Comparative analysis of PWM techniques for Photovoltaic application with HERIC inverter

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ABSTRACT

Photovoltaic inverters achieves an effective and efficient system and plays an important role in reducing the total cost of the system. The main objective of this paper is to develope mathematical model and analyse the performance of photovoltaic fed HERIC inverter for different Pulse-Width Modulation (PWM) techniques. The two different carrier signals such as sinusoidal carrier signal and triangular carrier signals are used. The required PWM pulses are generated by comparing the trapezoidal reference signal with those carrier signals. The simulation is carried out using MATLAB/Simulink. The performance indices used in this comparison are THD, output power, fundamental output voltage and RMS value of output voltage.

Indexing terms/Keywords

HERIC; transformerless inverter; photovoltaic; PWM; THD; renewable energy

Academic Discipline And Sub-Disciplines

Electrical Engineering

SUBJECT CLASSIFICATION

Power Electronics

TYPE

Research Article

1. INTRODUCTION

Grid connected photovoltaic inverters converts the available DC source to ac and feed it into the grid. The grid-tied inverters should be designed carefully to achieve high efficiency, low cost, small size and less weight. Photovoltaic inverters can be classified into two groups: transformer type and transformerless type inverter. The full bridge inverters are widely used for photovoltaic applications. The transformer based inverter has many drwbacks which includes bulky, less efficiency, less durability and high cost. To overcome these drawbacks, a transformerless inverters are introduced for photovoltaic appilications. The elimination of transformers increases the flow of leakage current due to the absence of galvanic isolation [1] . The flow of leakage current increases the total harmonic distortion (THD), reduces the efficiency and introduces electromagnetic interference. Many researchers proposed different techniques to reduce the leakage current and improve the efficiency of the transformerless inverter [2]-[4]. To reduce the leakage current in the transformerless photovoltaic inverters, a HERIC (Highly Efficient and Reliable Inverter Concept) topology was used which was derived from full bridge converter and was commercialized by Sunways[8]. The HERIC topology has many advantages which includes higher efficiency, lower cost, less complexity and minimum leakage current. In this paper, the performance of photovoltaic fed HERIC inverter is analysed for different PWM techniques. The name photovoltaic is included sinch the solar cell is acted as a DC source.

2. MODEL OF PV ARRAY

A photovoltaic cell is basically a P-N semiconductor junction diode. It helps to convert solar energy into electrical energy. A practical solar cell is modeled as a current source in parallel with a diode, a series resistor (R_S) and a shunt resistor (R_P) called as 'single-diode' model of solar cell is shown in Fig. 1 [5]-[7]. The value of series resistor is small when compared with shunt resistor. By Kirchhoff's Current Law (KCL), we get

$$I_S = I_D + I_R + I_{PV} \quad (1)$$

$$\text{or } I_S = I_D + \frac{V_D}{R_p} + I_{PV} \quad (2)$$

Where, I_D is the current in the bypass diode, I_{PV} is the solar cell current, I_S is the isolation current, and V_{PV} is the voltage across solar cell.

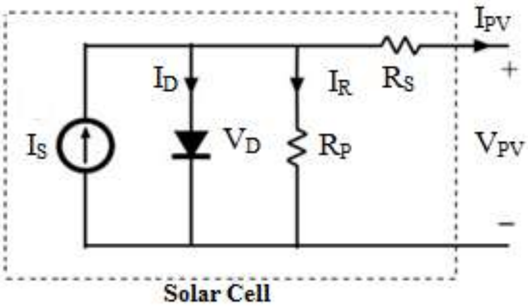


Fig. 1. Equivalent circuit of a solar cell

The characteristics equation of bypass diode across the photovoltaic module is given by the equation,

$$I_D = I_O(e^{V_D/V_T} - 1) \quad (3)$$

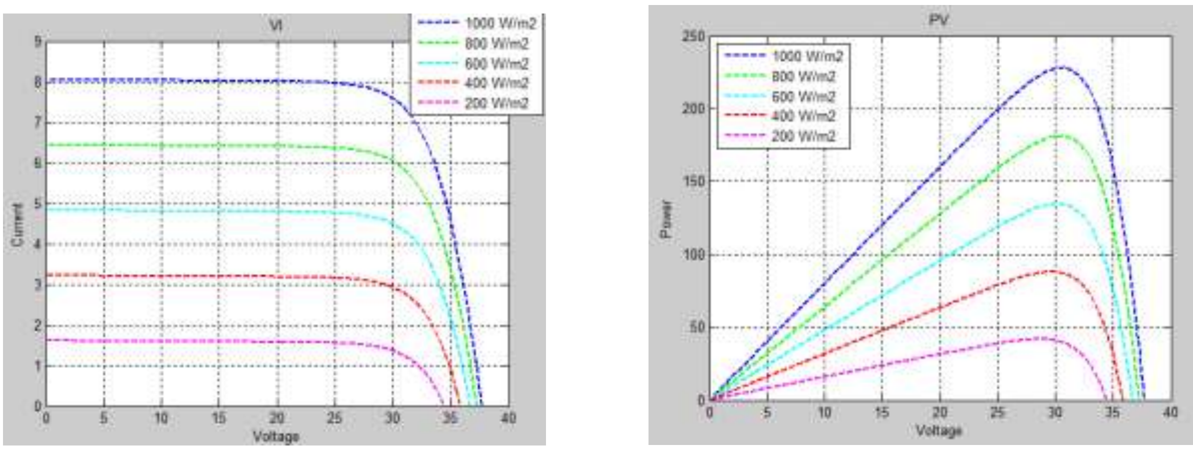
Where, I_O is the reverse saturation current and V_T is the thermal voltage.

Since, the photovoltaic array is made up of several solar cells connected in series; the current in each of the series solar array is given by the equation,

$$I_{PV} = I_S - I_o\left(e^{V_D/N_s V_T} - 1\right) - \frac{V_{PV} + R_S I_{PV}}{R_P} \quad (4)$$

Where, N_S is the number of solar cells in series.

The voltage-current (VI) and power-voltage (PV) characteristics of the typical single diode solar cell for different isolation is shown in Fig.2. Due to the variation in the solar irradiation, the photovoltaic array exhibits nonlinear power-voltage (PV) and voltage-current (VI) characteristics.



(a) (b)

Fig. 2. Solar cell (a) VI characteristics (b) PV characteristics

3. HERIC INVERTER

The Highly Efficient and Reliable Inverter Concept (HERIC) topology which consists of DC link capacitor, output inductor filters and output capacitor filter is shown in Fig. 3. [8].

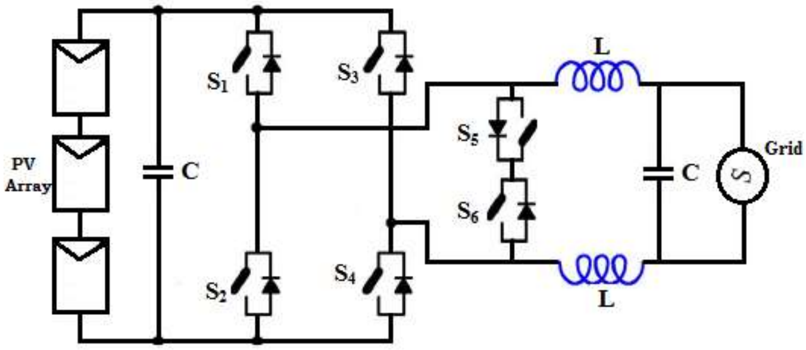
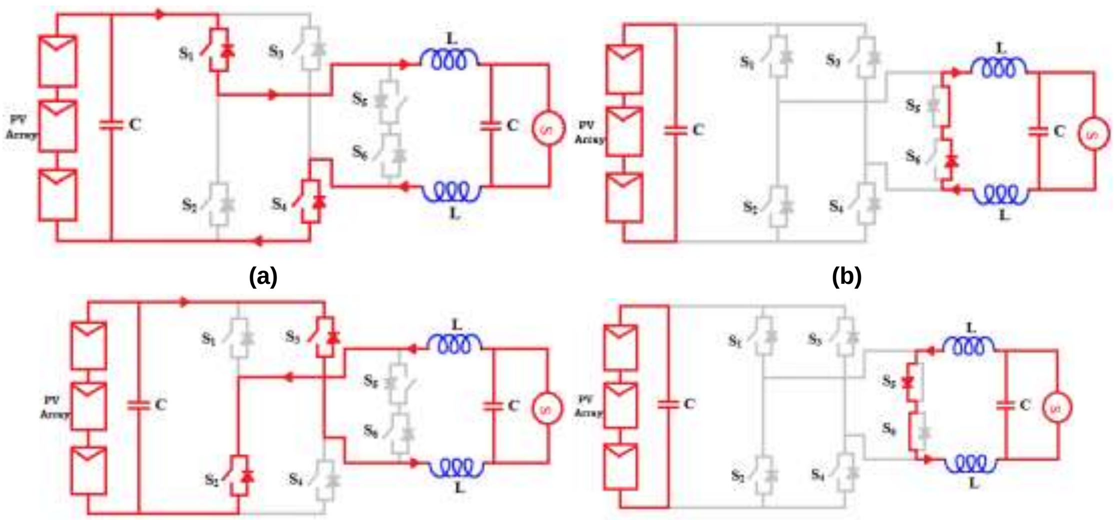


Fig. 3. HERIC inverter

A bypass leg in the AC side of the converter is made of two back-to-back power electronic switches. These switches are operating at the grid frequency. The bypass leg helps to decouple the photovoltaic array from the grid during overvoltage conditions and prevent the reactive power exchange between the output filters and the input capacitor. Thus, it increases the efficiency of the converter. The different modes of operation of the HERIC inverter are shown in Fig. 4.



(a) **(b)**

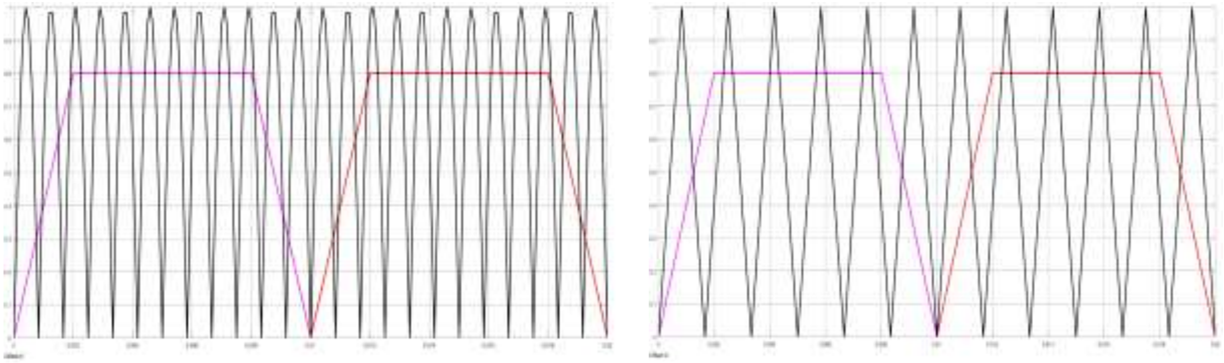
(c) **(d)**

Fig. 4. Modes of operation (a) Active mode during positive half period (b) Freewheeling mode in the positive half period (c) Active mode during negative half period (d) Freewheeling mode during negative half period

In mode-1, the switches S_1 and S_4 are ON and the current flows from the DC side to the load as shown in Fig. 4 (a). In mode-2, the switches S_1 and S_4 are OFF and the direction of current flow to the load is shown in Fig. 4 (b). The switches S_2 and S_3 are ON during mode-3 and hence the current will flow on the reverse direction as shown in Fig. 4 (c). The direction of current flow to the load during mode-4 is shown in Fig.4(d) where the switches S_2 and S_3 are OFF. Here, the switch S_5 is turned ON during the positive half cycle and the switch S_6 is turned ON during the negative half cycle. The switch S_5 or S_6 is used during the isolation of the grid from the photovoltaic array, which considerably reduces the leakage current.

4. SIMULATION RESULTS AND DISCUSSION

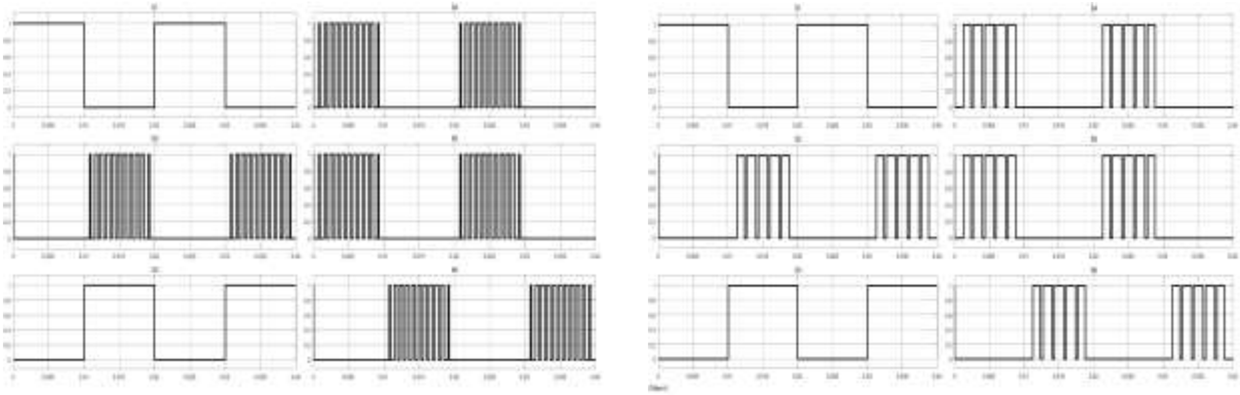
In this paper, the performance of the HERIC inverter is analysed for both the triangular carrier signal and sinusoidal carrier signal based PWM techniques.The trapezoidal signal is used as a reference in both the cases. Fig. 5. shows the generation of switching pulses using sinusoidal carrier and triangular carrier based PWM methods.



(a) **(b)**

Fig. 5. PWM methods (a) Sinusoidal carrier based PWM method (b) Triangular carrier based PWM method

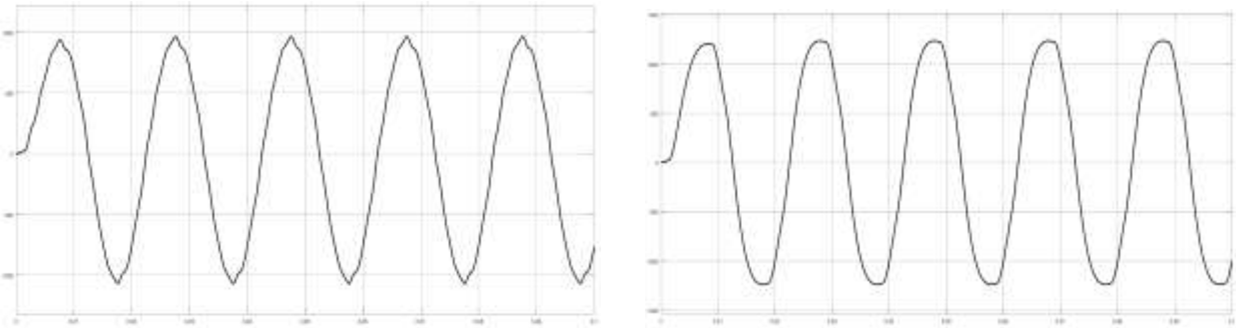
Fig. 6 shows the switching pulses generated for HERIC inverter using sinusoidal carrier based PWM technique and triangular carrier based PWM technique.



(a) **(b)**

Fig. 6. Switching Pulses generated using (a) Sinusoidal carrier based PWM method (b) Triangular carrier based PWM method

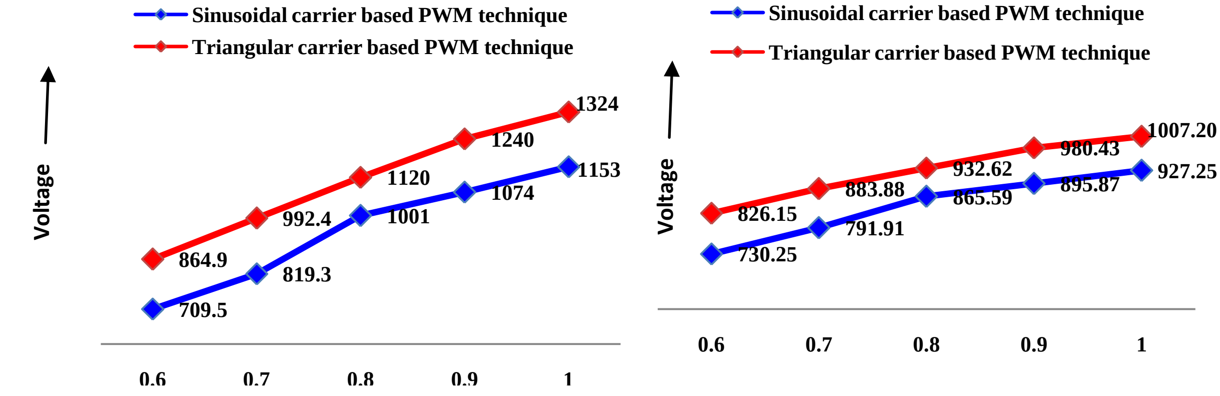
Fig.7 shows the output voltage of HERIC inverter obtained using sinusoidal carrier based PWM technique and triangular carrier based PWM technique.



(a) **(b)**

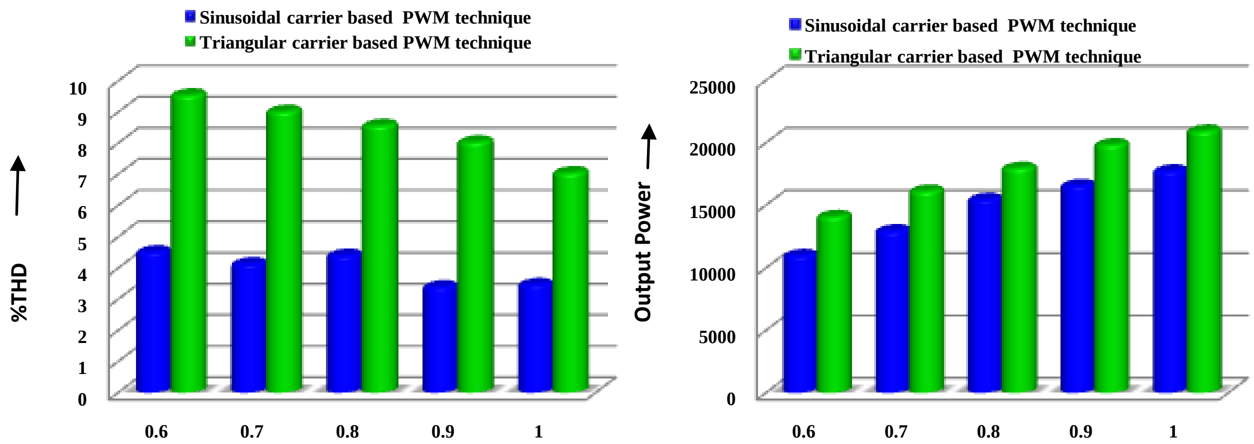
Fig. 7. Output voltage (a) Sinusoidal carrier based PWM method (b) Triangular carrier based PWM method

Fig. 8 shows the comparison of the fundamental value and RMS value of the output voltage for both the sinusoidal carrier based PWM technique and triangular carrier based PWM technique. The results shows that both fundamental value and RMS value of the output voltage for triangular carrier based PWM technique are higher than those with conventional sinusoidal carrier based PWM technique. It is also observed that increase in the modulation index increases both these values for both conventional sinusoidal and triangular carrier based PWM techniques. The comparison of the total harmonic distortion and output power are shown in Fig. 9 (a) and (b) respectively.



(a) (b)

Fig. 8. Comparison (a) Fundamental value of output voltage (b) RMS value of output voltage



(a) (b)

Fig. 9. Comparison (a) Total harmonic distortion (b) Output power

The result shows that triangular carrier based PWM technique introduces more total harmonic distortion as compared with the sinusoidal carrier based PWM technique. However, triangular carrier based PWM technique achieves higher output power as that of sinusoidal PWM technique.

5. CONCLUSION

The performance of the HERIC inverter is analysed for both sinusoidal carrier based and triangular carrier based PWM techniques. A single diode photovoltaic model is developed using MATLAB/Simulink software. It is observed that increase in the modulation index decreases the %THD and increases the output voltage and the load power for both PWM techniques. The results shows that the triangular PWM technique provides satisfactory performance to achieve higher output voltage and load power from the photovoltaic fed HERIC inverter as compared to the conventional sinusoidal PWM technique. However, lesser total harmonic distortion is achieved with the sinusoidal PWM technique as compared with the triangular PWM technique

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