Power Conditioning in Four-Wire Distribution System for High Level Cascaded Multi-Level Inverter with Solar Photovoltaic Array

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ABSTRACT--This paper presents a photovoltaic (PV) array based cascaded H-bridge multilevel inverter (CHBMLI) working active power filter as a shunt for four wire distribution system. This system is used for the power adjustments of distribution network as it is made of linear, nonlinear and unbalanced loads. Solar Photovoltaic formed isolated source for CHBMLI. This active filter reduces line harmonics, reduce neutral wire current around to zero and it also introduce real power as per requirement of the system. The grid interface and required reference signal generation is convey with the help of Instantaneous power theory. The simulation studies are conveyed in MATLAB Simulink environment.

Keywords: — Photovoltaic array, Cascaded H-bridge multilevel inverter (CHBMLI), Nonlinear and Unbalanced load, Harmonics compensation, Active and Reactive power.

I. INTRODUCTION

Currently with the evolution of Power electronics, different non linear loads like switched mode power supply, uninterruptable (interminable) power supply; speed control drives etc. are used tremendously. These loads introduce current harmonics in power lines [1]. These current harmonics causes low power factor of the line, high voltages or current due to resonance and also affects the operation of the equipment operating simultaneously with the nonlinear load To overcome this problem and to use renewable energy sources like solar power, shunt connected inverter with solar PV module is an assured solution. LC tuned shunt connected passive filter and high pass filter were used in power line to enhance the power factor of the line as well as to reduce current harmonics. But shunt passive filter has some disadvantages as described by Akagi [3]. Hence shunt active filter may be an alternative solution. So many methods have been discovered [2] for shunt active filter but in this paper Instantaneous power theory [6] has been taken. The Basic principle of active power filter is proposed in[4].In [5] a new concept of instantaneous reactive power (p-q) theory was introduced. This p-q theory was only made for three phase balanced system without neutral wire. System with neutral wire and zero sequence power was introduced [5]. Nothing is said in those references about the contribution of zero sequence power to the real and imaginary powers of the line. The zero sequence power is introduced as the real power to each phase [11].Here an inverter is connected in shunt with a four wire distribution system to compensate the current harmonics. Insulated Gate Bipolar Transistor (IGBT) switches are used in this inverter. It will supply harmonic components as well as reactive power components in the distribution system in steady state and transient state as well. The inverter used here is a seven-

Level Cascaded Multilevel Inverter as a shunt device for controlling the current. Three H-bridges are connected in cascade formation in each phase. Each H -bridge is supplied isolated solar PV array.

II. PROJECT SPECIFICATIONS & MODELS

1. Photovoltaic Module & Characteristics

Solar cell is the basic unit of a solar pv module. Solar modules are made by assembling the several solar cells. The photovoltaic module is shown in figure 1. This is a combination of number of solar panels which are made of solar cells. The ebullient circuit of photovoltaic module is show in figure 2.

A Current source in parallel with a diode will form an ideal solar cell, but there are no ideal solar cells. To reduce the internal and lead connection loss shunt and series resistances are introduced. The solar cell characteristic equation is give in equation (1).

As shown in the Figure2. I is photocurrent; I_0 is diode saturation current; q is coulomb constant (1.602×10^{-19}C); K *is* Boltzmann's constant (1.381×10^{-23} J/K): T is cell temperature in K; α is P-N junction ideality factor; R_s and R_{sh} are the intrinsic series and shunt resistances of the cell, respectively. R_{sh} is very large for all practical purpose hence the last term is ignored.

Hence short circuit current and open circuit voltage are I_{sc} &V_{oc} respectively in equations (2) & (3) The varying irradiance and temperature effects on solar PV modules is discussed [9].Simulation studies are discussed in reference [8]. The power is increased with increasing irradiance the current and generated voltage is increased with constant temperature. Current and developing power with voltage is shown in figure 3. The generated voltage is decreases with increase in current with increased temperature and constant irradiance and it is shown in figure 4.

1. Proposed Active Power Filter Topology

High level cascaded multi-level inverter is connected in shunt with grid to eliminate the current harmonics[10]. Solar photovoltaic panels will supply dc to the inverter. This inverter is formed by connecting 3 H bridge inverters in cascaded manner. 36 IGBT switches are used in this inverter. A coupling inductor and a small resistance are connected t the grid at common coupling point at inverter terminal. Schematic diagram of proposed topology is shown in figure 5.

The load draws current which is non-linear in nature because here the load is itself a non-linear load. By applying Kirchhoff's law after compensation at common coupling point $\boldsymbol{i_s = i_l - i_c}$ source voltage is given by $\boldsymbol{v_s = v_m \sin\omega t}$ As the load current is non-linear it can be expressed in Fourier trigonometric series,

$$i_l = I_0 + \sum_{n=1}^{\infty} I_n \sin(n\omega t + \theta_n)$$

Where I_0 is the dc component of load and n is the order of harmonics. Now the inverter will decrease the neutral current to zero and supply this harmonic current and also compensate the dc current.

The references signals for three phases are generated and are compared with multiple phase shifted carrier signals pulses are generated to trigger 36 IGBT switches. To generate the pulses phase shifted multi carrier PWM is used. For x level (x-1) carrier signals are used for each phase and the phase shift is 360/(x-1).

III. Simulation Results

The simulation process has been carried out in MATLAB Simulink environment. The amount of harmonic current at the point of common coupling drawn by the non-linear load is supplied to the inverter which is in shunt. Here the load is a non-linear load. The parameters used are given in the Table (1).

Before Compensation

Before compensation the value of source current is 120Amp and it is non-sinusoidal in nature, and also contains harmonics in it. The source current and the FFT analysis is shown in figure 6 and figure 7. The neutral current without compensation is shown in Figure 8.

After Compensation

The source current has less harmonics after compensation. Here the inverter will act as filter and it will mitigate the harmonics i source current and reduce the neutral current to zero. Source current and voltages and FFT analysis of high level inverter (7 level inverter) are show in figure 9 to figure 12.

IV. Indentations and Equations

$$I = I_L - I_0 * \left[e^{\left(\frac{q(v+IR_S)}{\alpha KT}\right)} - 1 \right] - \frac{V+IR_S}{R_{sh}} \quad (1)$$

$$I_{SC} = I_L \quad (2)$$

$$V_{OC} = \frac{\alpha KT}{q} \ln\left(\frac{I_L}{I_0} + 1\right) \quad (3)$$

V. Figures and Tables

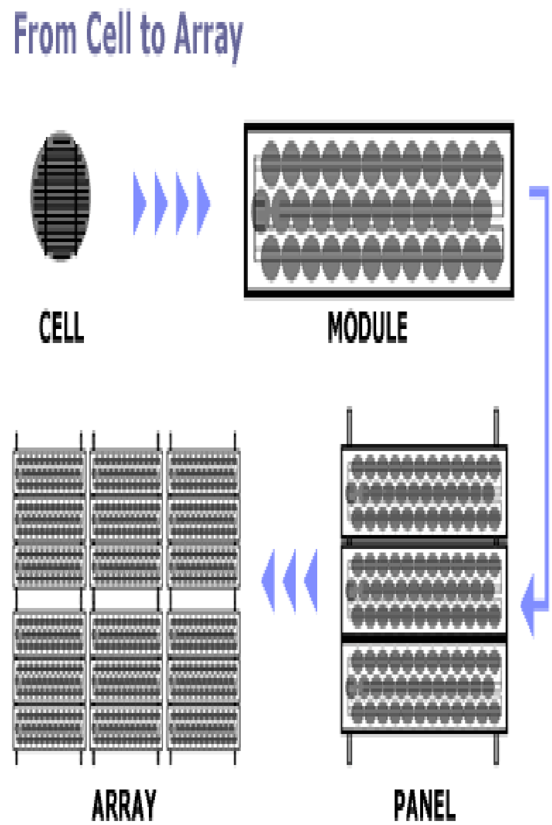

Figure 1: PV System

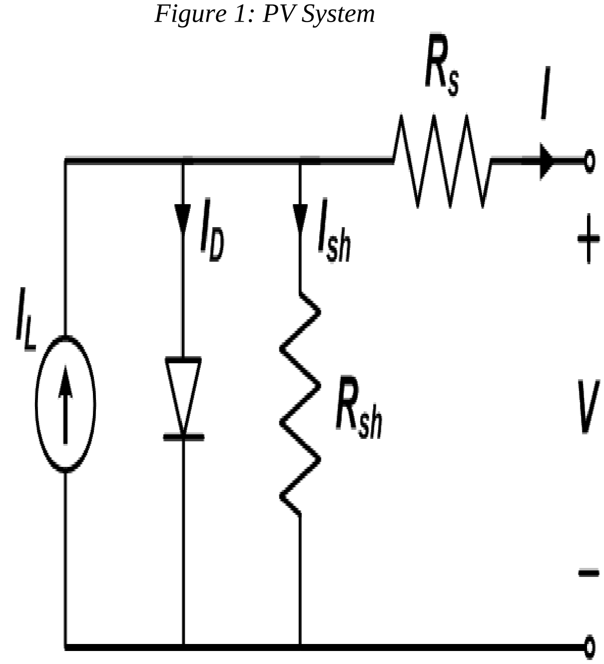

Figure 2: Equivalent Circuit of solar cell

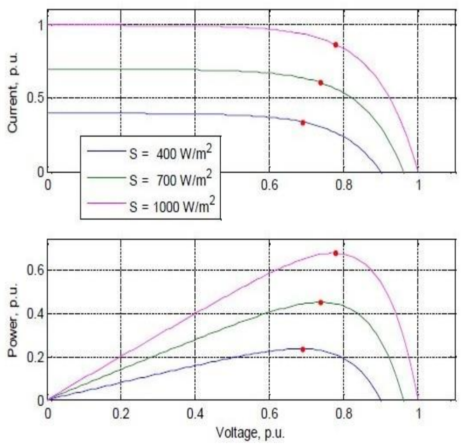

Figure 3: Solar cell characteristics with variable irradiance and constant temperature

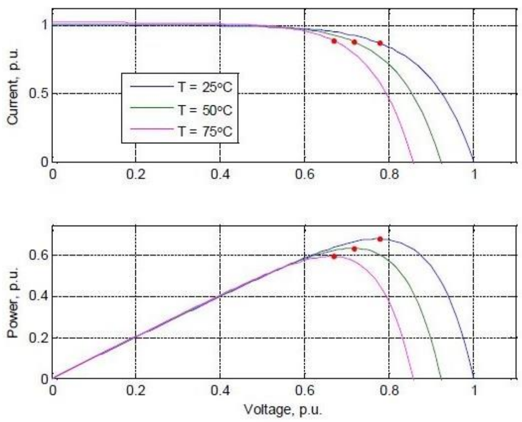

Figure 4: Solar cell characteristics with variable temperature and constant irradiance

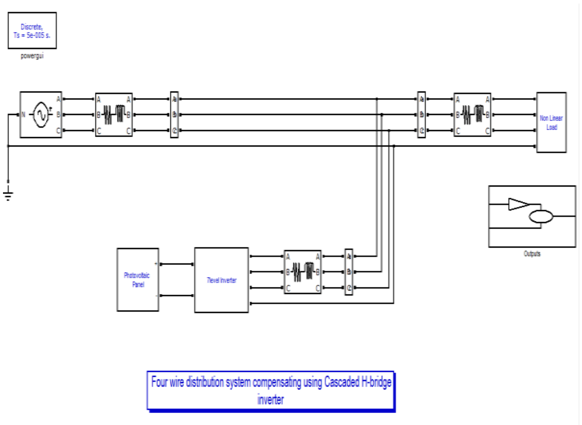

Figure 5: Photovoltaic array supported multilevel inverter for shunt active filtering in four wire distribution system

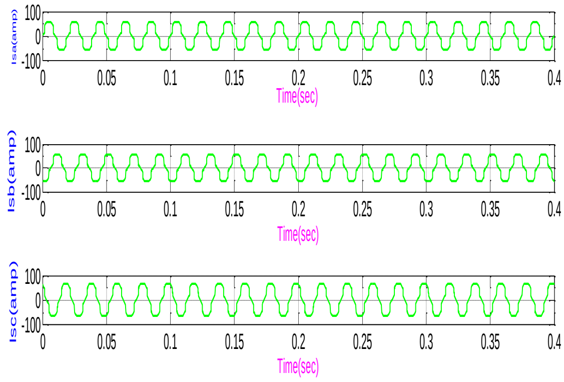

Figure 6: Source current before compensation

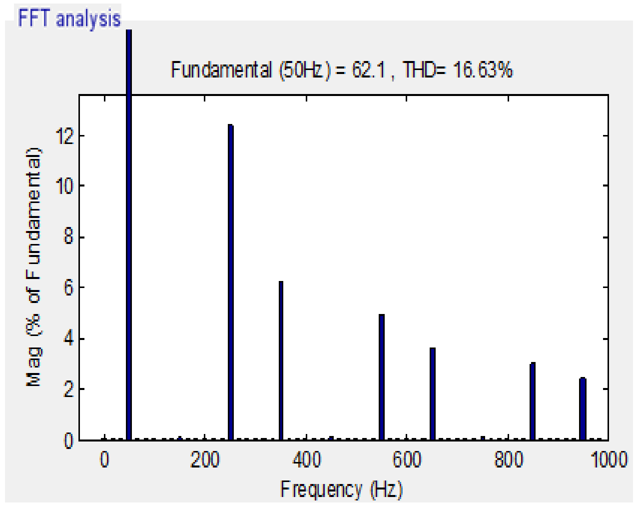

Figure 7: FFT analysis of source current before compensation (16.63%)

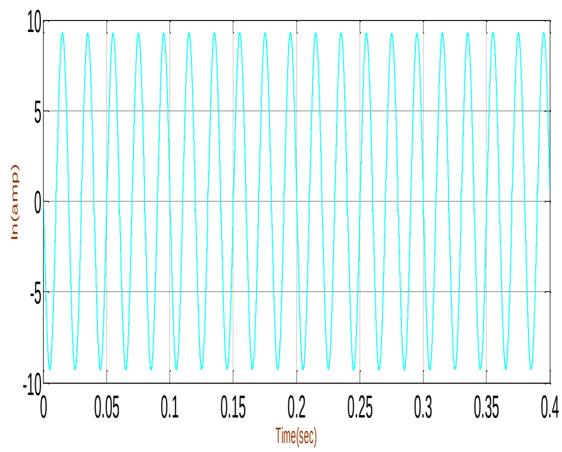

Figure 8: Neutral current without compensation

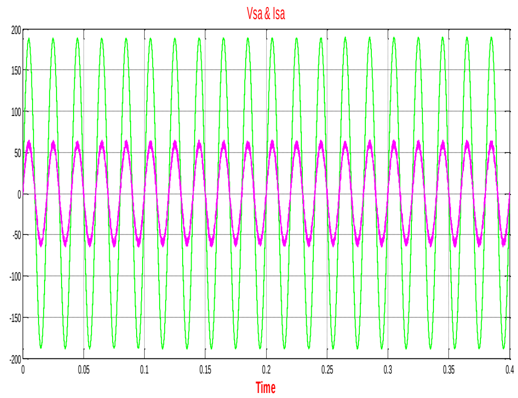

Figure 9"Source current and voltage after compensation using high(7)level cascaded H-bridge inverter

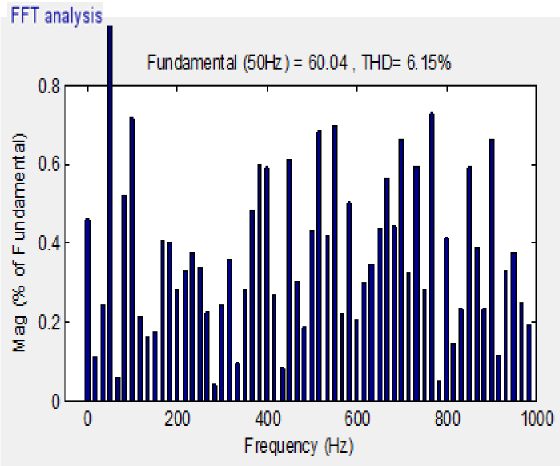

Figure 10 : FFT of source current after compensating using high(7) level cascaded H-bridge inverter (6.15%)

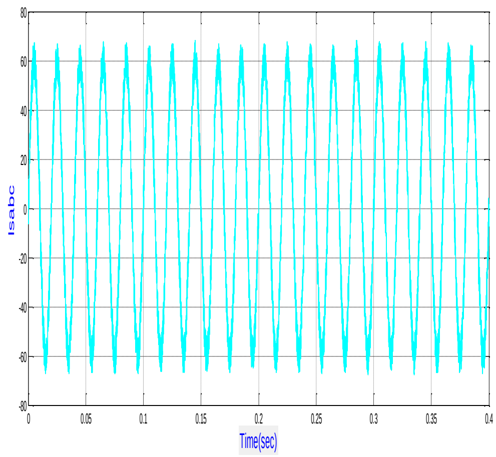

Figure 11: Neutral current after compensating using high (7) level Cascaded H-bridge inverter

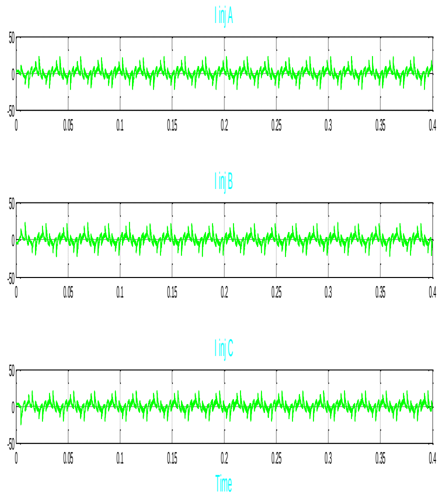

Figure 12:Compensating current injected by high(7) level cascaded H-bridge inverter

Table 1. Parameters Used For Simulation

Parameters	Numerical Values
Source Voltsge per phase	230 Volts
System Frequency	50 Hz
Source Resistance(R_s) per phase	0.001 Ohms
Source Inductance(I_s) per phase	0.01 µH
Line Resistance(R_{line}) per phase	0.002 Ohms
Line Inductance(L_{line}) per phase	2 µH
Coupling Resistance(R_c) per phase	5 Ohms
Coupling Inductance(L_c) per phase	2 mH
DC side capacitance C_{dc}	1000 µF
1. Nonlinear load: i.3-ph full rectifier load(R_l) ii.1-ph full bridge rectifier with neutral as return path (R_l&L_l)	10 Ohms 20 Ohms, 5
2. Unbalanced Load	10 Ohms, 7, Ohms, 5 Ohms

V. Conclusion

For current control in electrical system cascaded multilevel inverters are well suited. Here photovoltaic array based high (7 level) level multi level inverter using instantaneous power theory for current control in grid connected system is explained. The high (7 level) multilevel inverter is in shunt and acts as active power filter, thus reduces the THD level of source current and increases the efficiency of the whole system. By using the PV panels in the system whenever there is a excess demand of active power is supplied to the line. The complexity and the cost is high.

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