

Improvement of Power Quality in Distribution System with Grid Connected RES

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Abstract: With the help of power electronic Converters/Inverters renewable energy resources (RES) are being increasingly connected in distribution systems. In this paper, Photo Voltaic (PV) system is integrated to a three phase four wire distribution system. The non-linear loads and use of power electronics based equipments at PCC generate harmonic currents, which may deteriorate the power quality. This paper suggests a new method that consists of a four leg inverter i.e. capable of simultaneously compensating problems like current imbalance and current harmonics, and also of injecting the power generated by renewable energy power sources. The fourth leg of inverter is used to compensate the neutral current of load. The grid interfacing inverter can be utilized as power converter to inject power generated from RES to the grid, and shunt APF to compensate current unbalance, load current harmonics and load reactive power demand. The inverter is actively controlled in such a way that it draws/supplies fundamental active power from/to the grid. All of these functions may be accomplished either individually or simultaneously.

Keywords: Active power filters (APF), distributed generation (DG), power quality (PQ), renewable energy (RE) and Voltage source Inverter (VSI).

I. INTRODUCTION

The widespread use of non-linear loads is leading to a variety of undesirable phenomena in the operation of power systems. The harmonic components in current and voltage waveforms are the most important among these. Conventionally, passive filters have been used to eliminate line current harmonics. However, they introduce resonance in the power system and tend to be bulky. So active power line conditioners have become popular than passive filters as it compensates the harmonics and reactive power simultaneously. The active power filter topology can be connected in series or shunt and combinations of both. Shunt active filter is more popular than series active filter because most of the industrial applications require current harmonics compensation. Different types of active filters have been proposed to increase the electric system quality; a generalized block diagram of active power filter is presented in [2]. The classification is based on following criteria.

- i) Power rating and speed of response required in compensated system
- ii) System parameters to be compensated (e.g. current harmonics, voltage harmonics)
- iii) Technique used for estimating the reference current/voltage.

Current controlled voltage source inverters (VSI) can be utilized with appropriate control strategy to perform active filter functionality. The electrical grid will include a very large number of small producers that use renewable energy sources, like solar panels or wind generators. One of the most common problems when connecting small renewable energy systems to the electric grid concerns the interface unit between the power sources and the grid, because it can inject harmonic components that may deteriorate the power quality. However, the extensive use of power electronics based equipment and non-linear loads at

PCC generate harmonic currents, which may deteriorate the quality power [3],[4]. In [5] an inverter operates as active inductor at a certain frequency to absorb the harmonic current. A similar approach in which a shunt active filter acts as active conductance to damp out the harmonics in distribution network is proposed in [6].

Generally, current controlled VSI is used to interface the intermittent RES in distributed system. This paper suggests a new method that consists of four leg VSI that is capable of simultaneously compensating problems like current imbalance and current harmonics, and also of injecting the power generated by renewable energy sources with a very low total harmonic distortion (THD). Even when there is no energy available from the power source the Voltage source inverter can still operate, increasing the power quality of the electric grid. Thus the grid interfacing inverter is effectively utilized to perform the following functions

- a. Active power injection
- b. Current unbalance and neutral current compensation in 3-phase 4-wire system.
- c. Current harmonics compensation at PCC.
- d. Load reactive power demand support.

In 3 phase application with three leg inverter, if the load requires a neutral point connection a simple approach is to use two capacitor to split the dc link and tie the neutral point to the midpoint of two capacitors [6]*.

In this case the unbalanced loads will cause the neutral currents that flow through the fourth wire distorting the output voltage. Another drawback is the need for excessively large dc link capacitors. The important parameters of VSIs are the level of dc link voltage, value of interface inductor and hysteresis band. These parameters must be carefully selected to provide

satisfactory performance while tracking reference currents [7], [8].

II. SYSTEM TOPOLOGY

The proposed system consists of RES connected to the dc-link of a grid-interfacing inverter as shown in Fig. 1. It is assumed that a non-linear unbalanced load consisting of a three phase and single phase diode rectifier is connected to a three-phase balanced source voltages. The voltage source inverter is a key element of a DG system as it interfaces RES to the grid and delivers the generated power. The RES may be a DC source or an AC source but this proposed system uses the photovoltaic (PV) system.

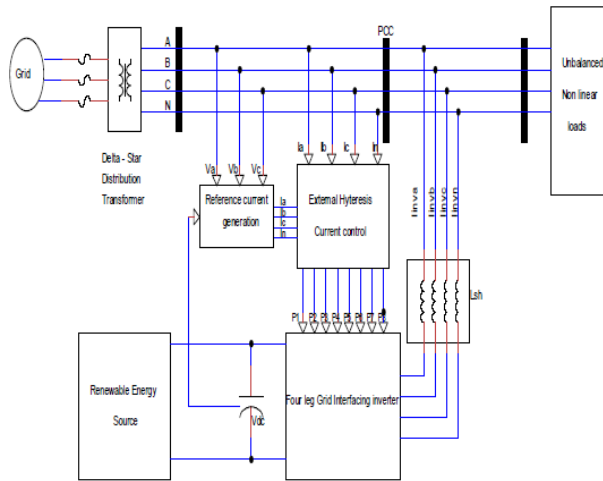


Fig.1 Schematic of Proposed Distributed Generation system

Generally, the power circuit of shunt APF consists of a three phase Voltage Source PWM VSI using IGBTs coupled at the Point of Common Coupling (PCC) via coupling inductance. During the last few years, power electronics has undergone a fast evolution, which is mainly due to two factors. The first one is the development of fast semiconductor switches that are capable of switching quickly and handling high power. The second factor is the introduction of real-time computer controllers that can implement advanced and complex control algorithms. These factors together have led to the development of cost-effective and grid-friendly converters. In this paper, new trends in power-electronic technology for the integration of renewable energy sources. The active filter compensates the harmonics generated by nonlinear loads by generating the same harmonic components in the opposite phase. Harmonics are thus cancelled and the result is a non-distorted sinusoidal current. Each leg of VSI consists of two IGBT. The single phase equivalent circuit of the system is shown in Fig.2. Load current can be written as,

$$\dot{i}_{La} = \dot{i}_{Laf} + \dot{i}_{Lah} \quad (1)$$

$$\dot{i}_{La} = \dot{i}_{inva} + I_s \quad (2)$$

In equation (1), \dot{i}_{Laf} is the fundamental component and \dot{i}_{Lah} harmonic component of load current. Since the harmonic component of load current should not be transferred to the supply side, the inverter has to inject a

current whose magnitude should be equal to harmonic component.

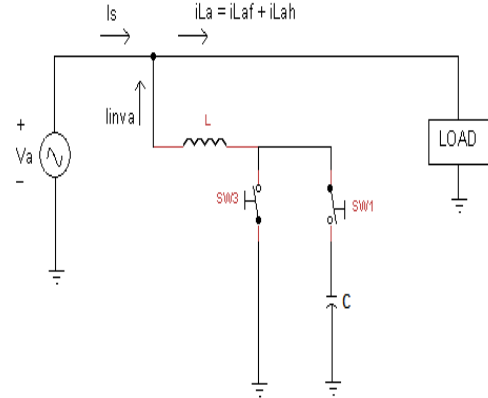


Fig.2 Single Phase Equivalent Circuit of the system and VSI

We should have,

$$\dot{i}_{Lah} = \dot{i}_{inva} \quad (3)$$

From equation (2) and (3), we get

$$I_s = \dot{i}_{Laf} \quad (4)$$

If $\dot{i}_{Lah} > \dot{i}_{inva}$ switch 2 should be OFF and switch 1 should be ON so the current generated by dc capacitor \dot{i}_{inva} is equal to \dot{i}_{Lh} .

If $\dot{i}_{Lah} < \dot{i}_{inva}$ switch 2 should be ON and switch 1 should be OFF so the current \dot{i}_{inva} should be transferred to the ground in order to have

$$\dot{i}_{inva} = \dot{i}_{Lah}$$

III. CONTROL STRATEGY

The main aim of the proposed approach is to inject the power from RES (i.e. PV cell) and also to make the voltage source inverter to function as an APF. The fourth leg of inverter is used to compensate the neutral current of load. The main aim of proposed approach is to regulate the power at PCC during:

- 1) $P_{RES} = 0$
- 2) $P_{RES} < P_L$
- 3) $P_{RES} > P_L$

Where,

P_L -Total load power

There are many control approaches available for the generation of reference source currents for the control of VSI system in the literature [10], [11]. The block diagram of the control scheme is shown in Fig. 3. The control strategy applied to the grid side inverter consists mainly of two cascaded loops. Usually there is a fast internal current control loop, which regulates the grid current and an external voltage loop which controls the DC-link voltage [12]. Conduction and switching losses of diodes and IGBTs in inverters increase voltage ripple in DC-link which affects the performance of the filter. These effects controlled by a feedback loop where PI regulator compares the DC-link voltage with a reference voltage.

The control scheme approach is based on injecting the currents into the grid using hysteresis current controller.

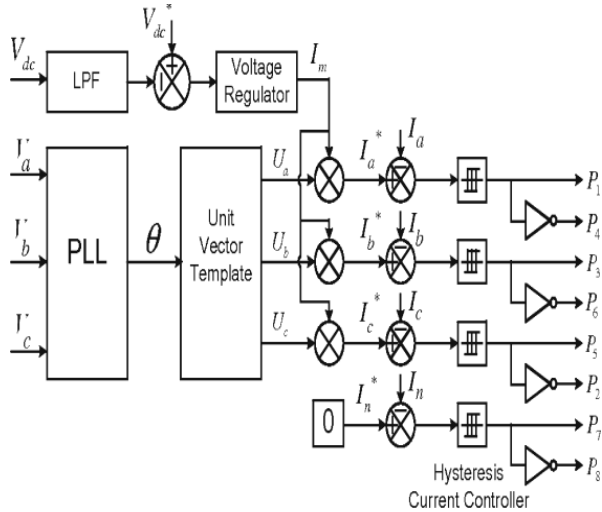


Fig.3 Block diagram representation of control scheme

A. VOLTAGE CONTROL OF DC CAPACITOR

The DC link voltage regulates balanced power flow in the grid system so the DC link voltage is maintained constant across the capacitor. A PI controller is used to maintain the DC link voltage at specified value. The DC link voltage is sensed and compared with reference value and the error is passed through a PI controller.

$$V_{dcerr} = V_{dc}^* - V_{dc} \quad (5)$$

Thus the output of dc link voltage regulator results in current I_m .

$$U_a = \sin(\theta) \quad (6)$$

$$U_b = \sin(\theta + 2\pi/3) \quad (7)$$

$$U_c = \sin(\theta - 2\pi/3) \quad (8)$$

The multiplication of current I_m with unit vector template (U_a, U_b, U_c) generates reference grid currents (I_a^*, I_b^*, I_c^*). The instantaneous values of reference grid currents are computed as

$$I_a^* = I_m \cdot U_a \quad (9)$$

$$I_b^* = I_m \cdot U_b \quad (10)$$

$$I_c^* = I_m \cdot U_c \quad (11)$$

The neutral currents present if any due to the loads connected to the neutral conductor should not be drawn from the grid. Thus reference grid neutral current is considered as zero and can be expressed as

$$I_n^* = 0 \quad (12)$$

Current errors are obtained by comparing reference grid currents (I_a^*, I_b^*, I_c^*) with actual grid currents (I_a, I_b, I_c). These current errors are given to the hysteresis current controller.

$$I_{aerr} = I_a^* - I_a \quad (13)$$

$$I_{berr} = I_b^* - I_b \quad (14)$$

$$I_{cerr} = I_c^* - I_c \quad (15)$$

$$I_{nerr} = I_n^* - I_n \quad (16)$$

B. SWITCHING CONTROL OF IGBTs

The Switching pulses are generated using hysteresis current controller. There are various current control methods for active power filter configurations but hysteresis method is preferred among other current control methods because of quick current controllability, easy implementation and unconditioned stability [13].

The conventional current control scheme is the hysteresis method where the actual filter currents are compared with their reference currents with a predefined hysteresis band in their respective phases. Thus the actual currents track the reference currents generated by current control loop.

The switching pattern of each IGBT is formulated as,

If $(I_a^* - I_a) = +hb$ then the upper switch S1 will be ON in the phase a leg of inverter.

If $(I_a^* - I_a) = -hb$ then the lower switch S4 will be ON in the phase a leg of inverter.

Where, hb width of hysteresis band. Similarly switching pulses are derived for other three legs.

IV. SIMULATION RESULTS

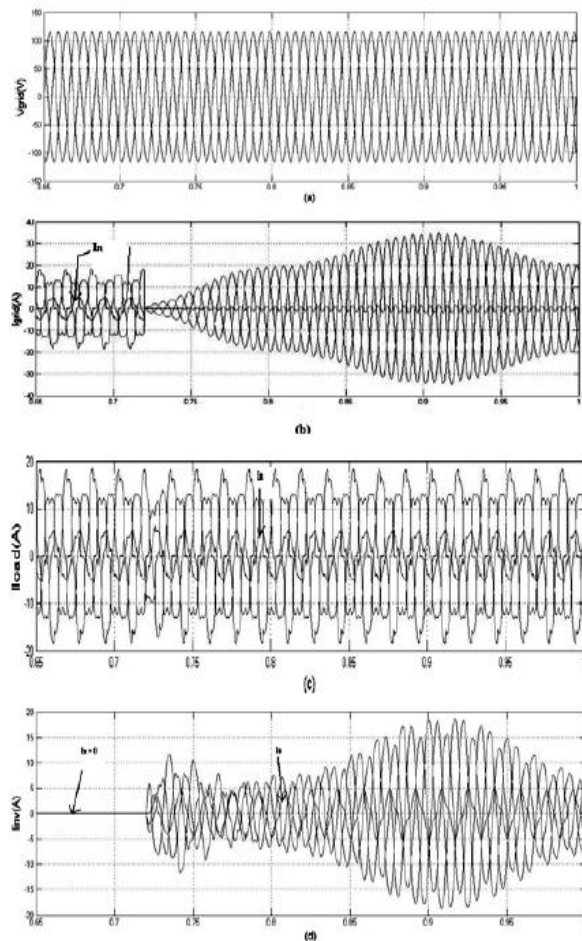


Fig. 5.2 Simulation Results: (a) Grid Voltage, (b) Grid Currents, (c) Unbalanced Load Currents, (d) Inverter Currents.

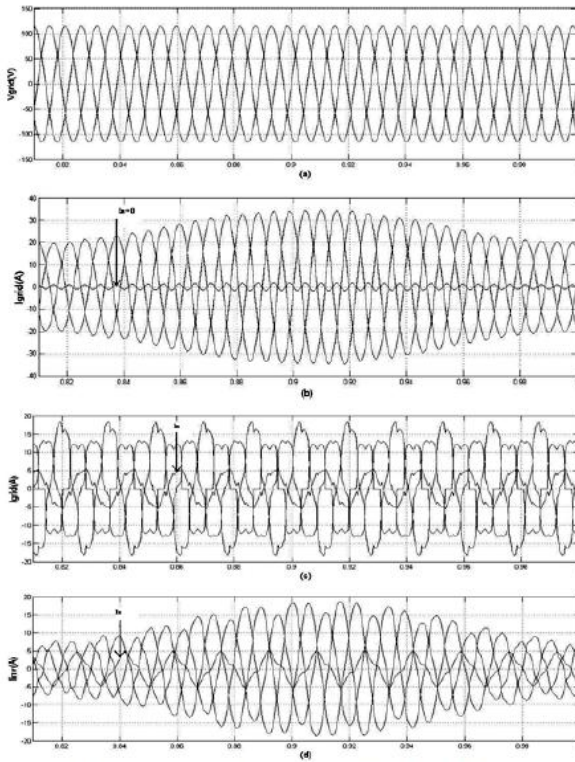


Fig. 5.3 Expanded Simulated Results: (a) Grid Voltage, (b) Grid Currents, (c) Unbalanced Load Currents, (d) Inverter Currents

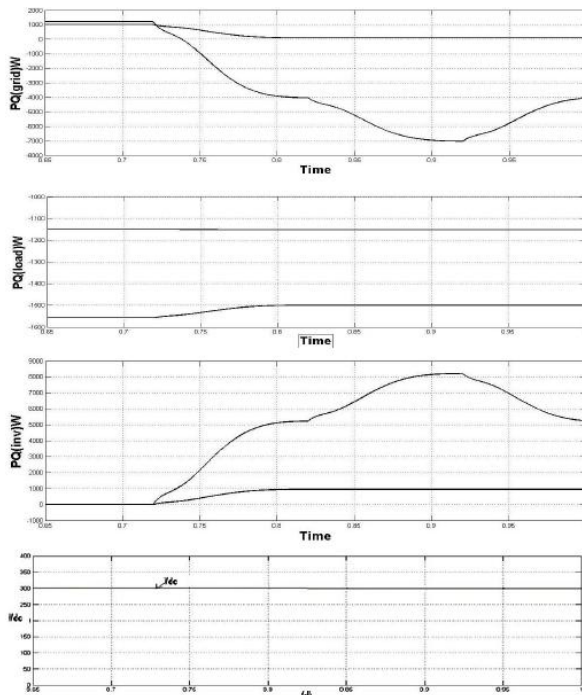


Fig. 5.4: Simulation Results: (a) PQ Grid, (b) PQ Load, (c) PQ Inverter, (d) De-Link Voltage.

V. CONCLUSION

This paper presented a control of an Three phase Four leg grid interfacing inverter improve the power of quality at PCC for a 3 phase 4 wire system. It has been shown that the grid interfacing inverter can simultaneously be utilized to inject power generated from RES to PCC and to improve the quality of power at PCC.

The current harmonics caused by non linear load connected at PCC are compensated effectively such that the grid currents are always maintained sinusoidal. This approach thus eliminates the need for additional power conditioning equipment to improve the quality of power at PCC. Thus the load neutral current is prevented from flowing into the grid side by compensating it locally from the fourth leg of the inverter.

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