Harmonic reduction technique on multilevel single phase transformerless photovoltaic inverter

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Abstract

This paper presents a new topology of multilevel single phase transformerless photovoltaic (PV) inverter. In this topology, a 240V AC system is developed from a full bridge inverter circuit using PIC microcontroller (PIC16F628A-I/P) connected to a PV array through a power factor correction circuit. The output waveform of the inverter depends on the type of pulse driver. Objective of this paper is to optimize the maximum voltage angle to obtain the lowest current total harmonic distortion (CTHD) on the multilevel single phase transformerless inverter. In this paper, the maximum voltage angle optimization of the AC multilevel waveform transformerless PV inverter is developed and created by a microcontroller PIC16F627A-I/P changing maximum voltage angle of the AC multilevel waveform from 20° to 180°. Resistive load of 30 W lamp and inductive load of 20 W water pump are applied to the multilevel single phase transformerless PV inverter. The result shows that the lowest CTHD of 15.448% is obtained when the maximum voltage angle is 134°.

Keywords: current total harmonic distortion; transformerless photovoltaic inverter; solar irradiance.

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1. Introduction

A 1.5 kW inverter using full bridge topology is designed and tested by [1]. It gave an excellent result for the high power PV module application. An alternative approach of inverter is proposed by [2] to replace the conventional method with the use of microcontroller. The use of the microcontroller brings the flexibility to change the real-time control algorithms without further changes in hardware. It is also low cost and has small size of control circuit for the single phase full bridge inverter.

In grid or off grid connected installation, the inverter input power is determined by the solar irradiance on the PV module, that is, both the efficiency and the electricity supply quality depend on the inverter work point (obviously this depends on the solar irradiance incident on the surface of the PV module) [3].

This paper presents a new topology of multilevel single phase transformerless PV inverter. It consists of three main circuits; they are a pulse driver circuit, a full bridge inverter circuit and a power factor correction circuit that have functions as production of pulse waves, to develop alternating current (AC) waveform and to stable voltage of PV array. The advantage of the proposed topology compared to the conventional inverter is low cost, small size, high efficiency, the pulse waves to drive the full bridge inverter circuit is easy to create using the microcontroller PIC16F627A-I/P (programmable maximum and zero voltage angle of AC waveform) and therefore CTHD of the same loads can be optimized.

2. Methodology

2.1. Solar irradiance and PV array

The multilevel single phase transformerless PV inverter is installed in front of Centre of Excellence for Renewable Energy (CERE), Universiti Malaysia Perlis, Northern Malaysia. Its main energy source is a PV array that consists of three unit of 81 V, 60 W PV modules. The PV array converts solar energy (solar irradiance) to be direct current (DC) electricity. In this research, the solar irradiance is recorded by a weather station every minute.
2.2. Components of proposed topology

The realized system is a typical stand alone multilevel single phase transformerless PV inverter that can feed AC loads. The complete system is shown in Fig. 1 that consists of three main circuits; they are a pulse driver circuit, a full bridge inverter circuit and a power factor correction circuit.

The pulse driver circuit is used to produce two pulse waves that needed to drive the full bridge inverter circuit. The pulse waves are developed by a microcontroller PIC16F628A-I/P as shown in Fig. 2. A listing program is created to produce the pulse waves using C language in PIC C compiler and formed at pin 11 and 12 of the microcontroller.

The full bridge inverter circuit is used to produce an AC waveform that input signal is the two pulse waves. The circuit is modification result of [4] as shown in Fig. 2. The point $A$ and $A'$ are pulse wave input signal terminals that needed to drive the circuit, the point $C$ and $C'$ are AC output waveform that its magnitude depends on DC input at point $B$ and $B'$ around 200 V – 280 V. Some full bridge inverter circuits are connected in cascaded connection to obtain an AC multilevel output waveform. Number of cascaded connection will effect on number of level waveform and CTHD.

2.3. Experimental set up

Experimental set up equipments of the multilevel single phase transformerless PV inverter consist of PV array, pulse driver circuit, full bridge inverter circuit, power factor correction circuit, battery, and two load types, the first is inductive load of 20 W 220 V 50 Hz AC water pump and the second is 30 W resistive load. The measurement equipments consist of Vantage Weather Station Pro2, voltage logger, and PM 300 Analyzer. The experiment setup is shown in Fig. 3.

3. Results and discussion

3.1. Solar irradiance, temperature, PV array output and AC voltage

As shown in Fig. 3, the transformer-less inverter input is connected to the PV array and its output is connected to the load of 20 W 220 V 50 Hz AC water pump and 30 W lamps. The PV array output voltage is measured by voltage logger which its value depends on solar radiation and temperature. The solar radiation and temperature are measured by the Vantage Weather Station Pro2. Performances of the load are measured by the PM 300 .
Analyzer. The measurements are real time system and recorded every minute.

In this research, AC multilevel waveform and square wave single phase source of the transformerless inverter are developed and created by the microcontroller PIC16F627A-I/P and observed on 30 September 2011 from 9.0 am to 17.00 pm, and also analyzed their performance comparisons which depend on weather condition.

The weather condition of the solar radiation and temperature on 30 September 2011 are shown in Fig. 4. Minimum, maximum and average of the solar radiation are 156 W/m², 1125 W/m², and 592.96 W/m². Minimum, maximum and average of the temperature are 27.8 °C, 31.3 °C and 29.96 °C.

The solar irradiance and temperature as shown in Fig. 4 will effect on the PV array output voltage and AC voltage. If the solar irradiance increase and assuming the temperature is constant will cause the PV array output and AC voltage increase, otherwise if the temperature increase and assuming the solar irradiance is constant will cause the PV array output and AC voltage decrease [5,6]. The PV array output voltage on 30 September 2011 is shown in Fig. 5 (a), its minimum, maximum and average value are 242.195 V, 299.425 V and 270.57 V, respectively. The AC voltage on 30 September 2011 is shown in Fig. 5 (b), its minimum, maximum and average value are 203.8V, 257.20 V and 231.64 V, respectively.

3.2. Current total harmonic distortion (CTHD)

Maximum AC voltage angle from 20° to 180° are developed by the full bridge inverter circuit using the microcontroller PIC16F627A-I/P as shown in Fig. 2, and varied every 20°. Figs. 6 and 7 show four parts of AC waveform and current harmonic spectrum of the maximum AC voltage angle varied from 20° to 180°. The variation of...
maximum voltage angles affect the current harmonic spectrum and the CTHD. Effect of maximum voltage angle on the CTHD is shown in Fig. 8.

When the maximum voltage angle is 20°, the AC waveform is not perfect, therefore it produces a highest current harmonic spectrum and CTH as shown in Figs. 6 (a) and 7 (a). Its CTHD is 108.94% as shown in Fig. 8. A multilevel AC waveform starts to develop when the maximum voltage angle is 40°. It produces CTHD of 74.33% as shown in Fig. 8. It is lower CTHD compared to the...
CTHD that produced by the maximum voltage angle of 20°. Fig. 6 (b) shows multilevel AC waveform when its maximum voltage angle is 100°. It produces lower current harmonic spectrum and CTHD compared to the CTHD that produced by the maximum voltage angle of 20° and 40° as shown in Figs. 7 (b) and 8.

A lowest current harmonic spectrum and CTHD are obtained when the maximum voltage angle is 134°. Its AC multilevel waveform is shown in Fig. 6 (c), its current harmonic spectrum is shown in Fig. 7 (c) and its CTHD of 15.448 % is shown in Fig. 8. The maximum voltage angle is a optimal angle to obtain a lowest CTHD.

If the maximum voltage angle is increased, therefore the current harmonic spectrum and CTHD will increase as shown in Fig. 6 (d) as AC waveform for maximum voltage angle of 180°, Fig. 7 (d) as its current harmonic spectrum and Fig. 8 as its CTHD of 30.34%.

4. Conclusion

According to result shown, the proposed topology can be applied to the multilevel single phase transformerless PV inverter, from the results can be summarized as below:

a. Performance of the multilevel single phase transformerless PV inverter depends on the solar irradiance and temperature. For the average solar radiation of around 592.96 W/m² and temperature of around 29.96°C will produce the PV array voltage of 270.57 V and AC voltage of 231.64. These values are enough to develop AC waveform of the transformerless single phase inverter.

b. The maximum AC voltage angle will effect on the CTHD, the lowest CTHD of 15.448% is obtained when the maximum voltage angle is 134°.

References


