International Journal Of Multidisciplinary Research In Science, Engineering and Technology (IJMRSET)

| ISSN: 2582-7219 | www.ijmrset.com |

| Volume 3, Issue 1, January 2020 |

Modified Voltage Controlled DSTATCOM with External Inductor for Power Quality Improvement

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ABSTRACT:This study proposes a three-leg Voltage Source Inverter (VSI)-based distribution static compensator (DSTATCOM) topology to compensate unbalanced and non-linear loads in three-phase four-wire distribution systems. This project proposed the design, operation, and flexible control of a DSTATCOM operating in voltage control mode. This inductor helps of DSTATCOM to improve the load voltage to compute the value of external inductor to reduce the current rating of VSI and system losses. The main purpose of DSTATCOM is load balancing, power factor correction, and reactive power compensation. A proportional-integral (PI) controller is used to regulate the dc split-capacitor voltage at a reference value. The deadbeat predictive controller is used to generate firing pulses. Analysis and modelling of the proposed topology is explained in detail. Simulation studies are carried out to verify the performance of the proposed system and results are presented.

KEYWORDS:Distribution Static Compensator (DSTATCOM), Voltage Source Converter (VSC), Hysteresis Current Controller (HCC)

I. INTRODUCTION

Nowadays, reacting loads that consume lagging current and result in low power factor are the main source of energy consumption in distribution networks. Unbalanced loads are frequently found in distribution networks as well. The aforementioned factor increases the need for reactive power, increases feeder losses, and decreases the flow of active power in the distribution feeder system. Additionally, the use of nonlinear loads in distribution systems causes an increase in supply voltage distortion due to the nonlinear load current consumption. Therefore, poor power factor, unbalance, and harmonics are the Power Quality (PQ) issues that arise in the distribution system. Then, to address these PQ issues, passive filters, active filters, and hybrid filters were developed. In which case using passive filters alone is not very effective in reducing the PQ issues.

Modern active filters are power electronics-based converters that effectively solve PQ issues. The distribution system is connected to these active filters either in series, shunt, or both ways. These Shunt Active Filters (SAF) offer a better solution for PQ problems that are currently present. The custom power devices (DSTATCOM, DVR, and UPQC), which include DSTATCOM shunt connected devices, are also known as the power electronic converter based filters used in distribution systems. The topology of DSTATCOM and the control method used to generate reference current determine how well it can compensate for PQ issues.

The theories underlying the traditional control methods for DSTATCOM include instantaneous PQ, synchronous reference frame, and others. Deadbeat control method, SOGI best control method, direct power control strategy, and others are other control techniques. Back propagation control and conductance estimation-based algorithms are two additional recent neural network-based control techniques. The ease of implementation and automatic system parameter adjustment based on dynamics are two benefits of this adaptive filtering technique.

II. PROPOSED SYSTEM

The DSTATCOM topology's power circuit diagram is shown in Fig. 1 connected in a distribution system. Source inductance and resistance are denoted by Ls and Rs, respectively. Between the load and source points, an external inductance called Lext is connected in series. Even in the worst grid conditions, such as a resistive or stiff grid, this inductor aids DSTATCOM in achieving load voltage regulation capability. According to the IEEE-519 standard, the point of common coupling (PCC) should be the location where the utility and the customer can both access it for direct measurement [20]. Lext's connection to the source is therefore made at the PCC. At the junction where load and Lext are connected, the DSTATCOM is connected. The three-phase, four-wire VSI used by the DSTATCOM.To filter out high frequency switching components, an LC filter that is passively connected to each phase is used. Vdc1 and Vdc2 voltages across dc capacitors are kept at a reference level of Vdcref.

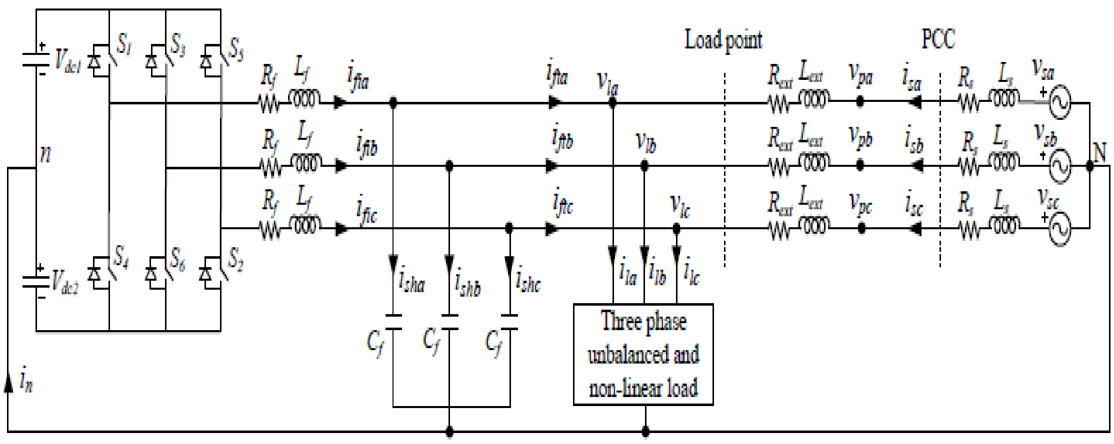

Fig. 1:Schematic diagram of distribution system with proposed DSTATCOM

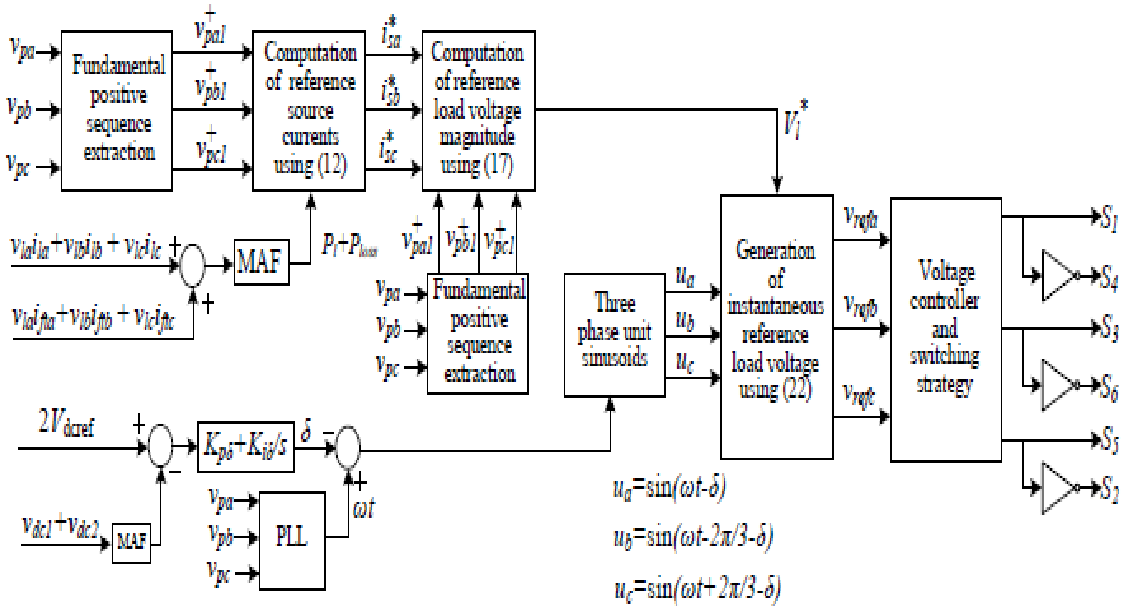

Fig. 2:Control scheme diagram of proposed system

III. DESIGN OF PROPOSED EXTERNAL INDUCTOR DSTATCOM

1.DC Capacitor Voltage

For effective PWM control of VSC of DSTATCOM, the PCC voltage is used to estimate the DC voltage (V_dc), and it must be more important than other aspects of the AC mains voltage. It is stated that the DC reference voltage is,

$$V_{dc} = 2\frac{\sqrt{2}}{\sqrt{3}}\frac{\sqrt{V_{ll}}}{\sqrt{m}} \qquad ---------- \quad (1)$$

Where Vll is the DSTATCOM's AC line output voltage and m-modulation index, which by default is set to 0.8.

2. DC Bus Capacitor

The voltage of the DC bus decreases as loads are added, and it increases as loads are removed. On the basis of the principle of energy conservation, the equation for Cdc is as follows.

$$½\, C_{dc}(V_{dc}^2 - V_{dc1}^2) = 3Vt(I * a) \quad - - - - - - - - (2)$$

where Vdc1 is the DC bus's minimum voltage level, 'a' is the overloading factor, V is the phase voltage, I is the phase current of the VSC, and t is the time it takes to restore the DC bus voltage.

3. AC Inductor

The switching frequency, fs, and ripple current, icr, are used to calculate the AC inductance. As shown below, the AC inductance is calculated.

$$L_f = \frac{\sqrt{3mV_{dc}}}{12} * a * f_s * i_{cr} \quad - - - - - - - (3)$$

where Lf is the AC inductance. The new ripple is estimated to be 1%. The load voltage is controlled by a DSTATCOM by adding fundamental reactive current. Vector diagrams are drawn in Fig. 2 to illustrate the DSTATCOM voltage regulation capability at various supply voltages for various Rs=Xs. To create diagrams, reference phasor Vl, with a nominal value of OA (1.0 p.u.), is used as the load voltage. A semicircle with a radius of Vl will be the locus of Vs in order to achieve Vl = Vs = 1.0 p.u. Inductive feeders have a maximum load angle of 90, so phasor Vs can be located anywhere inside curve. It is clear that for zero voltage regulation, the value of s must be greater than 90. Additionally, it can only occur when the load terminal's power factor is leading, as it cannot otherwise.

IV. SIMULATION RESULTS

Table 1 System parameters

Parameters	Values
Programmable AC source	3-phase , 220Vrms(ph-ph)
Source Impedence	Zs=0.12+j0.7 Ω
DC link capacitor	CDc=4300 μ F
Reference dc link voltage	VDc=650v
Filter inductor	Lf=3mHand 1.7mH in neutral
DC pi controller gains	Kpd=0.5 and Kid=0.033
AC PI controller gains	Kpa=0.089 and Kia=0.88

Figure 3 depicts the simulation model, which consists of a source, load, DSTATCOM, and control block. The linear load is a series combination of resistance and inductance for each phase, while the nonlinear load is a diode bridge rectifier. The source current becomes distorted and the harmonics in the load current increase when a non-linear load is connected. Using the controller, harmonics are reduced while good efficiency is maintained. The simulation's outcomes are displayed below.

| ISSN: 2582-7219 | www.ijmrset.com |

| Volume 3, Issue 1, January 2020 |

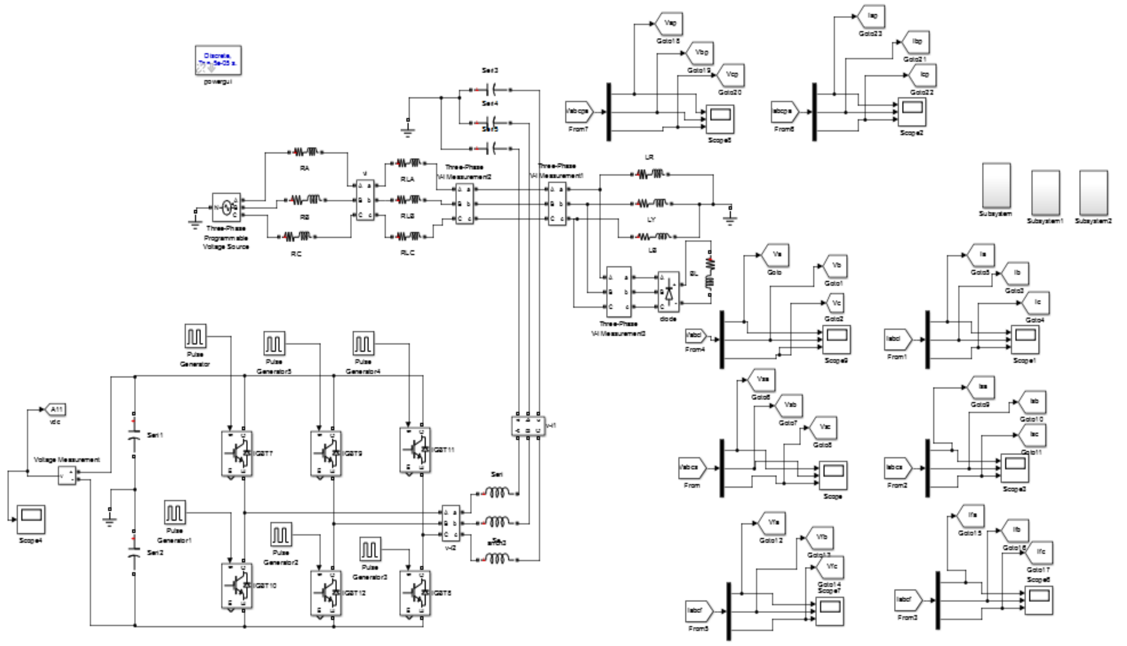

Figure 3Simulation diagram of proposed system

The reference filter current cannot be produced by the distorted PCC voltage, which is why the PCC voltages are displayed in positive order. The distorted PCC voltages are consequently converted into sinusoidal PCC voltages with equal magnitude and phase difference using transformation techniques.

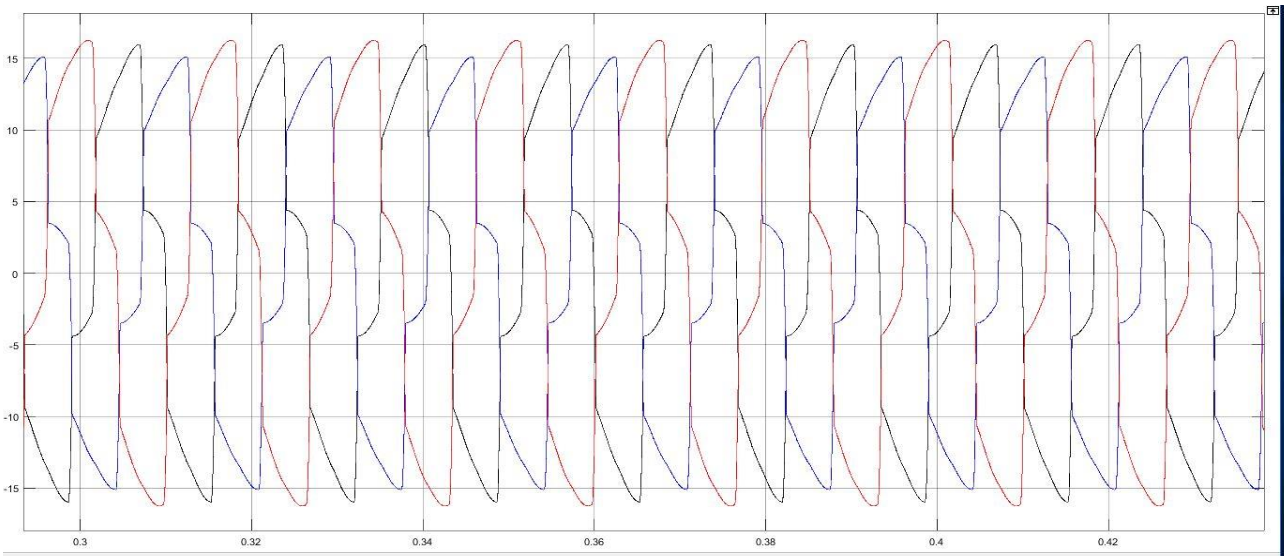

Figure 4Source current before compensation

After connecting a non-linear load, the source current in the previous Figure 4 is distorted. Here, it is almost rated valu for current value. Because of impedance changes, a non-linear load does not consume a sinusoidal current. Consequently, that source current will also be deformed.

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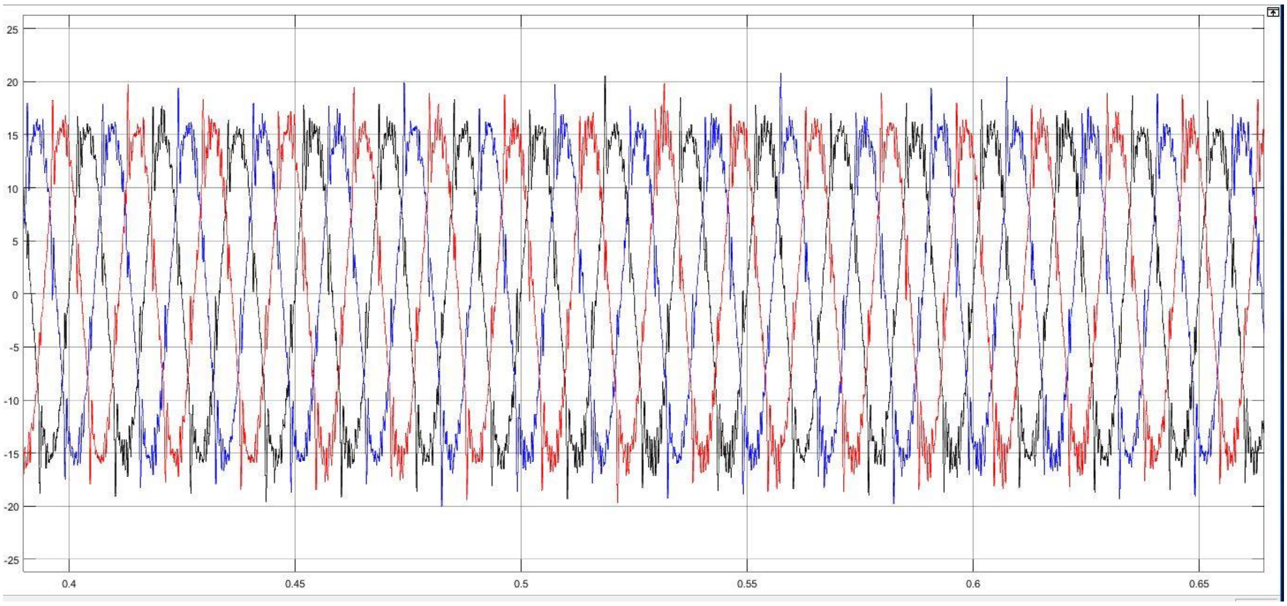

Figure 5 Three phase Source currents after compensation (Isa,Isb,Isc)

Figure 5 displays the three phase source currents (Isa, Isb, and Isc) after DSTATCOM's compensation. An External inductor is used to introduce the compensator source current into the line and make the source currents balanced sinusoidal ones. After compensation, the source current has an appropriate phase offset and equal magnitude.

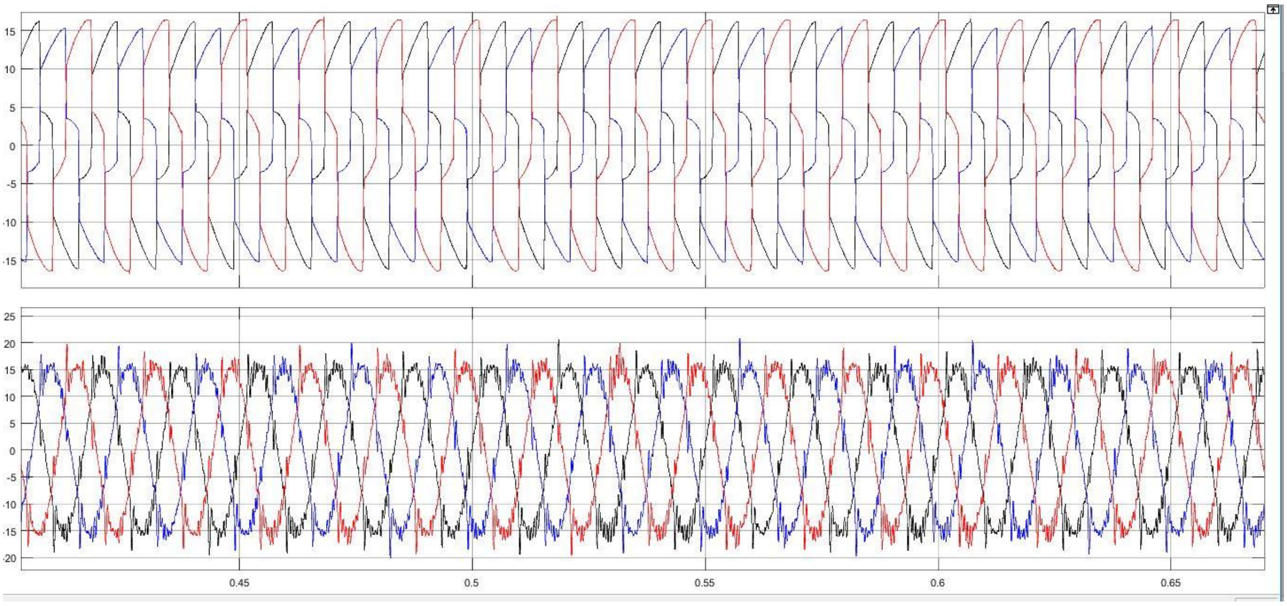

Figure 6 Three phase load currentsand source currents

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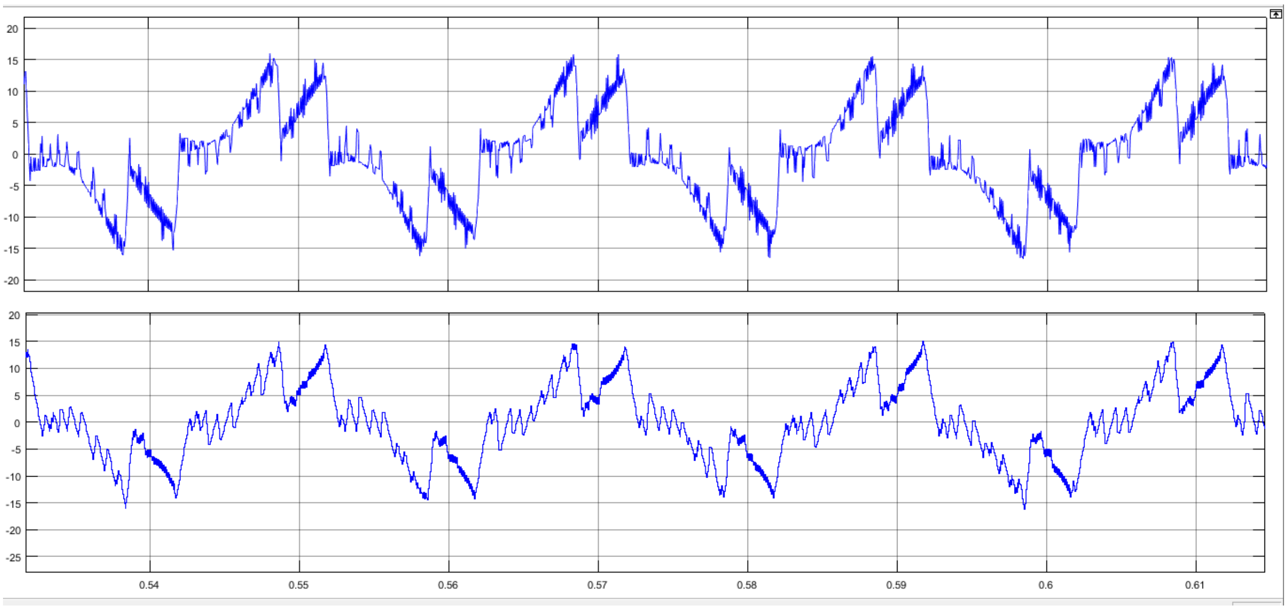

Figure 7Dead beat voltage control

Figure 7 shows the effectiveness of dead beat control scheme in creating reference source current to compensate the load at PCC and make the source current to be Sinusoidal and linear

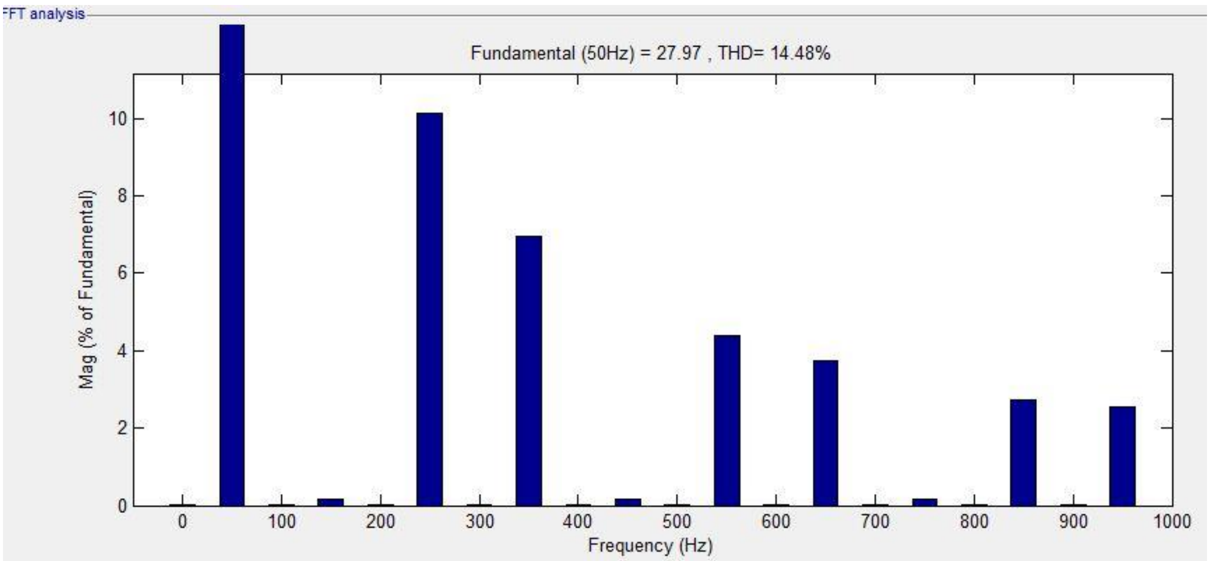

Figure 8 THD for source current before compensation

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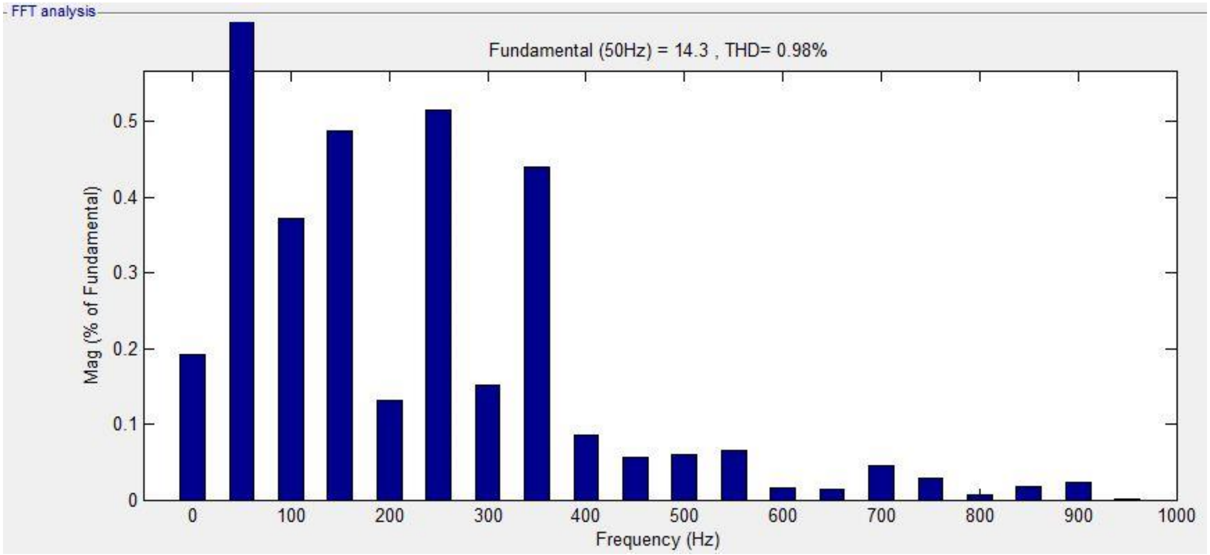

Figure 9THD for source current before compensation

Figure 8 and 9 shows the effectiveness ofproposed system in alleviating power quality issues and compensating loads, load balancing done by the proposed controller.

V. CONCLUSION

The performance of three-leg VSI-based DSATCOM topology to compensate unbalanced and non-linear loads in three-phase four-wire distribution systems are demonstrated by simulation results. The capability of the proposed scheme with associated control algorithms to share unbalanced, harmonics and reactive powers between VSIs and to control the voltage, source current are verified. Since, the DSTATCOM is used for compensation it reduces the current rating of VSI and system losses. The proposed scheme is able to achieve comparable compensation performance of leaving DSTATCOM. Moreover, it avoids voltage unbalancing issues associated with split capacitor VSI-based DSTATCOM topology.

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