

# Irwanto 12

*by Irwanto Irwanto*

---

**Submission date:** 13-Jul-2022 04:42PM (UTC+0700)

**Submission ID:** 1870016638

**File name:** Alam\_2020\_J.\_Phys.\_Conf.\_Ser.\_1432\_012056-1.pdf (789.24K)

**Word count:** 3865

**Character count:** 17921

PAPER • OPEN ACCESS

## Design of multiple Pulse Width Modulation (MPWM) Transformerless Photovoltaic Inverter (TPVI) system

9

To cite this article: H Alam *et al* 2020 *J. Phys.: Conf. Ser.* **1432** 012056

View the [article online](#) for updates and enhancements.

### You may also like

- [Design and analysis of the mooring system for the box-type inverter-transformer floating platform](#)

H B Liu, F Yu, S Zhang *et al.*

9

- [A Grid Tied Short-Through Proof Solar PV Inverter](#)

M U Ägu, E C Ejogu, D B N Nnadi *et al.*

- [Sinusoidal inverter using pulse width amplitude modulation](#)

M H Mohs, **20** K Alshamaa, Dalal A Hammood *et al.*



The Electrochemical Society  
Advancing solid state & electrochemical science & technology

## 242nd ECS Meeting

Oct 9 – 13, 2022 • Atlanta, GA, US

Early hotel & registration pricing  
ends September 12

Presenting more than 2,400  
technical abstracts in 50 symposia

The meeting for industry & researchers in

**BATTERIES**  
**ENERGY TECHNOLOGY**  
**SENSORS AND MORE!**



Register now!



**ECS Plenary Lecture featuring**  
**M. Stanley Whittingham,**  
Binghamton University  
Nobel Laureate –  
2019 Nobel Prize in Chemistry



## Design of multiple Pulse Width Modulation (MPWM) Transformerless Photovoltaic Inverter (TPVI) system

H Alam<sup>1</sup>, Irwanto M<sup>1,2</sup>, Mashor Y M<sup>3</sup>, Masri M<sup>1</sup>

<sup>1</sup>Department of Electrical Engineering, Institut Teknologi Medan (ITM, Medan, Indonesia

<sup>2</sup>Fellow of Centre of Excellence for Renewable Energy, School of Electrical System Engineering, Universiti Malaysia Perlis (UniMAP), Perlis, Malaysia

<sup>3</sup>School of Mechatronic Engineering, Universiti Malaysia Perlis, Pauh Putra Campus, Malaysia

**Abstract:** A normal inverter always uses a transformer. By presenting a transformer in the inverter causes its size, losses and efficiency to be relative big, high and low, respectively. An alternative to remove the transformer is very important to solve the problems, but it is still has good performance, especially in the required power quality. This paper presents a design of multiple pulse width modulation (MPWM) transformer less photovoltaic inverter (TPVI) system. It consists of a full bridge inverter circuit, a photovoltaic (PV) voltage storage circuit, a pulse driver circuit, and a circuit of LC filter. An experimental setup is conducted to observe the performance of MPWM TPVI system. The result shows that its performance depend on the solar irradiance and temperature because it operates directly on the sunny day.

### 1. Introduction

The installation of photovoltaic standalone system grows rapidly, it serves a small electrical load and it is suitable installed in rural area where no utility grid connection. An analysis of solar irradiation at the potential site should be made at stage of inception, it is due to meteorological condition (solar irradiation and temperature) in different area are always different. Knowing solar irradiation potential in an area, it can be decided that it can be suitable or not to develop photovoltaic power generation [1].

Normally, low frequency (50 Hz) inverter uses a transformer that it is bigger in size, heavy and expensive. The simplest technique to invert DC power into AC power is to generate a square wave. However, the harmonic content of the square wave is relatively high, also the efficiency of this waveform is relatively low. [2] – [7] stated that for reducing the size, weight and manufacturing cost, the transformerless PV inverter is suitable, it improves the efficiency system.

[3] stated that the full-bridge inverter with bipolar PWM generates no common-mode voltage. This inverter is simple, as it only requires four IGBTs. The IGBTs that are used in this inverter must deal with input voltages ( $V_{in}$ ) close to 800 V, so 1200 V IGBTs are chosen. Consequently, it is used nowadays in some transformerless inverter.

[6] stated for reducing the manufacturing cost and for increasing the efficiency of module-integrated converter the transformerless concept is suitable. The new type inverter, which is proposed, basically works as buck boost DC-DC converter. Therefore, it is possible to reduce the number of the active switches in comparison with conventional inverter for AC modules because of simple circuit topology. The control method and operation test results including both stand alone and grid connected for the new type transformerless inverter are presented. These measurement results show that the performances can compete with the conventional small inverter (rated capacity around 50 W).

This paper presents the solar irradiation in Kangar for observing and analyzing the potential of MPWM TPVI system application. A MPWM TPVI system was constructed by four main circuits, namely photovoltaic (PV) voltage storage circuit, pulse driver circuit, full bridge circuit and LC circuit. The AC output voltage waveform of MPWM TPVI system is sinusoidal that it is driven by microcontroller PIC 16F877A in the full bridge circuit. It is due to the MPWM TPVI system is operated directly by PV module.

Transformerless PV inverter presented by some researchers still uses diode or capacitor as DC link (connection between PV array and inverter), it can still produce leakage current. They also still use IGBT as switching, in which it can produce high losses when operating as switching mode. They also use conventional pulse wave conventional (PWM) to produce pulse wave, it do not perform well and it is easy to burn. A proposed MPWM TPVI is interesting to be designed which consists of power factor correction (PFC) circuit, pulse driver circuit, full bridge inverter circuit and LC filter. The PFC circuit has diode and capacitor, it is as DC link. It can eliminate leakage current and store DC voltage of the PV array. The pulse driver circuit produces pulse wave. It is easy to create the pulse wave using microcontroller PIC16F628A-I/P. The full bridge inverter circuit is constructed by high switching MOSFET, it has low losses, thus high efficiency of inverter can be obtained. The LC filter has function to generate the pure AC voltage waveform.

## 2. Methodology

This section presents a design of the MPWMTPI system which consists of photovoltaic (PV) voltage storage circuit, a full bridge inverter circuit, a pulse driver circuit, and a circuit of LC filter. The detail explanation of each circuit is stated in this sub section.

### Circuit and components of PWM TPVI system

The PV voltage storage circuit as shown in Figure 1 is applied to store the PV voltage for the momentary time if there is fluctuation of solar irradiance and temperature. The point +S and -S are the input voltage terminal which is supplied by the PV array. The output of this circuit at point +PV and -PV is connected to the full bridge inverter circuit to produce the multiple PWM AC waveform.

The choice of integrated circuit (IC) MC 34262 is due to it is a power motor control IC designed for use as pre-converter in power converter application (PV standalone). The IC is fully protected and eliminates the often noise sensitive line voltage sensing requirement of existing solution. The MC 34262 features include programmable switching frequency, programmable dedicated over voltage protection, open loop and micro power start up current.

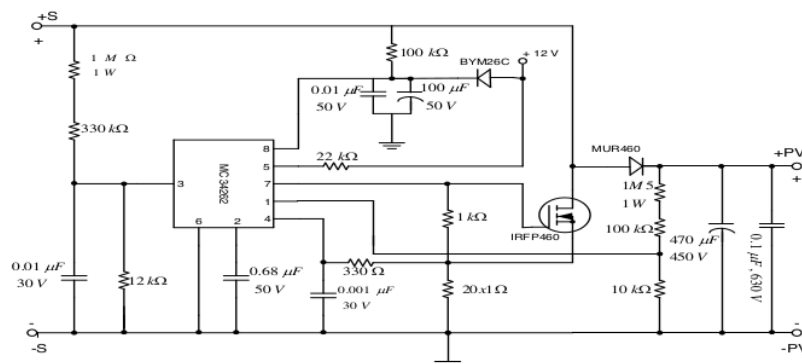


Figure 1. PV voltage storage circuit

The MC 34262 can be applied into DC voltage up to 400 V, while the multiple input pin of the MC 34262 at pin 3 needs DC voltage -1 V to +10 V. Therefore resistor divider is needed to divide the DV voltage. The resistor of 1 MΩ, 330 kΩ and 12 kΩ are suitable for this case. The DC voltage across

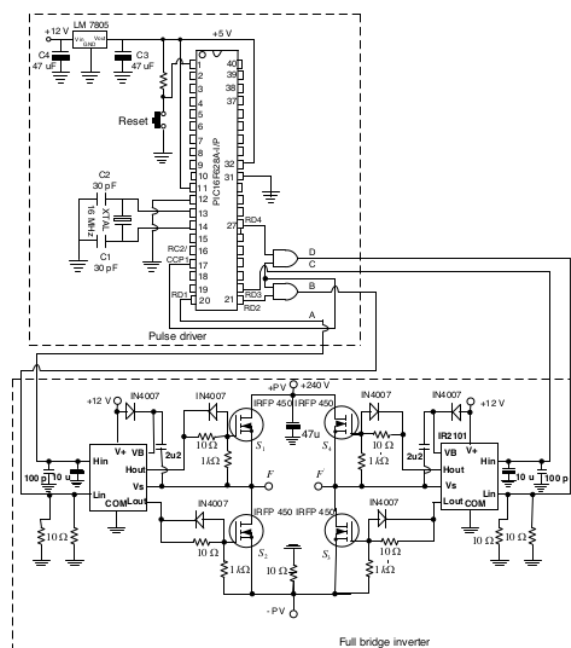
the resistor of  $12\text{ k}\Omega$  is around  $3.6\text{ V}$  and it is paralleled to the capacitor of  $0.01\text{ }\mu\text{F}$ ,  $30\text{ V}$ . The choice of the capacitor is suitable to be applied into DC voltage of  $3.6\text{ V}$ .

The pin  $V_{cc}$  of the MC 34262 at pin 8 needs DC voltage of 12 V which is connected to a diode BYM26C and capacitor of  $0.01 \mu F$ , 50 V and  $100 \mu F$ , 50 V. The capacitors are suitable to be applied into the DC voltage of 12 V and their function is as filter.

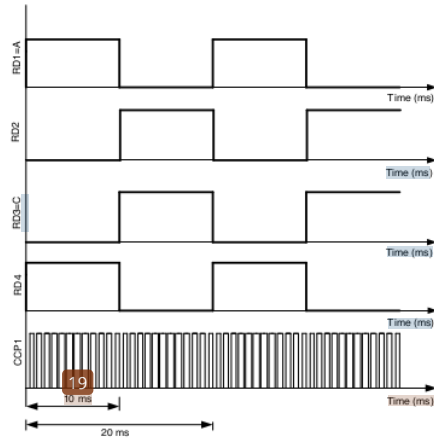
Switching frequency selection is based on capability of the current flowed through the system. A MOSFET IRFP460 is selected as switching frequency that it has rating current 20 A and it has high switching mode. It is accomplished by selecting the value of resistor of 1 k $\Omega$  and 330  $\Omega$ . A parallel combination of 20 units of 1  $\Omega$  resistance is to reduce the effect of soldering resistance. This is difficult if one 0.05  $\Omega$  resistance is used.

Capacitor of  $470\ \mu F$ ,  $450\ V$  and  $0.1\ \mu F$ ,  $630\ V$  at the end of the power factor correction circuit are chosen that they can store the DC voltage and also the choice is suitable to be applied into the DC voltage of  $400\ V$ .

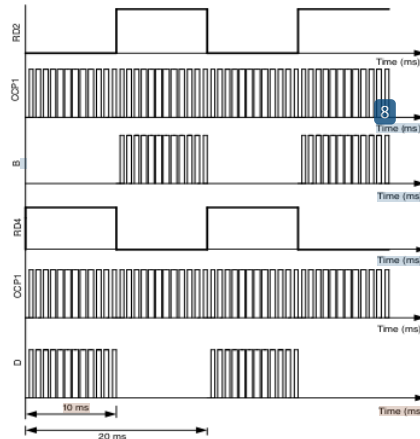
The pulse driver circuit is used to produce four square waves and 160 PWM outputs with difference duty cycle but same period in time of 10 ms as shown in Figure 2. They are needed to drive the MOSFETs IRFP450 in the full bridge inverter circuit. The square waves and PWM outputs are developed by a microcontroller PIC16F877A-I/P at PORT RD1, RD2, RD3, RD4 and RC1/CCP1 as shown in Figure 3. Two AND gates are needed to convert the square waves and PWM outputs at PORT RD2, RD4 and RC1/CCP1. The square waves and PWM outputs at PORT RD2, RD4 and RC1/CCP1 and the AND gate outputs at point B and D are shown in Figure 4.



**Figure 2.** Proposed pulse driver and full bridge inverter circuit of MPWM TPVI system

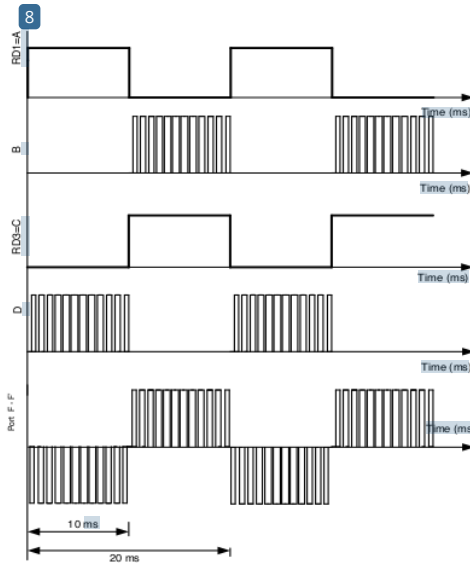


**Figure 3.** Four square waves and 160 PWM output with difference duty cycle but same period in time of 10 ms

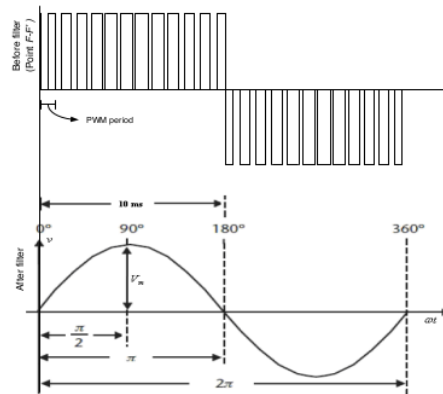


**Figure 4.** The square waves and PWM outputs at PORT RD2, RD4 and RC1/CCP1 and the AND gate outputs at point B and D

The full bridge inverter circuit which is shown in Figure 2 is used to convert the 240V DC PV voltage to an AC waveform. The square waves and PWM outputs from the pulse driver circuit as shown in Figure 2 are needed to drive the MOSFETs IRFP450. The point  $F$  and  $F'$  are the AC output waveform as shown in Figure 5 in which its magnitude depends on DC input at point +PV and -PV between 200 V and 240 V. A circuit of LC filter connected at the point  $F$  and  $F'$  are needed to generate pure sinusoidal voltage waveform as shown in Figure 6 [8].



**Figure 5.** AC output waveform generation



**Figure 6.** AC voltage waveform before and after LC filter

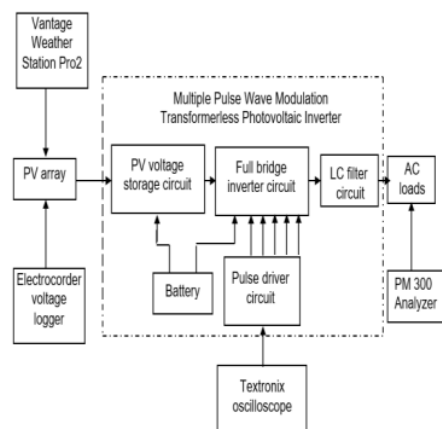
#### Experimental setup of MPWM TPVI System

Main experimental setup equipments of the MPWM TPVI system consist of PV module, PV voltage storage, pulse driver, full bridge, LC filter and AC load types. The measurement equipments consist of electrocorder voltage logger, Vantage Weather Station Pro2, tectronix oscilloscope and PM 300

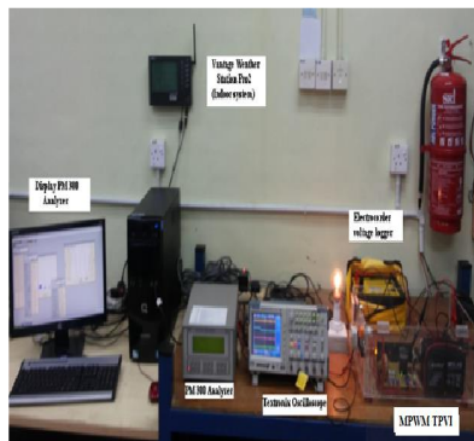


Analyzer as represented in block diagram in Figure 7.

The MPWM TPVI input is connected to the PV array and its output is connected to the resistive lamp load. The PV array output voltage is measured by electrocorder voltage logger which its value depended on solar irradiance and temperature. The solar irradiance 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.



(a) Block diagram



(b) Equipments

Figure 7. Experimental setup of the MPWM TPVI system

### 3. Result and Discussion

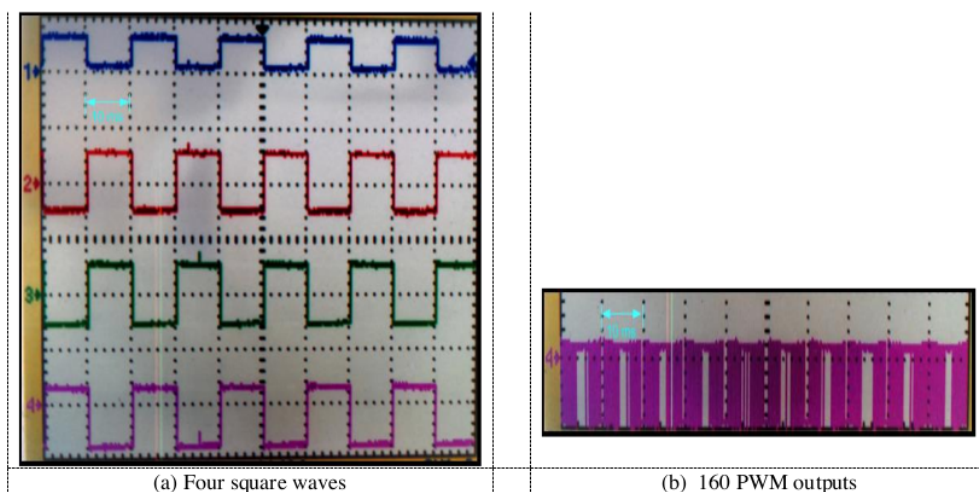
The pure sinusoidal AC voltage waveform is generated based on the conversion of PV voltage source that it is fed into port +PV and -PV of the full bridge circuit as shown in Figure 2. The full bridge circuit is constructed by four MOSFETs IRFP450 and each gate is driven by two square waves and two PWM outputs that have duty cycle of 10 ms. The square waves and two PWM outputs are generated by PIC16F877A at PORT RD1, RD2, RD3, RD4 and RC1/CCP1 via two AND gates.

#### *Square wave and PWM output generated by PIC16F877A*

Four square waves and 160 PWM outputs are generated by PIC16F877A at PORT RD1, RD2, RD3, RD4 and RC2/CCP1 as shown in Figure 8. For the first half cycle of 10 ms PORT RD1 and RD4 generate the high value square wave, PORT RD2 and RD3 generate low value square wave, while the PORT RC2/CCP1 generate the 160 PWM outputs. For the second half cycle of 10 ms PORT RD1 and RD4 generate the low value square wave, PORT RD2 and RD3 generate high value square wave, while the PORT RC2/CCP1 still generate the 160 PWM outputs.

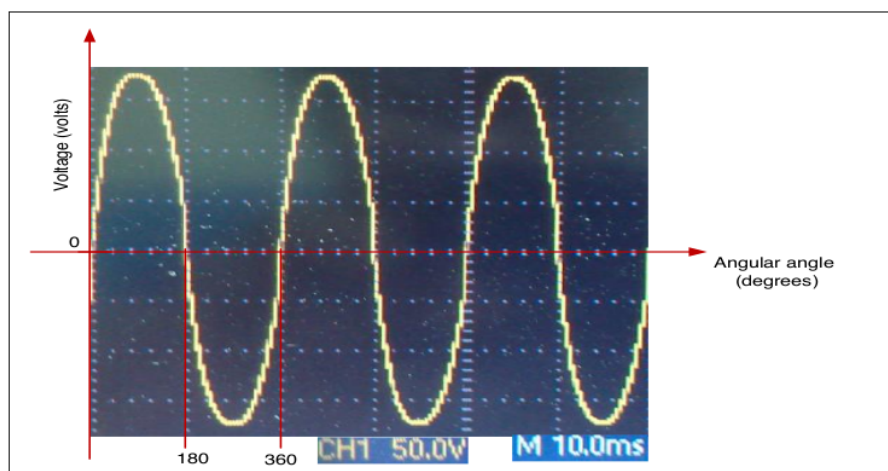
#### *Pure sinusoidal AC voltage waveform*

The pure sinusoidal AC voltage waveform is generated at output terminal of LC filter. The inductance of inductor and capacitance of capacitor affect the pure sinusoidal AC voltage waveform. The choice of suitable value is very important to obtain the pure sinusoidal AC voltage waveform. Some inductance of inductors and capacitance of capacitors have been tested to obtain the pure sinusoidal voltage waveform. The testing was done by increasing the inductance of inductor and decreasing the capacitance of capacitor. Every change of the inductance of inductor and capacitance of capacitor were observed and recorded to obtain the pure sinusoidal AC voltage waveform using Textonix oscilloscope.



**Figure 8.** Measurement result of four square waves and 160 PWM outputs using Textronix oscilloscope

The increasing of capacitance of capacitor to be 0.022  $\mu\text{F}$  and the decreasing of inductance of inductor to 4.498 mH have been done. This condition produces a pure sinusoidal AC voltage waveform as shown in Figure 9. The 0.022  $\mu\text{F}$  capacitance of capacitor and the 4.498 mH inductance of inductor are fix values in the LC filter circuit of the MPWM TPVI system.



**Figure 9.** Sinusoidal AC voltage waveform  $C = 0.022 \mu\text{F}$  and  $L = 4.498 \text{ mH}$

#### Performance of MPWM TPVI System

To understand and analyze the performance of MPWM TPVI system, it was tested by connecting to the three PV modules that connected in series as DC voltage source input of the MPWM TPVI system, each PV module has data sheet of 91.8 V, 9 A and 60 W. It indicates that the DC voltage source input has 275.4 V, 0.9 A and 180 W for the standard test condition (STC) of solar irradiance of  $1000 \text{ W/m}^2$  and temperature of  $25^\circ\text{C}$ . The output terminal of MPWM TPVI system is connected to a 15 W resistive lamp.

The performance of MPWM TPVI system depends on the capacity of PV module connected its input and PV module performance depends on the solar irradiance and temperature. If the solar irradiance increase and the temperature is constant, the performance of PV module will also increase



and it can increase the power capacity of MPWM TPVI system. Inversely, if the solar irradiance is constant and the temperature increase, the performance of PV module will decrease and it can decrease the power capacity of MPWM TPVI system.

In the experiment, the solar irradiance and temperature are measured using weather station Pro2. The PV module voltage and current are measured using electrocorder voltage logger. The performance of MPWM TPVI, in term of AC load voltage and power are measured using PM 300 analyzer. The measurements were done on the real system and they were recorded every 5 minutes on 23<sup>rd</sup> April 2015 from 7.45 am to 6.45 pm.

The MPWM TPVI system was observed on 23<sup>rd</sup> April 2015 from 7.45 am to 6.45 pm and also analyzed their performance which depended on solar radiation and temperature. The weather condition of the solar irradiance and temperature are shown in Figure 10. The average of solar irradiance is 445.46 W/m<sup>2</sup> or 5320.7 Wh/m<sup>2</sup>. It means that the solar irradiance on 23<sup>rd</sup> April 2015 is classified in very high solar radiation and it is suitable to run the MPWM TPVI.

Values of the solar irradiance and temperature as shown in Figure 9 affect the PV array output power. If the solar irradiance increase and assuming the temperature is constant will cause the PV array output power increase, otherwise if the temperature increase and assuming the solar irradiance is constant will cause the PV array output power decrease [9]. The PV array output power capacity affects the performance of MPWM TPVI system.

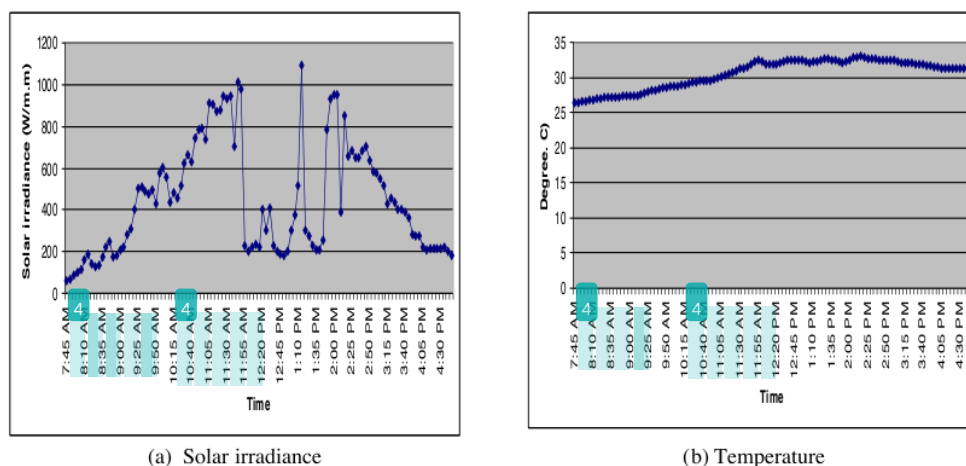
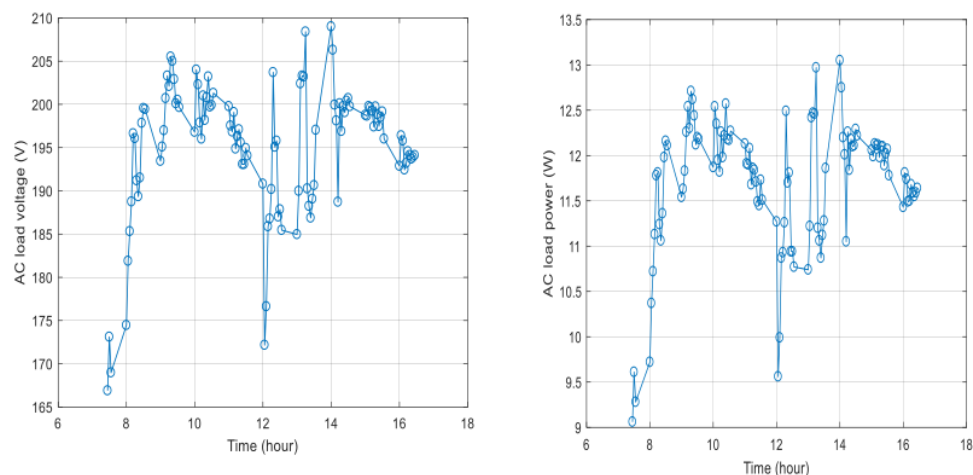


Figure 10. Weather condition on 23<sup>rd</sup> April 2015

The measurement and simulation rms load voltage and power on 23<sup>rd</sup> April 2015 are shown in Figure 11. The solar irradiance as shown in Figure 10 affects the AC load voltage and power. Exactly, on the time of 12.00 noon to 2.00 PM, the solar irradiance is fluctuation and forward to decrease, it is followed by the decreasing of AC load voltage and power.



(a) rms AC load voltage

(b) AC load power

Figure 11. rms AC load voltage and AC load power on 23<sup>rd</sup> April 2015

#### 4. Conclusion

From the study of solar radiation potential in Kangar, Malaysia to generate the multiple pulse wave modulation (MPWM) transformerless photovoltaic inverter (TPVI) following conclusions can be deduced:

Based on solar radiation data through the year 2015, the average monthly solar radiation for the year of 2015 is 407.0 W/m<sup>2</sup> or 4861.44 Wh/m<sup>2</sup>. It is classified as a very high solar radiation and indicates that the sky in Kangar is very clear and very suitable for generating the MPWM TPVI system.

Normally, the low frequency (50 Hz) inverter uses a transformer that it is bigger in size, heavy and expensive. For reducing the size, weight and manufacturing cost, the MPWM TPVI is suitable, it can generate a sinusoidal AC waveform which is suitable for the long life of AC loads. The MPWM TPVI system is designed by using MOSFET IRFP 450 and LC filter that can flows the current of 5 A .

#### References

- [1] Saleh K, Irwanto M, Haziah A. H, Ismail B, Gomesh N, Alam H, Masri M and Irwan Y. M2017 Estimation of Solar Irradiation in Medan Using Hargreaves Method Based on Minimum and Maximum Temperature for Potential Assessment of Photovoltaic Power Generation Advanced Science Letters 23(2017) 003
- [2] Kavidha B and Rajambal K 2006 Transformerless Cascaded Inverter Topology for Photovoltaic Applications Proceeding of Indian International Conference on Power Electronics 328-331.
- [3] Gonzales R, Lopez J, Sanchis P, Gubia E, Ursua A and Marroyo L 2006 High-efficiency transformerless single-phase photovoltaic inverter, IEEE Explore
- [4] Lopes O, Teodorescu R. and Gandoy J.D 2006 Multilevel transformerless topologies for single-phase grid-connected converter IEEE Explore.
- [5] Yang B, Li W, Deng Y, He X, Lambert S and Pickert V 2006 A novel single-phase

transformerless photovoltaic inverter connected to grid IEEE Explore.

- [6] <sup>13</sup> Kusakawa M, Nagayoshi H, Kamisako K and Kurokawa K 2011 Further Improvement of a Transformerless, Voltage-Boosting Inverter for AC Modules Solar Energy Materials & Solar Cells 67(2007)008.
- [7] <sup>33</sup> Patrao I, Figueres E, Espin F.G and <sup>22</sup> Garcera G 2011 Transformerless Topologies for Grid-Connected Single-Phase Photovoltaic Inverters Renewable and Sustainable Energy Reviews 15(2001)008.
- [8] <sup>16</sup> IrwantoM, Alam H, Mashor Y.M, Masri M, Haziah A. H, Ismail B and Butar-Butar A.H 2017 Analysis of AC Voltage and Current Waveform Distortion on SPWM Transformerless Photovoltaic Inverter Far East Journal of Electronics and Communications FEJEC17(2017)010
- [9] <sup>5</sup> Daut I, Irwanto M, Irwan Y.M, Gomes N and Ahmad N.S 2011 Combination of Hargreaves Method and Linear Regression as a New Method to Estimate Solar Radiation in Perlis, Northern Malaysia Solar Energy 85(2011)009.

## ORIGINALITY REPORT

18%

SIMILARITY INDEX

12%

INTERNET SOURCES

12%

PUBLICATIONS

6%

STUDENT PAPERS

## PRIMARY SOURCES

1	shura.shu.ac.uk Internet Source	1 %
2	Roberto Gonzalez. "High-Efficiency Transformerless Single-phase Photovoltaic Inverter", 2006 12th International Power Electronics and Motion Control Conference, 08/2006 Publication	1 %
3	www.ingentaconnect.com Internet Source	1 %
4	jp.translink.com.au Internet Source	1 %
5	krishikosh.egranth.ac.in Internet Source	1 %
6	Anis, W.R.. "Analysis of a three-level bridge inverter for photovoltaics", Solar Cells, 19881201 Publication	1 %
7	coek.info Internet Source	1 %

8

Andrea H. Mason. "Coordination and control of bimanual prehension: effects of perturbing object location", Experimental Brain Research, 06/2008

Publication

1 %

9

Frank Verhaegen, Roel-Germ Wanders, Cecile Wolfs, Daniëlle Eekers. "Considerations for shoot-through FLASH proton therapy", Physics in Medicine & Biology, 2021

Publication

1 %

10

[www.farnell.com](http://www.farnell.com)

Internet Source

1 %

11

A.K. Mukerjee, Nivedita Dasgupta. "Power factor controller used as DC-DC converter for photovoltaic sources", Renewable Energy, 2008

Publication

1 %

12

Sweeka Meshram, Ganga Agnihotri, Sushma Gupta. "Advanced photovoltaic/hydro hybrid renewable energy system for remote areas", Journal of Renewable and Sustainable Energy, 2014

Publication

1 %

13

[lib.buet.ac.bd:8080](http://lib.buet.ac.bd:8080)

Internet Source

1 %

14

[academic.hep.com.cn](http://academic.hep.com.cn)

Internet Source

1 %



15	<a href="http://www.onesearch.id">www.onesearch.id</a> Internet Source	1 %
16	<a href="http://www.aminer.org">www.aminer.org</a> Internet Source	1 %
17	Stornelli, Muttillio, de Rubeis, Nardi. "A New Simplified Five-Parameter Estimation Method for Single-Diode Model of Photovoltaic Panels", Energies, 2019 Publication	<1 %
18	<a href="http://mts.intechopen.com">mts.intechopen.com</a> Internet Source	<1 %
19	Mahmoud A. Sayed, Kazuma Suzuki, Takaharu Takeshita, Wataru Kitagawa. "Soft-switching technique for a three-phase bidirectional grid-tie DC-AC-AC converter", 2018 IEEE Applied Power Electronics Conference and Exposition (APEC), 2018 Publication	<1 %
20	<a href="http://redmine.iasfbo.inaf.it">redmine.iasfbo.inaf.it</a> Internet Source	<1 %
21	<a href="http://www.ijeetc.com">www.ijeetc.com</a> Internet Source	<1 %
22	<a href="http://www.springerprofessional.de">www.springerprofessional.de</a> Internet Source	<1 %
23	Ashutosh Sudhirrao Werulkar, Prakash S. Kulkarni. "A case study of residential solar	<1 %

# photovoltaic system with utility backup in Nagpur, India", Renewable and Sustainable Energy Reviews, 2015

Publication

24

M. G. Wani, V. K. Sharma, K. M. Soni. "High Frequency SMPS Based Inverter With Improved Power Factor", 2006 International Conference on Power Electronic, Drives and Energy Systems, 2006

Publication

<1 %

25

[ir.lib.uwo.ca](http://ir.lib.uwo.ca)

Internet Source

<1 %

26

Submitted to Case Western Reserve University

Student Paper

<1 %

27

[iosrjournals.org](http://iosrjournals.org)

Internet Source

<1 %

28

I.H. Atlas, A.M. Sharaf. "A novel on-line MPP search algorithm for PV arrays", IEEE Transactions on Energy Conversion, 1996

Publication

<1 %

29

Submitted to Universiti Teknikal Malaysia Melaka

Student Paper

<1 %

30

[hdl.handle.net](http://hdl.handle.net)

Internet Source

<1 %

[tel.archives-ouvertes.fr](http://tel.archives-ouvertes.fr)

31

Internet Source

<1 %

32

"Proceedings of ISES World Congress 2007 (Vol. I – Vol. V)", Springer Nature, 2009

Publication

<1 %

33

Mekhilef, Saad, and Monirul Islam. "H6-type transformerless single-phase inverter for grid-tied photovoltaic system", IET Power Electronics, 2015.

Publication

<1 %

Exclude quotes Off  
Exclude bibliography Off

Exclude matches Off