U.P.B. Sci. Bull., Series C, Vol. 77, Iss. 3, 2015 ISSN 2286-3540

A NOVEL REFERENCE CURRENT GENERATION METHOD OF PV BASED THREE LEVEL NPC SHUNT ACTIVE POWER FILTER

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This paper proposes a new reference current calculation method for the PV based three level Neutral Point Clamped (NPC) shunt active power filter. The shunt active power filter demands a source of energy for compensating the current based distortions, which utilizes the photovoltaic array with DC-DC boost converter as a source of DC power. The shunt connected inverter controls the DC- link voltage as well as the active and reactive power transferred between the renewable energy sources to grid with improved power quality. The main benefits of the proposed system are that it will provide uninterrupted compensation for the whole day and compensate the voltage interruption. This system utilizes the renewable energy and accordingly saves the energy , shares the load and provides uninterruptable power supply to critical/sensitive load, through the PV array/battery bank during day and night.The proposed controller is based on the use of High Selectivity Filter (HSF) for reference current generations. In addition the fuzzy logic controller is implemented for better current control accuracy of shunt active filter.To maintain the constant DC link voltage and compensate the power losses of the voltage source inverter a PI controller is used in the outer control loop.The gating signals were generated through the carrier based Sinusoidal PWM (SPWM) technique.A simulation study of the proposed topology has been carried out in the MATLAB/Simulink environment and results are presented to confirm the effectiveness of the proposed configuration.

Keywords: Photovoltaic array, High step-up DC-DC boost converter, Three-level NPC Voltage source inverter, Reference current generation,Total Harmonic Distortion

1. Introduction

With the Proliferation of power electronic converters are ever increasing in the processingof electrical energy in industrial applications like as adjustable-speed motor drives, electronic power supplies, direct current motor drives, battery chargers, etc. These devices are non-linear loads which draw nonlinear currents from the source and degraded the power quality (PQ) in the power distribution network [1]. The severe power quality problems occurred in the distribution feeders are such as flicker, resonance and interference with electronic equipment,

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losses and heating in transmission lines, vibrations and noise in motors, malfunction and failures of metering/sensitive equipments. The several Custom power devices have been proposed for enhancing the power quality and reliability of electrical power. Initially, passive filters with tuned *LC* components have been mostly used to suppress harmonic current becauseof its low initial cost, simple in configuration and high efficiency[2, 3].However, passive filters have many drawbacks such as fixed compensation, large size, parallel and series resonance with load, and utility impedances [4]. All the above mentioned drawbacks of passive filters can be overcome by using active power filters (APFs) [5, 6] for the harmonic elimination and reactive power compensation. Active power filters can be classified as a series or shunt according to their system configuration. The combination of series and shunt active power filters is called the unified power-quality compensator (UPQC). The Shunt active filter is one of the most important corrective measures to solve source current harmonic problems [7].

The shunt active power filter is connected in parallel to the load and it generatesthe compensation current opposes to the load harmonic current. In recent years, multilevel Neutral Point Clamped (NPC) inverters are becoming increasingly popular in the active power filter application environment. This is due to the advantages obtained from these topologies, together with the low harmonic distortion of the voltage and current generated, the size of required filter elements are small, the higher efficiency of the system, the low *dv/dt*, the reduced common-mode voltages and less electromagnetic interference [8]. The performances of an active filtertopologies mainly depend on the reference current generation method, since any inaccuracy in the reference currents yields toincorrect compensation [9].The various methods have been used to determine the reference current of the SAPF in the literature [10], can be categorized in frequency domain or time domain methods. The time domain methods require lesser computations compared to the frequency domain methods.One of the most commonly used method is based on the conventional instantaneous reactive power theory or *p-q* theory[11]. However, the identification of the harmonic components with the *p-q* theory mainly depends on the quality of voltage of the electrical power system. The SAPF schemes based on the *p-q* theorythus need the voltage components and this is conventionally done with a PLL (Phase Locked Loop) system [12].But, this theory requires a number of transformations. However, these transformations mostly consider the electrical system in balanced conditions which is not the real condition of electric networks. To overcome this problem the proposed control strategy used is based on a modified version of *p-q* theory using two HSFs to extract the fundamental component directly from electrical signals (voltage and current) in $\alpha - \beta$ reference frame. In this method, the HSF has been used instead of classical harmonic extraction based on high pass filters (HPF) or low pass filters (LPF). After the efficient extraction of the reference current, anappropriate SAPF currents controller is used to maintain the active power filter currents at the imposed reference value[13,14].

Various control approaches, such as the PI, PID, sliding-mode controllers, etc., are used by many authours in several works. However, the PI controller requires a specific linear mathematical model, which is complicated to obtain and may not give acceptable performance under different conditions such as parameter variations, unbalanced or distorted AC voltages, etc.The fuzzy logic controllers have advantages over the PI controller such as: it does not need aprecise mathematical model; it can work with imprecise inputs, it can handle nonlinearity and it is more robust than the PI controller [15,16]. This paper extends the use of the proposed HSF within the SAPF based on a three-level inverter for a three-phase distribution system under the unbalanced conditions.

The main objectives of this paper are to maintain the DC link voltage of the three level neutral point clamped (NPC) parallel connected inverter to provide uninterrupted compensation, utilizes the renewable energy, shares the load and provides the uninterruptable power supply to critical/sensitive load. The photovoltaic (PV) array is used to drive the High step-up DC-DC boost converter to step-up the voltage and maintain the DC-link voltage as constant. The PV array is connected to the boost converter in day time for continuous compensation and shares the load to the distribution system. During the night time, the battery will act as a DC source for the boost converter.This power only is used for compensation. When the compensation is not required for the system or excess power generated from the PV array, it charges the battery. The proposed system also eliminates the requirement of UPS and stabilizers for the individual equipments. In order to achieve the optimal utilization of PV system, a low step-up DC–DC converter associated with a function called MPPT is introduced between the PV array and battery. The simulation and experimental results are presented to validate the proposed method.

The remainder of this paperis organized as follows. Section 2 of this work presents a design of the three-level SAPF. In section 3, modeling of PV array is discussed,In section 4, the generation of the compensating currents with modified version of the *p-q* theory and fuzzy-logic current controller are clearly presented.In Section 5, the simulation results of the proposed system.Finally, the conclusions regarding this contribution are summarized in Section 6.

2. Design of Three Level NPC Shunt Active Power Filter

The current harmonics elimination is achieved in the shunt active power filter by the injection of equal but opposite phase of the harmonic components of the nonlinear load current at the PCC, accordingly it makes the source current in phase with the source voltage.

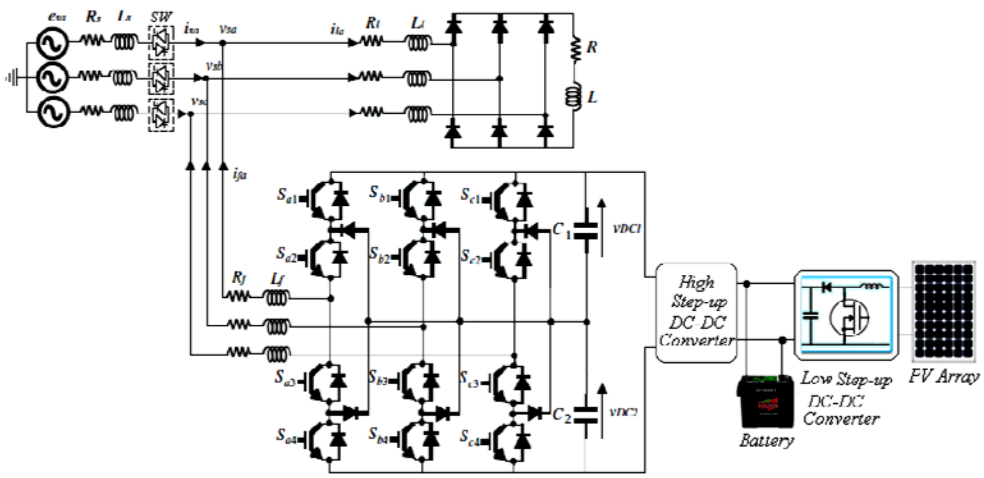


Fig. 1. PV based Neutral Point Clamped shunt active power filter configuration

The proposed PV based shunt active power filter configuration is shown in Fig.1 For three-level NPC inverter, each leg is constituted by four controllable switches ($Sx1 - Sx4$) , where x is specified phase (a , b , or c), with two clamping diodes. If we consider that two capacitor voltages v_{DC1} and v_{DC2} in the DC link are equal, three voltage levels (0, $v_{DC}/2$and $- v_{DC}/2$) are generated on the AC terminal output of the proposed inverter.

Table 1

Switching states of 3 level NPC inverter

C_x	S_{x1}	S_{x2}	S_{x3}	S_{x4}	v_{fx}
1	1	1	0	0	$v_{DC}/2$
0	0	1	1	0	0
-1	0	0	1	1	$- v_{DC}/2$

It is assumed that the upper-leg and lower-leg capacitor voltages are identical, with the value $v_{DC}/2$ each. In this case, the phase-to-midpoint voltage of each phase can be defined as:

$$v_{fx} = C_x v_{DC} / 2 \tag{1}$$

Where x is thephase index, $x = a,b, c$; $C_x$is the state variable, C_x= 1, 0, -1 and corresponding to the three- levels are $v_{DC}/2$, 0 and $- v_{DC}/2$.

Then, the phase-to-neutral voltage of the inverter can be given as:

$$v_{fa} = \frac{v_{DC}}{3}\left(C_a - \frac{C_b}{2} - \frac{C_c}{2}\right) \tag{2}$$

$$v_{fb} = \frac{v_{DC}}{3}\left(C_b - \frac{C_a}{2} - \frac{C_c}{2}\right) \tag{3}$$

$$v_{fc} = \frac{v_{DC}}{3}\left(C_c - \frac{C_a}{2} - \frac{C_b}{2}\right) \tag{4}$$

The proposed PV-SAPF operation has been divided into three modes of operation. The modes are (i) Inverter mode (ii) Compensator mode (iii) UPS mode.

3. Modelling of Photovoltaic array

The PV array is the whole power generating unit , containing more number of solar panels to convert sunlight into electricity. The developments of efficient solar panels with MPPT algorithm have increased the usage of solar panels as an alternative source of renewable energy conversion. In the proposed system, PV array with DC-DC boost converter joined with a function called MPPT is incorporated to work as a DC voltage source for the shunt inverter. The electrical system powered by the PV array requires DC-DC converter because of the varying nature of the generated solar powered energy, caused by sudden changes in weather conditions, which modify the solar irradiation level along with cell operating temperature. The equivalent circuit model of photovoltaic array with DC-DC boost converter is shown in Fig.2.

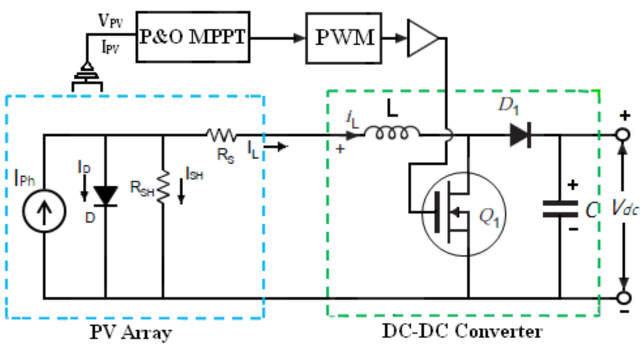


Fig. 2 .equivalent circuit model of photovoltaic array with DC-DC boost converter

The PV array model is developed by the basic equations of photovoltaic cells including the effects of temperature changes and solar irradiation level [17-19].

The output voltage of the PV cell is a function of photo current that is normally determined by load current depending on the solar irradiation level. The PV cell output voltage is expressed as

$$V_C = \frac{AkT_C}{e}\ln\left(\frac{I_{ph} + I_0 - I_c}{I_0}\right) - R_S I_C \tag{5}$$

$$V_{PV} = V_C \times N_S \tag{6}$$

$$I_C = \frac{I_{PV}}{N_P} \tag{7}$$

where, $e$is the charge the of electron $(1.602 \times 10^{-19} c)$, V_c is the output voltage of PV cell in volts ,A is curve fitting factor (0.001) , I_{Ph} is the photo current in A, $I_0$is thereverse saturation current of diode, k is Boltzmann constant $(1.38 \times 10^{-23} J /^0 k)$, $T_c$is the operating temperature of the reference cell (25 ^{0}c), $I_c$is the cell output current in Ampere, R_s is the cell internal resistance (0.001 Ω), $V_{pv}$is the output voltage of PV array, $I_{PV}$is the output current of the PV array, N_s is the number of series cell and $N_p$is the number of parallel cells.

The design parameters I_{ph}, I_o, R_s and T_c are determined from the data sheet and I-V characteristics of the PV array. The curve fitting factor A is used to adjust I-V characteristics of the cell to the actual characteristics obtained by the testing.

4.Proposed Control Scheme

The proposed control structure of the three-level shunt active power filter comprises of four basic elements: To identify the harmonic current and form a synchronised reference, Generation of the gate signal of the active power filter , Provide closed-loop control to force the filter current to follow the reference and To regulate the DC capacitor voltage of SAPF to maintain the DC voltage at a constant value.

4.1 Calculation of Reference Currents

In order to control the SAPF to supply a current that is equal to the amplitude and opposite in direction of the load current, a reference current was required. In this control scheme the reference current signal is derived from the measured quantities by the utilization of the instantaneous reactive power theory associated with 2 HSFs. The key steps of this approach are summarized in the simplified block diagram shown inFig. 3. The reference currents are identified by using a modified version of the instantaneous active and reactive power theory.We used HSF in place of classical harmonic extraction based on High Pass Filters (HPF) or low pass filters (LPF). The HSF is focused on to extract the fundamental component directly from unbalanced electrical signals (voltage or current) in α - β reference frame.

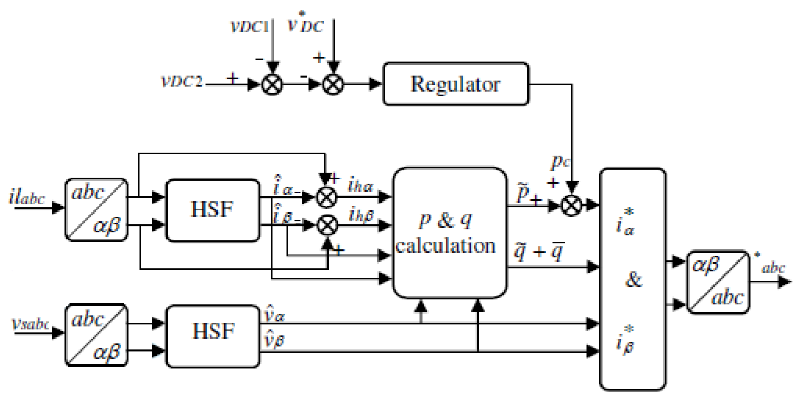


Fig. 3. Block diagram of proposed controller

Based on the instantaneous reactive power theory, the system voltage and the load current are transformed from *a* -*b* -*c* coordinates into α - β coordinates using the transformations (17) and (18) [20-22]:

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

$$\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} i_{la} \\ i_{lb} \\ i_{lc} \end{bmatrix} \tag{9}$$

The alternating components of the instantaneous real and imaginary power are identified by:

$$\begin{bmatrix} \tilde{p} \\ \tilde{q} \end{bmatrix} = \begin{bmatrix} \hat{v}_\alpha & \hat{v}_\beta \\ -\hat{v}_\beta & \hat{v}_\alpha \end{bmatrix} \begin{bmatrix} i_{h\alpha} \\ i_{h\beta} \end{bmatrix} \tag{10}$$

Fundamental component of the instantaneous imaginary power is given as follows

$$\bar{q} = \hat{v}_\beta \tilde{i}_\alpha - \hat{v}_\alpha \tilde{i}_\beta \tag{11}$$

After adding the active power required for regulating DC bus voltage, p_c, to the alternative component of the instantaneous real power, $\tilde{p}$, the current references in the α -β reference frame are calculated:

$$i^*_\alpha = \frac{\hat{v}_\alpha}{\hat{v}^2_\alpha + \hat{v}^2_\beta}\left(\tilde{p} + p_c\right) - \frac{\hat{v}_\beta}{\hat{v}^2_\alpha + \hat{v}^2_\beta}\left(\tilde{q} + \overline{q}\right) \tag{12}$$

$$i^*_\beta = \frac{\hat{v}_\beta}{\hat{v}^2_\alpha + \hat{v}^2_\beta}\left(\tilde{p} + p_c\right) - \frac{\hat{v}_\alpha}{\hat{v}^2_\alpha + \hat{v}^2_\beta}\left(\tilde{q} + \overline{q}\right) \tag{13}$$

In order to acquire the reference compensation currents in the *a*-*b* -*c*co-ordinates, the inverse of thetransformation given in expression (17) is used as follows:

$$\begin{bmatrix} i^*_a \\ i^*_b \\ i^*_c \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & 0 \\ -\frac{1}{2} & \frac{\sqrt{3}}{2} \\ -\frac{1}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} i^*_\alpha \\ i^*_\beta \end{bmatrix} \tag{14}$$

4.2 SAPF Gating Signals Generation

The performances of SAPF will depend essentially on the type of modulation and adopted current controller. The several modulation strategies have been proposed for multilevel converters in three-phase system. The modulation techniques are normally divided into two main categories. The first technique is based on hysteresis comparators, which is characterized by a very simple and easy to implement, moreover, it has the disadvantage of uncontrollable switching frequency. The next technique is based on pulse width modulation (PWM), which allows operating at a fixed switching frequency such as for example Sinusoidal Pulse Width Modulation (SPWM) and Space Vector Modulation (SVM).

In this proposed system, the carrier-based Sinusoidal Pulse Width Modulation is used to generate the appropriate switching signals of the power switches, since it has the advantage of making significantly simpler the calculation process and due to their operation at fixed switching frequency [23,24].The switching SPWM pulses are generated by subtracting the filter currents (i_{fa},i_{fb},i_{fc}) with the reference currents(i_a^*, i_b^*, i_c^*).The resulting error(e)($e = i^* - i_f$) is sent to a fuzzy logic controller. Then the output signal of the fuzzy logic controller is compared with a two triangular carrier bipolar signals shown in Fig.4. The comparison result is sent to the combinational logic circuit for the switching devices. Here, the gating signals generator has three inputs: $\Delta i_f = i^* - i_f$(corresponding to Δi_{fa}, $\Delta i_{fb}$and Δi_{fc}), the first carrier-signalC_{s1} ,and the second carrier-signal C_{s2} .

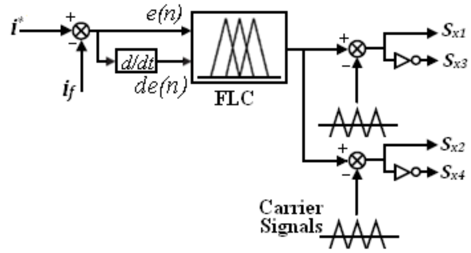


Fig. 4. Gate signal generating scheme

Intially, we have to determine the intermediate signalsT_1 ,T_2 and T_3 as follows:
• if $\Delta if \geq Cs_1$, then $T_1 = 1$, else $T_1 = 0$;
• if $\Delta if \geq Cs_2$, then $T_2 = 0$, else $T_2 = -1$;
• $T_3 = T_1 + T_2$.

After that, we obtain the switching function of the two switches S_{x1} and S_{x2} of the upper leg $x(x = a,b,c)$, the two other legs have switching signals delayed of 120° compared to the first one, and the lower half bridge contains the complementary switches.

4.3Proposed Fuzzy Control Scheme

The current control loop is responsible for controlling the active power filter currents in the proposed control scheme circuit such that the current will try to be the same as the current reference. For this purpose, we are interested to control the active power filter current by a fuzzy controller as shown in Fig.5. In our application, the fuzzy controller has two inputs: the difference between the injected current and the reference current is error(e) ($e = i^{*} - i_f$) and the derivation of the error (de) while the output is the command (cde).

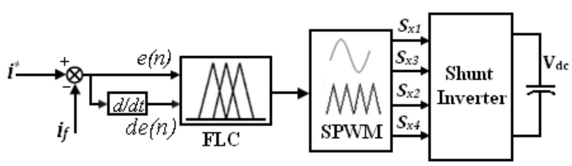


Fig. 5. Fuzzy logic controller scheme

We choose three fuzzy sets for each of the two inputs (e , de) with gaussian membership functions, and five fuzzy sets for the output with triangular membership functions. For this, each linguistic variable (e,de,cde) is characterisedby five terms of fuzzy subsets: Negative big (NB),Negative(N),zero(ZE),Positive (P),Positive big (PB).

The fuzzy controller uses the following five simplified rules:
1. If (e) is zero (ZE), then (cde) is zero (ZE).
2. If (e) is positive (P), then (cde) is big positive (BP).
3. If (e) is negative (N), then (cde) is big negative (BN).

4. If (*e*) is zero (ZE) and *(de)* is positive (P), then *(cde*) is negative (N).
5. If (*e*) is zero (ZE) and *(de)* is negative (N), then *(cde*) is positive (P).

The inference engine output variables are converted into the crisp values in the defuzzification stage. Various defuzzification algorithms have been proposed in the literature. In this paper, the centroid defuzzification algorithm is used, in which the crisp value is calculated as the centre of gravity of the membership function 5.

Table 2

Parameters of the Simualtion Model

Description	**Parameter**	**Value**
AC Supply	Nominal Line Voltage	400 V
	Frequency	50 Hz
Reactor	Inductance	38 mH
DC Bus	Voltage	520 V
Battery Bank	Nominal Voltage	2×12 V
	Capacity	180 Ah
Low Step-up DC-DC Converter	Inductance	0.716 μH
	Switching frequency	20 kHz
	Nominal Voltage	12 V
	Maximum Power	2000 W
	Vmp	27.22 V
	Imp	73.47 A
	Open Circuit Voltage	32.67 V
	Short Circuit Current	80.08 A
High Step-up DC-DC Converter	Inductance	L_m=48 μH, L_k=0.25 μH
	Switching frequency	25 kHz
	Capacitance	C_1=3.151 μF /100V, C_2= C_3=1.062 μF /200 V, C_o=500 μF/450 V

5. Simulation results

In this paper, the proposed control scheme based on a modified version of p-q theory using a HSF for the PV based SAPF is evaluated using Matlab/Simulink software under unbalanced and distorted load-current and source-voltage conditions. In the simulation studies, the results are specified before and after the operation of the PV based three level SAPF system. The simulation study was conducted under three different conditions are balanced voltages with balanced loads, balanced voltages with unbalanced loads and unbalanced voltages with unbalanced loads. The system parameters of the simulation study is shown in Table 2. The comprehensive simulation results are presented below.

5.1 Balanced Voltages with Balanced Loads

Fig.6 Shows the simulation results of load currents($\boldsymbol{i}_{labc}$), source currents($\boldsymbol{i}_{sabc}$),active filter currents($\boldsymbol{i}_{fabc}$), inverter output line voltage, and source voltage($\boldsymbol{e}_{sa}$) superimposed by the source current($\boldsymbol{i}_{sa}$) of the proposed system for the case of balanced condition.Fig.6 (e) shows the source current($\boldsymbol{i}_{sa}$) after the compensation, from this result examined that the source current is in phase with source voltage($\boldsymbol{e}_{sa}$) confirming that the compensation is being done correctly.

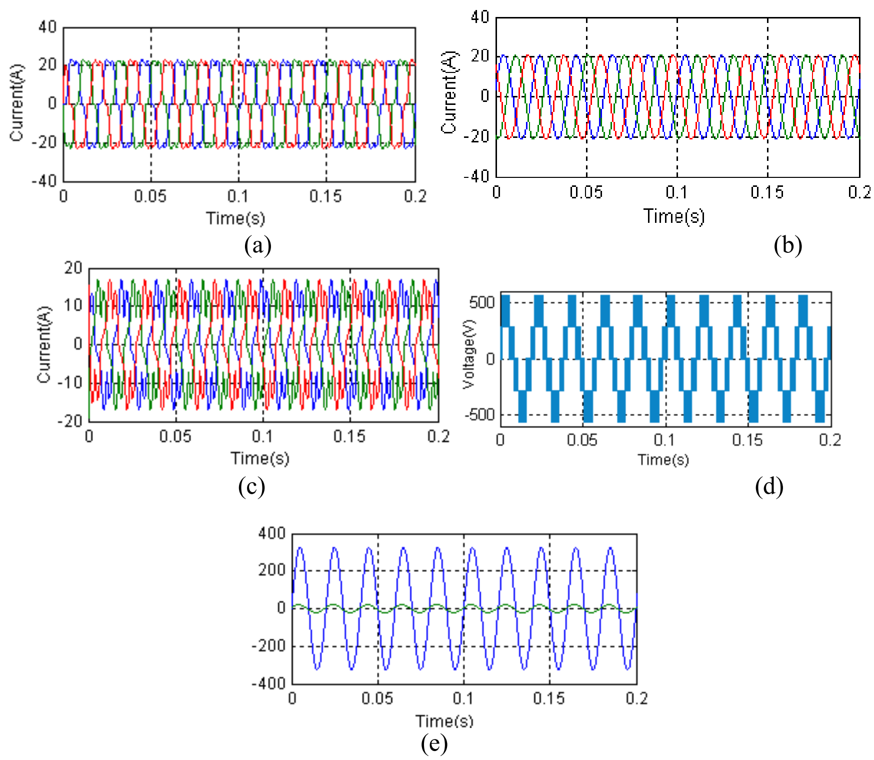
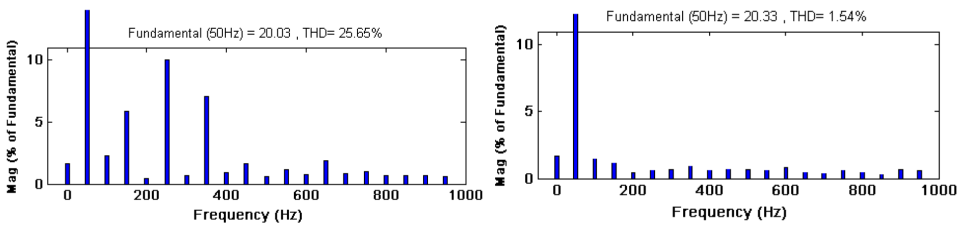


Fig. 6.Simulation results under balanced voltages with balanced loads: (a) load currents($\boldsymbol{i}_{labc}$) (b) source currents($\boldsymbol{i}_{sabc}$) (c) active filter currents($\boldsymbol{i}_{fabc}$) (d) inverter output line voltage (e) source voltage($\boldsymbol{e}_{sa}$) superimposed by the source current($\boldsymbol{i}_{sa}$).

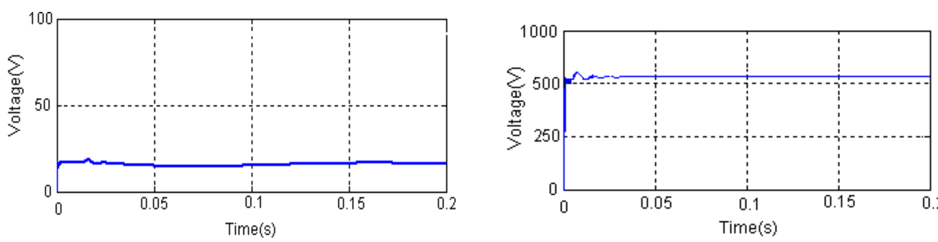
The harmonic analysis of the source current before and after compensation in phase “a” are shown in Fig.7(a) and 7(b) respectively. Before compensation, the measured THD level of the source current in phase “a” was 25.65% ; after compensation, the THD level of the source current is about 1.54% , which is well within the limit specified by IEEE Std. 519-1992 .



(a) (b)

Fig. 7. THD levels of source current (a) THD level of souce current before compensation in phase ‘a’ (b) THD level of souce current after compensation in phase ‘a’.

Fig. 8 shows the PV array output voltage and high step-up DC–DC converter output voltage. A control circuit is incorporated with the proposed high step-up DC-DC converterto regulate the output voltage at 520 V.The DC-link voltages, v_{DC1} and v_{DC2} must be maintained almost as a constant value within certain limits in order to provide energy to generate the required harmonic compensation current from the shunt active filter. Fig. 9 shows the discharge characteristic of the battery for various current outputs. From the characteristics, it is observed that the battery can feed 60 A for 8 hours duration.



(a) (b)

Fig. 8.PV array output voltage and high step-up DC–DC converter output voltage.

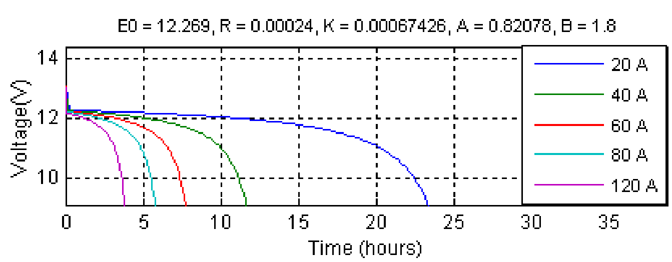


Fig. 9. Discharge characteristics of the battery for various output currents

5.2 Balanced Voltages with Unbalanced Loads

In this case, the load currents are unbalanced by connecting a single phase diode rectifier connected between two phases. Fig.10 Shows the simulation results of load currents($\boldsymbol{i}_{labc}$), source currents($\boldsymbol{i}_{sabc}$),active filter currents($\boldsymbol{i}_{fabc}$), and source voltage(e_{sa}) superimposed by the source current(i_{sa}). THD level of the three phase currents before installing the active power filter are 25.7%,26.61% and 26.71% respectively.

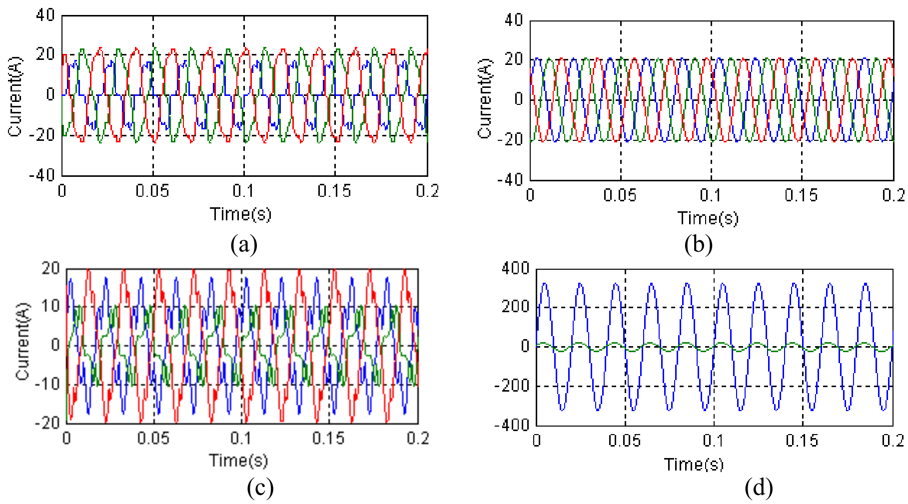


Fig. 10.Simulation results under balanced voltages with unbalanced loads: (a) load currents(i_{labc}) (b) source currents(i_{sabc}) (c) active filter currents(i_{fabc}) (d) source voltage(e_{sa}) superimposed by the source current(i_{sa}).

The harmonic spectrum of the source current in phase "a" after installing the active power filter with modified *p-q* theory is shown in Fig.11. The THD level has reduced to 2.02%,1.82% and 1.74% in phase "a", "b" and "c" respectively. In addition, the source current is in phase with the source voltage so that the power factor is equal to one as shown in Fig.10(d).

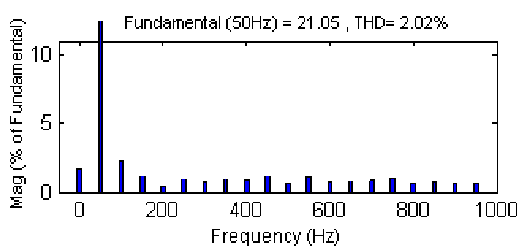


Fig. 11. THD level of souce current after compensation in phase 'a'.

5.3 Unbalanced Voltages with Unbalanced Loads

For evaluating the performance of the SAPF under the unbalanced voltages with unbalanced loads, the previous unbalanced non-linear load is fed by unbalanced AC voltages. The unbalanced source voltages(e_{sabc}), unbalanced load currents(i_{labc}), source currents(i_{sabc}),active filter currents(i_{fabc}) and source voltage(e_{sa}) superimposed by the source current(i_{sa}) are depicted in Fig. 12.

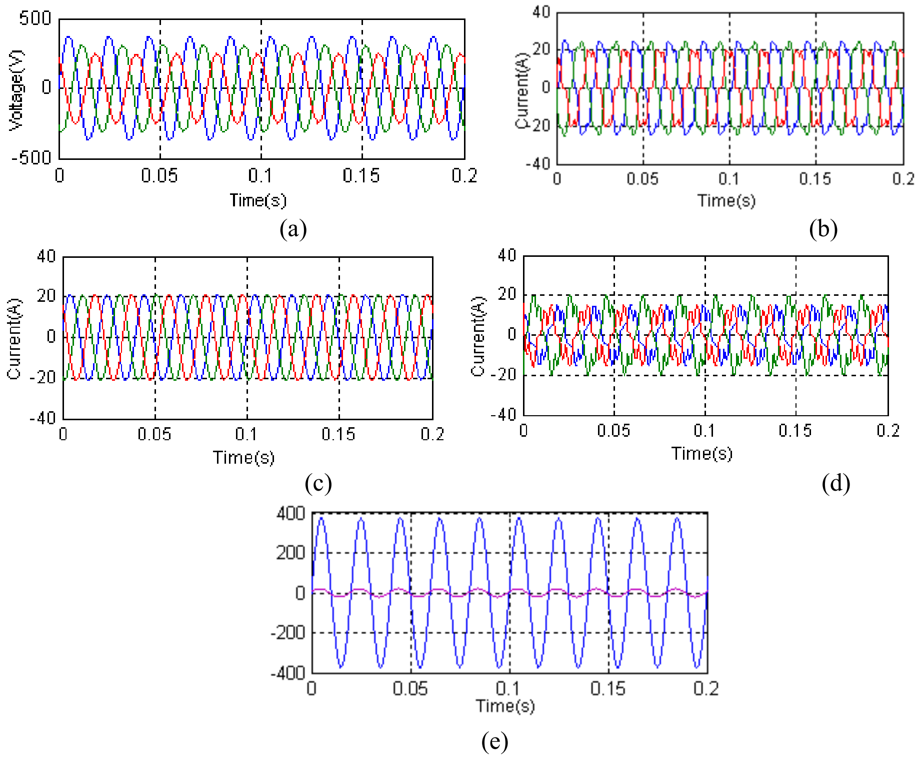


Fig. 12.Simulation results under unbalanced voltages with unbalanced loads: (a) unbalanced source voltages($\boldsymbol{e_{sabc}}$) (b) load currents($\boldsymbol{i_{labc}}$) (c) source currents($\boldsymbol{i_{sabc}}$) (d) active filter currents($\boldsymbol{i_{fabc}}$) (e) source voltage($\boldsymbol{e_{sa}}$) superimposed by the source current($\boldsymbol{i_{sa}}$).

The results shown in Fig.18 confirm that the PV based SAPF system is able to improve the power quality.

As shown in Fig. 12(c), it is evident that three phase source currents are balanced and sinusoidal after compensation, with power factor close to the unity, as can be observed in Fig.12(e). The frequency analyses of the source current after compensation in phase "a" is shown in Fig.13. The THD of the source currents before compensation are 22.53%, 26.11% and 30.64%; and are reduced to 2.12%, 1.87% and 1.83% after compensation respectively.

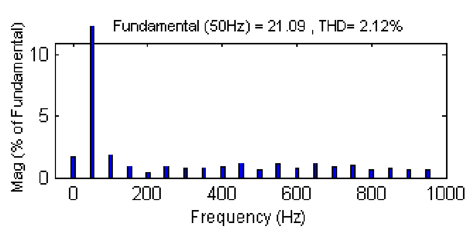


Fig. 13. Frequency analyses of the source current after compensation in phase "a"

Simulation results show that the proposed control strategy compensates harmonic components as well as most of the other unbalanced load current distortion in electric power systems with three-phase four-wire.

6. Conclusions

This paper investigates a new reference current generation approach based on modified version of the p–q theory using a high selectivity filter. This approach is proposed in the PV based three level SAPF for current based compensation, reactive power and voltage interruption compensation at residence or small industry. A DC–DC converter with P&O MPPT algorithm is implemented to track the maximum power point of the PV array. Additionally, fuzzy logic controller is introduced for controlling compensation currents of the shunt active power filter.This novel PV- three level shunt active power filter is designed to reduce the energy consumption from the utility grid by sharing the common load, when the PV array generates required real power to meet the load demand. The added advantages of the system are: reducing the panel tariff and avoiding the use of UPS and power quality conditioner for the individual equipment at a residence, small industry and educational institution. The simulation results show that, when under balanced ,unbalanced and non-linear load conditions, the proposed control scheme eliminates the impact of distortion and unbalance of the load current on the power system.

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