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Three Level Single Phase Photovoltaic and Wind Power Hybrid Inverter

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Abstract

This paper presents a new topology of three-level single phase photovoltaic (PV) and wind power hybrid inverter. It consists of three main circuits; they are a hybrid controller circuit, a charger circuit, a pulse driver and full bridge circuit. The 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 and wind power generation. In this research, AC three-level waveform and square wave single phase PV and wind power hybrid inverter are developed and created by a microcontroller PIC16F627A-I/P and analyzed their performance comparisons. The result shows that the AC waveform which is formed by the PV and wind power hybrid inverter will effect on AC load rms voltage, AC current and current total harmonic distortion (CTHD), for a load of 20 W 220 V 50 Hz AC water pump, its AC load rms voltage and current are higher when the single phase PV and wind power hybrid inverter is formed as AC square wave than as AC three-level waveform, but the CTHD is lower when the single phase PV and wind power hybrid inverter is formed as AC three-level waveform than as AC square wave.

Keywords: Hybrid system; Inverter; Solar irradiance; Temperature; wind speed

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

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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 three-level single phase PV and wind power hybrid inverter. It consists of three main circuits; they are a hybrid controller circuit, a charger circuit and a pulse driver and full bridge circuit. 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.

2. Methodology

2.1. PV and wind power hybrid generation

The three-level single phase PV and wind power hybrid inverter and a Vantage Weather Station Pro2 are installed in front of EEIES Cluster, Universiti Malaysia Perlis, Northern Malaysia as shown in Fig. 1. The inverter main energy source consists of two parts, the first is a PV array that consists of two unit PV modules, each unit has capacity of 22 V, 50 W and the second is a wind power generation as shown in Fig. 1. In this research, the data of solar irradiance, wind speed, PV voltage and wind power generation voltage are measured every minute on the same time through 24th to 25th March 2011. This objective is to relate between the solar irradiance, wind speed and PV, wind power generation performance. The solar irradiance and wind speed are measured by the Vantage Weather Station Pro2, the PV voltage and wind power generation voltages are measured by a voltage logger.

(a) Weather station (b) PV array and wind power generation

Fig. 1 Weather station, PV array and wind power generation are installed in front of EEIES Cluster, Universiti Malaysia Perlis

2.2. Components of proposed topology

The realized system is a three-level single phase PV and wind power hybrid inverter that can feed AC loads. The complete system is shown in Fig.2 that consists of three main circuits; they are a hybrid system controller, a charger and a three-level single phase inverter circuit.

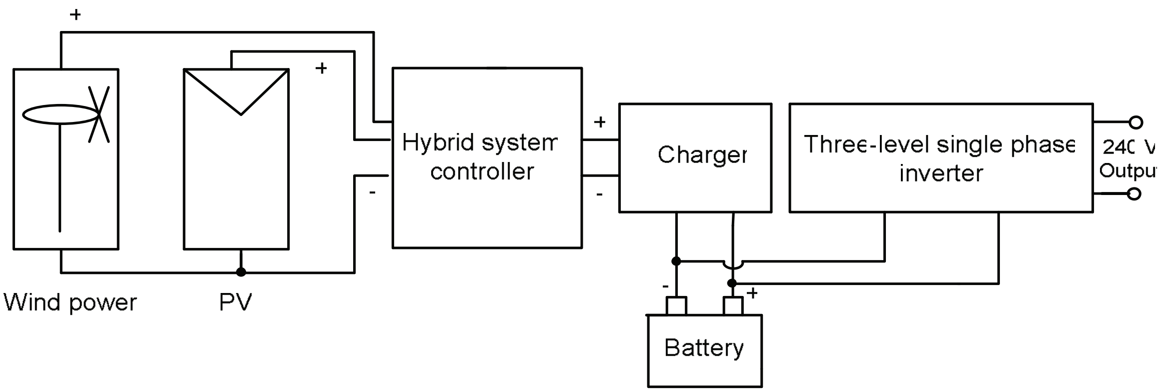


Fig. 2 Realized three-level single phase PV and wind power hybrid inverter system

The hybrid system controller is used to control input of the PV and wind power generation voltage to the charger, its circuit is shown in Fig. 3. During the night time, the PV array can not produce DC voltage, but during the day time will produce DC voltage that its value depends on the solar irradiance. The wind power generation can produce DC voltage during the night and day time that its value depends on the wind speed. The hybrid system controller is designed to control the battery charger, it will operate if the PV array voltage or wind power generation voltage or PV array and wind power generation voltage is higher the battery voltage. This system is controlled by microcontroller PIC16F677A.

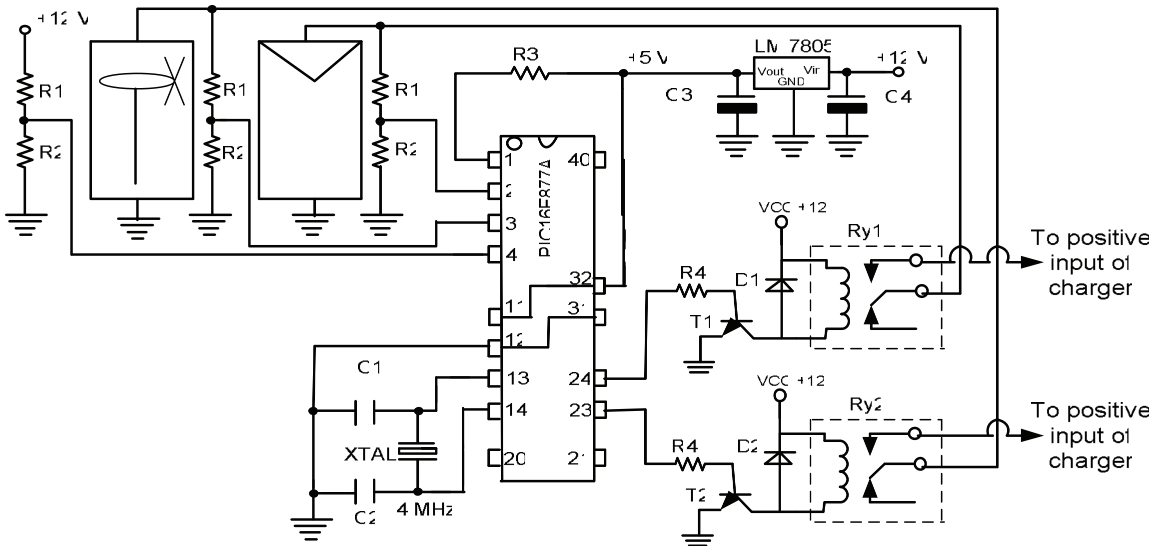


Fig. 3 Hybrid system controller circuit

Fig. 4 shows a charger circuit that is used to charge the battery. The 15 V to 40 V DC voltages are sent to input of the charger circuit. The diode D_3 is used as a crowbar device, if reverse power is applied to the circuit, the diode causes a short circuit and the 4 Amp fuse blows. The input voltage is stabilized with the capacitor C_5, this is also used as a local power reservoir for the switching regulator. The optional 1 kΩ green LED in series with the 1 kΩ resistor provides an indication that the circuit is powered.

The LM2576-ADJ voltage regulator provides variable width DC pulses to the inductor L_1. When the output pulse is on, the inductor stores energy, when the pulse turns off, the inductor discharges energy into the capacitor C_6 through the current loop with the schottky diode D_4. The resistor R_5 and trimmer potentiometer R_6 form a voltage divider circuit, this is used as feedback by the LM2576-ADJ IC for setting the output voltage.

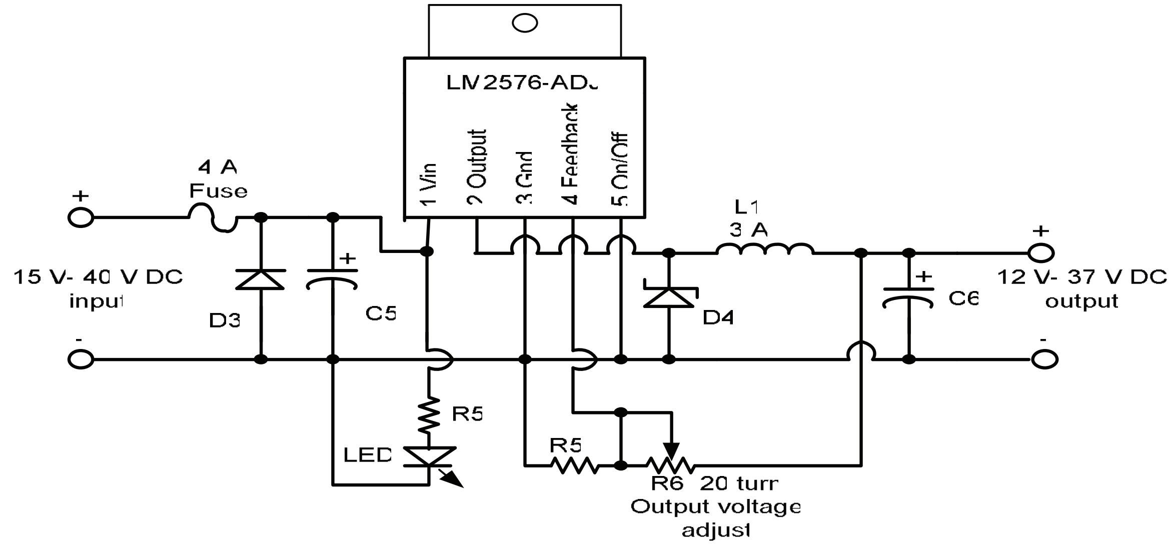


Fig. 4 Charger circuit

Fig. 5 shows a full bridge inverter circuit that is drived by five pulse waves and created by the microcontroller PIC16F627A-I/P at pin 10, 11, 12, 17 and 18.

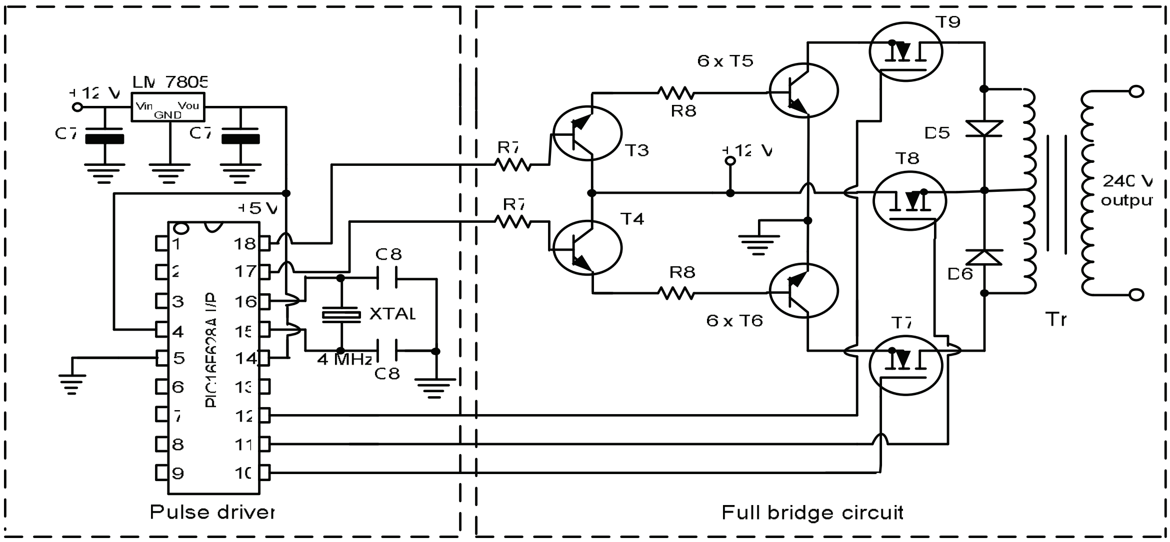


Fig. 5 Three-level single phase inverter circuit

3. Experimental set up

Main experimental set up equipments of the three-level single phase PV and wind power hybrid inverter consist of PV array, hybrid controller circuit, charger circuit, pulse driver circuit, full bridge circuit, battery, and a load of 20 W 220 V 50 Hz AC water pump, and the measurement equipments consist of Vantage Weather Station Pro2, electrocorder voltage logger, and PM 300 Analyzer. The experimental setup is shown in Fig. 6.

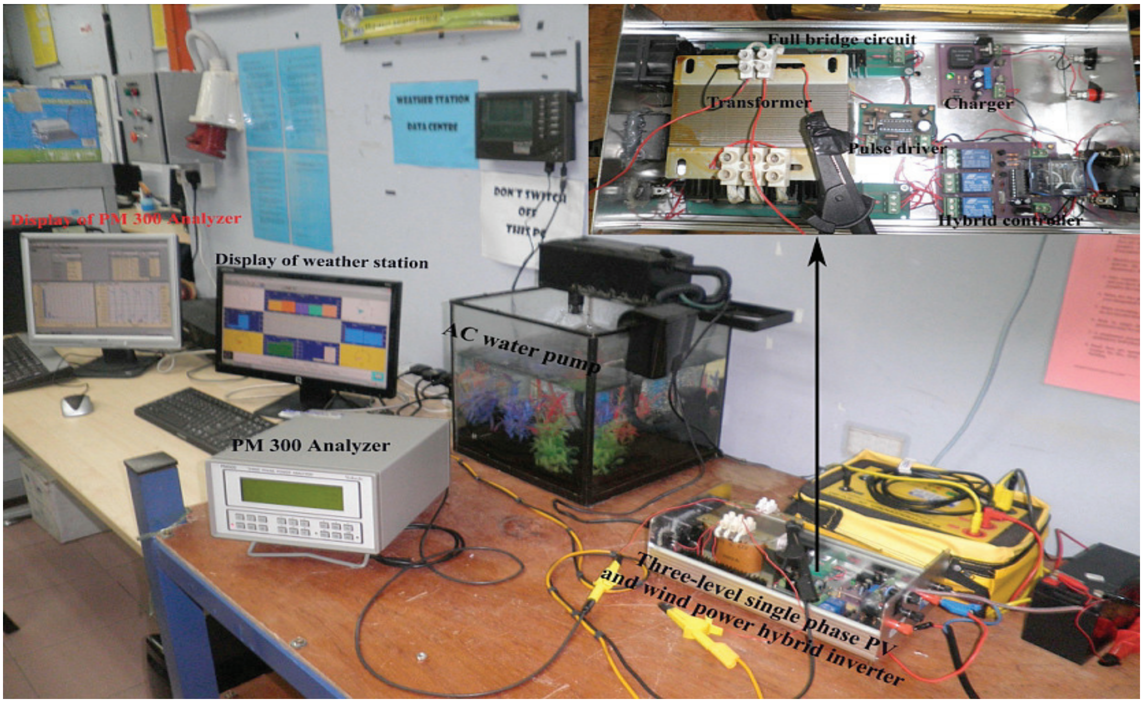


Fig. 6 Experiment set up

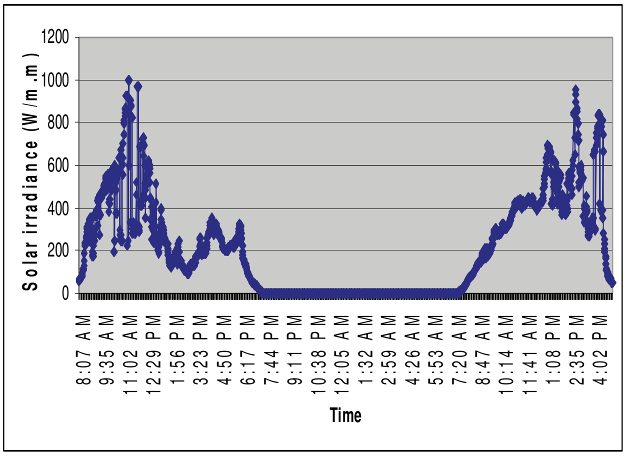
4. Result and discussion

4.1. Weather condition, PV array and wind power generation voltage

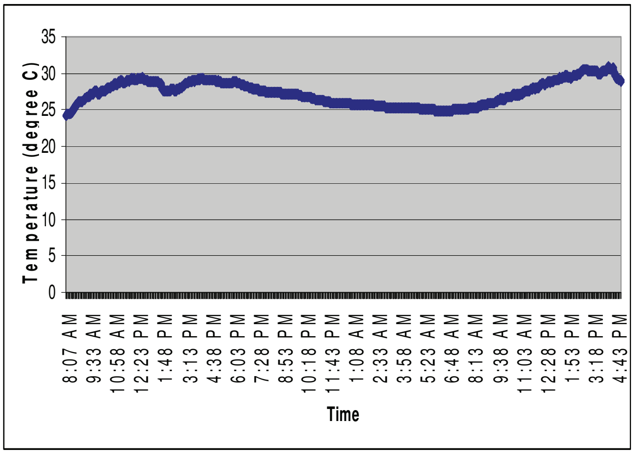
As shown in Fig. 6, input of the three-level single phase PV and wind power hybrid inverter is connected to the PV array and wind power, its output is connected to the load of 20 W 220 V 50 Hz AC water pump. The PV array and wind power output voltage are measured by electrocorder voltage logger which their value depend on solar radiation, temperature and wind speed. The solar radiation, temperature and wind speed 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 through 24^{th} to 25^{th} March 2011.

The weather condition of the solar radiation, temperature and wind speed on 24^{th} to 25^{th} March 2011 are shown in Fig. 7. Minimum, maximum and average of the solar irradiance are 0 W/m^2, 997 W/m^2, and 207.3 W/m^2. Minimum, maximum and average of the temperature are 24.3 ^{0}C, 30.9 ^{0}C and 27.34 ^{0}C. Minimum, maximum and average of the wind speed are 0 m/s, 4.92 m/s and 2.39 m/s.

Value of the solar irradiance and temperature as shown in Fig. 7 will effect on the PV array output voltage, and value of wind speed will effect on the wind power generation voltage. If the solar irradiance increase and assuming the temperature is constant will cause the PV array output voltage increase, otherwise if the temperature increase and assuming the solar irradiance is constant will cause the PV array output voltage decrease [4, 5, 6]. If the wind speed is lower than cut-in speed and highest than cut-off speed, thus the wind power generation voltage is zero, if the wind speed is higher than the nominal speed and lowest the cut-off speed, thus the wind power generation voltage is its rated voltage [7]. The PV array and wind power generation output voltage on 24th to 25th March 2011 are shown in Fig. 8.



(a) Solar irradiance



(b) Temperature

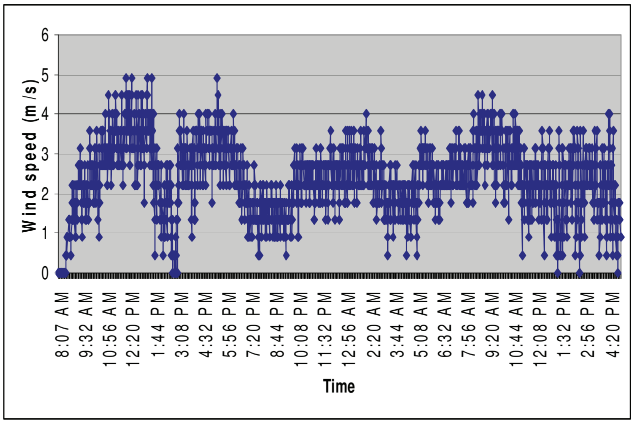


Fig. 7 Weather condition

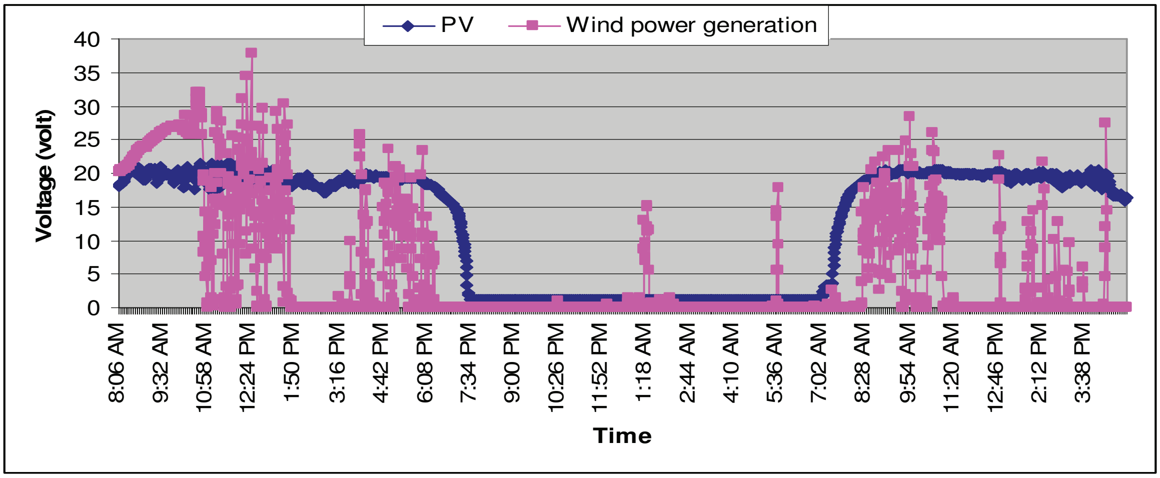


Fig. 8 PV array wind power generation output voltage

4.2. Voltage waveform of square and three-level single phase PV and wind power hybrid inverter

The full bridge inverter circuit is drived by the pulse waves that created by the pulse driver circuit, exactly by the microcontroller PIC16F627A-I/P as shown in Fig. 5. If the outputs of the pulse driver circuit at pin 10, 11, 12, 17 and 18 are pulse waves as shown in Fig. 9 and 10, therefore secondary side voltage waveform of the transformer are AC square wave and three-level waveform as shown in Fig. 11(a) and (b), respectively . The load of 20 W 220 V 50 Hz AC water pump is connected to secondary side of the transformer which is inductive load therefore the load voltage leads its current by 53.13^0 as shown in Fig. 11.

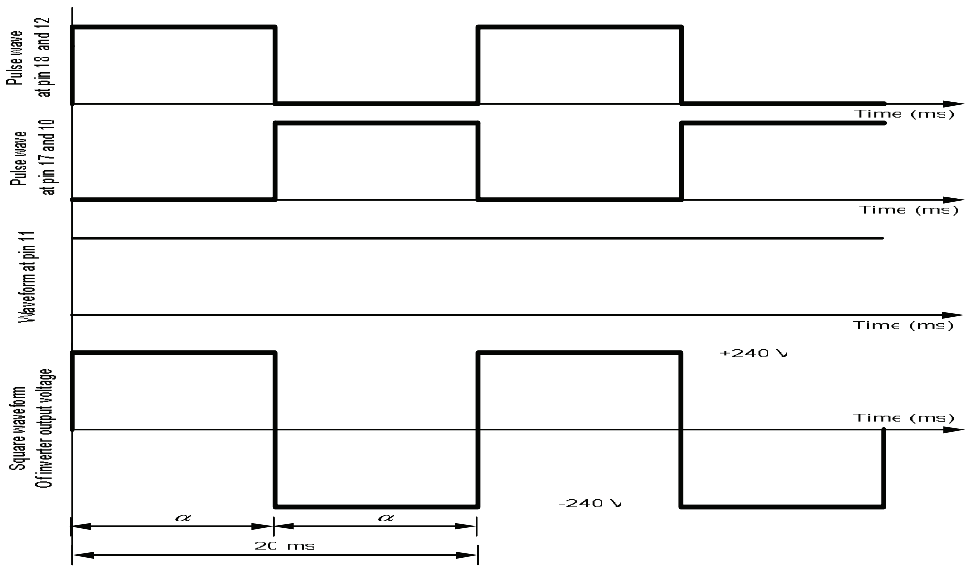


Fig. 9 Pulse and square output waveform of the single phase PV and wind power hybrid inverter

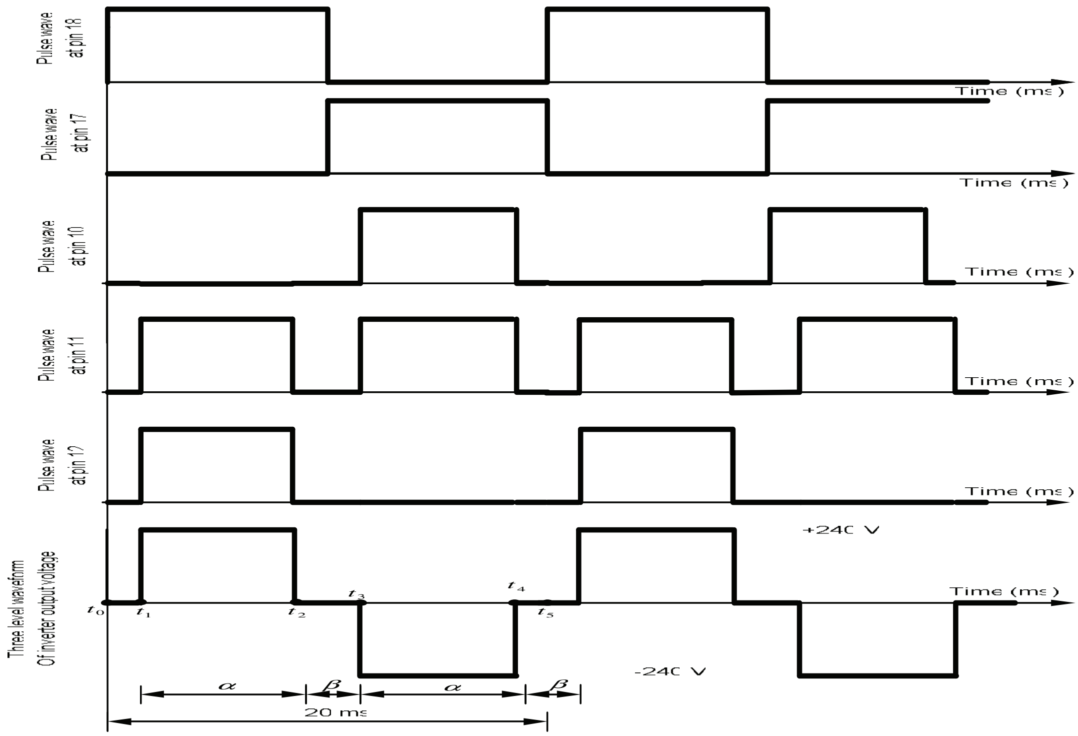
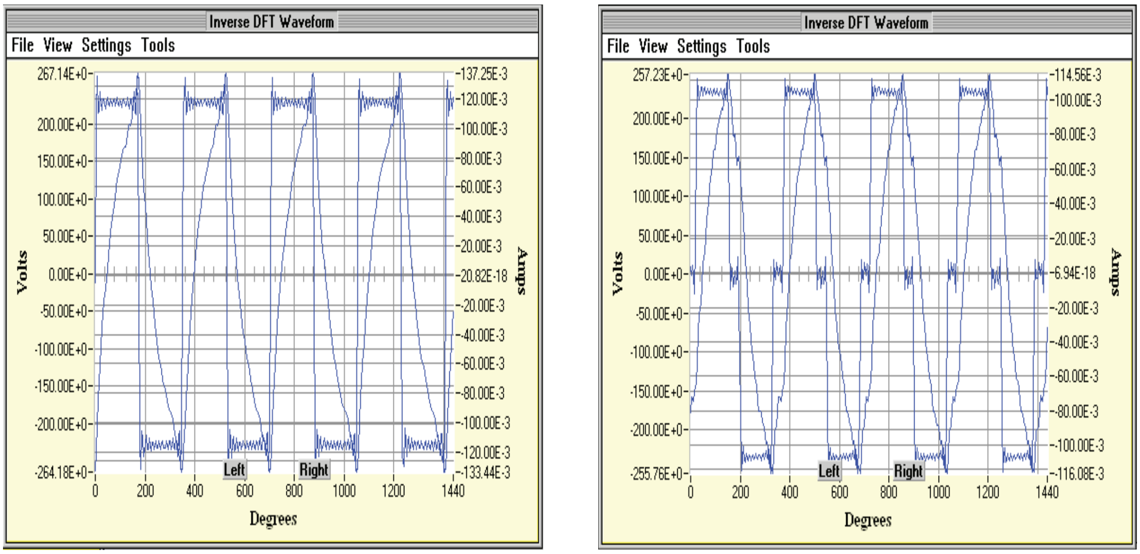


Fig. 10 Pulse and three-level output waveform of the single phase PV and wind power hybrid inverter



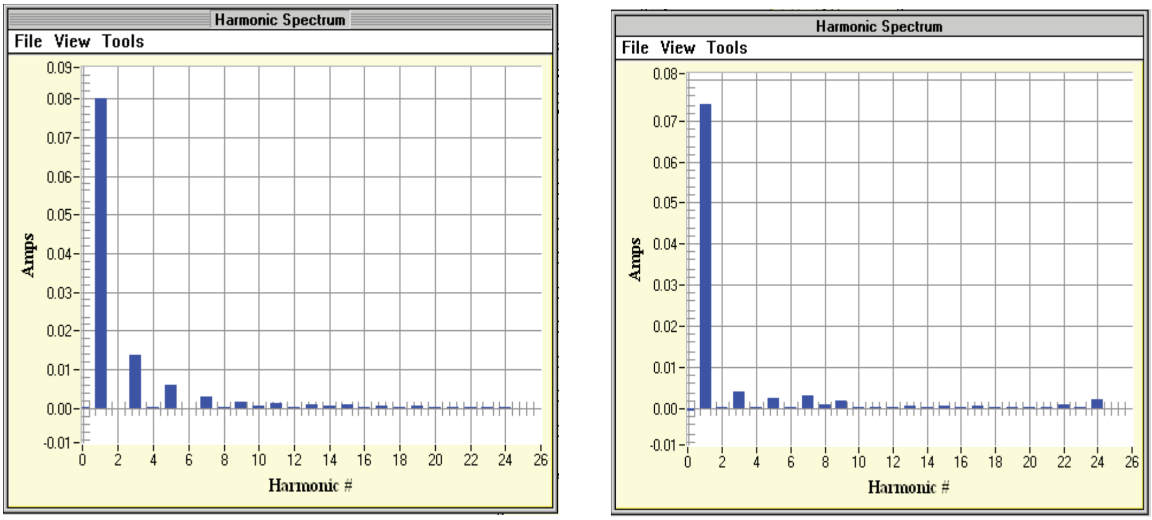
(a) Square wave (b) Three-level waveform

Fig. 11 AC load voltage and current waveform of the single phase PV and wind power hybrid inverter

Fig. 11 shows that AC load rms voltage and current are higher when the single phase PV and wind power hybrid inverter is formed as AC square wave than as AC three-level waveform. It means the AC waveform which is formed by the PV and wind power hybrid inverter will effect on AC load rms voltage and current.

4.3. Current total harmonic distortion (CTHD)

The load of 20 W 220 V 50 Hz AC water pump which is connected to secondary side of the transformer will produce CTHD and depends on type of AC waveform. Current harmonic spectrums of square and three-level single phase PV and wind power hybrid inverter are shown in Fig. 12. The current harmonic spectrum is lower when the single phase PV and wind power inverter is formed as AC three-level waveform than as AC square wave. It indicates that the single phase PV and wind power hybrid inverter is formed as AC three-level waveform is better than as AC square wave.



(a) Square wave (b) Three-level waveform

Fig. 12 Current harmonic spectrum of the single phase PV and wind power hybrid inverter

From Fig. 12 can be concluded that in the case of square wave (where $\delta = 180^0$ or 10 ms) and three-level waveform (where $\delta = 134^0$ or 7.5 ms) of the PV and wind power hhybrid inverter, their average CTHD are 19.84% and 7.56%, respectively. Hence the improvement in the average CTHD obtained when a three-level waveform of the PV and wind power hybrid inverter is used will be about 62% if compared with the square wave.

Conclusion

According to result shown, the proposed topology can be applied to the single phase PV and wind power hybrid inverter, from the square wave and three-level waveform developed can be summarized as below:

1. The Solar irradiance and temperature will effect on the PV array voltage. The wind speed will effect on the wind power generation voltage. The voltages are used to charge the battery that controlled by the hybrid controller circuit.
2. For the load of 20 W 220 V 50 Hz AC water pump, AC load rms voltage and current are higher when the single phase PV and wind power hybrid inverter is formed as AC square wave than as AC three-level waveform. It indicates that the AC waveform which is formed by the PV and wind power hybrid inverter will effect on AC load rms voltage and current.
3. The current harmonic spectrum is lower when the single phase PV and wind power hybrid inverter is formed as AC three-level waveform than as AC square wave. It indicates that the single phase PV and wind power hybrid inverter is formed as AC three-level waveform is better than as AC square wave. Average CTHD of the square wave is 19.84% and average CTHD of the three-level waveform is 7.56%. Hence the improvement in the average CTHD obtained when a three-level waveform of the PV and wind power hybrid inverter is used will be about 62% if compared with the square wave.

References

[1] Taib S, Sutanto Y, and Razak A. R. A. Development of Simple PWM Inverter Using Photovoltaic Celss. 2002 Student Conference on Research and Development Proceeding, 2002.

[2] Ismail B, Toib S, Saad A. R. M, Isa M, and Hadzar C. M. Development of a Single Phase SPWM Microcontroller-Based Inverter, First International Power and Energy Conference PECon 2006, 2006.

[3] Cardona M. S, Carretero J. Analysis of the Current Total Harmonic Distortion for Different Single-Phase Inverters for Grid-Connected PV Systems. Science Direct, Solar Energy Materials & Solar Cells, Vol. 87, 2005, p. 529-540.

[4] Wani M.G, Sharma V.K and Soni K.M. High frequency SMPS based inverter with improved power factor, IEEE Xplore 2006.

[5] Mukerjee A.K, Dasgupta N. Power factor controller used as DC-DC converter for photovoltaic source, Renewable Energy, vol. 33. 2007. p.1374-1378.

[6] Irwanto M, Daut I, Sembiring M, Ali R, Hardi R, Maizana D. Optimization of photovoltaic module electrical characteristics using genetic algorithm, International Postgraduate Conference on Engineering (IPCE 2010)16-17 October 2010, Universiti Malaysia Perlis (UniMAP).

[7] Irwanto M, Daut I, Sembiring M, Ali R, Champakeow S, Shema S. Effect of Solar Irradiance and Temperature on Photovoltaic Module Electrical Characteristics, International Postgraduate Conference on Engineering (IPCE 2010)16-17 October 2010, Universiti Malaysia Perlis (UniMAP).