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High Power Transformerless Photovoltaic Inverter

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Abstract

This paper presents a new topology of high power three-level transformerless photovoltaic inverter (TPVI). It consists of three main circuits; they are a pulse driver circuit, a full bridge inverter (FBI) circuit and a power factor correction (PFC) circuit that have functions as production of pulse waves, to develop alternating current (AC) waveform and to stable voltage of PV array, respectively. To obtain the high power of the TPVI, five FBI circuits are connected in parallel. Each FBI circuit uses MOSFET IRFP460 which has rating current of 20 A, therefore the total FBI circuit has applicable maximum current of 100 A. The high power TPVI is installed in front of Centre of Excellent for Renewable Energy (CERE), Universiti Malaysia Perlis, Northern Malaysia. Its main energy source is a PV array that consists of three unit PV modules are connected in series, each unit has 81 V, 60 W. Some three unit PV modules are connected in parallel to fulfill the demand of high AC power. In this research, an AC three-level waveform of the TPVI is developed and created by a microcontroller PIC16F627A-I/P.

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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 module) [3].

This paper presents a new topology of high power three-level single phase TPVI. It consists of three main circuits; a pulse driver, a power factor correction (PFC) and five full bridge inverter (FBI) circuits.

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The advantage of the proposed topology compared to the conventional inverter is that 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), therefore CTHD of the same loads can be improved and also it can be applied to run high AC loads.

2. Methodology

2.1 Weather station and PV array

The Weather Station Pro2 and high power three-level single phase TPVI are installed in front of Centre of Excellent for Renewable Energy (CERE) , Universiti Malaysia Perlis, Northern Malaysia as shown in Fig. 1. The TPVI main energy source is a PV array that consists of three unit PV modules are connected in series, each unit has 81 V, 60 W. Some three unit PV modules are connected in parallel to fulfill the demand of high AC power. In this research, the data of solar irradiance, temperature, PV voltage. The solar irradiance and temperature are measured by the Vantage Weather Station Pro2. The PV voltage is measured by a voltage logger.

Fig. 1 Weather station and PV array installed in front of CERE, Universiti Malaysia Perlis

2.2 High power inverter

Inverter power which uses transformer is determined by switching components and transformer.

MOSFET which has a rating current in ampere and a rating AC voltage, therefore it has applicable maximum power of production of the rating current and AC voltage. It also needs rating transformer of equals or above the applicable maximum power [1].

Parallel operation of the inverters is needed to obtain a high power inverter. By increasing number of paralleled inverters, it can be applied to very high power inverters [4]. Inverter in the market states that power of above 2000 W is classified as a high power inverter. Ideal operation status of the paralleled inverters has to be given attention, their output voltages have the same frequency, phase, amplitude and also waveform [5].

In case of paralleled inverters, total load power is summation of each inverter power or total load current is summation of each inverter current as shown in Fig. 2. The total load current, i_t is given below.

$$i_t = i_1 + i_2 + ... + i_n \quad (1)$$

where:

i_1 = current flow through inverter 1

i_2 = current flow through inverter 2

i_n = current flow through inverter n

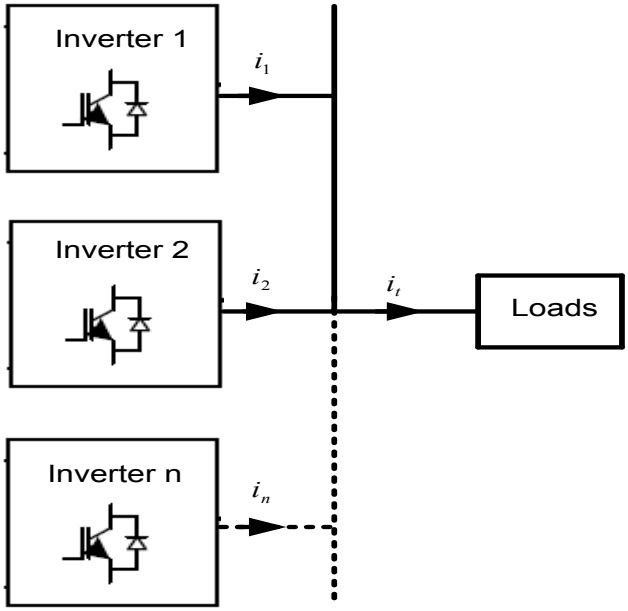

Fig. 2 n paralleled inverter

2.3 Proposed topology of high power TPVI

A proposed topology of high power TPVI consists of a pulse driver circuit, five full bridge inverter (FBI) circuit and a power factor correction (PFC) circuit. The pulse driver and PFC circuits are explained

by [6] and the five FBI circuits connected in parallel as shown in Fig. 3. Each FBI is constructed by MOSFET IRFP460 which has rating current of 20 A and for 240 V AC system, therefore each FBI has applicable maximum power of 4.8 kW. For fiveFBI connected in parallel equals 5 x 4.8 kW.

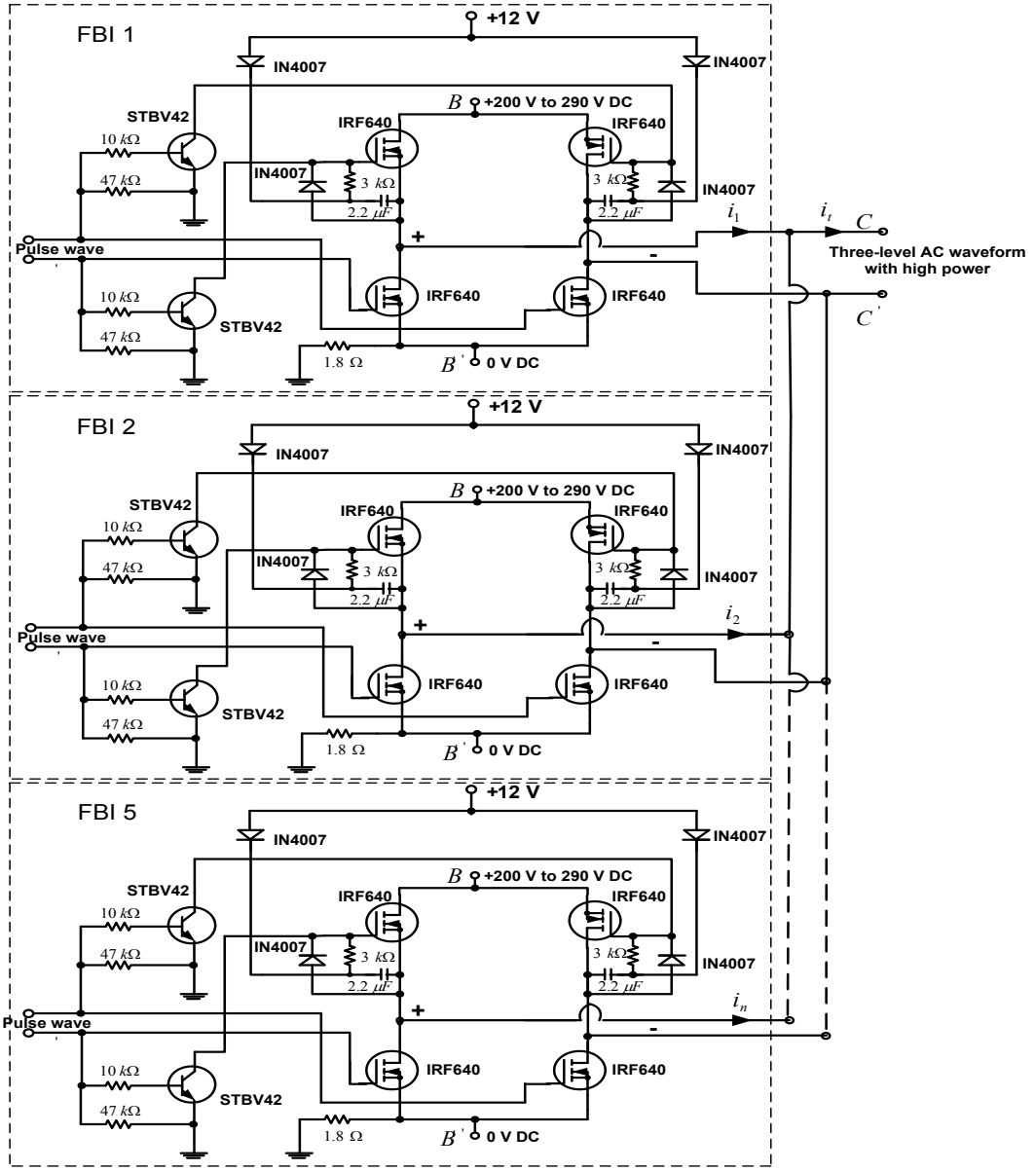

Fig. 3 Five paralleled FBI circuits

Based on connection of paralleled inverters, advantages of the proposed topology are:

1. It is easy to create same frequency, phase and waveform of output voltage of each FBI. It is due to each FBI is driven by pulse wave which is created by microcontroller PIC16F628A-I/P. Each pulse

wave has same frequency and duty cycle.

2. It is easy to create same amplitude of output voltage of each FBI. It is due to each FBI at point B and B' has same DC voltage which is output voltage of the PFC.

3. Experimental set up

Main experimental set up equipments of the high power three-level single phase TPVI consist of PV array, pulse driver circuit, full bridge circuit, and AC loads. The measurement equipments consist of Vantage Weather Station Pro2, electrocorder voltage logger, and PM 300 Analyzer. The experimental setup is shown in Fig. 4.

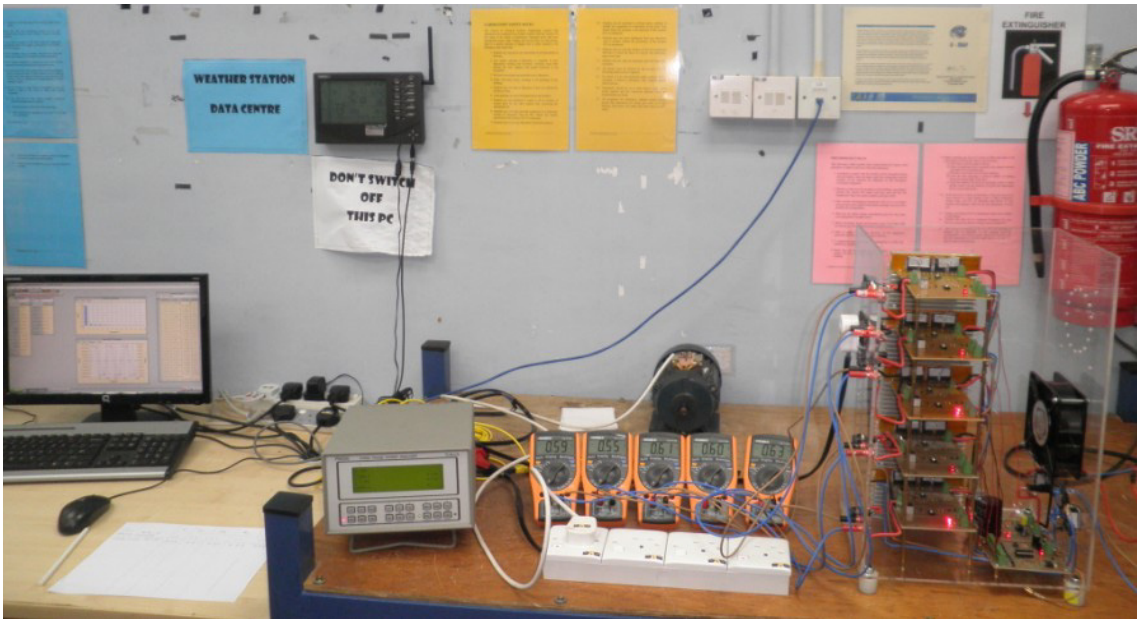

Fig. 4 Experiment set up

As shown in Fig. 4, the TPVI input is connected to the PV array and its output is connected to the AC loads. The solar irradiance and temperature are measured by the Vantage Weather Station Pro2, their condition are 780 W/m^2 to 970 W/m^2 and 30^0 to 31^0, respectively. Performances of the load are measured by the PM 300 Analyzer.

4. Result and discussion

Varies AC loads are applied in to the TPVI. Performances of the TPVI are shown in Table 1. Voltage and current waveform of the transfromerless PV inverter for running varies AC loads are shown in Fig. 5. Also their current harmonic spectrums are shown in Fig. 6.

Table 1: Performance of the TPVI for running varies AC loads

AC Loads	Sol. irrad. (W/m^2)	Temp. (^0C)	Power (W)	Voltage (V)	Current (A) Total	CTHD (%)
0.5 hp Induction motor	904	31	94.41	221.7	0.607	24.05
	847	30	99.61	226.9	0.465	33.60
	963	31	155.5	220.9	0.837	57.57
	851	31	234.6	215.8	1.102	17.56
	849	31	274.1	213	1.287	21.49
	805	30	461.9	200	3.087	9.09

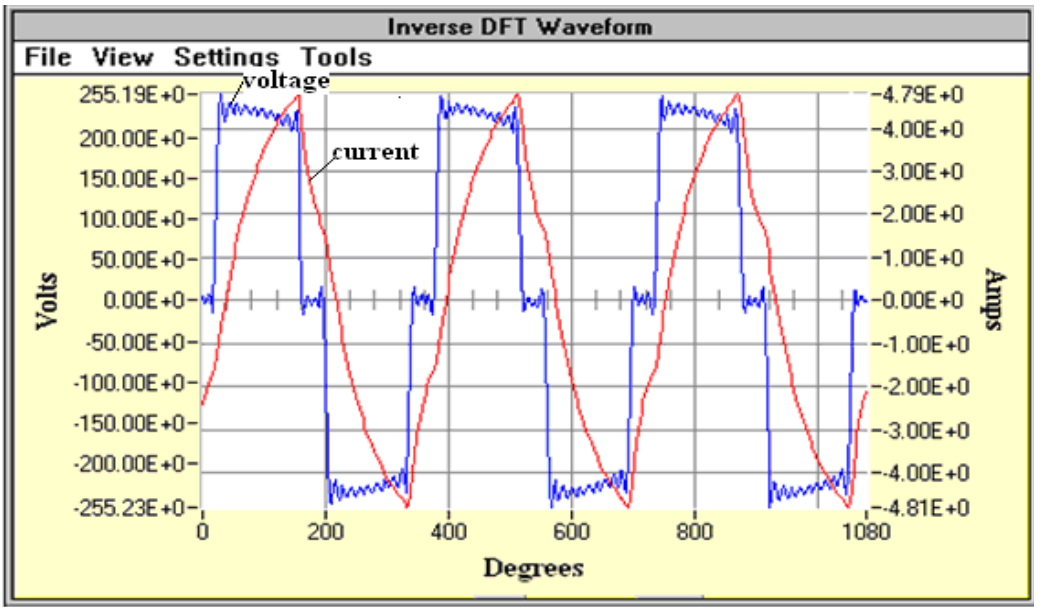

Fig. 5 Voltage and current waveform of 0.5 hp induction motor

Fig. 5 shows AC three-level voltage waveform. It has maximum voltage angle, α of 134^0, choose of the maximum voltage angle is explained by [6]. AC current waveform depends on type of AC loads which affect current harmonic spectrum and current total harmonic distortion as shown in Fig. 6 and Table 1.

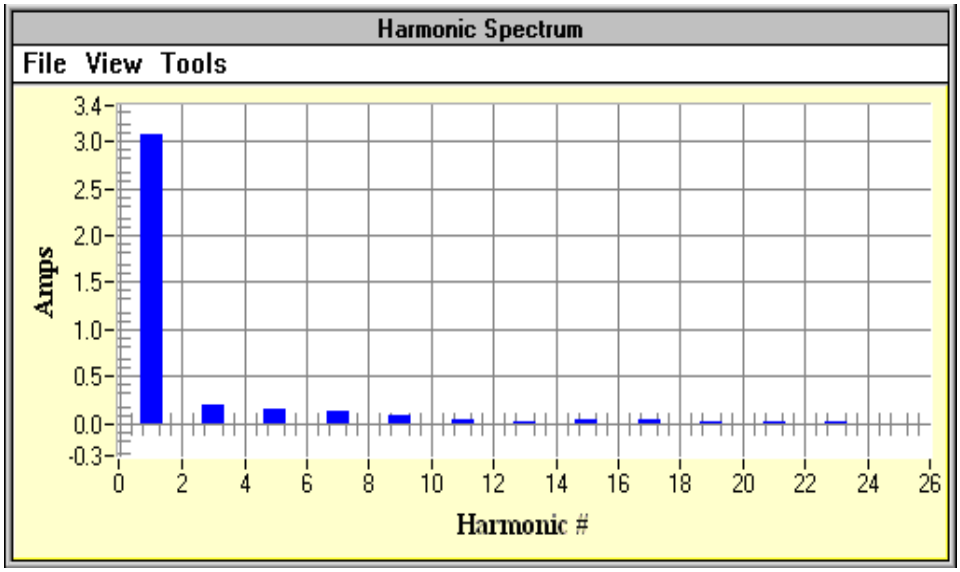

Fig. 6 Current harmonic spectrum of 0.5 hp induction motor

Conclusion

According to result shown, the proposed topology can be applied to the high power three-level single phase TPVI, from the result can be summarized as below :

1. The Solar irradiance and temperature affect the PV array voltage. The PV array voltage directly is converted become AC voltage using FBI circuit.
2. Some FBI circuits can be connected in parallel to obtain high AC power. Using MOSFET IRFP460 of the FBI circuit which has rating current of 20 A, therefore the total five FBI circuits have applicable maximum current of 100 A. If it is applied into 240 V AC system, therefore each FBI has applicable maximum power of 4.8 kW. For fiveFBI connected in parallel equals 5 x 4.8 kW.
3. AC three-level voltage waveform has maximum voltage angle, α of 134^0 with AC current waveform depends on type of AC loads which affect current harmonic spectrum and current total harmonic distortion.

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