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Study and analysis of modified LMF control method for power quality improvement

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ABSTRACT

This paper presents a least fourth-based control method for distribution static compensator for compensation of power quality issues that are reactive power, issues of current, unbalancing loads. The direct current (DC) link voltage of distribution static compensator operated as self-supported. The control method used to extracting the tuned mass reactive and active power values of load values. They are significant divisions in source reference currents. The comparison of harmonic distraction with PI and PSO-PI controller is discussed. The proposed DSTATCOM is tested under nonlinear load condition and its working is seen as palatable. The proposed system is developed and simulated by utilizing MATLAB/Simulink with accessible sim power tool (SPS).

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1. INTRODUCTION

The different types of nonlinear loads create various quality of power problems in the source and at the PCC and this issues are causing distrotion of waveform [1]. The nonlinear loads includes varible drives speeds, power electronic devices, rectifiers with active filters and regulated power sources [2]. The devices influence the supply system due to distrbuance current flowing to the various parts in the source. Singh and Jain talked about different control methods for harmonics analysis and their effect [3]. In the way, harmonics are the essential parts of the system that are answerable and causequality of power issue. The invention of power conditioner, particularly active shunt compensator device developed for compensation of other power quality of power issues utilizing different control method [4]. The harmonic flows to supply side is discussed by different control methods [5], [6]. The Peng discussed problems of power active filter devolpment in voltage and current sort to nonlinear burdens [7]. The current crest factor (CF) connected to associated loads significantly affects the choose and devolpement of the compensator. El-Habrouk *et al.* [8] introduced a study ofpower active filters maximum utilization to various power positions and furthermore looked at converter-based setups. Some of the authors are detailed study for shunt active compensators which are three leg voltage source converter (VSC)-based, four leg VSC-based [9], three-leg equal, three-leg secluded, and two-leg measured [10]. The regulating of harmonic and reactive power a good plan and functioning active filters are to be taken as one more use to VSC [11], [12]. A functioning power filter utilized to power factor rectification or neutral voltage position is called to be distrubution static compensator (DSTATCOM). It can utilized to mitigation of load reactive power, harmonic contortion, load adjusting [13].

The functionofthe DSTATCOM, needs the suitable signals, a good control methodis required. The proposed algoritham might be planned either in time space or frequency area relying upon the kind of signal creating process. The gate signals of VSC are to be produced by separating reference source/grid current and afterward contrasting these and noticed source flows. Different arrangement and different control methods are very much made in literature [14]–[17]. These methods are, for example, Unit template, coordinated turning outline (SRF) hypothesis, momentary receptive power hypothesis (IRPT), power balance hypothesis (PBT), single PQ hypothesis, Adaline based neural organization, single DQ hypothesis and so on.

Adaptive filter method has shown its capacity to vary the climate and attributes to the characteristics of system this type of filters is utilized. The evolving climate, the filter boundaries are regulating their own way for behavior of the arrangement to the filter and climate is maintained to control its need. LMF technique is one of the good alogritham compared to the other group of the adptive filters. LMF's are used previously developed by Widrow and Wallach, they changed to the least mean square (LMS) calculation [18]. LMF technique is essentially low niose to loads other regular LMS calculation. The time consistent qualities for both the strategies are set to be equivalent. The primary objective of this calculation is to give a decreased consistent condition of djustment for the expected pace of advancing when contrasted with the LMS strategy. It has been seen that the LMS procedure can't accomplish great consistent state execution in conditions having low noise ratio, when it can be used as a low request filter adaptive. The beat of issue has been to further develop to consistent position execution system framework, a fourth-order optamization of poweris applied and it can dispense with commotion obstructions even in lower noise ratio districts [19]. Consequently, the LMF strategy goes about tolarge value of adaptive filters in that refreshing condition includes fourth order optamization of power. It seen that adaptive method same as LMF of large request snapshots to mistakes and perform good mean square error (MSE). Otherexisting LMS calculations is demonstrated in [20], [21]. MSE is a boundary that suggests a thought regarding to exhibition of mistake engaged to calculation. In addition, confirmation to steadiness to LMF strategy of various scopes tovary small/adaptive constants are likewise revealed in the authors survey [22]–[25]. The capability of LMF algoritham is to extract precise gate signals and limits the error suitably fortheproper activity of DSTATCOM. The proposed arrangement is consrtructed and developed and ssimulated in MATLAB/Simulink software for compensation of harmonics, load adjusting and reactive power mitigation.

2. SYSTEM CONFIGURATIONS

The Proposed system design as shown in Figure 1. It comprises of three phase supply with source resistance (Rs) and inductance (Ls) associated with the three-phase bridge rectifier. This VSC based DSTATCOM is connected at the PCC. The VSC converter comprise of six IGBT switches of S1-S6, direct current (DC) link capacitor of Cdc, used for keep up the DC link voltage constant. Interface inductor (Lf), ripple filters (Cf, Rf). The switching sign to IGBT switches got from control algorithm. The ripple filter is to smother high switching frequency noise.

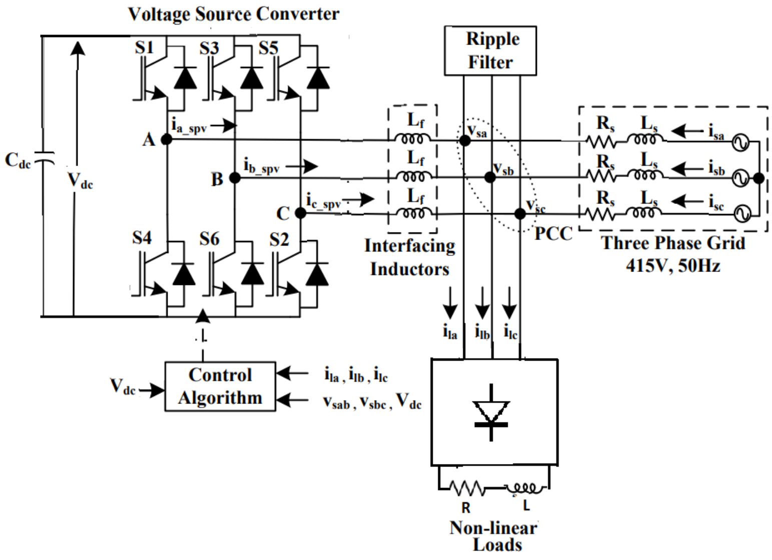


Figure 1. System configuration

3. CONTROL ALGORITHM

The LMF based control calculation is as shows Figure 2. The control method is utilized to extract the current control reference signal for exchanging of VSC-DSTATCOM for reactive power and harmonic mitigation. Voltages at PCC (Vsr, Vsy and Vsb), unit layout (u_{dr}, u_{dy}, u_{db}) and (u_{qr}, u_{qy}, u_{qb}), source currents (isr, isy, isb), load flows (iLr , iLy and iLb), VSC voltages (Vspv), VSC current (Ispv), VSC-DC link voltage (Vdc) are contributions for control method and fundamental active (mdr, mdy and mdb) as well as reactive (mqa, mqb and mqc) power parts are yields processed utilizing the control calculation. A definite numerical calculation of the control method is given as Figure 2.

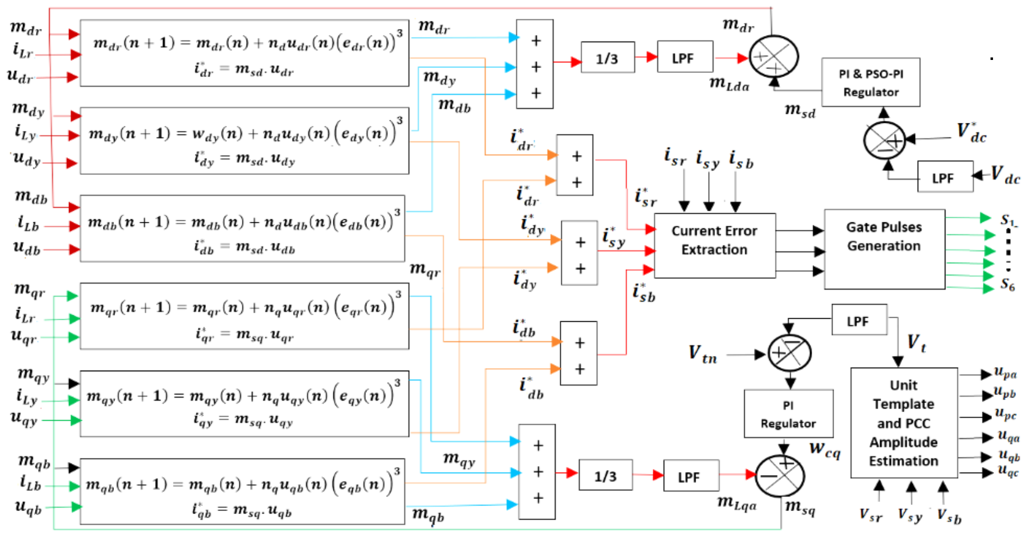


Figure 2. Proposed LMF based control method

The fundamental mass of direct load current components of the r,y and b phases is given below:

$$m_{dr}(n+1) = m_{dr}(n) + n_d u_{dr}(n)\left(e_{dr}(n)\right)^3 \quad (1)$$

$$m_{dy}(n+1) = m_{dy}(n) + n_d u_{dy}(n)\left(e_{dy}(n)\right)^3 \quad (2)$$

$$m_{db}(n+1) = m_{db}(n) + n_d u_{db}(n)\left(e_{db}(n)\right)^3 \quad (3)$$

where n_d is adaptive constant chosen approximately for getting desired results and $e_{dr}(n)$, $e_{dy}(n)$ and $e_{db}(n)$ are the adaptive error component. These adaptive error equations are:

$$e_{dr}(n) = i_{Lr}(n) - u_{dr}(n) \times m_{dr}(n) \quad (4)$$

$$e_{dy}(n) = i_{Ly}(n) - u_{dy}(n) \times m_{dy}(n) \quad (5)$$

$$e_{db}(n) = i_{Lb}(n) - u_{db}(n) \times m_{db}(n) \quad (6)$$

the $m_{dr}(n)$, $m_{dy}(n)$, $m_{db}(n)$ is the mass of direct reference components, $i_{Lr}(n)$, $i_{Ly}(n)$, $i_{Lb}(n)$ is load currents and $u_{dr}(n)$, $u_{dy}(n)$, $u_{db}(n)$ are unit values of n^{th} instant.

The mass of fundamental quadrature component of the currents of loads for phase r, y and b is given as:

$$m_{qr}(n+1) = m_{qr}(n) + n_q u_{qr}(n)\left(e_{qr}(n)\right)^3 \quad (7)$$

$$m_{qy}(n+1) = m_{qy}(n) + n_q u_{qy}(n)\left(e_{qy}(n)\right)^3 \quad (8)$$

$$m_{qb}(n+1) = m_{qb}(n) + n_q u_{qb}(n)\left(e_{qb}(n)\right)^3 \quad (9)$$

where n_p is adaptive constant chosen approximately for getting desired results and $e_{qr}(n)$, $e_{qy}(n)$ and $e_{qb}(n)$ are the adaptive error component. These equations are a given as:

$$e_{qr}(n) = i_{Lr}(n) - u_{qr}(n) \times m_{qr}(n) \quad (10)$$

$$e_{qy}(n) = i_{Ly}(n) - u_{qy}(n) \times m_{qy}(n) \quad (11)$$

$$e_{qb}(n) = i_{Lb}(n) - u_{qb}(n) \times m_{qb}(n) \quad (12)$$

where $m_{qr}(n)$, $m_{qy}(n)$, $m_{qb}(n)$ are the mass of quadrature reference components, $i_{Lr}(n)$, $i_{Ly}(n)$, $i_{Lb}(n)$are load currents and $u_{qa}(n)$, $u_{qb}(n)$, $u_{qc}(n)$ are unit values of n^{th} instant.

The loss component can be obtained by comparing the dc buss voltage (vdc) of DSTATCOM with DC link reference voltage (Vdc *). The error signal vde as given by (13).

$$\text{Vde} = \text{vdc}^* - \text{vdc} \quad (13)$$

The generated error signal is applied to the PI controller and then the loss value mcd is given as (14).

$$m_{cd}(n+1) = m_{cd}(n) + T_{pD}\big(V_{de}(n+1) - V_{de}(n)\big) + T_{iD}V_{de}(n+1) \quad (14)$$

For better selection of P&I valves of PI Controller, the P&I valves tuning is done by using PSO-PI control method.

The loss reactive component is comparing with the voltage terminal (Vt) with reference voltage terminal (Vtn). Thus, an error signal Vte is generated and applied to PI Controller. The m_{cq} is the PI controller output of loss quadrature (reactive) component. The m_{cq} are regulating the PCC.

$$m_{cq}(n+1) = m_{cq}(n) + T_{pt}\big(V_{te}(n+1) - V_{te}(n)\big) + T_{it}V_{te}(n+1) \quad (15)$$

The , T_{pt}, T_{it} proportional and integral controller's constant of PI controller.

The voltage terminal Vt is obtained from the (16).

$$V_t = \sqrt{\frac{2}{3}(V_{sr}^2 + V_{sy}^2 + V_{sb}^2)} \quad (16)$$

The in-phase unit template are calculated from the (17).

$$u_{dr} = \frac{v_{sr}}{v_t}, \quad u_{dy} = \frac{v_{sy}}{v_t}, \quad u_{db} = \frac{v_{sb}}{v_t} \quad (17)$$

The quadrature unit template is calculated from the (18) and (19).

$$u_{qr} = -\frac{u_{dy}}{\sqrt{3}} + \frac{u_{db}}{\sqrt{3}}, \quad u_{qy} = \frac{\sqrt{3}u_{dr}}{2} + \frac{u_{dy} - u_{db}}{2\sqrt{3}}, \quad u_{qb} = -\frac{\sqrt{3}u_{dr}}{2} + \frac{u_{dy} - u_{db}}{2\sqrt{3}} \quad (18)$$

$$u_{qr} = -\frac{u_{dy}}{\sqrt{3}} + \frac{u_{db}}{\sqrt{3}}, \quad u_{qy} = \frac{\sqrt{3}u_{dr}}{2} + \frac{u_{dy} - u_{db}}{2\sqrt{3}}, \quad u_{qb} = -\frac{\sqrt{3}u_{dr}}{2} + \frac{u_{dy} - u_{db}}{2\sqrt{3}} \quad (19)$$

The total grid three phase weight value of m_{sd} of reference currents is obtained using the DC bus component to fundamental active mass component.

$$m_{sd} = m_{Ld} + m_{cd} \quad (20)$$

The m_{Lda} is obtained

$$m_{Lda} = \frac{(m_{dr} + m_{dy} + m_{db})}{3} \quad (21)$$

The grid (source) active reference currents are given as:

$$i_{dr}^* = m_{sd}.u_{dr}\ ; \ \ i_{db}^* = m_{sd}.u_{dy}\ ; \ \ i_{db}^* = m_{sd}.u_{db} \quad (22)$$

The total reactive reference component of mass is m_{sq} of grid three phase grid currents is obtained by comparing the reactive average mass component fundamental loss of AC component and it is given as:

$$\mathrm{m_{sq} = m_{cq} - m_{Lqa}} \quad (23)$$

the w_{Lqa} is obtained

$$m_{Lqa} = \frac{(\mathrm{m_{qr}+m_{qy}+m_{qb}})}{3} \quad (24)$$

The PCC quadrat are reference currents is given as:

$$\mathrm{i^*_{qr} = m_{sq}.u_{qr}\ ;\ \ i^*_{qy} = m_{sq}.u_{qy}\ ;\ \ i^*_{qb} = m_{sq}.u_{qb}} \quad (25)$$

The three-phase total reference current is obtained by:

$$\mathrm{i^*_{sr} = i^*_{dr} + i^*_{qr}\ ; \qquad i^*_{sy} = i^*_{dy} + i^*_{qy}\ ; \qquad i^*_{sb} = i^*_{db} + i^*_{qb}} \quad (26)$$

The obtained total reference three phase current $\mathrm{si^*_{sr}, i^*_{sy}, i^*_{sb}}$ is verified with used PCC waveform $(\mathrm{i_{sr}, i_{sy}, i_{sb}})$ using controller of hysteresis for better gating pulses for VSC.

4. RESULTS AND DISCUSSION

The behavior of proposed DSTATCOM model with LMF control algorithm is studied by using MATLAB/Simulink Software under nonlinear load condition. The proposed system results involve PCC voltages (Vsabc), PCC currents (i_{sabc}), load currents (i_{Labc}), reference grid currents (i_s*), DC link voltage (Vdc). The results also includes study the harmonic analysis with PI and PSO-PI controller at the DC-bus.

4.1. Nonlinear load without DSTATCOM

Figure 3 (in Appendix) shows the wave form of the three phase PCC voltage, three phase PCC current and harmonic distortion analysis, when nonlinear load connected to the distribution. The connected nonlinear load introduces harmonics in the current wave form at the PCC as observed in the Figure 3(b). The active and reactive power of source, DSTATCOM as well as Load is observed in the form Figures 3(c)-3(e). The total harmonics distortion is 29.75% as shown in Figure 3(f).

4.2. LMF based controled DSTATCOM

By connecting the DSTATCOM at the PCC with the proposed LMF based controlled algorithm the harmonic and reactive power is compensated as shown in Figure 4 (see Appendix). Figure 4(a) shows the wave form of the three phase PCC voltage, Figure 4(b). Shows the compensated three phases PCC current wave form, and the harmonic distortion analysis of the PCC current waveform as shown in Figure 4(f). The order of the harmonic order is reduced from 29.75% to 1.93. The active and reactive power of source, inverter, Load is observed from Figures 4(c)-(e).

4.3. PSO-PI LMF based controled DSTATCOM

The tuning of PI valves of PI controller of DC bus voltage of the proposed LMF based controlled DSTATCOM is done by using PSO method. With PSO-PI LMF based controlled DSTATCOM better harmonic compensation is obtained as shown in Figure 5 (see Appendix). Figure 5(a) shows the wave form of the three phase PCC voltage, Figure 5(b). Shows the compensated three phases PCC current wave form, and the harmonic distortion analysis of the PCC current waveform as shown in Figure 5(c). The order of the harmonic order is reduced from 29.75% to 0.59%.

5. CONCLUSION

The development of the proposed LMF control method was shown through the simulation for mitigation of nonlinear loads with VSC based DSTATCOM. Thecontrol method calculationhas been utilized for the getting of tuned esteem reactive and activepower components of load currentflows to estimate reference source current with flexible error components. The obtainedsource references currentsare utilized to give switching signals to VSC based DSTATCOM. A DSTATCOM, used for reactive power compensation, harmonics suppress and load adjusting, are exhibited at PCC. And furthermore with PSO-PI controlleris giving better performance as compared with the ordinary PI controller. In view of the execution results, it has conculded thatthedeveloped control method of DSTATCOM had better shape for source current equal to sinusoidal and adjusted to unity power factor.

APPENDIX

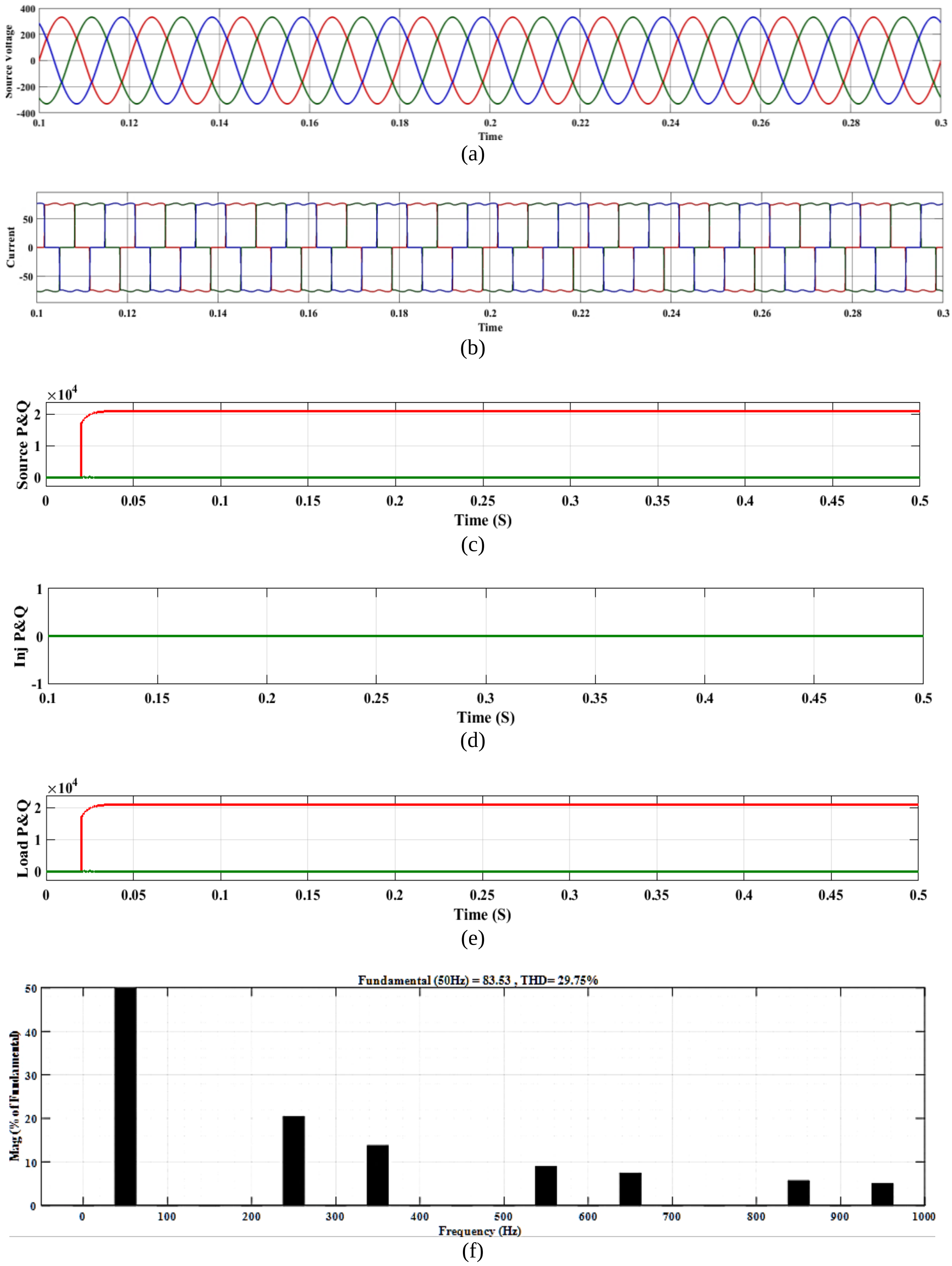
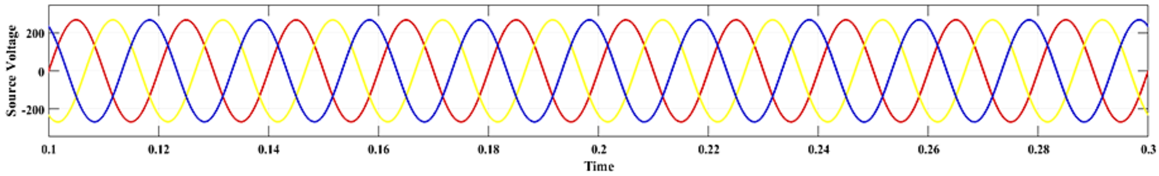
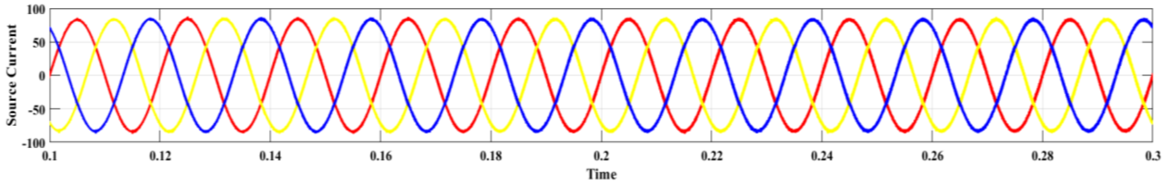


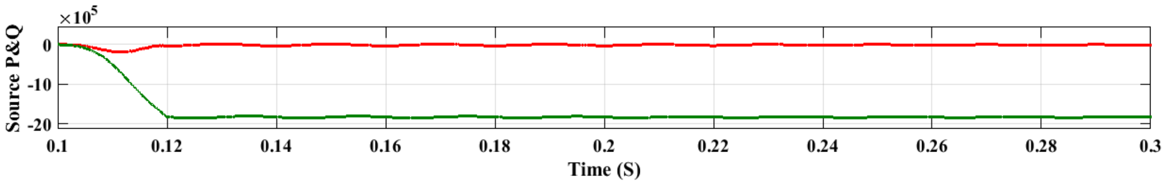
Figure 3. Simulation results of three phase three wire nonlinear load without DSTATCOM: (a) PCC voltage, (b) PCC current, (c) source active power & reactive power, (d) injected active power & reactive power, (e) load active power & reactive power, and (f) harmonic distortion, under nonlinear load condition without DSTATCOM



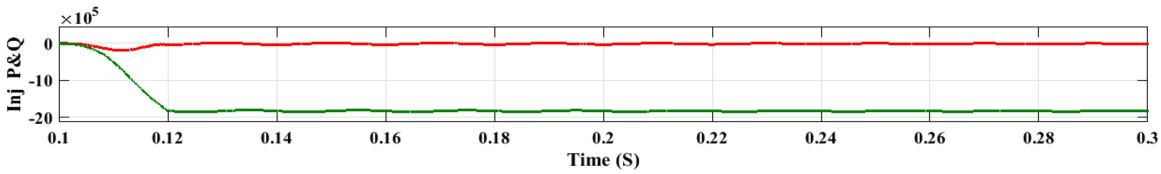
(a)



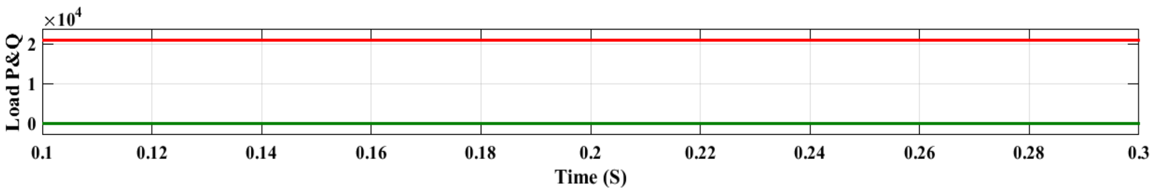
(b)



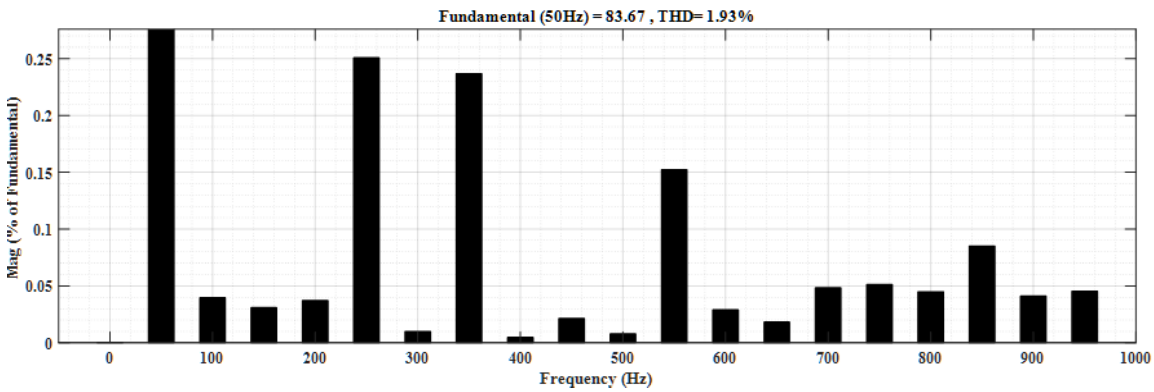
(c)



(d)

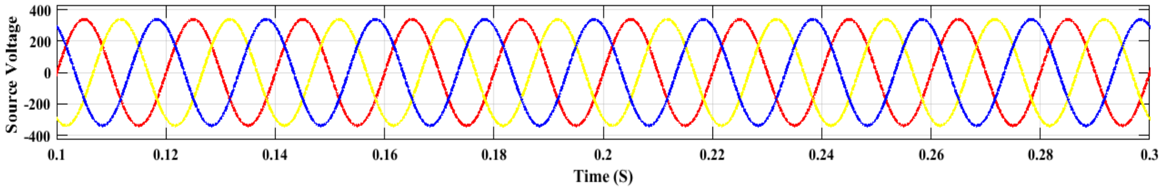


(e)

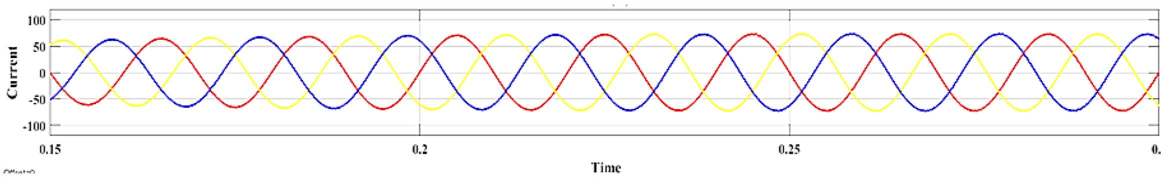


(f)

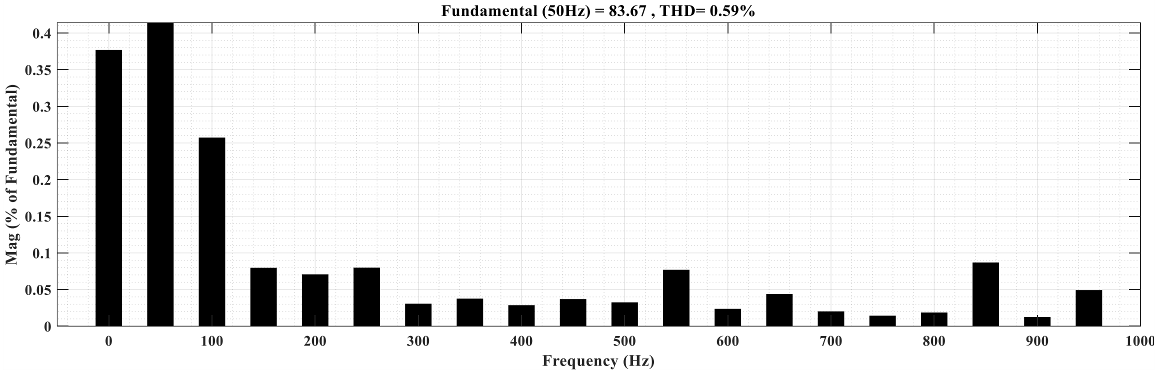
Figure 4. Simulation results of three phase three wire nonlinear load with PI controlled DSTATCOM: (a) PCC voltage, (b) PCC current, (c) source active power & reactive power, (d) injected active power & reactive power, (e) load active power & reactive power and (f) harmonic distortion, nonlinear load condition with PI controlled DSTATCOM



(a)



(b)



(c)

Figure 5. Simulation results of three phase three wire nonlinear load with PSO-PI controlled DSTATCOM: (a) PCC voltage, (b) PCC current, and (c) harmonic distortion under nonlinear load condition with LMS based PSO-PI controlled DSTATCOM

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