Power Quality Improvement Using Solar Based Grid Interfacing Inverter

P. Prabu
Assistant Professor,
Department of EEE,
V.S.B. Engineering College,
Karur-111. Tamilnadu, India.

Jebaraj Sargunam
Professor,
Dept of Mechanical Engineering,
V.S.B. Engineering College,
Karur- 111, Tamilnadu, India.

Abstract

In distribution systems the renewable energy sources are widely connected for utilizing power electronic converters. A novel control strategy is implemented in this paper for achieving the maximum benefits from the solar based grid interfacing inverter when installed in the distribution system at three phase four wire power systems. By incorporating active power filter functionality the inverter is controlled to perform as a multi-function device. The inverter can thus be used as power converter to inject power generated from Renewable energy source to the grid, and the shunt APF to compensate current unbalance, load reactive power demand, load current harmonics, and load neutral current. With such the control, a combination of grid-interfacing inverter and the 3-phase 4-wire linear/non-linear unbalanced load at point of common coupling delivers as balanced linear load to the grid. This new control concept is described with extensive MATLAB-SIMULINK simulation studies.

1. Introduction

Electric utilities and end users of electric power are becoming increasingly concerned about meeting the growing power demand. Seventy five percent of total global energy demand is produced by the burning of fossil fuels. But increasing air pollution, diminishing fossil fuels global warming concerns, and their increasing cost have made it important to look towards renewable sources as a future energy solution. Since the past series of ten, there has been an enormous interest in many countries on renewable energy for power generation. The market liberalization and the Government's incentives had further accelerated the renewable energy sector growth.

In [1] discussed a load-sharing technique that will share harmonic currents among converters equipped with active compensation for harmonic distortion without mutual communication. In [2] proposes cooperative control of multiple active filters based on voltage detection. The cooperative control is based on information exchanging among the active filters with automatic gain adjustment. The general objective for [3] is investigated the power quality problems and the interaction of these inverters with the distribution network.

For this paper the generated current harmonics, effect of background voltage distortion in the network and possible resonances between the inverters and the network are investigated. In this [4] a novel control scheme that is able to improve the transient response of parallel-connected inverters without using communication signals. In [5] the recent papers about DGS focus on two applications: a standalone ac system and a grid-interconnection to the utility mains. In [6] new trends in power electronic technology for the combination of energy-storage systems and renewable energy sources are presented.

The [7] gives an overview of the main DPGS structures, PV and fuel cell (FC) systems being first discussed. Active power filter technology is the most efficient way to compensate reactive power and cancel out low order harmonics generated by nonlinear loads [8].

Voltage harmonics due to the current harmonics in the non-linear load and it can develop the dangerous power quality problem in the three phase power system. To compensate the distribution level load unbalance and harmonics in the load current active power filters are mainly used.

The active power filters, which eliminate the harmonics, can be connected in both shunt and series. Shunt active power filter can perform power factor

ISSN: 2278-0181
Vol. 2 Issue 10, October - 2013

correction, harmonic filtering when connected at the load terminals [10].

2. Conventional Electric Grid

In conventional electric grid system consist of large number of units. They are generation, transmission and distribution. The loads are connected in the distribution side. The loads are basically classified as non linear and linear. Non linear loads are injecting the harmonics at a distribution side.

Due to the harmonics injection voltage levels are increased or decreased. So voltage sag or swells occur. Fig 1 shows the schematic diagram of electric grid.

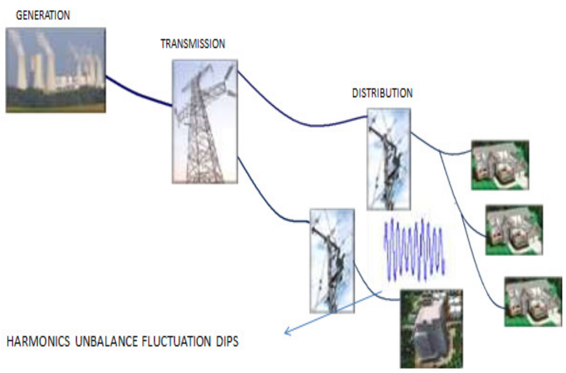

Figure 1. Schematic diagram of conventional electric grid

- The Conventional sources are insufficient to meet the ever increasing power demand.
- At distribution level the utility is disturbed about the very high level saturation of intermittent renewable energy sources.
- The variable (intermittent) nature of RES may pose a threat to the power system stability.
- Due to this, voltage regulation, lag and dip occur.
- Use of PED causes harmonic current and voltages.
- Use of nonlinear equipments and loads causes poor power factor.
- All these factors ultimately cause detoriation in power quality.

In conventional electric grid some of the problems are presented. In order to eliminate or reduced these problem, using the Shunt Active Power Filter (SAPF) in this paper.

3. Shunt Active Power Filter

A shunt active filter is designed to be connected in parallel with the load and it detects the harmonic current of load and injects into the system a compensating current and identical with the load harmonic current but in opposite phase. Therefore, the net current tense from the distribution network system at the point of coupling of filter and the load will be a sinusoidal current of only fundamental frequency.

Fig 2 schematic diagram of SAPF. Harmonic current and/or negative sequence current compensation and dc link voltage regulation between both active filters. The aim of the shunt active filter is primarily to compensate current harmonics generated from the distributed lines.

Thus, it has to examine the voltage at the point of installation and is controlled as to present infinite impedance for the fundamental frequencies and low impedance for the harmonic frequencies. In order to perform additional functions, as reactive power compensation and Flicker/imbalance compensation etc., The overall method must be equipped with the other feedback or feed forward control loops of the system.

Harmonics are sinusoidal voltages or currents having frequencies that are integer multiples of the frequency at which the supply system is designed to run, that combine with the essential voltage or current, and the produce waveform distortion. It is denoted by nonlinear loads. Lower order harmonic is defined as the harmonic component whose frequency is closest to fundamental one and its amplitude is greater than or equal to 3% of the fundamental component.

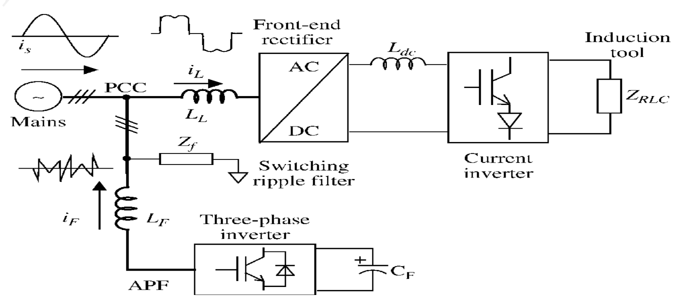

Figure 2. Schematic diagram of SAPF

The connection procedure and the principle of operation shunt active power filter is shown in the fig 3 and 4.

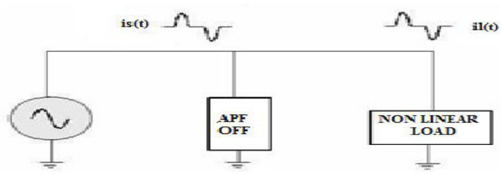

Figure 3. Block diagram of a simple power system with APF OFF

The above diagrams describe the function of Active Power Filter in a system. When the APF is OFF, the input current is distorted. When the APF is ON, the input current is sinusoidal and the distortions are reduced, APF will inject the harmonic currents 180 degree out of phase in to the point of common coupling as exhibit in fig. 2.

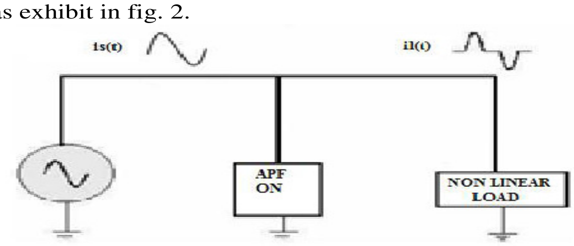

Figure 4. Block diagram of a simple power system with APF ON

4. Grid Interfacing Inverter

A grid interfacing inverter is a combination of both current controlled VSI and APF. Thus both the functions can be performed selectively or collectively.

4.1 Functions of grid interfacing inverter

- Active power generation Transfer from RES to the grid system.
- It supports the demand of load reactive power.
- Compensation of Current harmonics at the point of common coupling.
- Neutral current and current unbalance compensation in case of three phase three wire and three phase four wire system.

4.2 Four Leg Inverter

- The main feature of a three phase inverter, with the additional neutral leg is the ability to deal with load unbalance in a standalone power supply system.
- The goal of the three phase four leg inverter is to maintain the desired sinusoidal output voltage waveform over all loading conditions and transients.
- It is ideal for applications like data communication, the industrial automation and military equipment which necessitate high performance of uninterruptible power supply.

5. System Description

The proposed method consists of renewable energy sources connected to the dc-link of a grid-interfacing inverter as shown in Fig. 5. The key element of the Distributed Generated system is the voltage source inverter it interfaces the RES to the grid system and it delivered the generated power of the power system. The renewable energy source may be an AC source or an DC source coupled to dc-link with rectifier arrangements.

Normally, the photovoltaic energy sources and fuel cell energy sources generate the power at very low variable DC voltage and the wind turbines of variable speed generate power at very low variable ac voltage and the generated power from these renewable sources needs the power conditioning before connecting on the dc-link capacitor. The dc-link capacitor allows the separate control of converters on the both side of dc-link and it de-couples the Renewable energy sources from grid power system.

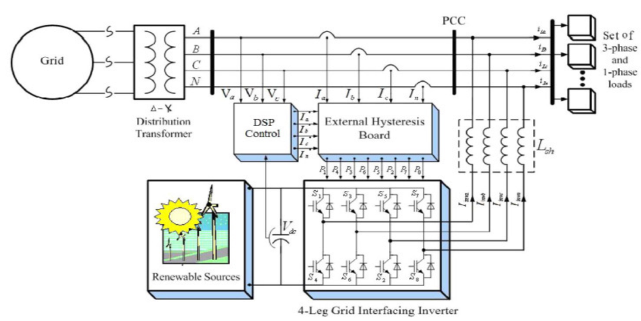

Figure 5. Schematic diagram for proposed renewable based distribution generation system

5.1 Operation of Power Control and Dc-Link Voltage

Due to the nature of renewable energy source is intermittent so the power generated from the RES is variable nature and the main role of dc-link system is transferring this variable power from the RES to the grid system. Fig. 6 shows the transfer of power from the RES to the grid system via the dc-link system.

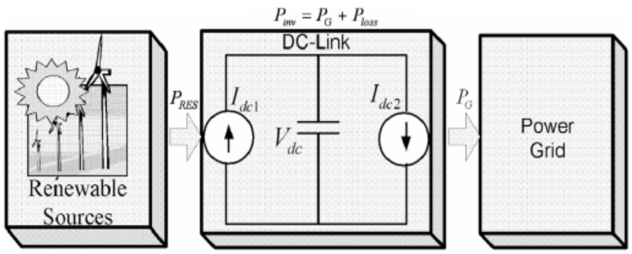

Figure 6. DC-Link equivalent diagram

5.2 Role of Power Electronic Components in Solar Power System

Grid-connected PV systems are currently being widely installed in many of the developed countries. In addition to their environmental benefits, PV systems have a number of technical and economical benefits. They can be operated to decrease the losses and improve the voltage profile of the feeder to which they are connected. One of the main characteristics of PV systems is the high variability of their output power.

The variability stems from the fact that these systems are static, and thus, any instantaneous change in the irradiance reaching the PV arrays leads to a corresponding change in their output power. The time frame for the short-term fluctuations in irradiance is in the order of seconds to few minutes thus, some studies have considered the fluctuations in the PV power to be within the same time frame. However, other studies have recommended the use of 10-min irradiance data when studying the power fluctuations generated from PV systems.

This is especially suitable for systems with ratings in the order of tens of megawatts that extend over a large land area, such as the 10-MW PV plant in Pocking, Germany. A recent report published by the North American Electric Reliability Corporation showed that the output power of existing large PV systems with the ratings of tens of megawatts, can change by 70% in a five to ten-min time frame.

It should be noted that for a number of small systems that are distributed over a large land area, the resulting combined fluctuations are much less due to the smoothing effect. Also, the fluctuation in the power of these systems can lead to unstable operation of the electric network prior to the fault conditions, high power swings in the feeders.

This will lead a situation where the PV generators will be required to share some of the duties, such as load frequency control. The increasing number of renewable energy sources and distributed generators requires new strategies for the operation and management of the electricity grid in order to maintain or even to improve the power-supply reliability and quality.

5.3 PV System Characteristics and Impacts

Today's grid-connected, residential system and commercial systems naturally have the following characteristics and associated impacts:

- The PV system and the inverter are connected to the grid in parallel with the load.
- The load is served whenever the grid is available.
- Energy produced by the PV system decreases the apparent load and the Energy produced in excess of the load flows into distribution system.
- The PV system has no storage and cannot serve the load in the absence of the grid.
- The PV system produces power at unity power factor and utility supplies all Volt Ampere reactive power.
- For residential and commercial systems the grid interconnection is naturally net-metered at a smooth rate.

6. Simulation Results

The proposed method is to achieve multi-objectives for grid system interfaced to the DG systems. The distributed generation system is connected to three phase three wire and three phase four wire system with an general simulation test is carried out using the MATLAB/Simulink software. Here 4-leg voltage source inverter of current control method is dynamically controlled and achieves the balanced sinusoidal grid system currents at Unity Power Factor (UPF) and despite of extremely unbalanced condition of nonlinear load at the point of common coupling under varying the renewable system generating conditions.

The variable output power at renewable energy source is coupled on the dc-link system of grid interfacing inverter arrangements. At the point of common coupling an unbalanced three phase three wire and three phase four wire non linear load, whose harmonics, unbalance and reactive power is connected.

The simulation waveforms of the grid currents (I_a,I_b,I_c,I_n), grid voltage (V_a,V_b,V_c), inverter current (I_{inva},I_{invb},I_{invc},I_{invn}) and unbalanced load current (I_{la},I_{lb},I_{lc},I_{ln}) are shown in the fig 7 and the resultant active-reactive powers of the load (P_{load},Q_{load}), grid (P_{grid},Q_{grid}) and inverter (P_{inv},Q_{inv}) are shown in Fig. 8. The active-reactive powers of grid is positive values it flows from grid side towards PCC and another side inverter active reactive powers flows from inverter towards the PCC. The active power and reactive powers are immersed by the loads are noted by positive signs of the system.

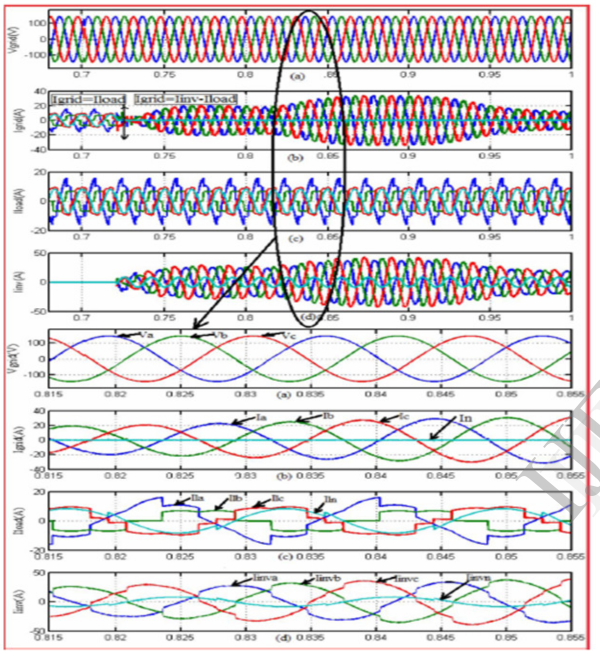

Figure 7. Simulation results for (a) Grid voltages, (b) Grid Currents (c) Unbalanced load currents, (d) Inverter Currents

The grid interfacing inverter is initially not connected to the power system. Therefore, In Fig. 7(b) before the staring time t=0.72s, the grid current is identical to the load current of Fig. 7(c). At time t=0.72s, the grid-interfacing inverter system is connected to the network system. The inverter is starts to inject the current this instant and such a way that the summary of grid system current is starts to change from unbalanced non linear current to balanced sinusoidal current as denoted in the Fig. 7(b).

The load side neutral current is supplied by the inverter and the grid side neutral current is zero after the time of t=0.72s. At the time t=0.72s, from the renewable energy source the active power is generated at the time inverter starts to inject the power.

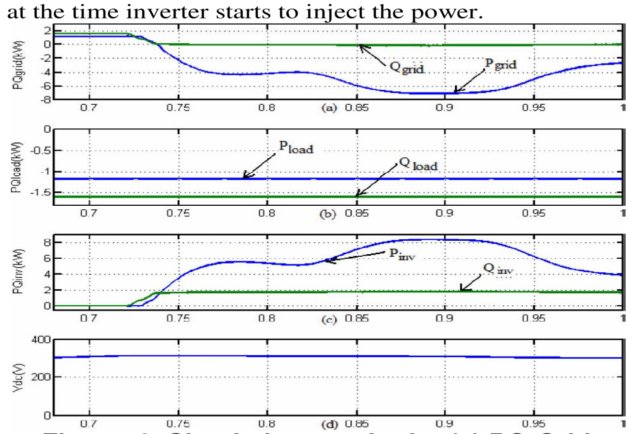

Figure 8. Simulation results for (a) PQ-Grid, (b) PQ-Load, (c) PQ-Inverter, (d) dc-link voltage.

So the generated power is higher than the total load power demand the extra power is fed back to the grid system.

In grid system the negative grid power, after the time t=0.72s suggests that the grid system is now receiving the power from renewable energy sources. In addition, the load side reactive power demand is supplied by the grid-interfacing inverter also. At the time of operation of the inverter the grid system only supplies or receives the fundamental active power component. At the time of t=0.82s, the active power generation from renewable energy source is increased to calculate the performance of grid system under the variable generation power from renewable energy sources.

It results in the increased magnitude of grid inverter current. At time t=0.92s, the available power from renewable energy source system is highly reduced. The related changes in the grid currents and inverter can be shown in the Fig. 7. The active power flows between the load, inverter and grid system during decrease and increase of generated energy from renewable energy source are shown in the fig. 8.

In order to maintain the active and reactive power flow of the system the dc-link system of voltage across the grid interfacing inverter shown in fig. 8 at constant level of different operating conditions. Finally from the simulation results the grid-interfacing inverter is efficiently used to balance the current unbalance, load reactive power and the current harmonics in calculation to active power system injection from renewable energy system.

7. Conclusion

In this paper presented a new control method of an existing grid system interfacing inverter to increase the power quality at point of common coupling for a three phase three wire and three phase four wire Distributed Generation system and it is shown that the grid system interfacing inverter is efficiently utilized for the power system without affecting its normal method of transfer in the real power to the grid system. The proposed method of grid system interfacing inverter can be utilized to a) grid system inverter operate as a shunt active power filter in the system. b) To inject the real power generation from renewable energy source to the grid system.

8. References

[1] Uffe Borup, Frede Blaabjerg, and Prasad N. Enjeti, "Sharing of Nonlinear Load in Parallel-Connected Three-Phase Converters" IEEE Transactions on Industry Applications, Volume. 37, No. 6, November/December 2001, pp: 1817-1823.

[2] Pichai Jintakosonwit, Hideaki Fujita, Hirofumi Akagi Satoshi Ogasawara, "Implementation and Performance of Cooperative Control of Shunt Active Filters for Harmonic Damping throughout a Power Distribution System", 0-7803-7420-7/02/ 2002 IEEE, pp: 51-58.

[3] J.H.R. Endin, P.J.M. Heskes, "Harmonic Interaction between a Large Number of Distributed Power Inverters and the Distribution Network" 0-7803-7754-0/030 2003 IEEE, pp: 1742-1747.

[4] Josep M. Guerrero, Luis García de Vicuña, José Matas, Miguel Castilla and Jaume Miret, "A Wireless Controller to Enhance Dynamic Performance of Parallel Inverters in Distributed Generation Systems" , IEEE Transactions On Power Electronics, Volume. 19, No. 5, September 2004, pp: 1205-1213.

[5] Mohammad N. Marwali, Jin-Woo Jung, and Ali Keyhani, "Control of Distributed Generation Systems Part II: Load Sharing Control" IEEE Transactions On Power Electronics, Volume. 19, No. 6, November 2004, pp:1551-1561.

[6] Juan Manuel Carrasco, Leopoldo Garcia Franquelo, Jan T. Bialasiewicz, Eduardo Galván, Ramón C. Portillo Guisado, Ma. Ángeles Martín Prats, José Ignacio León, and Narciso Moreno-Alfonso,"Power-Electronic Systems for the Grid Integration of Renewable Energy Sources: A Survey" IEEE Transactions On Industrial Electronics, Volume. 53, No. 4, August 2006, pp: 1002-1016.

[7] Frede Blaabjerg, , Remus Teodorescu, , Marco Liserre, and Adrian V. Timbus," Overview of Control and Grid Synchronization for Distributed Power Generation Systems", IEEE Transactions On Industrial Electronics, Volume. 53, No. 5, October 2006, pp: 1398-1409.

[8] J.Vikramarajan, Rasmi ranjan das and Razia sulthana. "Three phase shunt active power filter with unipolar PWM technique to compensate reactive power and low order harmonics", National Power Electronics Conference (NPEC-10) June 10-13, 2010, pp:1-7.

[9] Mukhtiar Singh, Vinod Khadkikar, Ambrish Chandra and Rajiv K. Varma, "Grid Interconnection of Renewable Energy Sources at the Distribution Level With Power-Quality Improvement Features", IEEE Transactions On Power Delivery, Volume. 26, No. 1, January 2011, pp: 307-315.

[10] G. Vamsi Krishna and P. Ramesh, "Mitigation of Harmonics in Distribution System Using SAPF", International Journal of Modern Engineering Research (IJMER), Volume.2, Issue. Sep-Oct. 2012, ISSN: 2249-6645, pp-3522-3526.