# MODELING AND DESIGN OF SINGLE PHASE PV INVERTER FOR HARMONIC MITIGATION

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**ABSTRACT**

*Here in this paper a simple single phase grid connected photovoltaic (PV) inverter topology contains of a boost switch a single phase low voltage inverter with a filter of an inductive, this control approach will not provide any lower order harmonics into the grid due to high frequency pulse width modulation control scheme. Even though the non-ideal factors in the system such as core saturation induced distorted magnetizing current of the transformer and the dead time of the inverter, etc., donate to a substantial amount of lower order harmonics in the grid existing. A new design of inverter current control that reduces lower order harmonics is examined here in this paper. An adaptive harmonic compensation control scheme and its design are recommended for the lower harmonic compensation. Moreover a sinusoidal pulse width modulation controller and its design are also suggested. This controller mitigates the dc component in the control system, which presents even harmonics in the grid current in the design considered. The dynamics of the system due to the communication between the controller compensation strategy is also examined. The main control strategy has been validated with experimental results and good agreement with theoretical analysis of the overall system is observed.*

***Keywords: Adaptive Filter, Harmonic Distortion, Inverters, Solar Energy.***

## I. INTRODUCTION

Renewable sources of energy such as solar energy, wind energy, and geothermal energy have gained popularity due to the depletion of traditional energy sources. Hence number of distributed generation (DG) system making use of the renewable energy sources are being designed and connected to a grid. The design of the solar inverter system is simple, which consists of the following three power circuit steps.

1) A boost converter level to perform maximum power point tracking (MPPT).
2) A low voltage single phase H bridge inverter.
3) A filter of an inductive and a step-up transformer for interfacing with the grid.

Fig. 1 illustrates the power circuit topology considered. This design scheme has been chosen due to following benefits. The switches are all rated for low voltage which reduces the cost and lesser component count in the system develops the overall reliability. This design will be good choice for low rated PV inverters of rating less than a kilowatt. The problem would be the comparatively big size of the interface transformer compared to schemes with a high frequency link transformer. In the ideal case will not have any lower order harmonics which is illustrated in Fig.1 Even though the following factors results in lower order harmonics in the system. The distorted magnetizing current drawn by the transformer core, the dead time bring together between switching of devices of the same leg, voltage reduced on the power electronic devices, and the distortion of the grid voltage itself. It is significant to attenuate these harmonics in order for the PV inverter to meet ratings. Here, this paper focuses on the design of the inverter current control to accomplish a good attenuation of the harmonics of lower order. It must be noted that variation of the lower order harmonics using a larger output filter inductance is not a good option as it upturns losses in the system along with a larger fundamental voltage drop and with a higher cost. The boost stage and the MPPT control strategy are not talk over in this paper as a number of methods are available in the literature to accomplish a very good MPPT. There has been extensive research work done in the area of harmonic mitigation using specialized control scheme. In, multi resonant controller-based methods are utilized for selective low-voltage inverter with 40V dc bus connected to 230V grid using a step-up transformer harmonic elimination

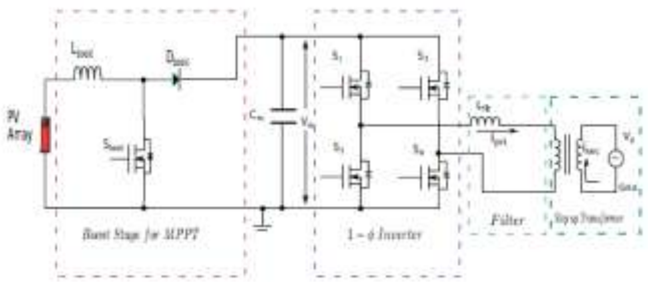

**Fig.1. Power Circuit Topology of the 1 − $\Phi$ PV System**

## II. EXISTED SYSTEM

The benefit of these methods is the easiness in implementation of the resonant blocks. Though, Discretization and variations in grid frequency affect the performance of these controllers and making them frequency adaptive growths overall complexity. Also, as specified in, the phase margin of the system becomes small with multi resonant controllers and added compensation is needed for acceptable operation. The analysis considers the usage of repetitive controller-based harmonic elimination which involves complex analysis and structure as discussed. The performance of the repetitive controller is very sensitive to frequency fluctuations and requires structural change for good performance, which might affect the stability. The benefit of the adaptive filter-based method is the inherent frequency adaptability which would result in same amount of harmonic compensation even when there are shifts in grid frequency. The operation of adaptive filters is easy in design. Thus, here in this paper, an adaptive filter-based method is suggested. This method guesses a particular harmonic in the grid current using a least-mean-square (LMS) adaptive filter and produces a harmonic voltage reference utilizing a proportional controller. This voltage reference is added with appropriate polarity to the fundamental voltage reference to attenuate that particular harmonic. This paper comprises an analysis to design the value of the gain in the proportional controller to achieve a sufficient level of harmonic mitigation. The effect of this control scheme on overall system dynamics is also examined. This approach is simple for development and hence it can be implemented in a low-end digital controller. The existence of dc in the inverter terminal voltage results in a dc current flow into the transformer primary. These dc current effects in drawing of even harmonics from the grid. If the central controller utilized is a PR controller, any dc offset in a control loop will spread through the system and the inverter terminal voltage will have a nonzero average value. Thus, here in this paper, a modification to the traditional PR controller strategy is recommended. An integral block is used along with the PR controller to safeguard that there is no dc in the output current of the inverter. This would mechanically mitigate the even harmonics. This control technique scheme is named as proportional-resonant-integral (PRI) control and the design structure of the PRI controller parameters is provided. The whole control scheme is examined experimentally and the results show a good correspondence with the analysis. Experimental response also shows that the transient behavior of the system is in agreement with the theoretical estimate.

## III. ORIGIN OF LOWER ORDER HARMONICS AND FUNDAMENTAL CURRENT CONTROL

This section deliberates the origin of the lower order harmonics in the system under deliberation. The sources of these harmonics are not modeled as the method recommended attenuating those works independent of the harmonic source. The fundamental current control using the projected PRI controller is also described.

### 3.1 Origin of Lower Order Harmonics

**1) Odd Harmonics***:* The dominant causes for the lower order odd harmonics are the inaccurate magnetizing current drawn by integrated the transformer, the single phase inverter dead time, and the semiconductor device voltage fluctuations. Other reasons are the inaccurate in the grid voltage itself and the voltage ripple in the dc bus. The magnetizing current drawn by the transformer contains lower order harmonics due to the nonlinear characteristics of the *B–H* curve of the core. The exact magnitude of the harmonics drawn can be achieved theoretically if the *B–H* curve of the transformer is known. The phase angle of the harmonics due to the magnetizing current will depend on the power factor of operation of the system. As the operation will be at unity power factor (UPF), the current injected to the grid will be in phase with the voltage of the grid. Though, the current of magnetizing lags the grid voltage by $90^\circ$. Hence, the harmonic currents will have a phase displacement of either $+90^\circ$ or $-90^\circ$ depending on harmonic order.

**2) Even Harmonics***:* The topology under consideration is very delicate to the presence of dc offset in the inverter voltage of the terminal. The dc offset component can enter from a number of constraints such as varying power reference given by an effective quick MPPT control device, the offsets in the Analog to Digital converter, and the sensors. To understand how a fast MPPT presents a dc offset phenomenon, deliberate Figures. 2 and 3. In figure. 2, the duty ratio command given to the boost converter switch, $V_{pv}$ and $I_{pv}$ are the panel voltage and current, respectively, $P_{pv}$ is the panel output power, $V_g$ is the r.m.s value of the voltage of the grid, is the in-phase unit vector for the potential of the grid, and the reference to the current control loop from an MPPT control device. As the power flow reference keeps on changing due to fast MPPT action.

## IV. PROPOSED SYSTEM

### 4.1 Design Scheme of Controller Parameters

The fundamental current corresponds to the power injected into the grid connected bus. The control objective is to achieve UPF working of the inverter. The main control block diagram is shown.

## V. ADAPTIVE HARMONIC COMPENSATION

Here in this section, first the LMS adaptive filter is briefly examined. Then, the concept of lower order harmonic compensation and the design control strategy of the adaptive harmonic compensation block using this adaptive filter are described.

### 5.1 Review of the LMS Adaptive Filter

The adaptive harmonic compensation control technique is based on the usage of an LMS adaptive filter to estimate a particular harmonic in the output response. This is then utilized to produce a counter voltage reference using a proportional controller to attenuate that particular harmonic.

### 5.2 Adaptive Harmonic Compensation

The LMS adaptive filter discussed earlier can be used for selective harmonic compensation of any quantity, say grid current. To minimize a particular lower order harmonic (say $i_k$) of grid current.

1) $i_k$ is projected from the samples of grid current and phase locked loop (PLL) unit vectors at that frequency;

2) a voltage reference is produced from the estimated value of $i_k$ ;

3) Developed voltage reference is subtracted from the main controller voltage reference.

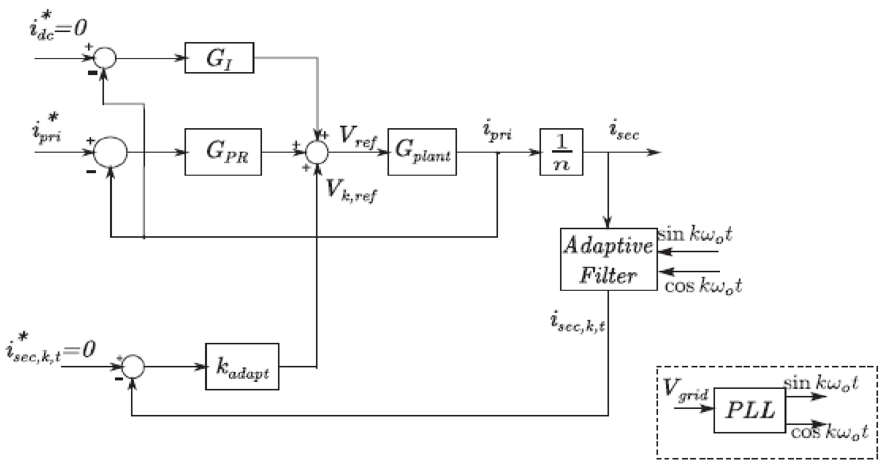


**Fig.4. Complete Ac Current Control Structure of the Inverter**

Fig. 4 shows only one adaptive harmonic compensation block for the kth harmonic. Seventh essential to be varied, then three adaptive filters and three gain terms Kadapt are required and the net voltage reference added to the output of the PRI controller will be the sum of the voltage references made by each of the control block. Thus, presenting on the number of harmonics to be attenuated the number of blocks can be elected. In Figure. 4 is the transformer turns ratio from secondary winding to primary winding. The available kth harmonic current in the secondary circuit, which is predictable utilizing the LMS adaptive filter. This is mostly due to the variations in the magnetizing current and the dead-time period effect. A single-phase PLL make used to engender the reference sine–cosine signals synchronized with the grid voltage for the adaptive filter. Next, computation of the adaptive gain is conversed. Computation *of* $k_{adapt}$ Based on the estimated net *k*th harmonic in the current of the grid, the voltage reference $v_{k,ref}$ is produced by multiplying the estimated harmonic with Kadpt. The consequence of this voltage reference is that it results in purified voltage at that harmonic frequency at the inverter terminals and this will inject a current at that frequency in the primary side of the transformer. The reproduced secondary current will oppose the original current that was present in the secondary and hence there will be a net decrement in that particular harmonic in the current of the grid. Therefore, the current present in the primary side will be more distorted. The amount of reduction of the harmonic content in grid current will depend on kadpt.

## VI. CONCLUSION

Adjustment to the inverter current control for a grid connected single-phase photovoltaic inverter has been suggested here in this paper, for consent to high significance of the current injected into the grid. For the power circuit design structure considered, the dominant reasons for lower order harmonic injection are identified as the distorted transformer a centralizing current and the dead time of the inverter. It is also shown that the presence of dc offset in control loop results in even harmonics in the injected current for this topology due to the dc biasing of the transformer. A new explanation is recommended to attenuate all the dominant lower order harmonics in the system. The suggested method uses an LMS adaptive filter to estimate a particular harmonic in the grid current that needs to be distorted. The evaluated current is make change into an equivalent voltage reference using a proportional controller and added to the inverter voltage reference. The design of the gain of a proportional controller to have an adequate harmonic compensation has been described. In order to escape dc biasing of the transformer, a different control scheme of SPWM controller has been proposed and its design has been offered. The communication between the SPWM controller and the adaptive compensation scheme has been studied. It is illustrated that there is minimal interaction between the fundamental current controller and the methods responsible for dc offset compensation and adaptive harmonic compensation. The SPWM control technique and the adaptive compensation scheme together increase the quality of the current injected into the grid. The complete current control strategy consisting of the adaptive harmonic compensation and the SPWM controller has been tested experimentally and the results show good development in the grid current THD once the recommended current control is applied.

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