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Grid Connected Micro Inverter System Using Half Bridge Converter

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Abstract- This Article focuses a micro-inverter system connected to a grid. Past and present conditions of inverters are also focused. In this topology a dc-dc boost half bridge converter is connected to a low voltage PV side. A Pulse width modulated inverter is also integrate with this converter to supply synchronized current to the grid. An adopted Maximum power point tracking (MPPT) system is used to get maximum output.

Keywords- Boost-half-bridge, maximum power point tracking (MPPT), micro inverter.

1. Introduction

Photovoltaic (PV) Technology has developed rapidly over the last two decades from a small scale. The advancement of power electronics and semiconductor technologies the declining cost of solar panels and the favorable incentives of countries had insightful impact on the commercial acceptance of Grid-connected PV system. Which have been uses in peak shaving, demand reduction, and supply the remote loads[1][2].Apart from the solar panels ,the core technology associated with these systems is a power-conditioning system(Inverter) that converts the solar output electrically compatible with the utility grid[3].

Most inverters in the mid 1990's consisted of a central inverter of dc power rating over 1kw.They connect several solar panel strings via a dc-bus. However the concept has the draw-backs causing a complete loss of generation during inverter outage and losses due to the mismatch of strings[4].Later string inverter which are designed for a system of one string panels were used to lessen the problems and become popular at the present time. The Photovoltaic array system is widely used to generate power. Being a semiconductor device it can PV cell is static and the maintenance cost is low. Since PV module is non-linear it is necessary to model it for the design and simulation of maximum power point tracking (MPPT) for PV system application [5].A dual boost half bridge dc-dc converter is implemented [10]. In this paper the boost-half-bridge converter is incorporated as the dc-dc conversion stage for the grid connected PV micro-inverter system. A PWM inverter with LCL filter is used to synchronize with grid current.

2. Modeling of Grid Connected PV System

2.1. Model of PV array

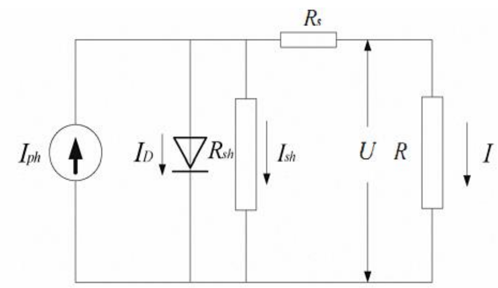


Fig. 1. Equivalent Circuit of the photovoltaic cell.

An ideal solar cell may be modeled by a current source in parallel with a diode [6]. In practice no solar cell is ideal and hence a shunt resistance and a series resistance are added to the model as shown in Fig.1.

An ideal solar cell may be modeled by a current source in parallel with a diode [6]. In practice no solar cell is ideal and hence a shunt resistance and a series resistance are added to the model as shown in Fig.1.

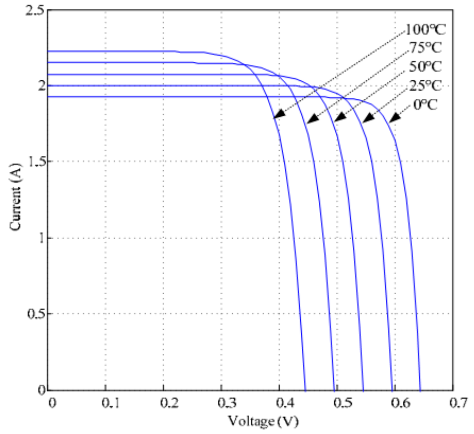
R_{sh} is the shunt resistance of the solar cell whose value is very large. R_s is the series resistance whose value is very small. Being the current-voltage relationship defined in equation 1 for grid connected PV system.

$$I = I_{sh}.\left\{1-\alpha\left[e^{\beta.U}-1\right]\right\} \quad (1)$$

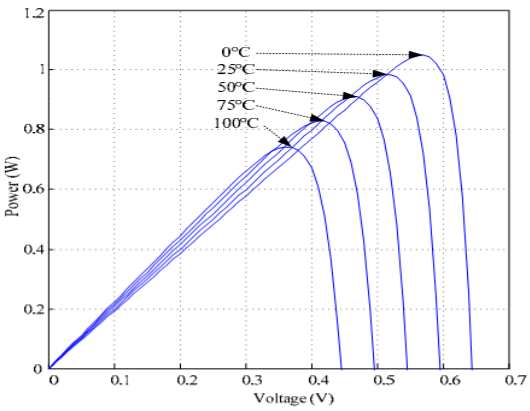
Where $\alpha = [\frac{I_{sc}-I_m}{I_{sc}}]^{\frac{U_{oc}}{U_{oc}-U_m}}$ and $\beta = \frac{1}{U_{oc}} \times \ln(\frac{1+\alpha}{\alpha})$

U_{oc} =open circuit voltage.
U_m =maximum power point voltage
U =PV array output voltage
I_0 =solar cell reverse saturation current.
I_m =current at maximum power-point.
I_{sc} =short-circuit current.
R_s =cell intrinsic series resistance
R_{sh} =cell intrinsic shunt or series resistance.

As can be clearly derived from (1) a highly nonlinear radiation and temperature dependent I-V and P-V characteristic curve is shown in below.



(a)



(b)

Fig. 2. a) I-V Characteristics of Different temperature b) P-V Characteristics of Different temperature.

2.2. Overview of PV Inverters

The past and present technology is illustrated in Fig.4. In past the system was based on centralized inverters that interfaced a large numbers of modules to the grid [7]. The PV modules were divided into series connections (called a string), each generating a sufficiently high voltage to avoid further amplification. Losses in the string diodes and a non flexible design where the benefits of mass production could not be reached. The present technology consists of the string inverters and the module. Where a single string of PV modules is connected to the inverter. Several strings are interfaced with their own dc-dc converter to a common dc-ac inverter. Since every string can be controlled individually.

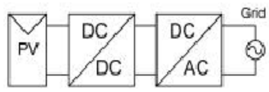


Fig. 3. Dual power processing inverter where the DC-DC converter is responsible for MPPT and the dc-ac inverter control the grid current. [7]

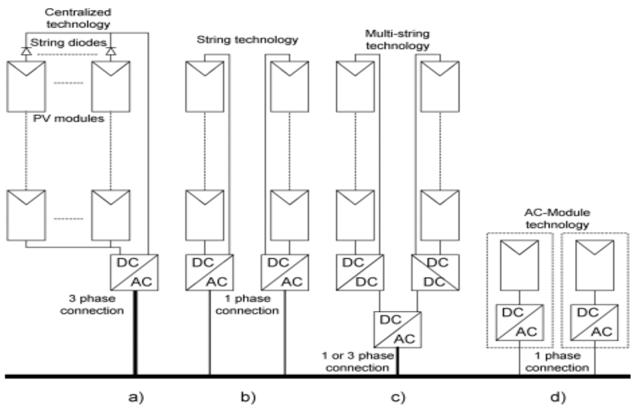


Fig. 4. Historical overview of PV inverters. (a) past centralized technology (b)present string technology (c) present and future multi string technology (d) present and future ac module and ac cell technologies[7].

3. Boost-Half Bridge PV Micro Inverter

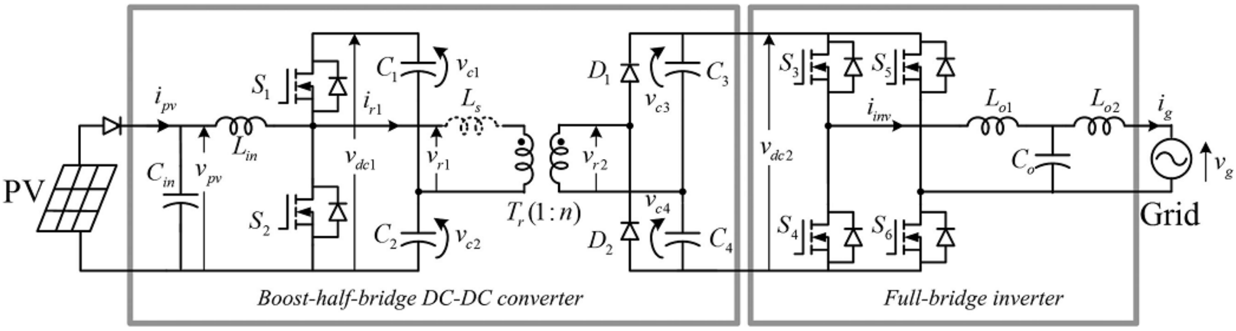


Fig. 5. Boost Half-Bridge micro-inverter.

The boost-bridge micro-inverter is shown in figure 5.It is composed of two decoupled power processing stages [8][9].In the forward dc-dc converter. a usual boost converter is modified by divided the output dc capacitor into two separate ones. C_{in} and L_{in} denote the input capacitor and boost inductor respectively. The center taps of the two MOSFETs (S_1 and S_2) and the two output capacitors $C_1$and $C_2$are connected to the primary terminals of the transformer T_r.As like half bridge. The transformer leakage inductance reflected to the primary is represented by L_s.and the transformer turns ratio is (1: n). A voltage doublers composed of two diodes D_1 and D_2 and two capacitors C_3 and C_4 is incorporated to rectify the transformer secondary voltage to the inverter dc link. A full-bridge inverter composed of four MOSFETs S_3 and S_6 using synchronized PWM control serves as the dc–ac conversion stage. Sinusoidal current with a unity power factor is supplied to the grid through a third-order LCL filter L_{01},L_{02} and C_0.

4. Operation of the Converter

The boost-half-Bridge converter is controlled by S_1 and S_2 with complementary duty cycle. Neglect all switching dead bands for simplifications. The idealized transformer operating waveforms are illustrated in Fig6. When S_1 is ON and S_2 is OFF, vr1 equals to vc1 when S_1 is OFF and S_2 is ON, v_{r1} equals to $-v_{c2}$. At the steady state, the transformer volt-second is always automatically balanced. In other words, the primary volt-second A1 (positive section) and A2 (negative section) are equal, so are the secondary volt-sec A3 (positive section) andA4 (negative section). Normally, D1 and D2 are ON and OFF in a similar manner as S_1 and S2, but with a phase delay t_{pd} due to the transformer leakage inductance. Ideally, the transformer current waveform is determined by the relationships of v_{c1} $-v_{c4}$, the leakage inductance L_S , the phase delay t_{pd} , and S_1 turn-ON time d_1T_{sw1} [8].The PV voltage v_{pv} and current i_{pv} are both sensed for calculation of the instantaneous PV power P_{pv}, the PV power variation ΔP_{pv}, and the PV voltage variation Δv_{pv}. The MPPT function block generates a reference $v*_{pv}$ for the inner loop of the PV voltage regulation, which is performed by the dc–dc converter. At the inverter side, the grid voltage v_g is sensed to extract the instantaneous sinusoidal angle θ_g , which is commonly known as the phase lock loop. The inverter output current i_{inv} is pre filtered by a first-order low-pass filter on the sensing circuitry to eliminate the HF noises. The filter output $i'_{i_{inv}}$ is then fed back to the controller for the inner loop regulation. Either vdc1 or vdc2 can be sensed for the dc-link voltage regulation as the outer loop. The power input P_{pv} from the panel is constant under a constant insolation and the power output P_g to the grid is time varying at twice of the grid frequency [2].

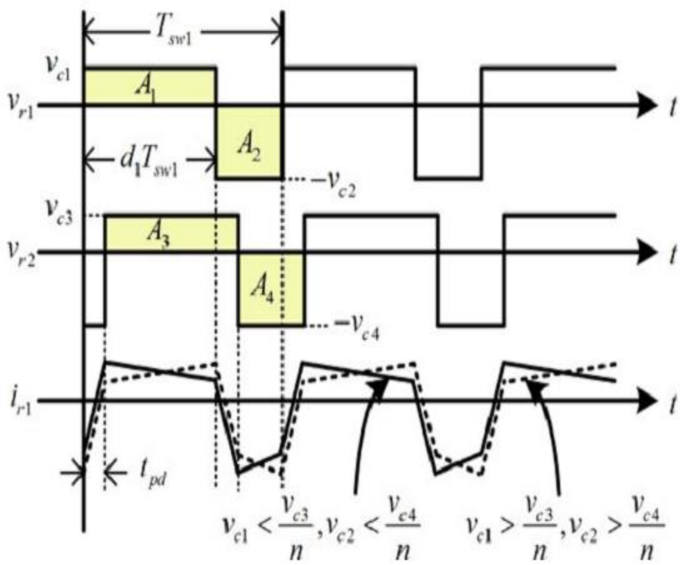


Fig. 6. Transformer Voltage and current.

Mathematically,

$$v_{c1} = \frac{1-d_1}{d_1} v_{pv} \quad (2)$$

$$v_{c2} = v_{PV}$$

$$v_{dc1} = \frac{v_{PV}}{d_1}$$

$$v_{c3} = \frac{n(1-d_1)}{d_1} v_{PV} \quad (3)$$

$$v_{c4} = nv_{PV}$$

$$v_{dc2} = \frac{nv_{pv}}{d_1}$$

$$v_g(t) = V_m \sin \omega t \quad (4)$$

$$i_g(t) = I_m \sin \omega t \quad (5)$$

$$P_g(t) = v_g(t) i_g(t) \quad (6)$$

$\left[v_g \right]$ the grid voltage is can be calculated by [8]

$$\left[v_g \right] = \frac{1}{2} \int_0^{\pi} v_g \, d\theta_g \quad (7)$$

The MPPT function block in a PV converter/inverter system periodically modifies the tracking reference of the PV voltage, or the PV current, or the modulation index, or the converter duty cycles. Table I & II summarizes the key parameter of Boost-Half-Bridge converter and Full-Bridge Inverter.

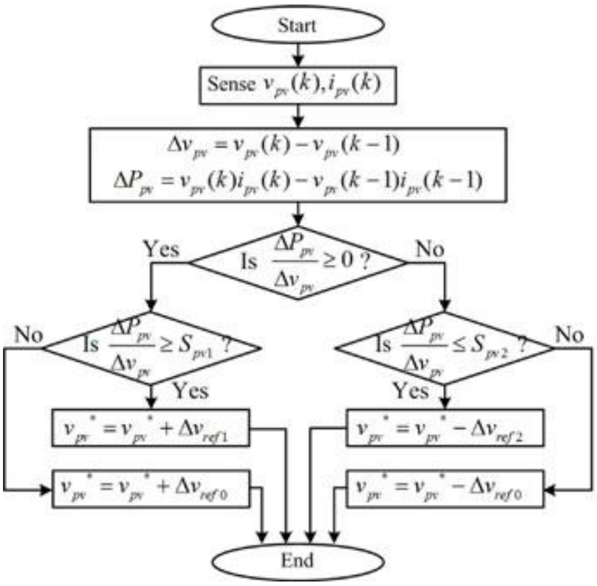


Fig. 7. Flow chart of MPPT

Table 1. Full Bridge Inverter

HVS DC link voltage	360V
Switching frequency	10.8 KHZ
Sampling frequency	10.8 KHZ
Rated output power	200W
Grid Voltage	180V
Grid Line frequency	60 HZ
Filter inductor L_{01} L_{02}	8.25 mH
Filter Capacitor	350mH

Table 2. Boost Half Bridge converter parameters

Input Voltage(MPPT)	25-60 V
Nominal PV Power	200W
Switching frequency	21.6 KHz
LVS DC link voltage	63V
Transformer turn ratio	1:6
Transformer magnetization inductors	0.7mh:25mH
Input Inductor	200 µH

5. Simulation Results

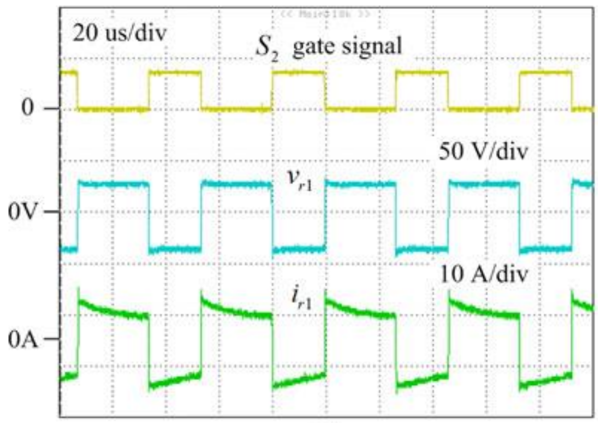


Fig. 8. Transformer voltage responses.

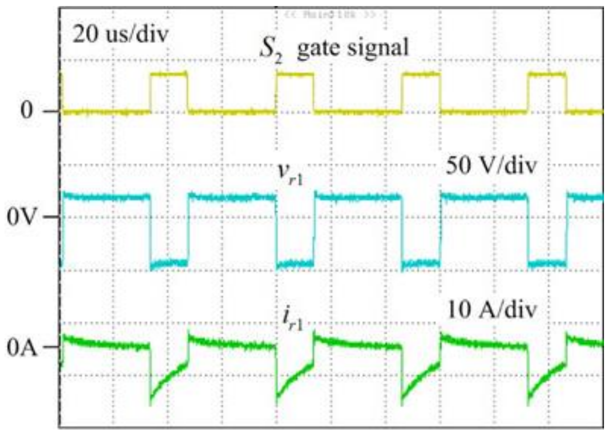


Fig. 9. Transformer current responses.

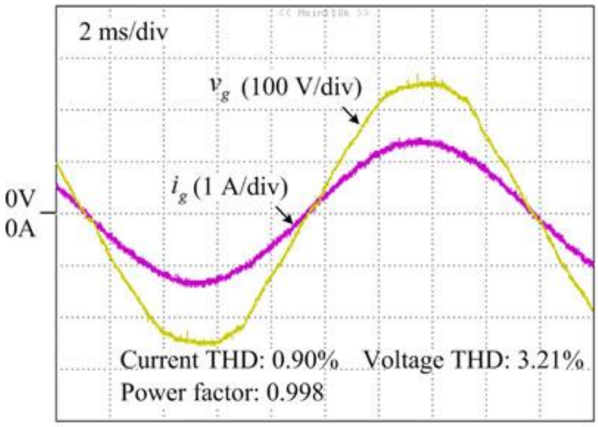


Fig. 10. Steady-state grid voltage and current at heavy load.

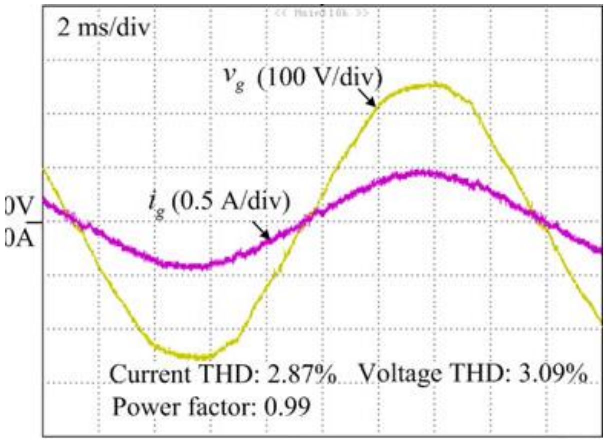


Fig. 11. Steady-state grid voltage and current at light load.

6. Conclusion

A boost half-bridge micro-inverter is presented in this paper. The operation principle is analyzed. Simulation result is shown to verify the circuit. The customized MPPT method is ensured that reliable operation of PV micro-inverter system. So it could be the model of the Distributed Generation system.

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