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A Review on Power Quality Improvement in the Distributed Generation System

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ABSTRACT: This paper consists of novel control strategy for compensating problems like power factor, current imbalance and current harmonics, and also injects the energy generated by renewable energy power sources simultaneously with the help of four leg inverter. The fourth leg of inverter is used to compensate the neutral current of load. The grid interfacing inverter can thus be utilized as: 1) power converter to inject power generated from RES to the grid, 2) 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 fundamental active power from the grid or supplies to the grid. All of these functions may be accomplished either individually or simultaneously. This new control concept is demonstrated with extensive MATLAB/Simulink simulation studies.

KEYWORDS: Active power filter (APF), Distributed Generation (DG), power quality (PQ) and Voltage source Inverter (VSI), RES.

I.INTRODUCTION

In the electric utility seventy five percent of total global energy demand is supplied by the burning of fossil fuel but increasing air pollution, global warming concerns, there increasing cost so it necessary to look toward renewable energy sources.

The electrical grid will include a very large number of small producers that use renewable energy sources, like 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 detoriate the power quality. However, the extensive use of power electronics based equipment and non-linear loads at PCC generate harmonic currents, which may detoriate the power quality [1].

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 [2]. 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.
Due to use of non-linear loads is leading to a variety of undesirable phenomena in the operation of power systems. The non linear load create current harmonic may result in voltage harmonic can create serious PQ problem in power system network [3]. In recent with advanced power electronic and digital control technology the DG system controlled. The system is controlled the system operation with improved quality at PCC. The shunt active power are used to compensate the current harmonics and load unbalanced at distribution level. This features of active power filter gives four leg inverter interfacing renewable with grid.

This paper suggests a new method that consists of four leg VSI that is capable of simultaneously compensating problems like power factor, current imbalance and current harmonics, and also of injecting the energy generated by renewable energy power sources with a very low THD [4].
The use of four leg inverter performs following important function:
1) Transfer of active power harvested from the renewable resources (wind).
2) Load reactive power demand support.

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3) Current harmonics compensation at PCC.
4) Current unbalance and neutral current compensation in case of 3-phase 4-wire system.

Hence the power quality at PCC can be strictly maintained within the utility standard [5].

II. LITERATURE REVIEW

U. Borup, F. Blaabjerg, and P. N. Enjeti, "Sharing of nonlinear load in parallel-connected three-phase converters," IEEE Trans. Ind. Appl... In previous solution they are not able to distinguish harmonic current that flow to load and between converters. These controllers are struggling to distinguish the harmonic current. So it is needed to solve this problem that arises when two converters with harmonic compensation are connected in parallel. In order to struggle of integrating controllers drop coefficient can be introduced with harmonic voltages similar to the ones used to adjust fundamental voltage amplitude and frequency. So the load current is divided much more equally between the two converters. The author had presents equal sharing of linear and nonlinear loads in three-phase power converters connected in parallel, without communication between the converters.

J. H. R. Enslin and P. J. M. Heskes, "Harmonic interaction between a large number of distributed power inverters and the distribution network," IEEE Trans. Power Electronic. This paper presents Power quality problem associated with distributed power (DP) inverters, implemented in large numbers onto the same distribution network, are investigated. Currently, these power quality problems are mainly found in projects with large penetration of photovoltaic's (PVs) on rooftops of houses and commercial buildings. The main object of this paper is to analyze the observed phenomena of harmonic interference of large populations of these inverters and to compare the network interaction of different inverter topologies and control options. These power quality phenomenon's are investigated by using extensive laboratory experiments, as well as computer modeling of different inverter topologies. A complete network simulation study on an existing residential network with large penetration of PVs is included.

P. Jintakosonwit, H. Fujita, H. Akagi, and S. Ogasawara, "Implementation and performance of cooperative control of shunt active filters for harmonic damping throughout a power distribution system." The previous search more focused on equal sharing of harmonic load current throughout the parallel connected controllers. But this search has not suggested that how harmonics at distribution system is damp out. This fact introduces that there is need of active power filter in distribution system. The author had proposed co-operative control of multiple active filters based on voltage detection for harmonic damping throughout a power distribution system.

J. M. Guerrero, L. G. de Vicuna, J. Matas, M. Castilla, and J. Miret, "A wireless controller to enhance dynamic performance of parallel inverters in distributed generation systems" It was observed that PV inverters under certain circumstances switched off undesirably or exceeded harmonic regulations. As a result there was more attention required on power quality standards at PCC, though all PV inverters individually satisfy their standards. For that purpose analysis on PV inverters, distributed network, and simulation study was required.

So author had analyzed the observed phenomena of harmonic interference of large populations of these inverters and to compare the network interaction of different inverter topologies and control options. In order to improve the inverter PQ characteristics in a network in the inverter design, the author concluded that, parallel and series resonance phenomenon between the network and these inverters are responsible for higher than expected current and voltage distortion levels in DP networks.

P. Rodríguez, J. Pou, J. Bergas, J. I. Candela, R. P. Burgos, and D.Boroyevich, "Decoupled double synchronous reference frame PLL for power converters control," IEEE Trans. Power Electron. This paper deals with a crucial aspect in the control of grid connected power converters, i.e., the detection of the fundamental-frequency positive sequence component of the utility voltage under unbalanced and distorted conditions. Specifically, it proposes a positive-sequence detector based on a new decoupled double synchronous reference frame phase-locked loop (DDSRF–PLL), which completely eliminates the detection errors of conventional synchronous reference frame PLL's (SRF–PLL). This is achieved by transforming both positive- and negative-sequence components of the utility voltage into the double SRF, from which a decoupling network is developed in order to cleanly extract and separate the positive- and negative-sequence components. The resultant DDSRF–PLL conducts then to a fast, precise, and robust

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positive-sequence voltage detection even under unbalanced and distorted grid conditions. The paper presents a detailed description and derivation of the proposed detection method, together with an extensive evaluation using simulation and experimental results from a digital signal processor-based laboratory prototype in order to verify andvalidate the excellent performance achieved by the DDSRF–PLL.

III. PROPOSED SYSTEM DISCRIPTION

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 the renewable energy source to the grid and delivers the generated power. The RES may be a DC source or an AC source with rectifier coupled to dc-link.

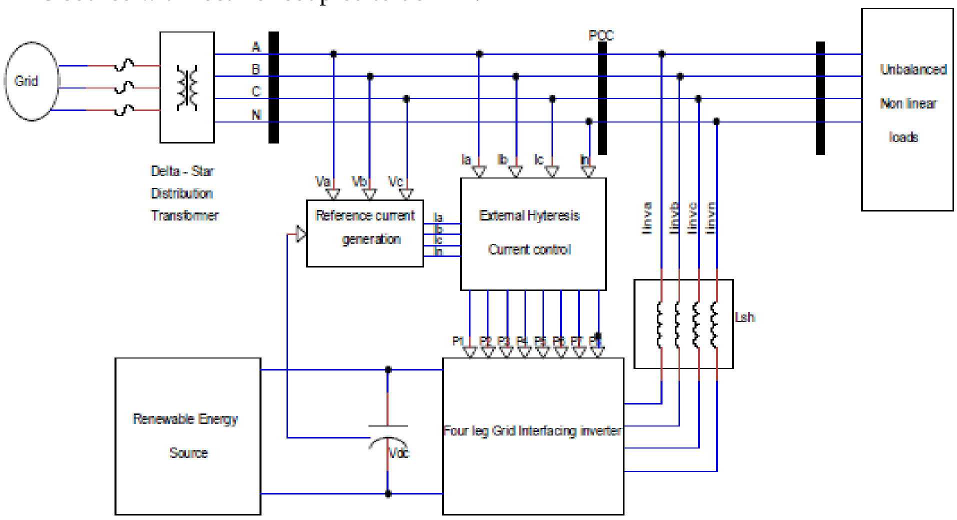

Fig.1. Schematic of proposed renewable based distributed generation system.

Generally, the power circuit of shunt APF consists of a three phase Voltage Source PWM Inverter (VSI) using IGBTs coupled at the Point of Common Coupling (PCC) via coupling inductance. 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.

A voltage source converter (VSC) is a power electronic device that connected in shunt or parallel to system. It can generate a sinusoidal voltage with any required magnitude, frequency and phase angle. It also convert the dc voltage across storage devices into a set of three phase ac output voltage. It is also capable to generate or absorb reactive power. If the output voltage of the VSC is greater than ac bus terminal voltages, is said to be in capacitive mode. So, it will compensate reactive power through ac system. The type of power switch used is an IGBT. Three phase four leg VSI is modelled in Simulink by using IGBT.

IV. CONTROL STRATEGY

The main aim of proposed approach is to inject the power from RES and also to make the voltage source inverter to function as an APF. There are many control approaches available for the generation of reference source currents for the control of VSI system in the literature. The block diagram of the control scheme is shown in Fig. 2. 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. 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.

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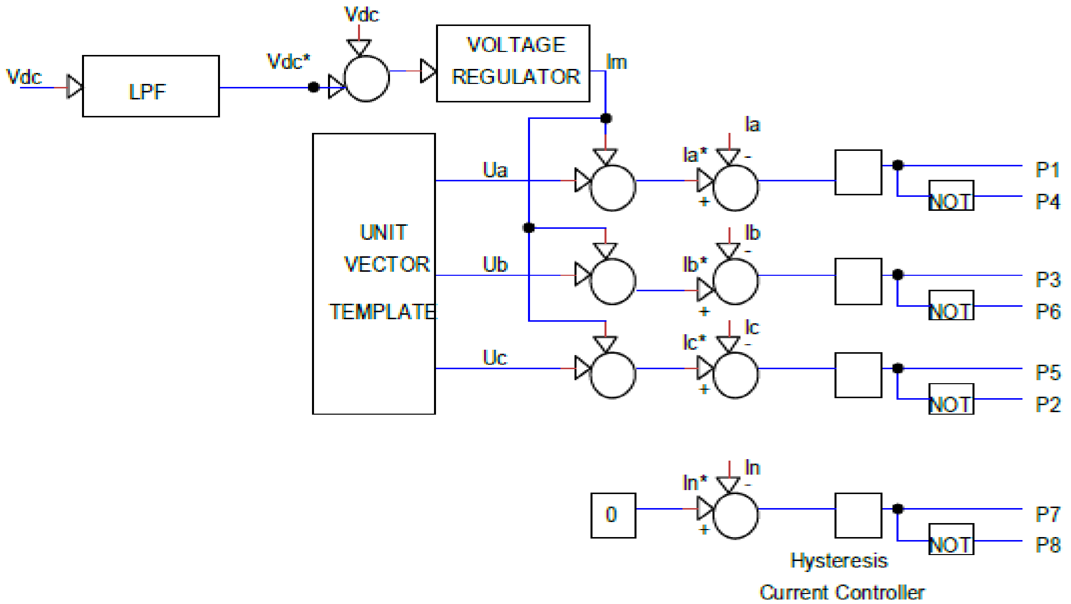

Fig.2. Block diagram representation of grid-interfacing inverter control.

A. DC-Link Voltage and Power Control Operation

Due to the intermittent nature of RES, the generated power is of variable nature. The dc-link plays an important role in transferring this

power from renewable energy source to the grid. RES are represented as current sources connected to the dc-link of a grid- interfacing inverter.

The current injected by renewable into dc-link at voltage level Vdc can be given as

$$I_{dc}=P_{RES}/V_{dc} \quad (1)$$

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.

$$V_{dcerr} = V_{dc}^{*} - V_{dc} \quad (2)$$

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

B. Current Control of VSI

$$U_a = \mathrm{Sin}\theta \quad (3)$$

$$U_b=\sin\theta(\theta-2\Pi/3) \quad (4)$$

$$U_c=\sin\theta(\theta+2\Pi/3) \quad (5)$$

The multiplication of current Im 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

$$I_a^{*} = I_m.U_a \quad (6)$$

$$I_b^{*} = I_m.U_b \quad (7)$$

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$$I_c^* = I_m.U_c \qquad (8)$$

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

$$I_n^* = 0$$

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

$$I_{aerr} = I_a^* - I_a \qquad (9)$$

$$I_{berr} = I_b^* - I_b \qquad (10)$$

$$I_{cerr} = I_c^* - I_c \qquad (11)$$

$$I_{nerr} = I_n^* - I_n \qquad (12)$$

C. Switching Control of IGBTs

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 .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 S_1 will be ON in the phase a leg of inverter.

If (I_a^* - I_a) = -hb then the lower switch S_4 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.

V. SYSTEM PARAMETERS

To verify the proposed control approach to achieve the multi function of four leg inverter simulation study is carried out using MATLAB/Simulink. The System Parameter is given in Table I shown. The performance of the proposed control approach is validated with the help of MATLAB simulation parameters as given in Table I. The RES is emulated using an auxiliary controlled converter, which injects varying active power at the dc-link of an insulated gate bipolar transistor (IGBT) based 4-leg voltage source inverter connected to grid. A 3-phase 4-wire nonlinear load, composed of 3-phase non-linear balanced load, 1-phase R-L load between phase and neutral and 1-phase non-linear load between phase and neutral, is connected to the grid.

Table I: System Parameter

3 phase supply	**30V,50Hz**
3 phase non-linear load	R=26.6Ω,L=10mH
1 phase linear load	R=36.6Ω,L=10mH
1 phase non-linear load	R=26.6Ω,L=10mH
DC-link Capacitance and Voltage	C=3000µF,90V
Coupling Inductance	2Mh

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VI. FUTURE STUDY

While considering system parameter as mentioned in above table I the total harmonics distortions (THDs) of phase and load currents are more. FFT analysis is utilized to generate the reference grid current signals in real-time. The proposed control approach requires a sampling time of 75 s to execute MATLAB/Simulink generated output. It will give the highly unbalanced load currents and after compensation, appear as pure sinusoidal balanced set of currents on grid side by using four leg VSI.

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