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Modeling and Simulation of Grid Current Controller for Grid Connected Distributed System under Nonlinear Loads and Voltage Distortion

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ABSTRACT

Distributed generation is a path that employs small scale technologies to produce electricity close to the end users power. The main purpose of DG is to transmit a high quality grid current into the utility grid with the minimum total harmonic distortion of the grid current at 5%, as recommended in the IEEE 1547 standard. To produce the high quality grid current various current control strategies has been developed like hysteresis, predictive, proportional-integral (PI), proportional resonant (PR) controller. Whenever the nonlinear loads are connected to DG causes the bad impact on the grid current quality. To overcome this limitation can be developed advanced current control strategy for grid connected DG which can eliminate the effect of nonlinear load and voltage distortion. Current controller is designed using in d-q reference frame. In this paper enhanced a grid current compensator for grid connected photovoltaic under nonlinear load and voltage distortion. An advanced current control strategy for grid connected operation of distributed generation, which supports the DG to transfer a sinusoidal current into the utility grid despite the distorted grid voltage and nonlinear local load, as well as unbalanced condition.

Keywords: Distributed generation, grid connected inverter, harmonic compensation, nonlinear load, self tuning PID controller

I.INTRODUCTION

The main source of current harmonics is nonlinear load which mostly used in system. In addition, most of these loads impose varying reactive-power demands that have to be compensated in order to improve the power factor (PF) and efficiently deliver the active power to the loads. This results in harmonic distortion-related problems, reducing the quality of the electrical power and the performance of the power system. The operation of these devices may, therefore, prove to be very problematic. Distributed energy resource (DER) systems are small-scale power generation technologies used to provide an alternative to or an enhancement of the traditional electric power system. The usual problems with distributed generators are their high costs. A large number of grid connected PV connected to a distribution network through PV inverters are potentially able to cause harmonic problems. Harmonic problem can be defined as a particular disturbance, which is created by the presence of non-linear components in the electrical system that determines a permanent modification of the

voltage and current sinusoidal wave shapes in terms of sinusoidal components at a frequency different from the fundamental

In a grid-interconnected photovoltaic power system, the direct current (DC) output power of the photovoltaic array should be converted into the alternating current (AC) power of the utility power system. Under this condition, an inverter to convert DC power into AC power is required.

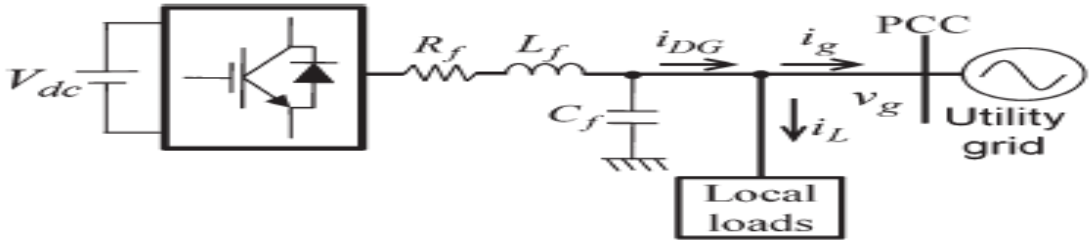

Fig.1 System configuration of a grid-connected DG system with local load.

Local load of the DG also causes a negative impact on the grid current quality. To overcome the limitation of this this paper proposes the new current control strategy for grid connected PV.

A. System configuration and analysis of grid Voltage distortion and nonlinear local load

Fig.1 shows the proposed circuit configuration. In this system consist of DG voltage source, voltage source inverter, output RLC filter, nonlinear local load and the utility grid. The main objective of system is to supply power to its local load and transfer remaining power to the utility grid at the point of common coupling. The current from DG transfer to grid should be balanced and sinusoidal and have a low THD value. Because of the distorted grid voltage and unbalanced nonlinear load that typically exist in the power system it's difficult to satisfy these requirement.

II -PROPOSED SYSTEM

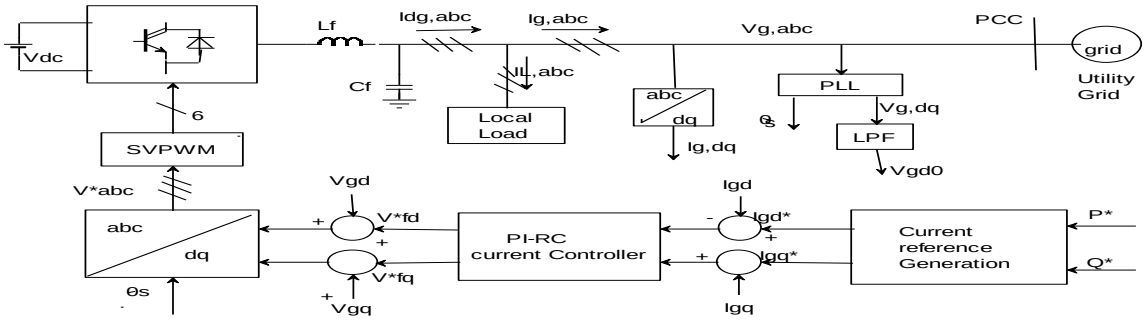

Fig.2 Overall block diagram of the proposed control strategy.

In order to transfer sinusoidal grid current ig into the grid, DG current should include the harmonic components that can compensate the load current harmonics. Therefore, it is important to design an effective and low-cost current controller that can generate the specific harmonic components to compensate the grid current harmonics. Generally, traditional current controllers, such as the PI or PR controllers, cannot realize this demand because they lack the capability to regulate harmonic components. So we designed the proposed current controller in d-q reference frame.

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Fig 2 shows the proposed control strategy proposed control strategy is the combination of Current reference generation, Phased locked loop, and Current controller. Constant DC Voltage fed to inverter that can convert the DC to AC,Converted AC are not purely sinusoidal that DG current passes through LC filter which eliminate the harmonic part come form DG.afterthat current passes to local load,that may be balanced linear nonlinear or unbalanced load.abc and dq0 transformation are used to convert the three phase component to two phase component that help in controlling process. Phase Locked loop are used to detect the grid frequency variation.

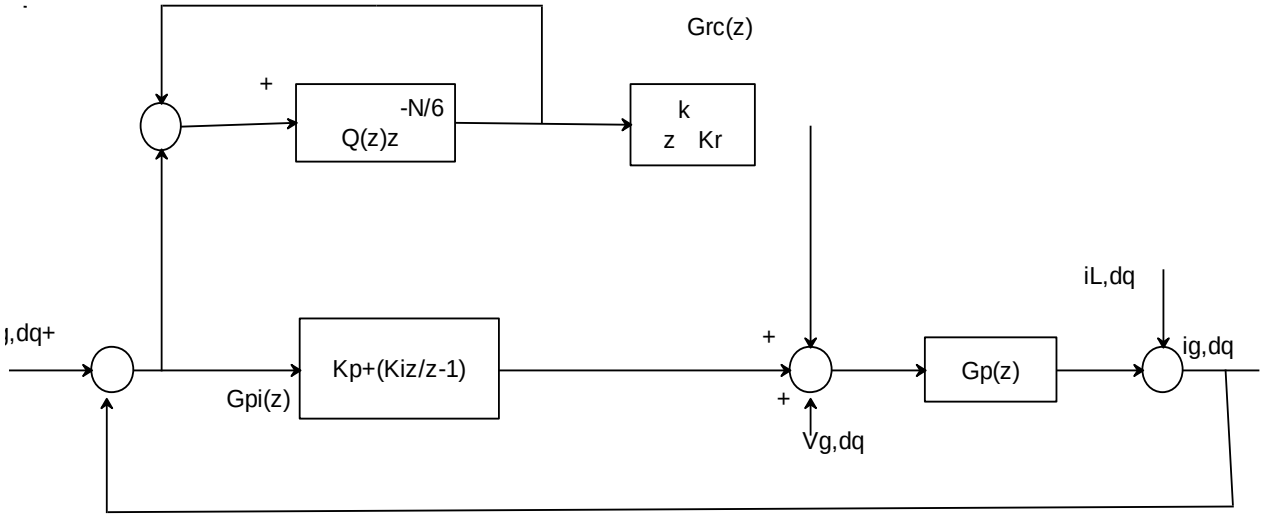

Fig.3. Block diagram of the current controller

To enhance grid current quality, an advanced current control strategy, as shown in Fig. 2, is introduced. Although there are several approaches to avoid the grid voltage sensors and a phase-locked loop (PLL), Fig. 3 contains the grid voltage sensor and a PLL for simple and effective implementing of the proposed algorithm, which is developed in the d–q reference frame. The phase locked loop, current reference generation, and current controller are three main blocks in proposed control stratergy.That strategy operates without the local load current measurement and harmonic voltage analysis on the grid voltage. It can simultaneously adjusting nonlinear local load and distorted grid voltage on the grid current quality.

A. Current Reference Generation

In fig.2 Current reference of current controller can be generated in the d-q reference frame based on the desired power and grid voltage.

$$i_{gd}^{*} = \frac{2}{3}\frac{P^{*}}{v_{gd}}$$

$$i_{gq}^{*} = -\frac{2}{3}\frac{Q^{*}}{v_{gd}} \qquad (1)$$

Where $P*$ and $Q*$ are the reference active and reactive power, respectively; *Vgd* represents the instantaneous grid voltage in the *d–q* frame; and $i*gd$ and $i*gq$ denote the direct and quadrature components of the grid current, respectively.

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Under ideal conditions, the magnitude of *Vgd* has a constant value in the *d–q* reference frame because the grid voltage is pure sinusoidal. However, if the grid voltage is distorted, the magnitude of *Vgd* no longer can be a constant value. As a consequence, reference current $i*gd$ and $i*gq$ cannot be constant in (1). To overcome this problem, a low-pass filter (LPF) is used to obtain the average value of *Vgd*, and the *d–q* reference currents are modified as follows:

$$i_{gd}^{*} = \frac{2}{3}\frac{P^{*}}{V_{gd0}}$$

$$i_{gq}^{*} = -\frac{2}{3}\frac{Q^{*}}{V_{gdo}} \qquad (2)$$

B.Current Controller

Proposed current controller is design using a PI and RC in the d-q reference frame. The block diagram of current controller is shown in fig 3.The open loop transfer function of the PI-RC in a discrete time domain is respectively in

$$G_{PI}(z) = K_p + \frac{K_i z}{z-1} \qquad (3)$$

$$G_{RC}(z) = \frac{K_r z^{k} z^{-\frac{N}{6}}}{1-Q(z)z^{-\frac{N}{6}}} \qquad (4)$$

Where,

Kp=Proportional Gain and

Ki =Integral Gain of PI Controller

Z−N/6 = Time delay unit,

zk=phase lead term,

Q(z) = filter transfer function,

Kr= RC gain.

The RC is used to eliminate the harmonic components in the grid current caused by the unbalanced nonlinear local load and/or distorted grid voltage. Meanwhile, the role of the PI controller is to enhance the dynamic response of the grid current and to stabilize the whole control system.

In this paper, the proposed current controller is basically designed to compensate both the current harmonic and the grid frequency variation, simultaneously. When the grid frequency varies, the grid frequency (*fs*) is quickly detected by the PLL,and the frequency variation is compensated directly by adjusting the number of delay samples, i.e., *N*/6 = *f*sample/(6*fs*), inside the RC in Fig. 3

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C.Parameters Specification

Parameter	Values
Grid Voltage	110V (rms)
Grid frequency(fs)	50Hz
Rated output power	5Kw
DC-Link voltage (Vdc)	350V
Sampling Frequency	9kHz
Output filter resistance	30Ω
Output Filter Capacitance	27μF
Output Filter Inductance	0.7mH
Three phase diode rectifier	R=30Ω C=2200μF
Phase lead term (z^k)	3
Three phase linear load	R=30Ω

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Table I

IV-SIMULATION MODEL AND RESULT

Simulation done in MALAB software to verify the effectiveness of the proposed control Method. System parameter given in Table 1.We can done the simulation for the grid voltage distortion and nonlinear unbalanced

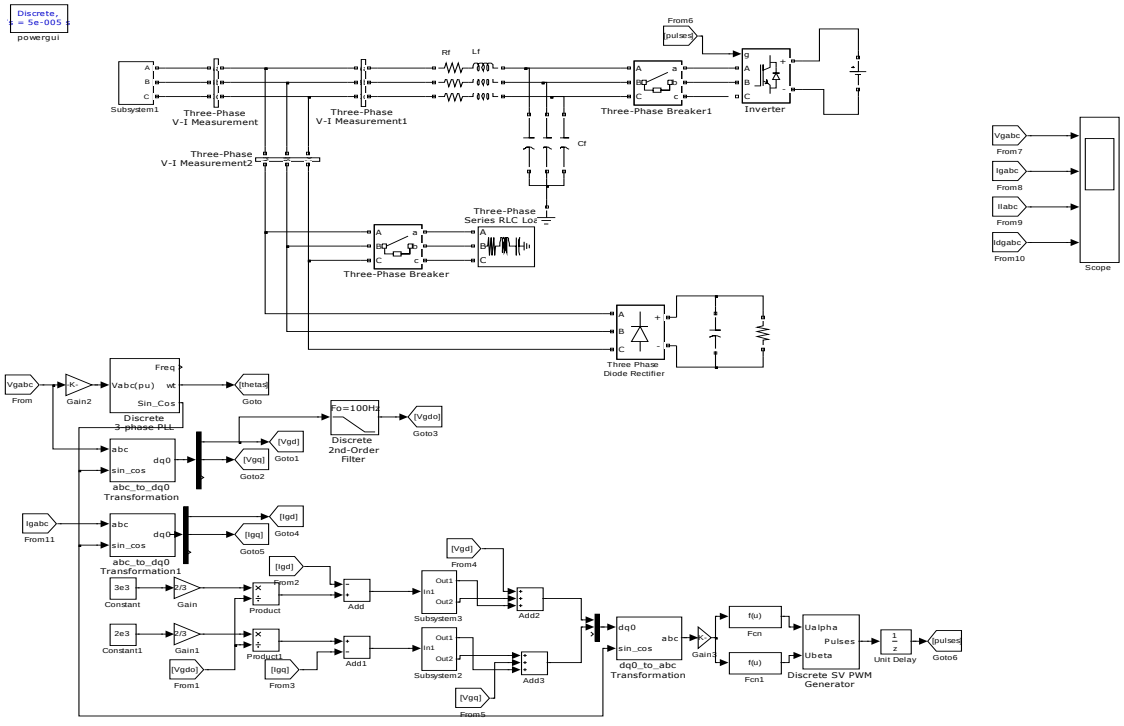

Fig 4. Simulation when grid voltage is distorted and unbalanced nonlinear load are conneted

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Three phase programmable voltage source are used as the grid where we can apply the voltage is 110V connected with the three phase line with photovoltaic source as distributed generation PV cell are connected with DC source and universal bridge to forming a distributed generation. Low pass filter are used to filter out the current and voltage harmonic in the circuit as well as it give the average value of Vd0. Diode rectifier used as nonlinear load. Current passes through load is measured by voltage measurement parameter $i_{L.}$.To eliminate the effect of nonlinear load current controller are designed that is proportional –integral proportional-resonant controllers are designed.

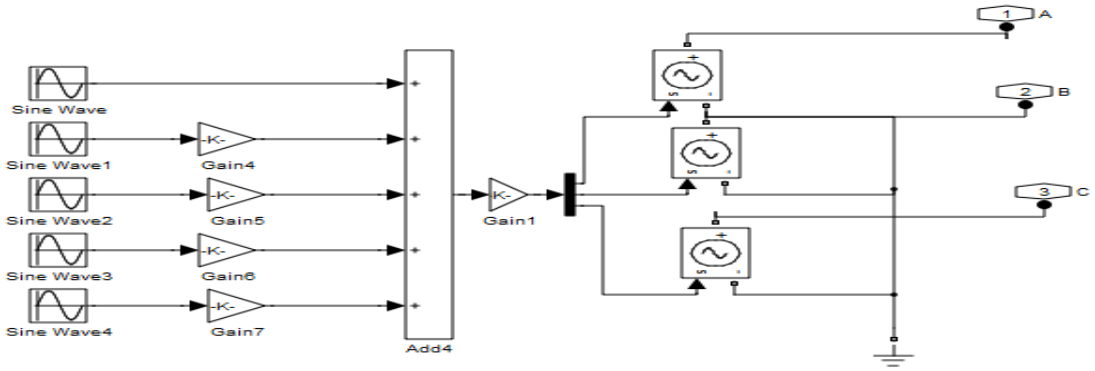

Fig 5.Subsystem block for provide grid voltage distortion

To eliminate the effect of nonlinear load and voltage distortion we designed the proposed current controller. Fig 5.3.is the subsystem block are connected to the three phase line as a programmable voltage source, where the five sine wave block are connected to the adder with Gains that give the result distorted grid voltage at the end

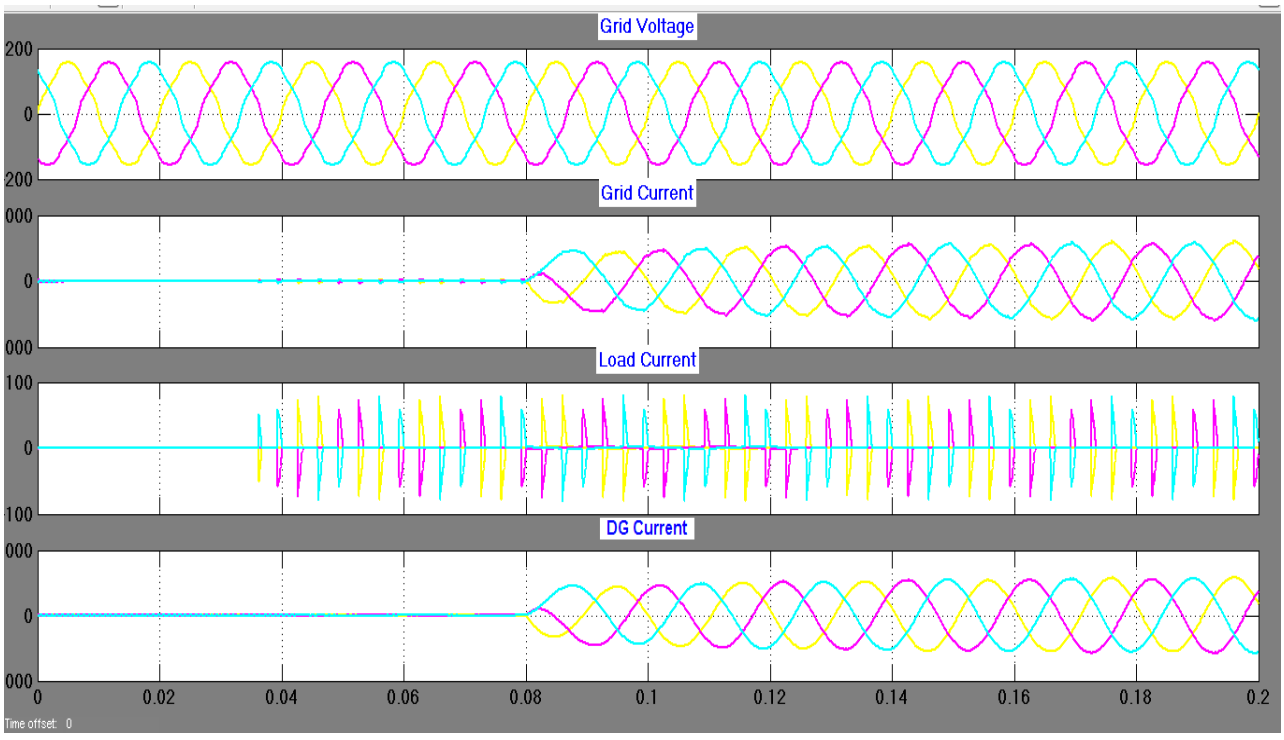

Fig 6. Simulation result of grid voltage distortion and unbalanced nonlinear load condition

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XII. DISCUSSIONS

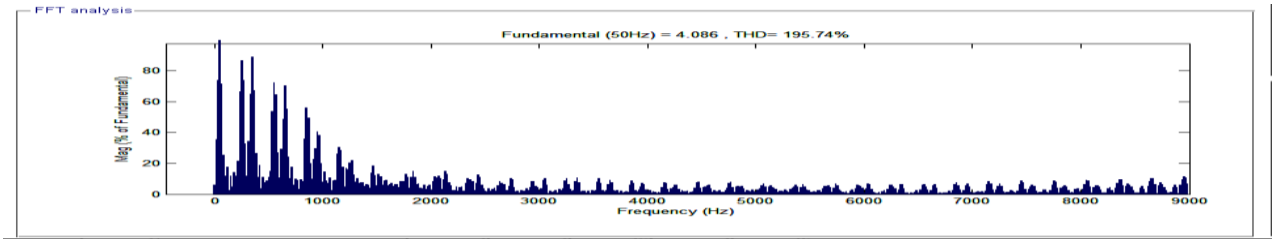
Simulation work carried out in MATLAB assuming grid voltage as distorted and unbalanced nonlinear load .This case provide the distorted grid voltage is given with the harmonic components 3.5% .In this simulation works used the constant voltage as a input connected to grid, and developed current compensator for grid connected DG when the grid voltage distortion present and unbalanced nonlinear load condition. Three phase breaker are connected before inverter which helps to see result before controller and after controller.

TABLE 2: Summary of THD value of grid current before controller and after controller

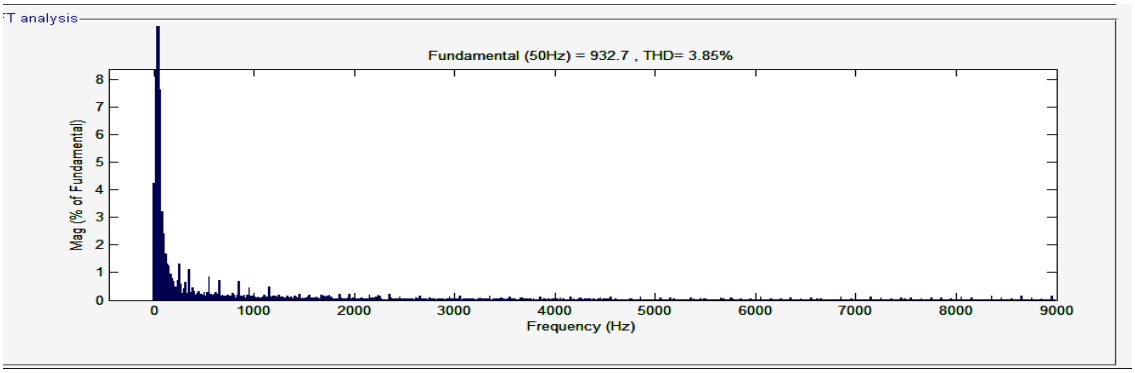
	Before current Controller	**After PI-RC current Controller**
THD of I_g	195.74%	3.85%

FFT Analysis

Before Controller



With PIRC Controller



V.CONCLUSION

This paper work studied the performance of grid connected system under different load condition. When the grid connected under different load condition and also providing the disturbance in voltage the current and voltage harmonic are present in the system. To eliminate or reduced the effect of that harmonic this studied is done. In that case we compare without controller and proposed control strategy. Simulation result of proposed current controller is better than previous one. It can be easily integrated with convectional control scheme. PI-RC current controller can reduced the number of sensor used and maintains the better quality of grid current under frequency variation as well as voltage disturbance.

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