International Journal of Sustainable and Green Energy
2015; 4(3-1): 14-18
Published online November 12, 2014 (http://www.sciencepublishinggroup.com/j/ijrse)
doi: 10.11648/j.ijrse.s.2015040301.13

High performance for real portable charger through low-power PV system

Yousif I. Al-Mashhadany[1], Hussain A. Attia[2]

[1]Electrical Engineering Dept., College of Engineering, University of Al-Anbar, Al-Anbar, Iraq
[2]Electronics and Communications Eng. Dept., American University of Ras Al Khaimah, Dubai, UAE

Email address:
yousif.almashhadany@uoanbar.edu.iq (Y. I. Al-Mashhadany), hattia@aurak.ae (H. A. Attia)

To cite this article:
Yousif I. Al-Mashhadany, Hussain A. Attia. High Performance for Real Portable Charger through Low-Power PV System. *International Journal of Sustainable and Green Energy.* Special Issue: Engineering Solution for High Performance of Solar Energy System.
Vol. 4, No. 3-1, 2015, pp. 14-18. doi: 10.11648/j.ijrse.s.2015040301.13

Abstract: This paper proposes a novel design for a solar-powered charger for low-power devices. The level of the charging current is controllable and any residue power is saveable to a rechargeable 9V battery. Two power sources (AC and solar) are used, and two charging speeds are possible. Quick charging is 20% of the battery output current (almost 180mA/hr) so the current is limited to 34 mA. Two types of cellular batteries (5.7V and 3.7V) can be charged. Normal charging is 10% of the cellular battery output current (almost 1,000mA/hr), so the charging current is limited to 100mA. The design uses only a few components so the system is cost effective besides being highly portable. It was simulated on MultiSim Ver. 11 before being implemented practically to validate it. The results from the simulation and the experiment show the design's sufficient feasibility for practical implementation.

Keywords: PV Energy System, Portable Charger, Current Limiting

1. Introduction

The emergence of alternative energy sources and new forms of exploration will rise with the technological evolution and development of societies. In the Eighteenth Century with rudimentary technology there was renewable energy. At the First Industrial Revolution, was the discovery of coal associated with the steam machine? In the Nineteenth Century is the World War I with the discovery of the principles of thermodynamics, development of transport, discovery of oil and natural gas in the Mid-twentieth Century. With World War II, nuclear power appears later computer science, robotics, which together gives rise to the Third Industrial Revolution in the last decades of the twentieth century [1-3].

In the recent past, many countries have strengthened their efforts to increase the fraction of electricity produced from renewable energy sources in order to reduce the greenhouse gas emissions from fossil fuel power plants. While most modern electrical appliances receive their power directly from the utility grid, a growing number of everyday devices require electrical power from batteries in order to achieve greater mobility and convenience. Rechargeable batteries store electricity from the grid for later use and can be conveniently recharged when their energy has been drained. Appliances that use rechargeable batteries include everything from low-power cell phones to high-power industrial fork lifts. The sales volume of such products has increased dramatically in the past decade [4-6].

The system used to draw energy from the grid, store it in a battery, and release it to power a device is called a battery charger system. While designers of battery charger systems often maximize the energy efficiency of their devices to ensure long operation times between charging, they often ignore how much energy is consumed in the process of converting ac electricity from the utility grid into dc electricity stored in the battery. Significant energy savings are possible by reducing the conversion losses associated with charging batteries in battery-powered products [3].

Mobility and mobile computing systems are systems that can easily be physically moved or may be performed while being moved. The small size, limited memory and processing power, low power consumption and limited connectivity are the main characteristics of mobile devices.

The reliance on small devices and the ones which makes easier the daily tasks increases every day. With advances in solar technology, batteries and electronics in general, have been increasingly possible to develop new devices that require less energy to operate. Of course all mobile devices (without network connection) could have, because the power required for solar modules is suitable for battery use. Furthermore, mini charge regulators that reach the maximum power devices without causing overload of the batteries.

Portable devices (mobile phones, tablets, notebooks and netbooks) have become increasingly popular, especially with the proliferation of access to wireless technology. One of its main characteristics is to rely on battery power for its operations. Techniques that allow energy savings, therefore, have been researched to meet the need for immediacy in which the world currently requires [3].

Batteries are nowadays the main energy provider to portable devices. They are used for their high power density and ease of use. Their disadvantages, however, limit their application. Their energy density can drop to as low as 200Wh/kg and their technology seem to improve slower than do other technologies [5-8].

Depleting fossil fuel and increased demand for energy have spurred the search for other sources of energy such as solar, wind, ocean thermal, tidal, biomass, geothermal, nuclear energy, etc. The abundance and widespread availability of solar energy, however, make it the most attractive among other energies that can be feasibly extracted. It can be converted into electricity through low-power PV energy systems, for portable applications (charging of mobile phones) and used in rural areas (solar lamps). The high cost of PV panels and their low efficiency, however, reduce solar energy's competitiveness in the energy market as a major source of power generation. It still, however, is better than conventional energy sources where portability is required [9-12].

This paper considers a novel design for, and the physical implementation of, a solar-charger-based PV energy system for charging of cellular and rechargeable batteries. The charger current can be controlled and any residue power saved in a rechargeable battery (9V). Sources for the design are a solar panel (3W, 18V) and an AC power supply. Two charging speeds are possible (slow and fast). The paper next presents the design of the novel system and its simulation, the experiment results, and the practical implementation [13-16].

2. Battery Charging

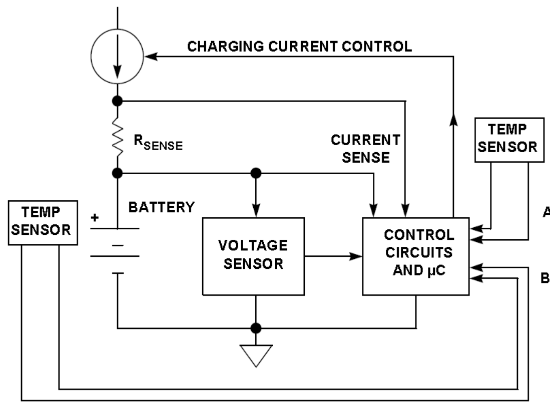

Fig. 1. *Generalized Battery Charging Circuit[6]*

A generalized battery charging circuit is shown in Fig. 1. The battery is charged with a constant current until fully charged. The voltage developed across the RSENSE resistor is used to maintain the constant current. The voltage is continuously monitored, and the entire operation is under the control of a microcontroller which may even have an on-chip A/D converter. Temperature sensors are used to monitor battery temperature and sometimes ambient temperature.

This type of circuit represents a high level of sophistication and is primarily used in fast-charging applications, where the charge time is less than 3 hours. Voltage and sometimes temperature monitoring is required to accurately determine the state of the battery and the end-of-charge. Slow charging (charge time greater than 12 hours) requires much less sophistication and can be accomplished using a simple current source.

3. Novel Design of the Solar-Powered Portable Charger with Current Limiter

Fig. 2 is a block diagram of the proposed charger. The solar and dc power sources join through two decoupling diodes. The meeting point provides the dc supply voltage to the main part of the design, which has two charging circuits of different specifications. One charging circuit delivers suitable voltage and (limited) charging current to a rechargeable battery, whereas the other is for charging of two types of mobile devices (3.7V and 5.7V).

In general the battery chargers operate in three modes:

1. Active charge mode, during which the battery is being charged from a discharged state. Most battery chargers draw the most power from the outlet during this mode.
2. Maintenance charge mode, during which the battery charge state is being maintained at a fully-charged state. A battery charger typically draws less power in this mode than in active charge mode.
3. No battery mode, during which no battery is connected to the charger at all. Many chargers continue to draw a current in this mode, even though they are doing no useful work [5,6].

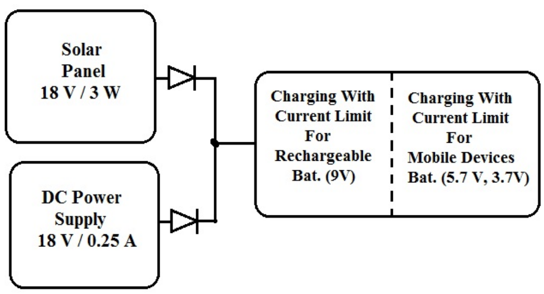

Fig. 2. *The proposed portable charger*

- DC Power Supply Circuit

Fig. 3 shows an 18V/250mA dc power source supplying two successive charging circuits. The power supply circuit is a full-wave rectifier with a step-down transformer (T1: 220 / 15V, 250mA).

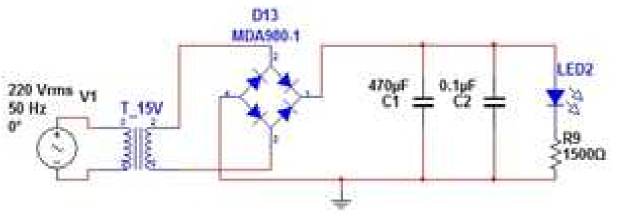

Fig. 3. The 18V / 0.25A, DC Power Supply

- Charging with the Current Limiter Circuit

The circuit delivers the higher power supply between the two to the next part of the circuit. Its second function is to provide a suitable charging voltage to a 9V rechargeable battery and supply a high level of charging current (20% of the battery output current, i.e., almost 180mA/hr, so the proposed design limits the current to 34mA, for which the shunt resistor controlling the charging limit should be R3=20Ω. The maximum voltage Vbe must be 0.7V. Of the transistor, R3 = Rbe = (0.7V / 34mA) = 20.5Ω.

The second part of the circuit provides charging voltages to 5.7V and 3.7V cellular batteries during suitable selection of the Zener diode connections D2 (ZDP7.5) and D6 (ZDP6.2), also supplies 100mA of charging current when the shunt resistor (R6, 7Ω) is connected (see Fig.4).

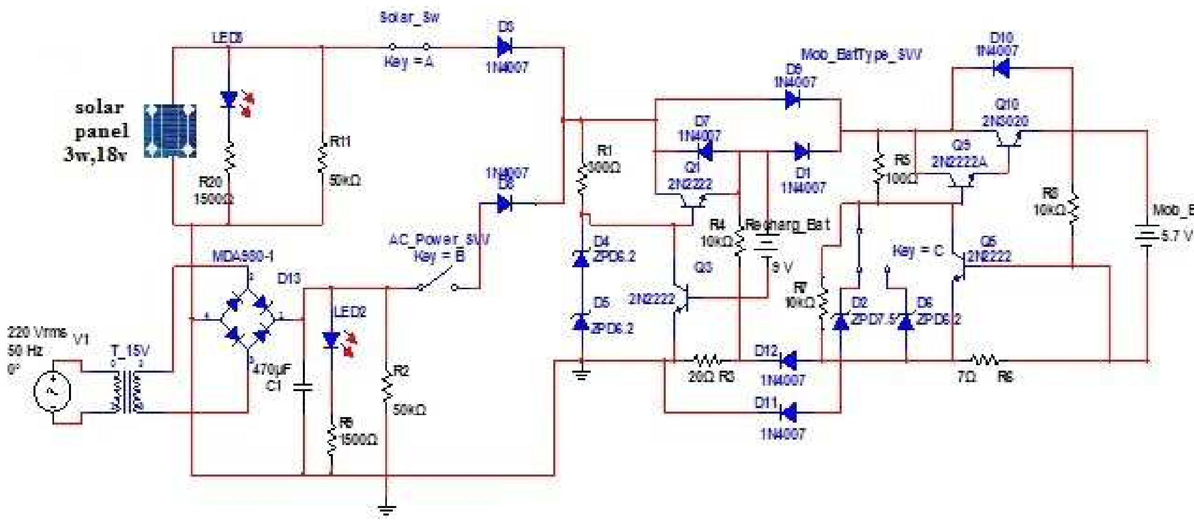

Fig. 4. The Proposed Design for the Solar Charger with Current Limiter

The current-limiting action is effected from measuring the current that passes through the shunt resistor. If it reaches the value lead to the voltage across the base and emitter equal 0.7V in will effect directly on the load voltage to make continuous current control on the load current (Charging Current), this action was done for 9V rechargeable battery during transistors Q1 and Q3. The same was done for cellular battery, with transistor Q4 and Darlington transistors Q9 and Q10. Fig. 3 is the proposed practical electronic circuit and all the distributed meters for the complete simulated measurements.

4. Simulation Results

The secondary coil of the stepdown transformer provided 15Vac, the load current was 124.79mA, the load resistance was 150Ω, and the dc load voltage was 18.7V; all these were measured by the third meter. The dc power supply delivered the required load currents in normal charging of rechargeable battery and cellular device.

- The Complete Charging Circuit with Current Limiter

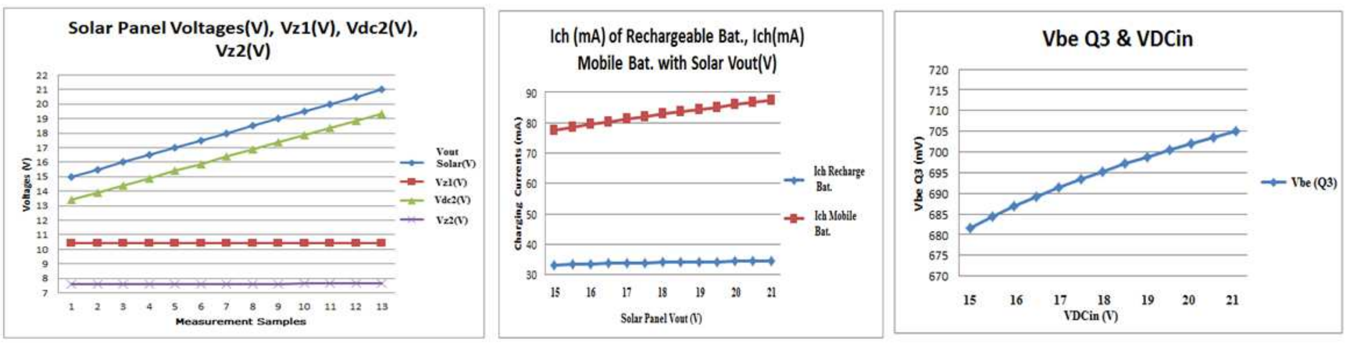

Fig. 5. Simulation Data for the Charging Circuit, the Charging Current, and the Controlling Voltage

Fig. 5 shows the complete simulations for the proposed charger. One is for rechargeable-battery charging current limited to 34mA (high-speed charging level), the other for cellular-battery charging current limited to 100mA (normal level). Calculations for the charging current levels were based on these: base emitter resistor R3=0.7V for transistor Q3 forward voltage (limiting to 34mA the rechargeable battery charging current). The value for a suitable base resistor will thus depend on the following: *R(be) = Vbe / I(pass through Rbe).* The maximum value for Vbe was limited to 0.7V. After correct selection of the current to pass through the resistor (for rechargeable battery, we selected the current level to equal the high-speed charging limit of 34 mA), a suitable resistor value would be Rbe = Vbe / Ibe = (0.7V) / (34mA) = 20.5Ω.

Through the same procedure but for different levels of charging current, the resistor selected to limit the maximum charging current was 7Ω. Fig. 5 include all related records as a drawings data came from distributed multimeters, the reads cover different case with suitable range of dc input voltage which came from the meeting point of diodes connection of the switching supply and DC power supply, from data and the related drawing in the Fig. 4 that fixed zeners voltages for range of Vdc input, It explains the charging current level around the current value of 34mA for rechargeable battery, and It explains the controlling of the level of charging current came from the designed value of resistor and the effect of the base emitter voltage, by same principle the recorded data of the charging current (XMM8) in mobile devices battery not pass more than 100mA.

5. Implementing the Design

The design is a PV-based (3W, 18V) energy system for mobile applications. It contains a PV array, a circuit design model, an oscilloscope, and a 9V DC battery for charging (see Fig. 5). After full charging, the battery starts converting energy through the 9V DC battery (which is used when the solar source dries up or at night). Control of the battery charging involves maintaining the current level at the high-speed charging limit equaling 34mA.

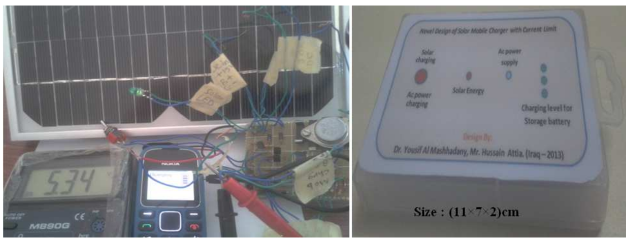

Fig. 6. *Practical Implement of System Design and Final Product Form.*

Different levels of charging current are possible (the normal charging level is 100mA). The rechargeable battery was charged to 34mA and the results fully correspond with the simulation results. Fig. 6 also shows the final display of the mobile charger. The selection for the source type (either solar energy or AC) depends on the source available. The level of charging of the external battery also shows up on the panel.

6. Conclusion

The proposed design is novel. It is simple and cheap but high performance. It also functions on two sources. Its simulation and experiment results show:

- Above 95% charging efficiency (proving solar energy's feasibility in supplying energy to mobile phones).
- Its current limiter circuit extending battery life and it is safe even after full charging.
- Possible future work in increasing the solar panel efficacy and reducing the system size.

References

[1] Attia H. A, Getu B, Ghadban H, Abu Mustafa K, Portable Solar Charger with Controlled Charging Current for Mobile Phone Devices, Int. J. of Thermal & Environmental Engineering, Vol. 7, No. 1, 2014 , pp.17-24

[2] Hild S, Leavey S, Sorazu B, Smart Charging Technologies for Portable Electronic Devices, Journal Of Latex Class Files, 2014.

[3] Geist T, Kamath H, Porter S, Designing Battery Charger Systems for Improved Energy Efficiency, Prepared for the California Energy Commission, Sep 28, 2006.

[4] F. Boico, B. Lehman, Multiple-input Maximum Power Point Tracking algorithm for solar panels with reduced sensing circuitry for portable applications, J. Solar Energy 86 (2012) 463–475

[5] P. Görbe , A. Magyar, K. M. Hangos, Reduction of power losses with smart grids fueled with renewable sources and applying EV batteries, J. Cleaner Production 34 (2012) 125-137

[6] P. Bajpai, V. Dash, Hybrid renewable energy systems for power generation in stand-alone applications: A review, J. Renewable and Sustainable Energy Reviews 16 (2012) 2926–2939

[7] B. ChittiBabu, et. al, Synchronous Buck Converter based PV Energy System for Portable Applications, Proceeding of the 2011 IEEE Students' Technology Symposium 14-16 Jan. (2011), 335 - 340

[8] A. Robion, et. al, Breakthrough in Energy Generation for Mobile or Portable Devices, 978-1-4244-1628-8/07/$25.00 ©2007 IEEE, (2007), 460 - 466

[9] M. H. Imtiaz, et. al, Design & Implementation Of An Intelligent Solar Hybrid Inverter In Grid Oriented System For Utilizing PV Energy, International Journal Of Engineering Science And Technology, Vol. 2(12), 2010, 7524-7530

[10] M. S. Varadarajan, Coin Based Universal Mobile Battery Charger, IOSR Journal of Engineering (IOSRJEN) ISSN: 2250-3021 Vol. 2, Issue 6 (June 2012), 1433-1438

[11] R. M. Akhimullah, Battery Charger with Alarm Application, Thesis of Bachelor Of Electrical Engineering (Power System), University Malaysia Pahang, November, 2008, pp: 1-24

[12] M. A. Baharin, Solar Bicycle, thesis MSc. Bachelor Of Electrical Engineering (Power Systems), University Malaysia Pahang, November, 2010, pp:1-24

[13] J. Tyner, et. al, The Design of a Portable and Deployable Solar Energy System for Deployed Military Applications, Proceedings of the 2011 IEEE Systems and Information Engineering Design Symposium, University of Virginia, Charlottesville, VA, USA, April 29, (2011), 50 - 53

[14] C. Li, et. al, Solar Cell Phone Charger Performance in Indoor Environment, 978-1-61284-8928-0/11/$26.00 ©2011 IEEE, (2011), pp: 1-2.

[15] Q. I. Ali, Design & Implementation of a Mobile Phone Charging System Based on Solar Energy Harvesting, Iraq J. Electrical and Electronic Engineering, Vol.7 No.1,(2011), 69 - 72

[16] K. Ishaque, Z. Salam, A review of maximum power point tracking techniques of PV system for uniform insolation and partial shading condition, J. Renewable and Sustainable Energy Reviews, 19, (2013), 475–488.

[17] A. Higier, Design, development and deployment of a hybrid renewable energy powered mobile medical clinic with automated modular control system, J. Renewable Energy ,50, (2013), 847 - 857

[18] M.H. Taghvaee, et. al, A current and future study on non-isolated DC–DC converters for photo voltaic applications, J. Renewable and Sustainable Energy Reviews, 17, (2013) 216–227

[19] R. Komiyama, Analysis of Possible Introduction of PV Systems Considering Output Power Fluctuations and Battery Technology, Employing an Optimal Power Generation Mix Model, Electrical Engineering in Japan, Vol. 182, No. 2, (2013), pp. 1705–1714