Grid Tied Solar Inverter at Distribution level With Power Quality Improvement

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***Abstract* - The aim of this project is to analysis and improve the performance of the power quality problems (voltage sag, swell and harmonics) at point of common coupling (PCC) in distributed generation with help of solar gird tie inverters. Renewable energy resources demand is continuously increasing nowadays, it connected in distribution systems utilizing power electronic converters. This paper presenting concept of grid tie solar inverter sharing power at PCC as hardware & Power Quality (P-Q) improvement with PI and fuzzy logic controller in MATLAB/ SIMULINK. It is also interfacing with Renewable Energy Resources (RES) with the electric grid. The grid interfacing inverter can improve the perform of following functions they are (1) power converter to inject power generated from RES to the grid, (2) shunt Active power filter to compensate current unbalance, load current harmonics, load reactive power demand. The controller controls the real power and reactive power supplied by the distributed generation at the PCC. In the gird side currents always maintained as balanced and unity power factor. This work is carried out using software MATLAB/SIMULINK.**

***Keywords*- Active power filter, Distributed generation, Power quality (PQ), Renewable energy, PI & fuzzy controller, Solar Grid interfacing inverter.**

I. INTRODUCTION

In recent years there has been an increasing interest in moving away from large centralized power generation towards distribution energy resources. 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. Hybrid method like solar energy and wind energy generation presented. Many advantages for use as a distributed energy resource, mainly as a peaking power source. Renewable energy source because of its environment friendliness, sufficient availability, and it produce the good efficiency.

RES synthesis distribution level is termed as distributed generation (DG). The utility is concerned due to the high penetration level of intermittent RES in distribution systems. By using this it improve the voltage stability, voltage regulation and power-quality (PQ) problems. With the power electronics and digital control technology, the Distribution energy systems can now be easily controlled to improve the circuit operation with improving the power quality performances at the place of PCC. The non-linear load current harmonics may result in voltage harmonics and can create a power quality problem in the power system network. Active Power Filter (APF) is mainly used to compensate the load current harmonics and load unbalance at distribution level.

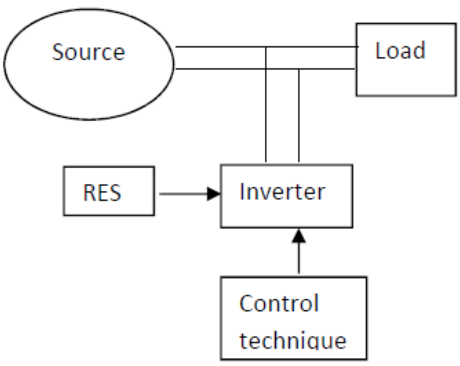

Fig 1 Basic block diagram of solar grid tie Inverter

The grid-interfacing inverter can excellently be utilized to produced functions as transfer of active power harvested from the renewable energy resources (wind, solar, etc.), load reactive power demand, current harmonics compensation at PCC, current unbalance and neutral current compensation in case of 3-phase 4-wire system.

Fig 1. & 2. Are representing the block diagram of the P-Q improvement & power sharing with help of renewable energy & control system.

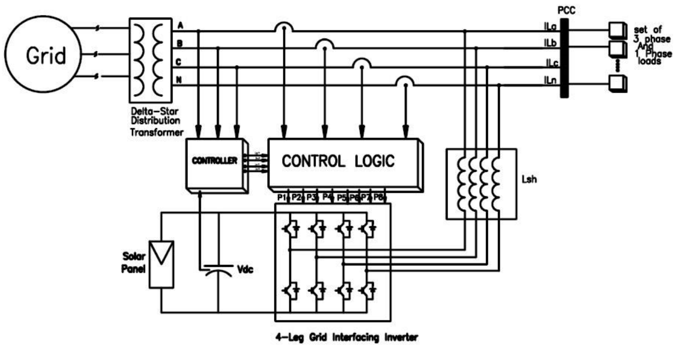

Fig. 2 Proposed circuit with Renewable Energy System

II. OVERVIEW OF A PHOTOVOLTAIC (PV) MODULE

To understand the PV module characteristics it is necessary to study about PV cell at first. Fig. 3 is representing the mathematical equation (1) of solar cell. A PV cell is the basic structural unit of the PV module that generates current carriers when sunlight falls on it. The power generated by these PV cell is very small. To increase the output power the PV cells are connected in series or parallel to form PV module.

After that also if the voltage is not sufficient Boost converter is use for maintaining required DC voltage.

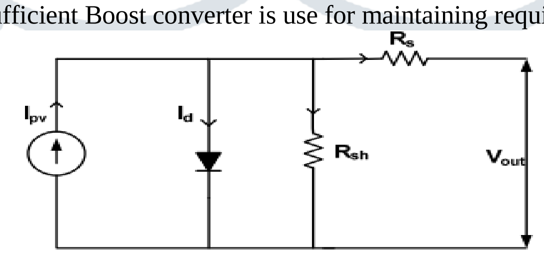

Fig. 3 Equivalent circuit of PV cell

The main characteristics equation of the PV module according to fig. 3.is given by

$$I = I_{pv} - I_o\left[\frac{exp(q(v+IR_S))}{\propto KT} - 1\right] - \frac{v+IR_S}{R_{sh}} \qquad \ldots(1)$$

Solar PV module in Matlab simulation:

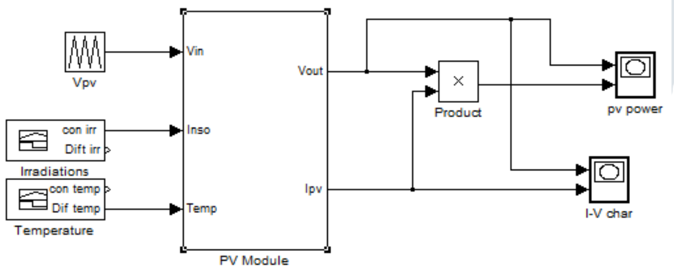

Fig.4 Matlab Solar PV model

In Matalab Simulink model solar cell from power sys library is used & connects them in series. Each cell voltage of 0.5Amps, 36 solar cells are connected in series. Using Boost converter 17V is boosted at 170V DC. This voltage is voltage across capacitor of inverter. Fig. 4 shown the solar model with boost converter in Matalab simulation. Fig. 4 (a) & (b) results of PV & IV curve obtained by the Matalab model Fig.4

With the help of this module we can studied varying temperature & varying irradiation characteristics of Solar PV module.

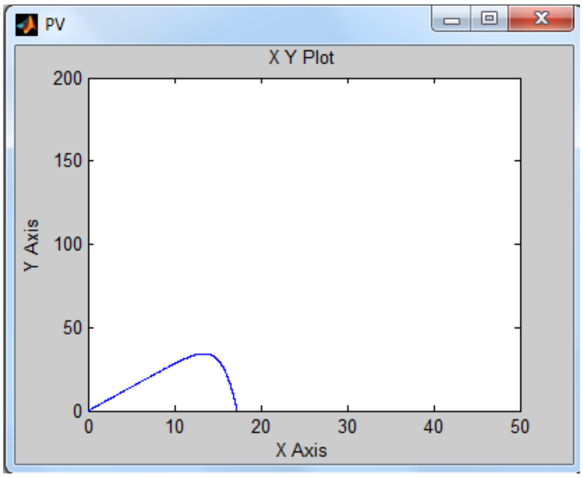

Fig. 4(a) solar cell PV characteristics

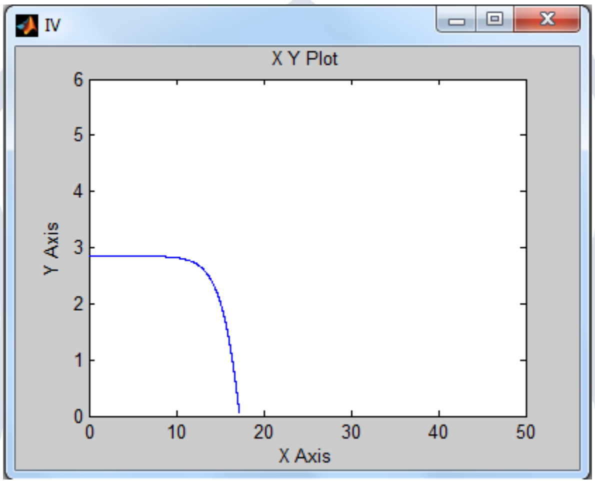

Fig. 4(b) IV characteristics

III. SYSTEM DESCRIPTION

The RES may be a DC source or an AC source with rectifier coupled to dc-link. Usually, the fuel cell & 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 dc-link.

1. DC-Link Voltage and Power Control Operation
2. Control of Grid Interfacing Inverter

DC-Link Voltage and Power Control Operation

Due to the intermittent nature of RES, the generated power is of variable nature. The dc-link plays an important role in transferring this variable power from renewable energy source to the grid. RES are represented as current sources connected to the dc-link of a grid-interfacing inverter. The current injected by renewable into dc-link at voltage level can be given

$$I_{dc1} = \frac{P_{RES}}{V_{dc}} \quad \text{--(2)}$$

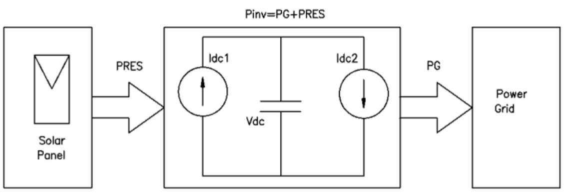

Fig 5 DC-Link equivalent diagram

Control of Grid Interfacing Inverter

The control diagram of grid- interfacing inverter for a 3-phase 4-wire system as shown fig.5 The fourth leg of inverter is used to compensate the neutral current of load. The approach is to regulate the power at PCC. It is shown in this paper that the grid interfacing inverter can effectively be utilized to perform following important functions: 1) transfer of active power harvested from the renewable resources 2) load reactive power demand support; 3) current harmonics compensation at PCC; and 4) current 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 the actual dc-link voltage Vdc is sensed and passed through.

Controller circuit

3ph inverter is acts as a shunt active power filter to compensate current harmonics, reactive power and load current unbalanced. It generate reference current signal & injecting to load or grid to nullify the distortion of sine wave.

For generating reference signal & control according to the reference value two methods are proposed PI & Fuzzy logic control.

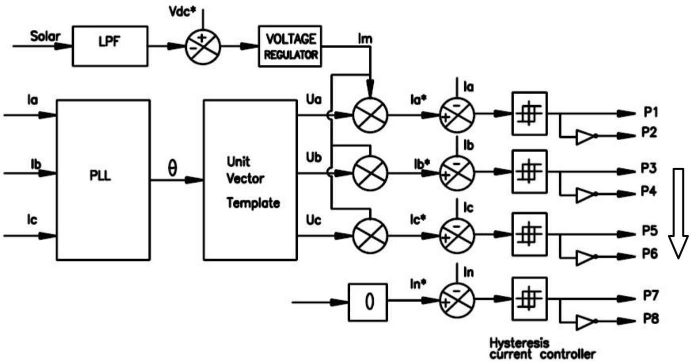

Fig 6a Block diagram of-Hysteresis controllers

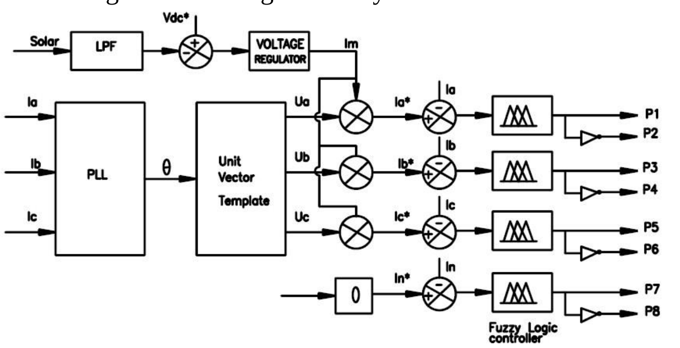

Fig 6b Block diagram of Fuzzy logic controllers

PI controller

The actual dc link voltage is sensed and passed through a first order low pass filter (LPF) to eliminate the presences 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 (Vdc*) is given to a discrete PI regulator to maintain a constant dc link voltage under varying generation and load conditions. The dc link voltage error Vdcerr(n) at nth sampling instant is given as

$$V_{\mathrm{dcerr}(n)} = V^*_{\mathrm{dc}(n)} - V_{\mathrm{dc}(n)}. \quad \ldots(3)$$

The output of discrete PI regulator at nth sampling instant is expressed as

$$I_{m(n)} = I_{m(n-1)} + K_{PV_{\mathrm{dc}}}(V_{\mathrm{dcerr}(n)} - V_{\mathrm{dcerr}(n-1)}) + K_{IV_{\mathrm{dc}}} V_{\mathrm{dcerr}(n)} \quad \ldots(4)$$

Fuzzy Logic Controller

The disadvantage of PI controller is its inability to react to abrupt changes in the error signal, ε, because it is only capable of determining the instantaneous value of the error signal without considering the change of the rise and fall of the error, which in mathematical terms is the derivative of the error denoted as Δε. The configuration of the Fuzzy logic control system that is employed for designing the Fuzzy supplementary controller. The FLC contains four main components, the fuzzification interface (FUZZIFICATION), the knowledge base (FUZZY RULE BASE), the decision making logic (FUZZY INFERENCE ENGINE) and de fuzzification interface DEFUZZIFICATION). A Mamdani type double input single output (DISO) FLC has been designed

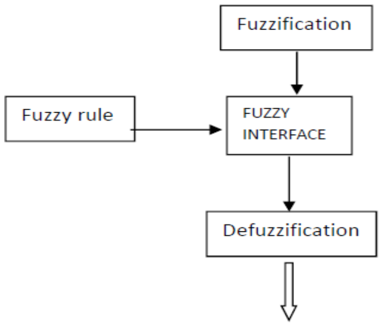

Fig.7 Fuzzy logic controller

The determination of the output control signal is done in an inference engine with a rule base having if-then rules in the form of "IF ε is .... AND Δε is ...., AND THEN output is ……"

With the rule base, the value of the output is changed according to the value of the error signal ε, and the rate-of-error Δε.

Table 1 Fuzzy logic table

Δe \ e	NL	NM	NS	EZ	PS	PM	PL
NL	NL	NL	NL	NL	NM	NS	EZ
NM	NL	NL	NL	NM	NS	EZ	PS
NS	NL	NL	NM	NS	EZ	PS	PM
EZ	NL	NM	NS	EZ	PS	PM	PL
PS	NM	NS	EZ	PS	PM	PL	PL
PM	NS	EZ	PS	PM	PL	PL	PL
PL	NL	NM	NS	EZ	PS	PM	PL

Fuzzification: the process of converting a numerical variable (real number) convert to a linguistic variable (fuzzy number) is called fuzzification.

De-fuzzification: the rules of FLC generate required output in a linguistic variable (Fuzzy Number), according to real world requirements, linguistic variables have to be transformed to crisp output (Real number).

Database: Database stores the definition of the membership Function required by fuzzifierand defuzzifier. Rule Base: the elements of this rule base table are determined based on the theory that in the transient state, large errors need coarse control,which requires coarse input and output variables;in the steady state, small errors need fine control, which requires fine input/output variables.

Thus the output of DC link voltage results in active current component using PI block or Fuzzy block. The multiplication of active current component (Im) with unity grid voltage vector templates (Ua,Ub & Uc) generates the reference grid currents (Ia*,Ib* & Ic*) The grid synchronizing angle (Ø) obtained from phase locked loop (PLL) is used to generate unity vector template. As shown in control block dia Fig.6

The reference grid currents (Ia*,Ib*,Ic* & In*) are compared with actual grid currents (Ia, Ib, Ic & In) to compute the current errors. These current errors are given to hysteresis current controller. The controller then generates the switching pulses for the gate drives of grid-interfacing inverter.

IV. FINAL SIMULATION MODEL WITH SOLAR GRID TIE INVERTER FOR PQ IMPROVEMENT

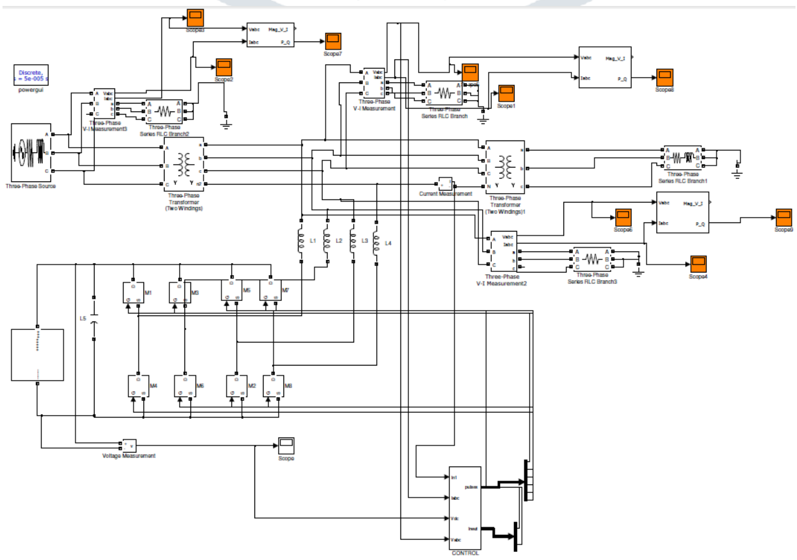

Fig. 9 Simulation circuit diagram

Fig. 9 shows the matlab model for power quality improvement at PCC with Fuzzy & PI control method.

V. SIMULATION RESULTS

From the model Fig. 9 grid current, grid voltage, Inverter current & voltage, P-Q curve at grid & at Inverter, Load current are find out. In Fig.10 at T=0.73 sec load is supply by grid only after 0.73 sec Inverter is start to inject the power to load & compensate the reactive power required by load. Further at T=0.95sec Inverter feeding power to load & excess power feed to grid.

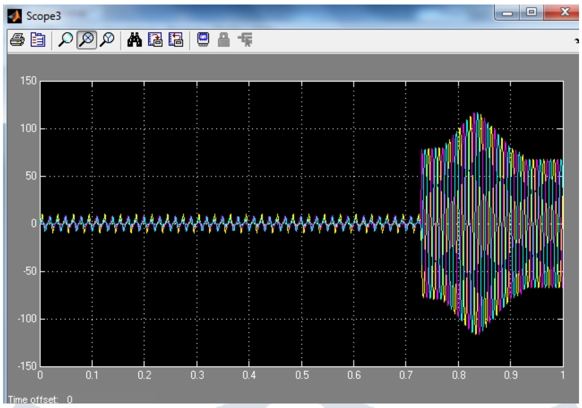

Fig 10 Grid current

FFT Analysis of grid current for PI & Fuzzy:

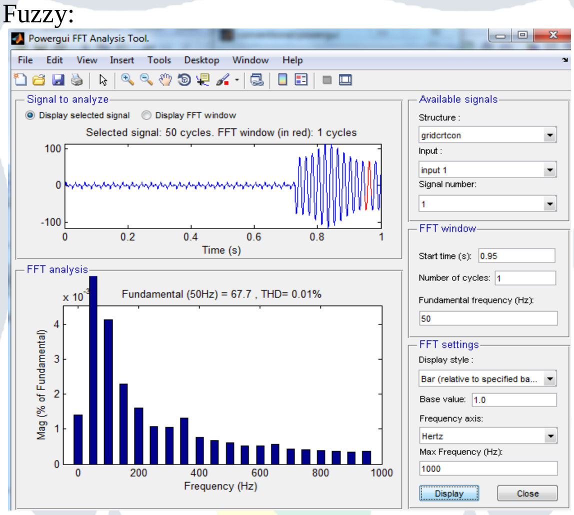

Fig.11a Load current THD with PI controller:

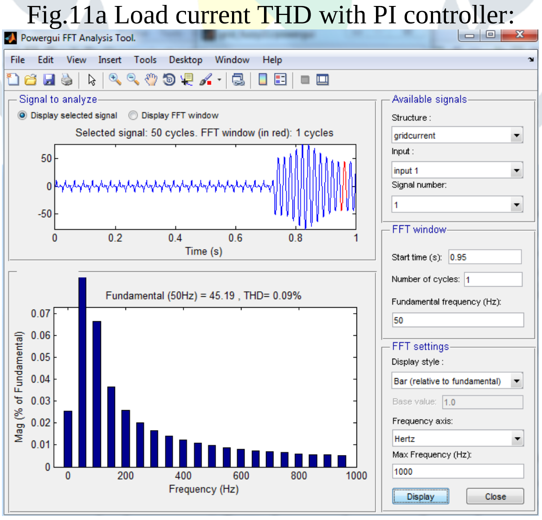

Fig.11b Load current THD with fuzzy

At T=0.95 It is observe that the THD value for PI is 0.01% & Fuzzy logic its 0.09% for single cycles. There is not very huge difference between the results of PI & Fuzzy logic control as shown in fig 11a & 11b.

Active & Reactive power Results at grid & inverter :

Negative value of the active power shown that in fig. 12 it indicate that the power is feed to grid.

In fig. 13 shown the inverter output active reactive power results.

It was observe that the reference signal generated by inverter to compensate the reactive power is same as grid signal with 180deg phase shift.

Inverter active & reactive power Results

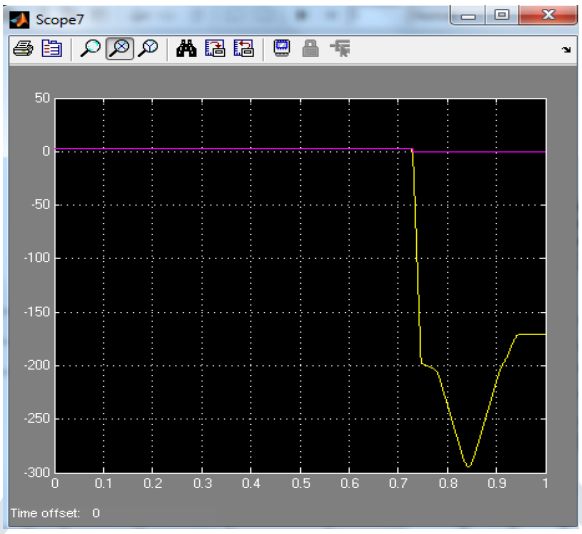

Fig.12 Grid active & Reactive power

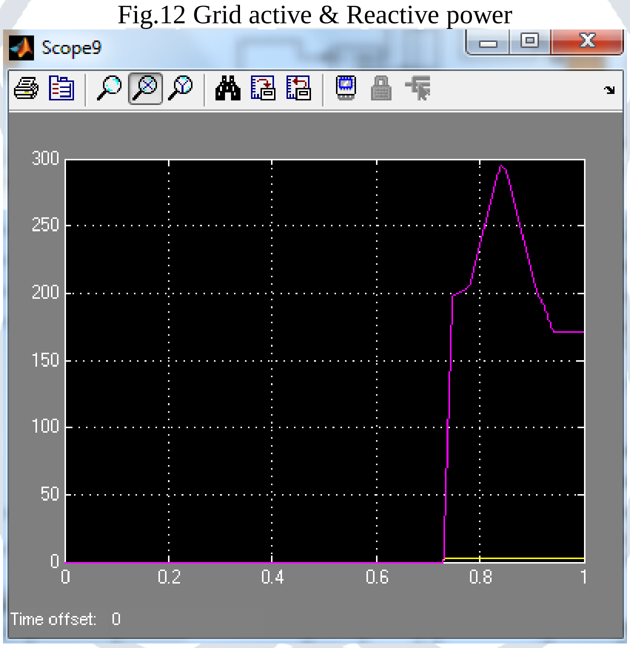

Fig. 13 Inverter active & reactive power

VI. HARDWARE DESCRIPTION

As shown in Fig. 1 Basic block diagram of grid tie inverter. Single phase Prototype Hardware is prepared & shown that voltage amplitude & waveform at grid side & inverter side are matching the starting point so inverter can synchronize with grid. Also observe that inverter is share the power to load.

Hardware results:

Waveform are shown in fig.14 & 15 with hardware photographs. Inverter Phase angle & frequency is matching with inverter Phase angle & frequency.

Further observation of power Sharing is also observed Reading are taken for three different cases. Load power by grid only, Inverter only & 3rd case is Both inverter & grid power sharing..

Hardware phographs with results:

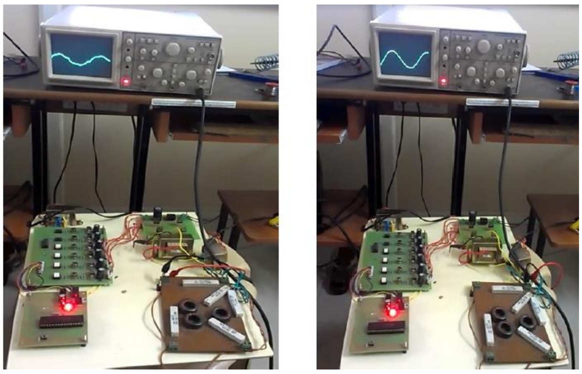

Fig. 14 Grid & Inverter output waveform.

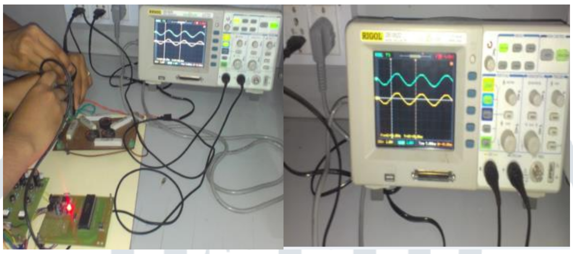

Fig. 15Synchronized Grid & Inverter output waveform.

VII. CONCLUSION

In this project improved the performance of the power quality problems (voltage sag, swell and harmonics) and to grid connection with help of inverter which act as shunt active power filter in distributed generation. This paper presented a fuzzy logic controller in order to improve the performances of PQ. It is also interfaced with RES with the electric grid & load sharing with 1ph prototype hardware. The grid interfacing inverter can improved the performance of power converter to inject power generated from Renewable energy sources to the grid. The controller controls the real power and reactive power supplied by the distributed generation at the PCC. In the gird side currents always maintained as balanced and unity power factor. Compared the fuzzy logic controller with the PI controller for controlling the DC capacitor voltage. The simulation results are compared between fuzzy and PI controller as shown in above simulation results.

VIII. ACKNOWLEDGMENT

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