A Novel Control Strategy of DSTATCOM for Load Compensation under Distorted Utility Condition

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Abstract—**The Distribution STATic COMpensator (DSTATCOM) has proved to be a useful custom power device to eliminate harmonic components and to compensate reactive power for balanced/unbalanced linear/nonlinear loads. This paper presents a novel approach to calculate the reference compensation current of three phase DSTATCOM under distorted utility condition at instantaneous state. The proposed approach is compared with reviewed control strategies viz. instantaneous p-q theory, synchronous reference frame Method(SRF), Modified SRF Method(MSRF), instantaneous symmetrical component theory(ISCT) and Average unit power factor theory(AUPFT) for different three conditions. The performance of the system simulated in Matlab Platform and evaluated considering the source current total harmonic distortion. The result shows the Proposed Method has improved system performance as compared to others.**

Keywords- Modified Synchronous Reference Frame; Synchronous Reference Frame; Instantaneous Symmetrical Component Theory; Average Unit Power Factor Theory.

I. INTRODUCTION

During the last decade, there has been sudden increase in the nonlinear load (Computers, Laser printers, SMPS, Rectifier etc.), which degrades the power quality causing a number of disturbances e.g. heating of home appliances, noise etc. in power systems [1], [2] due to harmonics. To compensate the harmonics due to nonlinear load, a Distribution STATic COMpensator (DSTATCOM) is used [3]. The performance of DSTATCOM largely depends on the control strategies used for reference current extraction.

In this paper performance of five control strategies such as instantaneous p-q theory[6], instantaneous symmetrical component theory[12], SRF Method[7][8], Modified SRF Method[11] and AUPF theory[13] are investigated in **three phase three wire system** for balanced/distorted source and non-linear balanced and unbalanced Load. The measures of the performance are the source current total harmonic distortion. The results obtained show that under normal operating condition all control strategies are suitable for compensation, but the distorted and unbalanced operating condition deteriorates the performance of different theories.

Rest of the paper is organized as follows. In section II system configuration and in section III brief discussion on different control theories/methods are presented. In section IV the performance indices used for evaluation are discussed. Simulation results are described in section V. Finally in section VI, conclusion is drawn.

II. SYSTEM CONFIGURATION

Fig.1 shows the basic circuit diagram of a DSTATCOM [3] system with non-linear load connected to three phase three wire distribution system. A nonlinear load is realized by using a three phase full bridge diode rectifier. A three phase voltage source converter (VSC) working as a DSTATCOM is realized using six insulated gate bipolar transistor (IGBTs) with anti-parallel diodes. At ac side, the interfacing inductors are used to filter high frequency components of compensating currents.

The first harmonic load currents of positive sequence are transformed to DC quantities. The first harmonic load currents of negative sequence and all the harmonics are transformed to non-DC quantities and undergo a frequency shift in the spectrum.

The voltage regulator in the converter DC side is performed by a proportional–integral (P-I) controller. Its input is the capacitor voltage error (vdcref-vdc) and it regulates the first harmonic active current of positive sequence. It is possible to control the active power flow in the VSC and thus the capacitor voltage Vdc remains constant.

The dynamics of each VSC are modeled by solving differential equations governing two-level inverter. The switching of the inverter is done by monitoring the reference and actual currents and comparison of error with the hysteresis band. The VSC model is based on discrete switching variables g_a, g_b, g_c [4].

$$\begin{bmatrix} v_{fa} \\ v_{fb} \\ v_{fc} \end{bmatrix} = \frac{Vdc}{\sqrt{3}} \begin{bmatrix} 2 & -1 & -1 \\ -1 & 2 & -1 \\ -1 & -1 & 2 \end{bmatrix} \begin{bmatrix} g_a \\ g_b \\ g_c \end{bmatrix} \tag{1}$$

The *R–L* network on the ac side of the converter is represented by three differential equations. These differential equations are solved by using Runge-Kutta’s 4th order method.

$$\left.\begin{aligned} L_f \frac{di_{fa}}{dt} &= -i_{fa}.R_f + v_{sa} - v_{fa} \\ L_f \frac{di_{fb}}{dt} &= -i_{fb}.R_f + v_{sb} - v_{fb} \\ L_f \frac{di_{fc}}{dt} &= -i_{fc}.R_f + v_{sc} - v_{fc} \end{aligned}\right\} \qquad (2)$$

The dc side equations are:

$$i_{dc} = g_a.if_a + g_b.if_b + g_c.if_c \qquad (3)$$

$$-C_{dc}.\frac{dv_{dc}}{dt} = i_{dc} \qquad (4)$$

The equation for discrete PI controller is defined as

$$u(n) = u(n-1) + k_p \; e(n) - e(n-1) \; + k_i e(n) \qquad (5)$$

Where u(n)= PI controller output , e(n)= V_{dcref}-V_{dc}, K_p= Proportional gain constant and K_i= Integral constant of PI Controller.

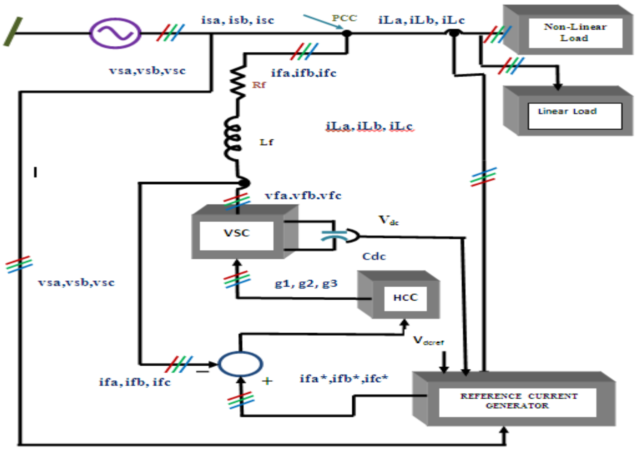

Fig.1 system configuration of DSTATCOM

III. CONTROL STRATEGIES

A. *Instantaneous p-q Theory*

Instantaneous P-Q Theory was initially proposed by Akagi [5]. This theory is based on the transformation of three phase quantities to two phase quantities in α-β frame and the Instantaneous active and reactive power is calculated in this frame [5],[6]. Sensed inputs v_{sa} ,v_{sb} and v_{sc} & i_{La} ,i_{Lb} and i_{Lc} are fed to the controller and these quantities are processed to generate reference commands $(i^*_{fa}, i^*_{fb}, i^*_{fc})$ which are fed to a hysteresis based PWM current controller to generate switching pulses for DSTATCOM.

The system terminal voltages are given as

$$\left.\begin{aligned} v_{sa} &= V_m \sin(wt) \\ v_{sb} &= V_m \sin(wt - 2\pi/3) \\ v_{sc} &= V_m \sin(wt + 2\pi/3) \end{aligned}\right\} \qquad (6)$$

And the respective load current are given as

$$\left.\begin{aligned} i_{La} &= \Sigma I_{Lan} \sin\{n(wt) - \theta_{an}\} \\ i_{Lb} &= \Sigma I_{Lbn} \sin\{n(wt - 2\pi/3) - \theta_{bn}\} \\ i_{Lc} &= \Sigma I_{Lcn} \sin\{n(wt + 2\pi/3) - \theta_{cn}\} \end{aligned}\right\} \qquad (7)$$

In a, b and c coordinates a, b and c axes are fixed on the same plane apart from each other by 2π/3. These phasors can be transformed into α-β coordinates using Clarke's transformation as follows.

$$\begin{bmatrix} v_\alpha \\ v_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \end{bmatrix} \begin{bmatrix} v_{sa} \\ v_{sb} \\ v_{sc} \end{bmatrix} \qquad (8)$$

0

$$\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \end{bmatrix} \begin{bmatrix} i_{La} \\ i_{Lb} \\ i_{Lc} \end{bmatrix} \qquad (9)$$

Where α and β axes are the orthogonal coordinates. Conventional instantaneous power for three phase circuit can be defined as $p = v_\alpha i_\alpha + v_\beta i_\beta$ (10)

Where p is equal to conventional equation

$$p = v_{sa} i_{sa} + v_{sb} i_{sb} + v_{sc} i_{sc} \qquad (11)$$

Similarly, the instantaneous reactive power is defined as

$$q = v_\beta i_\alpha - v_\alpha i_\beta \qquad (12)$$

Therefore in matrix form, instantaneous real and reactive power are given as

$$\begin{bmatrix} p \\ q \end{bmatrix} = \begin{bmatrix} v_\alpha & v_\beta \\ v_\beta & -v_\alpha \end{bmatrix} \begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} \qquad (13)$$

The α-β currents can be obtained as

$$\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} = \frac{1}{\Delta} \begin{bmatrix} v_\alpha & v_\beta \\ v_\beta & -v_\alpha \end{bmatrix} \begin{bmatrix} p \\ q \end{bmatrix} \qquad (14)$$

Where $\Delta = v_\alpha^2 + v_\beta^2$

Instantaneous active and reactive powers p and q can be decomposed into an average (dc) and oscillatory component

$$\left.\begin{aligned} p &= \bar{p} + \tilde{p} \\ q &= \bar{q} + \tilde{q} \end{aligned}\right\} \qquad (15)$$

Where $\bar{p}$ and $\bar{q}$ are the average dc part, $\tilde{p}$ and $\tilde{q}$ are the oscillatory (ac) part of these real and reactive instantaneous power. Reference currents are calculated to compensate the instantaneous oscillatory component of the instantaneous active and reactive power. Therefore the reference compensating currents $i^*_{f\alpha}$ and $i^*_{f\beta}$ in α-β coordinate can be expressed as

$$\begin{bmatrix} i^*_{f\alpha} \\ i^*_{f\beta} \end{bmatrix} = \frac{1}{\Delta} \begin{bmatrix} v_\alpha & v_\beta \\ v_\beta & -v_\alpha \end{bmatrix} \begin{bmatrix} -\tilde{p} \\ -\tilde{q} \end{bmatrix} \qquad (16)$$

The oscillatory part of real power p and reactive power q is obtained by using 4th order low pass Butterworth filter of cut-off frequency 25 Hz. These currents can be transformed in abc quantities to find reference currents in a-b-c coordinates using reverse Clarke's transformation.

$$\begin{bmatrix} i^*_{fa} \\ i^*_{fb} \\ i^*_{fc} \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & 0 \\ -1/2 & \sqrt{3}/2 \\ -1/2 & -\sqrt{3}/2 \end{bmatrix} \begin{bmatrix} i^*_{f\alpha} \\ i^*_{f\beta} \end{bmatrix} \tag{17}$$

B. *Synchronous Reference frame Method (SRF)*

This theory is based on the transformation of currents in synchronously rotating d-q frame [7],[8],.Voltage signals are processed by the PLL[9] to generate the unit vectors. Current signals are transformed into d-q frame and then filtered .Then compensating current transformed back to a-b-c frame and fed to hysteresis current controller [10] for switching pulse generation.

The current components are transformed into α-β coordinates and using θ as a transformation angle again transformed from α-β to d-q frame with help of park's transformation.

$$\begin{bmatrix} i_d \\ i_q \end{bmatrix} = \begin{bmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} \tag{18}$$

SRF controller extracts the oscillating part of i_d and i_q by use of a low pass Butterworth filter. The extracted compensating currents i^*_{fd} and i^*_{fq} are transformed back in to α-β frame using reverse Park's transformation.

$$\begin{bmatrix} i^*_{f\alpha} \\ i^*_{f\beta} \end{bmatrix} = \begin{bmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} i^*_{fd} \\ i^*_{fq} \end{bmatrix} \tag{19}$$

Then these reference currents are transformed back to a-b-c coordinates.

$$\begin{bmatrix} i^*_{fa} \\ i^*_{fb} \\ i^*_{fc} \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & 0 \\ -1/2 & \sqrt{3}/2 \\ -1/2 & -\sqrt{3}/2 \end{bmatrix} \begin{bmatrix} i^*_{f\alpha} \\ i^*_{f\beta} \end{bmatrix} \tag{20}$$

C. *Modified Synchronous Reference frame Method (MSRF)(Id-Iq)*

In this method the compensating currents are obtained from instantaneous active and reactive currents id and iq of the non-linear load [11]. However the dq load currents are derived from a synchronous reference frame based on the transformation where θ represent the voltage vector angle.

$$\begin{bmatrix} i_d \\ i_q \end{bmatrix} = \begin{bmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} \tag{21}$$

The transformation angle is sensitive to voltage harmonics and unbalanced voltage sources, therefore dθ/dt may not be constant. Due to geometric relation

$$\begin{bmatrix} i_d \\ i_q \end{bmatrix} = \frac{1}{\sqrt{\Delta}} \begin{bmatrix} v_\alpha & v_\beta \\ -v_\beta & v_\alpha \end{bmatrix} \begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} \tag{22}$$

Where $\Delta = v_\alpha^2 + v_\beta^2$

Performing the elimination of the average current components by high pass filter the compensating reference current i^*_{fd} and i^*_{fq} are obtained. Then the compensating reference current is obtained in α-β coordinates.

$$\begin{bmatrix} i^*_{f\alpha} \\ i^*_{f\beta} \end{bmatrix} = \frac{1}{\sqrt{\Delta}} \begin{bmatrix} v_\alpha & -v_\beta \\ v_\beta & v_\alpha \end{bmatrix} \begin{bmatrix} i^*_{fd} \\ i^*_{fq} \end{bmatrix} \tag{23}$$

Then these reference currents are transformed back to a-b-c coordinates.

$$\begin{bmatrix} i^*_{fa} \\ i^*_{fb} \\ i^*_{fc} \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & 0 \\ -1/2 & \sqrt{3}/2 \\ -1/2 & -\sqrt{3}/2 \end{bmatrix} \begin{bmatrix} i^*_{f\alpha} \\ i^*_{f\beta} \end{bmatrix} \tag{24}$$

D. *Instantaneous Symmetrical Components Theory*

The objective of this theory [12] is to make source current balanced and harmonic free.

$$\text{So } i_{sa} + i_{sb} + i_{sc} = 0 \tag{25}$$

The positive sequence voltage to a phase is as follows.

$$V^+ = \frac{1}{\sqrt{3}}(v_{sa} + a v_{sb} + a^2 v_{sc}) \tag{26}$$

Where $a = e^{j2\pi/3}$.The angle of vector of +ve sequence is

$$\angle\{v_{sa} + a v_{sb} + a^2 v_{sc}\} = \angle\{i_{sa} + a i_{sb} + a^2 i_{sc}\} + \phi \tag{27}$$

Where

$$\phi = \angle(V^+) = \tan^{-1}\left\{ \frac{\frac{\sqrt{3}}{2} v_{sb} - \frac{\sqrt{3}}{2} v_{sc}}{v_{sa} - \frac{1}{2} v_{sb} - \frac{1}{2} v_{sc}} \right\} \tag{28}$$

$$(v_{sb} - v_{sc} - 3\beta v_{sa}) i_{sa} + (v_{sc} - v_{sa} - 3\beta v_{sb}) i_{sb} + (v_{sa} - v_{sb} - 3\beta v_{sc}) i_{sc} = 0 \tag{29}$$

Where $\beta = \dfrac{\tan\phi}{\sqrt{3}}$

The source deliver power must equal to the average of active power i.e.

$$v_{sa} i_{sa} + v_{sb} i_{sb} + v_{sc} i_{sc} = p_{lav} \tag{30}$$

From the above relations following matrix is formed.

$$\begin{bmatrix} 1 & 1 & 1 \\ (v_{sb} - v_{sc} - 3\beta v_{sa}) & (v_{sc} - v_{sa} - 3\beta v_{sb}) & (v_{sa} - v_{sb} - 3\beta v_{sc}) \\ v_{sa} & v_{sb} & v_{sc} \end{bmatrix} \begin{bmatrix} i_{sa} \\ i_{sb} \\ i_{sc} \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ p_{lav} \end{bmatrix} \tag{31}$$

The source reference currents are obtained by solving the above equation (31),

$$i_{sa}^{*} = \frac{v_{sa} + (v_{sb} - v_{sc})\beta}{v_{sa}^{2} + v_{sb}^{2} + v_{sc}^{2}} p_{lav} \tag{32}$$

$$i_{sb}^{*} = \frac{v_{sb} + (v_{sc} - v_{sa})\beta}{v_{sa}^{2} + v_{sb}^{2} + v_{sc}^{2}} p_{lav} \tag{33}$$

$$i_{sc}^{*} = \frac{v_{sc} + (v_{sa} - v_{sb})\beta}{v_{sa}^{2} + v_{sb}^{2} + v_{sc}^{2}} p_{lav} \tag{34}$$

In the above relation β represents the power factor co-efficient proportionate to reactive power. Finally under balanced and unit power factor following reference currents are computed.

$$i_{fa}^{*} = i_{La} - i_{sa}^{*} = i_{La} - \frac{v_{sa}}{\Delta s}(p_{lav} + p_{loss}) \tag{35}$$

$$i_{fb}^{*} = i_{Lb} - i_{sb}^{*} = i_{Lb} - \frac{v_{sb}}{\Delta s}(p_{lav} + p_{loss}) \tag{36}$$

$$i_{fc}^{*} = i_{Lc} - i_{sc}^{*} = i_{Lc} - \frac{v_{sc}}{\Delta s}(p_{lav} + p_{loss}) \tag{37}$$

Where $\Delta s = v_{sa}^{2} + v_{sb}^{2} + v_{sc}^{2}$

Where p_{lav} is the average load power and p_{loss} is the losses in VSI which are computed as follows

$$p_{lav} = \frac{1}{T}\int (v_{sa} i_{La} + v_{sb} i_{Lb} + v_{sc} i_{Lc}) dt \tag{38}$$

$$p_{loss} = k_p (v_{dcref} - v_{dc}) + k_i \int (v_{dcref} - v_{dc}) dt \tag{39}$$

Where v_{dcref} and v_{dc} are the reference and actual capacitor voltage.

E. Average unit power factor theory (AUPF)[13]

The source must supply the sinusoidal currents in phase with the voltages.

$$\begin{bmatrix} i_{sa} \\ i_{sb} \\ i_{sc} \end{bmatrix} = \frac{p_{lav}}{V^{2}} \begin{bmatrix} v_{sa} \\ v_{sb} \\ v_{sc} \end{bmatrix} \tag{40}$$

$$p_{lav} = \frac{1}{T}\int (v_{sa} i_{La} + v_{sb} i_{Lb} + v_{sc} i_{Lc}) dt \tag{41}$$

$$V^{2} = \frac{1}{T}\int (v_{sa} v_{sa} + v_{sb} v_{sb} + v_{sc} v_{sc}) dt \tag{42}$$

The compensator current are derived as $i_f = i_L - i_s$

$$\begin{bmatrix} i_{fa}^{*} \\ i_{fb}^{*} \\ i_{fc}^{*} \end{bmatrix} = \begin{bmatrix} i_{La} \\ i_{Lb} \\ i_{Lc} \end{bmatrix} - \frac{p_{lav}}{V^{2}} \begin{bmatrix} v_{sa} \\ v_{sb} \\ v_{sc} \end{bmatrix} \tag{43}$$

The compensator reference currents can be compared with actual compensator currents pass through the hysteresis band controller which generates gate pulses for voltage source converter of DSTATCOM.

F. Proposed Control Strategy

This control strategy is best suitable for distorted utility condition. It is based on instantaneous symmetrical component theory in instantaneous state. The main objective is to find out active fundamental source peak current. The reference compensating current is equal to the difference between estimated source and load current. Fig.2 shows the control Structure of proposed controller. The peak source current is estimated as

$$I_{sm1} = \frac{p_{3\phi}}{3V_m^{+}} \tag{44}$$

Prime objective is to make source current balanced

$$i_a + i_b + i_c = 0 \tag{45}$$

Let formulate all sequence power in time domain. Zero sequence, positive sequence and Negative sequence complex power are denoted as s_0, s_+ and s_-. The real power of zero sequence, positive sequence and Negative sequence are denoted as p_0,p_+ and p_-. The Imaginary power of zero sequence, positive sequence and Negative sequence are denoted as q_0, q_+ and q_-.The instantaneous voltage and current of zero sequence ,positive sequence and Negative sequence are denoted as v_0,v_+ ,v_- and i_0,i_+, i_- respectively. Let zero sequence power is formulated as

$$\left.\begin{aligned} s_0 &= 3v_0 * i_0^{*} = p_o + jq_0 \\ p_0 &= \frac{1}{3}(v_a + v_b + v_c)(i_a + i_b + i_c) \\ q_0 &= 0 \end{aligned}\right\} \tag{46}$$

Let calculate the positive sequence power

$$\left.\begin{aligned} s_+ &= 3v_+ i_+^{*} = p_+ + jq_+ \\ p_+ &= \frac{1}{2}\left[(v_a i_a + v_b i_b + v_c i_c) - \frac{1}{3}(v_a + v_b + v_c)(i_a + i_b + i_c)\right] \\ q_+ &= -\frac{1}{2\sqrt{3}}\ v_a(i_b - i_c) + v_b(i_c - i_a) + v_c(i_a - i_b) \end{aligned}\right\} \tag{47}$$

Let calculate the negative sequence power

$$\left.\begin{aligned} s_- &= 3v_- i_-^{*} = p_- + jq_- \\ p_- &= \frac{1}{2}\left[(v_a i_a + v_b i_b + v_c i_c) - \frac{1}{3}(v_a + v_b + v_c)(i_a + i_b + i_c)\right] \\ q_- &= \frac{1}{2\sqrt{3}}\ v_a(i_b - i_c) + v_b(i_c - i_a) + v_c(i_a - i_b) \end{aligned}\right\} \tag{48}$$

Where total Instantaneous active power

$$s = (s_0 + s_+ + s_-) = (p_0 + p_+ + p_-) = p_{3\phi} = (v_a i_a + v_b i_b + v_c i_c) \tag{49}$$

In equation (49) putting $i_a+i_b+i_c=0$, we get

$$\frac{p_{3\phi}}{2} = p_+ = \frac{3V_m^{+}}{\sqrt{2}} \frac{I_{sm}^{+}}{\sqrt{2}} \tag{50}$$

$$\text{So } I_{sm}^{+} = I_{sm} = \frac{p_{3\phi}}{3V_m^{+}} \quad (51)$$

$$\text{So } \left.\begin{aligned} i_{sk}^{*} &= i_{skref} = I_{sm}U_{ck1} \\ i_{fk}^{*} &= i_{fkref} = i_{Lk} - i_{skref} \end{aligned}\right\} \quad (52)$$

Where k=a, b, c and Uck1 is fundamental unit vector template.

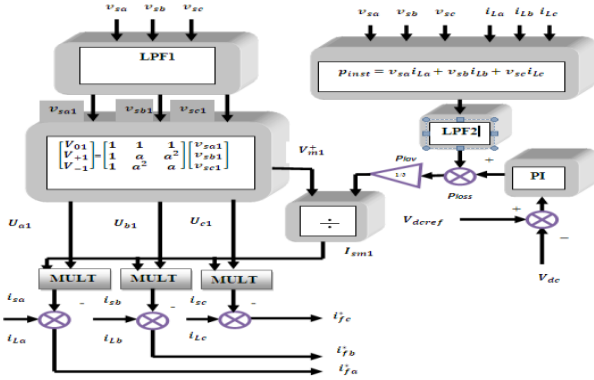

Fig. 2 Control structure of proposed algorithm

Fig.2 shows the basic control structure of proposed algorithm which constitute one PI controller, two low pass filter (LPF) and arithmetic calculators. The average power p_{lav} is calculated by adding PI output (P_{loss}) to LPF2 output. LPF1 is used to extract the fundamental from distorted PCC (point of common coupling) voltage.

IV. PERFORMANCE INDICES

The total harmonic distortion (THD) [14] is used to define the effect of harmonics on the power system voltage. It is used in low-voltage, medium-voltage, and high-voltage systems. It is expressed as a percent of the fundamental and is defined as

$$THD(voltage) = \sqrt{\sum_{h=2}^{50} V_h^2} \Big/ V_1 * 100\% \quad (53)$$

$$THD(current) = \sqrt{\sum_{h=2}^{50} I_h^2} \Big/ I_1 * 100\% \quad (54)$$

According to IEEE-519 the permissible limit for distortion in the signal is 5%.

V. RESULTS AND DISCUSSION

To investigate the performance of the DSTATCOM for six control strategies, simulations are performed on matlab platform. A three phase three wire distribution system with parameters given below is considered for simulation.

Supply voltage: 50Vrms (L-L), 50Hz, three phase balanced

Source impedance: Rs=0.1Ω, Ls=0.5mH

Nonlinear load: Three phase full bridge diode rectifier with load (L=10mH, R_L=3.7Ω)

DC storage Capacitor C_{dc}=2000μF

Interface inductor Lf=5mH, Rf=0.1Ω

DC Link voltage V_{dc}=100V.Hysteresis band=0.25A

Unbalanced Linear load: Za=67+j31.42Ω, Zb=37+j18.55Ω, Zc=28.5+j12.56Ω

PI regulator parameters: K_{pr}=1.0259, K_{ir}=227.9288

SRF Pll parameters: K_{ppl}=4.4429, K_{ipl}=21.9247

The performance of the different control strategies are evaluated based on three different cases.

Case1- Balanced Source and balanced Non-Linear load

Case2- Balanced Source and Unbalanced Non-linear load.

Case3- Balanced distorted Source and Unbalanced Non-linear load.

In **case 1** the source is assumed to be sinusoidal and balanced whereas the load is considered as non-sinusoidal and balanced with load as six pulse diode full bridge rectifier. Before compensation the THD of load current is found to be **23.2361%.** After compensation the THD for different control strategies are listed in the T**able1.** In **case 2** the source is balanced and sinusoidal but the load is unbalanced non sinusoidal (load current harmonic is found to be **22.2914%)** .The THD of the load current for phase **a** after compensation is summarized in **Table 1.** In **case 3** the source is balanced and distorted (**distorted** voltage source harmonic is **13.7477%)** but the load is unbalanced non sinusoidal (load current harmonic is found to be **22.2914%)**.The THD of the load current for phase **a** after compensation is summarized in **Table1.**The results demonstrated here are considered for phase a only. The simulations of best performance achieved proposed controller is demonstrated here for case-3.

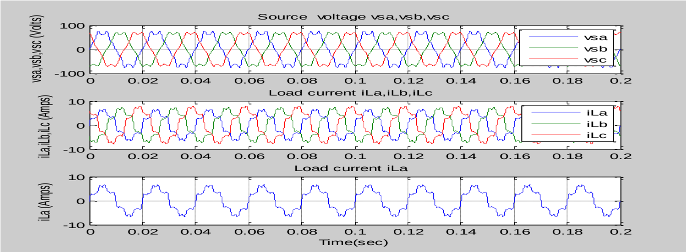

Fig. 3(a) Balanced distorted source voltage,Unbalanced Load current,Phase a Load current

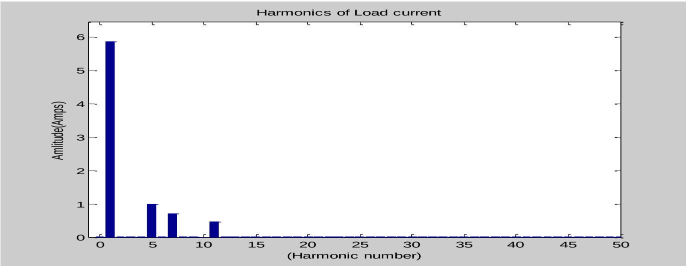

Fig. 3(b) Harmonics of Load current of Phase a

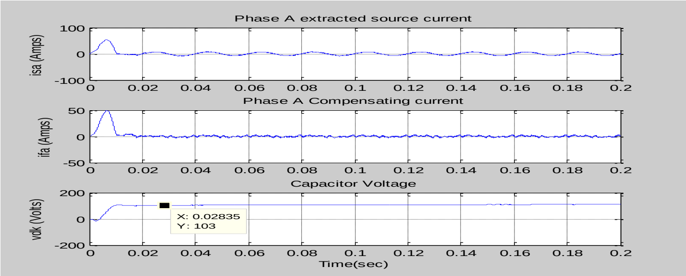

Fig. 3(c) Phase a extracted Source current, Compensating Current and DC link Capacitor Voltage

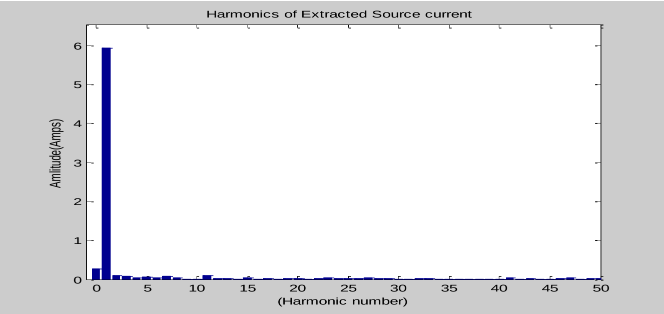

Fig. 3(d) Harmonics of extracted Source current of phase a

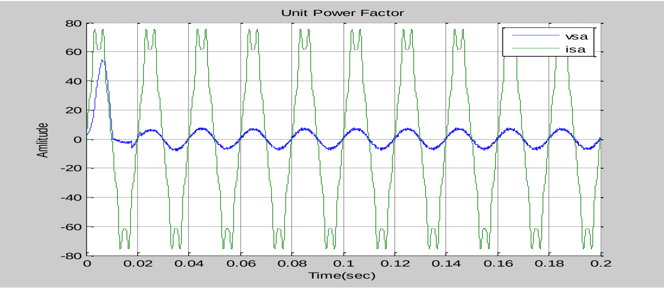

Fig. 3(e) Unit power factor of compensated load

Fig. 3 (a, b, c, d, and e) shows the dynamic performance of the system.

Table 1 Comparison

Control strategy	**THD(%) of Extracted source current**		
	CASE-1	**CASE-2**	**CASE-3**
p-q	**3.0748**	4.1519	10.7843
SRF	3.4017	4.6838	8.4101
MSRF(Id-Iq)	3.1867	**3.7313**	6.8771
ISCT	3.6914	4.2566	9.3249
AUPFT	3.6482	4.5317	14.6219
PROPOSED	3.6914	4.2566	**4.7217**

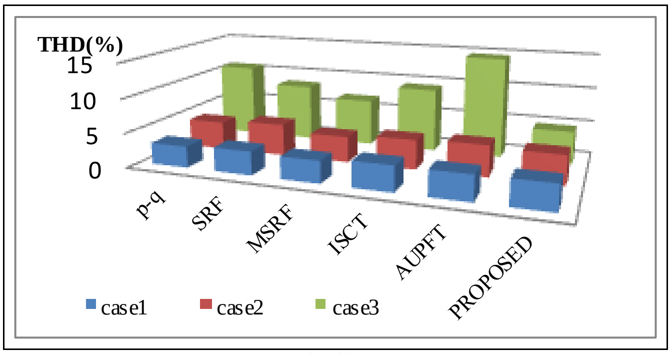

Fig. 4 Comparison of different control strategies

VI. CONCLUSION

In case1 and case2 it was observed that all strategies are working fine and able to compensate the nonlinear unbalanced load successfully and the THD obtained here are within the limit of 5% prescribed by IEEE 519. For case3 it has been found from the above comparison chart fig.4 and comparison table1 that PROPOSED control strategy has better performance than others for harmonic cancellation.

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