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Frequency Adaptive Disturbance Observer basedDSTATCOMfor PQ Alleviation

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ABSTRACT:The distribution static compensator scheme can be used to solve the harmonic-related power quality issues, but its performance is very susceptible to frequency non-adaptively and harmonic disturbance present in the control scheme. To enhance the power quality at the distribution supply, a new control strategy based on a frequency adaptive disturbance observer has been presented in this project. By removing the harmonics from the nonlinear load, the proposed disturbance observer improves the precision of the fundamental load current's magnitude estimation. The simulation's findings demonstrate that the DSTATCOM system is functioning satisfactorily in terms of enhancing power quality.

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

I. INTRODUCTION

Power quality problems have become more prevalent recently for both industrial and residential customers. The fact that front end rectifiers are the most frequent stage in non-linear loads and harmonic generating loads are common may be the cause of this. This could have negative consequences, including the overloading of transformers and neutral conductors as well as the tripping of switch gear equipment. Passive filters are typically used to address power quality issues. A DSTATCOM-based active compensator is used to overcome the harmonics in the nonlinear current when they are not reduced to a predetermined level. The recognition of harmonics, which controls how well the DSTATCOM performs, is the crucial component of the controller. There are a number of harmonic detection techniques that can be used to control DSTATCOM, including the p-q method, the d-q method, the Recursive Discrete Fourier Transform method (RDFT method), and the Enhanced Phase Locked-Loop method. These techniques have some benefits and drawbacks. For instance, the frequency domain RDFT technique offers quick response, but it necessitates at least one window period. However, because of integration constants, time-domain techniques have a slow response time but have a light computational load. The performance of EPLL method is superior to PLL method in the presence of undesirable signals like dc offset, harmonics, and unbalance. The reduced order SOGI-based current controller for Distributed Power Generating Systems (DGPS) is anticipated.

By incorporating multiple SOGI, different harmonic components from a severely polluted grid supply can be found. The SOGI method's weakness is that its parameter can change in situations with variable frequency. A highly unbalanced and distorted grid voltage will be subjected to an adaptive vectorial filter in the -reference frame in order to extract its harmonics. A DG system that runs at a constant frequency can track the primary component with the least amount of error. The composite observer lacks the frequency adaptive characteristics. As a result, any change in frequency, which occurs more frequently in DG systems, can have an impact on the performance of the presented algorithm.

The researchers created various disturbance observer-based controls independently, but they are all fundamentally similar. An observer system's primary goal is to limit disturbance influence. To reduce stator current harmonics in permanent magnet synchronous machine (PMSM) drives, DOB control is employed. A new disturbance rejection scheme can reduce the periodic disturbances in a linear PMSM drives. Based on the estimated frequency and angle values, the frequency adaptive observer in a PMSM has successfully reduced the undesirable signal from the flux. Although the DOB structure is straightforward, the type-2 system is used to calculate the frequency and angle values. It exhibits second order oscillations in the estimated value of frequency because it is thought of as a low pass filter. Hence,

In this project, a new controller for the DSTATCOM system based on a disturbance observer with adaptive frequency assessment has been proposed for the reduction of load harmonics in order to address the aforementioned issues. The disturbance observer has notch filter characteristics, and through a direct integration loop, a new frequency assessment loop is recommended. The frequency estimation loop of the projected disturbance observer is the key distinction between it and the vectorial filter observer. In addition to lowering the system's order, this new assessment loop also cuts the number of constants in half. Two constants are required for this project, of which is chosen based on the system parameter and is designed based on stability. This project involves carrying out the estimation of the basic elements of the load current in the frame.

II. PROPOSED SYSTEM

A typical DSTATCOM circuit's power circuit diagram in a four wire system for power quality improvement. The current controlled voltage source inverter (VSI) with self-supporting DC link voltage is the primary element of the entire power circuit. The difference between the desired source current and the load current determines the compensating current that the VSI injects into the ac mains. The loads used in this circuit are a full wave semi converter type nonlinear load and a single phase lagging power factor (R-L) linear load. The other parts include passive ripple filters (Rf, Cf) with a common neutral point (n) that are used to smear the mains voltage and compensating currents, as well as filter inductors at the neutral wire, line, and n. Hall effect sensors are used to measure the various voltages and currents.

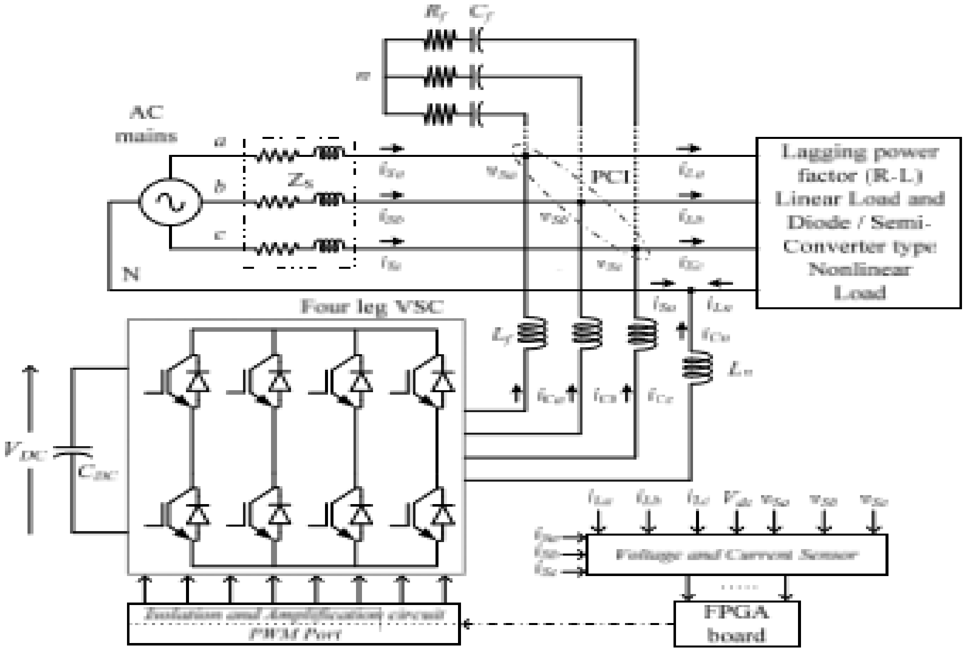

Fig. 1:Schematic diagram of distribution system with proposed DSTATCOM

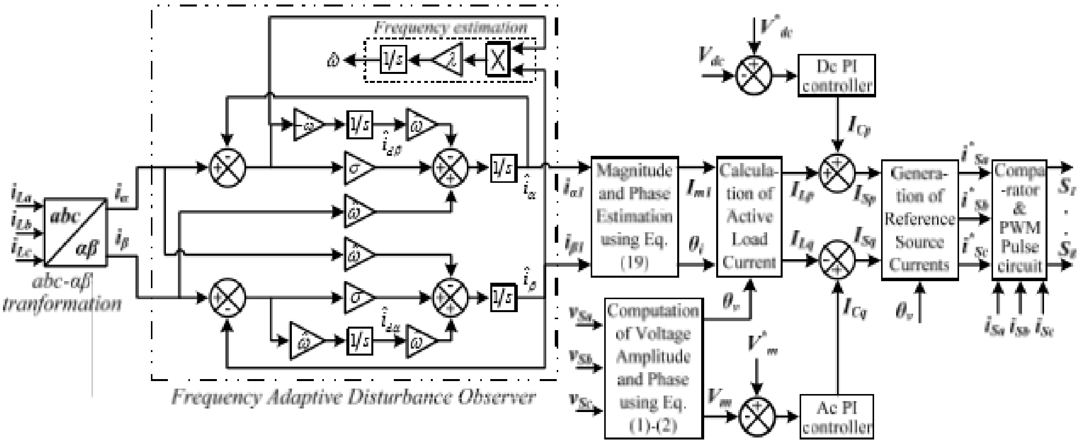

Fig. 2:Control scheme diagram of proposed frequency adaptive disturbance observer

III. PROPOSED FREQUENCY ADAPTIVE SYSTEM

(i) Reference Current Generation Scheme

The three phase supply voltage at the point of common interface (PCI), where the supply voltages Vsa, Vsb, and Vsc are represented as balanced sinusoidal functions, is subjected to the alpha-beta transformation.Unit templates and the phase Clark's transformation are used to calculate voltage amplitude.

$$\begin{bmatrix} v_\alpha \\ v_\beta \end{bmatrix} = \frac{2}{3}\begin{bmatrix} 1 & \frac{-1}{2} & \frac{-1}{2} \\ 0 & \frac{-1}{\sqrt{3}} & \frac{1}{\sqrt{3}} \end{bmatrix} \tag{1}$$

$$v_{m=\sqrt{v_\propto^2+v_\beta^2}}$$

$$\theta_v = tan^{-1}\left(\frac{v_\alpha}{v_\beta}\right) \tag{2}$$

Harmonics are present in all non-linear loads, and they have a negative effect on how well the control strategy works. The basic current component estimation is given by the equation.

$$i_\propto(t) = \sum_{\mathrm{n=1,3}} \mathrm{I_{mn}} \sin(n\omega t + \varphi_n)$$

$$i_\beta(t) = \sum_{n=1,5} I_{mn} \cos(n\omega t + \varphi_n) \tag{3}$$

The fundamental is denoted as $\theta_i$and harmonic components in α-β frame can be represented as a disturbance components $i_{d\alpha}$ and $i_{d\beta}$ it can be given as,

$$\begin{bmatrix} i_\propto \\ i_\beta \end{bmatrix} = \begin{bmatrix} I_{m1} sin\theta_i \\ I_{m1} cos\theta_i \end{bmatrix} + \begin{bmatrix} i_{d\propto} \\ i_{d\beta} \end{bmatrix} \tag{4}$$

The derivative of the above equation can be given as,

$$\begin{bmatrix} \dot{i_\propto} \\ \dot{i_\beta} \end{bmatrix} = \omega\begin{bmatrix} I_{m1} cos\theta_i \\ -I_{m1} sin\theta_i \end{bmatrix} + \begin{bmatrix} \dot{i_{d\propto}} \\ \dot{i_{d\beta}} \end{bmatrix} \tag{5}$$

The disturbance components in the aforementioned equation are mostly derivatives of higher order frequency terms, have a small amplitude relative to the fundamental, are negligible, and the assumption is fictitious. Higher order derivatives may be disregarded, which causes the disturbance observer to perform poorly.The aforementioned assumption has no bearing on the disturbance observer's ability to detect disturbances.When higher order terms are ignored, the planned observer is applicable and able to eliminate the persistent harmonic disturbances. The formula is as follows:

$$\begin{bmatrix} \dot{i}_\alpha \\ \dot{i}_\beta \end{bmatrix} = \omega \begin{bmatrix} I_{m1} cos\theta_i \\ -I_{m1} sin\theta_i \end{bmatrix} = \omega \begin{bmatrix} i_\beta - i_{d\beta} \\ i_{d\alpha} - i_\alpha \end{bmatrix} \qquad (6)$$

Now the state variables are i_α, i_β, $i_{d\alpha}$, and $i_{d\beta}$ and the output variables are i_α and i_β, the eqn can be formulated as,

$$i_{\alpha\beta d} = A_m i_{\alpha\beta d}$$

$$i_{\alpha\beta} = C_m i_{\alpha\beta d} \qquad (7)$$

Where $i_{\alpha\beta d}$ is the state, and A_m is its matrix, the output is $i_{\alpha\beta}$ and C_m is its matrix and are described as,

$$i_{\alpha\beta d} = \left[i_\alpha i_\beta i_{d\alpha} i_{d\beta} \right]^T$$

$$A_m = \begin{bmatrix} 0 & \omega & 0 & -\omega \\ -\omega & 0 & \omega & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix}$$

$$i_{\alpha\beta} = \left[i_\alpha i_\beta \right]^T$$

$$C_m = \begin{bmatrix} 1 & 0 & 00 \\ 0 & 1 & 00 \end{bmatrix} \qquad (8)$$

The linear system described here is observable and it has full rank. The state observer can be designed as,

$$\dot{\widehat{i_{\alpha\beta d}}} = [A_m - K_m C_m] \widehat{i_{\alpha\beta d}} + K_m i_{\alpha\beta}$$

$$i_{\alpha\beta} = C_m \widehat{i_{\alpha\beta d}} \qquad (9)$$

Where, $[A_m - K_m C_m] = \begin{bmatrix} -\sigma & 0 & 0 & -\omega \\ 0 & -\sigma & \omega & 0 \\ 0 & -\omega & 0 & 0 \\ \omega & 0 & 0 & 0 \end{bmatrix}$

Where $K_m = \begin{bmatrix} \sigma & -\omega & 0 & -\omega \\ \omega & \sigma & \omega & 0 \end{bmatrix} \qquad (10)$

The transfer function of the state observer can be given as,

$$\frac{i_{\alpha\beta}(s)}{i_{\alpha\beta}(s)} = C_m [sI_m - (A_m - K_m C_{m)}]^{-1} K_m, \qquad (11)$$

IV. CONTROL ALGORITHM

Upper and lower hysteresis band limits must be established for this HCC control technique. If the load is variable, the output DC voltage variation in open loop control strategies is a common issue; however, steady output is possible with closed loop control strategies. In closed loop control, the provided reference current signal is compared to the output current signal. Which produces the desired output while reducing output error. PID controllers can regulate the generated gate pulses. If there is a significant error, the power switching devices will not switch. The Ziegler Nicholas method can be used to fine-tune PID controllers. Two level hysteresis current control technique is the name of the traditional hysteresis control technique. It is based on a nonlinear method.

By comparing the reference source current (isa*, isb*, and isc*) produced by the frequency adaptive disturbance observer with the actual source current (isa, isb, and isc), the switching signals for the VSI switches are generated using HBCC.

The following is how the switching control law is obtained:

- The button switch is turned ON while the top switch is turned OFF if ifa>or equal to ifa*+h.
- The button switch is turned ON while the top switch is turned OFF if ifa is greater than or equal to ifa*+h.

The fundamental component of load current is identified from the σ-β current as given,

$$I_{m1} = \sqrt{i_\alpha^2 + i_\beta^2}$$

$$\theta_i = tan^{-1}\left(\frac{i_{\alpha 1}}{i_{\beta 1}}\right) \qquad (12)$$

I_{Lp} and I_{Lq}which is the active and reactive part of load current which can be given as

$$I_{Lp} = I_{m1}\cos(\theta_v - \theta_i)$$

$$I_{Lq} = I_{m1}\sin(\theta_v - \theta_i) \qquad (13)$$

I_{sp} which is the active component of source current is calculated by the sum of active component of load current I_{Lp} and active component of load current I_{Cp} and is given as,

$$I_{Sp} = I_{Lp} + I_{Cp} \qquad (14)$$

I_{Sq}which is the reactive power component of source current is given by the addition of reactive component of load I_{Lq} current and additional reactive current I_{Cq} which can be given as,

$$I_{Sq} = I_{Lq} + I_{Cq} \qquad (15)$$

The three-phase reference source current can be generated as,

$$i_{Sa}^* = I_{Sp}cos\theta_v + I_{Sq}sin\theta_v$$

$$i_{Sb}^* = I_{Sp}\cos\left(\theta_v - \frac{2\pi}{3}\right) + I_{Sq}\sin\left(\theta_v - \frac{2\pi}{3}\right)$$

$$i_{Sc}^* = I_{Sp}\cos\left(\theta_v + \frac{2\pi}{3}\right) + I_{Sq}\sin\left(\theta_v + \frac{2\pi}{3}\right) \qquad (16)$$

The reference and actual source currents are compared and sent to the PWM generation block in order to control the source current. The switching pulses from s1 to s6 are produced by the PWM circuit. The two pulses for the fourth leg are identified by comparing the reference neutral current with the actual neutral current.

V. SIMULATION RESULTS

Table 1 System parameters

Parameters	Values
Programmable AC source	3-phase , 120Vrms(ph-ph)
Source Impedence	zs=0.16+j0.5 Ω
DC link capacitor	CDc=2300 µ F
Reference dc link voltage	VDc=200v
Filter inductor	Lf=2.9mHand 1.5mH in neutral
DC pi controller gains	Kpd=0.43 and Kid=0.023
AC PI controller gains	Kpa=0.049 and Kia=0.98

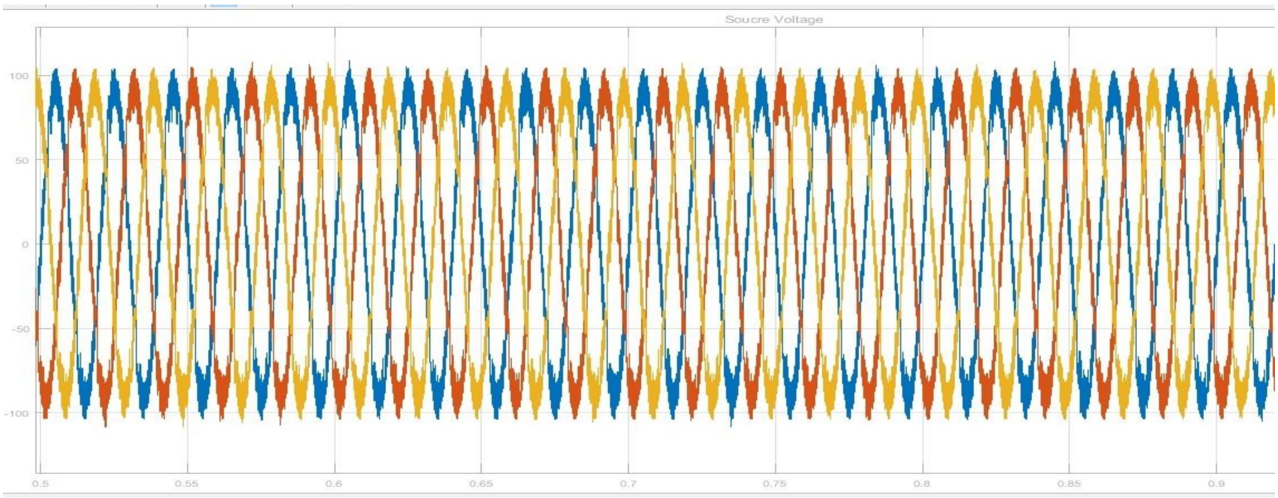

Figure 3 Three phase Supply Voltages (Vsa, Vsb, Vsc)

The PCC voltages are shown in positive order in Figure 3. The reference filter current cannot be produced by the distorted PCC voltage. Therefore, using transformation techniques, the distorted PCC voltages are transformed into sinusoidal PCC voltages with equal magnitude and phase difference.

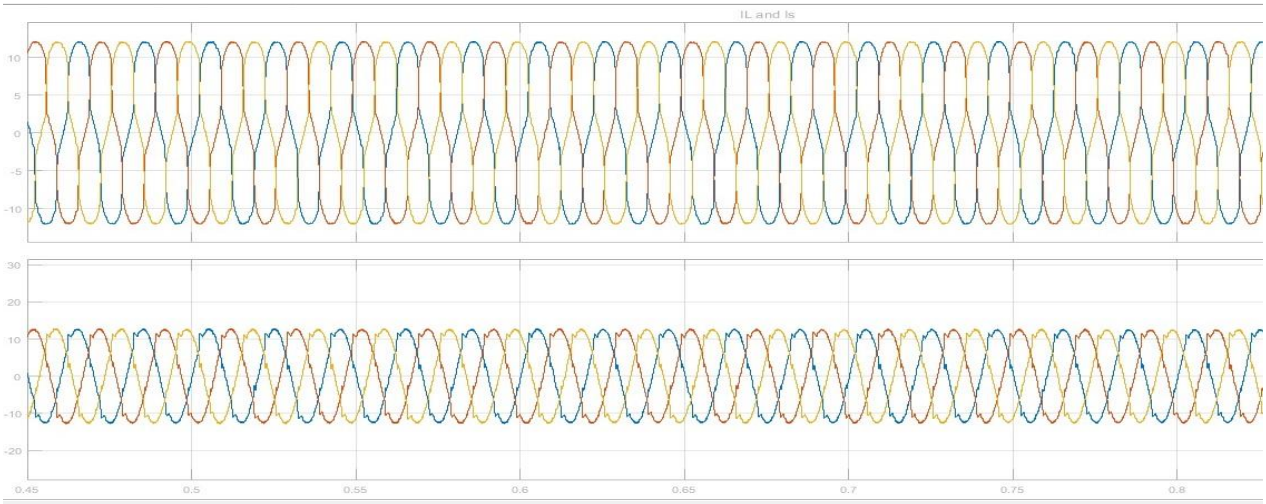

Figure 4Three phase load current and source current

Before any compensation techniques are employed, Figure 4 shows the distorted three phase source currents (Isa, Isb, and Isc). The flow of the neutral source current through the line is initiated by the imbalance in the three phase source currents. Thus, the neutral conductor will be overloaded. In order to balance the system's load, the DSTATCOM balances the distorted source current and reduces the source neutral current to zero.

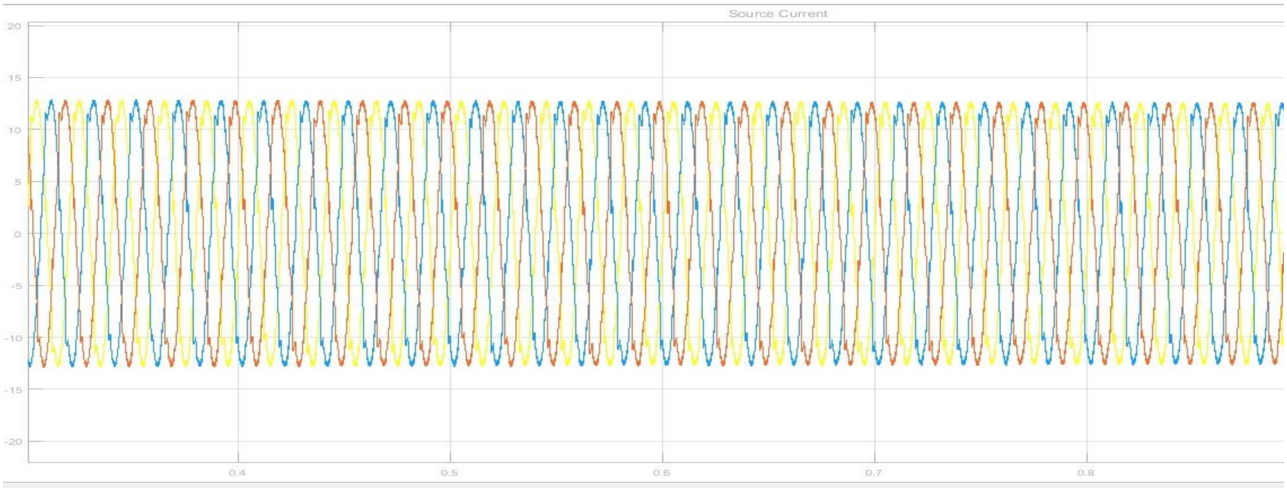

Figure 5 Three phase Source currents after compensation (Isa,Isb,Isc)

Following DSTATCOM's compensation, Figure 5 shows the three phase source currents (Isa, Isb, and Isc). To make the source currents balanced sinusoidal ones, the compensator source current is brought into the line using an interfacing inductor. The source current has a proper phase offset and equal magnitude after compensation.

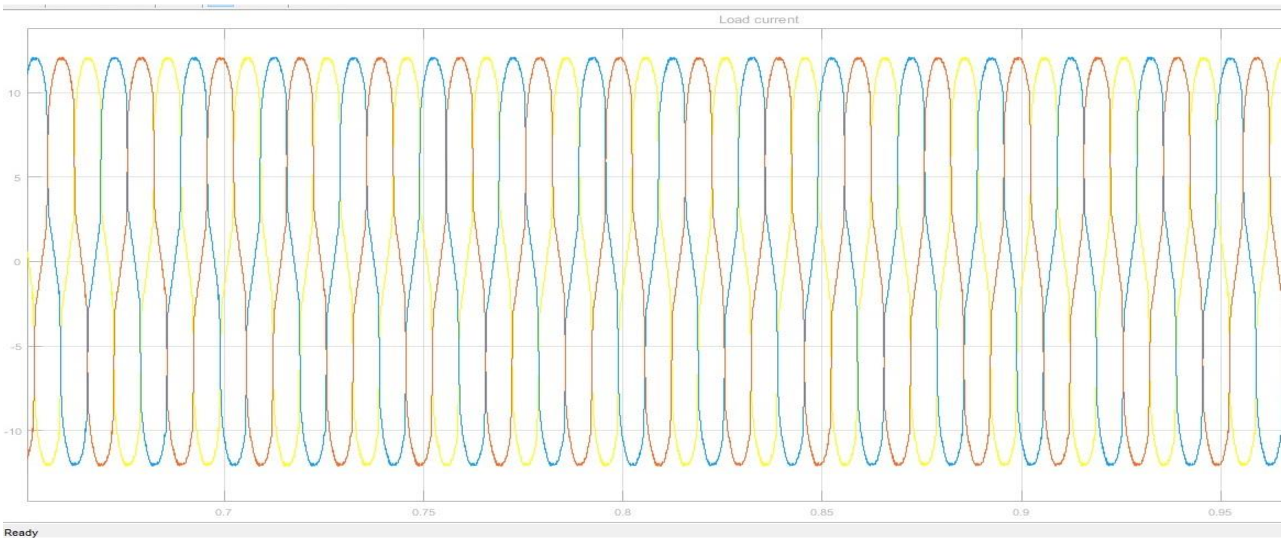

Figure 6 Three phase load currents (Ila,Ilb,Ilc)

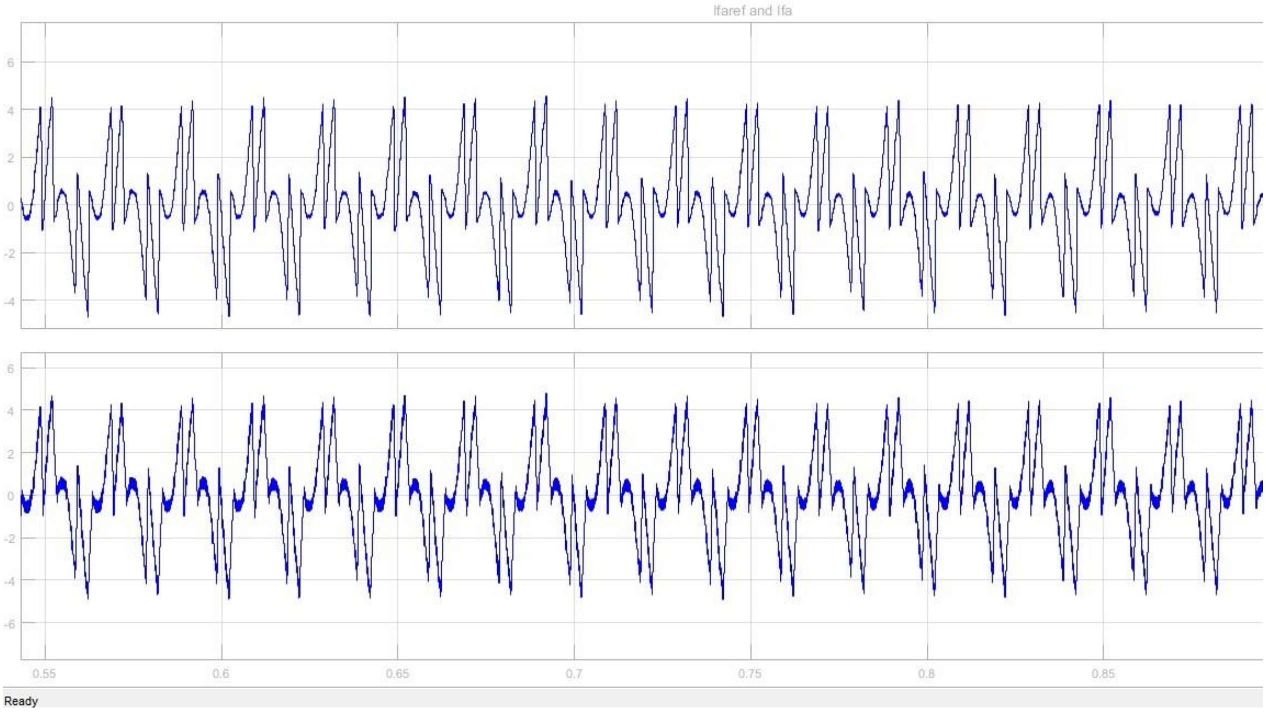

Figure 7 Reference filter current and actual filter current

Figure 7 shows how the DSTATCOM corrects the imbalance in the three phase source currents by injecting both actual filter current and three phase filter currents. The pulses for the DSTATCOM are provided by the control algorithm techniques. The distinction between reference filter current and actual filter current (ifa) is known as the hysteresis controller error (e).

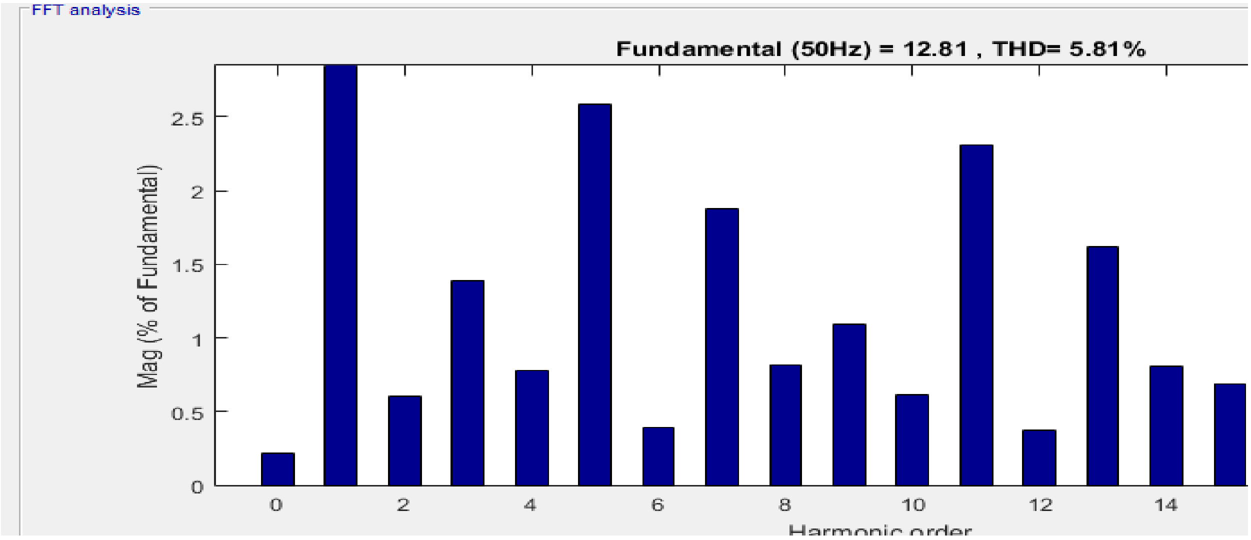

Figure 8 Harmonic Profile of Source Current (Isc)

VI. CONCLUSION

A new control strategy based on a frequency adaptive disturbance observer has been proposed in this project to operate a three-phase, four-wire DSTATCOM system. The proposed observer's control scheme incorporates two dynamic conditions. 1) Frequency variation in a simulation; and 2) Changes in load on an experimental setup. Throughout the entire operation of the DSTATCOM system, the power factor at the supply terminal must be nearly unity. By using this disturbance observer, the harmonics in the load - current are eliminated. Regardless of the type of dynamic, the DC bus capacitor voltage is established in three supply cycles. It can be expanded to power systems with TCSC, UPFC, and IPFC that have been generalized. It may be expanded to include STATCOM and SSSC.

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