# HIGH POWER QUALITY IMPROVEMENT IN 3-PHASE WITH 4-WIRE DISTRIBUTION SYSTEM OF RENEWABLE ENERGY SOURCES TO GRID INTER CONNECTION

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## Abstract

Abstract: Considering a rapid increase in the use of power electronic converters in distribution systems, renewable energy resources (RES) are becoming more and more integrated. Our study provides a thorough, cutting-edge control method for grid-interfacing inverters installed in three-phase, four-wire distribution systems to maximize their performance. In addition to its active power filtering capabilities, an inverter can be used as a Shunt Active Power Filter (SAPF), which can both replenish current imbalances and inject energy from renewable energy sources (RES) into the grid, and as a power converter. Specifically with current harmonics. By using the MATLAB/SIMULINK software the new concept is demonstrated for the user friendly control where the grid-interfacing inverter paired with a three-phase, four-wire linear or non-linear unbalanced load at the common coupling point appears to be a balanced linear load.

**Keywords:** Active power filter (APF), Shunt Active Power Filter (SAPF).

## 1.Introduction

With the drastic increase in areas of air pollution, concerns related to global warming, continuous reduction of fossil fuels and their increasing cost have made it necessary to look towards Renewable Energy Sources (RES) as a forth coming potential energy solution. In finding solutions to overcome a global energy crisis the Photo Voltaic (PV) system has attracted significant attention in recent years. As the government is providing incentives for further increasing the use of grid connected PV systems the Renewable Energy Sources are increasingly integrated at the distribution level due to increase in load demand utility which utilizes power electronic converters. Due to the massive use of power electronic devices conflicts occur on the electrical supply network where

these conflicts are raised due to the use of non-linear devices which introduces harmonics in the power system thereby causing equipment overheating or damaging devices and most often EMI related problems etc. Active Power Filters (APF) is majorly used to compensate the current harmonics and load unbalance which results in the additional hardware requirements. In this paper we propose that the existing PV inverter acts as Shunt Active Power Filter (SAPF) which is capable of simultaneously compensating problems like current unbalance, increase in current harmonics and also injecting the energy generated by RES since the shunt active filter is a voltage source inverter (VSI) that is connected in parallel with load and Shunt Active Power Filter has the ability to keep the mains current balanced and sinusoidal after compensation for various Load conditions.

The distributed generation(DG) systems are mandatory to act in accordance with strict technical and regulatory frameworks to ensure safe , reliable and efficient operation of overall network with the advancement in power electronics and digital control technology where the DG systems can now be actively controlled to enhance the system operation with improved power quality(PQ)at PCC but the extensive use of power electronics based equipment and non-linear loads at PCC generate harmonic currents which may deteriorate the quality of power [3], [4].

The paper is being classified into five sections for easy understanding and each section has got its own importance and relevance in the implementation of project and overview of the individual sections is presented below:

Section-1: This section gives the introduction to the project constituting overview of the proposed work.

Section-2: This section gives the details of the topology used and the components used in the proposed system.

Section-3: This section projects the simulation and tabular results of the whole implementation of proposed work.

Section-4: This section gives the complete list of references used.

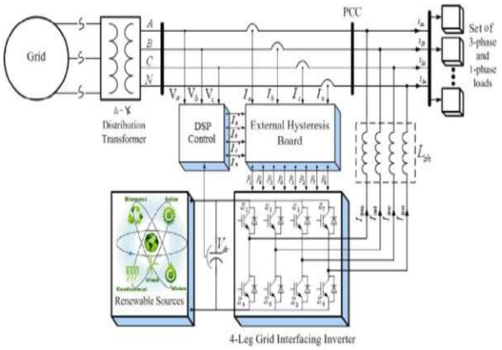


**Figure1** *Scheme of proposed renewable energy based distributed generation system*

## 2 System description

The proposed system consists of RES that is connected to the dc-link of a grid-interfacing inverter as shown in Figure 1 and the voltage source inverter is a key element of a DG system a sit interfaces with there newable energy source to the grid and delivers the generated power where the renewable energy source (RES) may be a DC source or an AC source with rectifier coupled to dc-link. Most often the fuel cell and photovoltaic energy sources generate power at variable low dc voltages while the variable speed wind turbines generate power at variable ac voltage and the power generated from these renewable sources needs power conditioning (i.e., dc-to-dc or ac-to- dc) before connecting on dc-link the dc-capacitor decouples the RES from grid and also allows independent control of converters on either side of dc-link.

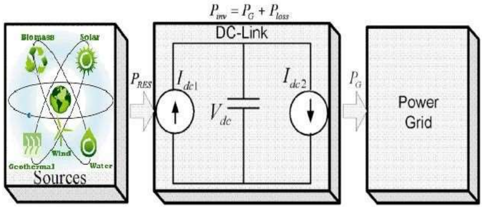


**Figure2** *Equivalent diagram of DC-Link*

### 2.1Topology

The 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 which is generated and the shunt active power filters compensate the load current harmonics by injecting equal-but opposite harmonic compensating current that is in general in a four-wire APFs have been conceived using four leg converters [5].

This topology has being proved better with respect to controllability [6] than the classical three-leg four-wire here in this paper it is shown that by adapting 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 figure 1 and it consists of a three-leg four-wire voltage source inverter where the VSI operates a current controlled voltage source in this application and the proposed system is a Three Phase Four wire which consists of Photovoltaic system connected to the dc-link of a grid-interfacing inverter as shown in Figure 1 where 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 produced power since the Photovoltaic system is connected to grid with an inverter coupled to dc-link where the dc-capacitor decouple s the Photovoltaic system from grid and also allows independent control of converters on either side of dc-link.

### 2.2Voltage source converter (vsc)

A Voltage Source Converter (VSC) is a power electronic device that is connected in shunt or parallel to the system which is used to generate a sinusoidal voltage with any required magnitude or frequency and phase angle. And it also converts the DC voltage across storage devices in to a set of three phase AC output voltages and also it is capable of generating or absorbing reactive power when the output voltage of the VSC is greater than AC bus terminal voltages which is said to be in capacitive mode and it will compensate the reactive power through AC system and the type of power switch used is an IGBT in anti-parallel with a diode and the three phase four leg VSI is modeled in Simulink by using IGBT. Due to the intermittent nature of RES the produced power is variable in nature and the dc-link plays an important role in moving this variable power from renewable energy source to the grid where as RES is represented as current sources connected to the dc-link of a grid-interfacing inverter

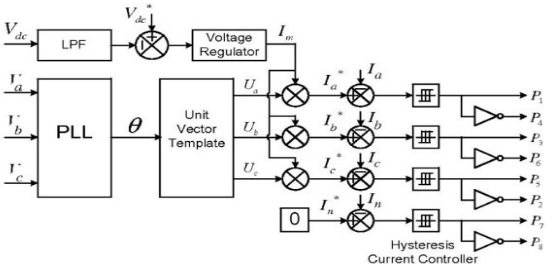


***Figure3****Block diagram representation of grid-interfacing inverter control*

## 2.3 Controller of grid interfacing inverter

The dc link voltage $V_{dc}$is sensed at regular intervals and is compared with its reference counterpart $V_{dc}$*and the error signal is processed in a PI-controller where the output of the picontroller is denoted as $I_m$where the reference current templates($I_a$*,$I_b$*and $I_c$*)are resulted by multiplying this peak value $I_m$by the three-unit sine vectors $U_a$, $U_b$and $U_c$ in phase with the three source voltages where these unit sine vectors are obtained from the three sensed line to neutral voltages. The reference grid neutral current $I_n$* is set to zero which is being the instantaneous sum of balance d grid current s and the multiplication of magnitude $I_m$with phases $U_a$,$U_b$,and $U_c$results in the three phase reference supply currents $I_a$*,$I_b$*and $I_c$* and the grid synchronizing angle  is obtained from phase locked loop (PLL) which is used to generate unity vector template as:

$$U_a=\sin(\emptyset) \quad (1)$$

$$U_b=\sin(\emptyset - (2\pi)/3) = \sin(\emptyset -2.095) \quad (2)$$

$$U_c=\sin(\emptyset+(2\pi)/3) = \sin(\emptyset +2.095) \quad (3)$$

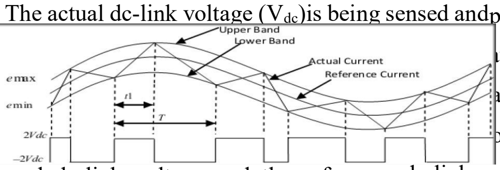


***Figure 4*** *Waveform of the Hysteresis current*

The actual dc-link voltage ($V_{dc}$)is being sensed andpassed th ate the pr and in th of this filtered dc-link voltage and the reference dc-link voltage ($V_{dc}$*)is given to a discrete PI regulator to maintain a constant dc-link voltage under varying generation and load conditions of the dc-link voltageerror $V_{dcerr(n)}$ at $n^{th}$ sampling instant is given as:

$$V_{dcerr(n)}= V_{dc(n)}^*- V_{dc(n)}. \quad (4)$$

Thecontroldiagramofgrid-interfacinginverterfora3-phase4-wire system is shown in figure3wherethefourth leg of inverter is used to compensate the neutral current of load and the main aim of proposed approach is to regulate the power at PCC during:

- $P_{RES}$= 0.0
- $P_{RES}$<total sum of load power ($P_L$)
- $P_{RES}$>total sum of load power ($P_L$)

When implementing the power management operation the inverter is actively controlled in such a way that it always draws or supplies the fundamental active power from or to the grid when the load is connected to the PCC is non-linear or unbalanced or the combination of both then the given control approach also compensates the harmonics or unbalance and neutral current.

The output generated at discrete-PI regulator at $n^{th}$ sampling instant can be expressed as:

$$I_{m(n)}=I_{m(n-1)}+K_{PVdc}(V_{dcerr(n)}-V_{dcerr(n-1)})+K_{IVdc}V_{dcerr(n)} \quad \ldots..(5)$$

Where the $K_{PVdc}$=10 and $K_{IVdc}$= 0.05 are proportional and integral gains of dc-voltage regulator and the instantaneous values of reference three phase grid currents are computed as:

$$I_a^*=I_m.U_a \quad (6)$$

$$I_b^*=I_m.U_b \quad (7)$$

$$I_c^*=I_m.U_c \quad (8)$$

If the neutral current if present any that may be due to the loads connected to the neutral conductor that should be compensated by forth leg of grid-interfacing inverter and thus should not be drawn from the grid that is in other words the reference current for the grid neutral current is considered as zero and can be expressed as:

$$I_c^*=0.0 \quad (9)$$

The reference grid currents($I_a$*, $I_b$* &$I_c$*) are compared with actual grid currents that are ($I_a$, $I_b$and $I_c$) supposed to be computed with the current errors as:

$$I_{aerr}= I_a^*-I_a \quad (10)$$

$$I_{berr}=I_b^*-I_b \quad (11)$$

$$I_{cerr}= I_c^*-I_c \quad (12)$$

$$I_{nerr}=I_n^*-I_n. \quad (13)$$

These current errors are given as input to the hysteresis current controller which then generates the switching pulses ($P_1$ to $P_8$) for the gate drives of grid-interfacing inverter.

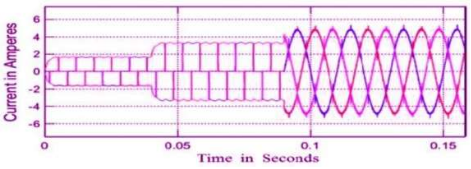
## 3 Hysteresis current control

The hysteresis current control (HCC) is the simplest control method available so-forth to implement the shunt APF with three phase current controlled VSI and is connected to the AC mains for compensating the current harmonics and the VSI gate control signals are brought out from hysteresis band current controller where a hysteresis current controller is implemented with the closed loop control system and waveforms which are shown in figure4hereaerror signal is used to control the switches in a voltage source inverter and the error is the only difference between the desired current and the current being injected by the inverter and when 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 of which the current starts decaying.

When the error crosses its defined lower limit of the hysteresis band then the lower switch of the inverter arm is turned off and the upper switch is turned on as a result of which the current gets back into the hysteresis band and the minimum and maximum values of the error-signal are $e_{min}$and $e_{max}$respectively and the range of the error signal $e_{max}$-$e_{min}$directly controls the amount of ripple in the output current from the VSI.

## 4 Simulation results

The proposed system is implemented in the academic environment and the results generated in the computer simulation using MATLAB Software are displayed below:



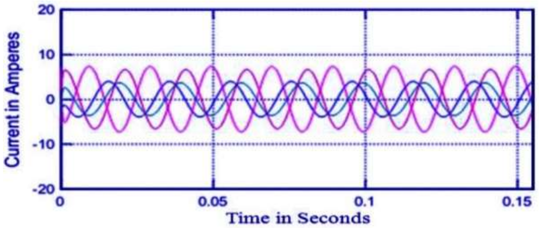


*Figure6 Non-Linear Load Current*

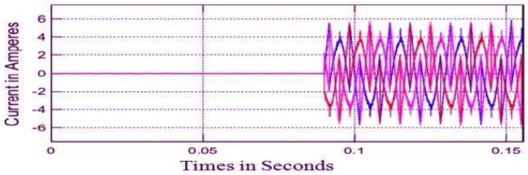
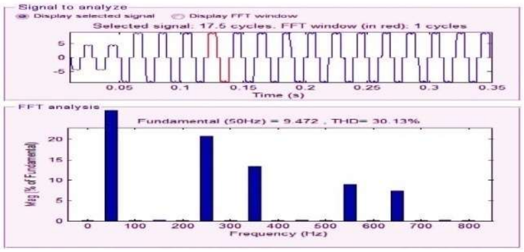


***Figure7*** *Non-LinearLoadInverter Current*

The above figures shows the Non-Linear Load source current, Non-Linear load current, Non-Linear load inverter compensating current respectively where the inverter is turned on at 0.09 seconds which clearly indicates the source current starting from 0 to 0.09 sec shows the non-sinusoidal nature due to the presence of nonlinear load which is at 0.09 seconds the nature of waveform is sinusoidal this represents the inverter compensated the non sinusoidal wave to balanced sinusoidal wave.



Selected signal: 17.5 cycles. FFT window (in red): 1 cycles

Fundamental (50Hz) = 9.472 , THD= 30.13%

***Figure8*** *Before Compensation source current of THD*

***Figure9*** *After Compensation source current of THD*

The Total Harmonic Distortion after compensation of Source Current = 3.32% and the THD of the source is reduced from 30.32% to 3.23% which is below the recommended 5% limit which is acceptable according to the theory specified above.

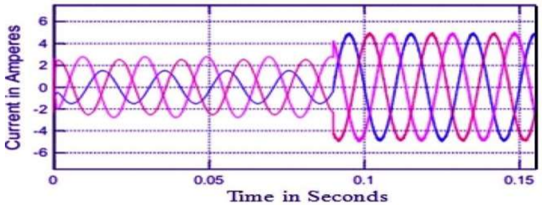
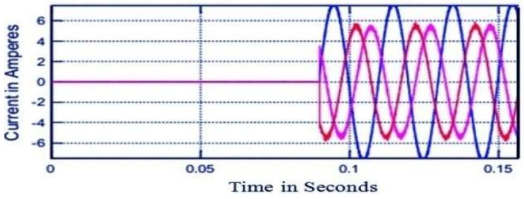


***Figure10*** *unbalanced Load source current*

***Figure11*** *unbalanced Load current*

***Figure12*** *unbalanced Load inverter current*



In the above figures it clearly indicated that the source current from 0 to 0.1 sec shows the unbalance nature due to the occurrence ofunbalance-loadandat0.1secondsthe nature of waveform is sinusoidal this represents the inverter compensated the unbalance wave form to balanced sinusoidal wave.

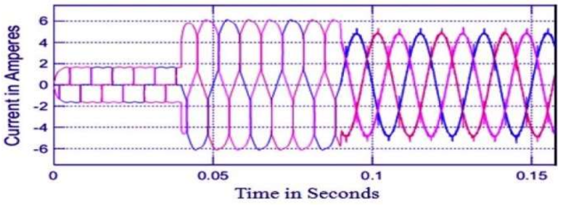


***Figure13*** *Balanced nonlinear load source current*

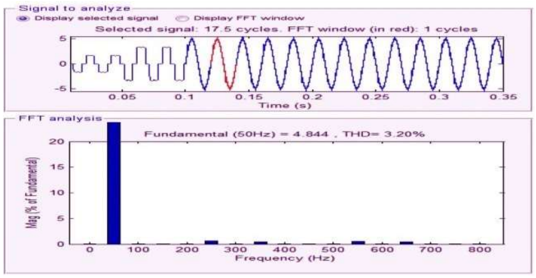


***Figure14*** *Balanced nonlinear load   current*

***Figure15****Balanced nonlinear load inverter current*

Total active and reactive powers are exchanged between grid; load and inverter which are shown in below figure which are represented as P grid, Q grid, P load, Q load ,Pinv and  Qinv respectively here the negative sign of total grid side active power is demonstrates with the excess power generated by RES that flows towards grid side and the main emphasis is on demonstration of grid-interfacing inverter which can simultaneously utilized to inject the power generated from RES to PCC and to improve the quality of power at PCC.

## 5 Conclusion

This paper has presented the novel control of an existing  grid interfacing inverter to improve the quality of power at PCC for a 3-phase 4-wireDGsystem and it has been shown that the grid-interfacing inverter can be effectively utilized for power conditioning with out affecting its normal operation of real power transfer and the proposed approach can be utilized to:

i) To inject the real power generated from RES to the grid and/or.

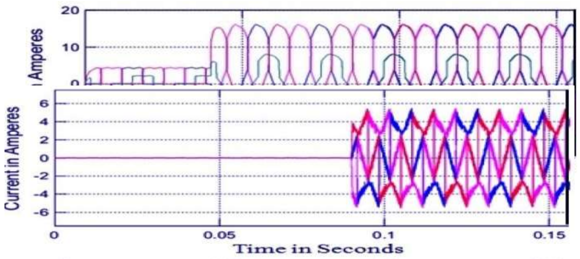
ii) To operate as a shunt Active Power Filter (APF). This approach eliminates the need of additional power conditioning equipment to improve the quality of power at PCC by extensive use of MATLAB / Simulink simulation based experimental results illustrate the proposed approach and have shown that the grid- interfacing inverter can be utilized as a multi-function device.

The feature enhancement to this proposed work is to enhance PQ to achieved under three different cenarios:

1) PRES=(0,2)
2) PRES<PLOADand
3) PRES>PLOAD.

The current harmonics, current unbalance and load reactive power which are due to unbalanced and non- linear load connected to the PCC are compensated effectively such that the grid side currents are always maintained as balanced and siinusoidal at unity power factor.

## References



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