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A NEW TRANSFORMERLESS INVERTER FOR SINGLE-PHASE GRID CONNECTED PHOTOVOLTAIC SYSTEM WITH LOW LEAKAGE CURRENT

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Abstract-The Photo Voltaic (PV) energy system, used in this project, is a very new concept in use, which is gaining immense popularity due to increasing system importance to research on alternative sources of energy over depletion of the conventional fossil fuels all around the world. Total systems which are being developed extract energy from the sun in the most efficient manner and suit them to the local available loads without affecting their performance. There is a strong trend in the photovoltaic (PV) inverter technology to use without transformer topologies in order to acquire higher efficiencies combining with very low ground leakage current. a new topology, based on the H Bridge with a new AC bypass circuit consisting in a output diode rectifier and a switch with clamping to the DC midpoint is proposed. The proposed topology is simulated and experimentally validated and comparison with other existing topologies is performed. Mainly High conversion efficiency and low leakage current is demonstrated. For the current controller a ramp time zero average current error control algorithm combined with a system optimized cyclic switching sequence is suggested. Simulation results have been presented to demonstrate the suitability of the control method. Simulation results exhibits improved performance under the system presence of harmonics and the studied system is modeled and simulated in the MATLAB/Simulink.

Keywords: Maximum power point Tracking, H6 Topology, DC-DC Buck Boost, and MATLAB.

1. INTRODUCTION

With in the world energy demand increasing at an exponential rate, the search for energy sources other than fossil fuels is no longer the luxury. Although the fossil fuels offer a temporary solution to this energy crisis, they cause the emission of the carbon dioxide and other greenhouse gases, which are harmful to the environment. This has paved the way for research on the renewable energy technology and other researches in the fields of power electronics and hence, the cost of utilizing the system renewable energy is at an ever decreasing rate [1]. One such source of renewable energy, the Sun, offers unlimited another energy for harnessing and for this very reason, Photovoltaic (PV) systems consisting of PV modules, for generating environmental friendly system power are gaining more and more recognition with each passing day. The PV modules system comprise of the several solar cells, which convert the energy of the sunlight directly into electricity, and are connected system as required to provide desired lev els of DC current and voltage. SPWM or sinusoidal pulse width modulation is widely used in the power electronics to digitize the power so that a sequence of voltage pulses can be generated by the energy on and off of the power switches (Ismail, 2006a). The pulse width modulation inverter has been the main choice in power electronic for decades, because of its circuit simplicity and rugged control scheme (Bellar et al., 1998). SPWM switching technique is commonly used in industrial applications (Ismail, 2006b) (Rashid, 2004). SPWM techniques are characterized by the constant amplitude pulses with different duty cycle for each period.

2. COMMON-MODE CURRENTS IN TRANSFORMERLESS PV SYSTEMS

When without transformer is used, a galvanic connection between the ground of the grid and the PV array exists. As a consequence a common-mode resonant circuit with appears, consisting of the stray capacity between the PV modules and the ground, the dc filter and ac filter elements, and the grid impedance (Fig. 2.1). A varying common-mode voltage can excite this resonant circuit and generate to a common-mode current. Due to the large surface of the PV generator, its stray capacity with the respect to the ground reaches values that can be even higher than 200 nF/kWp in damp environments or on rainy days. These system high values can generate ground currents with amplitudes well above the permissible levels, such as the system those concerning the standards. The currents can cause severe (conducted and radiated) electromagnetic interferences, distortion in the grid current connected and additional losses in the system. These leakage currents can be avoided, or at least limited, by system including damping passive components in the resonant circuit. Obviously, additional losses will appear in the damping elements, thus decreasing the conversion stage efficiency. The use of conversion topologies with a constant system common mode voltage is another option. The instantaneous common mode voltage Vcm in the full-bridge inverter of Fig. 1 can be calculated from the system voltage of the two mid-points of both legs, V_{AO} and V_{BO} as

$$Vcm = \frac{V_{AO}+V_{BO}}{2} \tag{2.1}$$

To avoid leakage currents, the common-mode voltage must be kept constant during all commutation states, that is

$$Vcm = V_{AO} + V_{BO}$$

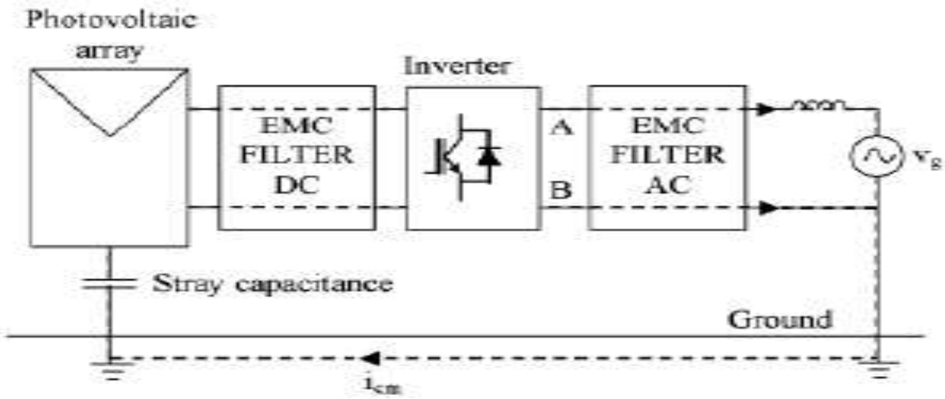

Fig. 2.1 common-mode currents in a transformer less conversion stage

3.1 MODELLING OF PV MODULE

The most commonly used model for PV-cell is one – diode equivalent circuit as shown in figure (3.1). Since the shunt resistance Rsh is large, it is normally neglected. This simplified circuit is used in this paper for modeling of a PV-cell.

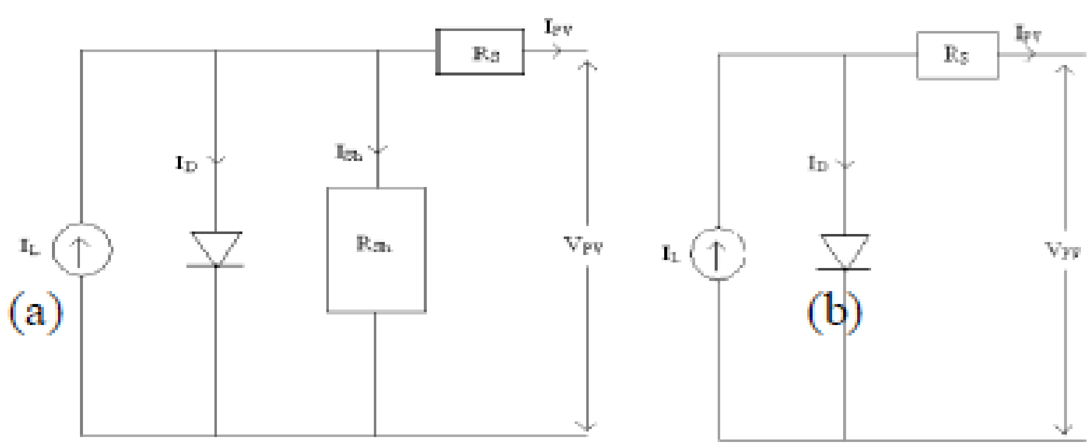

Fig. 3.1 One-diode equivalent circuit model for a PV cell. (a) Five parameters model; (b) Simplified four parameters model

The non-linear of V_{pv}-I_{pv} and P-V curves are correspondingly drawn as shown below:

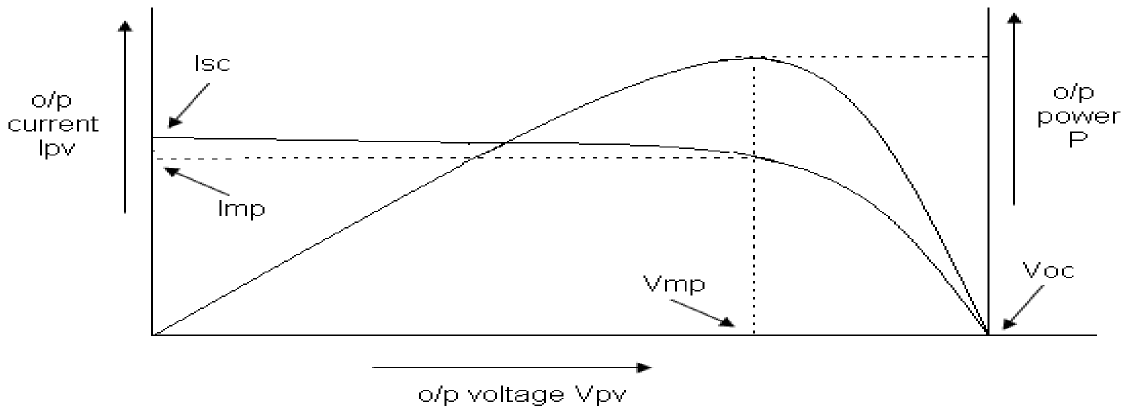

Fig. 3.2 Vpv-Ipv & P-Vpv characteristics of a PV cell from figure (b) the relation between the output Vpv and the output current Ipv can be expressed as:

$$I_{PV}=I_L-I_D$$

$$I_{PV} = I_L - I_O\left(exp\left(\frac{V_{PV}+I_{PV}R_S}{\propto}\right)-1\right) \quad (3.1)$$

Where IL= Light current; Io= Saturation current; Rs= Series Resistance; α = Thermal voltage timing completion factor. The above four parameters are need to be determined to obtain the I-V characteristics of PV-module. Thus, this model can be termed as Four-parameter model. The equations for determining the four parameters are given below:

3.1 Light Current (IL)

$$I_L = \frac{G}{G_{ref}}\left(I_{Lref} + \mu_{ISC}(T_C - T_{Cref})\right) \quad (3.2)$$

G=irradiance (W/m2); Gref = reference irradiance (1000 W/m2 is used in this study); I_{Lref}= light current at the reference condition (1000W/m2 and 25 ˚C); Tc = PV cell temperature (˚C); T_{cref} = reference temperature (25 ˚C is used in this study); μ_{Isc} = temperature coefficient of the short-circuit current (A/˚C). From the above equation for light current it can be observed that IL is a function of both temperature and irradiance. Both ILref and μIsc can be obtained from manufacturer data sheet.

3.2 Saturation Current (IO)

$$I_0 = I_{Oref}\left(\frac{T_c+273}{T_{cref}+273}\right)^3 \exp\left(\frac{e_{gap}\,q}{N_S \propto_{ref}}\left(1-\frac{T_{cref}+273}{T_c+273}\right)\right) \quad (3.3)$$

Where I_{oref}= saturation current at the reference condition (A); egap = band gap of the material 1.17 eV for Si materials); N_s = number of cells in series of a PV module; q = charge of an electron (1.60217733×10-19 C); α_{ref} = the value of α at reference condition. Ioref can be calculated as:
Where Vocref = the open circuit voltage of the PV module at reference condition (V).

3.3Calculation of α

$$I_{oref} = I_{Lref} \exp\left(-\frac{V_{OCref}}{\propto_{ref}}\right) \quad (3.4)$$

$$\propto = \frac{T_C+273}{T_{cref}+273}\propto_{ref} \quad (3.5)$$

The value of α_{ref} can be calculated as:

$$\propto_{ref} \frac{2v_{mpref}-v_{ocref}}{\frac{I_{scref}}{I_{scref}-I_{mpref}}+In\left(1-\frac{I_{mpref}}{I_{scref}}\right)} \quad (3.6)$$

Where V_{mpref} = maximum power point voltage at the reference condition (V); I_{mpref} = maximum power point current at the reference condition (A); I_{scref} = short circuit current at the reference condition (A).

3.4 Series Resistance (RS)

Some manufacturers provide the value of Rs. If not provided, the following equation can be used to estimate its value:

$$R_s = \frac{\propto_{ref} In\left(1-\frac{I_{mpref}}{I_{scref}}\right)+V_{ocref}-V_{mpref}}{I_{mpref}} \quad (3.7)$$

RS is taken as a constant in the model of this study.

3.5 Thermal Model of PV

From equations (2.1) to (3.7), it can be noted that the temperature plays an important role in the PV performance. Therefore, it is necessary to have a thermal model for a PV cell/module. In this study, a lumped thermal model is developed for the PV module. The temperature of the PV module varies with surrounding temperature, irradiance, and its output current and voltage, and can be written as:

$$C_{pv} \frac{d_{TC}}{dt} = K_{inpv}G - \frac{V_{pv}\, I_{pv}}{A} - K_{loss}\,(T_c - T_a \quad (3.8)$$

CPV =the overall heat capacity per unit area of the PVcell /module [J/(˚C-m2)]; K_{inpv}= Transmittance-absorption product of PV cells; K_{loss} = overall heat loss coefficient[W/(˚C-m2)];Ta=ambient temperature (˚C); A = effective area of the PV cell/module (m2).

4. H5 TRANSFORMERLESS TOPOLOGY

4.1 Circuit Configuration and Operation Principle

The new inverter topology proposed in [6] is called H5 topology which is shown in Figure 3. It is made up by adding an extra switch S5 with standard new H-Bridge topology. LA, LB, and Co constructs the LCL type filter which is coupled to the grid. In this topology, uni-polar SPWM is applied with three level output voltage. This topology can meet the condition of eliminating the CM leakage current. In the positive half cycle of grid current, switch S5 and S4 are commutates with switching frequency. During the test zero voltage vectors, S5 and S4 are turned-off and the freewheeling current flows through S1 and the convert anti-parallel diode of S3. In the negative half cycle, S5 and S2 are commutates with switching frequency and the freewheeling current flows through S3 switch and the anti parallel diode of S1.

4.2 Common Mode Voltage and Leakage Current

The CM voltage and the leakage current for H5 topology can be calculated using equation (2.1) and (3.1).

$$V_{cm} = \frac{V_{AO} + V_{BO}}{2} \quad (4.1)$$

$$i_{CM} = C_{PV} \frac{dV_{CM}}{dt} \quad (4.2)$$

Where, VAN and VBN are the voltages of the full-bridge inverter from mid-point A and B of the bridge leg to the reference terminal N. Figure 4 shows the waveform of CM voltage and leakage current of H5 topology. We can see that a small variation of CM voltage is existed and as a result, a non-negligible leakage current is generated.

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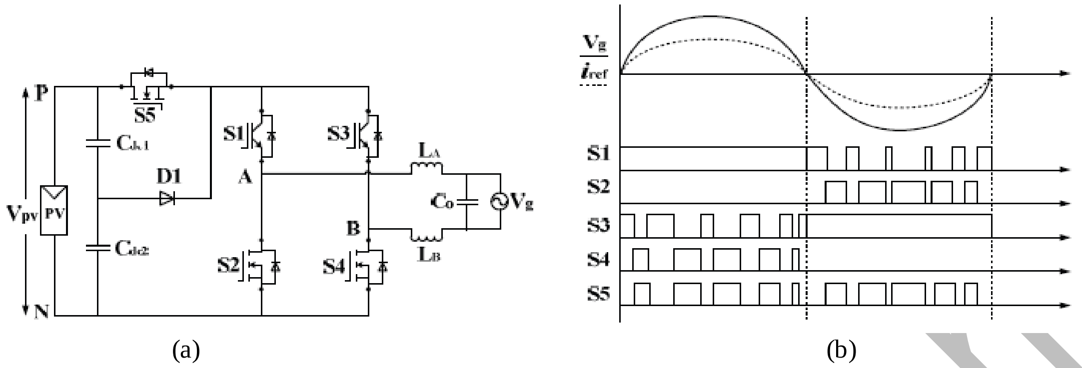

Fig. 4.1 Proposed transformers-less grid-tied PV inverter (a) proposed circuit configuration (b) Switching signals with unity power factor.

5. PROPOSED TOPOLOGY

5.1 Circuit Structure

In order to the system de-couple the AC-DC converter from the grid in the freewheeling mode, an extra MOSFET switch is added into the conventional full H-Bridge topology two lower high frequency IGBT switches of two phase legs are replaced by the MOSFET switches in this paper which is shown in Figure 5(a). Also a diode and a capacitor divider are added to clamp the short circuit output voltage at the mid-point of DC link voltage. LA, LB, and Co constructs the LCL type filter coupled to the grid. in this topology can achieve three level output voltage with uni-polar SPWM.

5.2 Operation Principle Analysis

Grid connected photovoltaic system generally operate at unity power factor. Figure 5(b) shows the waveform of the switching pattern for the new proposed topology. The operation principle is very similar to the H5 topology shown in Figure 6. Consequently, the four operational modes are proposed that produce the output voltage states of +VPV, 0, and –VPV.

1) Mode 1 is the active mode in positive half cycle of grid current. When S1, S4 and S5 are turned-on, the voltage VAN = VPV and VBN = 0, thus VAB = VPV and the CM voltage, Vcm = (VAN + VBN)/2 = VPV/2.

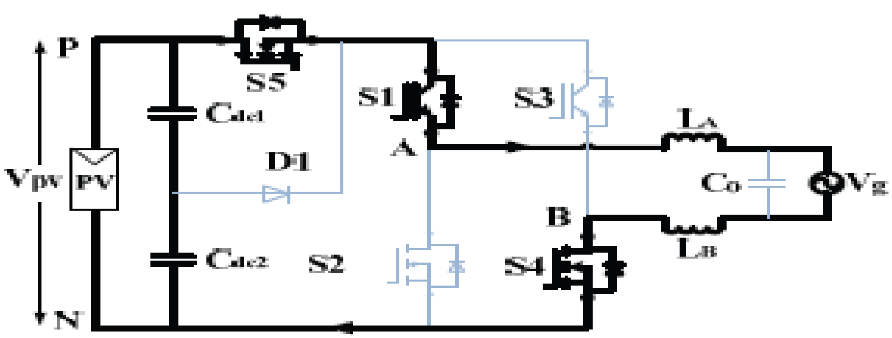

Fig. 5.1 Operation principle of the proposed topology active mode

2) Mode 2 is the freewheeling mode in the positive half cycle of grid current as shown in Figure 6(b). The freewheeling current flows through S1 and body diode of S3.

6. RESULTS

In order to verify the theoretical analysis, the proposed topology has been simulated by MATLAB/Simulink software using the test parameters given in Table I. Figure 7 shows the simulated and experimental waveform of VAN, VBN, and Vcm. From figure 7(a), it can be seen the CM mode voltage kept constant at the half of DC input voltage 200V. As a result, the generated leakage current value is almost zero which is shown in Figure 8(c). Experimental Results of CM mode voltages are shown in Figure 7(b) shows the same characteristics as simulation. Experimental result of leakage current is shown in Figure 9, shows that the peak and RMS values are successively limited within 45mA and 8mA, respectively.

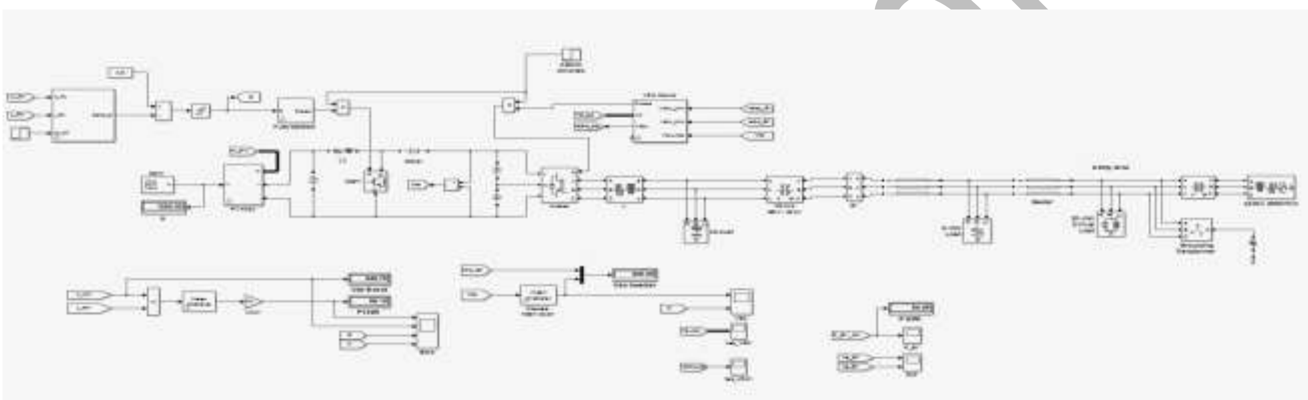

Fig. 6.1 Overall Simulation Diagram

Table 6.1 Parameters Used in Simulation

AC output current	4.1A
Switching Frequency	20kHz
DC bus capacitor	470µF
Filter capacitor	2.2µF
Filter Inductor LA, LB	3mH
PV parasitic capacitor Cpv1, Cpv2	75nF
Input Voltage	400VDC
Grid Voltage / Frequency	230V / 50Hz
Rated Power	1000 W
Inverter Parameter	Value

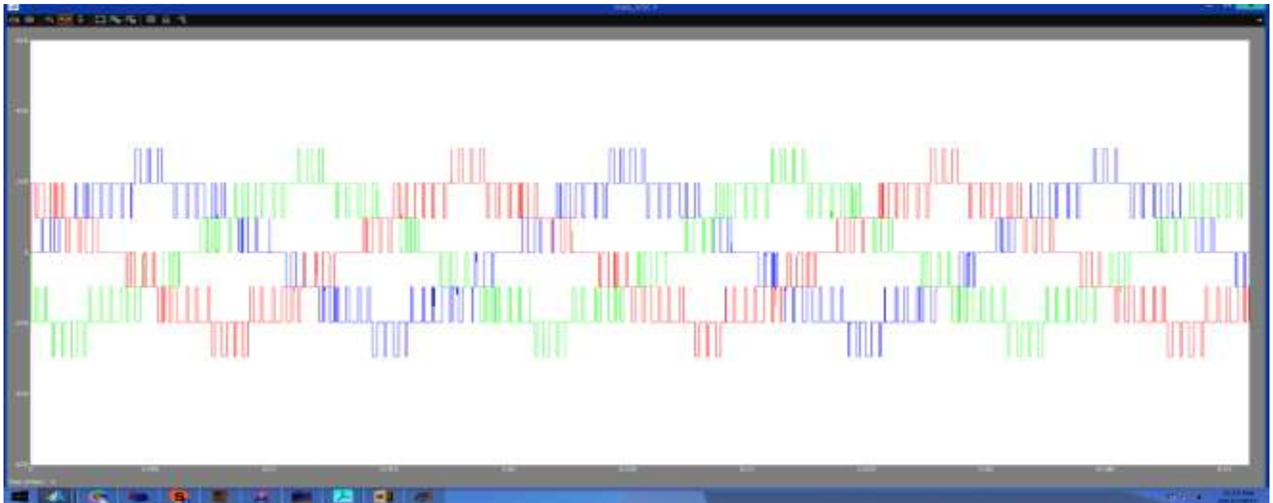

Fig. 6.2 Inverter Vabc

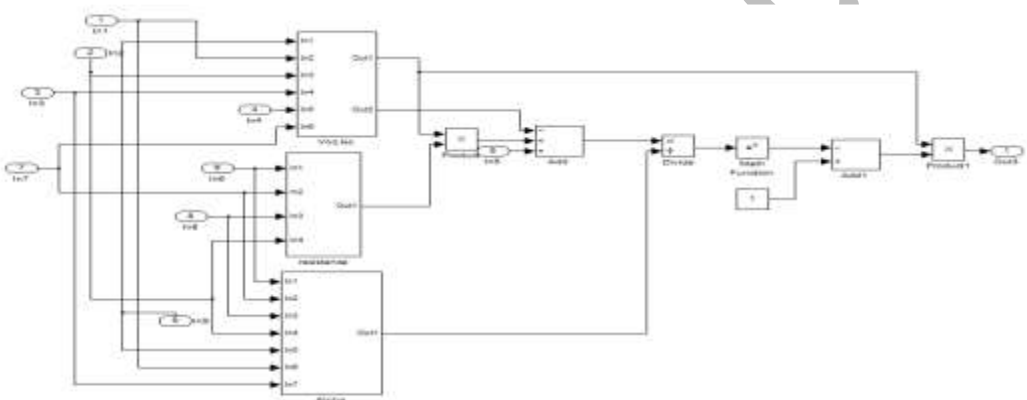

Fig. 6.3 PV Module Structure

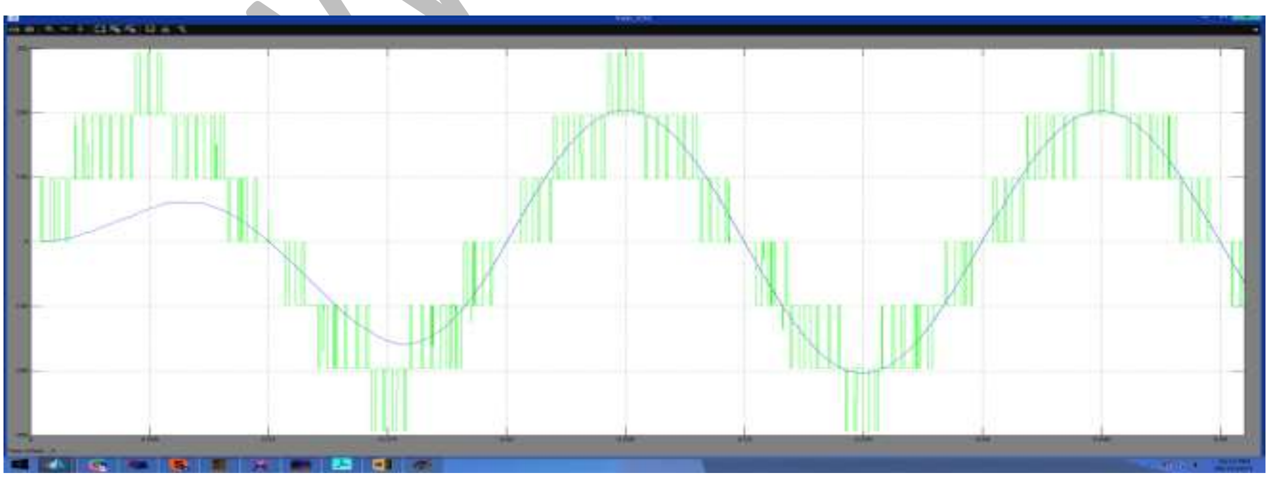

Fig. 6.4 Inverter Va

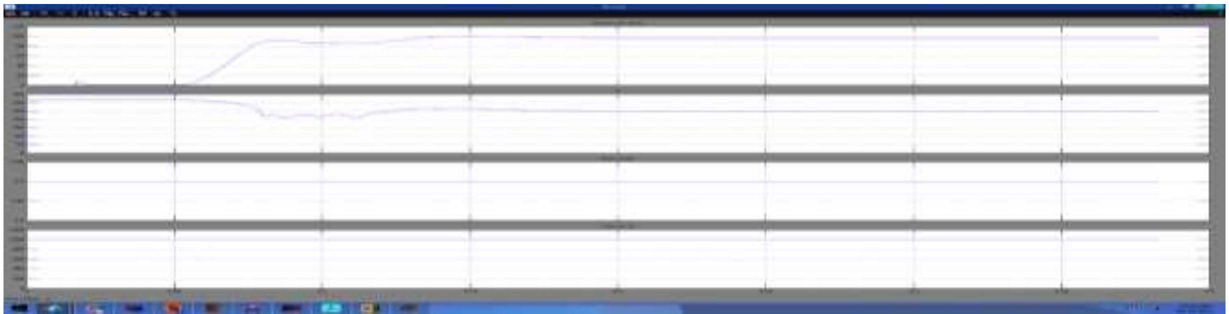

Fig. 6.5 PV Input Power, Voltage, and Ir

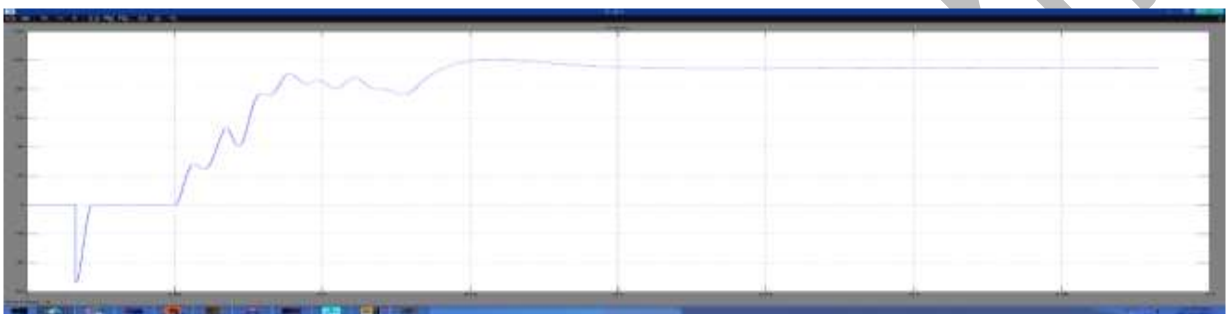

Fig. 6.6 Inverter Output Power

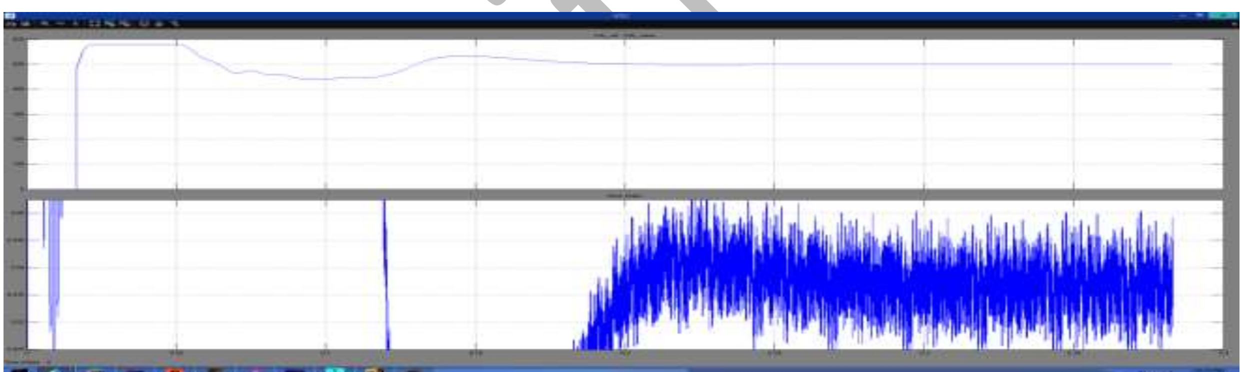

Fig. 6.7 MPPT Output Voltage and Mod. Index

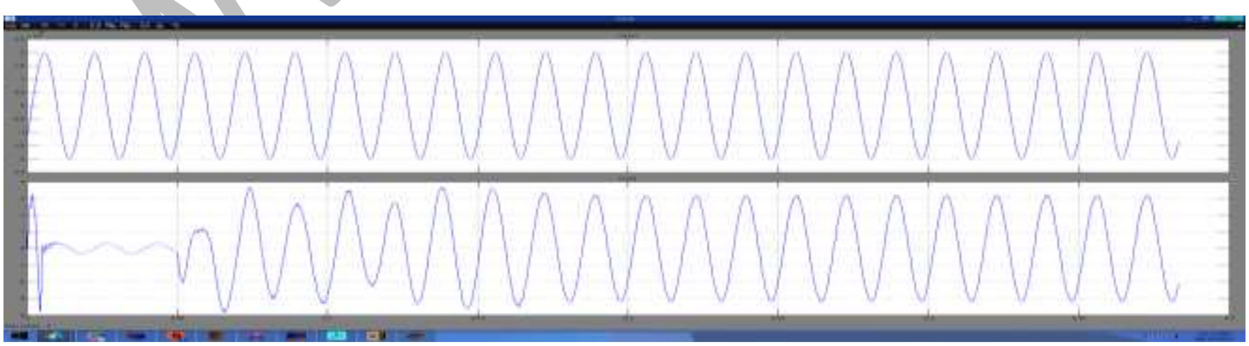

Fig. 6.8 Grid Voltage and Current

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CONCLUSION

A new single phase transformer-less inverter for grid connected PV system have been presented. Also major transformer-less all topologies are reviewed based on leakage current, advantages, and disadvantages. It is found that these topologies have some drawbacks such as current and efficiency. However, The CM voltage of the proposed topology is clamped to half of DC input voltage, thus leakage current is well suppressed. The inverter output, voltage has three levels by e employing uni-polar SPWM with good differential mode characteristics. The waveform of output current shows that the proposed inverter can convert the solar power to a high q quality ac power to inject into utility grid. Furthermore, the proposed inverter achieved higher efficiency. Therefore, it can be concluded that the proposed inverter is very suitable for single phase grid connected PV system.

REFERENCES

[1] I. Patrao, E. Figueres, F. González-Espín, and G. Garcerá, "Transformerless topologies for grid-connected single-phase photovoltaic inverters," Renewable and Sustainable Energy Reviews, vol. 15, pp. 3423-3431, 2011.

[2] X. Zhang, Y. Li, Z. Lin, H. Xu, “LCL filter of voltage-type PWM rectifiers, active damping control,” Electric Drive, vol. 37, no. 11, pp. 22-25, 2007.

[3] R. Gonzalez, J. Lopez, P. Sanchis, and L. Marroyo, "Transformerless Inverter for Single-Phase Photovoltaic Systems," IEEE Transactions on Power Electronics, vol. 22, pp. 693-697, 2007.

[4] C. Zhang, Y. Ye, and A. Chen, “Based on the output current control of grid- connected solar power inverter,” Electric Power Systems, vol. 22, no. 8, pp. 41-45, 2007.

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