

EFFECT OF LOAD TYPE ON PV MODIFIED SINE WAVE INVERTER CHARACTERISTICS

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ABSTRACT

As conventional energy sources near to be fully consumed soon, the interest in generating electricity from renewable energy sources increases rapidly especially from photo voltaic "PV" systems. To connect AC loads to a PV system, an inverter should be used to convert the DC output coming from the PV system to AC matching the load requirements. Modified sine wave "MSW" inverter is the most used type because of its low cost. The problem of using MSW inverter is that the load type affects the inverter performance. The object of this paper is to study the effect of different loads on the MSW inverter output waveforms. Throughout the present work, a simulation model for the PV system is built using MATLAB/SIMULINK. An experimental setup is implemented for verifying the simulation analysis. A comparison between the theoretical and experimental results confirms the validity of the simulation.

أوشكت مصادر الطاقة التقليدية علي النفاذ، لذلك زاد الأهتمام بإنتاج الكهرباء من مصادر الطاقة المتجددة و بالأخص انظمة الخلايا الفوتو فولتية. لتوصيل الأحمال التي تعمل على مصدر تيار متردد بنظام الخلايا الفوتو فولتية لابد من إستخدام عاكس ليقوم بتحويل الخرج الثابت لنظام الخلايا الفوتو فولتية لخرج متردد يتماشى مع متطلبات الحمل. العاكس ذو الموجة الجيبية المعدلة هو أكثر الأنواع المستخدمة بسبب رخص ثمنه. إستخدام العاكس ذو الموجة الجيبية المعدلة يعنيه أن جهد الخرج لا يكون ذى موجة جيبية خالصة بل وتتأثر هذه الموجة بنوعية الحمل المتصل به. يهدف هذا البحث إلي دراسة تأثير الأحمال المختلفة على أداء العاكس وشكل الموجة المعدلة.

خلال هذا العمل ، تم إعداد نموذج محاكاة لنظام الخلايا الفوتو فولتية بإستخدام برنامج الماتلاب. وتم بناء منظومة إختبار معملية للتحقق من نتائج نموذج المحاكاة. وبمقارنة كل من النتائج النظرية و المعملية تأكدت صلاحية نموذج المحاكاة.

Keywords: PV module, MPPT, MSW inverter, THD

1. INTRODUCTION

Conventional energy sources based on oil, coal, and natural gas have proven to be highly effective drivers of economic progress. However, the large consuming of conventional energy sources and increasing energy demand has led to an increased interest on generating power from various renewable energy sources [1].

Because of the spread use of Photo voltaic "PV" systems in generating electricity, recently, as a renewable energy source, it was very important to study this system. For connecting loads, that working on ac source, to the system DC-AC inverters have been used in the PV system to convert the system DC output to AC for matching the loads requirements [2-3]. Because of its low cost, MSW inverters are the most used types in the market. MSW inverters output has a high level total harmonic distortion "THD" ratio. It has been regarded that MSW inverter affect load performance. Not only all loads can't work correctly with this inverter, but also there are some loads can't work at all with it. A load classification has been made according to the load ability to work

with MSW inverter. This classification has showed that MSW inverters should be used only with certain loads. Each load type has its own performance with each inverter type according to the inverter output wave form and harmonics contained [4-5].

As the Induction drives are considered the backbone of the industry, it is important to maintain it working smoothly to ensure the continuity of the production process. So, inverters effects on induction drives performance have taken a big interest in [6-7].

Modifications have been started to be made in inverter designs aiming to eliminate harmonics, minimize THD and improve the output waveform to be as like as possible to pure sine wave ones. [8]

Using H-Bridge is one of the effective methods used in modifying the inverter output and enhancing its performance. It helps in matching inverter output with loads requirements. [9]

Eliminating harmonics using direct lookup table is one of the most cost elimination and performance improvement methods used in inverter modification.

It is based on microprocessor based inverters which is known with its low cost. [10] Then microcontrollers have been the next step used in inverters modification. [11-12]

In this paper a simulation model is built to predict the MSW inverter performance with different loads. An experimental setup is implemented to check the simulation results. A comparison between simulation and experimental results is introduced and the difference is evaluated.

2. SIMULATION MODEL

This paper is concerned with MSW inverter connected to PV system. So, a simulation for standalone PV system is illustrated as in fig. (1).

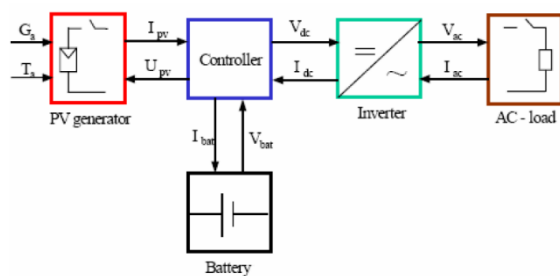


Fig. (1) Stand Alone PV System Block Diagram

A simulation for each system component is illustrated as follows.

2.1. PV Array Model

The mathematical model of PV cell is represented by a current source connected in parallel with a diode. R_s is the intrinsic series resistance whose value is very small. R_p is the equivalent shunt resistance which has a very high value as shown in fig. (2).

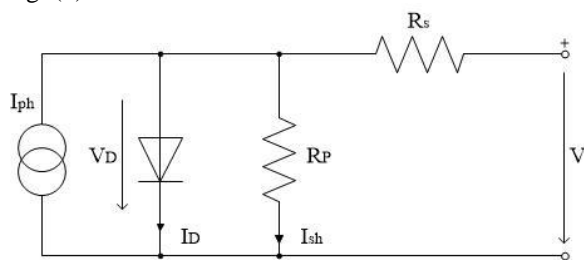


Fig. (2) PV Module equivalent circuit

The current of the solar module is defined as:

$$I = I_{ph} * N_p - I_{sh} - I_D \quad (1)$$

where: I the PV module current.
 I_{ph} the light generated current.
 N_p the number of parallel cells.
 I_{sh} the shunt resistance current.
 I_D the diode current.

This current is simulated as shown in fig. (3).

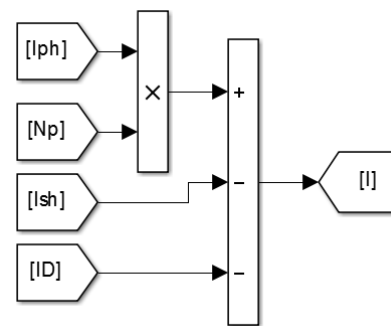


Fig. (3) PV module current

Each of those currents can be calculated as following:

2.1.1. The light generated current (I_{ph})

The light generated current is calculated as follows:

$$I_{ph} = I_{rr} * (I_{sc}/I_{r0}) \quad (2)$$

where: I_{rr} the irradiation.
 I_{sc} the short circuit current.
 I_{r0} the reference irradiation.

2.1.2. The shunt resistance current (I_{sh})

The shunt resistance current is calculated as follows:

$$I_{sh} = [V + (I * R_s)] / R_p \quad (3)$$

where: V the cell voltage.

2.1.3. The diode current (I_D)

The diode current is calculated as follows:

$$I_D = I_s * N_p * (e^{[(V/N_s) + (I * R_s/N_s)] / (N * V_T * C)} - 1) \quad (4)$$

where: I_s the reversed saturation current.
 N_s the number of series cells.
 V_T the thermal voltage.
 C the no. of cells in PV module.

The thermal voltage is calculated as follows:

$$V_T = K * T_{OP} * q \quad (5)$$

where: K the Boltzmann`s constant.
 T_{OP} the operating temperature.
 q the electron charge constant.

The reversed saturation current is calculated as follows:

$$I_{rs} = I_{rs} * (T_{OP}/T_{ref})^3 * e^{[(1/T_{OP}) - (1/T_{ref})] * [(1.12q^2)/(K * n)]} \quad (6)$$

where: I_{rs} reverse current sub system term.
 T_{ref} the reference temperature.
 n the emission coefficient.

The reverse current sub system term is calculated as follows:

$$I_{rs} = I_{sc} / (e^{[(V_{oc} * q) / (K * C * T_{OP} * n)]} - 1) \quad (7)$$

where: V_{oc} the open circuit voltage.

2.2. Charge Controller Model

The charge controller used in this work is MPPT type. The charge controller is simulated in MATLAB as shown in fig. (4).

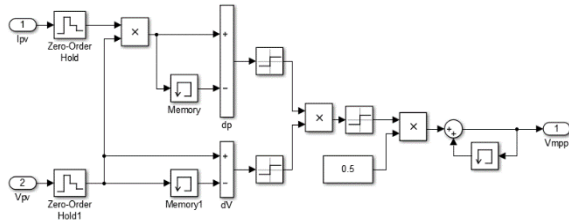


Fig. (4) MPPT Charge Controller model

2.3. Battery Model

Gel type batteries are used in this research. One of the batteries is simulated as shown in fig. (5).

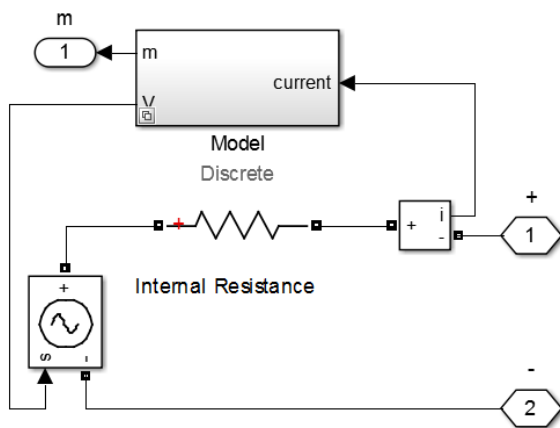


Fig. (5) Battery model

2.4. Inverter Model

The Inverter used in this simulation is a single phase MSW inverter type. A step-up transformer is used to rise up the 24V_{ac} inverter output to 220V_{ac}, required to operate the loads. The inverter is simulated as shown in fig. (6).

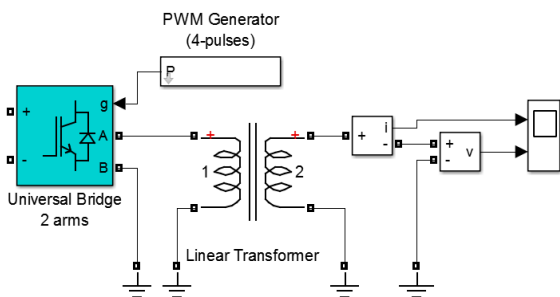


Fig. (6) Inverter model

3. SIMULATION RESULTS

A simulation program has been built, in MATLAB/SIMULINK, based on the proposed simulation model and implemented to study the effect of loads on the inverter output voltage and current. Three different loads types are used with the PV system in the simulation. Voltage and current waveforms are illustrated in figures (7-13). Figure (7) shows the no-load voltage waveform of the inverter. The voltage THD ratio is 79.53%.

The first load is an R-L series load with values ($R = 79.771\Omega$), ($L = 0.246256 H$). The voltage THD ratio is 82.77% and the current THD ratio is 12.14%. Figure (8) and fig. (9) show the inverter voltage waveform and current waveform, respectively.

The second load is an R-L parallel load with values ($R = 172.9\Omega$), ($L = 0.5336 H$). The voltage THD ratio is 47.85% and the current THD ratio is 32.73%. Figure (10) and fig. (11) show the inverter voltage waveform and current waveform, respectively.

The third load is an R-C parallel load with values ($R = 172.9\Omega$), ($C = 19.796 \mu F$). The voltage THD ratio is 4.72% and the current THD ratio is 48.24%. Figure (12) and fig. (13) show the inverter voltage waveform and current waveform, respectively.

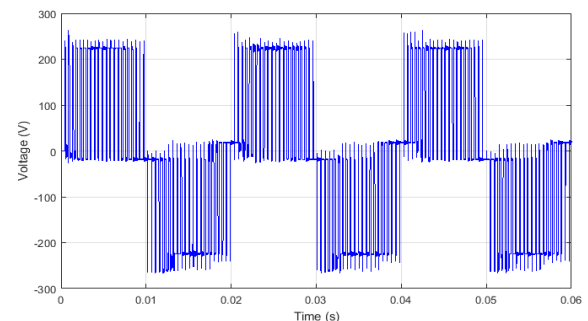


Fig. (7) Simulation voltage waveform with no-load

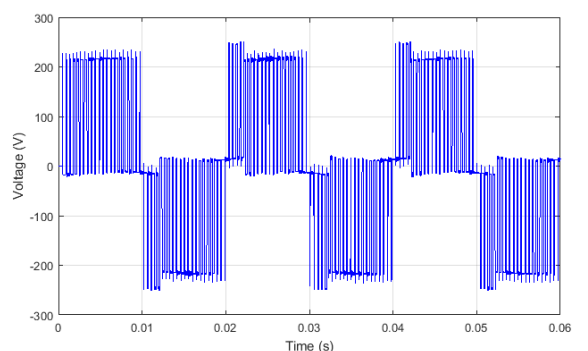


Fig. (8) Simulation voltage waveform with R-L series load

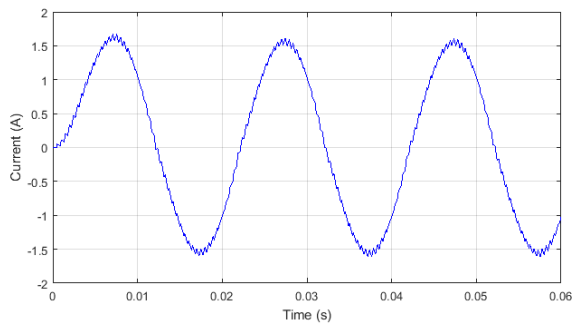


Fig. (9) Simulation current waveform with R-L series load

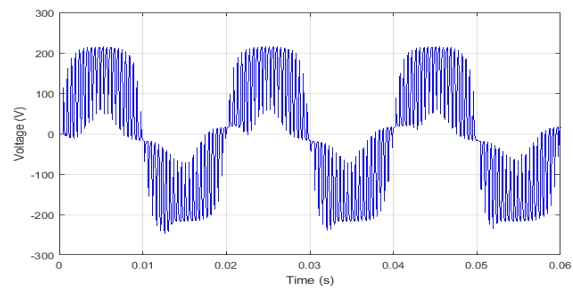


Fig. (10) Simulation voltage waveform with R-L parallel load

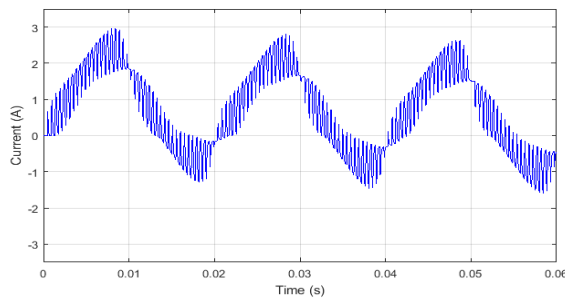


Fig. (11) Simulation current waveform with R-L parallel load

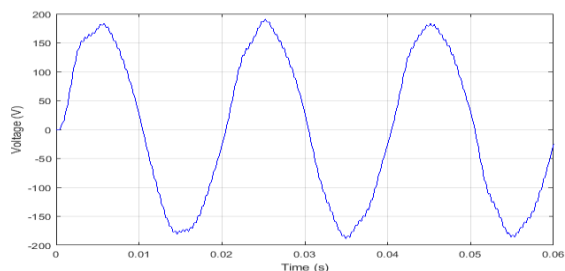


Fig. (12) Simulation voltage waveform with R-C parallel load

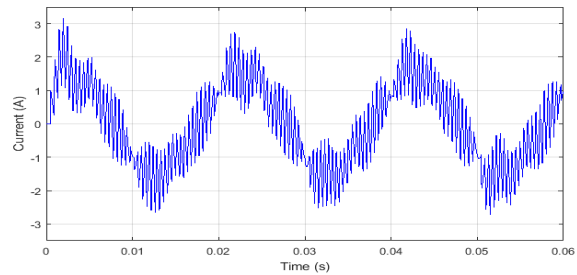


Fig. (13) Simulation current waveform with R-C parallel load

4. EXPERIMENTAL RESULTS

The experimental setup has been established using the following components:

- PV modules: 2 polycrystalline modules, each one with rated power 290W and rated voltage $24V_{dc}$. They are connected in parallel.
- Charge controller: MPPT type with rated current 50A and operating voltage range $(12:48) V_{dc}$.
- Battery: 2 Gel type batteries, each one with rated capacity 185Ah and rated voltage $12V_{dc}$. They are connected in series.
- Inverter: MSW inverter with rated power 1.0KW and rated input voltage $24V_{dc}$.

These components are connected together establishing the total PV experimental system as shown in fig. (14). The load types that have been employed with the simulation model are used with the experimental setup with the same values. Voltage and current waveforms are illustrated in figs. (15-21). Figure (15) shows the no-load voltage waveform of the inverter. The voltage THD ratio is 34.18%.

The first load is an R-L series load. The voltage THD ratio is 33.43% and the current THD ratio is 21.3%. Figure (16) and fig. (17) show the inverter voltage waveform and current waveform, respectively.

The second load is an R-L parallel load. The voltage THD ratio is 30.16% and the current THD ratio is 21.83%. Figure (18) and fig. (19) show the inverter voltage waveform and current waveform, respectively.

The third load is an R-C parallel load. The voltage THD ratio is 36.07% and the current THD ratio is 747.04%. The current THD value was increased to a very high value at the same conditions as the theoretical system. The system was disconnected automatically due to high current generated from

resonant made by the load circuit, so the R-C loads should not be connected to the system. Figure (20) and fig. (21) show the inverter voltage waveform and current waveform, respectively.



Fig. (14) Total PV experimental system

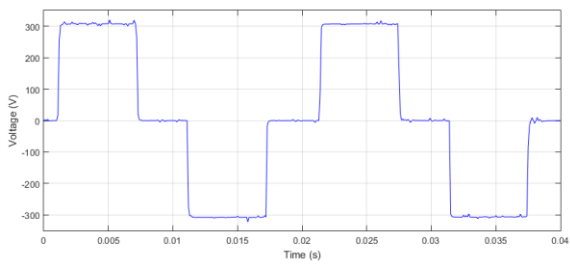


Fig. (15) Experimental voltage waveform with no-load

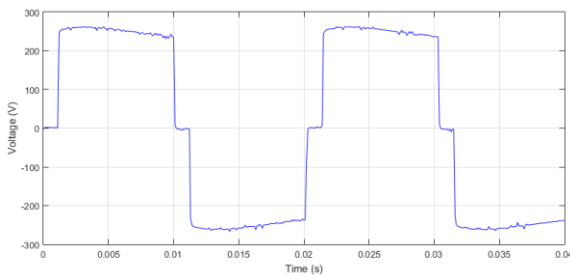


Fig. (16) Experimental voltage waveform with R-L series load

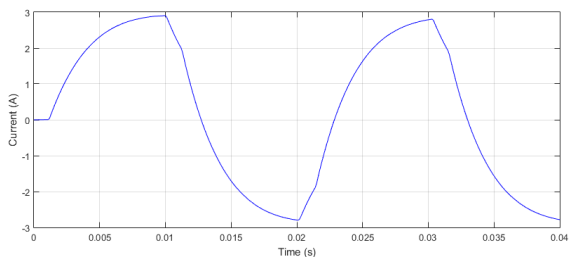


Fig. (17) Experimental current waveform with R-L series load

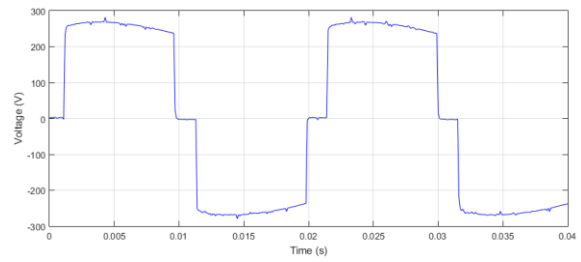


Fig. (18) Experimental voltage waveform with R-L parallel load

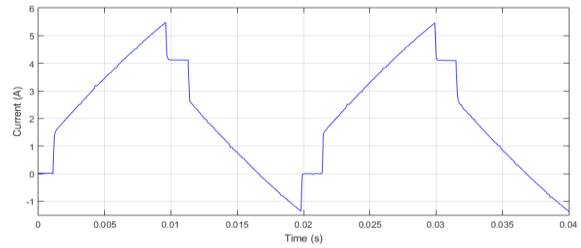


Fig. (19) Experimental current waveform with R-L parallel load

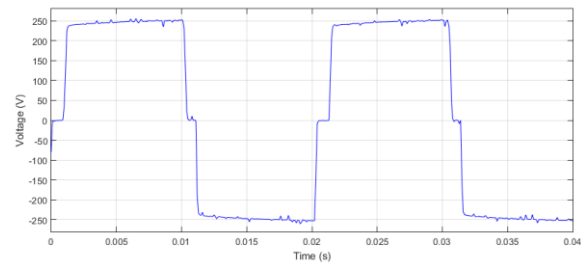


Fig. (20) Experimental voltage waveform with R-C parallel load

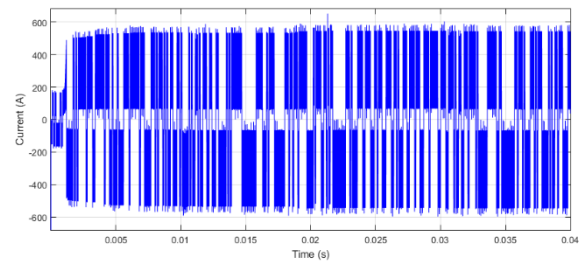


Fig. (21) Experimental current waveform with R-C parallel load

Table (1) shows a comparison between voltage THD values with both simulation system and experimental system.

Table (1) Voltage THD values

		Simulation system	Experimental system
Voltage THD	No Load	79.53%	34.18%
	R-L series	82.77%	33.43%
	R-L parallel	47.85%	30.16%
	R-C parallel	4.72%	36.07%

Table (2) shows a comparison between current THD values with both simulation system and experimental system.

Table (2) Current THD values

		Simulation system	Experimental system
Current THD	No Load	-	-
	R-L series	12.14%	21.30%
	R-L parallel	32.37%	21.83%
	R-C parallel	48.24%	747.04%

5. CONCLUSION

MSW inverter has been used in a PV system to supply various loads with AC voltage. Various types of loads have been connected to the MSW inverter. The simulation model has accurate results to evaluate the system performance. Both simulation and experimental systems give harmonious results. Good agreement obtained between simulation and experimental results. From experimental results, it has been found that the R-C load should not be connected to the MSW inverters as it makes resonant in the circuit making very high currents to flow which may damage the system.

6. REFERENCES

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