

Simulation And Analysis Of PV Panel Based Micro-Inverter With Its Control Techniques

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ABSTRACT: This paper presents the simulation and analysis of a PV panel based Micro-inverter for low power. The system consists of two stage of conversion i.e. DC-DC conversion and DC-AC conversion. The DC-DC half bridge push pull converter boosts the input DC voltage into the desired rated input voltage of the H bridge inverter. Moreover different control methods like simple boost control, maximum boost control, and maximum constant third harmonics injection control, methods for inverter is also analyze. The effectiveness of the inverter is examined through simulation. For pure sine wave LC filter has been used.

KEYWORDS: Micro-Inverter, DC-DC converter, H bridge inverter, PV Panel.

I. INTRODUCTION

India has relatively long sunny days for more than ten months and partly cloudy sky for most of the days i.e. almost two months. This makes India very rich in solar energy especially desert sides in west which include Gujarat, Rajasthan, Madhya Pradesh etc. Photovoltaic Panel or modules are used directly to create electricity. Besides this solar panels however, it also needs “Balance of System” components including inverters, wiring, breakers and switches, which can account for up to half of the system cost.

Inverters like string inverters, micro-inverters are used with PV panels. In string inverters the several numbers of panels are connected in series with one centralized inverter, while micro-inverter invert the electricity from single PV panel, as each panel has a single inverter attached beyond it. Micro-inverter is an upcoming field of research in PV technology as it has more advantage over other PV systems. It is used as plug and play devices. Typically, the micro-inverter are design for lower ranges; as the capacity of solar panel increases, the size of micro-inverter should increases as well[1,2].

In this paper the simulation of micro-inverter is discussed with analysis of control techniques of it.

II. RELATED WORK

In residential/commercial used the solar photovoltaic system is getting more and more attention. As in order to run AC loads a pure sine wave is needed for this it is to be generated from inverter. For this micro-inverter is an upcoming research for uses. As to run domestic appliances we need 230V AC, for this high frequency transformer is used, as it provides galvanic isolation. The inverter modules themselves must be small, temperature resistant, long lasting, efficient and low in harmonic distortion [3]. However when challenged with multi-angled roofing, installation cost and life-time restraint that limit residential and commercial central inverter installation, micro-inverter can become very feasible option.

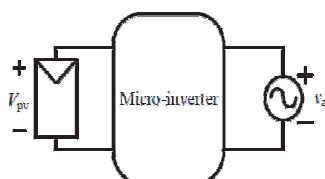


FIG.1 PV MICRO-INVERTER STRUCTURE

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly Peer Reviewed Journal)

Vol. 5, Issue 2, February 2016

III. SYSTEM DESCRIPTION

The proposed PV Micro-inverter is model with low power i.e. 50W solar panel, DC-DC converter, DC-AC converter, filters and load.

A. Solar PV Module

While designing Micro-inverter solar panel plays a crucial role. It consists of number of solar cell in series parallel combination to produce rated voltage and current. The equivalent circuit of solar cell is seen in fig.2. In its basic form, the current generated from the photocurrent source is directly conducted to the terminals. The diode connected across is used to model the I-V curve normally generated from the cells. The series resistance at the terminal of the cell is used to model the voltage drop [4]. The I-V characteristics of solar cell with series and parallel resistors can be represented by

$$I = I_L - I_o \left\{ \exp \left[\frac{q}{m k T} (V + I R_s) \right] - 1 \right\} - V + \frac{I R_s}{R_{sh}} \quad (1)$$

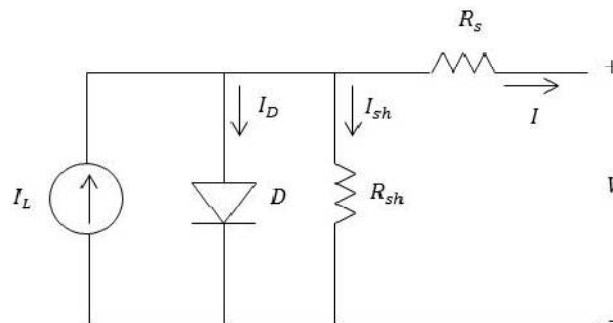


FIG.2 EQUIVALENT CIRCUIT OF SOLAR CELL

Where, I is PV array output current, V is PV array output voltage, I_o is Reverse saturation current of diode, T is Cell temperature (K), q is Charge of an electron, k is Boltzmann's constant, m is Ideality factor. Here for 50W solar panel, the specifications are as open circuit voltage is 21V. The voltage at maximum power 17V, short circuit current is 2.90A

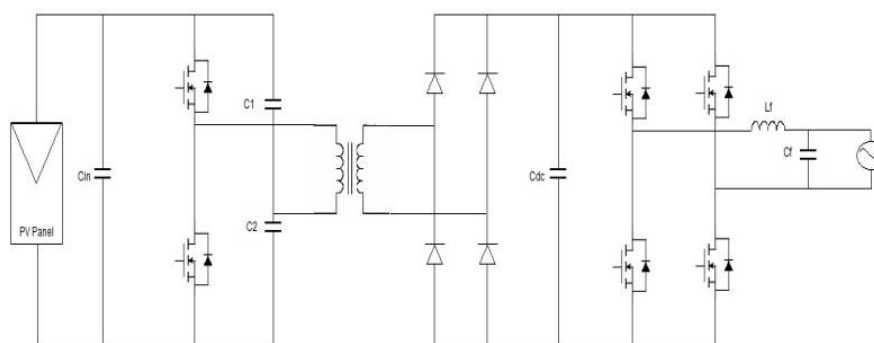


FIG.3 PROPOSED PV MICROINVERTER

Usually electrolytic capacitors of large capacitances paralleled to PV panel are employed for smooth input voltage and balance the instantaneous input and output power mismatching. But the life span of electrolytic capacitors is very less compared to decoupled capacitor. Thus for long life of micro-inverter decoupling capacitor is used [5]. It is connected in parallel with PV panel and inverter stage.

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly Peer Reviewed Journal)

Vol. 5, Issue 2, February 2016

The size of this capacitor is

$$C_{in} = \frac{P_{pv}}{2\pi f_{grid} V_{pv} V_{ripple}} \quad (2)$$

Where P_{pv} is the nominal power of PV panel, V_{pv} is mean voltage of panel and V_{ripple} is amplitude of ripple voltage of panel. Here it is assumed ripple voltage is 8% of the panel voltage.

B. DC-DC CONVERTER

There are several methods for DC-Dc converter. The need for DC-DC converter provides the inverter with a high voltage source. As the desired output voltage is 230V rms so DC-DC converter must supply 312V. Here in this scheme the half bridge push-pull converter is used as it has good efficiency at low power applications with 50% duty cycle.

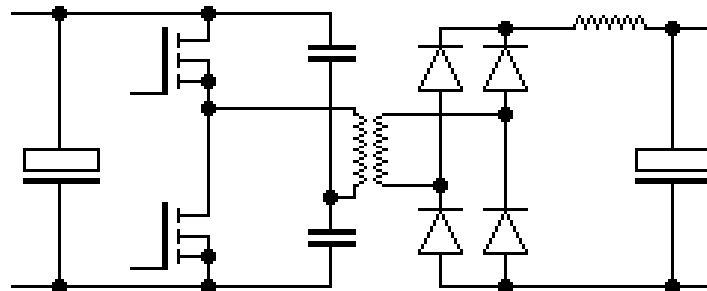


FIG.4 DC-DC CONVERTER

The half bridge push-pull converter belongs to primary switched converter family, since there is isolation between input and output. The switching frequency of 1 KHz is used.

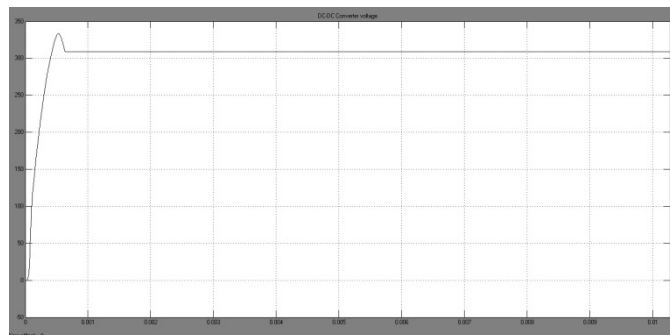


FIG. 5 OUTPUT VOLATGE OF DC-DC CONVERTER

C. DC-AC Converter

The H- Bridge inverter is used for the DC-AC conversion. The AC load needs pure sine wave and the expected output is 230V AC rms and 50 Hz.

The different control methods like simple boost, maximum boost and maximum constant boost with third harmonic injection method are used for the H-bridge inverter in micro-inverter.

i. Simple Boost control method

In this method, two straight lines are employed in the usual PWM control method. These two straight lines are equal to the peak value of the reference signals. When the carrier triangular wave is greater than the positive straight line or smaller than the negative line, the inverter works in shoot-through zero state that is prevented in traditional method. From the simple boost control method description, it can be concluded that carrier wave frequency and shoot-through

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly Peer Reviewed Journal)

Vol. 5, Issue 2, February 2016

are two main factors in this method and the output waveform is mostly affected by them. So by optimizing these two parameters, the output can be improved compared to that obtained from estimated values [7, 8].

In simple boost control method, the shoot-through duty ratio decreases with the increasing of modulation index M . The maximum shoot-through duty ratio of the simple boost control method is limited to $(1-M)$, reaching zero at a modulation index of one. So to generate an output voltage with a high voltage gain, a small modulation index has to be used. Because of the important role of M and carrier signal frequency, both of the parameters are used in the optimization problem. The reference signal is sine wave and carrier signal is of triangular wave. The switching frequency is 1KHZ. The PWM signal of simple boost control is show in fig 6.

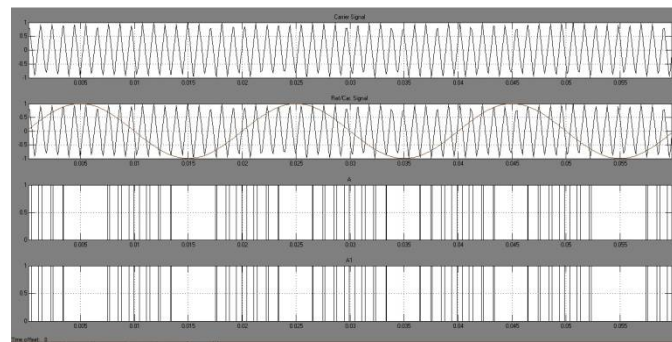


FIG 6 PWM SIGNAL OF SIMPLE BOOST CONTROL

ii. Maximum Boost control method

Maximum Boost Control (MBC) turns all traditional zero states into shoot-through zero state. The PWM signals with the use of the MBC control is shown in Fig. 7. MBC maintains the four active states unchanged and turns all zero states into shoot-through zero states.

Two straight envelopes are employed to realize the shoot through duty ratio (D_o). The first one is equal to the peak value of the sinusoidal reference voltages while the other one is the negative of the first one. When the triangular carrier waveforms are greater than the upper envelope, or lower than the bottom envelope, the circuit turns into shoot-through state. Otherwise it operates just as traditional carrier based PWM [7, 8].

To produce switching pulses, reference wave forms having peak value with modulation index (M) are compared with the same high frequency triangular signal. Comparator compares these two signals and produces. These pulses are then sent to gates of the power MOSFET's. This method is much uncomplicated; however, the resulting voltage stress across the device is relatively low because all traditional zero states are utilized fully. This characteristic will restrict the obtainable voltage gain.

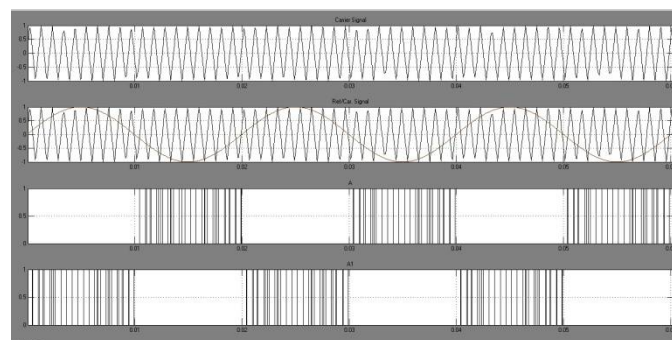


FIG. 7 PWM SIGNAL OF MAXIMUM BOOST CONTROL

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly Peer Reviewed Journal)

Vol. 5, Issue 2, February 2016

iii. Maximum Constant Boost with Third Harmonic Injection Control Method

The modulating signal is generated by injecting selected harmonics to the sine wave. This results in flat-topped waveform and reduces the amount of over modulation. It provides a higher fundamental amplitude and low distortion of the output voltage.

This method is opted to use the increased range of modulation indexes. Similarly to previous methods, the overshoot period can be maintained constant and variable. In third harmonic injection constant boost technique the sinusoidal reference signal is merged with third harmonic sinusoidal waveforms with one third amplitude of the fundamental, to generate non-sinusoidal waveforms. Constant shoot-through is introduced in zero states by comparing the triangular carrier wave with a positive, negative constant magnitude and generated non-sinusoidal sinusoidal reference waveforms as in simple boost control. In addition it is found that for over modulation of 1.2 with third harmonic injection scheme [7, 8].

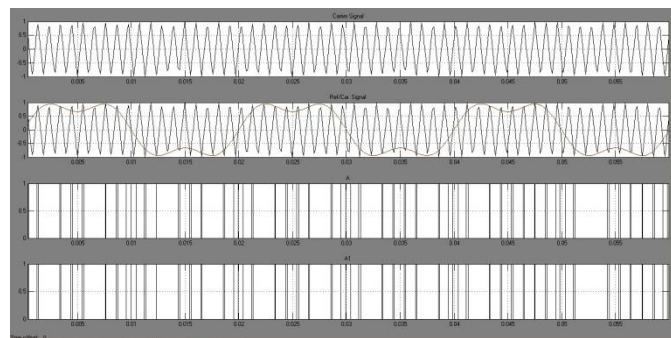


FIG 8 PWM SIGNAL FOR MAXIMUM CONSTANT WITH THIRD HARMONIC INJECTION

IV. RESULTS AND DISCUSSION

The proposed Micro-inverter is simulated using MATLAB. The different PWM strategy discussed above used for the gate pulse in Micro-inverter. There are certain variation observe in all this techniques.

TABLE I. INPUT PARAMETERS

Input parameter	Value
Solar Panel	50W, 21 Voc, 2.90A
C1,C2	10mF
Cdc	220 μ F
Lf	2.06mH
Cf	10 μ F
Switching Frequency	1KHz

The output voltage is 312V peak to peak. We observe that in maximum boost method voltage is less as compare with other technique. Fig 9 shows the output voltage and output current waveform micro-inverter with simple boost technique. Fig 10 shows the output voltage and output current waveform micro-inverter with Maximum boost technique. And fig 11 shows the output voltage and output current waveform micro-inverter with maximum constant boost with third harmonic injection technique.

International Journal of Innovative Research in Science, Engineering and Technology

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Vol. 5, Issue 2, February 2016

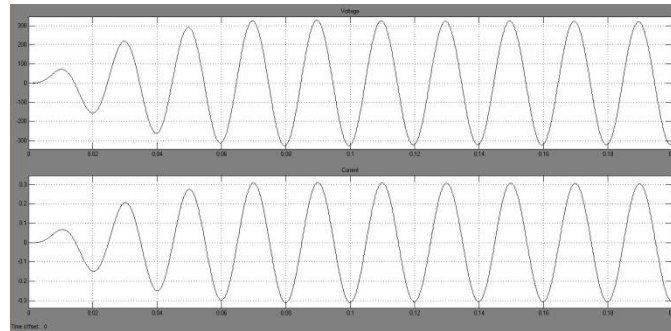


FIG .9 OUTPUT VOLTAGE AND OUTPUT CURRENT WAVEFORM MICRO-INVERTER WITH SIMPLE BOOST TECHNIQUE.

It should be noted that the harmonics are located at the switching frequency and multiples of the switching frequency. The switching frequency was intentionally set at 1 KHz so it would be rather distant from the 50 Hz fundamental frequency.

This would allow for a high cutoff frequency, which allows for small LC components. An L-C low-pass filter was chosen for the power inverter. The value of the L is 2.06mH and the value of C is 10 μ F. The total harmonics distortions obtain using above techniques are 3.20% for simple boost method, 4.73% for maximum boost method and 3.15 % for maximum constant boost with third harmonic injection.

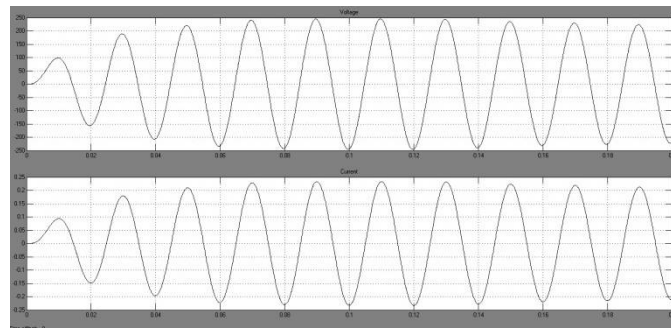


FIG 10 OUTPUT VOLTAGE AND OUTPUT CURRENT WAVEFORM MICRO-INVERTER WITH MAXIMUM BOOST TECHNIQUE.

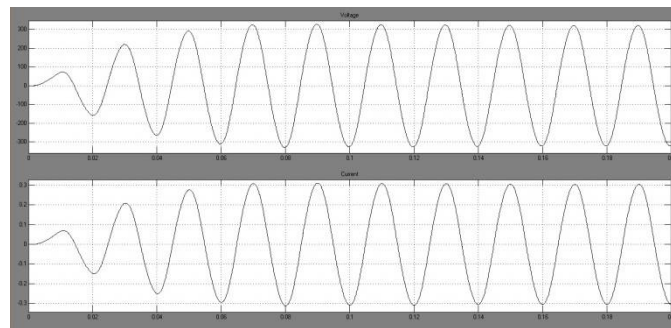


FIG 11 OUTPUT VOLTAGE AND OUTPUT CURRENT WAVEFORM MICRO-INVERTER WITH MAXIMUM CONSTANT BOOST WITH THIRD HARMONIC INJECTION TECHNIQUE.

The voltage gain of third harmonic injection method is more as compare to other. As in maximum boost method we are not getting the required voltage as desired. Thus from all this we can say that the maximum constant boost with third harmonic method is good compare to other.

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly Peer Reviewed Journal)

Vol. 5, Issue 2, February 2016

V. CONCLUSION

This paper proposed the simulation of micro-inverter with the different control techniques. The dual stage topology has been used. In dual-stage inverters, the DC voltage rising circuit and DC/AC voltage inverting circuit would be decoupled. The Half Bridge Push Pull DC-DC converter is used and H Bridge Inverter is use for DC-AC converter. The output of Micro-inverter is 230V AC rms is obtained in two techniques. While in maximum boost the desired output voltage is not obtained. Taking a look to the end results, the control techniques are discussed among which we observe that that the carrier frequency for controlling technique is 1 KHz. The total harmonics distortion in third harmonic injection method is less and the voltage gain is more as compare to other.

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