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TRANSFORMERLESS HYBRID POWER FILTER BASED ON A SIX-SWITCH TWO-LEG INVERTER FOR REDUCTION OF TOTAL HARMONIC DISTORTION AND IMPROVE THE VOLTAGE PERFORMANCE WITH DIFFERENT ASPECTS

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ABSTRACT

This paper deals with the power quality (PQ) improvement by using a transformer less Hybrid Active Power Filter (HAPF) based on a six switch two leg inverter with battery and solar system through boost converter which increases the reliability of power supply by reducing the Total Harmonic Distortion (THD) and increase the voltage level. The control methods of instantaneous reactive power theory (pq method) and synchronous reference theory (dq method) are used to extract the current. The comparison results of conventional, battery source with boost converter and solar system with boost converter are carried out by using MATLAB software.

Keywords: hybrid active power filters (HAPF), solar system, battery source, boost converter.

INTRODUCTION

Nowadays, the large number of computers and other sensitive electrical loads connected to the power grid are directly affected by power quality problems. One of the most important issues is related to current harmonics generated by the increasing number of nonlinear loads connected to the power grid, such as diode and thyristor front-end rectifiers. As consequence, these harmonics can cause voltage distortions, additional losses in the power system and malfunction of sensitive electronic equipment. Shunt passive filters, consisting of tuned LC filters and high-pass filters, have traditionally been used as a simple and low cost solution to compensate current harmonics. In the last decades, the increasing reliability of power semi-conductor devices has motivated the development of power electronics solutions to the problem of harmonic circulation into the grid. The shunt active power filter (APF), consisting basically of a voltage source inverter (VSI) with a large capacitor on its dc-link, is considered a well-established solution to reduce the current harmonics to the recommended standards limits. The major drawback of shunt APFs is the high power rating components required for compensating high peak harmonic currents and their associated costs. An alternative, called hybrid power filter (HPF) mixes low power rating active filters with passive filters, aiming the cost reduction. The converters used in HPFs require typically 5-8% of the load kVA rating, which is considerably lower than the power rating of conventional APFs, making HPF systems attractive and cost-effective. The principle of operation of these converters is based on improving the filtering characteristics of passive filters and avoiding the undesirable resonances with the grid. .

[1] deals with the harmonic compensation can be obtained by Passive Filters (PF), Active Power Filters (APF) and hybrid filters (HPF).

[2] explain different models of hybrid filters and the common HAPF is obtained by connecting PF and APF

[3] deals with APF generally consists of two distinct main blocks: the Current-Controlled Voltage-Source Inverter (CCVSI) and active filter controller. APF sense the load current continuously with control algorithm, and calculate the instantaneous values of the compensating current reference for the VSI.

[4-5] presents the configuration of HAPF. Then different control strategies including *pq* method, *dq* method are presented.

[6-8] represents the different hybrid active power filter (HAPF) topologies composed of active and passive components in series and/or parallel have been proposed, aiming to improve the compensation characteristics of PPFs and reduce the voltage and/or current ratings (costs) of the APFs, thus leading to improvements in cost and performance.

[9] Presents, A transformer less shunt hybrid active power filter (SHAPF) has been recently proposed and applied for current quality compensation and damping of harmonic propagation in distribution power systems.

[10] Deals, the combination of switched capacitor and coupled inductor techniques for a PV system produces a high voltage gain whereas the duty ratio will be high. Due to the less turn OFF time the peak value of current is very high which in turn has more conduction losses.

[11] Explain, the implementation of two techniques namely coupled inductor and switched

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capacitor limits the duty ratio and the voltage stress across the switches is also high.

[12] Represents a transformer less converters, the structure of the converter is complex and the efficiency becomes less for a multistage structure.

[13] Deals, in the active network using switched capacitors have two switches and an additional insulated gate drive circuit is needed.

[14] In dc-dc converter for micro grid applications, the leakage inductor causes voltage spikes across the switches due to which the voltage stress across the switch gets increased.

In this paper presents, performance of battery through boost converter connected system and solar system through boost converter connected system with transformerless back-to-back HPF used to reduce the total harmonics distortion and enhance the voltage level. The output voltages are connected to the PCC through two sets of passive filters.

PROPOSED SYSTEM CONFIGURATION

The schematic diagram of the transformerless hybrid Active power filter with boost converter and solar system is presented in Figure-1. This configuration of hybrid filter ensures the compensation of the source current harmonics by enhancing the compensation characteristics of the passive filter besides eliminating the risk of resonance. It provides effective compensation of current harmonics and limited supply voltage distortion. The hybrid filter is controlled such that the harmonic Currents of the nonlinear loads flow through the passive filter and that only the fundamental frequency component of the load current is to be supplied by the ac mains. The HAPF topologies in consists many passive components which increases the size and cost of the whole system which makes the topology non preferable.

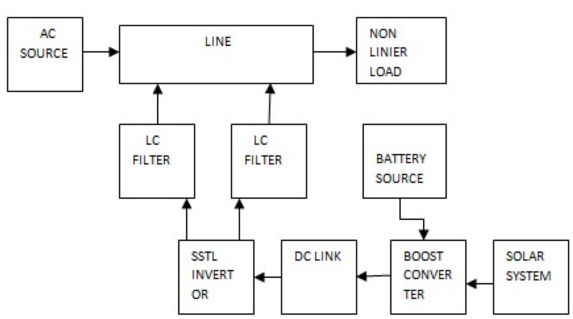

Figure-1. Proposed system.

Renewable sources of energy are increasingly valued worldwide because of energy shortage and environmental contamination. Renewable energy systems generate low voltage output thus, high step-up DC/DC converters are widely employed in many renewable energy applications, including fuel cells, wind power, and Photovoltaic systems. Among renewable energy systems, photovoltaic systems are expected to play an important role in future energy production. Such systems transform light energy into electrical energy, and convert low voltage into high voltage via a step-up converter. Recently Photovoltaic (PV) power systems are becoming more and more popular, with the increase of energy demand and the concern of environmental pollution around the world. Solar photovoltaic energy has gained recognition as an alternative source of energy.It was presented a HPF consisting of a low power rating three-phase VSI connected to the load at the point of common coupling (PCC) through a LC passive filter without any matching transformer. The LC filter absorbs some harmonic currents produced by the non-linear load, whereas the active filter improves the filtering characteristics of the LC filter. A transformerless back-to-back HPF is used to reduce the total harmonics distortion and voltage level improvement. The output voltages are connected to the PCC through two sets of passive filters.

CONTROL METHOD

There are three stages in the active filtering technology. In the first stage the essentials voltage and current signals are sensed to gather accurate system information.

In the second stage, compensating commands in terms of current or voltage levels are derived based on control methods.

In the third stage of control, the gating signals for the solid-state devices are generated using PWM techniques.

In this we have used the instantaneous p-q theory for deriving the compensating signal.

The generalized theory of the instantaneous reactive power in three phase circuits is also known as instantaneous power theory, or P-Q theory. It is based on instantaneous values in three-phase power system.

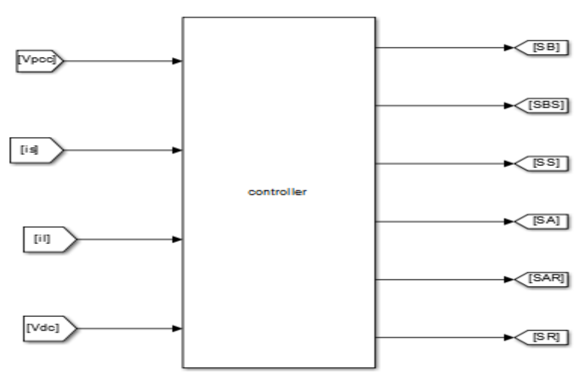

Figure-2. Controller.

Vsa, Vsb, Vsc are the main supply voltages, isa, isb, isc are the main supply currents, ila, ilb, ilc are the load

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currents and Vdc is the capacitor voltage (DC bus) and all currents and voltages are balanced

i.e. Vsa+ Vsb+Vsc=0,

isa + isb + isc =0,

The mains voltages Vsa(t), Vsb(t), Vsc(t) are co-sinusoidal of frequency fm, balanced and equilibrated.

Vsa(t) = Vm Cos (2π fmt)

Vsb(t) = Vm Cos (2π fmt-2 π/3)

Vsc(t) = Vm Cos (2π fmt+2 π/3)

Instantaneous Reactive Power Theory (pq Method*)*

This method is also known as *pq* method. Most APFs have been designed on the basis of instantaneous reactive power theory or *pq* method to calculate the desired compensation current.

The p-q theory is based on a set of instantaneous powers defined in the time domain [4]. The three-phase supply voltages (*ua, ub, uc*) and currents (*ia, ib, ic*) are transformed using the Clarke (or α-β) transformation into a different coordinate system yielding instantaneous active and reactive power components. This transformation may be viewed as a projection of the three-phase quantities onto a stationary two-axis reference frame.

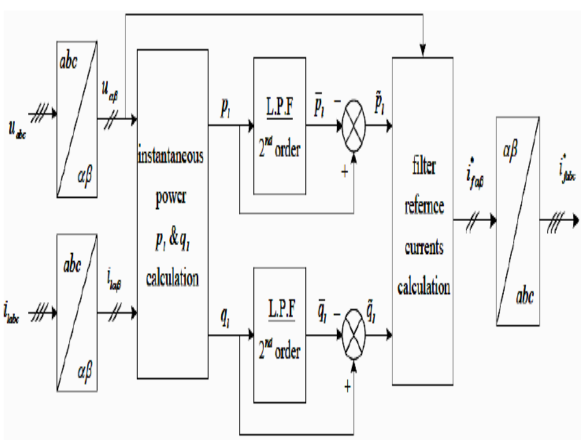

Figure-3. Principle of instantaneous active and reactive power theory.

The Clarke transformation for the voltage variables is given by

$$\begin{bmatrix} u_\alpha \\ u_\beta \\ u_0 \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \end{bmatrix} \begin{bmatrix} u_a \\ u_b \\ u_c \end{bmatrix}$$

Similarly, this transform can be applied on the distorted load currents to give

$$\begin{bmatrix} i_{l\alpha} \\ i_{l\beta} \\ i_{l0} \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \end{bmatrix} \begin{bmatrix} i_{la} \\ i_{lb} \\ i_{lc} \end{bmatrix}$$

The instantaneous active power *p(t)* is given by

$$p(t) = u_a i_{la} + u_b i_{lb} + u_c i_{lc}$$

In matrix form, the instantaneous active and reactive power can be given by

$$\begin{bmatrix} p \\ q \end{bmatrix} = \begin{bmatrix} u_\alpha & u_\beta \\ -u_\beta & u_\alpha \end{bmatrix} \begin{bmatrix} i_{l\alpha} \\ i_{l\beta} \end{bmatrix}$$

After separating the direct and alternating terms of instantaneous power, the harmonic components of the load currents can be given by using the inverse of above equation which gives

$$\begin{bmatrix} i_{l\alpha} \\ i_{l\beta} \end{bmatrix} = \frac{1}{v_{s\alpha}^2 + v_{s\beta}^2} \begin{bmatrix} v_{s\alpha} & v_{s\beta} \\ -v_{s\beta} & v_{s\alpha} \end{bmatrix} \begin{bmatrix} \tilde{p}_l \\ \tilde{q}_l \end{bmatrix}$$

The APF reference current can be then given by

$$\begin{bmatrix} i_{fa}^* \\ i_{fb}^* \\ i_{fc}^* \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & 0 \\ -\frac{1}{2} & \frac{\sqrt{3}}{2} \\ -\frac{1}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} \widetilde{i_{l\alpha}} \\ \widetilde{i_{l\beta}} \end{bmatrix}$$

Synchronous Reference Theory (d-q Method*)*

In this method, called also the method of instantaneous currents *id, iq*, the load currents are transformed from three phase frame reference *abc* into

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synchronous reference in order to separate the harmonic contents from the fundamentals [4]. It gives better performance even in the case where the three phase voltage is not ideal

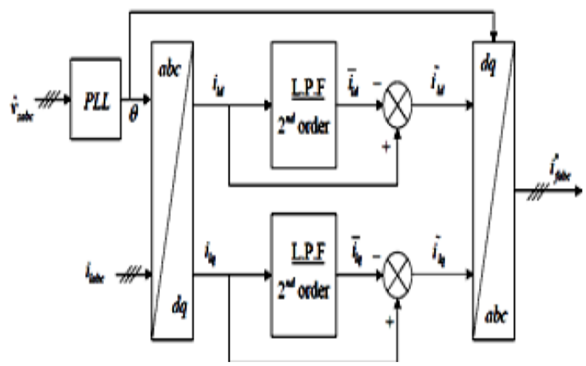

Figure-4. Principle of the synchronous reference method.

Transformation from three phase frame reference *abc* into synchronous reference is given by

$$\begin{bmatrix} i_{ld} \\ i_{lq} \\ i_{l0} \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} \cos\theta & \cos(\theta-\frac{2\pi}{3}) & \cos(\theta+\frac{2\pi}{3}) \\ -\sin\theta & -\sin(\theta-\frac{2\pi}{3}) & \sin(\theta+\frac{2\pi}{3}) \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \end{bmatrix} \begin{bmatrix} i_{la} \\ i_{lb} \\ i_{l0} \end{bmatrix}$$

The currents in the synchronous reference can be decomposed into two parts as

$$i_{ld} = \overline{i_{ld}} + \widetilde{i_{ld}}$$

$$i_{lq} = \overline{i_{lq}} + \widetilde{i_{lq}}$$

The APF reference currents are given by

$$\begin{bmatrix} i^*_{fd} \\ i^*_{fq} \end{bmatrix} = \begin{bmatrix} \widetilde{i_{ld}} \\ i_{lq} \end{bmatrix}$$

In three phase system, APF currents can be calculated by the inverse Park transform which is defined as

$$\begin{bmatrix} i^*_{fa} \\ i^*_{fb} \\ i^*_{fc} \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} \cos\theta & -\sin\theta \\ \cos(\theta-\frac{2\pi}{3}) & -\sin(\theta-\frac{2\pi}{3}) \\ \cos(\theta+\frac{2\pi}{3}) & \sin(\theta+\frac{2\pi}{3}) \end{bmatrix} \begin{bmatrix} i^*_{fd} \\ i^*_{fq} \end{bmatrix}$$

SIMULATION DIAGRAM AND RESULTS

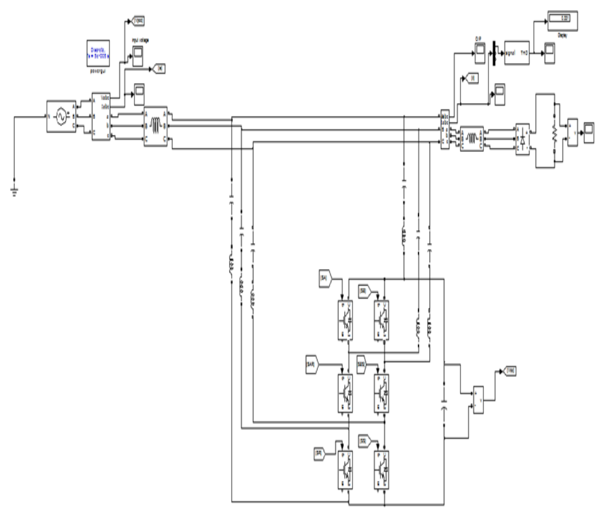

Figure-5. Without battery and Solar system.

The input supply voltage of 450 voltage applied to the distribution system that is reduced to 400 voltage and the total hormonic distortion level is 0.331.

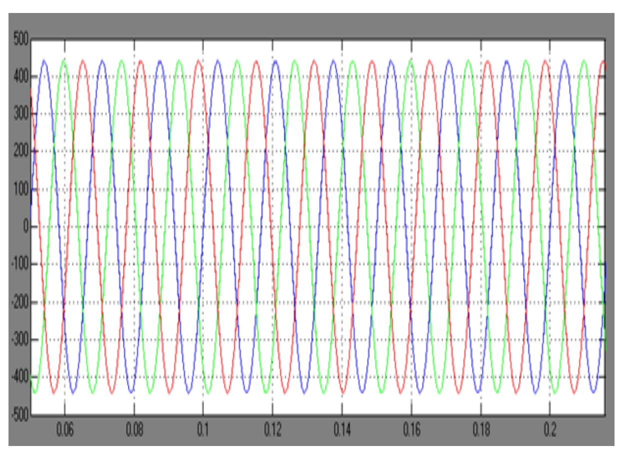

Figure-6. Supply voltage of 450 volts.

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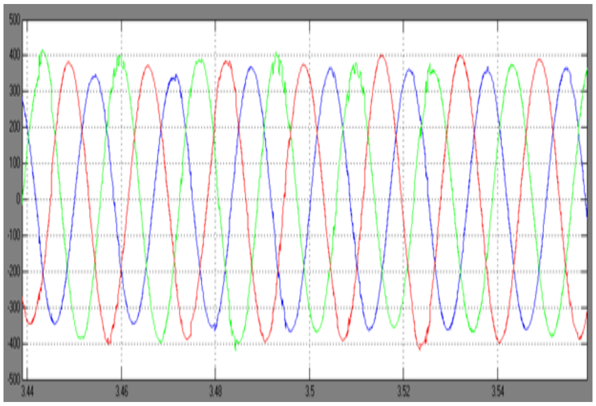

Figure-7. output voltage of 400 volts without battery and solar sysyem.

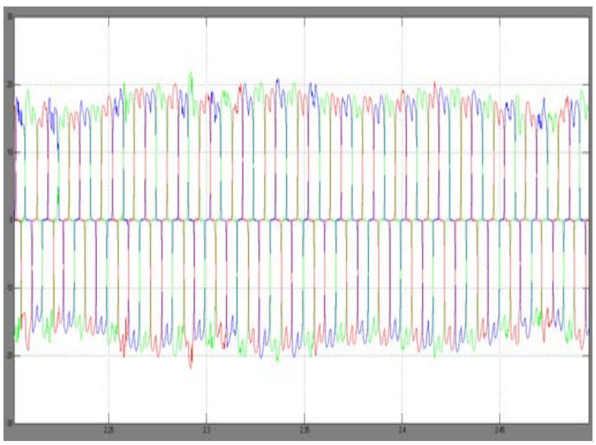

Figure-8. load current.

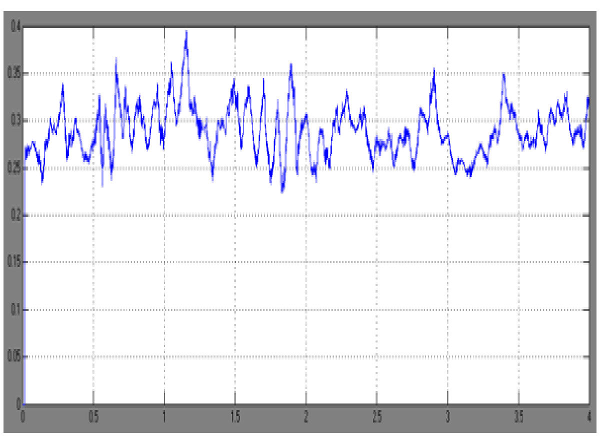

Figure-9. Total hormonic distortion level of 0.331.

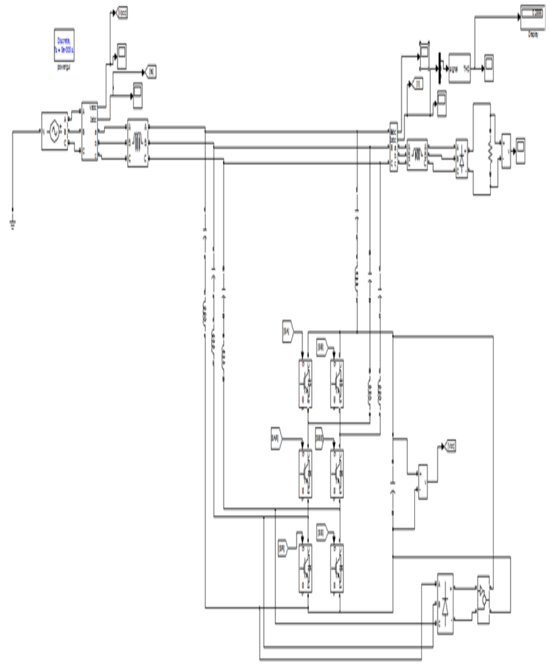

Figure-10. Battery source with boost converter.

The input supply voltage of 450 voltage applied to the distribution system that is increased voltage level of 580 voltage and reduce the total hormonic distortion from 0.331 to 0.2656 level when compare to previous distribution system 0.0654 is reduced because of injection of battery source supply voltage through a boost converter.

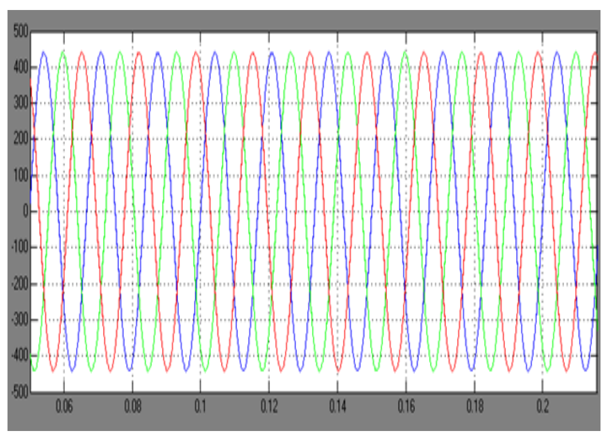

Figure-11. Supply voltage of 450 volts.

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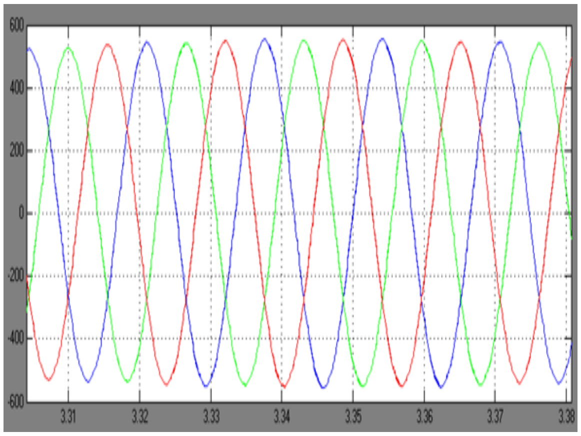

Figure-12. output voltage of 580 volts with battery source through boost converter.

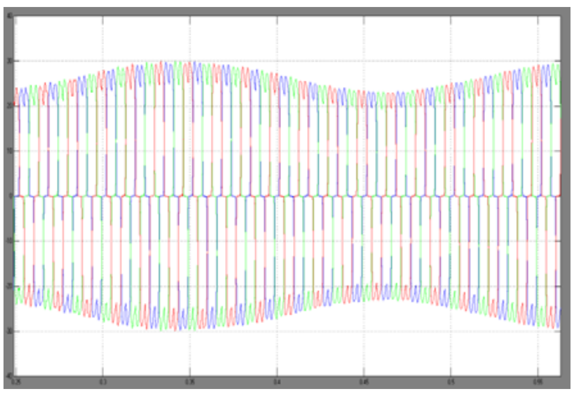

Figure-13. load current.

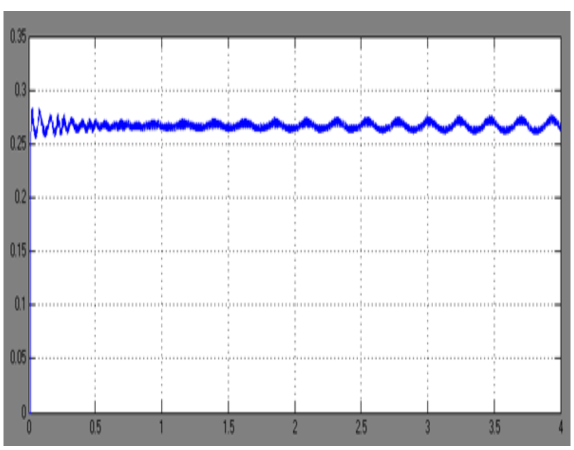

Figure-14. Total hormonic distortion level of 0.2656.

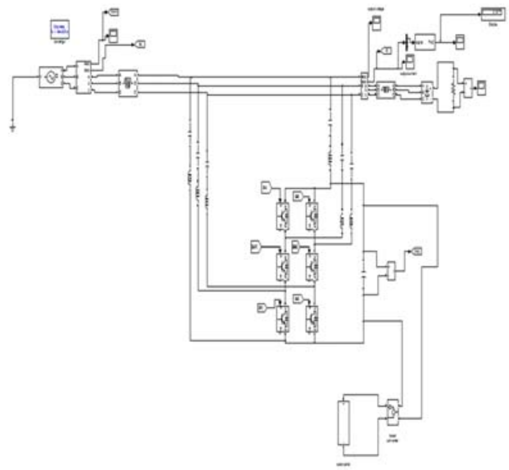

Figure-15. Solar system with Boost Converter.

The input supply voltage of 450 voltage applied to the distribution system that is increased voltage level of 1500 voltage and reduce the total hormonic distortion from 0.2656 to 0.1527 level when compare to battery source connected distribution system the THD 0.1527 is reduced because of solar system.

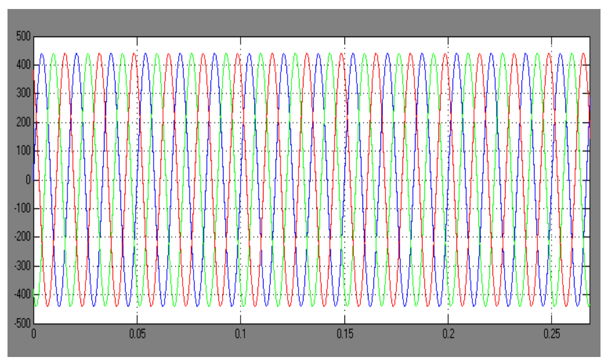

Figure-16. Supply voltage of 450 volts.

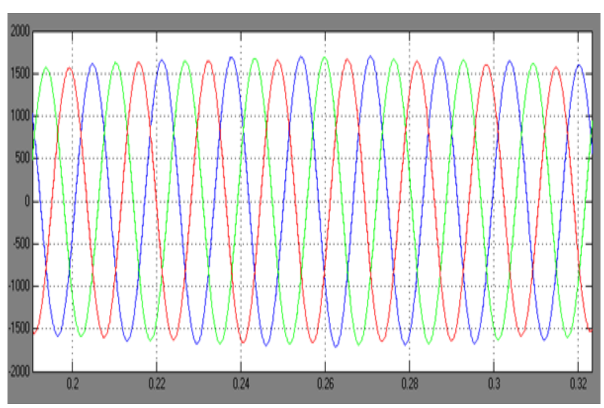

Figure-17. output voltage of 1500 volts with solar system through boost converter.

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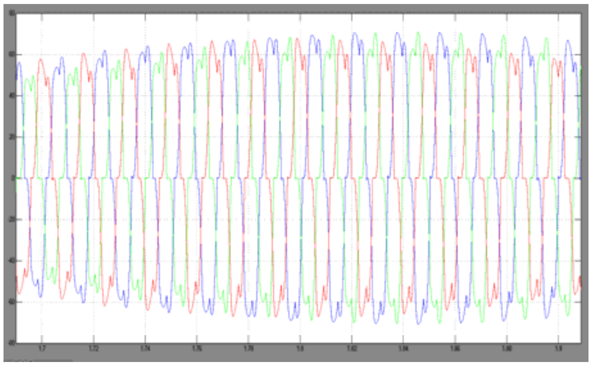

Figure-18. load current.

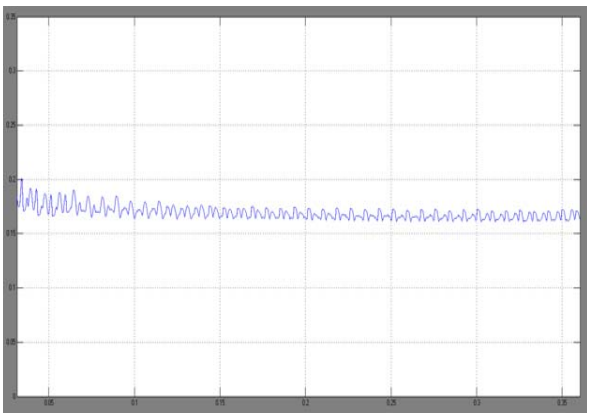

Figure-19. Total hormonic distortion level of 0.1527.

RESULT COMPARISON

S. No.	Parameters	Without boost converter and solar system	With boost	With boost and solar system
1	Input voltage	450	450	450
2	Output voltage	400	580	1500
3	Load current	20	30	65
4	THD level	0.331	0.2656	0.1527

CONCLUSIONS

Power quality improvement performance of battery source through boost converter connected system and solar through boost converter connected system with transformerless back-to-back HPF used to reduce the total harmonics distortion from 0.331 to 0.1527 and enhance the voltage level of 580 voltage for battery connected system and 1500 voltage for solar system using MATLAB software.

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