Applied Mechanics and Materials Vol. 793 (2015) pp 304-308
© (2015) Trans Tech Publications, Switzerland
doi:10.4028/www.scientific.net/AMM.793.304

Submitted: 2015-02-07
Accepted: 2015-06-17

# Effect of Maximum Voltage Angle on Inverter Performance Applied in Uninterrupted Power Supply (UPS)

M. Masri[1, a], R. Badlisha[2,b], M. Irwanto[3,c], N. Gomesh[4,d], Y.M. Irwan[5,e], F. Malek[6,f], H. Alam[7,g] and M.R. Mamat[8,h]

[3,4,5,6,7,8] Centre of Excellence for Renewable Energy (CERE), School of Electrical System Engineering,

Universiti Malaysia Perlis (UniMAP), Malaysia

[1,3,7] Department of Electrical Engineering, Medan Institute of Technology, Medan, Indonesia

[1,2] School of Computer and Communication , Universiti Malaysia Perlis (UniMAP), Malaysia

[a]mahrizalmasri @gmail.com, [b]badli@unimap.edu.my, [c]irwanto@unimap.edu.my, [d]gomesh@unimap.edu.my, [e]irwanyusoff@unimap.edu.my, [f]mfareq@unimap.edu.my, [g]hermans_itm@yahoo.co.id, [h]hrozailan@unimap.edu.my

**Keywords:** Maximum voltage angle, Inverter, Uninterrupted Power Supply.

**Abstract.** Uninterrupted power supply (UPS) sits between a power supply such as wall outlet and devices to prevent undesired feature that can occur within the power source such as outages, sags, surges and bad harmonics from the supply to avoid a negative impact on the devices. This paper presents a photovoltaic (PV) powered UPS using microcontroller PIC16F628A-I/P. It is a standby UPS whereas if the main power source fails to supply power to loads, a battery powered inverter turns on to continue supplying power. The battery is charged by the PV using solar charger and transfer switch controlled by the microcontroller. In this research, AC three-level waveform single phase inverter was developed and created by a microcontroller PIC16F627A-I/P with varied maximum voltage angle from $20^0$ to $180^0$ and tested to a load of 240 V, 20 W AC aquarium water pump, and also analyzed effect of maximum voltage angle on the three-level single phase inverter performance. The result showed that maximum voltage angles of the inverter effected on root mean square value of AC voltage, current and power. If the maximum voltage angle was increased, therefore value of the AC voltage, current and power would increase. The maximum voltage angle would effect on the current total harmonic distortion (CTHD), the lowest CTHD of 15.448% was obtained when the maximum voltage angle was $134^0$.

## Introduction

Uninterrupted power supplies are widely used as standby power for critical loads in case of utility power failure. It is usually derived directly from the power line, until power fails. After power failure, a battery powered inverter turns on to continue supplying power. Batteries are charged, as necessary, when line power is available. This type of supply is sometimes called “offline” UPS [1]. There are four major types of UPS [1, 2, 3]. They are stand by UPS, ferroresonant or hybrid UPS, line interactive UPS and online UPS.

Nowadays, PV power generations are widely used for converting solar energy to direct current (DC) electrical energy, the DC can be converted to alternating current (AC) using inverter. A method of relay controller that efficiently utilizes PV array to UPS is described by [4]. The UPS have three-relay controller using a low cost microprocessor. The relay controller, through its port, may indicate anomalies detected by examining open circuit and maximum voltage.

This paper presents a photovoltaic (PV) powered UPS using microcontroller. It is a standby UPS whereas if the main power source fails to supply power to loads, a battery powered inverter turns on to continue supplying power. The battery is charged by the PV using solar charger and transfer switch controlled by microcontroller.

**Proposed PV UPS System**

The proposed UPS in this paper is a photovoltaic powered uninterruptible power supply using the microcontroller PIC16F628A-I/P. Based on types of UPS that are discussed above, it is a standby UPS whereas if the main power source fail to supply power to loads, a battery powered inverter turns on to continue supplying power. The battery is charged by the PV using solar charger and transfer switch controlled by the microcontroller PIC16F628A-I/P.

A proposed circuit of photovoltaic powered uninterruptible power supply using the microcontroller PIC16F628A-I/P is shown in Fig. 1. Based on the circuit, its components will be discussed as this below.

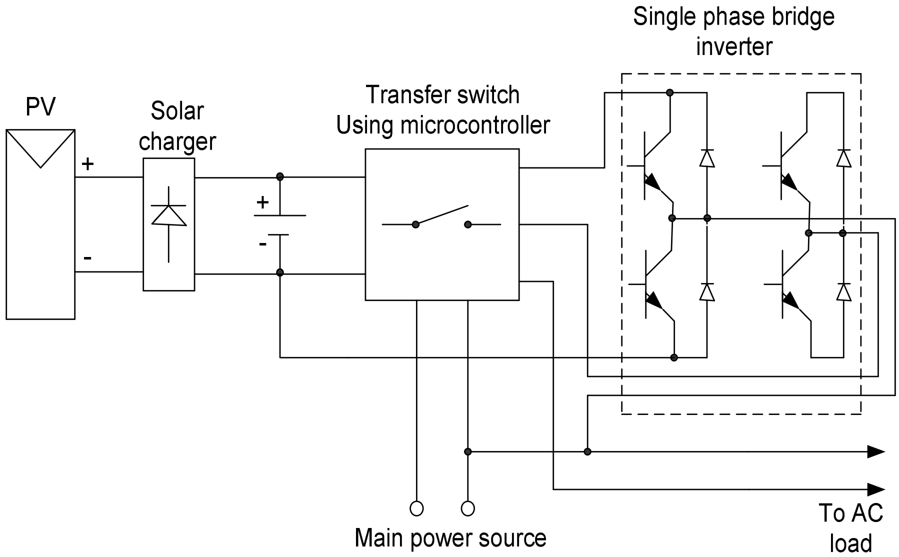



Fig. 1. A proposed block diagram of PV powered UPS using the microcontroller PIC16F628A-I/P

22 V, 50 W, 2.3 A photovoltaic is used in this UPS. The PV can convert solar energy become DC electrical energy. The PV is as main DC source and used to charge the battery using the solar charger. Output voltage and current of the PV depends on solar irradiance and temperature. The needed output voltage to charge battery is usually above 12 V and the flowing current through the solar charger follows the voltage change. Function of the solar charger is to charge the battery. The used solar charger in this UPS is as applied by [4,5].

The transfer switch of the UPS consists of microcontroller PIC16F628A-I/P and three 12 V DC relays. The supply of microcontroller is 5 V DC that produced by LM 7805. Each 12 V DC relay is connected to the pin 11, 12 and 13 of the microcontroller. This inverter is a modified square sine wave inverter where low orders of harmonics content are reduced using the microcontroller PIC16F628A-I/P.

**Results and Discussion**

The AC load of UPS is 240 V, 20 W AC water pump. The water pump is used to give water circulation of aquarium and have to run continuity. If the main power source fails, the water pump can be run by the UPS inverter. The hardware of proposed PV powered UPS using the microcontroller and experimental set up are shown in Fig. 2 and 3, respectively.

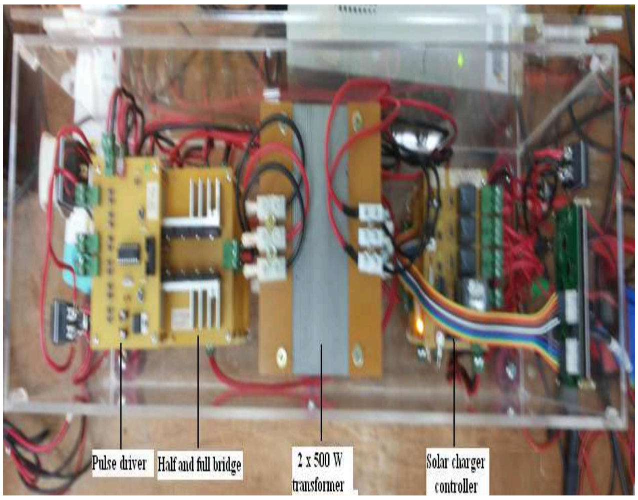



Fig. 2. Hardware of proposed PV powered UPS using microcontroller

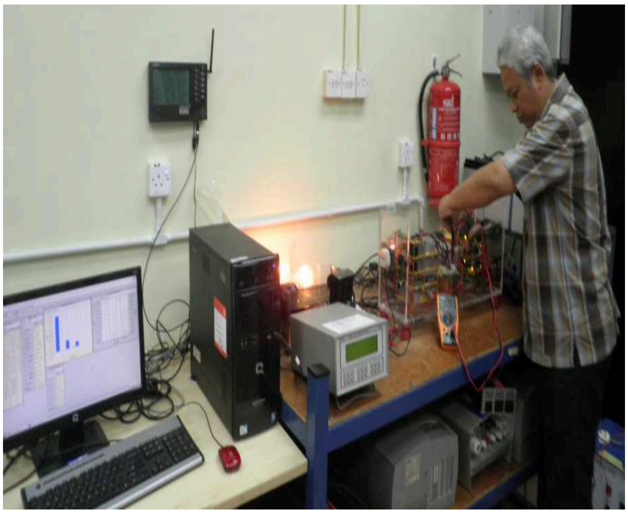
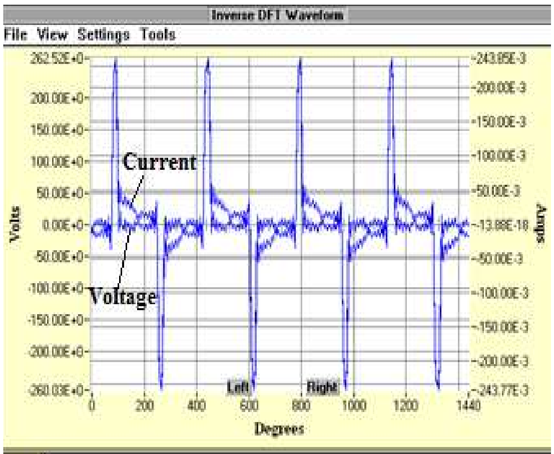
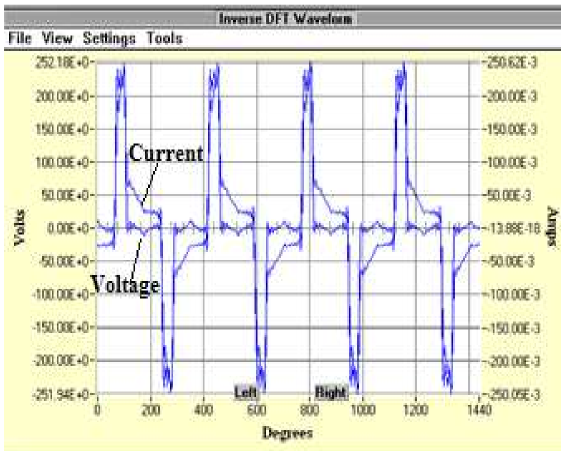


Fig. 3. Experimental set up

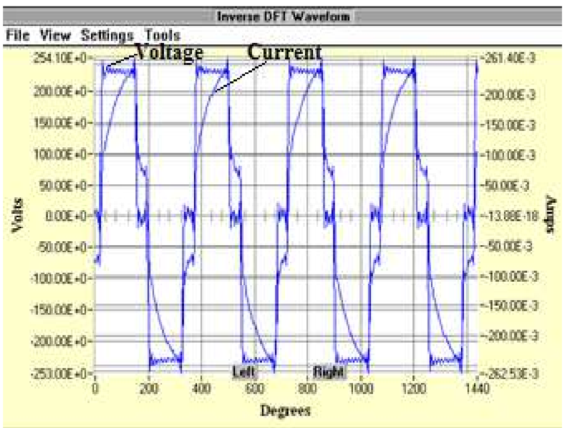
The experimental set up is done to know the performance of the inverter. The AC voltage and current waveform of the inverter for the maximum voltage angle of $20^0$, $40^0$, $134^0$ and $180^0$ are shown in Fig. 4. Change of maximum voltage angle of AC waveform of the inverter will effect on value of the AC voltage and current waveform. If the maximum voltage angle was increased, therefore value of the AC voltage and current waveform would increase as shown in Fig. 5 and 6, respectively. They also will effect on the power and CTHD as shown in Fig. 7 and 8, respectively.



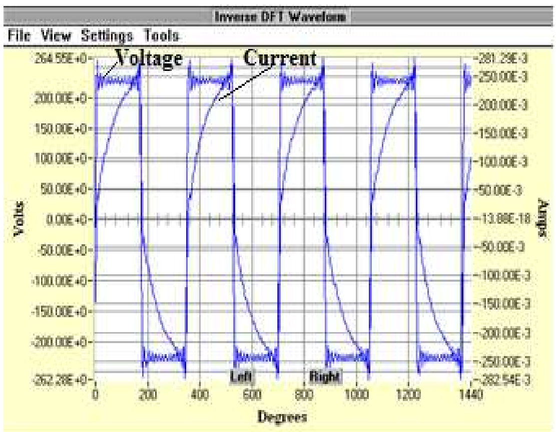

(a) Maximum voltage angle at $20^0$




(b) Maximum voltage angle at $40^0$




(c) Maximum voltage angle at $134^0$




(d) Maximum voltage angle at $180^0$

Fig. 4 AC voltage and current waveform of the inverter

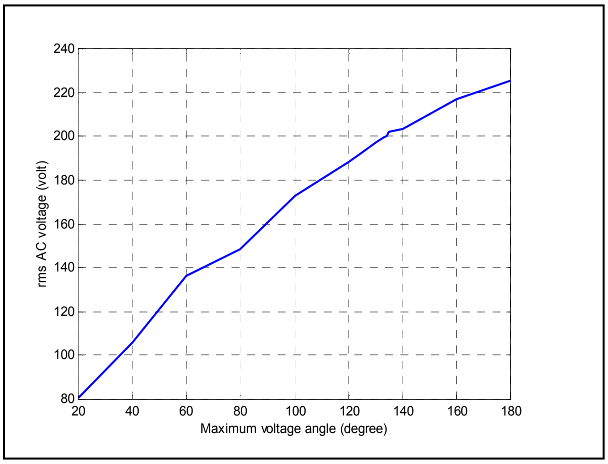



Fig. 5 Effect of maximum voltage angle on the AC voltage

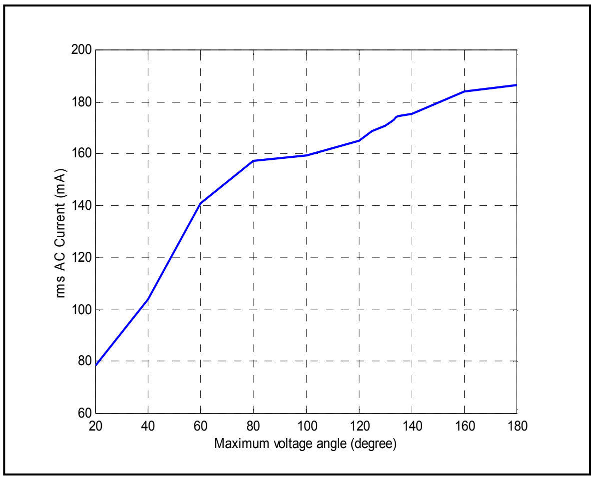



Fig. 6 Effect of maximum voltage angle on the AC current

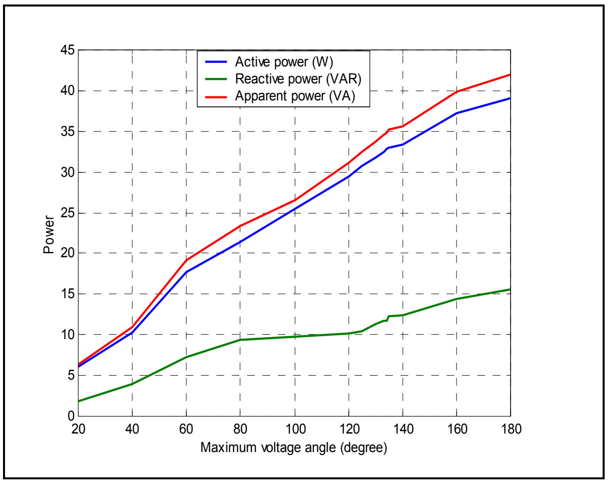



Fig. 7 Effect of maximum voltage angle

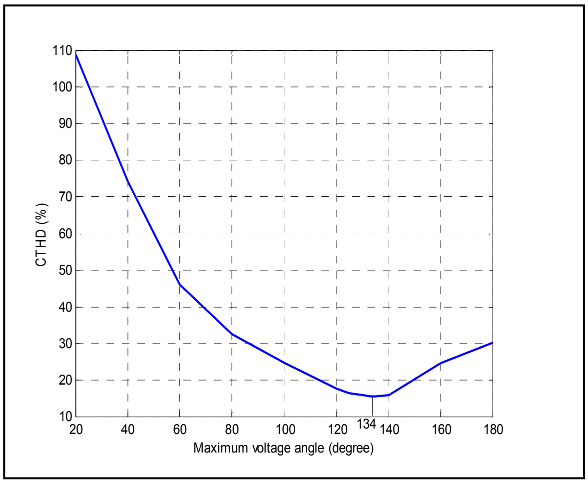



Fig. 8 Effect of maximum voltage angle on current total harmonic distortion (CTHD)

The inductive load of 20 W 240 V 50 Hz AC water pump which were connected to the inverter output produced current harmonic spectrum and CTHD in which their value depended on type of the AC waveform.

When the maximum voltage angle was $20^0$, AC voltage and current waveform of the TPVI was not perfect as shown in Fig. 4 (a), therefore it produced a highest CTHD of 108.94 % as shown in Fig. 8.

A three-level AC waveform started to be developed when the maximum voltage angle was $40^0$ as shown in Fig. 4 (b). It produced a lower CTHD of 74.33 % as shown in Fig. 8. It was lower CTHD compared to the CTHD that produced by the maximum voltage angle of $20^0$.

When the maximum voltage angle was increased from $60^0$ to $133^0$, the AC voltage and current waveforms were more perform, they produced lower CTHD.

A CTHD was obtained when the maximum voltage angle was $134^0$. Its AC three-level waveform is shown in Fig. 4 (c), its CTHD of 15.448 % is shown in Fig. 8. The maximum voltage angle was a optimal angle to obtain a lowest CTHD.

If the maximum voltage angle was increased to $180^0$ as shown in Fig. 5 (d), therefore the current harmonic spectrum and CTHD would increase back as shown in Fig. 8.

## Conclusion

This paper presents a photovoltaic (PV) powered UPS using microcontroller. It is a standby UPS whereas if the main power source fails to supply power to loads, a battery powered inverter turns on to continue supplying power. The battery is charged by the PV using solar charger and transfer switch controlled by microcontroller PIC16F628A-I/P. The UPS was tested to a load of 240 V, 20 W AC aquarium water pump. The test result shown that the UPS perform well, when the main power source fails, the battery could power inverter and the microcontroller controls the transfer switch of the UPS inverter and main power source. The maximum voltage angles of the inverter effected on root mean square value of AC voltage, current and power. If the maximum voltage angle was increased, therefore value of the AC voltage, current and power would increase. The maximum voltage angle would effect on the current total harmonic distortion (CTHD), the lowest CTHD of 15.448% was obtained when the maximum voltage angle was $134^0$.

## Acknowledgements

This work was financially supported by Incentive Journal Grant, Universiti Malaysia Perlis (UniMAP).

## References

[1] M. S. Racine, J. D. Parham and M.H. Rashid, “An overview of uninterruptible power supplies”, IEEE Explorer, 2005.
[2] W. bower, “ Bimode uninterruptible power supply compatibility in renewable hybrid energy system “, IEEE AES magazine, August 1990.
[3] I. Daut , M. Irwanto and Surya Hardi. *Photovoltaic Powered Uninterruptible Power Supply Using Smart Relay*. The 4rd International Power Engineering and Optimization Conference PEOCO2010), Shah Alam, Selangor, MALAYSIA. 23-24 June 2010. Published in IEEEXplore, p. 453-457.
[4] S. Jayasimha and T. P. Kumar, “ Photovoltaic UPS “, TENCON 2003.
[5] G. F. Cook, “Buck Mode Switching Regulator for Solar Applications”, http:// www.solorb.com/elect/solarcirc/buckreg1/ index.html, June 23, 2006.