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Grid Interfacing Inverter of Renewable Energy Sources to Improve the Power Quality in Distribution System

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Abstract: With the increase in load demand, the Renewable Energy Sources (RES) are increasingly connected in the distribution systems which utilizes power electronic Converters/Inverters. In this thesis, Photo Voltaic (PV) system is integrated to a three phase four wire distribution system. The Photo Voltaic (PV) Panel is modeled based on associated equations. The use of non-linear loads in the power system will lead to the generation of current harmonics which in turn deteriorates the power quality. Active Power Filters (APF) are extensively used to compensate the current harmonics and load unbalance. In this work, the existing PV inverter acts as Shunt Active Power Filter (SAPF) that is capable of simultaneously compensating problems like current unbalance, current harmonics and also of injecting the energy generated by renewable energy source. The inverter is controlled on the basis of hysteresis control and thus it can be utilized as a power converter injecting power generated from RES to the grid and as a shunt APF to compensate the Load disturbances. It is proposed to investigate in this paper, the performance of PV inverter for various loads. This work is carried out using MATLAB/SIMULINK 7.8 software.

Index Terms— Photo Voltaic Active Power Filter, Shunt Active Power Filter, Power Quality.

I. INTRODUCTION

Due to increasing air pollution, global warming concerns, diminishing fossil fuels and their increasing cost have made it necessary to look towards Renewable Energy Sources (RES) as a future energy solution. In finding solutions to overcome a global energy crisis, the Photo Voltaic (PV) system has attracted significant attention in recent years. The government is providing incentives for further increasing the use of grid-connected PV systems. Renewable Energy Sources are increasingly integrated at the distribution level due to increase in load demand which utilize power electronic converters. Due to the extensive use of power electronic devices, disturbances occur on the electrical supply network. These disturbances are due to the use of non-linear devices. These will introduce harmonics in the power system thereby causing equipment overheating ,damage devices ,EMI related problems etc. Active Power Filters (APF) is extensively used to compensate the current harmonics and load unbalance. This will result in additional hardware requirements. So, in this paper, the existing PV inverter acts as Shunt Active Power Filter (SAPF) that is capable of simultaneously compensating problems like current unbalance, current harmonics and also of injecting the energy generated by RES. The shunt active filter is a voltage source inverter (VSI), which is connected in parallel with load. Shunt Active Power Filter has the ability to keep the mains current balanced and sinusoidal after compensation for various Load conditions.

1.1 ORGANIZATION OF THE PAPER

The paper has been divided into five sections for easy understanding. Each section has got its own importance and relevance in the project.

An overview of the individual sections is presented below.
Section-1: This gives the introduction to the project constituting overview of the work.
Section-2: This section gives the details of topology and components of the proposed system.
Section-3: This section displays the simulation and tabular results of the whole work done.
Section-4: This section gives the references on which this work is done.
Section-5: This section comprises of bibliography of the authors, which gives brief introduction of them.

II.SYSTEM DESCRIPTION

A. TOPOLOGY

Active power filters are power electronic devices that cancel out unwanted harmonic currents by injecting a compensation current which cancels harmonics in the line current. Shunt active power filters compensate load current harmonics by injecting

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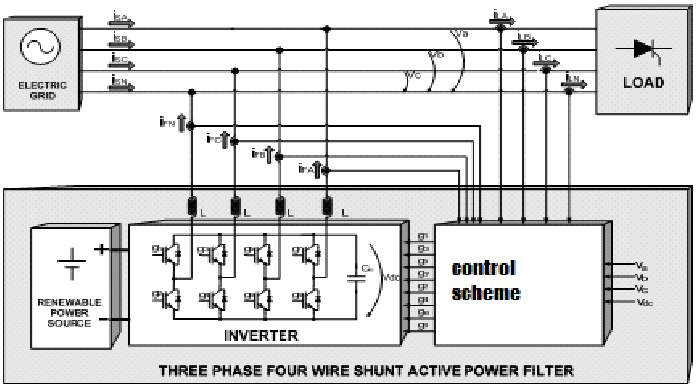
equal-but opposite harmonic compensating current. Generally, four-wire APFs have been conceived using fourleg converters [5]. This topology has proved better controllability [6] than the classical three-leg four-wire .In this paper, it is shown that using an adequate control strategy, even with a three phase four-wire system, The topology of the investigated APF and its interconnection with the grid is presented in Fig. 1. It consists of a three-leg four-wire voltage source inverter. In this type of applications, the VSI operates as a current controlled voltage source. The proposed system is Three Phase Four wire which consists of Photovoltaic system connected to the dc-link of a grid-interfacing inverter as shown in Fig. 1. The voltage source inverter is a key element of a PV system as it interfaces the renewable energy source to the grid and delivers the generated power. The Photovoltaic system is connected to grid with an inverter coupled to dc-link. The dc-capacitor decouples the Photovoltaic system from grid and also allows independent control of converters on either side of dc-link**.**



Elimination of current harmonics, compensation of reactive power, Correction of power factor

Fig.1 Proposed System

B.VOLTAGE SOURCE CONVERTER (VSC)

A Voltage Source Converter (VSC) is a power electronic device that connected in shunt or parallel to the system. It can generate a sinusoidal voltage with any required magnitude, frequency and phase angle. It also converts the DC voltage across storage devices into a set of three phase AC output voltages. It is also capable to generate or absorbs reactive power. If the output voltage of the VSC is greater than AC bus terminal voltages, is said to be in capacitive mode. So, it will compensate the reactive power through AC system. The type of power switch used is an IGBT in anti-parallel with a diode. The three phase four leg VSI is modeled in Simulink by using IGBT.

C.CONTROLLER FOR APF

The dc link voltage, Vdc is sensed at a regular interval and is compared with its reference counterpart Vdc*.The error signal is processed in a PI-controller. The output of the pi controller is denoted as Im.The reference current templates (Ia*,Ib*,and Ic*) are obtained by multiplying this peak value (Im) by the three-unit sine vectors (Ua , Ub and Uc) in phase with the three source voltages. Theseunit sine vectors are obtained from the three sensed line to neutral voltages. The reference grid neutral current (In*) is set to zero, being the instantaneous sum of balanced grid currents. Multiplication of magnitude Im with phases (Ua ,Ub, and Uc) results in the three phase reference supply currents (Ia*,Ib*,and Ic*).

The grid synchronizing angle (Θ) obtained from phase locked loop (PLL) is used to generate unity vector template as

$$U_a = \sin\theta \qquad \{1\}$$

$$U_b = \sin\left(\theta - \frac{2\pi}{3}\right) \qquad \{2\}$$

$$U_c = \sin(\theta + \frac{2\pi}{3}) \qquad \{3\}$$

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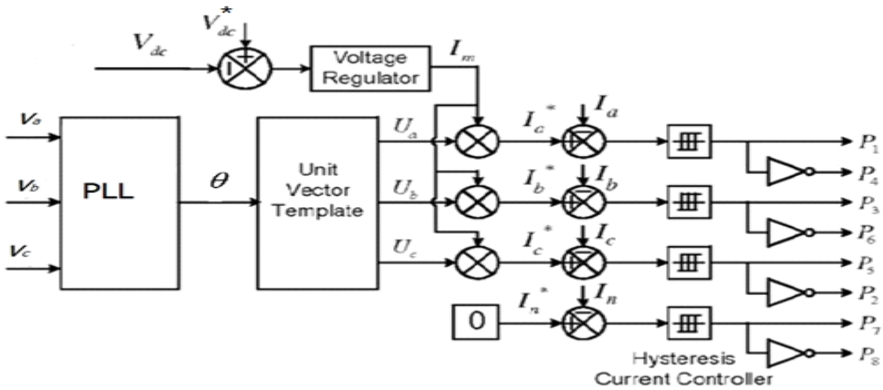

Fig. 2 Control Scheme

The instantaneous values of reference three phase grid currents are compute as

$$I_a^* = I_m * U_a \quad \{4\}$$

$$I_b^* = I_m * U_b \quad \{5\}$$

$$I_c^* = I_m * U_c \quad \{6\}$$

The neutral current is considered as

$$I_n^* = 0 \quad \{7\}$$

The reference grid currents(I_a*,I_b^*,$I_c^*$and I_n^*) are compared with actual grid currents(I_a, I_b,$I_c$and I_n) to compute the current errors as

$$I_{aerr} = I_a^* - I_a \quad \{8\}$$

$$I_{berr} = I_b^* - I_b \quad \{9\}$$

$$I_{cerr} = I_c^* - I_c \quad \{10\}$$

$$I_{nerr} = I_n^* - I_n \quad \{11\}$$

These error signals are given to hysteresis current controller then generates the switching pulses for six IGBTs of the grid interfacing inverter.

III.HYSTERESIS CURRENT CONTROL

The hysteresis current control (HCC) is the easiest control method to implement; it was developed by Brod and Novotny in 1985 . The shunt APF is implemented with three phase current controlled VSI and is connected to the ac mains for compensating the current harmonics. The VSI gate control signals are brought out from hysteresis band current controller.

A hysteresis current controller is implemented with a closed loop control system and waveforms are shown in Fig .3. An error signal is used to control the switches in a voltage source inverter. This error is the difference between the desired current and the current being injected by the inverter . If the error exceeds the upper limit of the hysteresis band, the upper switch of the inverter arm is turned off and the lower switch is turned on. As a result, the current starts decaying.

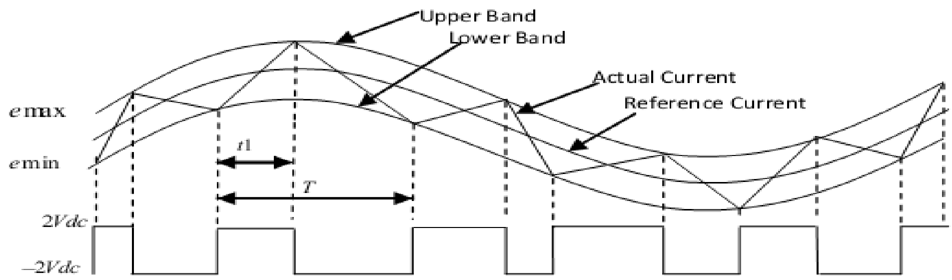

Fig. 3: Waveform of Hysteresis current controller

If the error crosses the lower limit of the hysteresis band, the lower switch of the inverter arm is turned off and the upper switch is turned on. As a result, the current gets back into the hysteresis band. The minimum and maximum values of the error

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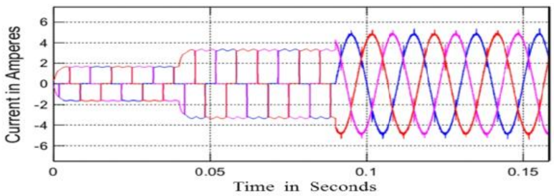
signal are e_{min} and e_{max} respectively. The range of the error signal $e_{max} - e_{min}$ directly controls the amount of ripple in the output current from the VSI.

IV.SIMULATION RESULTS

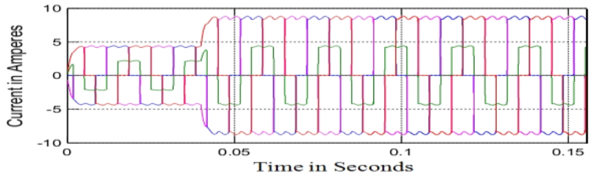
The performance of the proposed structure is assessed by a computer simulation that uses MATLAB Software. The parameters of the proposed system are given in the tables below. The performance of the system with proposed control scheme is discussed, which includes the following case studies.

CASE 1: NONLINEAR LOAD

a. Source Current



b. Load Current



c. INVERTER CURRENT

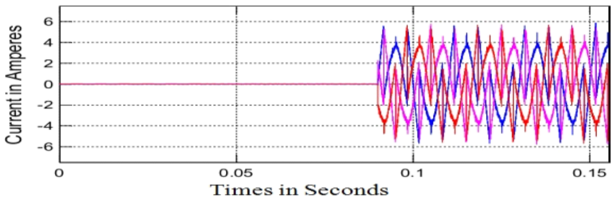


Fig. 4: Simulation results of Non- Linear Load (a) Source Current (b) Load Current (c) Inverter Current .

Fig. 4 shows the source current, load current, inverter compensating current respectively. The inverter is turned on at 0.09 seconds. Fig. 4 (a) : it clearly indicates the source current from 0 to 0.09 sec represents the non-sinusoidal nature due to the presence of nonlinear load .At 0.09 seconds the nature of waveform is sinusoidal this represents the inverter compensated the non sinusoidal wave to balanced sinusoidal wave. The load current waveform is shown in Fig. 4 (b) .The inverter supplies the compensating current that is shown in Fig. 4 (c). THD analysis for NON LINEAR LOAD is shown in figure (5) and (6) below.

THD OF SOURCE CURRENT BEFORE COMPENSATION

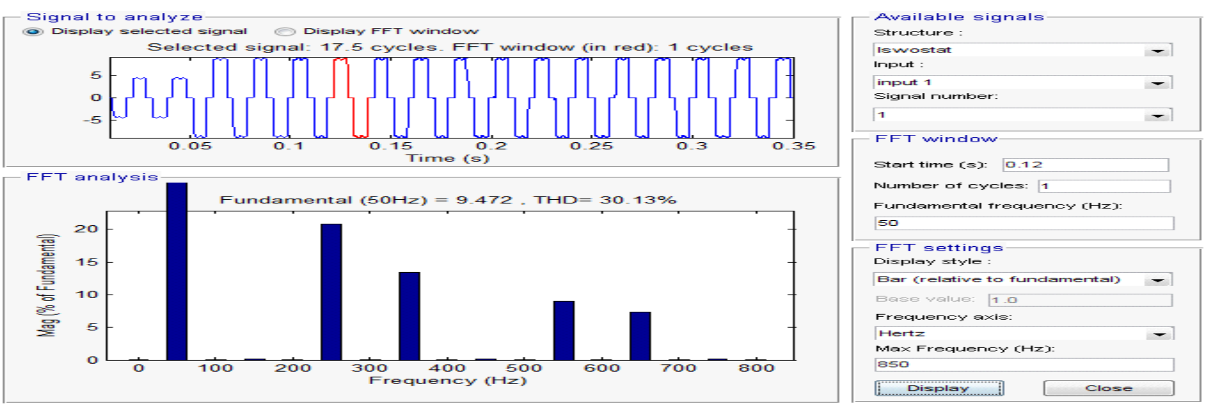


Fig. 5: THD of Source Current Before Compensation

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Total Harmonic Distortion of Source Current Before Compensation = 30.13%

THD OF SOURCE CURRENT AFTER COMPENSATION

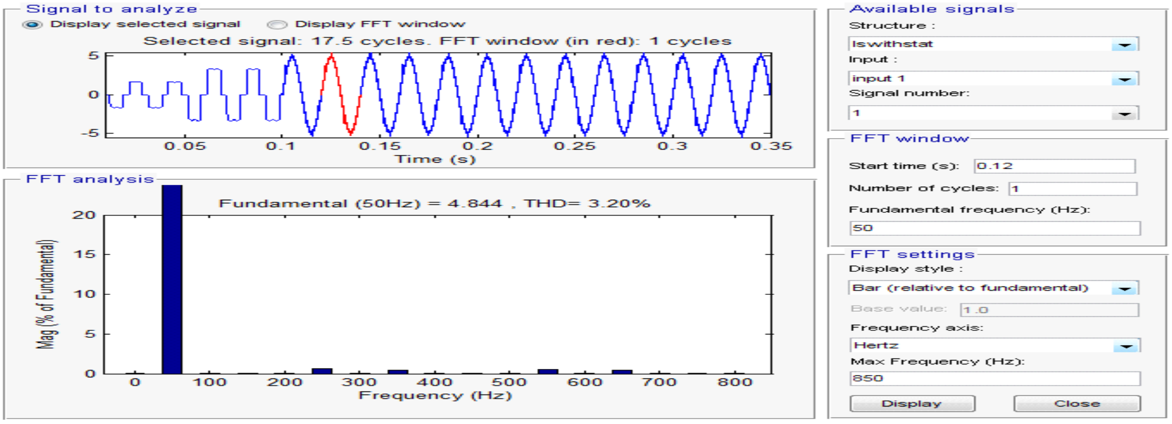


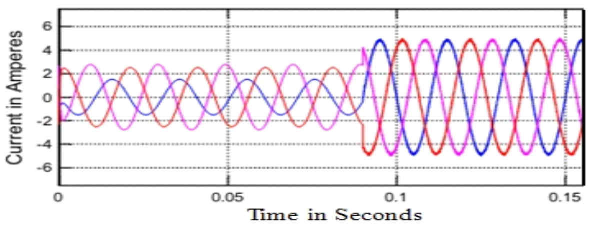
Fig. 6 :THD of Source Current After Compensation

Total Harmonic Distortion of Source Current after Compensation = 3.20%.

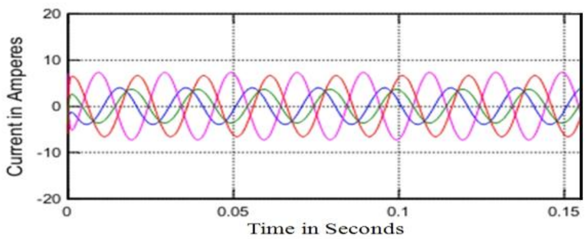
After compensation, THD of the source is reduced from 30.13% to 3.20% which is well below the recommended 5% limit.

CASE 2 : UNBALANCED LOAD

a. Source Current



b. Load Current



c. Inverter Current

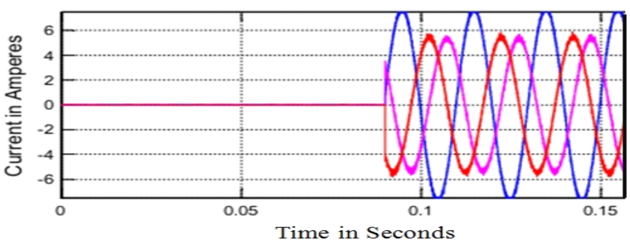


Fig. 7: Simulation results Unbalance Load (a) Source Current (b) Load Current (c) Inverter Current.

From Fig. 7, it clearly indicates the source current from 0 to 0.1 sec represents the unbalance nature due to the presence of unbalance load. At 0.1 seconds the nature of waveform is sinusoidal this represents the inverter compensated the unbalance wave to balanced sinusoidal wave. The load current waveform is shown in Fig .7(b). The inverter supplies the compensating current that is shown in Fig. 7 (c).

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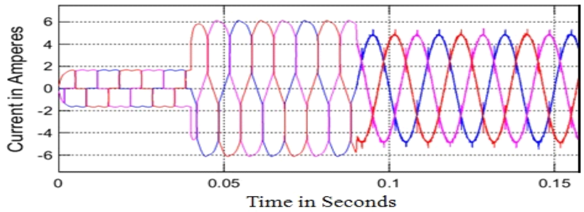
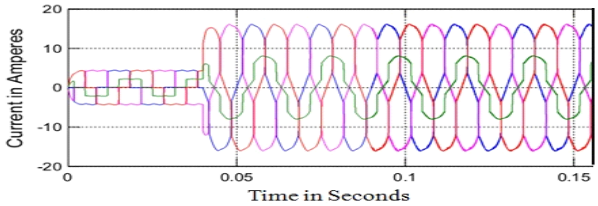
CASE 3: BALANCED NONLINEAR LOAD

a. SOURCE CURRENT



B. LOAD CURRENT



C. INVERTER CURRENT

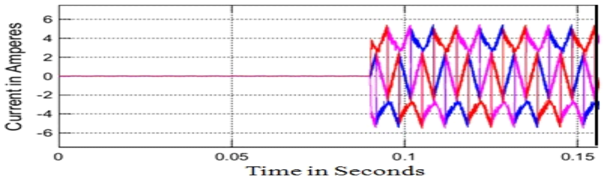
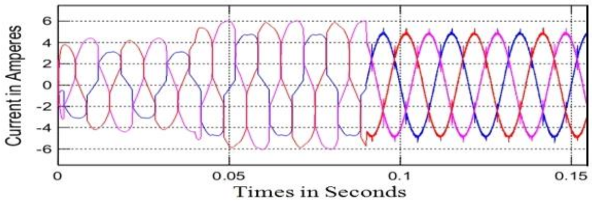


Fig. 8: Simulation results Balanced Nonlinear Load (a) Source Current (b) Load Current (c) Inverter Current.

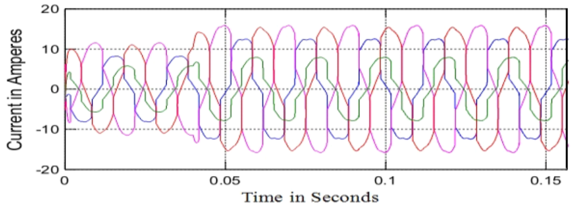
From Fig.8, it clearly indicates the source current from 0 to 0.1 sec represents the balance nonlinear nature due to the presence of balance nonlinear load. At 0.1 seconds the nature of waveform is sinusoidal this represents the inverter compensated the balanced nonlinear wave to balanced sinusoidal wave.

CASE 4: UNBALANCED NONLINEAR LOAD

a. Source Current



b. Load Current



c. Inverter Current

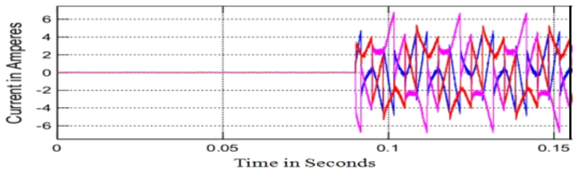


Fig. 9: Simulation results Unbalanced Nonlinear Load (a) Source Current (b) Load Current (c) Inverter Current.

Fig. 9, it clearly indicates the source current from 0 to 0.1 sec represents the unbalance and non sinusoidal nature due to the presence of unbalance nonlinear load. At 0.1 seconds the nature of waveform is sinusoidal this represents the inverter compensated the both unbalance and non sinusoidal wave to balanced sinusoidal wave.

CASE 5 : THD ANALYSIS FOR DIFFERENT HYSTERESIS BANDS

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TABLE 1: THD Analysis for Different Hysteresis Bands

S.NO	Hysteresis Band	Source Current THD Without Inverter	Source Current THD With Inverter
1	0.05	21.08	3.24
2	0.1	21.08	2.98
3	0.15	21.08	3.10
4	0.2	21.08	3.65
5	0.25	21.08	3.68
6	0.3	21.08	3.41
7	0.35	21.08	3.50
8	0.4	21.08	3.54
9	0.45	21.08	3.58
10	0.5	21.08	3.57
11	0.55	21.08	3.78
12	0.6	21.08	3.82
13	0.65	21.08	4.12
14	0.7	21.08	3.98
15	0.75	21.08	4.15
16	0.8	21.08	3.65
17	0.85	21.08	3.64
18	0.9	21.08	3.54
19	0.95	21.08	3.77
20	1.0	21.08	3.66
21	1.5	21.08	4.09
22	2	21.08	4.53
23	2.5	21.08	5.05

From the above table 1 it can be observed that as the hysteresis bands increase the THD valves of source current increased.

CASE 6: THD ANALYSIS FOR DIFFERENT PERCENTAGE OF UNBALANCED NONLINEAR LOAD

TABLE 2: THD Analysis for Different Percentage of Unbalanced Nonlinear Load

S.NO.	Percentage of Unbalanced Nonlinear Load	Source Current THD Without Inverter	Source Current THD With Inverter
1	10	28.63	3.18
2	20	27.54	3.21
3	30	26.53	3.53
4	40	25.59	3.11
5	50	24.71	3.22
6	60	23.89	3.52
7	70	23.12	3.19
8	80	22.40	2.95
9	90	21.72	3.20

From the above table 2 it can be observed that for different percentage of Unbalanced Nonlinear load the to eliminate harmonics for various load.

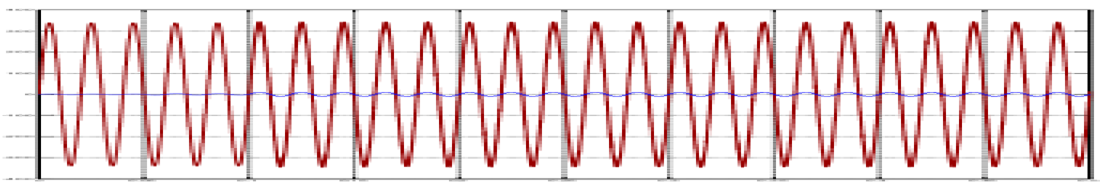

Fig. 10: Simulation results power factor for Non linear Load (indicating Unity Power Factor)

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