A House Solar Power Station

Dr. Kareem A. Hamad[1]

Abstract

Solar energy is one of the main power sources of electricity in the world. It has become widespread as an attractive solution to provide low power consumption to human groups live in remote villages or areas away from the national electric grid, also when the electric power is underproduction such as in our country (Iraq). For this reasons we designed a system of photovoltaic generator with facilities to be built in houses.

The system consists of three basic parts of equipment, 3KW peak solar panels, which could be spread easily at the housetop, a storage battery system and the electrical control system.

The electrical control system was completely designed and tested using ORCAD simulator, it consists of 4KW battery charge regulator with 300V system, and 220V, 50Hz transformerless three – level square wave inverter.

1. Introduction

Conventional methods of transmitting electrical power to human groups in remote villages or areas away from the national electric grid through along distances using high voltage network is not always an economic solution, sometimes, it is financially significant, also when the electric power is underproduction such as in our country (Iraq), the benefits of using photovoltaic will be arises.

Many stand – alone and hybrid devices using energy renewable sources like solar photovoltaic, wind has been developed in the past and reported by authors [1, 2, 3, 4, 5, 6, 7, 8] but their complexity in design and operational feature, difficulty in getting the system or its spare parts have resulted in less popularity among rural masses.

In the present study, a solar power system has been proposed with simple design which can work as a standalone device or as a primary source of hybrid power supply system; also transformerless inverter used has increased the system efficiency.

The present work involves a station of a house photovoltaic generator, which has been designed and tested using ORCAD simulator to provide electricity depending on conversion of solar energy. This work will enable us to produce supply system offers the following benefits.

1. More efficient and cost – effective photovoltaic power station.
2. Improved reliability
3. Reduced emissions of gases and pollution
4. increased operational live

The station consists of solar panels connected in parallel and in series to provide 3KW and 338 – 360V, electrical control system and storage batteries.

A suitable design of the photovoltaic system was applied according to the average solar radiation in Iraq by assuming three sorts of daily loads, summer, winter and spring or autumn loads [6, 7].

The most complicated part of this station is the electrical control system; its function is to control the operations of battery charging, protection against over and under charging conditions and inversion of dc voltage into ac voltage.

2. Electrical Control System Design

The electrical control system consists of the following devices

1. Battery charge regulator.
2. Transformerless three – level square wave inverter.

The battery charge regulator in this work was designed at a system voltage 300V and maximum power 4KW. The block diagram of this device shown in figure (1) consists of three basic units as follows [8]:

A. Voltage regulation unit.
B. Load isolation unit.
C. Battery checking unit.

Regarding the voltage regulation unit, the output of the regulator circuit is fed to a power circuit that consists of a group of power transistors (2N3055) fixed on a heat sink so as it works with in acceptable limit of temperature. The value of charging voltage can be modified within a certain limits by changing the value of variable resistance (Rval) shown in figure (2) and as a demand. This circuit is designed and tested at 13A load using ORCAD simulator. Figure (3) indicates the characteristic of this unit at 13A load. Figure (4) shows the effect of changing the value of Rval on the output voltage.

The load isolation unit is to prevent batteries from being loaded at low voltage level conditions; the design has been put by using a Schmitt trigger circuit, where a hysteresis loop of suitable voltage was set.

The third unit is the battery-checking unit; its function is to prevent batteries from over – charging condition. The design consists of timing circuit, it contains an "on" period of 4 seconds [8] used to check the actual voltage of batteries, through isolating them from the solar panels, then they will be connected again in case of mismatching the demandable level of the maximum battery voltage. The "on" period was followed by an "off" period of 34 minutes [8] used to keep charging, the process will repeated again and again till reaching the demandable battery voltage.

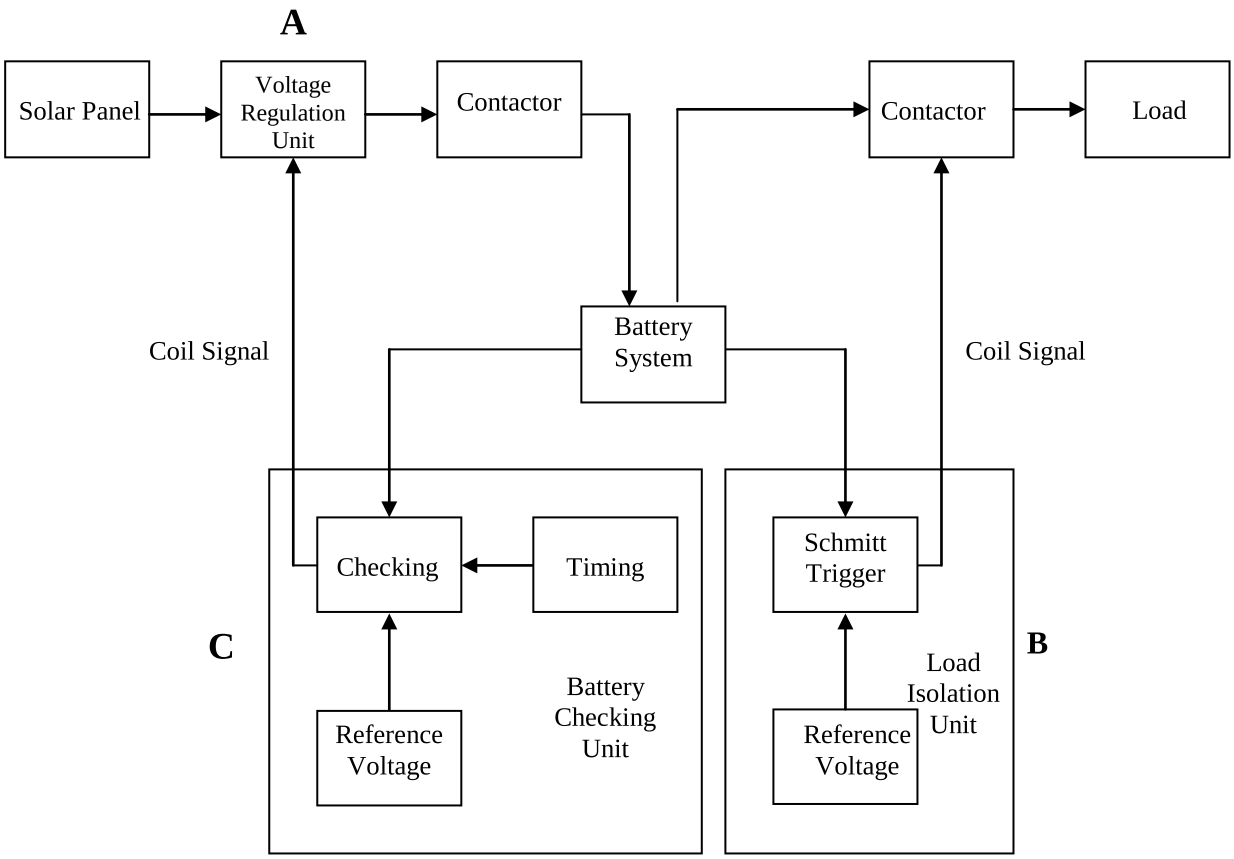

Fig. (1) Block diagram of the battery charge regulator

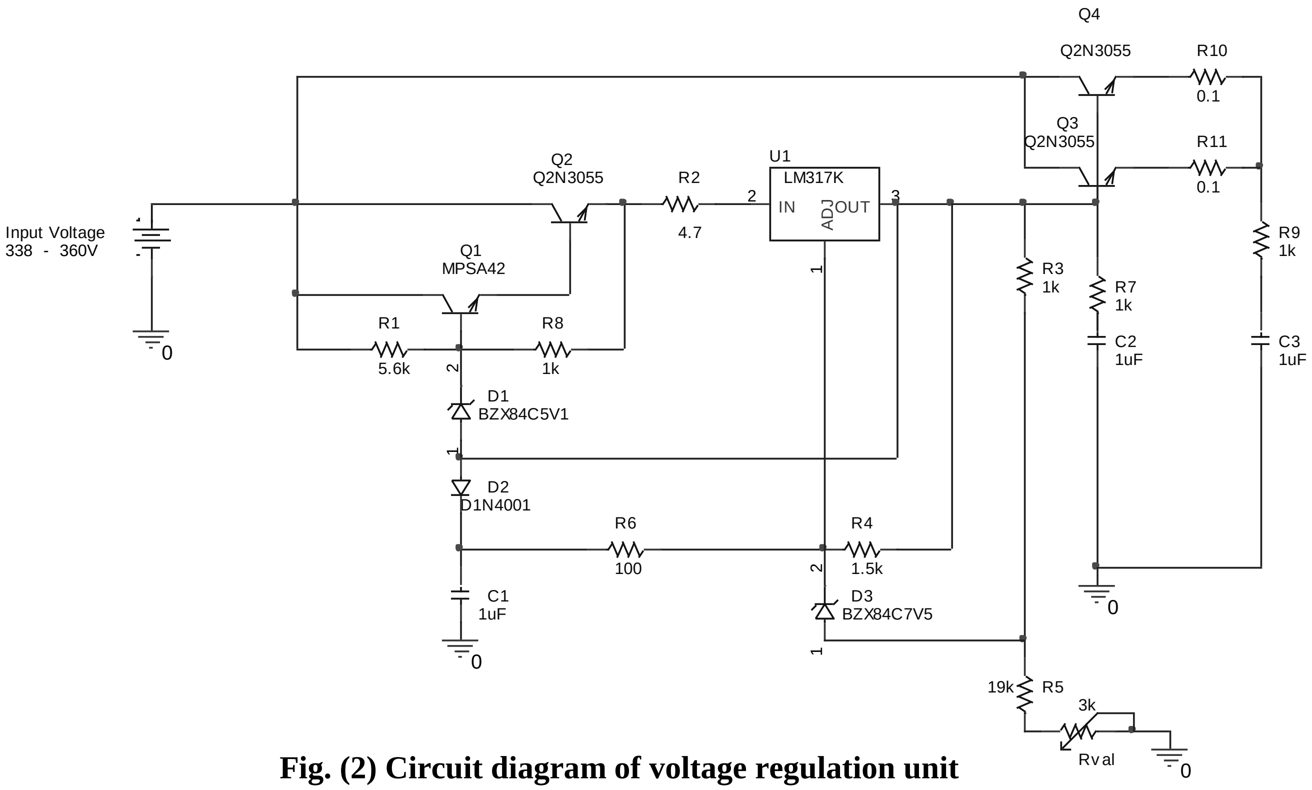

Fig. (2) Circuit diagram of voltage regulation unit

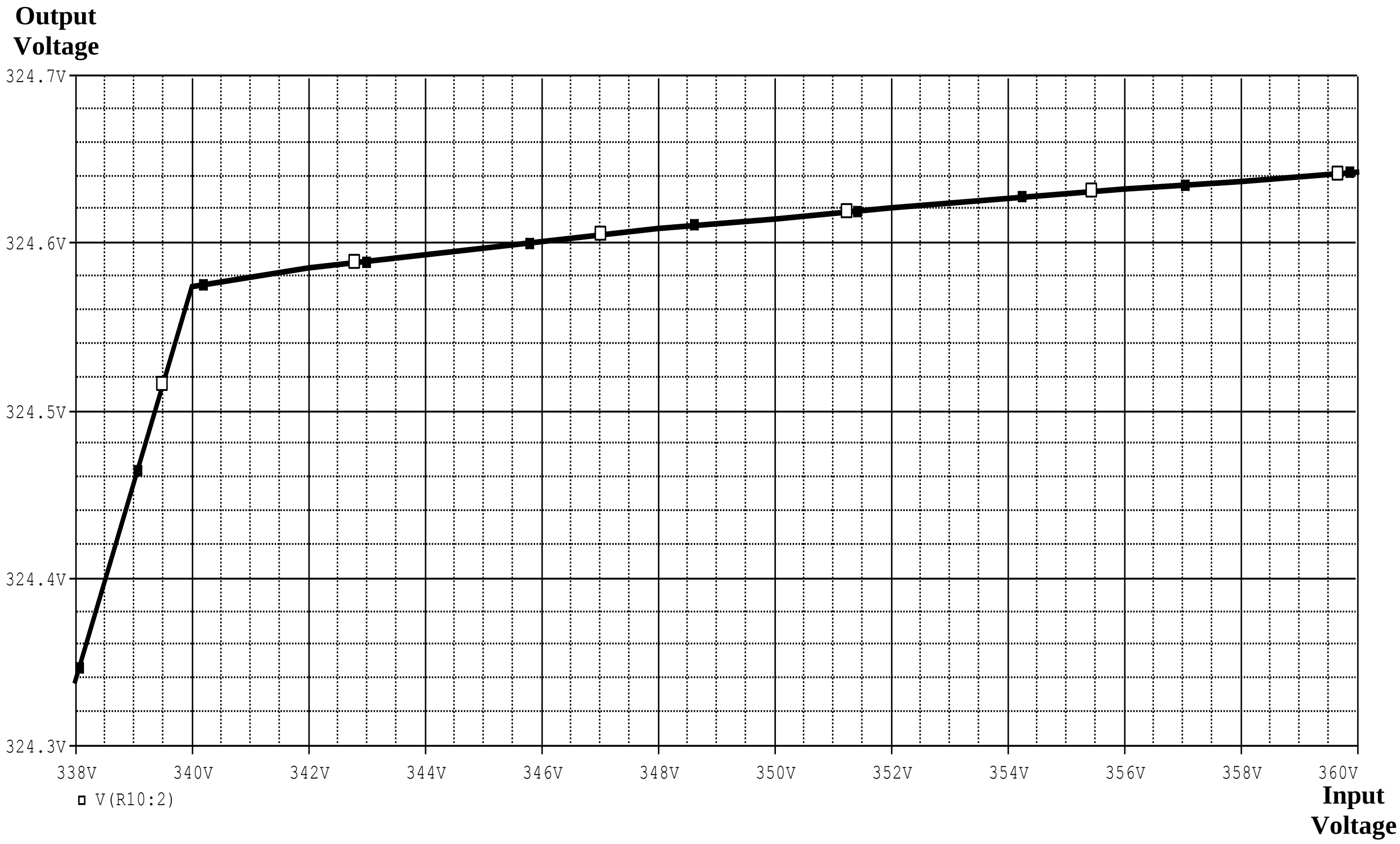

Fig. (3) Characteristic of load regulation unit at 13A load

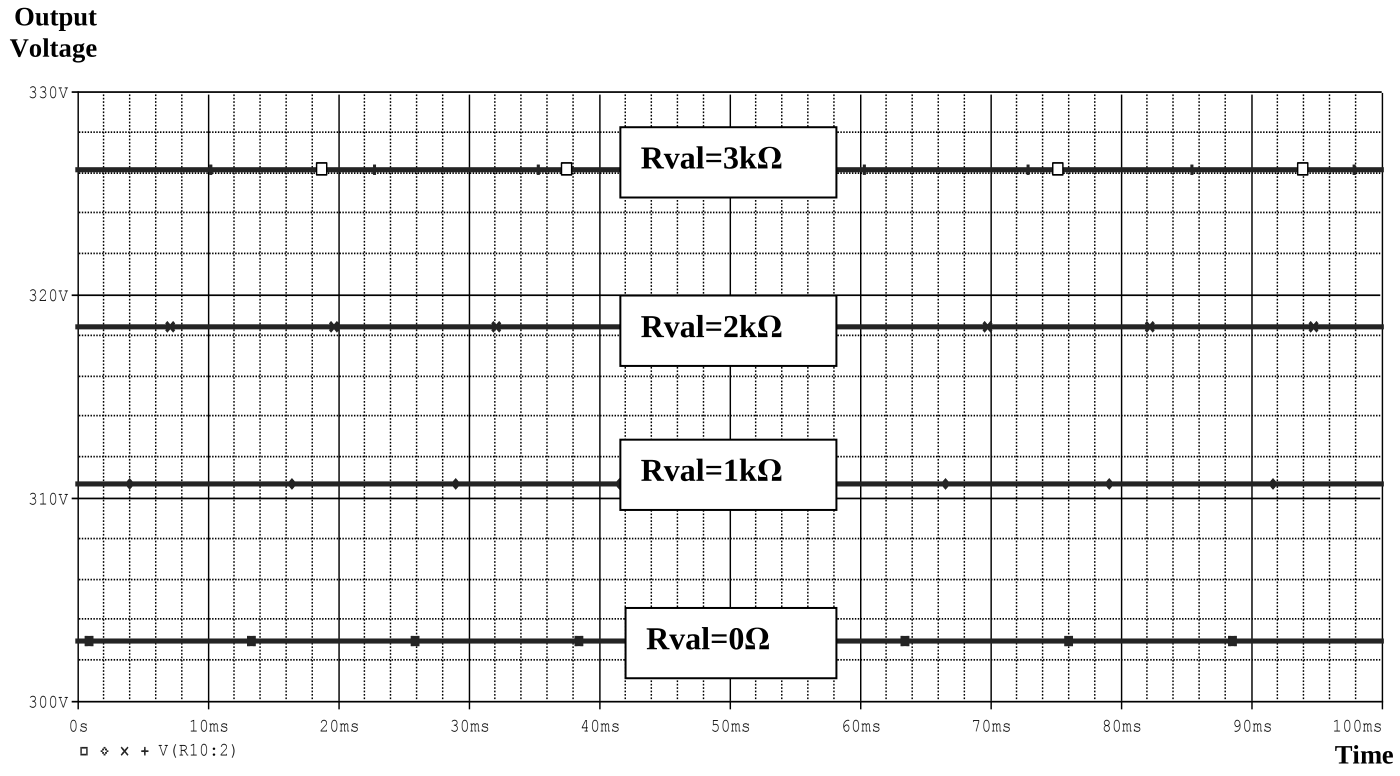

Fig. (4) Output voltage of voltage regulation unit with Rval=0Ω, Rval=1kΩ, Rval=2kΩ, Rval=3kΩ

3. Inverter

According to the high cost of solar panels, one of the basic steps of designing photovoltaic systems is to reduce the panels area as possible as could by using high efficiency devices, for this reason the presented inverter is transformerless voltage – source inverter.

The type of used inverter is the full – bridge inverter shown in figure (5). This type of inverter will generate square wave when $q_{1,1} = q_{2,2}$, $q_{2,1} = q_{1,2}$, and the duty ratio are 50% [9]. The waveforms in figure (5) can be produced by adjusting the phase shift between $q_{1,1}$ and $q_{2,2}$. This relative phase control provides output adjustment for variable loads. The term voltage – source inverter (VSI) often refers to inverters that use relative phase control. Important characteristics of the VSI include [9]:

1. The output wanted component amplitude can be adjusted from zero to $4/\pi = 1.27$ times V_{in}. The extra 27% of possible amplitude above the input value is helpful.
2. The switches operate at a low frequency, the output frequency, which is the minimum rate that meets frequency-matching requirements.
3. The duty ratios are maintained at 50%, so the dc components always cancelled. In fact, all even harmonics are cancelled when the duty ratios are held at 50%.
4. The output is composed of pulses like those of a square wave. Usually, low – frequency harmonics such as the third and fifth are relatively large. This is a challenge for filtering out unwanted components. It also means that the load is likely to alter filter behavior.

The ability to filter out unwanted components is a key concern. The unwanted frequencies begin at $3\omega_{out}$, and a low – pass filter should do the job.

The above technique was used in the presented inverter as shown in figure (6). It consists of four switching power MOSFET transistors, where two square wave (T = 10ms) inverted to each other, and then divided by two using D – Flip Flop, these four pulses will control the four MOSFET power transistor to obtain the ac 220V, 50Hz, three – level square wave output.

Figure (7) shows the complete circuit of the three – level square wave inverter. It consists of four groups of power MOSFET transistors; each group consists of three MOSFET transistors (IRF 740) to obtain the demandable power. This circuit was designed and tested using ORCAD simulator. Figure (8) shows the output of this inverter for 12 A load.

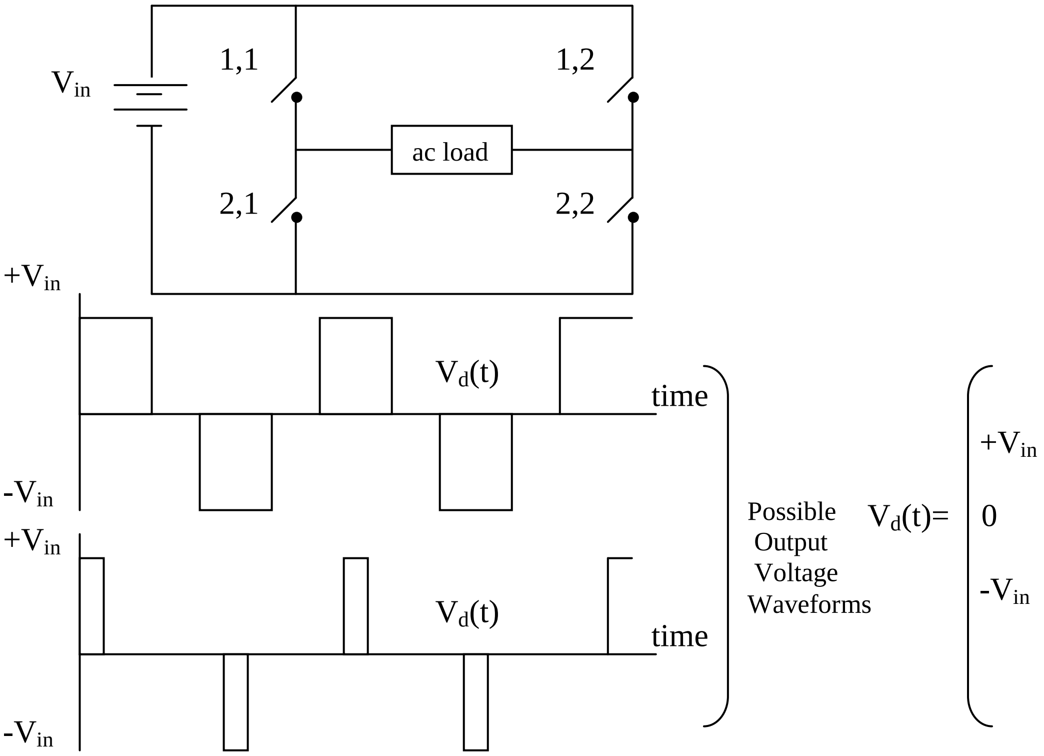

Fig. (5) Three – level inverter approach

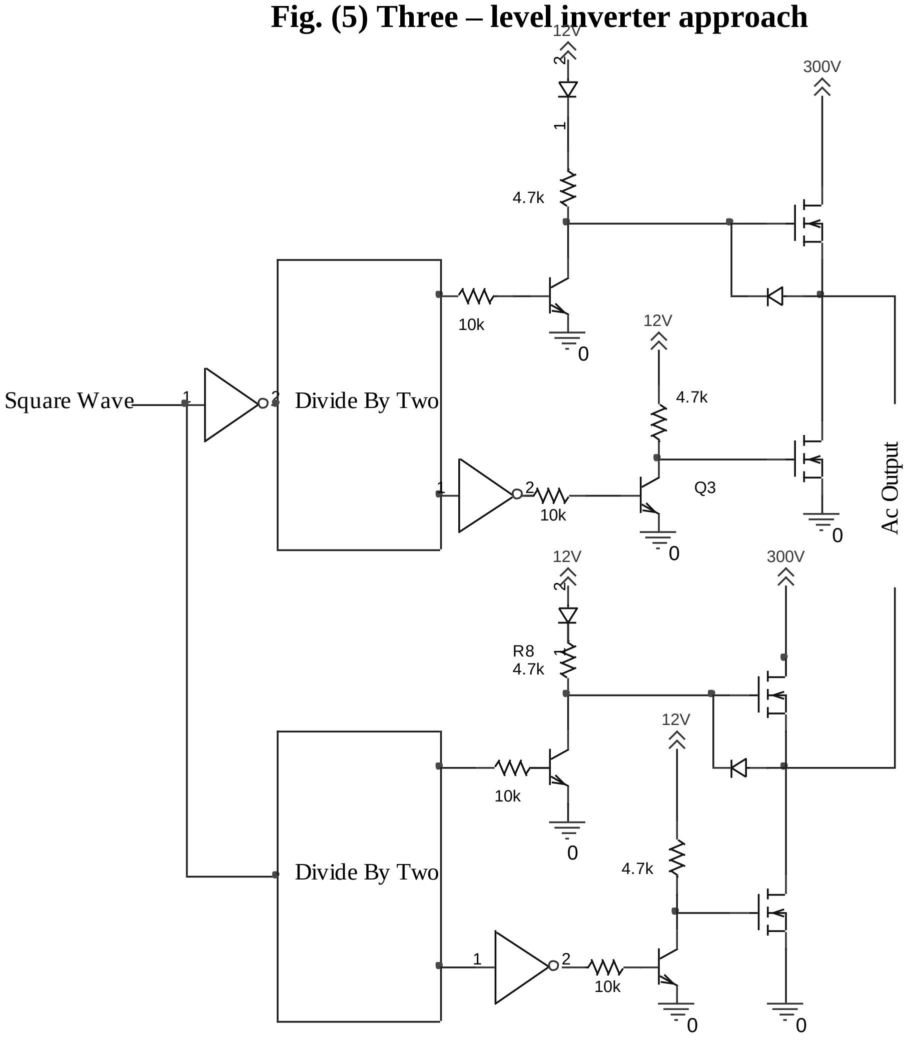

Fig. (6) Three – level square wave inverter

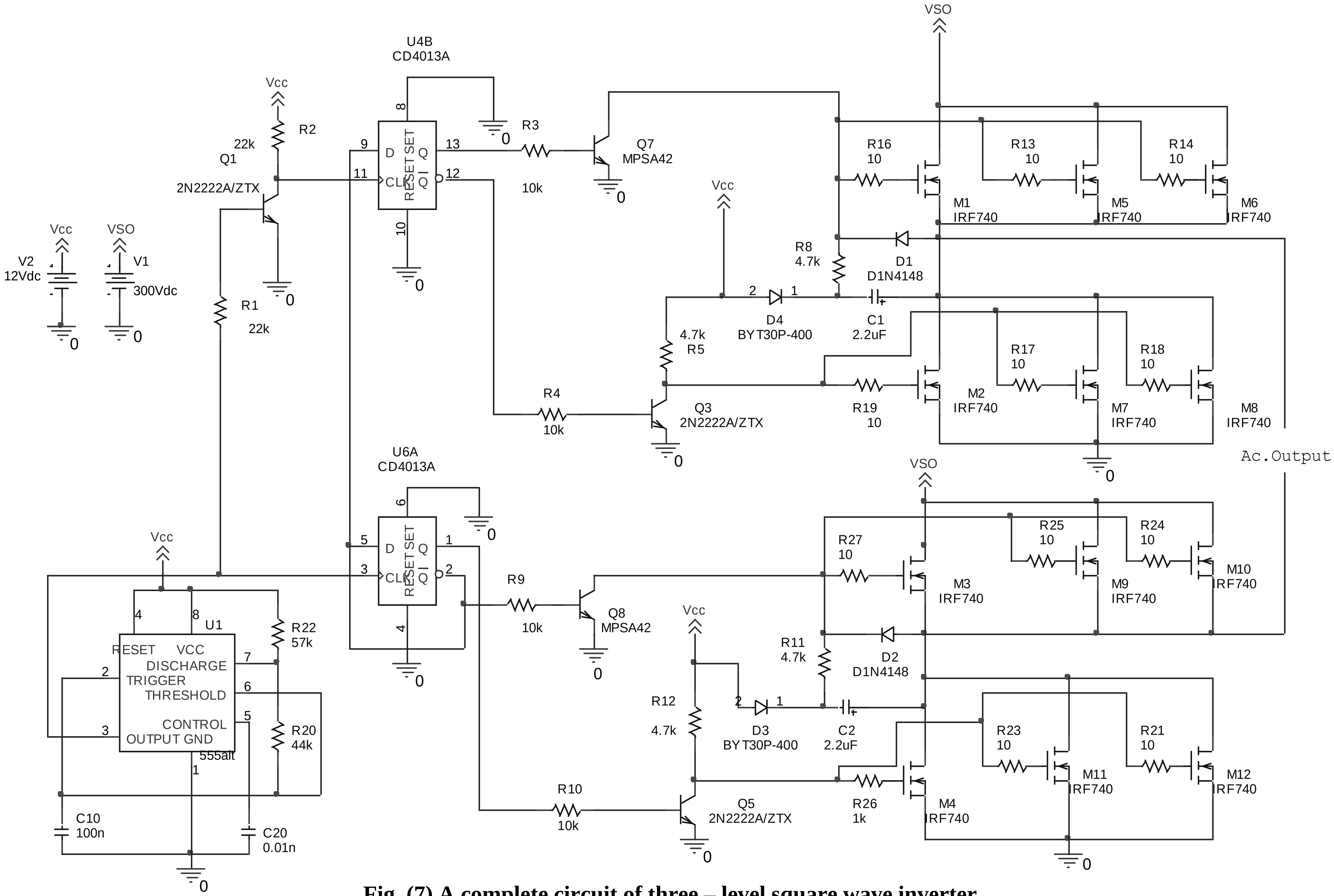

Fig. (7) A complete circuit of three – level square wave inverter

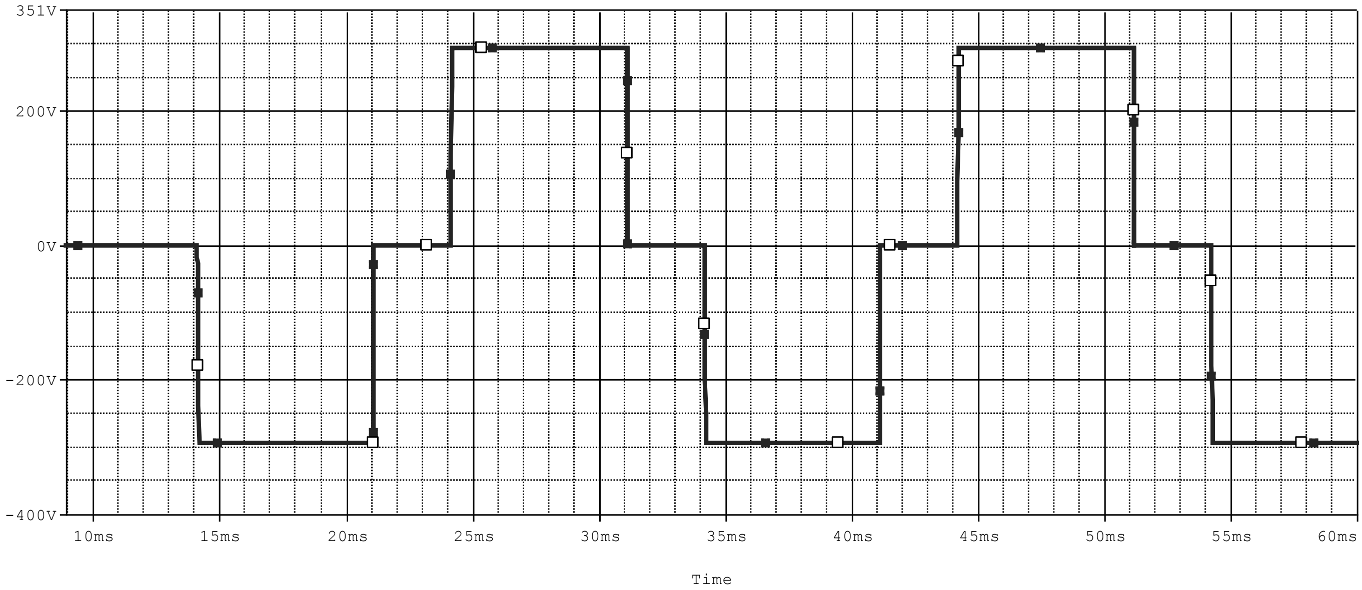

Fig. (8) Output of three – level square wave inverter at full load

4. Performance and Cost Evaluations of the System

Quality of Power

The qualitative analysis of output waveform simulated by ORCAD simulator show low (less than 200μV) change in output peak voltage of the inverter at temperature change from 0 to 70 ^{0}C (figure. 9).

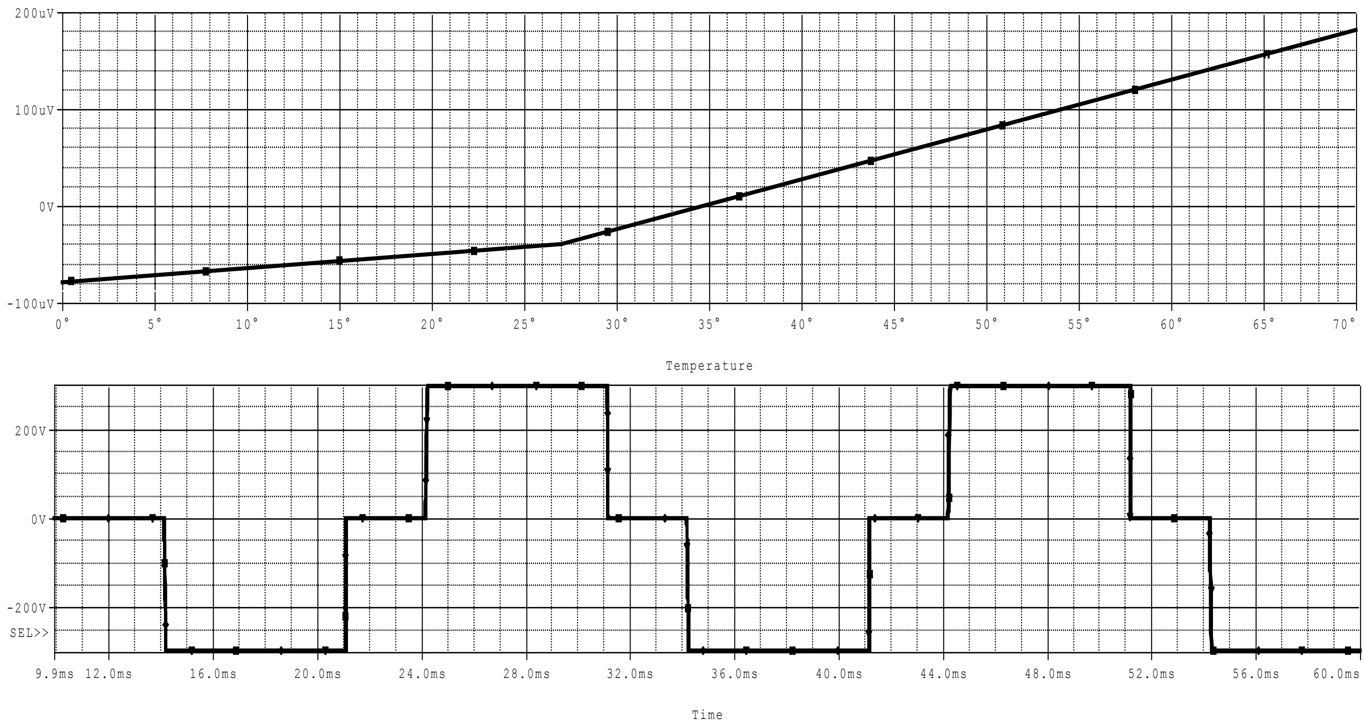

Fig. (9) Output peak voltage change of the inverter with varying temperature from 0 to 70 ^{0}C

4.2 Efficiency of the Inverter

The efficiency of the Inverter system was found to be constant value in the range of 97 % or more under variation of load conditions as shown in figure (10) leading to an indication of low loss and maximum utilization of energy resources.

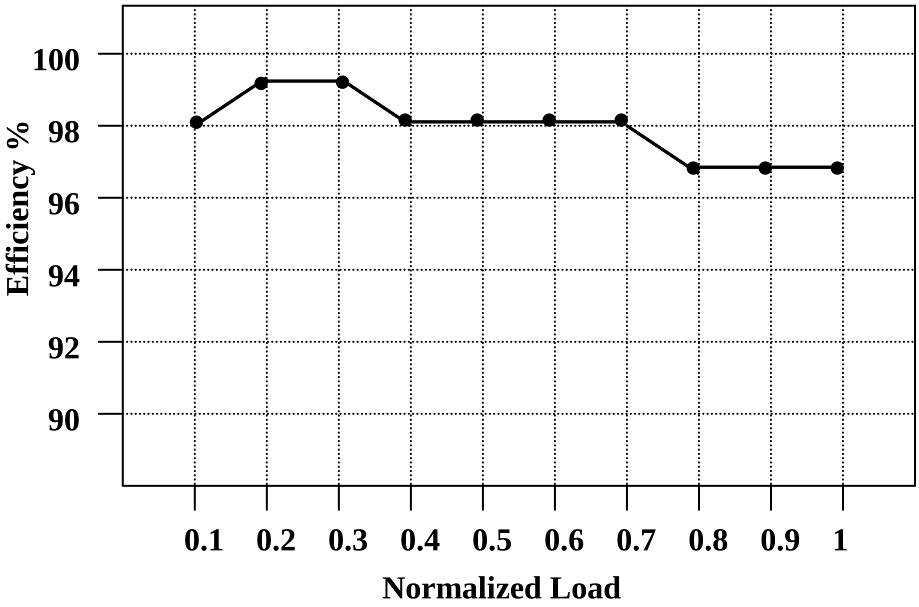

Fig. (10) Efficiency of inverter system

4.3 Cost Evaluation

Final cost of 3kW PV system at $5 per watt is $15000, the cost of the proposed inverter is $500 and the cost of storage batteries is $750. The total cost of solar power station is $16250.

5. Conclusion

A house photovoltaic has been designed and tested using ORCAD simulator. The output results from ORCAD simulator indicate satisfactory level of performance. However a better output power can be achieved by optimizing the operation of the main parts of the house solar power station system. This work will enable us to produce a more efficient and cost – effective photovoltaic power station.

References

[1].G. Tina, S.Gagliano and S. Raiti, “Hybrid solar/wind power system probabilistic modeling for long – term performance assessment, Solar energy, Vol. 80, pp. 578-588, May (2006).

[2]. Baharuddin Ali et al, “Hybrid photovoltaic diesel system in a cable car resort facility”, European journal of scientific research, Vol. 26, No.1, pp 13-19, (2009).

[3]. Sopitpan . S, “PV system with / without grid backup for housing applications”, Photovoltaic specialists conference, IEEE (2000).

[4]. Saha et al, “Grid interfaced urban domestic power pack”, Proceeding of 29th IEEE photovoltaic specialist, pp. 1625-1629, Neworlians Louiana, 19-24 May, (2003).

[5]. S. N. Singh, A. K. Singh**,** “Modeling and dynamics of a PWM sinusoidal inverter for water pumping system for use in agriculture and household applications”, Journal of ieema, Jan (2008).

[6]. M. R. I. Ramadan, " Load matching and performance of non – tracking stand – alone photovoltaic generator in Sana'a university", Solar and wind technology, Vol.3, No.3, pp.155 – 162, (1986).

[7]. J. G. Ingersol, " Simplified calculation of solar cell Temperature in terrestrial photovoltaic arrays ", Journal of solar energy engineering, Vol.108, pp. 95 – 101, May, 1986.

[8]. A. M. Al – Sabounchi, K. B. Al – Kurayshi, I. R. Fahmi, A. A . J. Al – Douri " A mobile Solar Power Station ", Proceedings of fourth Arab international solar energy conference held in Amman, Jordan, 20 – 25 November, (1993).

[9]. P.T. Krein, "Element of power electronics ", Oxford university press, (1998).

محطة طاقة شمسية للبيتِ

م. د. كريم عباس حمد

المستخلص

الطاقة الشمسيةِ هي إحدى المصادر الرئيسية للكهرباء في العالم. أَصْبَحَ استخدامها واسع الانتشار كحَل جذاب لتزويد كهربائيَ منخفضَ في القُرى أَو المناطقِ البعيدةِ عن الشبكةِ الكهربائيةِ الوطنيةِ أو عندما يكون إنتاج الطاقة الكهربائية غير كاف للطلب كما هو الحال في بلدنا (العراق). ولهذا السبب صمّمنَا نظام توليد للكهرباء يعتمد على الطاقة ألشمسيه بوسائل يمكن أن تبنى في البيوت. تتكون المنظومة من ثلاثة أجزاء أساسيه، ألواح شمسيه بقدرة3KW يمكن نشرها على سطح المنزل، بطاريات خزن ونظام سيطرة كهربائي.

نظام السيطرة الكهربائي صمم بالكامل واختبر باستعمال محاكي ORCAD . يستعمل هذا النظام منظم فولية لشحن البطاريات بقدرة 4KW بفولتية 300V، وعاكس لا يحتوي على محولة مربع الموجة بفولتية 220V وتردد 50Hz