Improving the Power Quality in a Grid Integrated PV System

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***Abstract*-With the increase in energy demand due to the depletion of fossil fuel resources, the Renewable Energy Sources (RES) are connected in distributed system which uses power electronics devices. The use of power electronics devices generate harmonic current and may reduce quality of power. This paper, presents a grid interfacing inverter control that compensates power quality problems and interface renewable energy sources with the grid. The RES used here is Photo Voltaic (PV) system. The grid interfacing inverter is given with hysteresis current control method to generate gate pulses and it has the capability of injecting RES power to the grid, reduces load unbalance, load harmonics, reactive power demand and distortions. Total Harmonic Distortion (THD) of the grid connected system is analyzed. This concept is modeled and simulated in MATLAB/Simulink.**

***Keywords*— Renewable Energy Sources (RES), Photo Voltaic (PV), *D*istributed generation (DG), power quality (PQ),**

I. INTRODUCTION

The energy demand is increasing due to the increase in population. There will be a decrease in the power generation due to the depletion of fossil fuel resources. But increasing air pollution, global warming, diminishing fossil fuels and their increasing cost have made it necessary to look towards renewable sources as a future energy solution for power generation as it has advantages like sustainability, low maintenance cost, environmental friendly, reduction of pollution, etc [8]. Despite of the high initial cost and low efficiency, PV system has small operation and maintenance cost as it is a permanent source of energy. Renewable Energy Sources (RES) integrated at distribution level is termed as Distributed Generation (DG). The high penetration level of RES in distribution regulation, stability, and Power Quality (PQ) problems like distortions, harmonics, etc. With the advancement in power electronic Converters and Inverters the PQ problems can be overcome. However, the extensive use of power electronics based equipment generate harmonic currents which affects the quality of power.

A few control strategies for grid connected inverters incorporating PQ solution have been proposed. In [2] inverter is controlled by active power filter and performance comparison for maximum power extraction was analyzed. In general, to interface the RES in distribution system the current controlled voltage source inverter are used. On integrating RES with the grid causes non-linear load current harmonics which can create serious PQ problem in the power system network. Here the main idea is by incorporating certain control technique the grid interfacing inverter can be utilized maximum to overcome the power quality problem without any additional hardware cost.

The paper is arranged as follows: Section II describes the system under consideration. Section III describes the Inverter control. Simulation study is presented in Section IV and finally Section V concludes the paper.

II. SYSTEM DESCRIPTION

The proposed system consist of RES (solar) connected to the dc link of the grid interfacing inverter as shown in Fig. 1. The load connected here is both linear and non-linear load. Grid is connected to the step down transformer to reduce the voltage level. The generated power from RES will be of variable in nature. The renewable output is around 11V and the dc link plays an important role in transferring this variable power from renewable energy source to the grid. The hysteresis current control method is used to generate switching pulses to the grid interfacing inverter.

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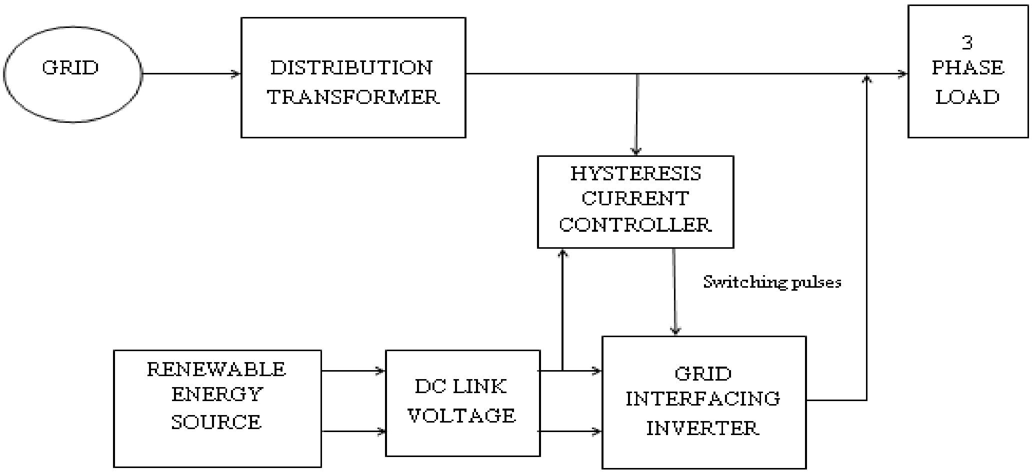

Fig. 1. Basic Configuration of the system

III.INVERTER CONTROL

The control technique of grid interfacing inverter is shown in Fig. 2. The regulation of dc-link voltage carries the information regarding the exchange of active power between renewable source and grid and it depends on the instantaneous energy available. The actual dc-link voltage (V_{dc}) is sensed and passed through first-order low pass filter to eliminate the presence of switching ripples. The difference of this filtered dc-link voltage and reference dc-link voltage is given to a discrete PI controller. The output of discrete PI controller is multiplied with the actual phase voltage to produce current errors. These current errors are given to hysteresis current controller to produce switching pulses (P_1 to P_8) for inverter working and the switching pattern is shown in Table.1.The neutral current present if any, due to the loads connected is compensated by fourth leg of the inverter.

Table.1 Switching Pattern for the Inverter

Logic	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8
$I_{sa}<(I_{sa}^{*}-h_b)$	0	1	0	1	0	1	0	1
$I_{sa}>(I_{sa}^{*}-h_b)$	1	0	1	0	1	0	1	0

If $I_{sa}<(I_{sa}^{*}-h_b)$, then the upper switch S_1 will be OFF(P_1=0) and lower switch S_4 will be ON(P_4=1)in the phase "a" leg of the inverter.

If $I_{sa}>(I_{sa}^{*}-h_b)$, then the upper switch S_1 will be ON(P_1=1) and lower switch S_4 will be OFF(P_4=0)in the phase "a" leg of the inverter.

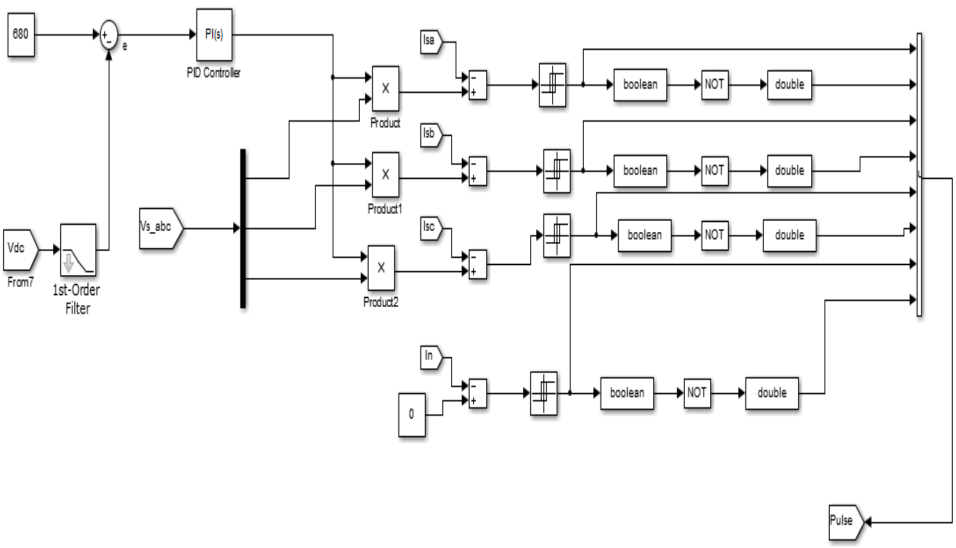

Fig.2 Control technique of grid interfacing inverter

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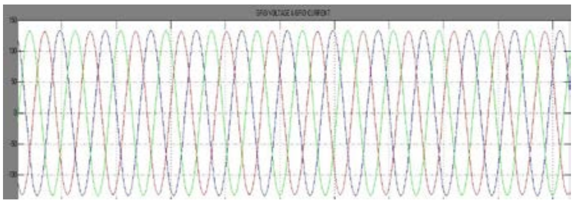

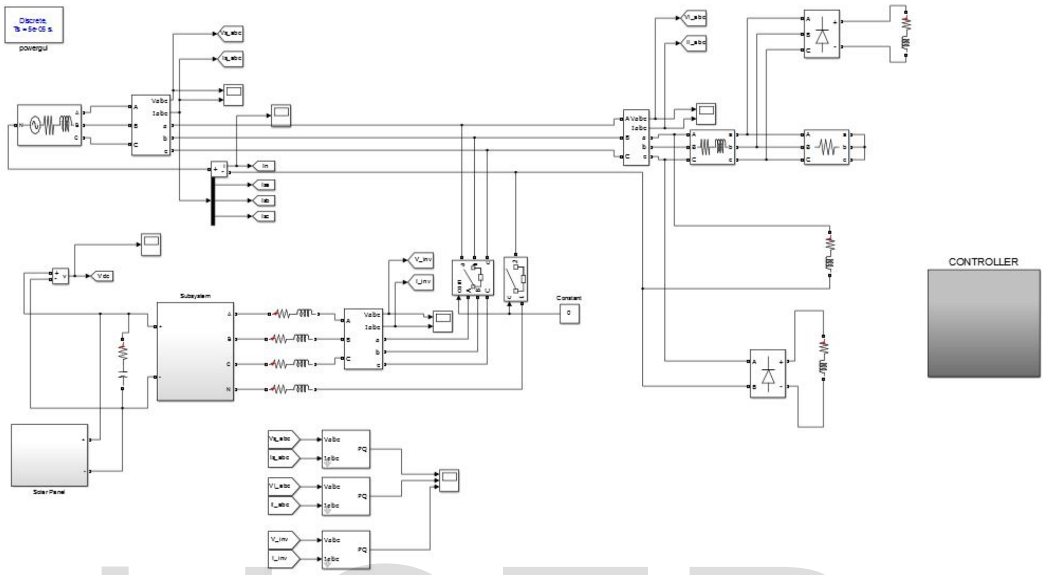

Fig. 3 Simulink model of the system

IV. SIMULATION RESULTS

In order to verify the proposed control approach of grid interfacing inverter, the simulation study is carried out using MATLAB/Simulink software. The Simulink model is shown in Fig.3.

A. Waveform analysis

Without Inverter Control:

The simulation results for grid voltage, grid current and load current without inverter control are shown in Fig.4 and Fig. 5. It is observed from the waveform that the amplitude of phase to phase r.m.s voltage is 100V, the r.m.s value of grid and load current is 6A and has more distortions.

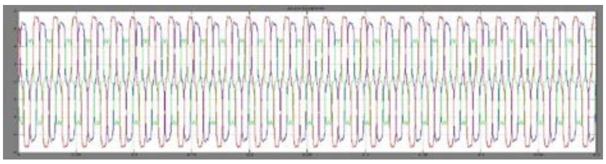

Fig. 5 Load Current

The corresponding active and reactive power waveforms for Grid and Inverter without inverter control are shown in Fig.6 and Fig.7 respectively. It is observed that without inverter control the amplitude of grid power is 1400W and the inverter is 0.0002W.

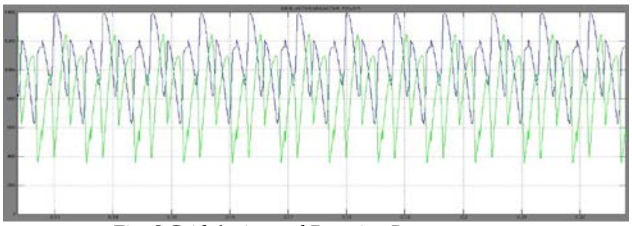

Fig. 6 Grid Active and Reactive Power

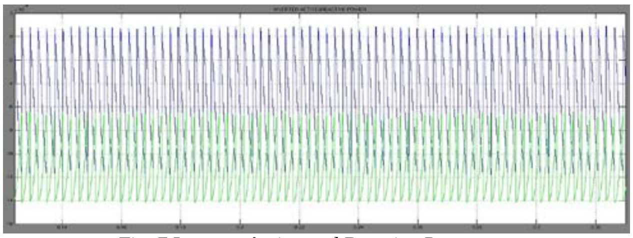

Fig. 7 Inverter Active and Reactive Power

The active and reactive power waveforms for Grid and Inverter with control are shown in Fig. 10 and Fig. 11 respectively. It is observed from the waveform that distortions are reduced and the amplitude of grid power is 4000W.

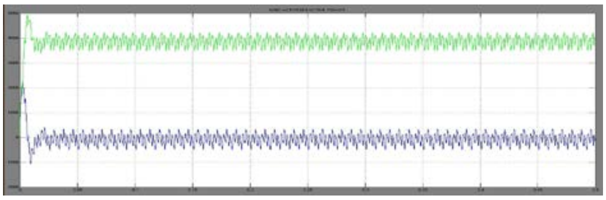

Fig. 10 Grid Active and Reactive Power

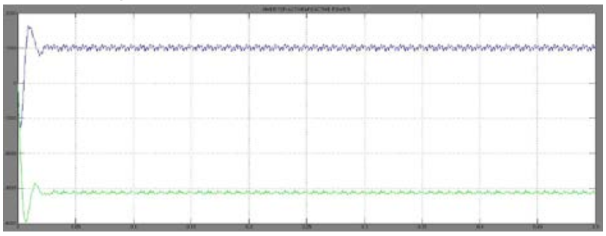

Fig. 11 Inverter Active and Reactive Power

With Inverter Control:

The simulation results for grid voltage, grid current and load current waveforms with inverter control are shown in Fig.8.and Fig. 9 respectively. It is observed from the waveform that with the grid interfacing inverter control the current harmonics can be effectively compensated and the distortions are reduced.

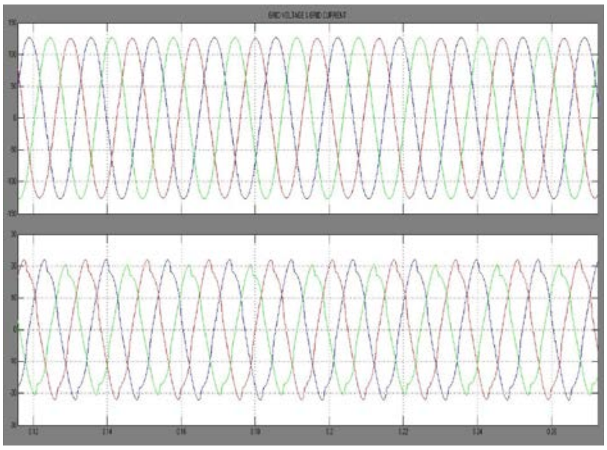

Fig. 8 Grid Voltage and Grid Current

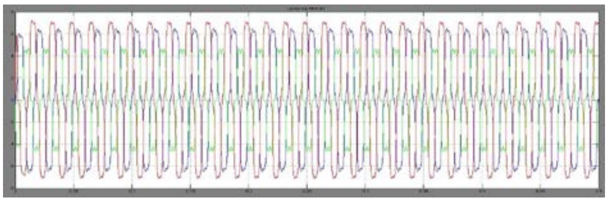

Fig. 9 Load Current

B. Total Harmonic Distortion (THD)

The Total Harmonic Distortion (THD) of the grid current without inverter and grid current with inverter connection is investigated. The waveform analysis for THD with and without inverter control are shown in Fig.12 and Fig.13 respectively.

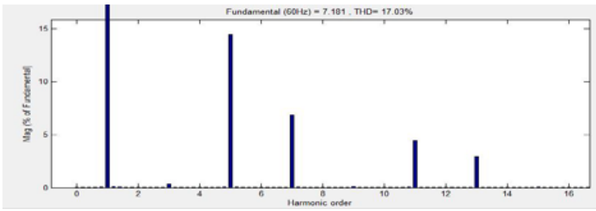

Fig. 12 THD without Inverter control

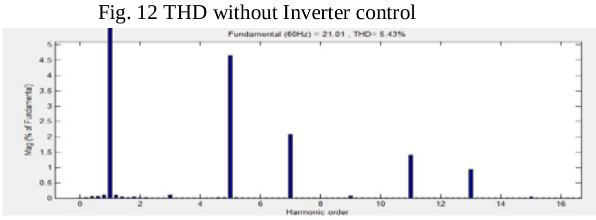

Fig. 13 THD with Inverter control

Table. 2 THD values of Grid current

S. No	Grid Current	Total Harmonic Distortion(%)
1.	Inverter –Without Hysteresis controller	17.03

2.	Inverter –With Hysteresis controller	5.43

The THD of the grid current without inverter and with inverter connection are 17.03% and 5.43% respectively. Table.2 shows the THD values of grid current before and after inverter connection.

V. CONCLUSION

This paper has presented a control for grid interfacing inverter to improve the quality of power for a 3 phase 4-wire system. It is shown that the grid interfacing inverter with the Hysteresis current control method can be effectively utilized for real power transfer. The voltage, current and power flow waveforms are obtained. The current harmonics and the reactive power demand of the grid is compensated. It has been found that total harmonic distortion of grid current is reduced from 17.03% to 5.43%. This approach thus eliminates the need for additional power conditioning equipment in grid connected PV system to improve the power quality.

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