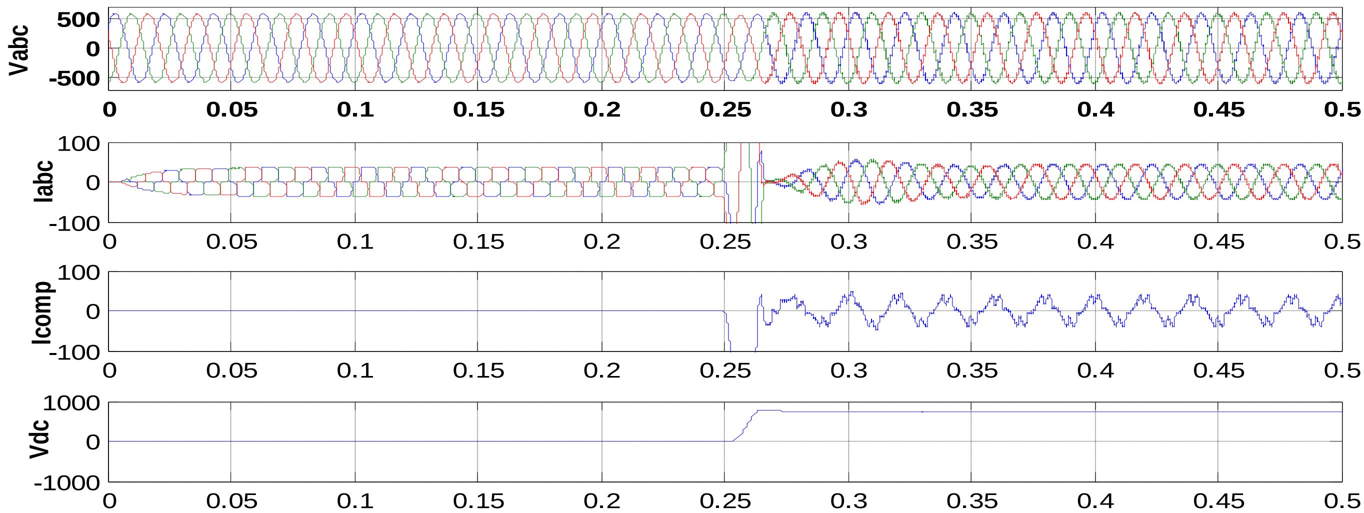

FIGURE 6: PERFORMANCE OF HYBRID SYSTEM UNDER BALANCED LOAD CONDITION

Performance Under balanced Load Condition

When the load is balanced then there is no current in neutral only the harmonics are present in system due to non-linear load which are reduced by DSTATCOM. At time t = 0.25 the DSTATCOM is turned on and THD reduces to 3.24%.

Performance Under Unbalanced Utility Voltage Condition

When 3 phase unbalanced non-linear load is connected across the 3 phase source and the unbalancing is provided in the utility voltage by changing the phase difference by 0º, -110º and 120º. The outcomes are shown in the Fig. 6. Trace 1: three phase source voltage, trace 2: three phase source current, trace

3: source neutral current, trace 4: DC side voltage, and trace 5: T-connected transformer neutral current. At time 0.25 sec D-STATCOM is turned on which improves the current but phase difference is still disturbed, then at time 0.5 sec APF is also turned on which reduces the harmonics in the system and neutral current is also reduced to a great extent that can be shown in figure.

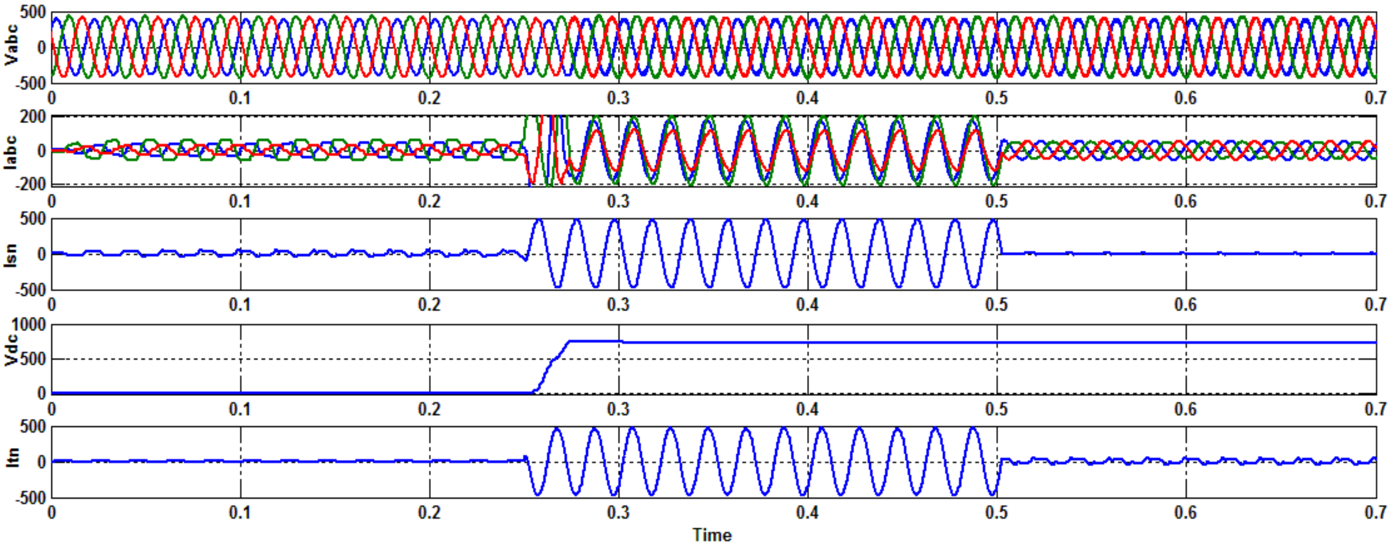

FIGURE 7: PERFORMANCE OF HYBRID SYSTEM UNDER UNBALANCED UTILITY VOLTAGE CONDITION

The total harmonic distortion (THD) at 0.1 sec is 17.82%. when D-STATCOM is turned on THD reduces to 2.69% but phase difference is still unbalanced, then APF is turned on at 0.5 sec and the THD is reduces up to 4.46% with balanced condition and neutral current also reduces to a great extent.

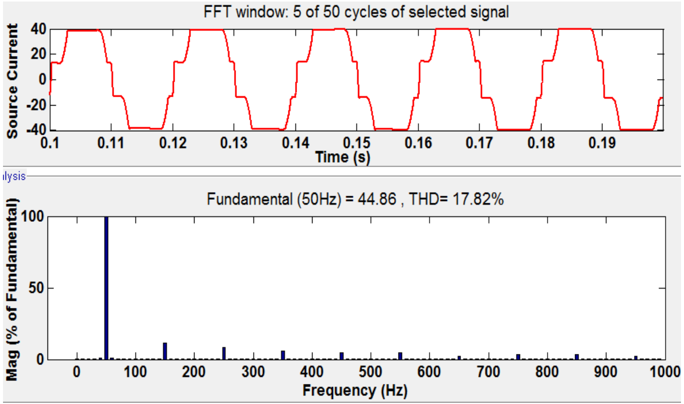

FIGURE 8

THD OF SOURCE CURRENT WHEN NO COMPENSATION IS PROVIDED

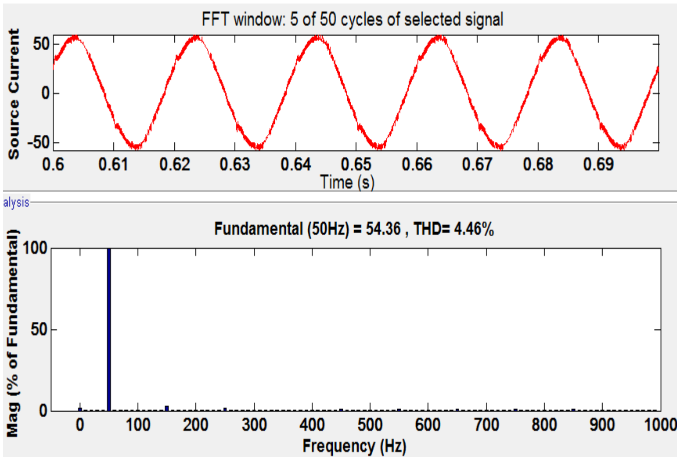

FIGURE 9

THD OF SOURCE CURRENT WHEN T-CONNECTED TRANSFORMER AND D-STATCOM ACTS AS COMPENSATING DEVICE WITHOUT APF

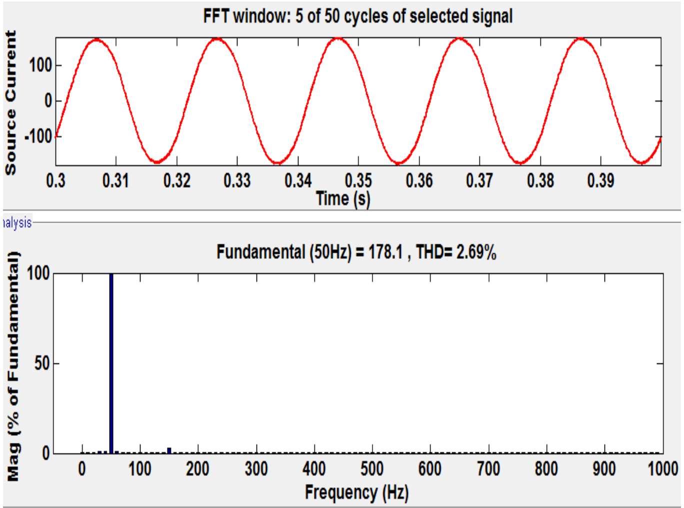

FIGURE 10

THD OF SOURCE CURRENT WHEN T-CONNECTED TRANSFORMER AND D-STATCOM ACTS AS COMPENSATING DEVICE WITH APF.

V. CONCLUSION

From the above results it can be observed that when no any compensation device is connected to the distribution system harmonics are present in the system and also the source neutral current of 60 Amps is present. As the D-STATCOM along with T-connected transformer acts as the compensating device harmonics reduces but source neutral current is not reduces. Therefore to reduce source neutral current and to further reduce the THD, Active Power Filter is connected to circuit which further reduces the source neutral current to great extent and THD becomes 4.64%. which is within the acceptable limit of THD given by IEEE.

TABLE 1. PARAMETERS USED IN THE SIMULATION.

Parameter	Value
AC line voltage	Three-phase, four-wire, 415 V, 50 Hz
Line impedance	R_s = 0.01 X, L_s = 1 mH
DC bus voltage of D-STATCOM	700 V
DC bus capacitance of D-STATCOM	2200 µF
D-STATCOM coupling inductor	L_{ac} = 3 mH
Single-phase APF output inductor	L_f = 0.1 mH
PWM switching frequency for 3P3W and single-phase inverter	10 kHz
T-connected transformer	1-ϕ, 20 kV A, 240/120/120 V; 1-ϕ, 20 kV A, 208/208 [15]
Load	3-ϕ controlled rectifier, R_{dc} = 20 Ω, L_{dc} = 200 mH, firing angle = 15º, commutation inductance = 2 mH. Single-phase uncontrolled rectifier connected between the a – phase and the neutral, R_{dc} = 15 Ω, L_{dc} = 500 mH, commutation inductance = 2 mH. Single-phase controlled rectifier connected between the b – phase and the neutral, R_{dc} = 5 Ω, L_{dc} = 50 mH, firing angle = 15º, commutation inductance = 3 mH.

REFERENCES

[1] D. Sreenivasarao, Pramod Agarwal, Bisarup Das "A T-connected transformer based hybrid D-STATCOM for three-phase, four-wire systems". Elsevier, International Journal of Electrical power and Energy System, Vol.44, No.1, PP 964-970, 2013.

[2] K Hussain, J Praveen "Power Quality Enhancement Using VSC Based DSTATCOM". International Journal of Engineering and Technology (IJET), Vol.2, No.1, jan 2012.

[3] P Jayaprakash, Bhim Singh, D P Kothari "Reduction in Rating of Voltage Source Converter of DSTATCOM using a Zig-Zag Transformer". IEEE International Symposium on Industrial Electrinics, PP 1066-1071, 2012

[4] Bhim Singh, P Jayaprakash, T. R. Somayajulu and D. P. Kothari "Reduced rating VSC with Zig-Zag transformer for current compensation in a three-phase four-wire distribution system". IEEE Transaction on Power Delivery, Vol.24, No.1, PP 249-259, jan 2009.

[5] Bhim Singh, P Jayaprakash, T. R. Somayajulu, D. P. Kothari, Ambrish Chandra and Kamal-Al-Haddad "Integrated three-leg VSC with a Zig-Zag transformer based three-phase four-wire DSTATCOM for power quality improvement". IEEE Conference on Industrial Electronics, PP 796-801, 2008

[6] Gaurav Kumar Kasal, Bhim Singh "Zig-Zag transformer based voltage controller for an isolated Asynchronous generator". IEEE Conference on TENCON, PP 1-6, 2010

[7] Bhim Singh, Jitendra Solanki "A comparison of control algorithms for DSTATCOM". IEEE Transaction on Industrial Electronics, Vol.56, No.7, PP 2738-2745, July 2009.

[8] Bhim Singh, Sabha Raj Arya "Adaptive Theory-Based Improved Linear Sinusoidal Tracer Control Algorithm for DSTATCOM". IEEE Transaction on Power Electronics, Vol.28, No.8, PP 3768-3778, Aug 2013.

[9] Sabha Raj Arya, Bhim Singh "Performance of DSTATCOM Using Leaky LMS Control Algorithm". IEEE Journal of Emerging and Selected Topics in Power Electronics, Vol.1, No.2, PP 104-113, June 2013.

[10] Chandan Kumar, Mahesh K. Mishra "A Voltage-Controlled DSTATCOM for Power-Quality Improvement" IEEE, Transaction on Power Delivery, Vol.29, No.3, PP 1499-1507 June 2014.

[11] Chandan kumar, Mahesh K. Mishra "An Improved Hybrid DSTATCOM Topology to Compensate Reactive and Nonlinear Loads". IEEE Transaction on Industrial Electronics, Vol.61, No.12, PP 6517-6527 Dec 2014.

[12] Hingorani, Narain G., Laszlo Gyugyi, and Mohamed El-Hawary. Understanding FACTS: concepts and technology of flexible AC transmission systems. Vol. 1. New York: IEEE press, 2000.

[13] Barrios-Martínez, Esther, and Cesar Ángeles-Camacho. "Technical comparison of FACTS controllers in parallel connection." Journal of Applied Research and Technology15.1 (2017): 36-44.