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Optimization of Current Total Harmonic Distortion on Three-Level Transformerless Photovoltaic Inverter

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Abstract

This paper presents a new topology of three-level transformerless photovoltaic (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 transformerless inverter is installed in front of Electrical Energy and Industrial Electronic Systems (EEIES) Cluster, Universiti Malaysia Perlis, Northern Malaysia. Its main energy source is a PV array that consists of three unit PV modules, each unit has 81 V, 60 W. In this research, optimization of current total harmonic distortion (CTHD) on AC three-level waveform transformerless PV inverter is developed and created by a microcontroller PIC16F627A-I/P with change maximum voltage angle of the AC three-level waveform from 20^0 to 180^0. Resistive load of 30 W lamp and inductive load of 20 W water pump are applied to the transformerless PV inverter. The result shows that the less CTHD of 15.448% is obtained when the maximum voltage angle is 134^0.

Keywords: Photovoltaic inverter; Transformerless; AC waveform; Solar irradiance; Temperature.

1. Introduction

The direct current (DC) electrical energy of PV module can be converted to AC electrical energy using inverter. The 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

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module) [3].

This paper presents a new topology of three-level 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 transformerless PV inverter is installed in front of Electrical Energy and Industrial Electronic Systems (EEIES) Cluster, 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 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.

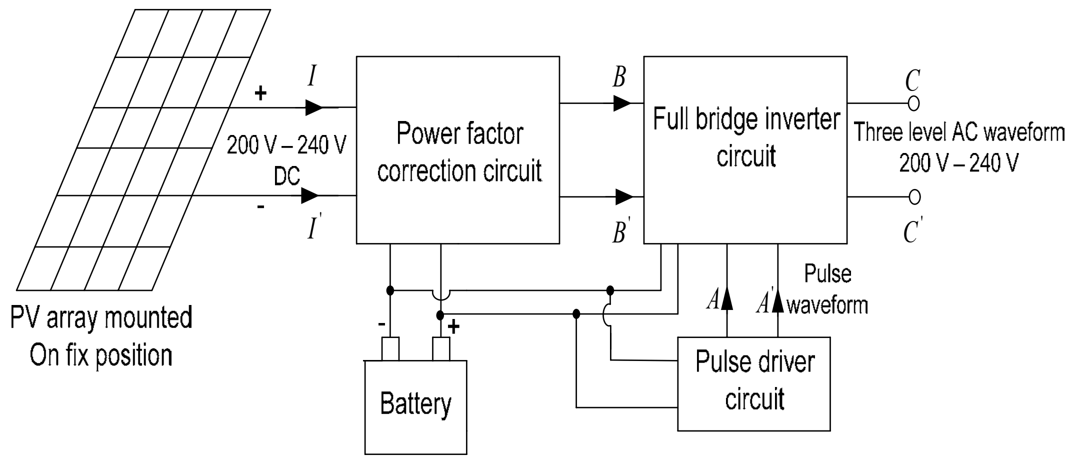


Fig. 1 Realized single phase transformerless PV inverter system

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.

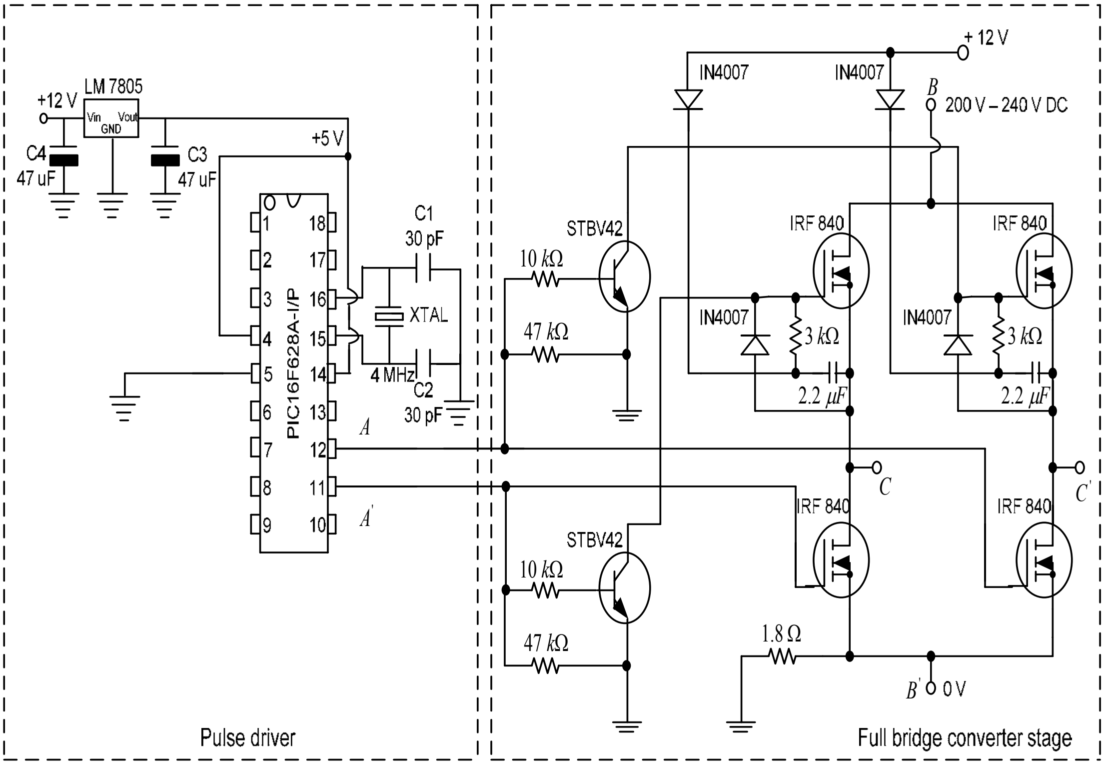


Fig. 2 Pulse driver and full bridge inverter circuit

3. Experiment set up

Main experiment set up equipments of the 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, electrocorder voltage logger, and PM 300 Analyzer. The experiment setup is shown in Fig. 3.

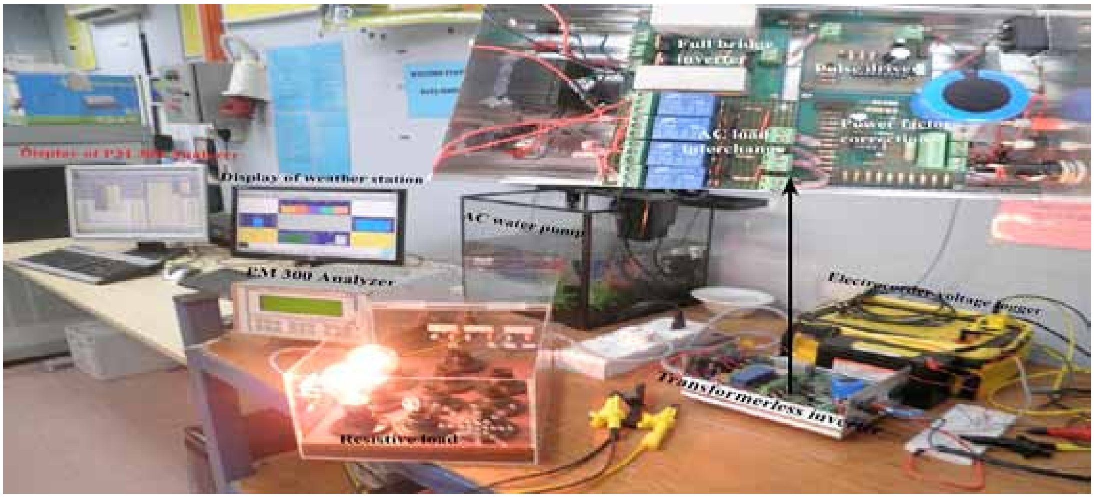


Fig. 3 Experiment set up

4. Result and discussion

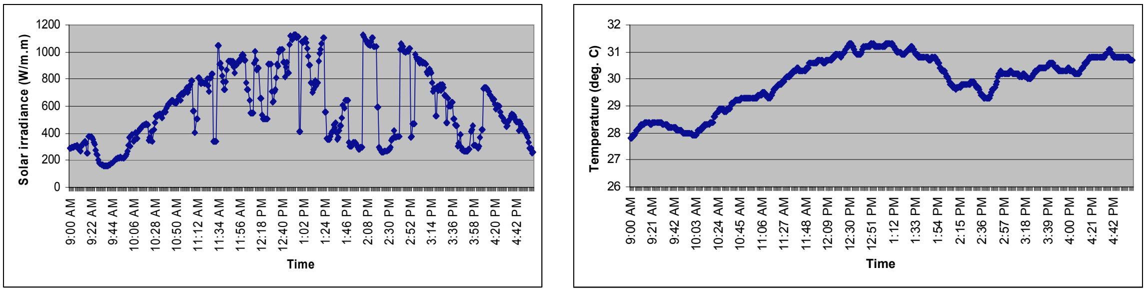
4.1. Solar irradiance, temperature, PV array output and rms AC voltage

As shown in Fig. 3, the transformerless 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 lamp. The PV array output voltage is measured by electrocorder 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 three-level 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.

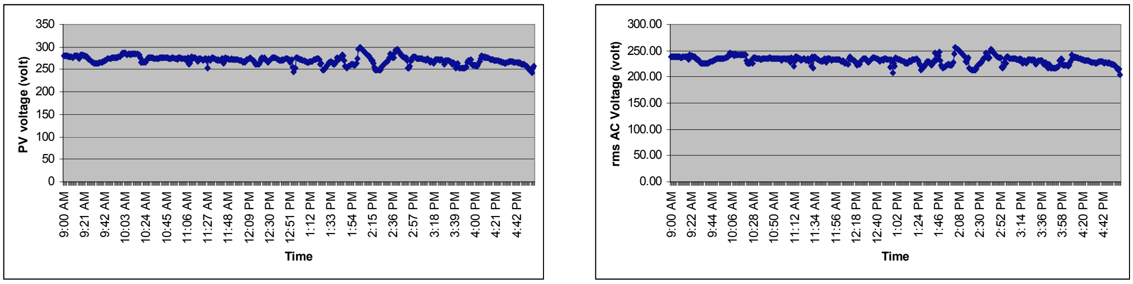
The weather condition of the solar radiation and temperature on 30 September 2011 are shown in Fig. 4. Minimum, maximum and average of the solar radiation are 156 W/m^2, 1125 W/m^2, and 592.96 W/m^2. Minimum, maximum and average of the temperature are 27.8 ^{0}C, 31.3 ^{0}C and 29.96 ^{0}C.

Value of the solar irradiance and temperature as shown in Fig. 4 will effect on the PV array output voltage and rms AC voltage. If the solar irradiance increase and assuming the temperature is constant will cause the PV array output and rms AC voltage increase, otherwise if the temperature increase and assuming the solar irradiance is constant will cause the PV array output and rms 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. The rms 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.



(a) Solar radiation (b) Temperature

Fig. 4 Weather condition

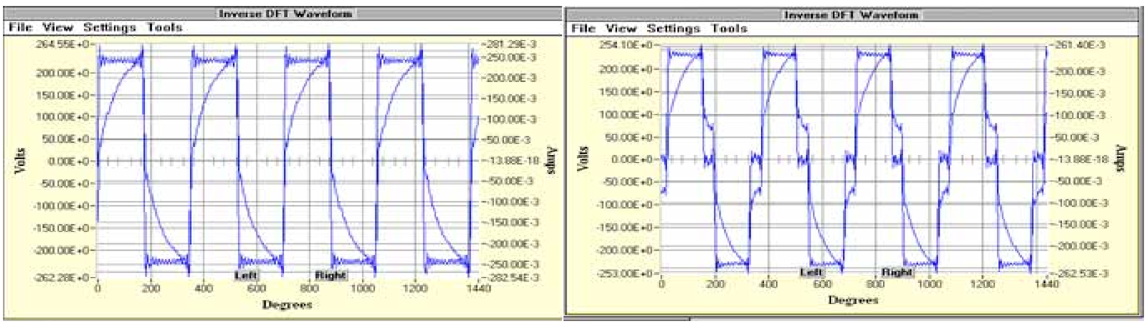


(a) PVvoltage (b) rms AC voltage

Fig. 5 PV voltage ans rms AC voltage

4.2. Optimization current total harmonic distortion (CTHD)

Fig. 6 shows maximum AC voltage angle of 180^0 and 134^0, the angle will effect on the CTHD. If the outputs of the pulse driver circuit at point A and A' as shown in Fig. 2 is varied to produce maximum AC voltage angle from 20^0 to 180^0 will be obtained the less CTHD of 15.448% when the maximum voltage angle is 134^0 as shown in Fig. 7.



(a) Maximum voltage angle is 180^0 (b) Maximum voltage angle is 134^0

Fig. 6 AC load voltage and current waveform of the transformerless PV inverter

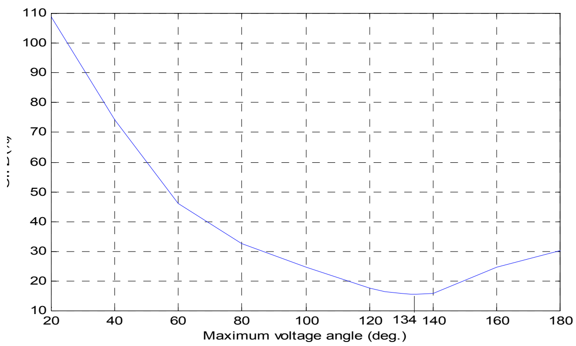


Fig. 7 CTHD versus maximum voltage angle for load of the lamp and AC water pump

Conclusion

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

1. Performance of the transformerless inverter depends on the solar irradiance and temperature. For the average solar radiation of around 592.96 W/m^2 and temperature of around 29.96 ^{0}C will produce the PV array voltage of 270.57 V and rms AC voltage of 231.64. These values are enough to develop AC waveform of the transformerless inverter.

2. The maximum AC voltage angle will effect on the CTHD, the less CTHD of 15.448% is obtained when the maximum voltage angle is 134^0.

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