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Compensation of Harmonics and Dynamic Reactive Power with Grid Interconnection using Shunt Hybrid Active Power Filter Control Technique

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Abstract:The matrix interconnection of sustainable power source is a mainstream issue in the electric utilities. Different sorts of converter topology in network interconnection have been enhanced by analysts to enhance control quality and effectiveness of the electrical system. The primary commitment of this paper is that shunt half and half dynamic power channel (SHAPF) with a DC-DC converter at dc connection is to give interconnection between sustainable source and network with direct unique burdens. The other commitment of this paper is to display a novel control system for responsive power pay and music disposal in modern systems utilizing a half and half dynamic power channel as a mix of a three stage, two level voltage source converter associated in parallel with single tuned LC aloof filter. In proposed control strategy, receptive power remuneration is accomplished effectively with discernible amount. Besides, the execution aftereffects of symphonious pay are acceptable. Hypothetical examinations and recreation results are gotten from a real mechanical system display in PSCAD. The reenactment results are introduced for proposed framework with a specific end goal to exhibit that the symphonious remuneration execution meets the IEEE-519 standard.

***Keywords*—Harmonics, power quality, Reactive power compensation, grid, hybrid active power filters**

I. INTRODUCTION

By the advancement of technology, electric utilities and use of electric power are expanded. The greater part some portion of vitality request is given by petroleum derivatives. However, fossil fills are limited assets and will in the long run diminish. Due to this condition, they turn out to be excessively costly or too ecologically harming, making it impossible to recover. In the current years, renewable vitality in power era has been developing as an option vitality source to moderate the weaknesses of fossil fuels. In any case, the escalated utilization of nonlinear burdens cause a few power quality issues at PCC[1].The matrix voltages and streams shape non sinusoidal frame that is called symphonious twisting because of these sorts of burdens.

Consonant bends can build control misfortunes, as well as lessen the lifetime of types of gear. Keeping in mind the end goal to decrease the present symphonious contamination, detached channel is one of the customary arrangement ineffectively. These channels may bring about undesirable reverberation conditions. Their other restriction can't adjust to the changing conditions in the system and their size. With amazing procedure in the speed and limit of semiconductor exchanging devices, active channels have been contemplated and put into down to earth use, because they can beat the inconveniences inalienable in latent filters. These sorts of channels are more powerful in consonant pay and enhance execution [2]. However, dynamic power channels have high starting cost, running cost and required relatively high power converter ratings. To overcome the previously mentioned disadvantages, passive and dynamic channels can be consolidated into a solitary gadget called cross breed dynamic power channels (HAPF).HAPFs successfully smooth the issues of the detached channel and an dynamic power channel arrangement; consequently guarantee savvy consonant pay. The inactive channel in the framework performs essential sifting activity at the prevailing consonant frequencies, though the dynamic channel part mitigates higher music with exact control methods. This will successfully diminish the general size and cost of dynamic filtering. In expansion, no central voltage is connected to the dynamic part. This brings about an extraordinary decrease of the voltage rating of the dynamic power channel part.

A few half and half APF (HAPF) topologies [2- 11,15-17] constitute dynamic and detached parts in arrangement as well as parallel have been proposed for receptive power and consonant current separating in [3-15]

.The most normal topologies are shunt HAPF (SHAPF)[3-10] comprising of an APF and latent channel associated in arrangement with each other and arrangement HAPF[11] which is a joined arrangement of shunt aloof channel and arrangement APF. An broad diagram of the topological structures is clarified in [2].

The controller configuration is a critical and testing assignment because of its effect on the execution and soundness of general framework. Hence, various control techniques, for example, pq hypothesis [3-5], quick fourier change [5], dq hypothesis [6-7], fluffy controller [8-9], corresponding thunderous current controller [10] are controller techniques connected in writing.

Most learns about SHAPF in writing cannot accomplish dynamic receptive power pay [7-9]. Besides, SHAPF can remunerate the dynamic responsive power with steady dc interface voltage in [5]. In this article, coordinate current controlled heartbeat width adjustment is utilized. Furthermore, the dc connection is controlled as both dynamic and receptive current segment. The outcomes are acquired for low voltage level with remunerating little measure of receptive power. Besides, SHAPF can accomplish the dynamic responsive power pay with versatile dc connect voltage in [3]. Moreover, the dc connection is controlled as dynamic current part. The reference dc interface voltage might be lacking to track the new reference esteem when the versatile dc connect voltage might be changed from low level to abnormal state [5]. Moreover, when this dc connection is controlled as dynamic current segment, an additional start up precharging control circuit is required. In the last article [4], SHAPF can accomplish the dynamic receptive power pay with versatile dc interface voltage. Additionally, particular consonant pay is accomplished. The dc connection is controlled as both dynamic and receptive current segment as in [5]. The outcomes are gotten for 220 V, 10 kVA framework. Be that as it may, SHAPF repays little measure of receptive power.

The developing measure of electric vitality created from circulated or decentralized vitality assets (DER), for the most part of renewables, requires their suitable framework coordination. Accordingly, the sustainable power source interfacing with network is the real issue in the electric utility side. Distinctive sorts of converter topology in matrix interconnection have been enhanced by specialists to create control quality and proficiency of the electrical framework [12-13]. This paper centers the shunt cross breed dynamic channel interfaces for the sustainable power source with proposed controller.

Because of the constraints between existing writings, the reason for this paper is the accompanying:

1. To give interconnection between inexhaustible source and lattice by utilizing shunt half and half dynamic power channel (SHAPF) with unidirectional disengaged DC-DC converter at dc connection.
2. To present another control system for receptive power pay and music disposal.
3. To adaptively controlled dc connect voltage as receptive current segment.
4. To accomplish responsive power pay which is about equivalent to 99% of load receptive power limit.

As this paper fundamentally concentrates on the aforementioned four parts of the shunt crossover dynamic power channel.

II. PROPOSED SYSTEM AND CONTROLLER

Figure.1 exhibits the proposed SHAPF framework. As can be found in Figure 1 inverter unit is associated with the lattice through a LC channel tuned on the region of the fifth symphonious.

As can be found in Figure 2, the controller of proposed framework comprises of four principle parts: symphonious reference era, responsive current reference era, dc connect voltage controller, dc-dc converter controller and last reference pay current-pwm control square.

The consonant current control, receptive current control and dc connect control are accomplished by circuitous current control. With this control technique, any additional start up precharging control process is a bit much for dc interface. In addition, reactive power remuneration is accomplished effectively with distinguishable sum. Moreover, the symphonious pay execution is agreeable.

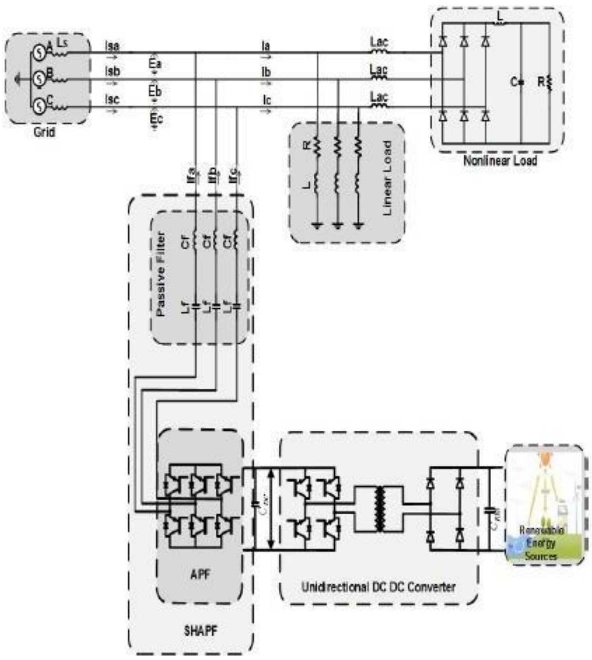


Figure1. Proposed Power System

A. Harmonic Current Control

The consonant control of SHAPF is appeared in Figure 2.The initial step is to seclude the symphonious parts from the central segment of the matrix streams. This is accomplished through dq change (1), synchronized with the PCC voltage vector, and a first request low pass channel with cut off recurrence of 10 Hz. At that point the dq reverse change (2) creates the symphonious reference streams in abc referential casing.

$$\begin{bmatrix} i_d \\ i_q \\ i_o \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} \cos\theta_p & \cos(\theta_p - 2\pi/3) & \cos(\theta_p + 2\pi/3) \\ -\sin\theta_p & -\sin(\theta_p - 2\pi/3) & -\sin(\theta_p + 2\pi/3) \\ \frac{\sqrt{2}}{2} & \frac{\sqrt{2}}{2} & \frac{\sqrt{2}}{2} \end{bmatrix} \begin{bmatrix} i_{sa} \\ i_{sb} \\ i_{sc} \end{bmatrix} \quad (1)$$

$$\begin{bmatrix} i_{a\_harmonic\_ref} \\ i_{b\_harmonic\_ref} \\ i_{c\_harmonic\_ref} \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} \cos\theta_p & -\sin\theta_p & \frac{\sqrt{2}}{2} \\ \cos(\theta_p - 2\pi/3) & -\sin(\theta_p - 2\pi/3) & \frac{\sqrt{2}}{2} \\ \cos(\theta_p + 2\pi/3) & -\sin(\theta_p + 2\pi/3) & \frac{\sqrt{2}}{2} \end{bmatrix} \begin{bmatrix} i_{d\_lpf} \\ i_{q\_lpf} \\ i_{o\_lpf} \end{bmatrix} \quad (2)$$

B. Reactive Power Control

Dynamic receptive power varieties in roughly 20% happened in load are repaid by inverter side of SHAPF. The reference current gave fundamental responsive power is delivered. Keeping in mind the end goal to accomplish the responsive power remuneration of SHAPF, the reference current having 90° stage contrast among the PCC point ought to be delivered. To create this reference current, the yield voltage of SHAPF inverter ought to be produced in stage with PCC voltage vector. The square graph of receptive power control is appeared in Figure 2.

The reference streams ought to be ascertained to remunerate receptive power in the framework. The reference streams are produced by the dq strategy. The initial step is to seclude the crucial parts from the consonant segments of the matrix streams. This is accomplished through the dq change (3). The quadrature part of the source current which is taken from dq change is straightforwardly gone through the LPF. Subsequently, the 50 Hz part of the source current is produced. At that point, this flag is connected to deliver the responsive power pay current by inversing dq change. Nonetheless, this reference current is in quadrature hub. To accomplish receptive power pay by voltage controlled voltage source SHAPF, the reference current must be in stage with source voltage. In this way, the reference current is changed by utilizing just d part reverse dq change (4).

$$\begin{bmatrix} i_d \\ i_q \\ i_o \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} \cos\theta_p & \cos(\theta_p - 2\pi/3) & \cos(\theta_p + 2\pi/3) \\ -\sin\theta_p & -\sin(\theta_p - 2\pi/3) & -\sin(\theta_p + 2\pi/3) \\ \frac{\sqrt{2}}{2} & \frac{\sqrt{2}}{2} & \frac{\sqrt{2}}{2} \end{bmatrix} \begin{bmatrix} i_{sa} \\ i_{sb} \\ i_{sc} \end{bmatrix} \quad (3)$$

$$\begin{bmatrix} i_{a\_reactive\_ref} \\ i_{b\_reactive\_ref} \\ i_{c\_reactive\_ref} \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} \cos\theta_p & -\sin\theta_p & \frac{\sqrt{2}}{2} \\ \cos(\theta_p - 2\pi/3) & -\sin(\theta_p - 2\pi/3) & \frac{\sqrt{2}}{2} \\ \cos(\theta_p + 2\pi/3) & -\sin(\theta_p + 2\pi/3) & \frac{\sqrt{2}}{2} \end{bmatrix} \begin{bmatrix} i_{q\_fund} \\ 0 \\ 0 \end{bmatrix} \quad (4)$$

C. DC Link Voltage Controller

Figure.2 demonstrates the square graph of the dc connect voltage controller. The initial step is to figure the quick load receptive power.

At that point utilizing the d and q part both three stage network voltage and current, the prompt load receptive power is computed. In next process, the reference dc connect voltage is resolved with the condition [3] appeared in Figure 2.

Figure 2 shows the control of the blunder flag. The blunder flag is controlled by regular PI controller [6].

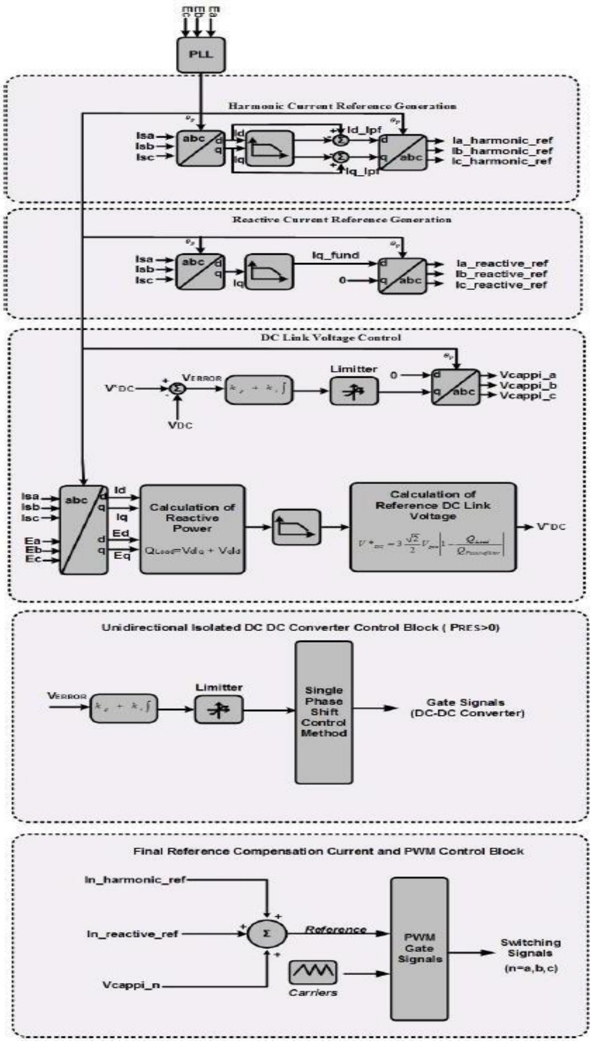


Figure.2. Proposed Controller Block Diagram

D. DC-DC Converter Controller

Single stage move (SPS) control technique which is the most generally utilized is connected for the proposed framework. In SPS control, the cross-associated switch matches in both full extensions are changed thus to produce stage moved square waves with half obligation proportion to the transformer's essential and optional sides. Just a stage move proportion (or point) D can be controlled. Through modifying the stage move proportion the equal air conditioning yield voltages of full-scaffolds, the voltage over the transformer's spillage inductor will change. Then, the control stream course and extent can be effectively controlled. A broad review of this control strategy is clarified in [14].

For the proposed framework, the power stream is acknowledged from RES to SHAPF. Hence, dc-dc converter create negative stage move plot for this power stream heading. This stage move point is controlled by basic PI controller.

This converter just performs when PRES>0 where PRES is the power created from RES appeared in Figure3.

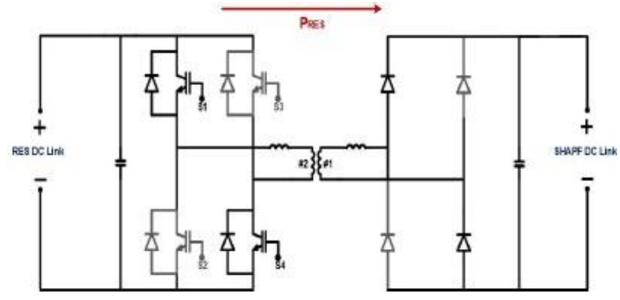


Figure.3. Unidirectional Isolated DC-DC Converter and Power Flow Direction

E. Final Reference Compensation Current and PWM Control Block

The last reference current comprises of three stage consonant reference current signs, three stage receptive reference current signs and dc interface control signals. The reference flag (In_harmonic_ref + In_reactive_ref +Vcappi_n) is created utilizing these signs together. Then,the reference signs are contrasted with bearer motion with produce exchanging signals appeared in Figure 2.

III. SIMULATION RESULTS

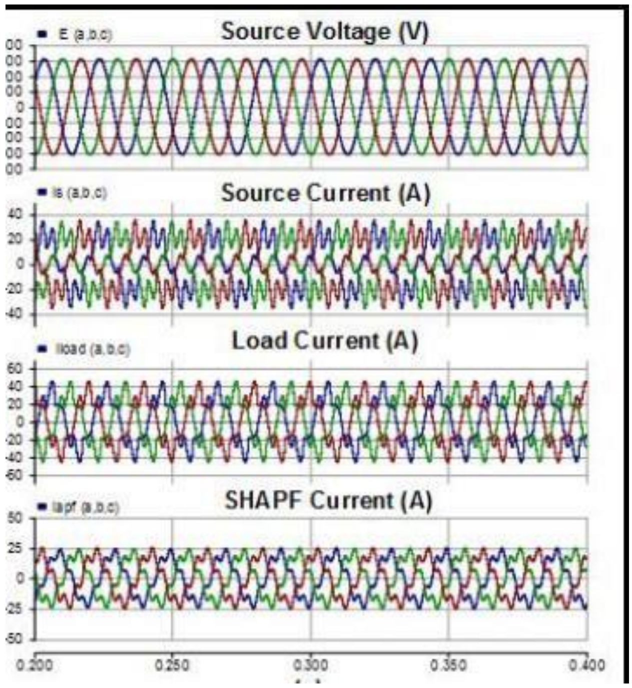
Reenactment studies are completed utilizing PSCAD/EMTDC. The principle reason for the reproduction is to assess the viability and accuracy of the control system utilized as a part of the SHAPF with varieties of straight loads.Parameters utilized as a part of reenactments are given in Table I. In reproduction, the ostensible recurrence of the power framework is 50Hz and the symphonious current source is produced by the three stage diode rectifier. Likewise, the dynamic receptive power changing is produced by direct loads appeared in Table II. The stage to stage lattice voltage is chosen as 380 V (crest peak).Passive channels are tuned at fifth and the control signs of IGBTs are created through the beat width adjustment generator whose adequacy and recurrence of transporter wave are ± 1 and 20 kHz, separately. The latent channel part bolsters a settled receptive power which is equivalent to 10 kVAR. The receptive power limit of the nonlinear load is 2 kVAR.

In this area, two method of operation are talked about in reenactment cases. A sustainable power source (RES) is associated on the dc connection of framework interface SHAPF. The primary point of proposed approach is to manage the power at PCC during: 1) PRES>0 and 2) PRES=0 where PRES is the power created from RES. While playing out the power administration operation, the SHAPF is effectively controlled in such a path, to the point that it generally draws/supplies major dynamic power from/to the matrix. At first, the SHAPF is not associated with the system. Before time t=0.5s, the source, load and SHAPF streams are shown in Figure 4 (a).

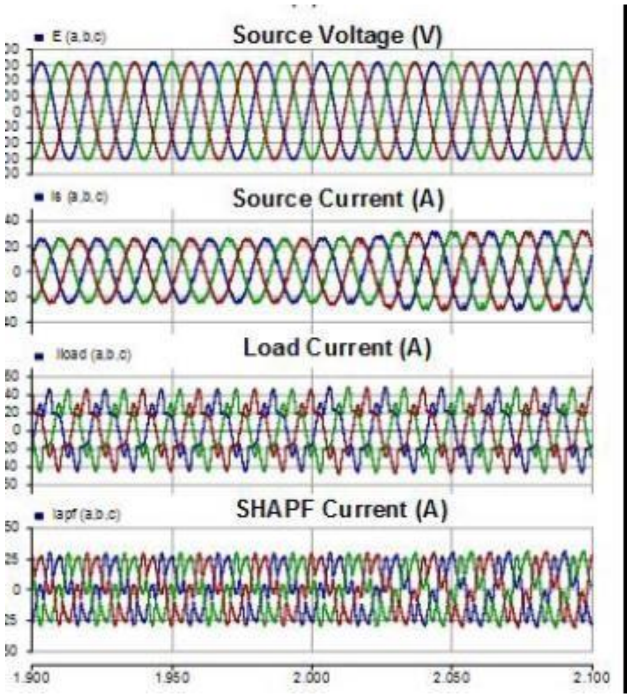
Initially method of operation considers a situation where PRES>0, the SHAPF infuses RES dynamic power into lattice and furthermore upgraded the nature of energy at PCC. Before time t=1s, RES is not associated with the system. The source, SHAPF and load dynamic power are appeared in Figure 5(a). At t=1 s, the RES associated with the system. The SHAPF begins infusing dynamic power created from RES as appeared in Figure 5 (b). Furthermore, SHAPF remunerates sounds effectively as appeared in Figure 4 (b).

Second method of operation considers a situation when there is no power era from RES. The SHAPF is to upgrade the nature of energy at PCC. The proposed control technique for dynamic responsive power pay with flexible dc connect voltage will be checked by reproductions. At the point when the stacking responsive power utilization is more prominent than given by the uninvolved channel part, the inverter side of the SHAPF can repay the rest of energy of the inactive channel. At time t= 2 s, the fourth load is associated with the framework. The receptive power rating of burdens is expanded 12kVAR. At the point when the heaps are associated with the framework, the framework gives a dynamic reaction. In this manner, the inverter side is remunerated the responsive power remainded by aloof channel limit. The source receptive power is about equivalent to zero appeared in Figure 5 (c). The lessened THD of the source current, while remunerating these heaps varieties, working adjusted supply implies in every one of the cases, sinusoidal current is drawn from the source appeared in Figure 4 (c). SHAPF dc connect voltage is adaptively changed from 160 to 225V appeared in Figure 5 (c). The measure of source side receptive power remains almost zero. In 2.5 s, the fifth load is associated with the framework. The receptive power rating of burdens is expanded 13kVAR. The inverter side is remunerated remainded by aloof channel limit. The measure of source side responsive power likewise remains almost zero appeared in Figure 5 (d).

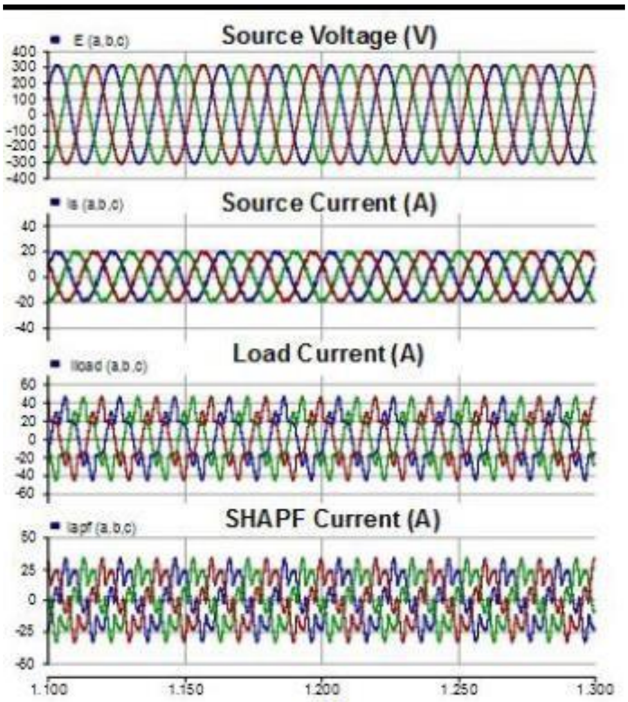
The dc connect voltage of SHAPF is adaptively changed from 225 to 290V appeared in Figure 5(d). The lessened THD of the source current, while repaying these heaps varieties, working adjusted supply implies in all the cases, sinusoidal current is drawn from the source appeared in Figure 4(d).



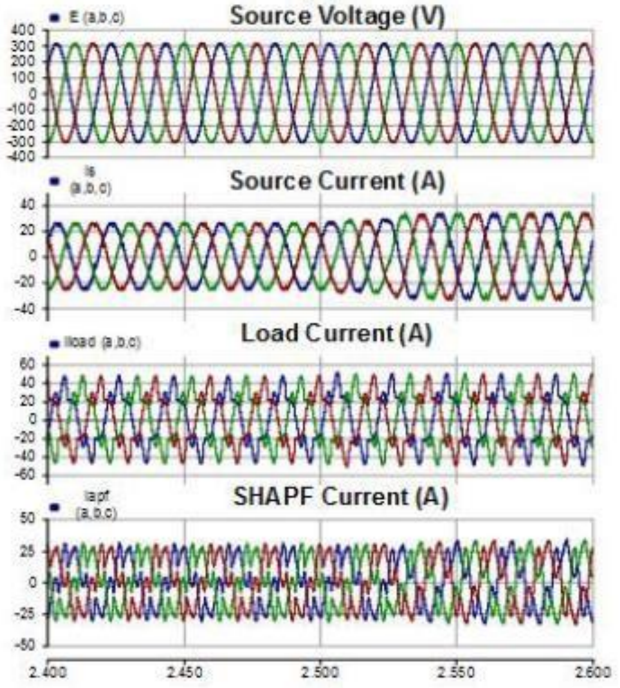
(a)



(c)



(b)



(d)

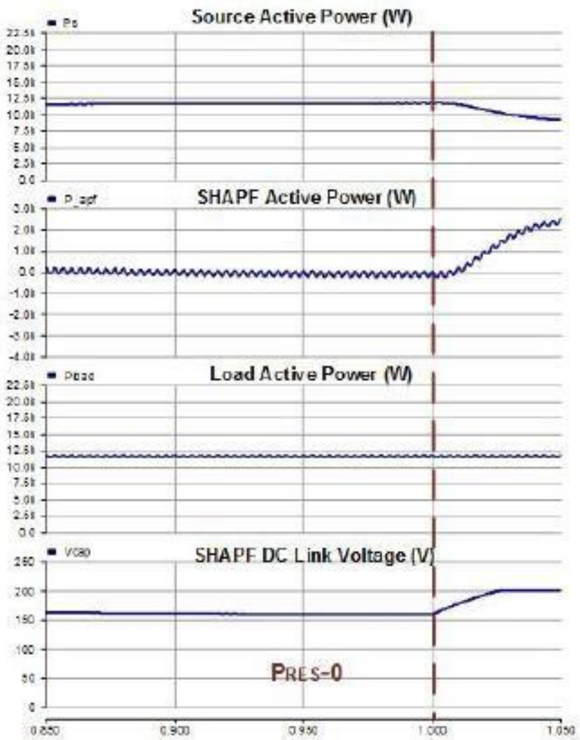
Figure.4. Three phase Source Voltages, Source - SHAPF - Load Currents (a)when SHAPF is not operated, (b) when PRES>0, (c) when PRES=0 and 1kVAR loads are connected (d) when PRES=0 and another 1kVAR loads are connected

Compared the simulation results with dynamic load changes, the proposed method can:

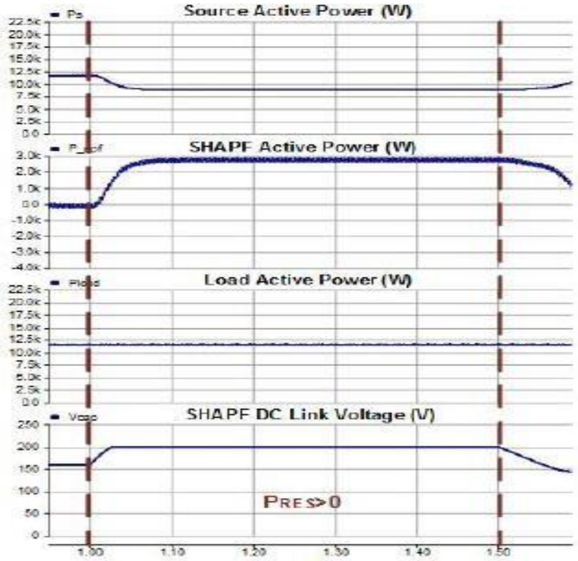
1) Interconnect between renewable source by using shunt hybrid active power filter (SHAPF)
2) Provide dynamic reactive power compensation
3) Reduce the THD of source side current
4) Adaptively change the dc link voltage value

TABLE I. SIMULATION PARAMETERS

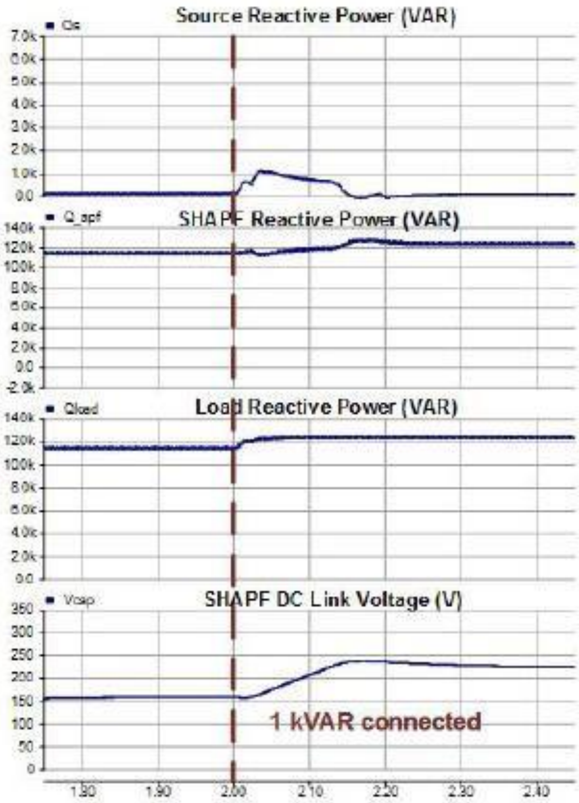
Parameters	**Value**
5) Line frequency	380 V
Filter Capacitor (CF)	50 Hz
Filter Inductance (LF)	200 µF
Tuned freq. of series filter(ftuned)	2 mH
Filter Capacitor (CF)	250 Hz
Load Inductances(Lac1	) 2.7 mH
Switching frequency (fswitching)	20 kHz
Simulation Step Time	40 µs
DC Link Reference Value	100-300 V
DC link Capacitors	12 mF



(a)



(b)



(c)

Figure.5. Source - SHAPF - Load Active power and SHAPF DC link voltage when PRES=0, (b) Source - SHAPF - Load Active power and SHAPF Dc link voltage when PRES>0, (c) Source - SHAPF - Load Reactive power and SHAPF DC link voltage when PRES=0 and 1kVAR loads are connected.

TABLE I.SIMULATION PARAMETERS FOR TESTING LOADING

Inductive Loads	Physical Value	Reactive Power Capacity
1st Load (Rload1 Lload1)	5 - 90 mH	5kVAR
2nd Load (Rload2 Lload2)	10 - 225 mH	2kVAR
3rd Load (Rload3 Lload3)	10 - 225 mH	2kVAR
4th Load (Rload4 Lload4)	20 - 450 mH	1kVAR
5th Load (Rload5 Lload5)	20 - 450 mH	1kVAR

As a result, it is clearly shown that shunt hybrid active power filter (SHAPF) with a DC-DC converter at dc link achieves interconnection between renewable source and grid with linear dynamic loads. Besides, SHAPF using the proposed method can provide better compensation performance both harmonic and dynamic reactive power compensation.

IV. CONCLUSION

In this paper, SHAPF gives interconnection between sustainable source and matrix with direct unique loads. Besides,the novel control plot for SHAPF is proposed in order to remunerate both consonant and dynamic responsive power with versatile dc connect voltage. The fundamental commitments of this paper are:

- The matrix interconnection is provided by SHAPF for the sustainable power source.
- To present another control procedure for receptive power remuneration and sounds disposal.
- To adaptively controlled dc interface voltage.
- To accomplish receptive power remuneration which is almost equivalent to 100% of load responsive power limit.

The symphonious current control, the dc interface control and receptive current control are accomplished by backhanded current control. With this control technique, any additional start up precharging control process is a bit much for dc connect. Also, responsive power remuneration is accomplished effectively with detectable sum. Additionally, the symphonious remuneration execution is palatable.

In a conclusion, the SHAPF infuses RES dynamic power into lattice and furthermore improved the nature of energy at PCC. Reenactment consequences of the three-stage three-wire SHAPF in unique responsive power remuneration.

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