MICRO INVERTER BASE GRID CONNECTED PHOTOVOLTAIC SYSTEM

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ABSTRACT: This paper gives a Simulink design of boost converter for reliability for PV system. In this circuit boost-half-bridge DC to DC converter using minimal device to interconnect to the low-voltage of distribution application with PV source. A cascaded full-bridge inverter operates with sinusoidal pulse width modulation (SPWM) and synchronized to the grid. In this system have been achieves best out voltage while changing load or changing solar irradiance rapidly. In addition to that, analyze the working behavior of the boost half bridge converter, half bridge photovoltaic (PV) for grid connected micro inverter with basic control system. The motivation of work to develop and in order to achieve less cost, simple control, enhance the efficiency, and high and adapted with maximum power point tracking –basic MPPT Perturb & Observe method , which generates a locational changed PV voltage and it is developed accordingly. Different step size is adopted for the fast tracking speed and enhances MPPT efficiency are to be obtained. Simulation developed and results are provided to while performing grid connected PV system with MPPT algorithm. This system implanted from basic mathematical model to achieve constant voltage and generated power transmitted to grid.

KEYWORDS: PV system modelling, MPPT, Perturb & Observe method, Boost converter, PWM control, grid connected inverter.

INTRODUCTION

Micro Inverter concept (also known as module integrated converter/ inverter) has become a present trend for single phase micro grids. Present Research papers MLI and MMC is more popular with photovoltaic (PV), wind energy etc in large scale and also small scale power systems[1-5].Also the possibility of individual PV-module-oriented design and independent maximum power point tracking (MPPT) concepts can be developed.The idea of micro inverter nothing but module integrated converter/inverter (MIC). MIC has become a present trend for single phase micro grid connected base photovoltaic (PV) small power systems. In this light energy lot of yield mismatches happen among the PV panels, more possibility of the oriented PV module for the maximum power point tracking (MPPT). In general, one single power system of micro inverter system interconnected by a low-voltage solar panel, which requires a high-voltage conversion step-up to develop desired ac output voltage. Hence, a cascaded dc–dc converter topology is the most popular, in which a HF transformer is often implemented within the direct current to direct current transformation stage. Pulse width modulation technique is more basic popular system for operate of converters/inverters, PV micro inverter system is mainly two major types are enticing most of the considerations. Similarly PWM technique is realistic for dc–dc converter and the inverter. [6-10]In addition that, a persistent voltage dc link connected to power flow in two conditional stages , those stages happen when connected to the dc input is not affected by the line frequency and power ripple performing at the ac connection side. By dissimilarity, the second type operates a PWM technique is Better control of dc–dc converter order to produce a resolved sinusoidal current (or voltage) at the inverter dc link. Consequently, a line-frequency-commutated inverter clarifies the dc-link current (or voltage) to find the sinusoidal form synchronized with the grid. While latter has the advantage of higher conversion efficiency due to the removal of high frequency (HF) switching losses at the inverter/converter, the twin line- frequency power wrinkle need be all enthralled by the dc input capacitor, MPPT decided the efficiency of the system (it is the ratio of the energy drained by the PV inverter within the certain measuring period at the (neglect transients) steady state to the theoretical available energy from the PV cells) compromised except a to large capacitance. Furthermore, the direct current to direct current conversion stages need extra inspiring control procedures the best grid current regulation requisite. In this paper performance of MPPT and the quality of the output current in this PV micro inverter is more suitable and will be adopted [11-16]

PV SYSTEM MODELING

The below equivalent circuit of a PV cell is shown in Fig.1. It has includes a current source, a diode and a shunt resistance similarly series resistance.

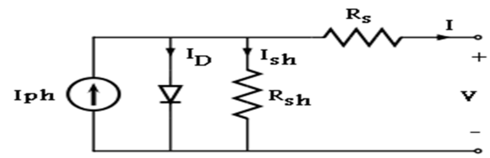


Figure. 1. Equivalent Circuit of PV Module

The mathematical expression for load current can be given as:

$$I = I_{ph} - I_s\left[e^{\frac{q(V+IR_S)}{kT_Cn}} - 1\right] - \frac{V + IR_s}{R_{sh}} \tag{1}$$

In above expression, photocurrent is denoted by Iph, Is gives the diode reverse saturation current,q(1.6×10^{-19}C) is the charge, V is voltage across the diode, Boltzmann's constant K value given as (1.38x10^-23J/K), Tc is junction temperature of the junction , N is the diode ideality factor, and Rs and Rsh are the series resistor , shunt resistor of internal PV cell, respectively.The complete behavior of PV cell and above said equation operate for environmental changes that means they changes with sun radiation and temperature and also having relation with Iph, Is, Rs and Rsh values of the employed in the circuit.From the equation (1), the simulation model of Fig.2 was developed. Results are generated after entered all the parameters values. The photocurrent of cell mainly depends on the location solar irradiation, and intensity of temperature the relation is given by,

$$I_{ph} = I_{sc} + K_i(T_c - T_{nom}) \times \frac{\beta}{1000} \tag{2}$$

Where ISC is short-circuit current of pv cells, at a 25 1kW/m2, Ki is the cell's temperature coefficient short-circuit current, Tnom is reference temperature of PV cells, and β is the solar irradiation. Second side the cell's temperature saturation current varies, which is given by

$$I_{sT} = I_{Rs}\left(\frac{T_c}{T_{nom}}\right)^3 e^{\frac{qE_g\left(\frac{1}{T_{nom}} - \frac{1}{T_c}\right)}{KA}} \tag{3}$$

The total parameters estimated by the cells number, its manufacture structure and the specification of PV cell. The important analysis of cell is electrical energy efficiency which depends on open-circuited voltage V_{oc} and short-circuit current I_{sc}. The normal conditions $I_{ph} >> I_{sc}$ and neglecting the small diode and earth leakage currents at the zero-terminal voltage, the cell short-circuit current I_{sc} is almost equal to the cell photocurrent i.e., $I_{ph}=I_{sc}$.On the second hand, the V_{oc} parameter is gained by assuming the zero output current. PV cell open circuit voltage V_{oc} at adjustable temperature and ignoring the leakage current at shunt level, the reference reverse saturation current at adjustable temperature can be given by

$$I_{Rs} = \frac{I_{SC}}{e^{\frac{qV_{oc}}{KT_{cn}}-1}} \tag{4}$$

maximum power is given by

$$P_{max} = V_{max} \times I_{max} = \Upsilon \times V_{oc} \times I_{sc} \tag{5}$$

Where, ϒ is property to Fill factor of a PV cell. The mathematical for PV module is expressed by from the each cell's. a PV module consisting of number of parallel cells (Npm) and number of series cells in module (Nsm). Thus, all currents and all voltages are multiplied by Npm & Nsm, respectively

$$I_{sm} = N_{pm} * I_s \quad (6)$$

$$I_{scm} = N_{pm} * I_{sc} \quad (7)$$

$$V_{ocm} = N_{sm} * V_{oc} \quad (8)$$

$$R_{sm} = (\frac{N_{sm}}{N_{pm}}) * R_s \quad (9)$$

Maximum Power Point Tracking

Present most typical solar panel input to output only 30 to 40 percent (efficiency) of the instance solar irradiation into electrical power. By using Maximum power point tracking (MPPT) the efficiency of the solar panel can be improved because it tracks maximum sun light direction to the panel.when the source impedance(resistor) of the circuit equal to load impedance(resistance) the power output of a circuit is maximum, as the Maximum Power Transfer theorem states that. Thus our problem of tracking the maximum power point reduces to an impedance matching problem.The different popular maximum power point tracker techniques are as follows:1) Perturb and observe (hill climbing method),2) Incremental Conductance method,3) Fractional short circuit current 4) Neural networks 5) Fuzzy logic

Perturb & Observe method

Perturb & Observe (P&O) is most preferably used method because of its simplicity and efficient in tracking maximum power. The voltage of PV array can be sensed by using a voltage sensor. Both analog and digital platforms can be implemented and the cost of implementation is less and easy. Periodic tuning is not required for this method. This method is developed by indicating the slope (dP/dV) by using P-V characteristics of PV module. So depending on the slope sign operating voltage is to be perturbed to track maximum power. Algorithm for P&O method is given as below

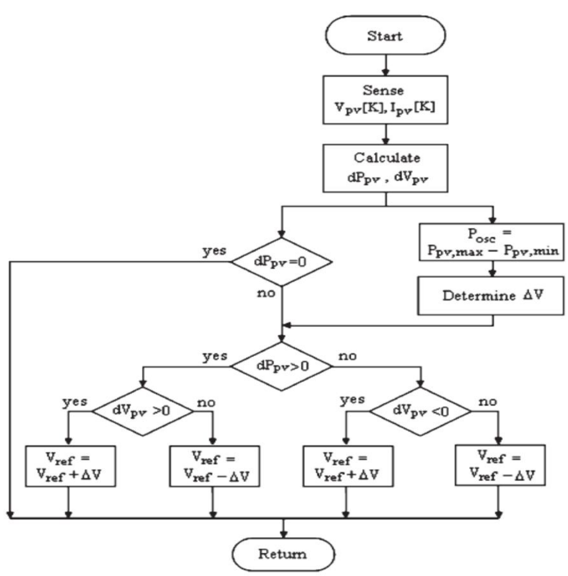


Figure 2. MPPT algorithm

On other hand it has a disadvantage of drifting from MPP with the atmospheric changes. A constraint to be applied on perturbation step size to overcome the drift problem. The implementing time and operational difficulty of the algorithm is very less but sometime its stops perturbing at MPP, it goes on perturbing on both sides. In this case an fitting function or a wait function is used to stop the time difficulty increase of algorithm. Step 1: If "P" is positive then the PV panel is to be perturbed by a small increment and one has to go in the direction of MPP if change in power P resulting positive.

Step 2: If “P” is negative one has to go in the opposite direction of MPP and the perturbation sign supplied has to be changed.

Boost converter

A boost converter is a step up DC-to-DC power converter as it boost up its input voltage and thus produces the output voltage greater than its input voltage. It comprises semiconductor devices with at least two a diode and a transistor, capacitor/inductor or both as energy storage elements and having a switched-mode power supply (SMPS). To reduce the ripple content in the output, filters are connected at the output side which is generally made up of capacitors; also capacitors with the combination of inductors can be used.

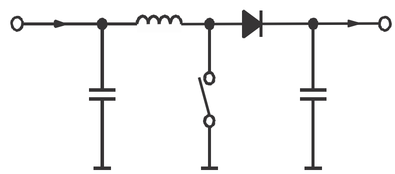


Figure 3. The Basic Schematic of A Boost Converter

To supply power to the boost converter one can use any type of DC source; they can be solar panels, DC generators, batteries and rectifiers. By using this boost converters one can increase the voltage so that reducing the number of cells. The principal of boost converter is based on the property of an inductor to restrict changes in current. It is also known as step-up converter as it always steps up the source voltage. Since the power (P=VI) to be conserved, the output current is lower than the source current. The operation of the boost converter is based on the switch “on and off” states and also on depending on the inductor value continuous and discontinuous modes of operation can be observed.on the inductor value continuous and discontinuous modes of operation can be observed.

Estimation of Parameters

Necessary parameters to be estimated :The four parameters needed to calculate the power stage are given as follows:1. Range of input voltage : V_{in}(min) and V_{in}(max) ,2. Nominal Output Voltage: V_{out}, 3. Maximum Output Current: I_{out} (max) 4. Integrated Circuit needed to build the boost converter. The necessary parameters for the calculations have to be taken out in the data sheet. If these parameters are taken the calculation of the power stage can be done.

Calculation of the Maximum Switch Current

Duty cycle (D) is determined for the minimum input voltage at first step to calculate the switch current. As the minimum input voltage leads to the maximum switch current.

$$D = 1 - \left(\frac{V_{in} \times \eta}{V_{out}}\right) \qquad (9)$$

Where, D = Duty cycle, Vin(min) = Minimum input voltage, Vout = Required output voltage , η = efficiency of the converter, e.g. estimated 80%.The efficiency is added here to the duty cycle calculation, because the energy dissipated by the converter has to deliver. This calculation gives a more practical duty cycle than proceeding the calculation without the efficiency factor.

Inductor Selection: Generally range of recommended inductor values is mentioned in the data sheet. So in this case, it is recommended to choose the value of an inductor from this range. If the inductor value is higher, the maximum output current is also high because of the reduced ripple current. For the lower inductor value, the solution size is smaller. Note that the inductor chosen must always have a higher current rating than the maximum current prescribed at any time, as because the current increases with decrease in inductance. For parts where no inductor range is given, the following equation is a good estimation for the right inductor:

$$L = \frac{V_{in}(V_{out} - V_{in})}{\Delta I_l \times f_s \times V_{out}} \qquad (10)$$

Where, V_{in} = typical input voltage, V_{out} = desired output voltage, f_s = minimum switching frequency of the converter, ΔI_l = estimated inductor ripple current. If the inductor is not known inductor ripple current is not possible to be calculated. The optimal estimation for the inductor ripple current is 20% to 40% of the output current.

$$\Delta I_l = (0.2\ or\ 0.4) \times I_{out(max)} \times \frac{V_{out}}{V_{in}} \tag{11}$$

ΔI_1 = estimated inductor ripple current, I_{out} (max) = maximum output current necessary in the application.
Input Capacitor Selection: The minimum value of the input capacitor is generally mentioned in the data sheet. This minimum value is to be specified necessary to stabilize the input voltage for the peak current requirement of a switching power supply. Low equivalent series resistance (ESR) ceramic capacitors utilization is most optimal. The dielectric material should be X5R or more than that. Otherwise, the capacitor may lose much of its capacitance due to temperature or DC bias . If the input voltage is noisy the value can be increased.
Output Capacitor Selection: To minimize the ripple content on the output voltage low ESR capacitors are most suitable. Ceramic capacitors are best choice of practice for theX5R dielectric material. Any capacitor value which is above the suggested minimum value in the data sheet can be employed if the converter has external compensation, but the compensation has to be altered for the used output capacitance. The recommended inductor and capacitor values should be applied in internally compensated converters or the recommendations in the data sheet for adjusting the output capacitors for the application to be followed for the ratio of L × C.The output capacitor values can be adjusted with external compensation for a desired output voltage ripple and the equation is given as follows,

$$C = \frac{I_{out(max)} \times D}{\Delta V_{out} \times f_S} \tag{12}$$

C_{out}(min) = minimum output capacitance, I_{out}(max) = maximum output current of the application, D = duty cycle calculated from previous equation, f_s = minimum switching frequency of the converter, ΔV_{out} = desired output voltage ripple

Grid Connected 3-phase Inverter and PWM Control

The proposed inverter topology is applied to grid connected pv system which converters direct current (DC) to alternating current (AC) and feed it into an interconnected electrical grid instead of load. These inverters are mostly used in case of renewable energy sources interconnected to grid for the conversion of direct current produced by them into AC for the utility purpose. The sources may either solar panels or small wind turbines. Generally these grid connected inverters are known as “grid- interactive inverters”. A pure sinusoidal wave to be fed into the grid with lesser harmonics. To reduce the harmonics an LC filter can be incorporated with inverter. The frequency of the signal which is injected should be match with the grid frequency. In many countries residences and some industries having grid connected electrical system are permitted to sell their energy to the utility grid.Electricity supplied to the grid can be compensated in different ways. "Net metering", is the method where for the net outflow of power the entity which owns the renewable energy power sources receives compensation from the utility i.e., for example, if in a given month a power system supplies 500 kilowatt-hours into the grid and utilize 100 kilowatt-hours from the grid, it would subjected a compensation for 400 kilowatt-hours. Another method is a feed-in tariff, in which for every kilowatt hour delivered to the grid is paid by the producer on a contract based with distribution company or other power authority by a special tariff based.
Pulse width modulation is a digital control technique; here width of the pulse is varying in accordance with modulation wave. Operation of the pulse width modulation is explained with carrier wave and reference wave. In this, leading edge of the carrier wave is fixed and trailing edge of the wave is varies with respect to reference wave. Majority of power electronic converters are controlled by PWM technique.By turning the switch between supply and load the average value of voltage or current to the load is controlled by on and off at a fast pace. The power supplied to the load is higher when the on period of the switch is longer than the off periods.The switching frequency of PWM has to be much faster as it affects the load. Usually switching has to be done several times in a minute for an electric stove, 120 Hz in a lamp dimmer, for a motor drive from few kilohertz (kHz) to tens of kHz and in the order of tens or hundreds of kHz in audio amplifiers and in computer power supplies.The term duty cycle illustrates as ratio to proportion of 'on' time to the total time in one cycle; a low duty cycle leads to low power, because the time of power off period is more. Duty cycle is expressed in percent, 100% duty ratio indicates fully on. The main advantage of PWM is that switching devices power loss is very low. Practically there is no current when a switch is in off state there is, and when it is on state there is almost no voltage drop across the switch, i.e., in both the cases power lose (product of voltage and current) is being close to zero. Because of flexible on/off nature of PWM it also works well with digital controls as the duty cycle can easily set. PWM has also been applied in specified communication systems, where the duty cycle has been used to deliver information over a communications channel.

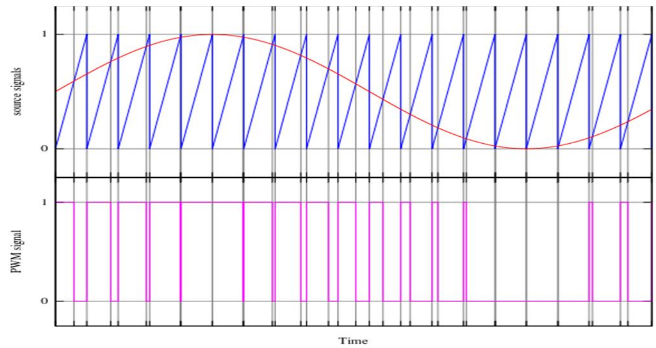


Figure 4. saw tooth PWM method for generation of pulses

Simulation and Results

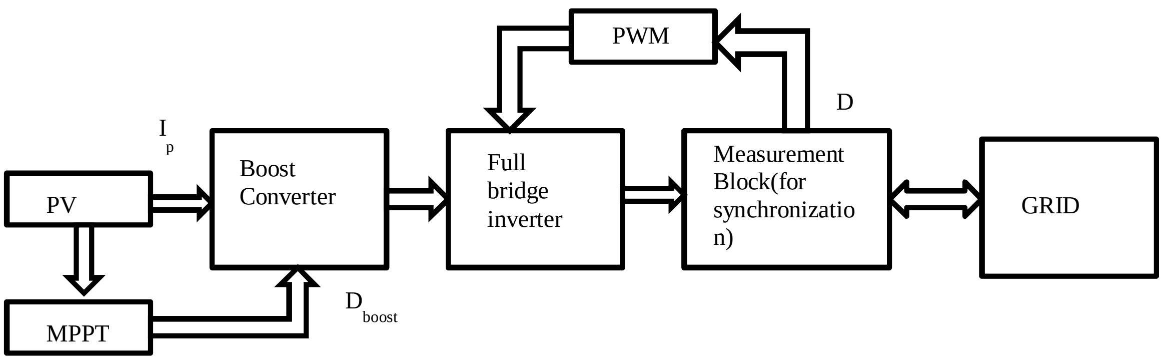
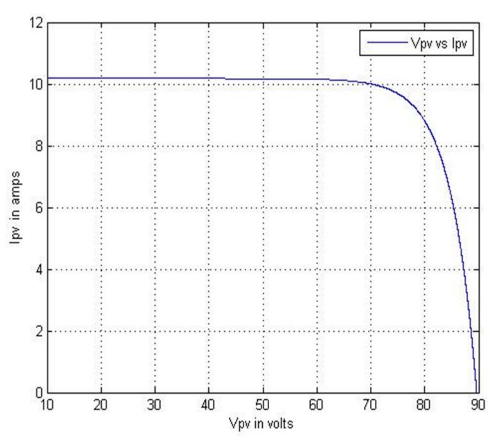


Figure 5. Block diagram of solar micro inverter with MPPT control



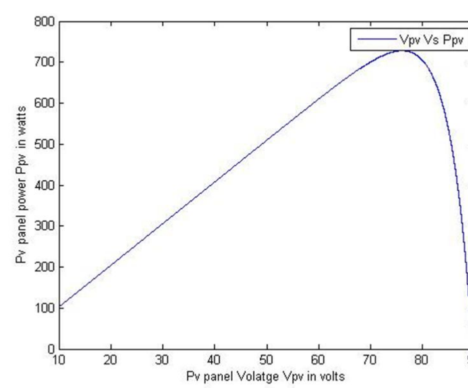


Figure. 6 output current (Ipv) vs output voltage (Vpv) **Figure 7.** output power(Ppv) vs output voltage (Vpv)

Block diagram shown in figure 5 is developed in Matlab/simulation. In this paper a simple micro inverter connected to grid with better basic MPPT algorithm with boost converter and PV system. In boost converter output waveform, the voltage and time relation is linear and thereafter, that relation has changed as IGBT drifts into saturation. In figure 6 and 7 got exact characteristics of PV system without oscillations. In figure 8 characteristics follows exact irradiations shown with MPPT algorithm it became stable due to the presence of control equipment. Boost converter current has attained steady state within 0.2 seconds shown in Figure 9.

Inverter output voltages little bit fluctuating due to inverter switching operation shown in figure 10 and figure 11. Current from grid to load is free from ripples whereas output current from micro inverter seems to be clipped at peek values which can be observed from the dips in figure 12 and figure 13. Voltage of grid and micro inverter is equal at every time instant which confirms the necessary requirement for grid connection. The power generation manages at any load through grid or PV cell.

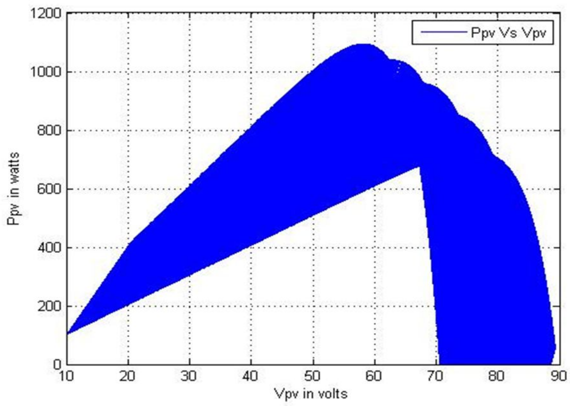


Figure 8. output power(Ppv) vs output voltage(Vpv) (MPPT)

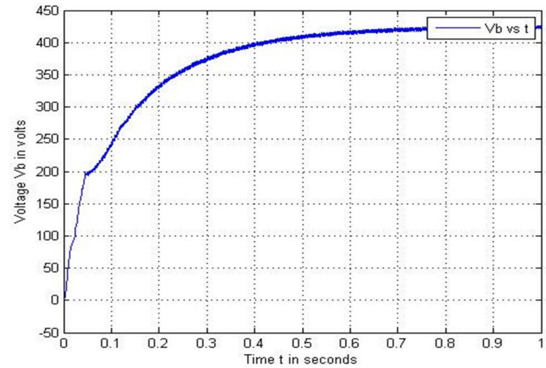


Figure 9. Boost converter output voltage (Vb) Vs time (t)

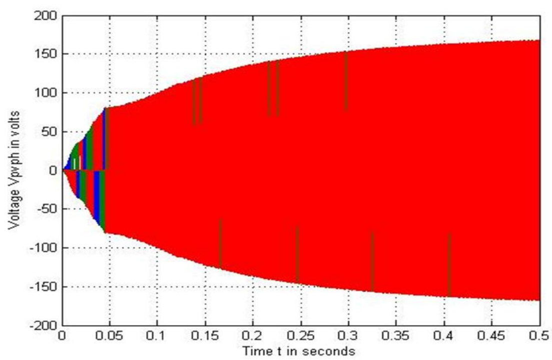


Figure 10. Output voltage from the inverter (Vpvph) Vs time (t)

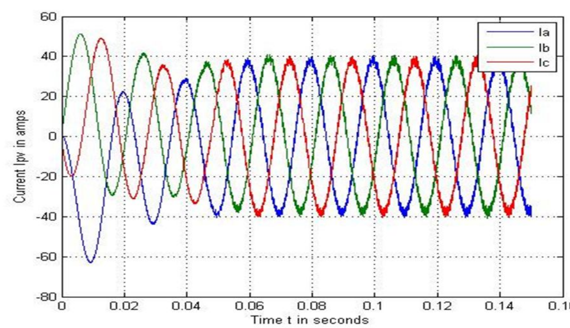


Figure 11. Output current from the inverter (Ipvph) Vs time (t)

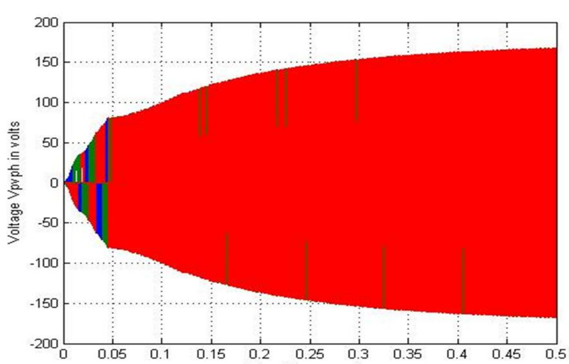


Figure 12. grid voltage (Vabc) vs time(t)

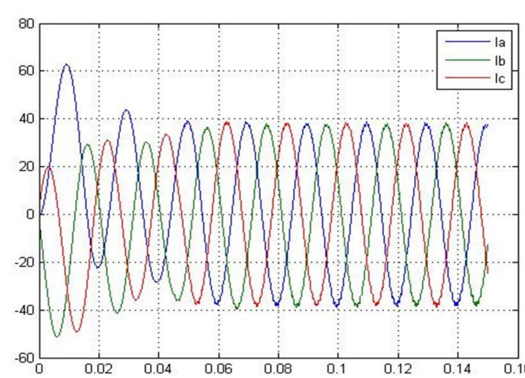


Figure 13. Grid current (Iabc) Vs time (t)

CONCLUSION

A novel boost-half-bridge micro inverter for PV systems interconnected to grid has been presented in this paper. The operating procedure and characteristics of boost dc–dc half bridge converter were examined and an optimized MPPT technique were also studied with that. Matlab simulation is done to verify and to prove the operating principles of the boost converter interconnected to grid along with a micro inverter. Because of its typical features such as less number of semiconductors usage, design simplicity, easy control this topology becoming a good trend for PV micro inverter as the cost is low and also possessing high reliability. Moreover, the current injected to the grid is regulated precisely and stiffly. Finally, the customized MPPT technique that generates a ramp-changed reference for the PV voltage regulation assures a correct and reliable operation of the PV micro inverter system. The variable step-size technique provides a fast

MPP tracking speed and a high MPPT efficiency. So that the texas instrument boost-half-bridge PV micro inverter system with its advanced control implementations will be a good one as compared to models for PV module grid-connected applications.

Scope

In future, a plug in repetitive current control can be employed on the grid side obtain better synchronization between the proposed solar micro inverter and the grid. Furthermore, along with the MPPT control a PID control to the boost converter might yield a better output. A model must be built to examine the results experimentally.

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