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Power Quality Improvement in Grid Connected Renewable Energy Sources

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Abstract

The Renewable Energy Sources (RES) usage have increased significantly due to environmental issues and fossil fuels elevated cost. The depletion of fossil fuel resources on a worldwide basis has necessitated an urgent search for alternative energy sources to meet up the present day demands. In distributed system, renewable energy resources are increasingly incorporated using power electronics interfaces. Extensive 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 it can also interface renewable energy sources with the grid. The grid interfacing inverter is connected to a 3-phase 4-wire system and hysteresis current control method is used to generate gate pulses. The grid interfacing inverter has the capability of injecting RES power to the grid and also reduces load unbalance, load harmonics and reactive power demand is compensated. Total Harmonic Distortion (THD) of the grid connected system is analyzed. This concept is modeled and simulated in MATLAB/Simulink .

Keywords: Distributed generation (DG), power quality (PQ), renewable energy sources (RES).

Reviewed by* **ICETSET'16 *organizing committee*

1. Introduction

The energy demand is increasing day by day which can create problem for electric utilitiesand end users of electric power. percent of total global energy demand is supplied by the burning of fossil fuels. 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.Integration of renewable energy sources to the utility grid depends on the scale of power generation. Large scale power generations are connected to transmission systems where as small scale distributed power generation is connected to distribution systems. Renewable Energy Sources (RES) integrated at distribution level is termed as Distributed Generation (DG).The high penetration level of RES in distribution systems causes issues in terms of stability, voltage regulation 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 [4] an inverter operates as active inductor at a certain frequency to absorb the harmonic current. But the exact calculation of network inductance in real-time is difficult and may affect the control performance.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. Active power filters are extensively used to compensate the load current harmonics, which results in additional hardware cost. 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.

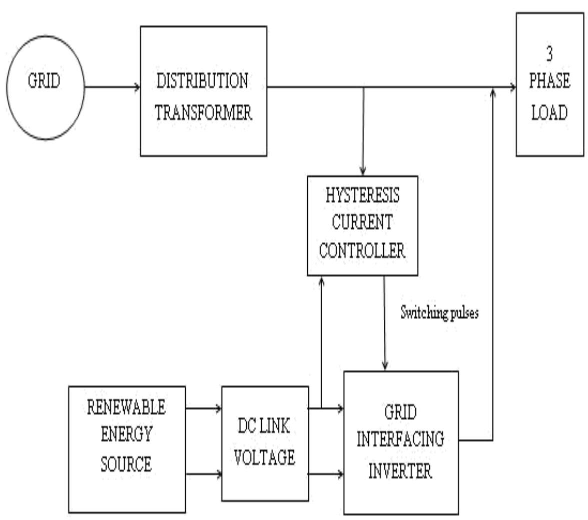

Fig. 1. Basic Configuration of the system

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

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II. SYSTEM DESCRIPTION

The Voltage source inverter is the main component of the DG system as it interfaces RES to the grid. The proposed system consist of RES (solar, wind) connected to the dc link of the grid interfacing inverter as shown in Fig. 1. The generated power from RES will be of variable in nature. The dc link plays an important role in transferring this variable power from renewable energy source to the grid. The control circuit will generate switching pulses to th grid interfacing inverter.

II.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 in 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 and these current errors are given to hysteresis current controller to produce switching pulse 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.

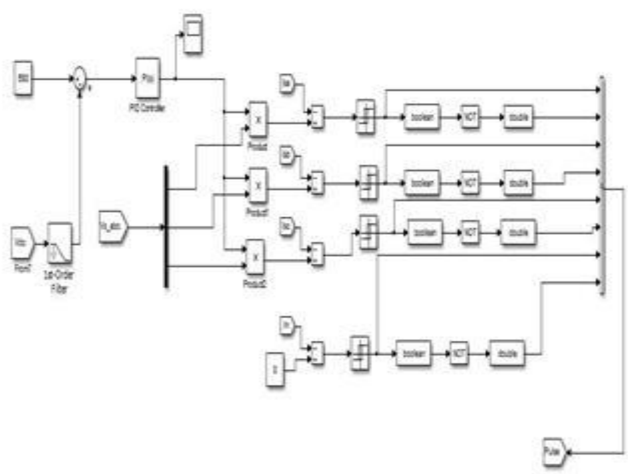

Fig.2 Control technique of grid interfacing inverter

Table.1 Switching Pattern for the Inverter

Logic	P1	P3	P4	P5	P6	P7	P8
$I_{sa}<(I_{sa}^{*}-h_{b})$	0	1	0	1	0	1	0
$I_{sa}>(I_{sa}^{*}-h_{b})$		1	0	1	0	1	0

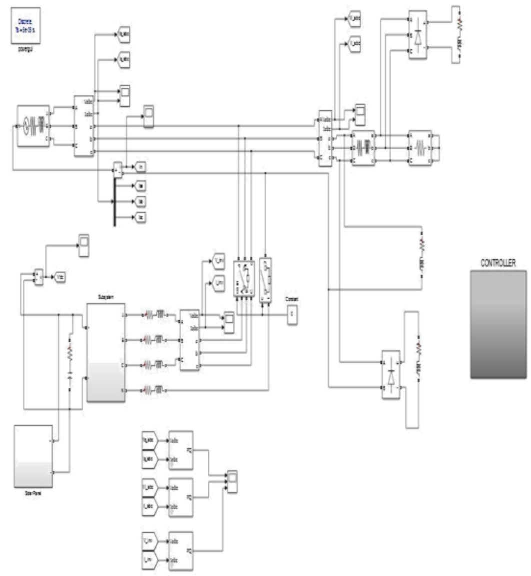

Fig. 3 Simulink model of the system

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 grid and load current is 6A and has more distortions

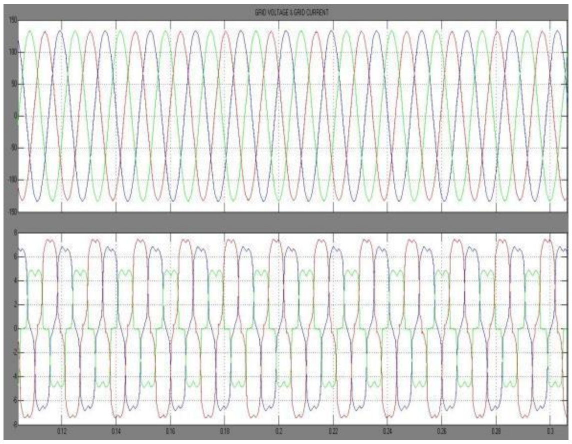

Fig. 4 Grid voltage and Grid current

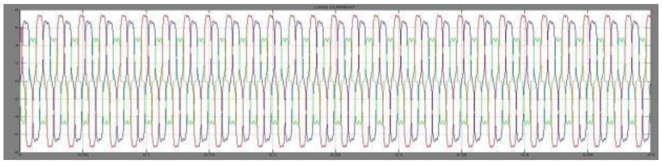
Fig. 5 Load Current

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.

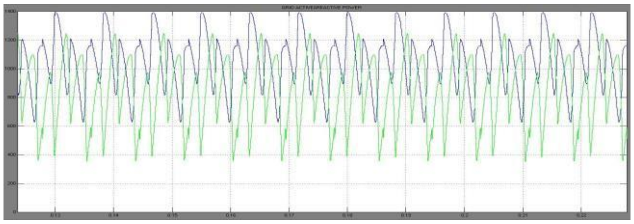
Fig. 6 Grid Active and Reactive Power

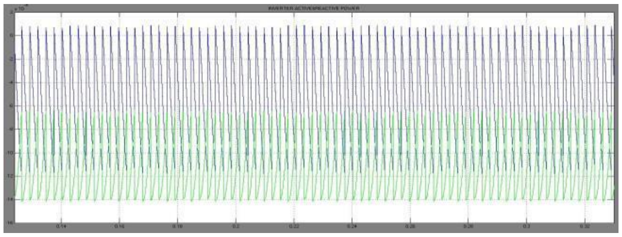
Fig. 7 Inverter Active and Reactive Power

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.

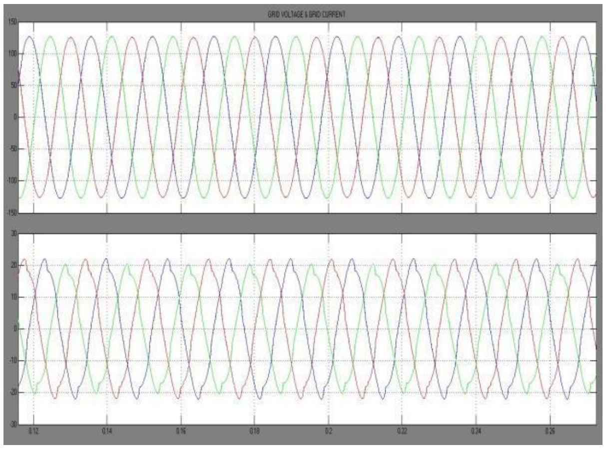
Fig. 8 Grid Voltage and Grid Current

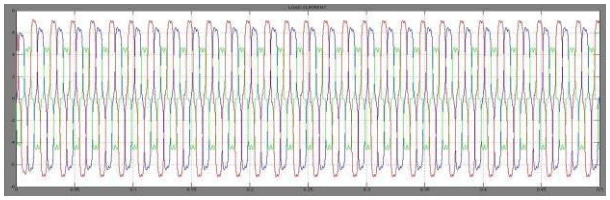

Fig. 9 Load Current

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.

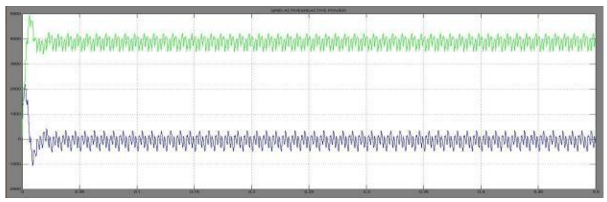

Fig. 10 Grid Active and Reactive Power

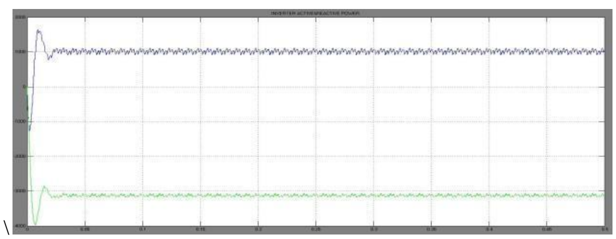

Fig. 11 Inverter Active and Reactive Power

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.

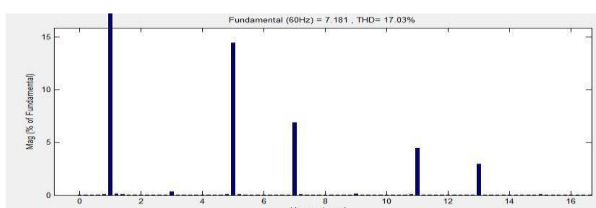

Fig. 12 THD without Inverter control

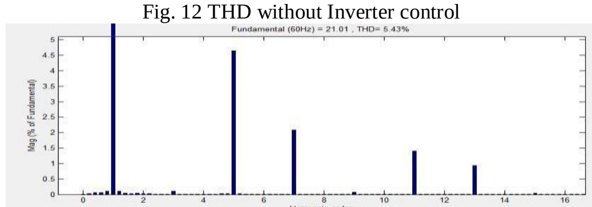

Fig. 13 THD with Inverter

Table. 2 THD values of Grid current

Total Horrmonic Distortion(%)	Grid Current
Without Inverter control	17.03
With Inverter control	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 has been 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. Reactive power demand of the grid is compensated and current harmonics is reduced. It has been found that total harmonic distortion of grid current is reduced from 17.03% to5.43%. This approach thus eliminates the need for additional power conditioning equipment to improve the power quality.

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