Optimum Maximum Voltage Angle and Current Total Harmonic Distortion of Uninterruptible Power Supply on Three level Single Phase Photovoltaic – Wind Power Hybrid Inverter

Muhammad Irwanto, Tunku Muhammad Nizar Tunku Mansur, Mohd Irwan, Gomesh nair Shasidharan

***Abstract*--This paper presents a new topology of optimum maximum voltage angle and current total harmonic distortion (CTHD) of uninterruptible power supply (UPS) on three level single phase photovoltaic (PV) - wind power hybrid inverter. It consists of four main circuits; they are a hybrid controller circuit, a charger circuit, a pulse driver and full bridge circuit. Its main energy sources are a PV array and wind power generation. In this research, a new technique to optimize the CTHD is by changing maximum voltage angle of the three level waveform that created by a microcontroller PIC16F627A-I/P and searched the lowest CTHD. This inverter is completed by stand by UPS, when the main power source fails, the battery can power the inverter and the microcontroller controls the UPS transfer switch. The result shows that for lamp load of 10 W, the lowest CTHD is obtained when the maximum voltage angle is 134^0.**

***Index Terms*--Hybrid system, solar irradiance, wind speed, Inverter, uninterruptible power supply**

I. Introduction

INVERTER is circuit that provides an AC load voltage from a DC voltage source. More precisely, inverter transfers power from a DC source to an AC load. The semiconductor switches can be BJTs, thyristors, MOSFETs, IGBTs. The choice of power switch will depend on rating requirements and ease the device can be turned on and off.

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A complete modeling, simulation and implementation of Solar Photovoltaic (SPV) source fed Current source inverter (CSI) system presented by [1] using SIMULINK MATLAB. Sinusoidal Pulse Width Modulation (SPWM) technique is applied for producing control pulses for CSI with current loop to maintain constant current at the output of the inverter.

Selective Harmonics Elimination (SHE) modulation is being widely used in multilevel inverters with base frequency switching. An improvement to this modulation has been proposed by [2] in order to reduce the voltage THD at point of common coupling. This method can be used in wind or solar farms, where multiple inverters are often employed to interface the generating units with the network.

A novel space vector pulse width modulation (SVPWM) algorithm for n-level three-phase inverters presented by [3]. The 3-D SVPWM can be applied practically in hybrid multilevel inverters with unequal or varying voltage steps; it can be applied to most multilevel topologies. The algorithm offers an intuitive method for minimizing the total harmonic distortion (THD) of the output voltage of the inverter and the proposed techniques lead to a significant reduction in THD.

This paper presents a new topology of optimum maximum voltage angle and CTHD of UPS on three level single phase PV - wind power hybrid inverter. It consists of four main circuits; they are a hybrid controller circuit, a charger circuit, 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.

II. Methodology

A. PV - Wind Power Hybrid Generation

The PV and wind power generation are installed in front of Electrical Energy and Industrial Electronic Systems (EEIES) cluster, Universiti Malaysia Perlis, Northern Malaysia. They are main energy source of the three level single phase PV -

wind power hybrid inverter that consist of two parts, the first is a PV array that consists of two unit PV modules, each unit has capacity of 21 V, 60 W and the second is a wind power generation of 300 W (cut-in, cut of and nominal wind speed are 2 m/s, 16 m/s and 8 m/s, respectively). In this research, the data of solar irradiance, temperature, wind speed, PV voltage and wind power generation voltage are measured every minute on the same time through 26[th] to 27[th] January 2012. This objective is to relate between the solar irradiance, wind speed, PV and 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 an electrocorder voltage logger.

B. Components of proposed topology

The realized system is a three level single phase PV - wind power hybrid inverter that can feed AC loads. The complete system is shown in Fig. 1 that consists of three main circuits; they are a hybrid system controller, a charger and a three level single phase inverter circuit.

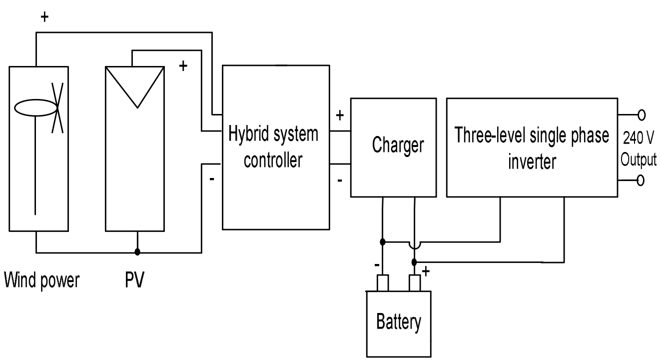


Fig. 1 Realized three level single phase PV - wind power hybrid inverter system

As shown in Fig. 2, the half and full bridge circuit before and after transformer are driven by four pulse waves at pin 1, 2, 11 and 12 that created by the microcontroller PIC16F628A-I/P as shown in Fig. 2. The operation principle of three level single phase inverter is explained below.

The transistor D313 and TIP35C in the half bridge circuit before transformer are main switches to create AC square waveform. MOSFET IRF 840 in full bridge circuit after transformer is main switch to create an AC three level waveform. Its operation principle is explained for the time of 20 ms that divided by two parts.

Part 1: AC square waveform

1. At the first time of 10 ms (the first half cycle) pin 1 has a pulse wave and pin 2 is zero, the transistor D313 and TIP35C in above and below part of the half bridge circuit before transformer are on and off, respectively. Thus for this time, primary and secondary side of the transformer, T_r have positive value.
2. At the second time of 10 ms (the second half cycle) pin 2 has a pulse wave and pin 1 is zero, the transistor D313 and TIP35C in above and below part of half bridge circuit before transformer are off and on, respectively. Thus for this time, primary and secondary side of the transformer, T_r have negative value.
3. For the time of 20 ms, the secondary transformer has an AC square waveform.

Part 2: DC waveform

The full bridge rectifier rectifies the AC square waveform. The DC voltage is around 200 V – 240 V and fed to the point B and B' of the full bridge circuit after transformer.

Part 3: AC three level waveform

The AC three level waveform is produced by the full bridge circuit after transformer. The circuit is driven by pulse waves that created by pin 11 and 12 of the microcontroller PIC16F628A-I/P. Changing the maximum voltage angle will produce a required AC three level waveform.

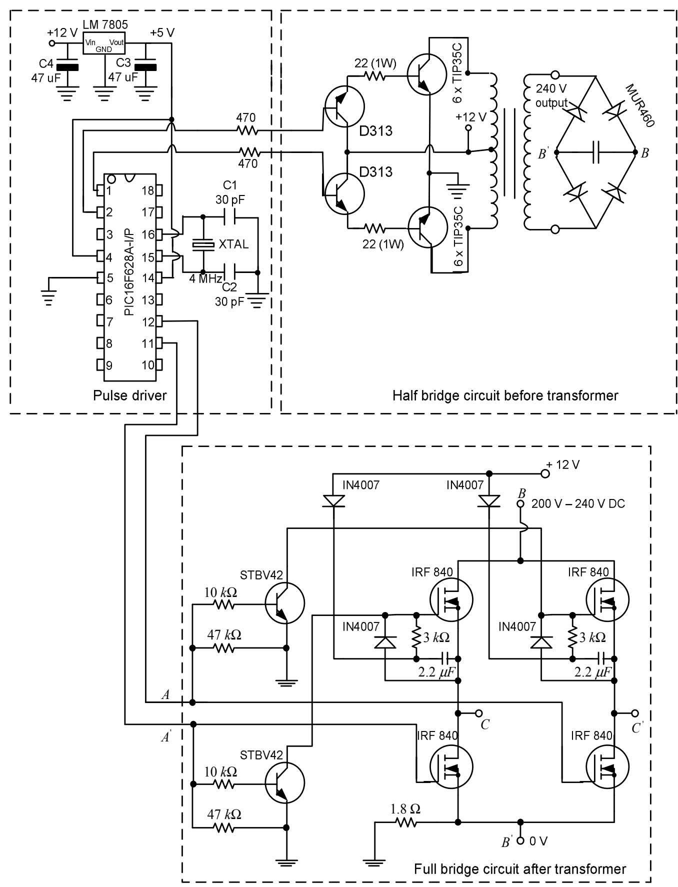


Fig. 2 Three level single phase inverter circuit

C. Experimental set up

Main experimental set up equipments of the three level single phase PV - wind power hybrid inverter consist of PV array, hybrid controller circuit, charger circuit, pulse driver circuit, half and full bridge circuit, battery, and lamp load of 10 W 220 V 50 Hz, and the measurement equipments consist of Vantage Weather Station Pro2, electrocorder voltage logger, and PM 300 Analyzer. The experimental setup is shown in Fig. 3.

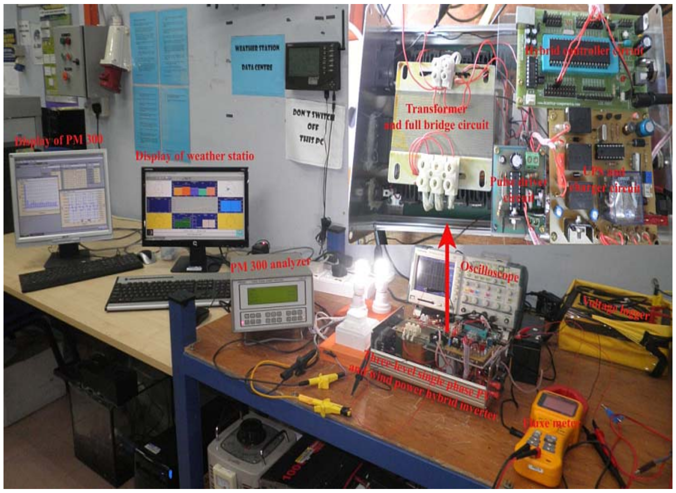


Fig. 3 Experimental setup of three level single phase PV - wind power hybrid inverter

As shown in Fig.3, inputs of the three level single phase PV - wind power hybrid inverter are connected to the PV array and wind power, its output is connected to the load of 10 W 220 V 50 Hz. The PV array and wind power generation 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 26th to 27th January 2012.

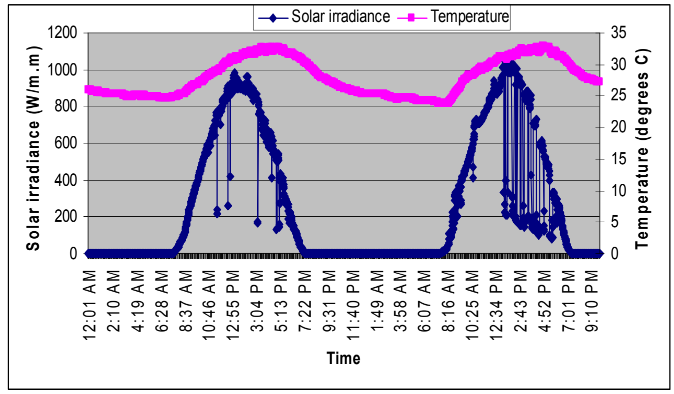
III. Result And Discussion

A. Weather Condition, PV Array and Wind Power Generation Voltage

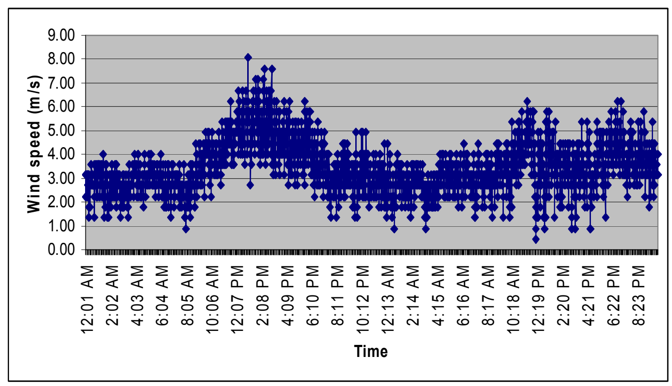
The weather condition of the solar irradiance, temperature and wind speed on 26th to 27th January 2012 is shown in Fig. 4.

For minimum, maximum and average of solar irradiance and temperature are observed on 7.00 am to 7.00 pm, because for this time gives potential of PV power generation and its average value is 489.52 W/m^2 that indicate it is suitable for PV power generation [4]. For minimum, maximum and average of wind speed is observed a long time, based on data sheet of wind power generation, the average and maximum wind speed are 3.45 m/s and 8.06 m/s, they indicate that the wind power generation is always run and reaches maximum power.

Value of the solar irradiance and temperature as shown in Fig. 4 effect on the PV array output voltage, and value of wind speed 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 [5, 6, 7]. 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 [8, 9, 10]. The PV and wind power generation voltage on 26th to 27th January 2012 are shown in Fig. 5.



(a) Solar irradiance and temperature



(b) Wind speed

Fig. 4 Weather condition

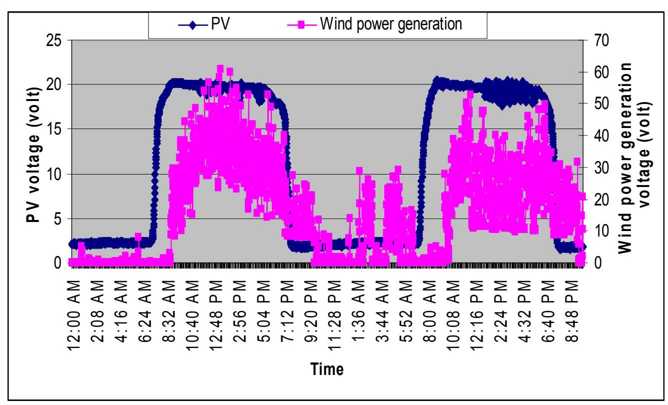
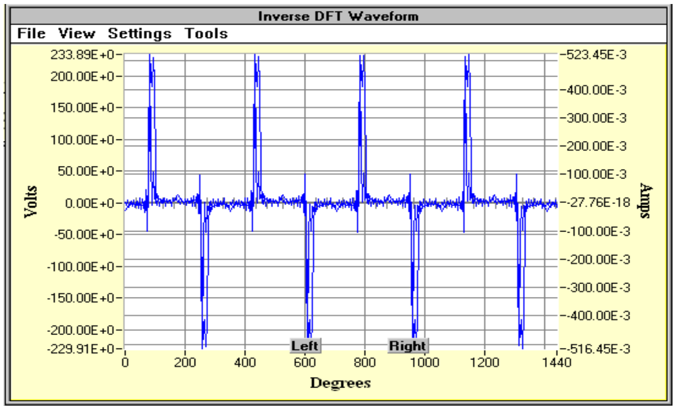
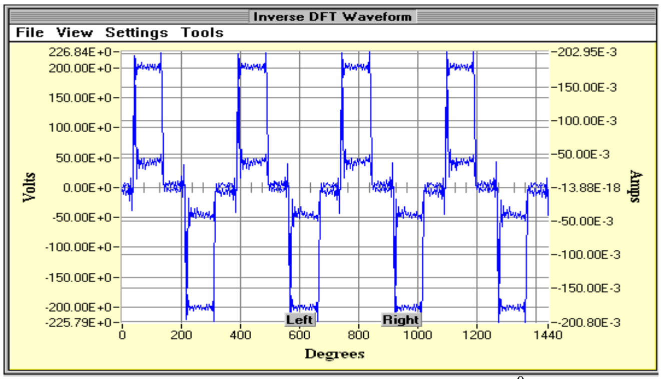


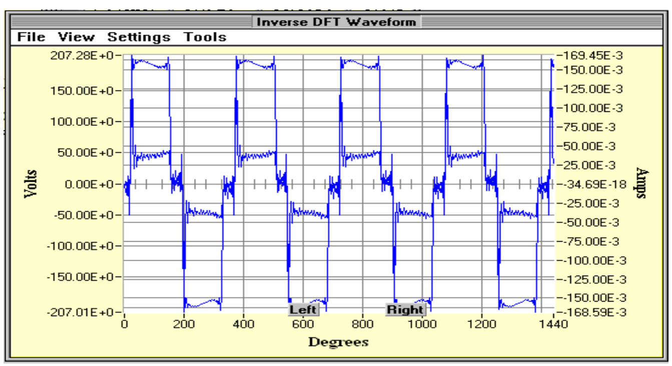
Fig. 5 PV and wind power generation voltage



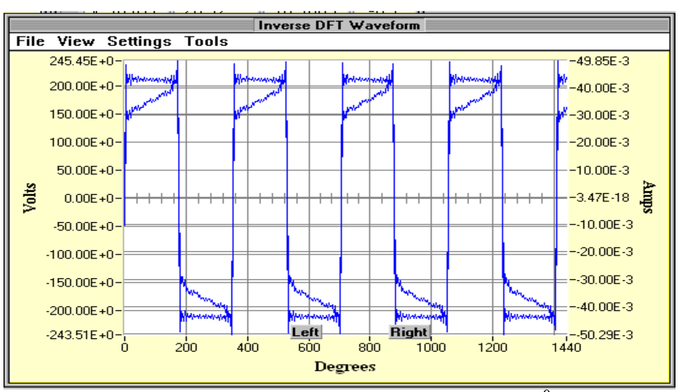
(a) Maximum voltage angle at 20^0



(b) Maximum voltage angle at 100^0

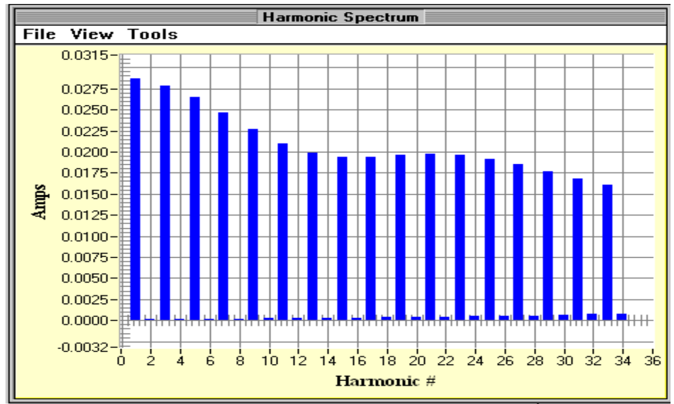


(c) Maximum voltage angle at 134^0

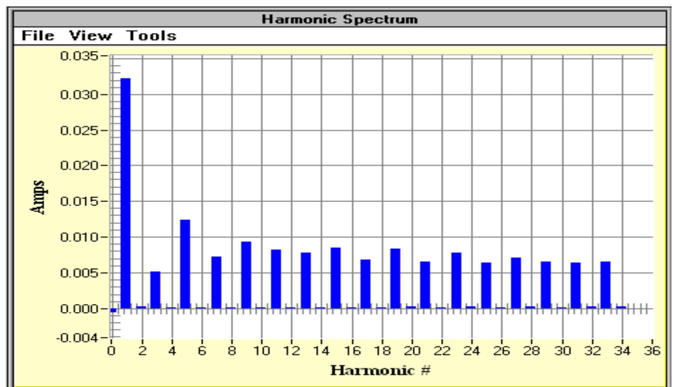


(d) Maximum voltage angle is 180^0

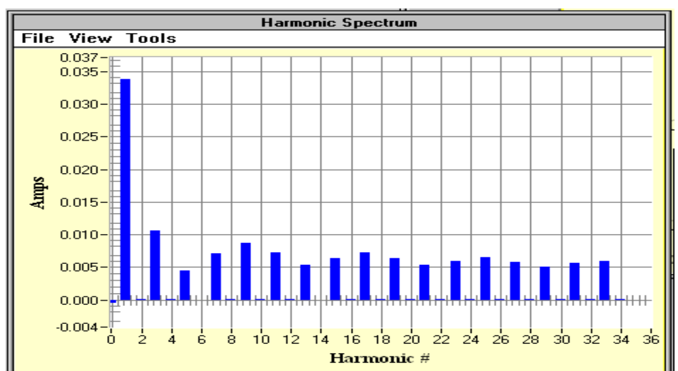
Fig. 6 AC load voltage and current waveform of the three level single phase PV-wind power hybrid inverter



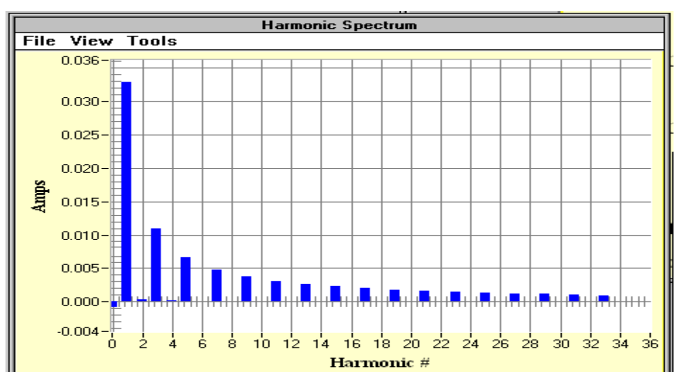
(a) Maximum voltage angle is 20^0



(b) Maximum voltage angle is 100^0



(c) Maximum voltage angle is 134^0



(d) Maximum voltage angle is 180^0

Fig. 7 Current harmonic spectrum of the three level single phase PV- wind power hybrid inverter

B. *Current total harmonic distortion (CTHD)*

Maximum AC voltage angle from 20^0 to 180^0 are developed by the full bridge inverter circuit using the microcontroller PIC16F627A-I/P as shown in Fig. 2, and varied every 20^0. Figs. 6 and 7 show four parts of AC waveform and current harmonic spectrum of the maximum AC voltage angle varied from 20^0 to 180^0. The variation of maximum voltage angles affect on 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 20^0, 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 159.42 % as shown in Fig. 8.

A three-level AC waveform starts to develop when the maximum voltage angle is 40^0. It produces CTHD of 120.35 % as shown in Fig. 8. It is lower CTHD compared to the CTHD that produced by the maximum voltage angle of 20^0.

Fig. 6 (b) shows three level AC waveform when its maximum voltage angle is 100^0. It produces lower current harmonic spectrum and CTHD compared to the CTHD that produced by the maximum voltage angle of 20^0 and 40^0 as shown in Figs. 7 (b) and 8.

A lowest current harmonic spectrum and CTHD are obtained when the maximum voltage angle is 134^0. Its AC three level waveform is shown in Fig. 6 (c), its current harmonic spectrum is shown in Fig. 7 (c) and its CTHD of 40.06 % 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 back as shown in Fig. 6 (d) as AC waveform for maximum voltage angle of 180^0, Fig. 7 (d) as its current harmonic spectrum and Fig. 8 as its CTHD.

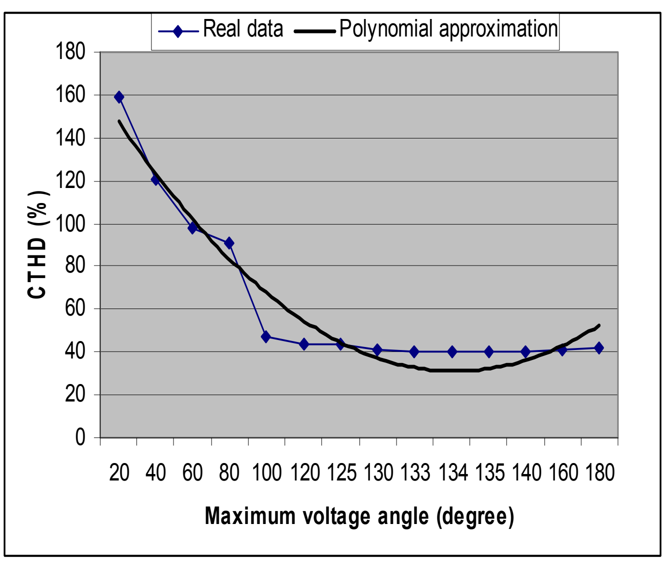


Fig. 8 CTHD versus maximum voltage angle for load of the lamp

IV. CONCLUSSION

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

1. Performance of the three-level single phase PV-wind power hybrid inverter depends on the solar irradiance, temperature and wind speed. For solar irradiance, temperature and wind speed on 26th to 27th January 2012. This time gives potential of PV power generation and its average value is 489.52 W/m^2 that indicate it is suitable for PV power generation, the average and maximum wind speed are 3.45 m/s and 8.06 m/s, they indicate that the wind power generation is always run and reaches maximum power.
2. The maximum AC voltage angle effects on the CTHD, the lowest CTHD of 40.06 % is obtained when the maximum voltage angle is 134^0.

V. REFERENCES

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