

# **Grid Interconnection of Renewable Energy Sources at the Distribution Level with Power-Quality Improvement Features**

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**ABSTRACT:** As there is increase in load demand, the Renewable Energy Resources (RES) are increasingly connected in the distribution systems which utilizes power electronic Converters or inverters. In this project, grid interfacing inverter is installed in three phase four wire distribution systems. 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. Hence, Active Power Filters (APF) [5] are extensively used to compensate the current harmonics and load unbalance. The inverter can be controlled to perform as a multi-function device by incorporating active power filter functionality. Thus the existing inverter acts as a Shunt Active Power Filter 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 renewable energy resource to the grid and as a shunt active power filter to compensate the load disturbances.

**KEYWORD:** Renewable energy resources (RES), Active power filter (APF), distributed generation (DG), distribution system, grid interconnection, power quality (PQ), renewable energy.

## **I. INTRODUCTION**

Electric utilities and end users of electric power are becoming increasingly concerned about meeting the growing energy demand. Seventy five percent of total global energy demand is supplied by the burning of fossil fuels. But increasing air pollution, global warming concerns, diminishing fossil fuels and their increasing cost have made it necessary to look towards renewable sources as a future energy solution [1] [2]. Since the past decade, there has been an enormous interest in many countries on renewable energy for power generation.

Renewable energy source (RES) integrated at distribution level is termed as distributed generation (DG). The utility is concerned due to the high penetration level of intermittent RES in distribution systems as it may pose a threat to network in terms of stability, voltage regulation and power-quality (PQ) issues. Therefore, the DG systems are required to comply 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, the DG systems [6] can now be actively controlled to enhance the system operation with improved PQ at PCC. Generally, current controlled voltage source inverters are used to interface the intermittent RES in distributed system.

A similar approach in which a shunt active filter acts as active conductance to damp out the harmonics in distribution network. In this strategy both load and inverter current sensing is required to compensate the load current harmonics. The non-linear load current harmonics may result in voltage harmonics and can create a serious PQ problem in the power system network. Active power filters are extensively used to compensate the load current harmonics and load unbalance at distribution level. This results in an additional hardware cost.

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Special Issue 6, May 2015

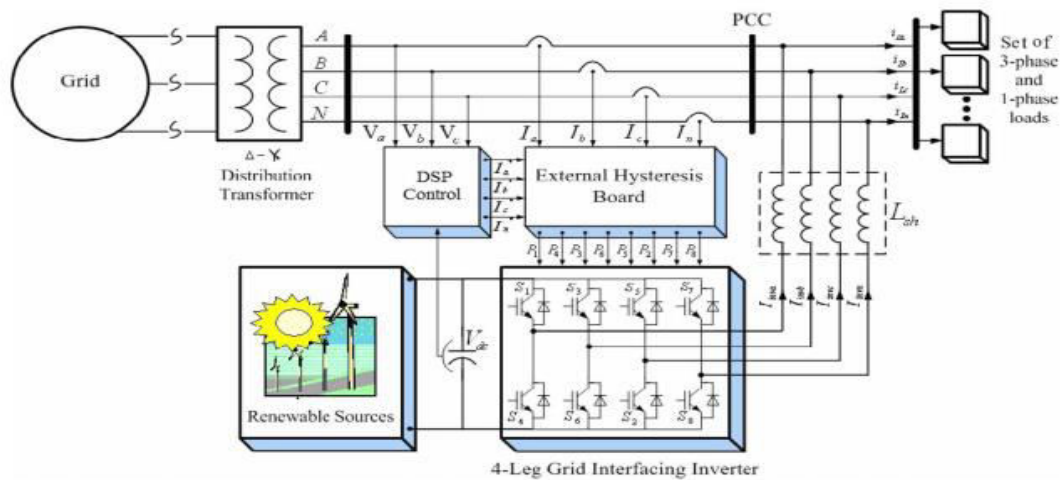


Fig. 1 Schematic of proposed renewable based distributed generation system

## II. SYSTEM DESCRIPTION

The proposed system consists of RES 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 DG system as it interfaces the renewable energy source to the grid and delivers the generated power. The RES may be a DC source or an AC source with rectifier coupled to dc-link. Usually, the fuel cell and photovoltaic energy sources generate power at variable low dc voltage, while the variable speed wind turbines generate power at variable ac voltage. Thus, the power generated from these renewable sources needs power conditioning (i.e., dc/dc or ac/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.

## II. SYSTEM MODELLING

A three-phase system is usually more economical than an equivalent single-phase or two-phase system at the same line to ground voltage because it uses less conductor material to transmit electrical power. Wye (star) configuration may utilize a fourth wire. The fourth wire, if present, is provided as a Neutral and is normally grounded. The '3-wire' and '4-wire' designations do not count the ground wire used above many transmission lines which is solely for fault protection and does not carry current under non-fault conditions. A four-wire system with symmetrical voltages between phase and neutral is obtained when the neutral is connected to the "common star point" of all supply windings. In such a system, all three phases will have the same magnitude of voltage relative to the Neutral. Other non-symmetrical systems have been used. The four-wire wye system is used when ground referenced voltages or the flexibility of more voltage selections are required. Faults on one phase to ground will cause a protection event (fuse or breaker open) locally and not involve other phases or other connected equipment.

### A.GRID INTERFACING INVERTER

A four leg VSI [5] that is capable of simultaneously compensating problems like power factor, current imbalance and current harmonics, and also of injecting the energy generated by renewable energy power sources with a very low THD. The grid-interfacing inverter can effectively be utilized to perform following important functions: 1) transfer of active power harvested from the renewable resources (wind, solar, etc.); 2) load reactive power demand support; 3) current harmonics compensation at PCC; and 4) current unbalance and neutral current compensation in case of 3-phase 4-wire system.. The PQ constraints at the PCC can therefore be strictly maintained within the utility standards without additional hardware cost.

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Vol. 4, Special Issue 6, May 2015

## Control of Grid Interfacing Inverter

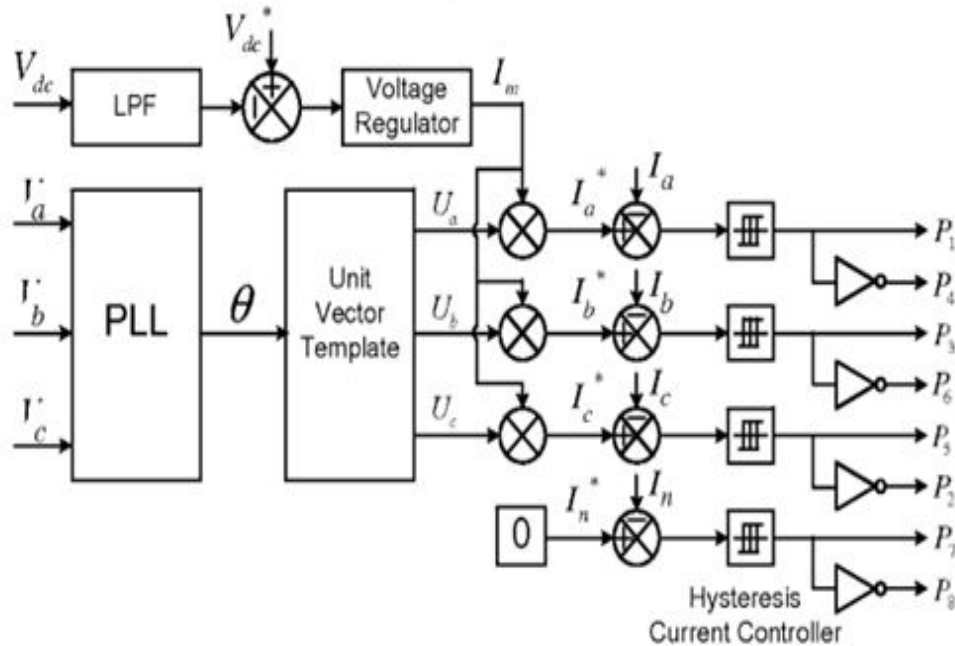


Fig. 2 Control of grid interfacing inverter

The fourth leg of inverter is used to compensate the neutral current of load. The main aim of proposed approach is to regulate the power at PCC during: 1)  $P_{RES} = 0$ ; 2)  $P_{RES} < \text{total load power}$ ; and 3)  $P_{RES} > \text{total load power}$ . While performing the power management operation, the inverter is actively controlled in such a way that it always draws supplies fundamental active power from to the grid. If the load connected to the PCC is non-linear or unbalanced or the combination of both, the given control approach also compensates the harmonics, unbalance, and neutral current. The duty ratio of inverter switches are varied in a power cycle such that the combination of load and inverter injected power appears as balanced resistive load to the grid. The regulation of dc-link voltage carries the information regarding the exchange of active power in between renewable source and grid. Thus the output of dc-link voltage regulator results in an active current. The multiplication of active current component with unity grid voltage vector templates generates the reference grid currents. The reference grid neutral current is set to zero, being the instantaneous sum of balanced grid currents. The grid synchronizing angle obtained from phase locked loop is used to generate unity vector template.

The actual dc-link voltage is sensed and passed through a first-order low pass filter to eliminate the presence of switching ripples on the dc-link voltage and in the generated reference current signals. The difference of this filtered dc-link voltage and reference dc-link voltage is given to a discrete-PI regulator to maintain a constant dc-link voltage under varying generation and load conditions

### B.LOADS AT DISTRIBUTION SIDE

At the distribution side four types of load is applied. Balanced, unbalanced, non-linear, induction motor. The balanced load can be considered as a resistive load. As it's a three phase system each resistor is connected to phase. The voltage and current magnitude must be same in the balanced load. The unbalanced load has variations in current and in voltage magnitude. So, STATCOM is used which removes the unbalance in current and in voltage by supplying real power.

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Vol. 4, Special Issue 6, May 2015

## C.TYPES OF LOADS

### 1. BALANCED LOAD

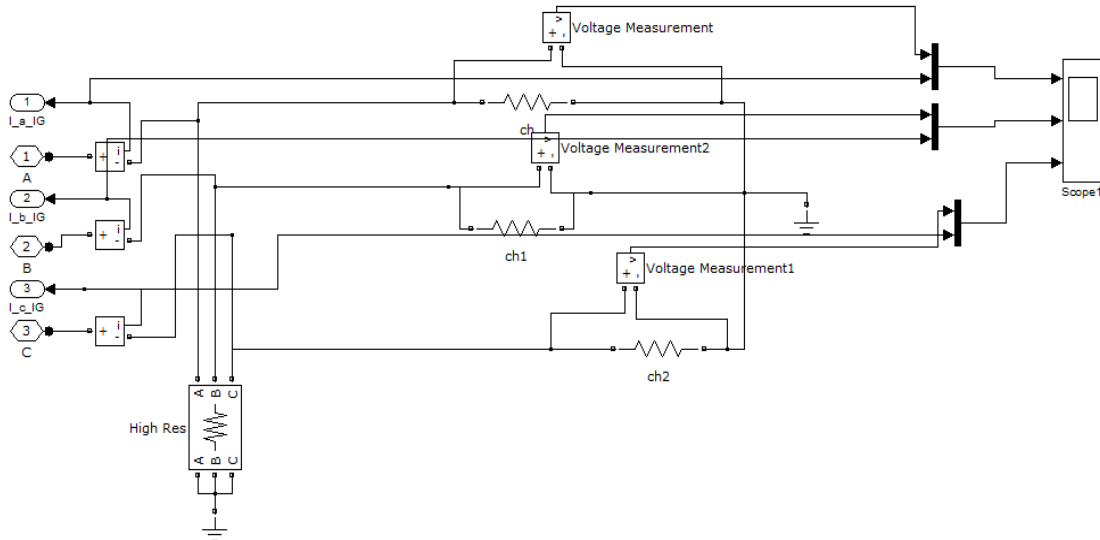


Fig. 3a The set of loads at the distribution side is considered as balanced. Hence, all the resistors have same value.

### 2. UNBALANCED LOAD

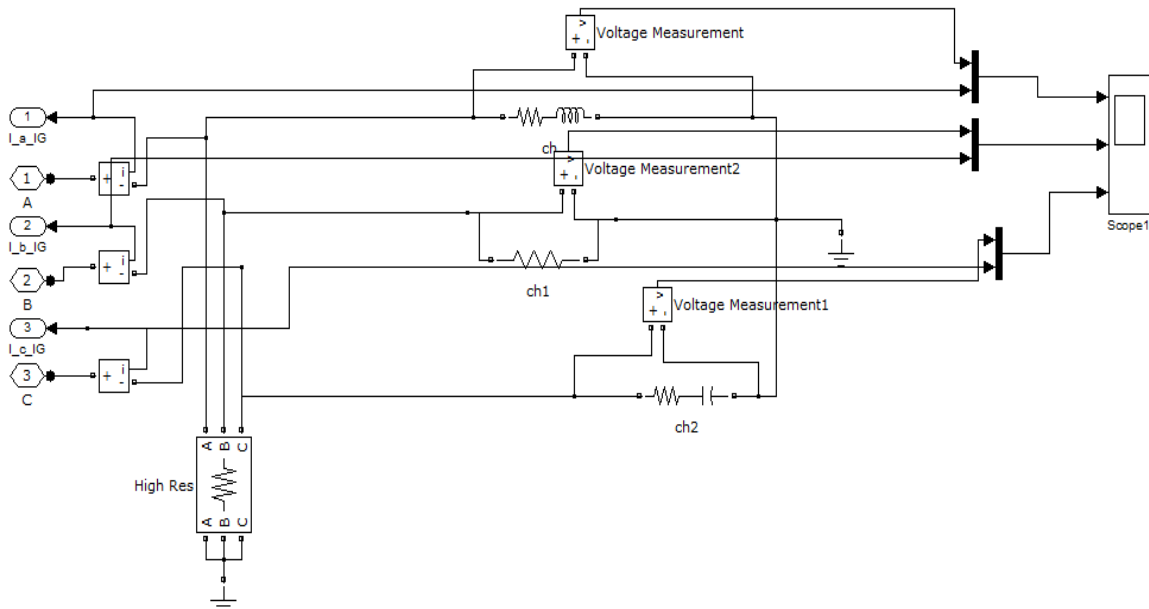


Fig. 3b In unbalanced load the inductors and resistors are introduced. Thus the voltage and current magnitude will not be same. So, this can be rectified by the operation of STATCOM.

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Vol. 4, Special Issue 6, May 2015

### 3. NON-LINEAR LOAD

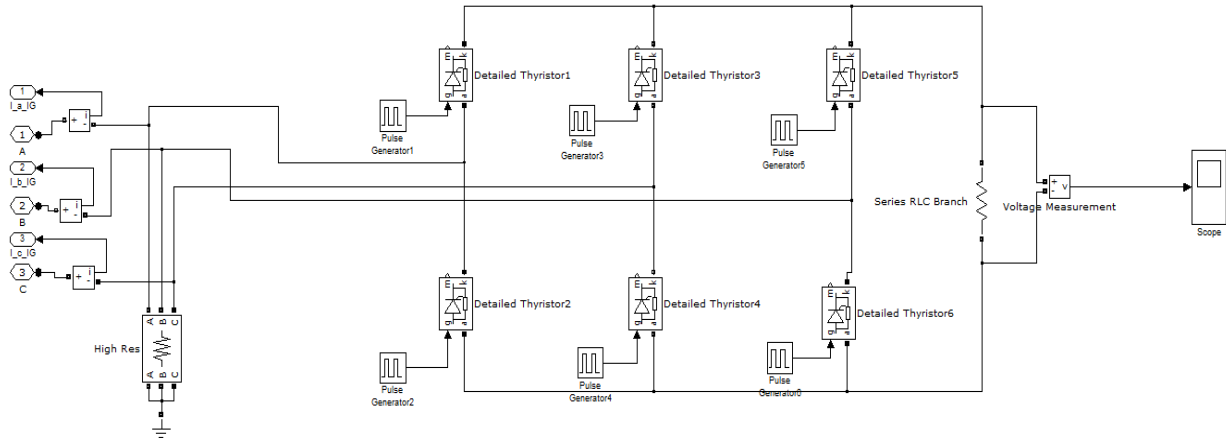


Fig. 3c

A diode bridge is an arrangement of four (or more) diodes in a bridge circuit configuration that provides the same polarity of output for either polarity of input. When used in its most common application, for conversion of an alternating current input into a direct current output, it is known as a bridge rectifier. A bridge rectifier provides full-wave rectification from a two-wire AC input, resulting in lower cost and weight as compared to a rectifier with a 3-wire input from a transformer with a center-tapped secondary winding.

### 4. INDUCTION MOTOR

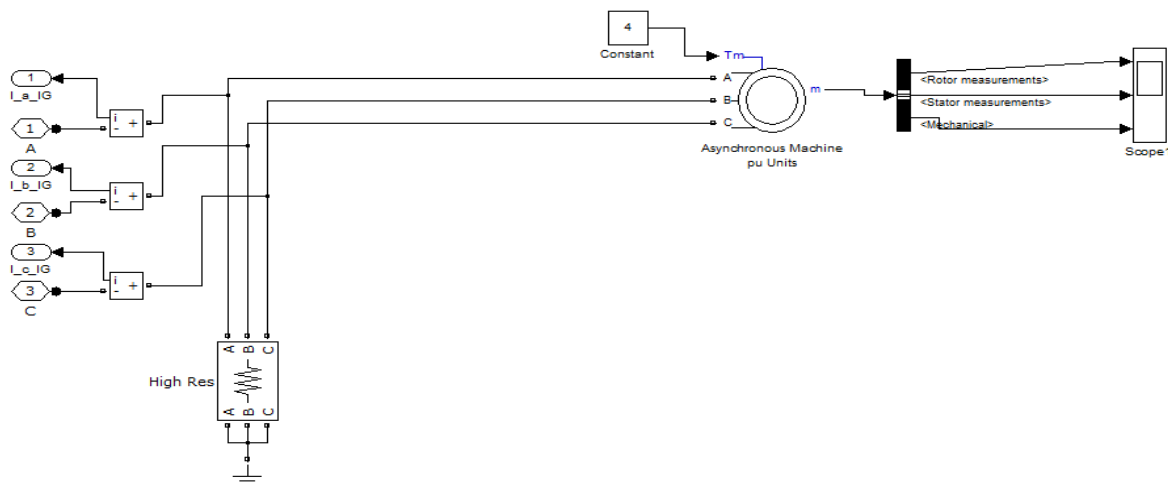


Fig. 3d

## III. EXPERIMENTAL RESULT

In order to verify the proposed control approach to achieve multi-objectives for grid interfaced DG systems connected to a 3-phase 4-wire network, an extensive simulation study is carried out using MATLAB/Simulink. A 4-leg current controlled voltage source inverter is actively controlled to achieve balanced sinusoidal grid currents at unity power factor (UPF) despite of highly unbalanced nonlinear load at PCC under varying renewable generating conditions. A RES with variable output power is connected on the dc-link of grid-interfacing inverter. An unbalanced 3-phase 4-wire nonlinear load, whose unbalance, harmonics, and reactive power need to be compensated, is connected on PCC. The generated power at grid-interfacing inverter is more than the total load power demand. Therefore, after meeting the load

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power demand, the additional RES power flows towards grid. The experimental results demonstrate the effective compensations of load current unbalance, harmonics and reactive power.

## A. Real Power and Reactive Power of balanced load

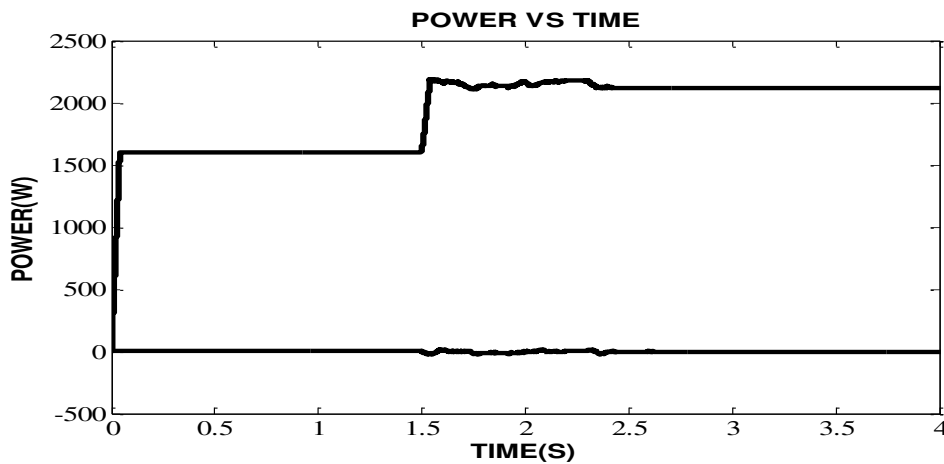


Fig. 4a

## B. Real Power and Reactive Power of unbalanced load

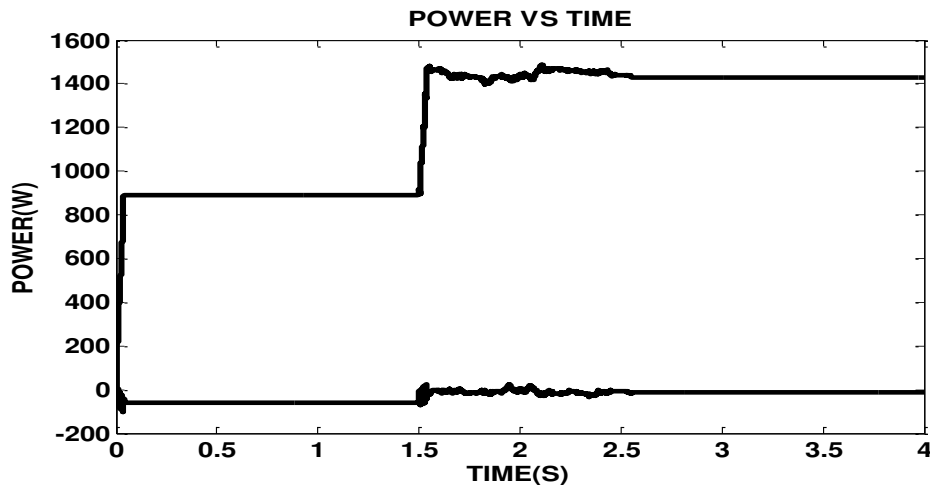


Fig. 4b

In the APF mode of operation, the inverter consumes a small amount of active power to maintain the dc-link voltage and to overcome the losses associated with inverter, while most of the load reactive power need is supported by inverter effectively. The grid-interfacing inverter now provides the entire load power demand (active, reactive and harmonics) locally and feeds the additional active power (sinusoidal and balanced) to the grid.

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### C. Real Power and Reactive Power of non-linear load

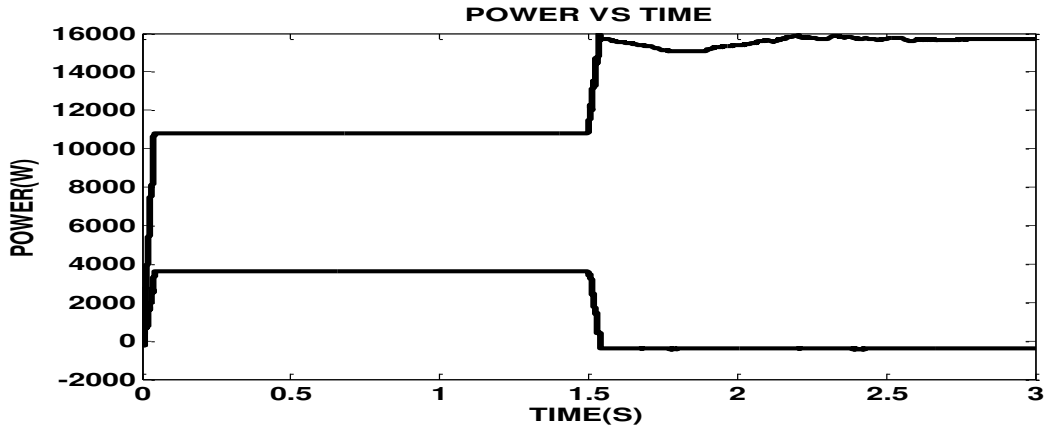


Fig. 4c

### D. Real Power and Reactive Power of induction motor

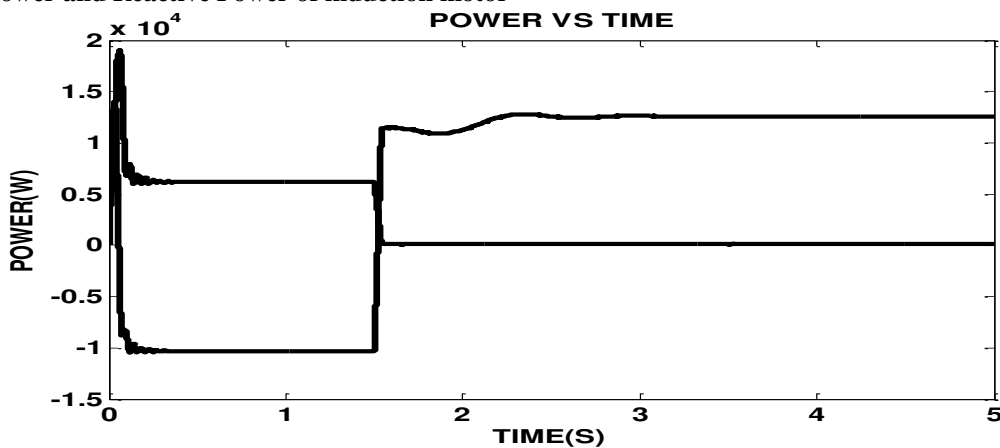


Fig. 4d

## IV. CONCLUSION

In this project work, a novel control of an existing grid- interfacing inverter to improve the quality of power at PCC for a 3-phase4-wire DG system is implemented. It has been shown that the grid-interfacing inverter can be effectively utilized for power conditioning without affecting its normal operation of real power transfer. The grid-interfacing inverter with the proposed approach can be utilized to: i) inject real power generated from RES to the grid, and/or, ii) operate as a shunt Active Power Filter (APF). This approach thus eliminates the need for additional power conditioning equipment to improve the quality of power at PCC. Extensive MATLAB/Simulink simulation as well as based experimental results have validated the proposed approach and have shown that the grid-interfacing inverter can be utilized as a multi-function device.

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