A Grid-Tied Solar Power System with Harmonic Filter to Enhance Power Quality

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Abstract: *This paper examines two performance analyzes Stage photovoltaic (PV) system integrated with shunt Active harmonic filter (SAHF). In the recent industrial revolution Distributed generation systems are affected by current harmonics Problems due to the widespread use of non-linear loads. The shunt Active harmonic filter system has harmonic relaxation, power factor correction, and load balancing. shunt Active harmonic filter system 3 leg voltage source converter and extracted DC current From the PV module. In this two-layer system, the first layer is Maximum mounted DC-DC boost converter Maximum power point tracking (MPPT) algorithm. To extract the maximum performance P & O algorithm is used. Extraction Reference current is obtained by PI controller and hysteresis A current regulator is used to control the PWM-VSI. Predict PV-based SAHF is implemented under the load of a diode rectifier Attenuates harmonics and reactive power*

Keywords: **P&O algorithm based MPPT; hysteresis controller; instantaneous real power theory; PV system grid integration; power quality.**

1. INTRODUCTION

Fossil fuels have been a major source of energy for many years, but they have some problems because they are finite, depleted and non-recyclable. They also make It pollutes and leads to global threats such as global warming. Therefore, the global trend is to shift generations to cleaner and more sustainable technologies as they grow [1]-[3]. Due to the advancement and popularity of PV-based systems as an alternative to traditional energy sources, PV-based systems are widely used in a variety of applications. As power electronics devices and non-linear loads become more prevalent, harmonics are introduced into the system. According to the IEEE standard 512-2014, most electrical equipment works well if the total harmonics do not exceed 5% [4]. Passive filters have been widely used to reduce harmonics, but they have some drawbacks. This causes resonance problems in the network and tends to complicate the design as the number of harmonics removed increases. PV-based APFs are becoming more popular because they can be removed. Harmonics from the converted DC power of the PV module. The cost of installing a PV system is very high, so it is advisable to get the maximum performance from your PV system. It is integrated with the MPPT algorithm to ensure maximum efficiency of the PV system. Modeling a PV system using MPPT technology is described in [5].

In a real system, the quality of power received from PV-APF depends on several factors, including: B. Irradiance, temperature, and how to configure the PV system. Many researchers use inverters to analyze the behavior of PV-APF-based systems in various configurations. [6] analyzes the performance of PV-APF-based systems with different configurations based on SIC, MSIC, and CIC. In [7], the three-phase PV system is designed with an integrated Universal Power Quality Conditioner (UPQC). This has the added benefit of both series and shunt compensators, and can provide voltage regulation and harmonic compensation, a d-q based moving average filter. Use of theoretical control base. In [8], researchers used UPQC to analyze the performance of PV systems under dynamic and static conditions. It is used to track the control strategy of the variable irradiance feed forward control loop (FFCL). [9] proposes a multipurpose lattice wave digital filter (LWDF) PV system that can inject active power, provide grid balancing, and reduce load harmonics. In [10], a two-stage PV system using the attenuation second-order generalized integrator algorithm is proposed. In [11], the control method based on the general-purpose notch has been improved.

A filter has been proposed and this scheme can extract the basic components of the load current regardless of the line voltage. In [12], researchers proposed a three-phase series hybrid active filter (SEHAF) integrated into a PV system. This scheme is further analyzed using both PI and fuzzy logic control. [13] with new MPPT technology based on perturbations and observations

It employs a control scheme based on a maximized M-Kalman filter, which has proven to be faster and more accurate than traditional P & O. In [14], researchers analyzed the performance of PV systems integrated with universal secondary sequential active filters. This method is based on proportional resonance control. The proposed method extracts the basic active ingredients very accurately from a distorted and unbalanced load with Mathematical calculation.

In this paper, we combine the PV module with an active shunt powerline conditioner and analyze its performance based on various parameters. This algorithm does not require a synchronization algorithm to synchronize the injected reference current to the supply voltage, so it uses the instantaneous active power theorem to extract the reference current. It draws DC current from the power supply and compares it to a fixed voltage with either a PI controller or a fuzzy logic controller. Converts the extracted reference current and DC. Pulse Width Modulation Hysteresis controller, the current absorbed by the filter to switch gate pulses. The P & O algorithm is used to track the maximum operating point of the PV module. Therefore, Section II introduces the generalized PV model and its properties, along with the generalized active power filter model. It also describes the combination with the selected MPPT topology. Section III describes a proposed PV system model with an active shunt harmonic filter. Section IV analyzes the performance of the proposed configuration with and without SAHF in the MATLAB / SimpowerSystems environment. Finally, the conclusions are given in Section V.

2. PHOTOVOLTAIC AND ACTIVE POWER FILTER MODELLING

The output of the PV module is DC and is connected to a DC-DC boost converter to provide a voltage level suitable for shunt Active harmonic filter systems. Shunt AHF has proven to be an effective way to eliminate harmonics by injecting an AC current that is as large as the harmonics. 180 ° out of phase, removing harmonics from the source current.

A. Generalized PV Modelling

A photovoltaic system consists of solar modules that convert the light energy of the sun into electrical energy by the photoelectric effect. The equivalent circuit of a solar cell

Where R_{se} and Rs represent series resistance and shunt resistance, as shown in Figure 1 (a). The -V and P-V characteristics are shown in Fig. 1 (b) and Fig. 1 (c), respectively. The Vmp, Imp, and Pmax points represent the maximum power points of the PV cell for maximum cell efficiency.

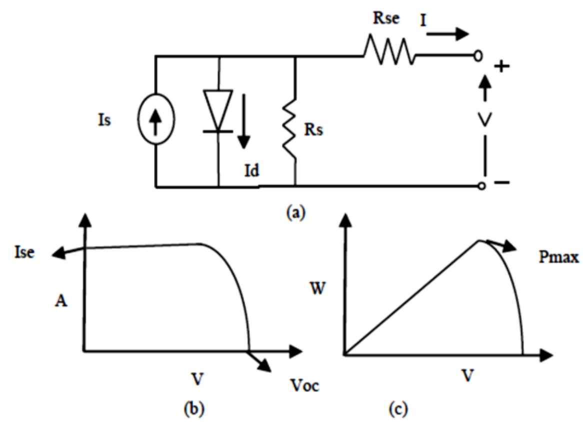


Fig. 1. (a). Simplified equivalent circuit diagram of PV cell (b) I-V characteristics of PV cell and (c) P-V characteristics of PV cell.

The diode current given by Shockley's equation is:

$$I_d = I_s[\exp(qv / nkt) - 1] \quad (2.1)$$

Where Is is the inverse saturation current, q is the charge carrier (1.6 x 10 ^ -19 C), K is the Boltzmann constant (1.380649 x 10 ^ -23), n is the ideal coefficient (1), and T is the cell. temperature (25 ° C). Two limiting components of the PV module, i. H. *Voc* and *Isc* determine Eq. (2.1) by first setting V = 0 to get the Isc and then setting the cell current I = 0 Eq 2.1 leads to:

$$V_{oc} = nkt / q \ln[I / I_0] \quad (2.2)$$

The performance of solar cells depends on the amount of solar radiation. The MPPT tracking algorithm is used to ensure that the PV system is operating at maximum efficiency. The maximum stress point is obtained by the following equation.

$$\dot{V}_{mp} = \ddot{V}_{oc} - KT / q \ln[(V_{mp} / nKT / q) + 1] \quad (2.3)$$

The form factor, which is a measure of the quality of cell connections, is given by the following formula:

$$FF = (V_{mp} * \mathrm{I}_{mp}) / (V_{oc} * I_{sc}) \quad (2.4)$$

The conclusion that the value of the form factor is high is quality. Finally, the efficiency of the PV module is given by:

$$\eta = FF * V_{oc} * I_{sc} / P_{in} \quad (2.5)$$

B. Generalised Active Power Filter

Non-linear loads introduce a harmonic component that is an integral multiple of the basic component of the current. SAHF cancels the harmonics by injecting a current that is the same magnitude as the harmonics but 180 ° out of phase, and cancels the harmonics so that the load current is free of harmonic components. This algorithm has the advantage that it does not require synchronization with the phase voltage. The reference current and the current required to set the intermediate circuit capacitor are then converted into switching pulses via PWM performed by the hysteresis controller.

The current supply voltage is as follows.

$$V_s(t) = V_{sm} \sin \omega t \quad (2.6)$$

The source current is given by node analysis in the PCC.

$$I_s(t) = I_L(t) - I_h(t) \quad (2.6)$$

$I_L(t)$ is load current

$$I_L(t) = I_1 \sin(\omega t + \phi_1) + \sum_{h=2}^{\infty} I_h \sin(n\omega t + \phi_h) \quad (2.7)$$

Here, the second term is the harmonic component. The instantaneous value of load power can be calculated from the load current and supply voltage. Total load power is calculated as:

$$P_L(t) = I_L(t) * V_s(t) \quad (2.8)$$

Active power comes from the load power given as follows:

$$P_f(t) = V_{sm} I_1 \sin^2 \omega t * \cos \Phi_1 = V_s(t) * I_s(t) \quad (2.9)$$

The source current after compensation is

$$I_s(t) = P_f(t) / V_s(t) = I_1 \cos \Phi_1 \sin \omega t = I_{sm} \sin \omega t \quad (2.10)$$

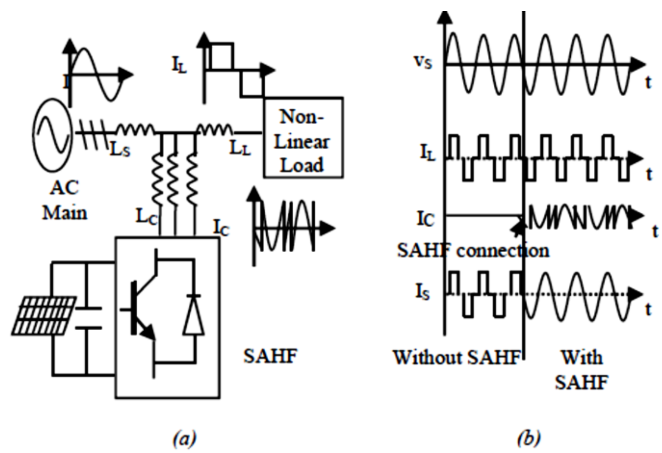


Fig. 2. (a). Schematic diagram of SAHF and (b). SAHF waveform

3. GRID TIED PV SYSTEM WITH HARMONIC FILTER

Figure 3 shows a block diagram of the PVSAHF system. A PV array system with a P & O MPPT controller powers a shunt Active harmonic filter system connected to a non-linear load in a shunt configuration. shunt Active harmonic filter is implemented using a PWM VSI controller. An adaptive hysteresis controller is implemented to generate VSI switching pulses. The PI controller extracts the reference current. This extracted reference current is then compared to the power supply current to generate a switching pulse. Non-linear loads introduce harmonic components into the supply current. Shunt Active harmonic filter produces a transient current that is as large as the source current, but its phase is 180 ° out of phase, canceling out the harmonics present in the source current to make it a sine wave and in phase with the source voltage. increase. Compensation current is generated by detecting the reference current obtained from the supply network.

A. DC-DC boost converter

The DC-DC boost converter consists of an IGBT controlled by a PWM signal generated by the MPPT controller. It consists of two energy storage elements, a conductor and an inductor. When the switch used with the IGBT is closed, current flows through the inductor and charges the inductor by creating a magnetic field. When the switch is open, the current is reduced. The energy of the generated magnetic field is reduced to maintain the load current. Therefore, the polarity of the inductor is reversed. As a result, the two sources are placed in series, increasing the voltage that charges the capacitor through the diode. The output of the DC-DC boost converter is as follows:

$$V_o = V_s\{1/(1-D)\} \quad (3.1)$$

Where Vo is the output voltage, Vs is the output voltage of the PV module, and D is the duty cycle of the boost converter.

The PV cell performance depends on solar irradiance. The MPPT tracking algorithm is used to ensure that the PV system is operating at maximum efficiency. maximum

Stress points are obtained in the following ways.

$$d(V*I)/dt = 0 \quad (3.2)$$

Thus

$$V_{mp} = V_{oc} - KT/q\ln\{V_{mp}/nKT/q\}+1] \quad (3.3)$$

Where Vmp is the maximum power point voltage, K is the Boltzmann constant, q is the charge carrier, T is the temperature in Kelvin, and Voc is the open circuit voltage of the PV module. The increased power from the PV module is DC power, which is passed to the DC-AC converter for use by the utility.

B. DC-AC Converter

This model uses a three-phase bidirectional DC / AC converter consisting of six branch switches. The three arms of the inverter are delayed by 120 ° to generate three-phase AC power. The 3-arm VSI solid-state switch is controlled by PWM pulses generated by the shunt Active harmonic filter controller.

The PI controller is used to extract the reference current. The three phases of supply current are evaluated using a unit sine vector template that is homeomorphic to the source voltage. The unit sine vector template is given as follows:

$$u_{sa} = V_{sa}/V_{sm} = \sin\omega t$$
$$u_{sb} = V_{sb}/V_{sm} = \sin(\omega t - 120^0)$$
$$u_{sc} = V_{sc}/V_{sm} = \sin(\omega t + 120^0) \quad (3.4)$$

The PI controller evaluates Imax, which is the magnitude of the peak reference current. Multiply the weighted peak current by the unit sine template output to produce the desired reference current.

$$i_{sa}* = I_{max} * u_{sa}$$
$$i_{sb}* = I_{max} * u_{sb}$$
$$i_{sc}* = I_{max} * u_{sc} \quad (3.5)$$

The PWM VSI hysteresis controller is used to generate switching pulses, and the hysteresis controller changes rapidly between the two stages depending on the permissible hysteresis band, such as:

$$i* - i \le -h \quad (3.6)$$

The lower switch is turned on to generate a negative voltage and increase the load current

$$i* - i > h \quad (3.7)$$

The top switch is turned on to generate a positive voltage and increase the load current

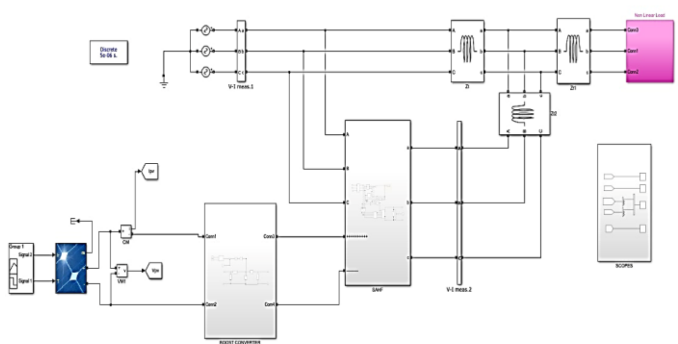
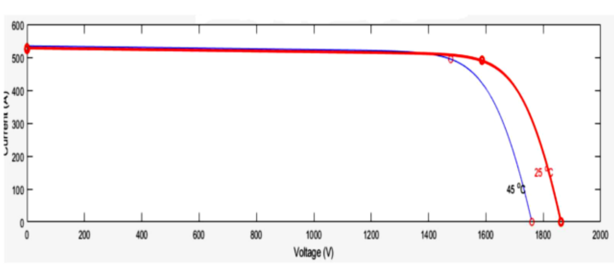


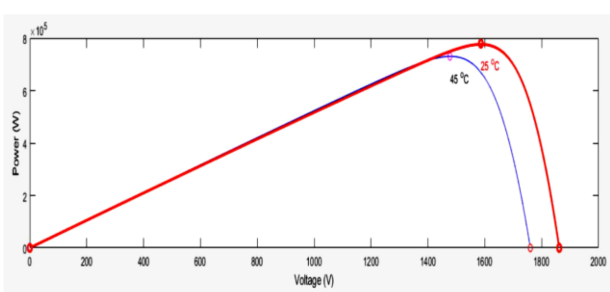
Fig. 3: Simulated model of grid tied PV system with harmonic filter

4. RESULTS

The Grid-Tied Solar Power System with Harmonic Filter to Enhance Power Quality system has been tested with MATLAB / Simulink software. The PV array powers the SAHF, which produces an equilibrium current from the reference current drawn from the grid. Figure 1 shows the P-V and I-V characteristics of the PV array at cell temperatures of 25 ° C and 45 ° C. 4 (b) or Figure 4 (a). The points obtained in the graph correspond to the maximum power points of the PV array. The P / O-MPPT based controller works at this point to maximize the efficiency of the PV array system. From the characteristic curve, it can be seen that as the temperature rises, the short-circuit current increases, but the open circuit voltage decreases. Figure 5 (a) shows the source current in the supply network without the harmonic filters integrated in the shunt configuration. From this figure, it can be seen that the source current contains higher-order harmonic components in addition to the fundamental wave components due to the non-linear load. The PWM VSI produces a compensating current to attenuate the harmonic components, as shown in Figure 5 (b). Compensated currents that are the same magnitude as the harmonic components but 180 ° out of phase cancel the harmonics. Figure 5 (c) shows the source current after integrating Shunt Active harmonic filter. This shows that the source current is a sine wave and harmonics are mitigated effectively.



(a)



(b)

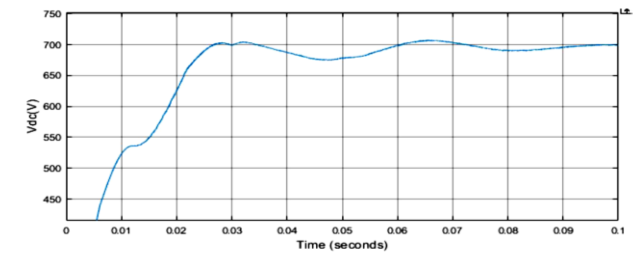
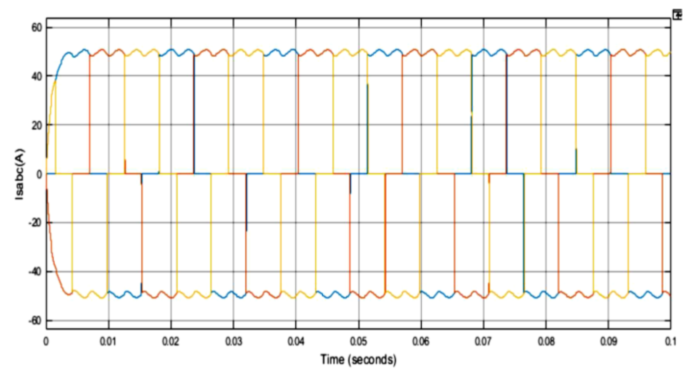
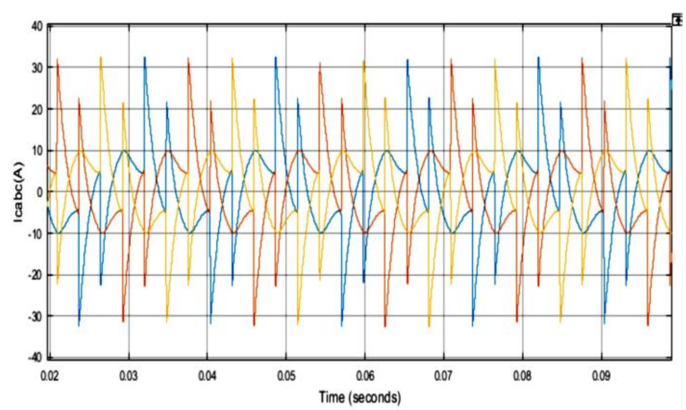


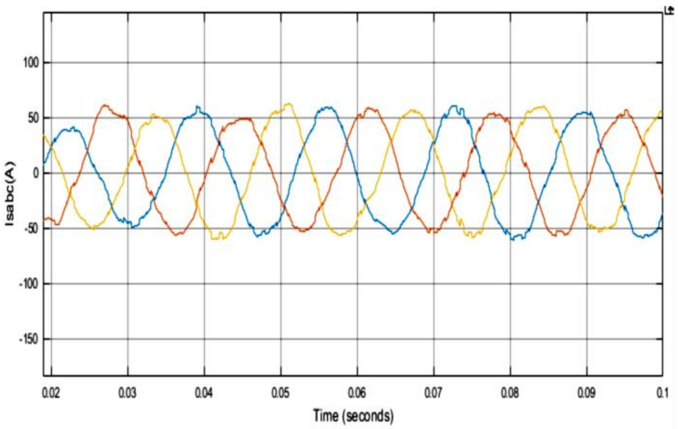
Fig. 4. (a) I-V (b) P-V characteristics of PV array and (c) Vdc



(a)

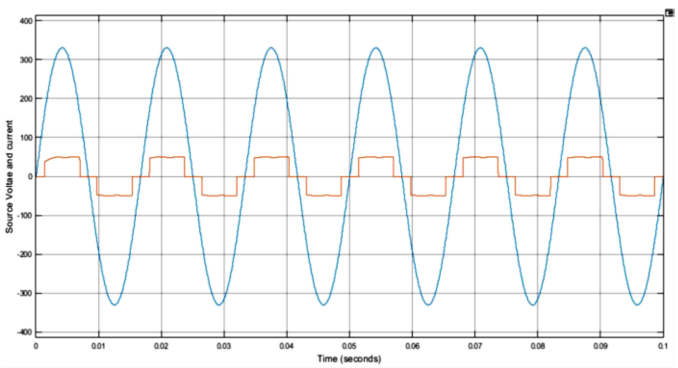


(b)

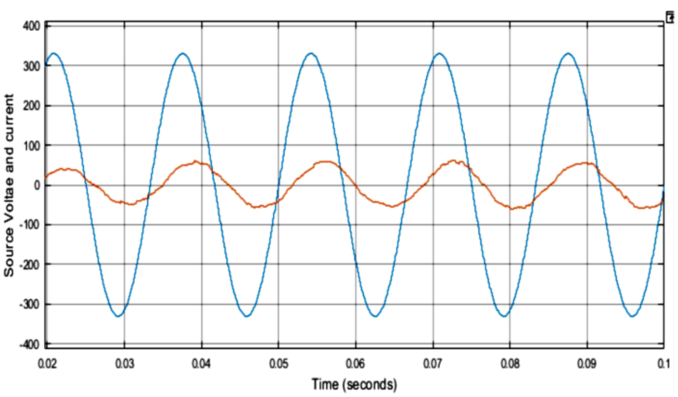


(c)

Fig. 5. Source current (a) without the connection of harmonic filter (b) compensating current and (c) with connection of harmonic filter

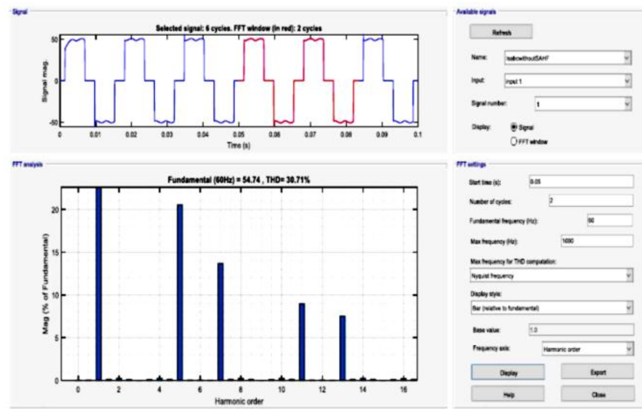


(a)

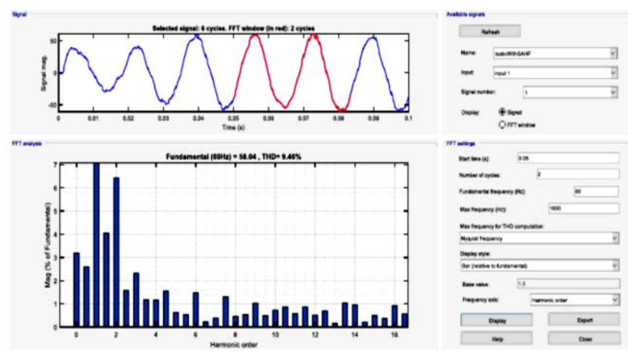


(b)

Fig. 6. (a) Power factor Without Integration of Harmonic Filter (b) Power factor improvement after the integration of Harmonic Filter



(a)



(b)

Fig: 7 THD present in source current (a) without harmonic filter (b) With harmonic filter

5. Conclusion

The performance of the Grid-Tied Solar Power System with Harmonic Filter to Enhance Power Quality system is analyzed. P & O-based MPPT technology faster than time domain approach Implemented successfully with boost converter. Shunt Active harmonic filter is implemented using a PWM VSI controller. An adaptive hysteresis controller is implemented to generate the switching PWM VSI pulse. The PI controller is used to draw the reference current. The PI control method was used to control the reference current by controlling the DC voltage obtained from the PV array system. Describes the concept of Shunt Active harmonic filter and the characteristics of harmonic components and compensation current.

The performance of Grid-Tied Solar Power System with Harmonic Filter to Enhance Power Quality system systems has been analyzed under various operating conditions in the MATLAB / Simulink environment. The harmonic content is well below the specified IEEE standard of 5%. The shunt configuration of the SAHF system not only reduces harmonics, but also improves the power factor. The proposed configuration is cheap and easy to assemble because it requires fewer sensors.

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