Power Quality improvement in Grid connected Renewable Energy Sources at the Distribution level

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Abstract: Around the world, conventional power system is facing the problems of gradual depletion of fossil fuel resources, poor energy efficiency and environmental pollution. These problems have led to a new trend of generating power locally at distribution voltage level by using non-conventional/ renewable energy sources like natural gas, biogas, wind power, solar photo voltaic cells, fuel cells, combined heat and power (CHP) systems, micro turbines, and stirling engines, and their integration into the utility distribution network. The above renewable energy sources are interconnected using various power electronics converters. Generally current controlled voltage source inverters are used to interface the intermittent RES in distributed system.

This paper provides control strategy for grid interfacing inverters when installed in three phase four wire distribution system. The interfacing inverter can be utilized to inject power generated from RES to the grid and act as Active power filter to compensate current unbalance, load current harmonics, load reactive power demand and load neutral current. By this novel control strategy, the combination of Grid-interfacing inverter and the 3 phase 4-wire linear/non-linear unbalanced load at the point of common coupling appears as balanced linear load to the grid. This control concept is demonstrated with the help of simulation using MATLAB/Simulink for non-linear load and validated through digital signal processor – based laboratory experimental results.

Keywords: *Power Quality, Distributed generation (DG), RES, PCC, Grid Interfacing Inverter, DC link..*

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I. INTRODUCTION

The demand for electricity is increasing day-by-day. Due to rapid load growth, the need for augmentation of conventional generation brings about a continuous depletion of fossil fuel reserve. Therefore, most of the countries are looking for non-conventional / renewable energy sources as an alternative. Reduction of environmental pollution and global warming acts as a key factor in preferring renewable energy sources over fossil fuels. To cut down greenhouse gas (carbon and nitrogenous by-products) emissions in order to counter climate change and global warming, it is necessary to look towards RES as a future energy solution. Even though Renewable Energy Sources (RES) helps to meet today's demand for electricity, its intermittent nature produces Power Quality problems, and its high penetration level in distribution systems may pose a threat to network in terms of stability and voltage regulation issues. Hence in order to ensure safe, reliable and efficient operation of overall network, the distributed generation system must comply with strict technical and regulatory frame works. Non-linear loads and use of power electronics based equipment at PCC generate harmonic currents, which affects the quality of power(1),(2). The DG systems can now be actively controlled to enhance the system operation with improved Power Quality at the point of common coupling (PCC).

II. NEED OF POWER QUALITY ENHANCENMENT

Electric power quality refers to maintaining a near sinusoidal power distribution bus voltage at rated magnitude and frequency. But enormous use of electronic devices creates power quality problems. The causes of power quality problems are generally complex and difficult to detect. Technically speaking, the ideal ac line supply by the utility should be a pure sine wave of fundamental frequency, but the actual ac line supply that we receive everyday departs from the ideal one. Power quality problems caused by electronic devices are poor load factor, harmonic contents in loads, notching in load voltages, supply voltage distortion, voltage sag/swell, and voltage flicker. Such power quality problems increase cost of electricity, which affects both consumer and supplies. So in order to decrease cost of electricity, economic energy supplies to consumers, increase power factor and compensate the power quality problems the need for enhancement of power quality is essential.

III. POWER QUALITY PROBLEMS

Power quality problem means deviation of the voltage, current and frequency of the power system. Power quality is maintaining a near sinusoidal power distribution bus voltage at rated frequency. Some important problems of power quality are power system stability, reliability, efficiency, cost etc. (3).Renewable energy sources are connected to the utility grid through power electronic devices. A current controlled voltage source inverter is used for interfacing RES to the grid. The use of power electronic devices creates various power quality issues like unbalance, load and grid current harmonics, load active and reactive power requirement (4). The other power quality problems are notching in load voltages, dc offset in load voltage, supply voltage distortion, voltage sag/swell, voltage flicker.

A. Voltage sag / swell

Voltage sag is a fundamental frequency decrease in the supply voltage for a short duration. The duration of voltage sag varies between 5 cycles to a minute. Voltage swell is defined as the increase of fundamental frequency voltage for a short duration.

B.Voltage Flicker

Voltage flicker is a problem of human perception. Usually the deviation in the flickering voltage is much less than the threshold of susceptibility of the electrical equipment. The main cause of voltage flicker is the arc loads like arc furnace, arc welder and arc lamp.

C.Harmonics

Power electronic loads are the major source of harmonic generation in power systems. The deformity in sine wave of voltage and current caused harmonics in the system. Every non- sinusoidal waveform contains harmonics. The grid interfacing inverter compensates load current harmonics.

D.Over voltage/ under voltage

An over voltage is a 10% or more increase in rms voltage for more than 1 minute. It is caused by switching off of a large load or the energization of a large capacitor bank. An under voltage is the result of an event, which is reverse of the event that causes overvoltage. These conditions may also occur by environmental phenomena such as direct or indirect lightening strikes on the grid. Such condition is rarely occurring and it can be reduced using grid components (3) ,(5).

E.Transients

It is that part of change in a system variable that disappears during transition from one steady –state operating condition to another. It is categorized into impulsive and oscillatory transients.

IV. SYSTEM DESCRIPTION AND CONTROL STRATEGY

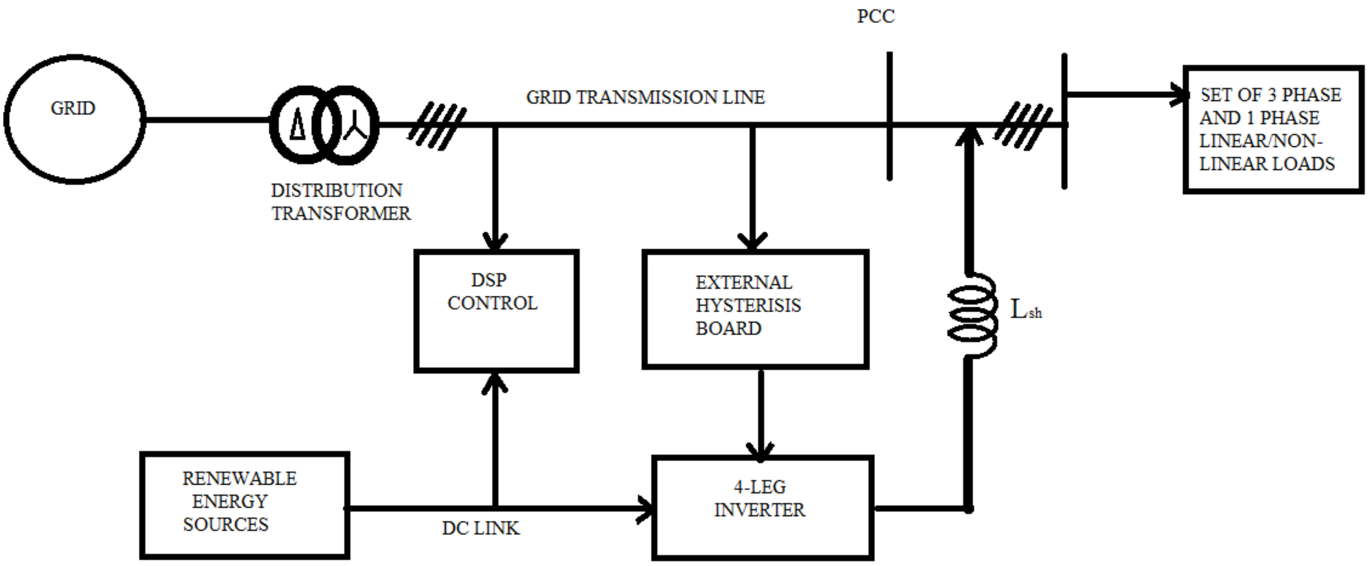

Fig.1

The proposed system consists of Renewable energy sources like solar, wind turbine, fuel cells are connected to the dc link of a grid-interfacing inverter as shown in fig.1. A distribution transformer is connected in series with the line to be compensated. It provides the final voltage transformation in distribution system. It is one of the important components of the system. A 4 leg, current controlled voltage source inverter interfaces the power generated from RES to the grid. It is a key component of the system. The RES may be a DC or AC source with rectifier coupled to DC-link. Since the power from RES may be d.c or a.c , it requires power conditioning before connecting on dc-link (6). The intermittent nature of RES produces variable power. This variable power is transferred to the grid through dc-link. The dc voltage plays an important role in variable power transfer from renewable energy source to the grid. The inverter consists of power electronic switches as IGBT in anti- parallel with diode. Since the inverter is a current controlled voltage source inverter if the output voltage of the converter is greater than the AC bus terminal voltage then it is said to be in capacitive mode. The shunt inductance is to isolate the power system and protected to transient distribution. It reduced the higher order harmonics at distribution. The control strategy of Grid interfacing inverter for a3 phase 4 wire system is shown in fig.2

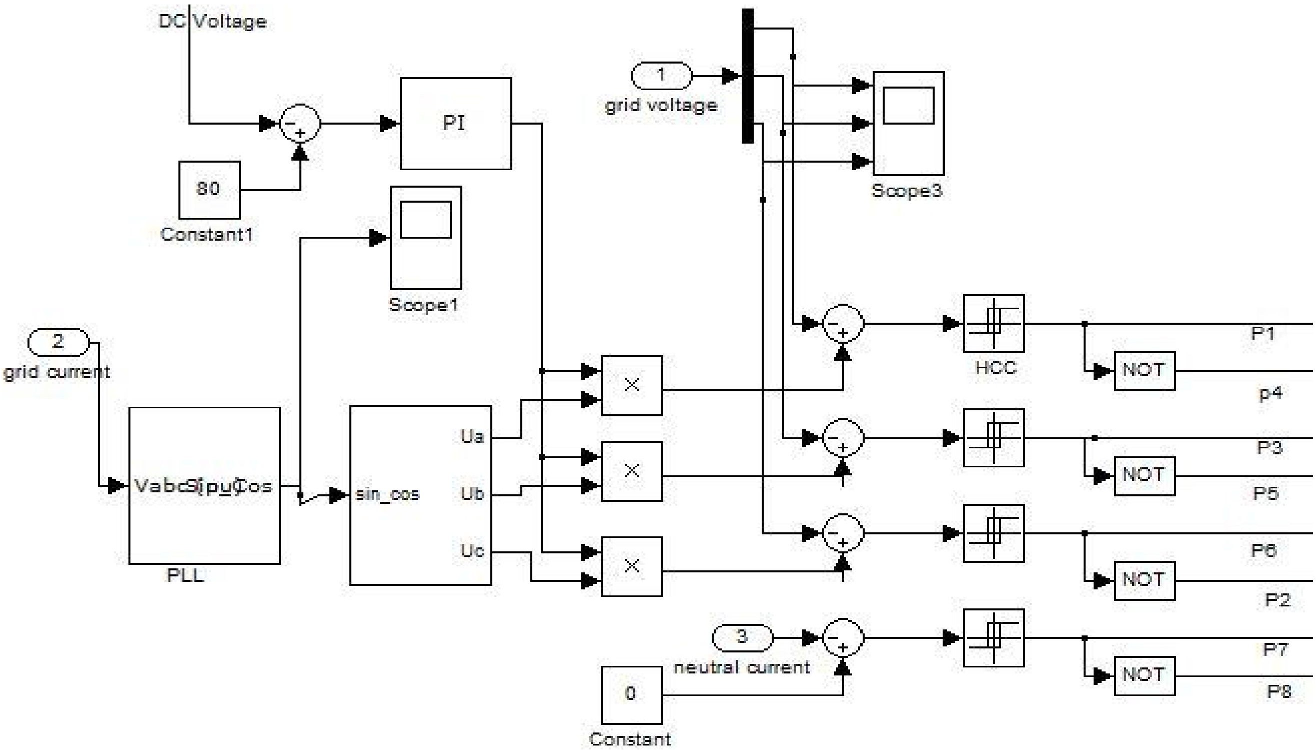

Fig 2

The fourth terminal of inverter is used to minimize the neutral current of the load. The main aim of proposed approach is to regulate the power to distribution level during :

1.P_{RES} =0

2.P_{RES} < total load power (P_L)

3.$P_{RES} > P_L$

This control performs the function at the above three conditions, power supplies at the point of common coupling (PCC) .in the distribution system. This control supplies active power demand from the grid or to the grid. If the load to PCC is non-linear, unbalance or combination of both, the given control compensates the harmonics, unbalance and neutral current (7).

V. SIMULATION RESULTS

To verify the proposed scheme result, four leg inverter simulation study in MATLAB/Simulink is carried out. The converter is effectively controlled and compensates the harmonics in the source current. The control strategy of inverter is shown in fig 2. An unbalance non-linear and linear loads whose unbalance and harmonics to be compensate. The waveform for grid voltage, grid current, inverter voltage and inverter current is non- sinusoidal nature due to presence of unbalanced non-linear and balanced linear load. At t = 0.3 sec the RES energy compensate the load current is to be sinusoidal.

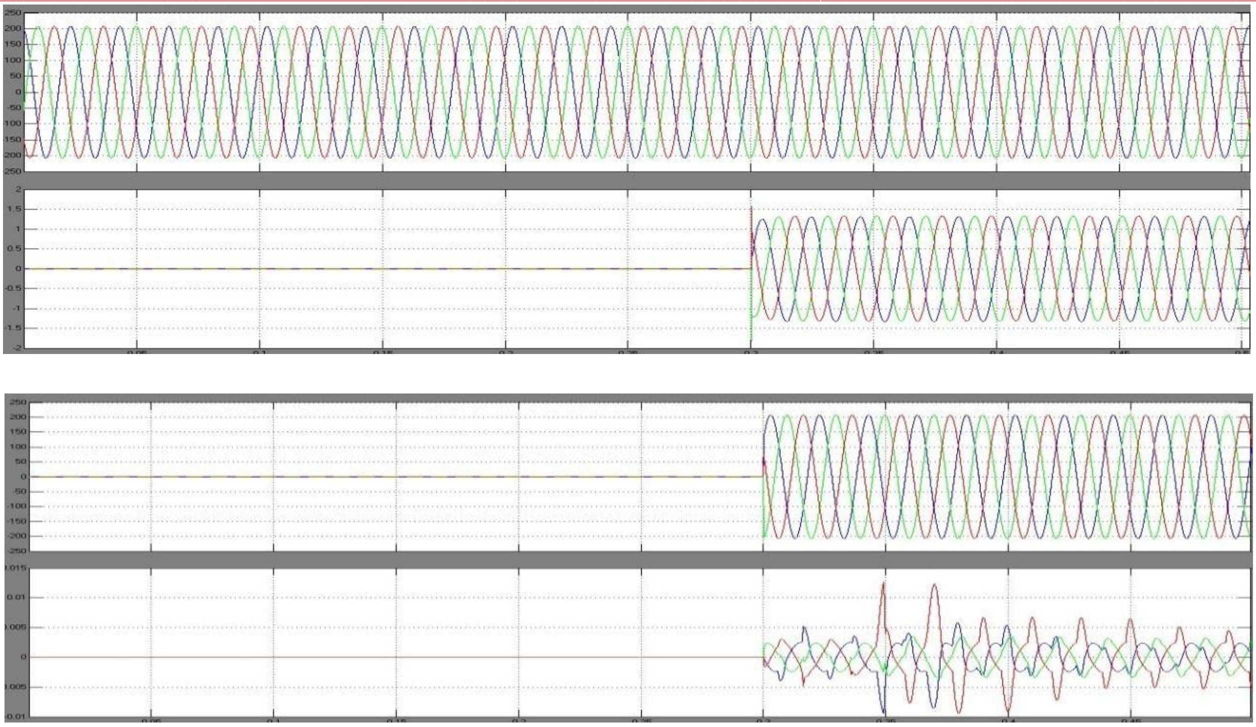

Fig 3: shows a) Grid voltage, b) Grid current, c) Inverter voltage, and d) Inverter current

Inverter current is unbalanced due to non-linear load after interfacing RES energy with new control strategy of inverter compensate load current , improve power quality, reduced harmonics at desired power factor.

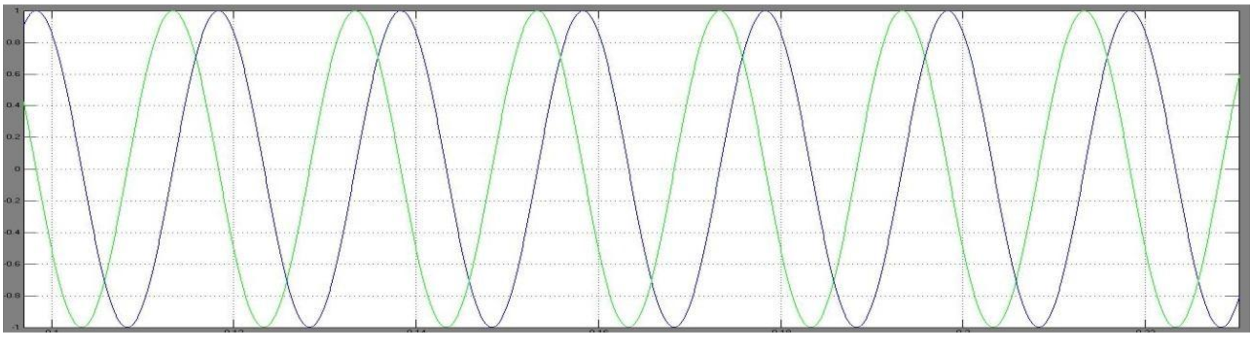

Fig 4: shows out of phase locked loop to generate ø

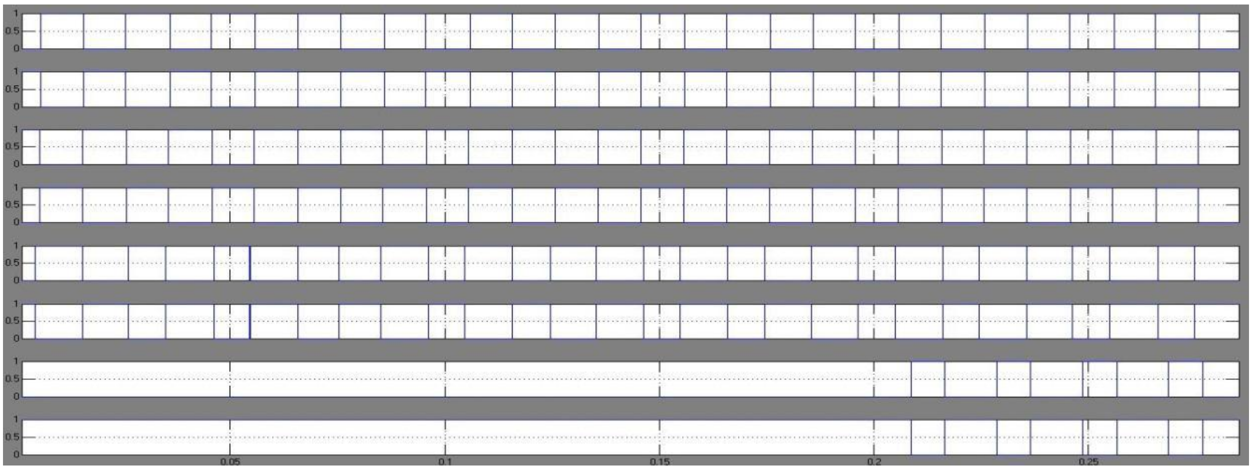

Fig 5: P1-P6 shows the switching signal of inverter, P7andP8 are switching signal to neutral current

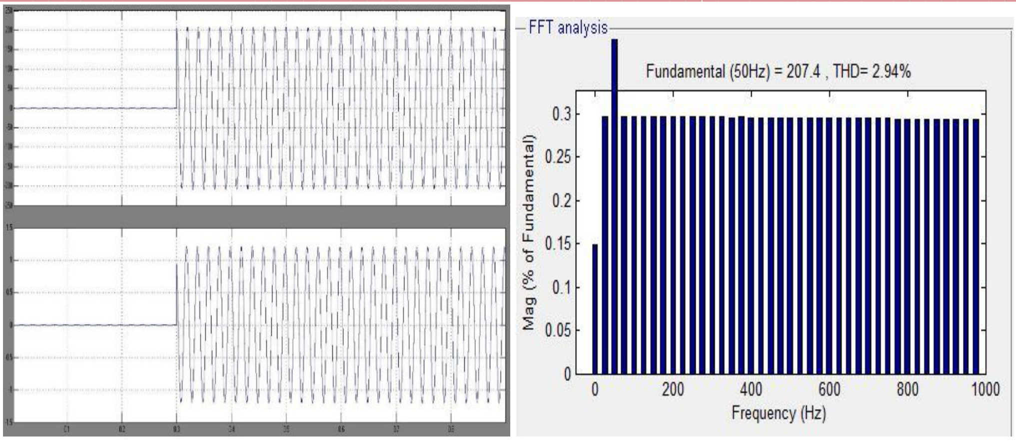

Fig 6: shows the load voltage, load current and its FET analysis of single phase current.

The total harmonic distortion is nearly 28% but after compensation it reduced to 2.94%. Load current and its FET analysis is shown in fig.6

Fig.4 shows the output of Phase Locked loop (PLL) is used to obtain the "ɵ" is used to generate the unit vector. The switching signal of inverter is shown in fig 5. Here P1 to P6 is controlled in such a way that the RES energy is interfaced with grid and compensates the load current harmonics and improve power quality.

VI. CONCLUSION

This paper presents a power quality improvement in grid connected RES at distribution by using three- phase four wire inverter. The harmonics level of source current is 28% without filtering, after implementing inverter (filter) the harmonic level is reduced to 2.94%. The grid inverter injects real power from RES and effectively utilized at lagging demand at distribution level. The neutral current is prevented to flow to the grid and this is done by fourth leg of inverter to compensate neutral current as nearly equal to zero. The THD level of the grid current is reduced hence improve the power quality.

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