PV System to Supply Lighting and Small Electronic Equipments of an off-Grid Rural School

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Abstract

This paper presents the development of a photovoltaic (PV) system to supply electric energy to a typical rural school in the countryside of Piauí, Brazil. The system is designed to supply a rural school for up to two days, even under minimum solar radiation condition. The solar energy is captured by PV panels and stored in lead acid batteries. A boost converter (the battery charger) allows the system to operate the PV panels at the maximum power point (MPP). The load is supplied through another boost converter (24 Vcc to 311 Vcc) and the entire system is controlled by a microcontroller, which runs the MPP algorithm, monitors the charge state of the batteries and controls the operation of the DC/DC boost converter according to the load demand.

Keywords: PV, Isolated System, Rural Electrification, Lighting.

1. Introduction

This paper presents an off-grid PV system suitable for isolated areas where the cost to extend the electric utility is prohibitive. The system was designed to guarantee a safe and user-friendly electric energy supply to rural residences, in accordance with the guideline 83 of September 2004, from the Brazilian National Electric Energy Agency – ANEEL. According to this guideline, the electric energy supplied by Electric Energy Production Units should have a sinusoidal waveform as output voltage with magnitude and frequency compatible with the grid used. However, aiming to boost the production of renewable electric energy in Brazilian remote areas with difficult access, ANEEL has authorized throughout the Resolution 927 of May 2007, the development of a pilot project with the objective to supply remote areas without consumption in AC, as required by the guideline 83, but with consumption in DC voltage.

The system is composed of five parallel PV panels (each one of 130 Wp), a 24 V battery bank of six 150 Ah batteries (three strings in parallel and each string made up by two units connected in series), a battery charger of 650 W that operates with a maximum power point tracker, and a 300 W boost converter to supply the loads with the required voltage.

The proposed solar home system

The proposed system is shown in Figure 1, and is able to supply a rural unit with the following loads: 6 electronic lamps of 23 W each, a television of 48 W, a parabolic antenna of 20 W for long distance TV signal, a portable sound system of 10 W, a DVD of 20 W, and a mobile phone charger of 10W.

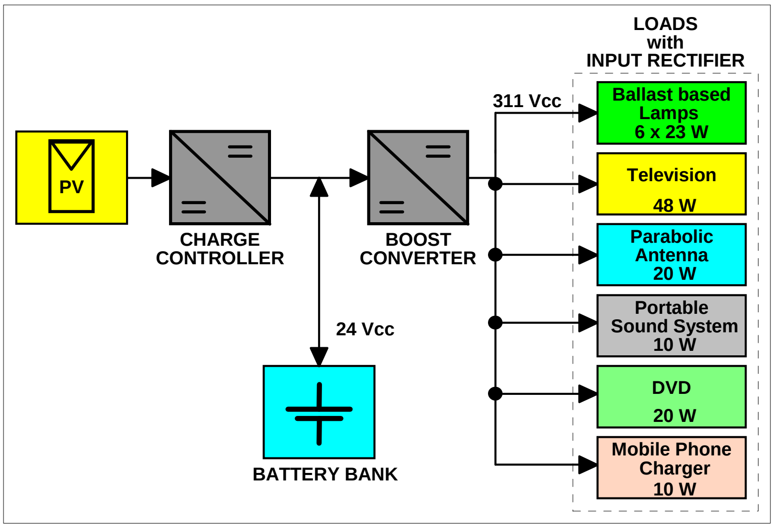


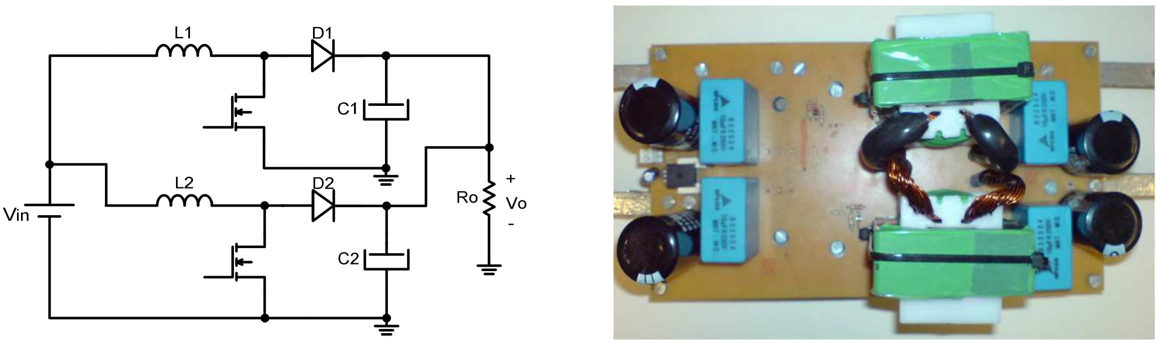
Fig. 1 - The proposed system.

2. The Battery Charger

The battery charger has the function of providing energy to a battery bank under controlled voltage and current, in order to improve the service lifetime of the battery bank. This energy is provided by solar panels which are capable of converting solar radiation into electricity.

Aiming to reduce the initial investment cost, it is important to take out the maximum power of the panel. The energy produced by the panels depends on the ambient temperature, solar radiation intensity and also on the characteristics of its load. If one or more of these parameters are modified, the produced power can be significantly changed. So, it is necessary to use a control system in order to adjust the dynamic electric impedance of the battery bank to the best operation point of the PV panels (MPP). In the implemented prototype, a microcontroller was used to control the battery charger and to implement the MPP algorithm.

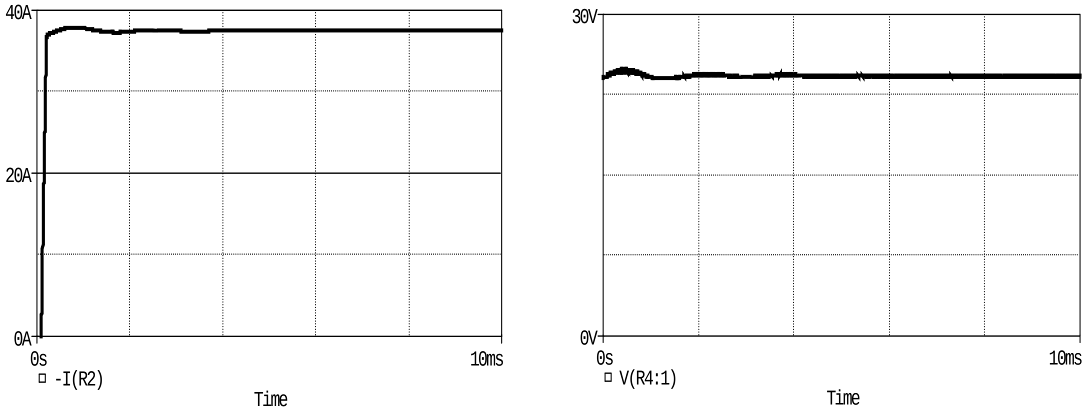
The battery charger power electronics is composed by a boost converter with a working cycle that can be digitally controlled. For a short range of time, the battery can be considered as a fixed source of voltage, which allows the system to achieve the maximum MPP operation by just observing the current in the battery bank [1]. The electric circuit of the proposed battery charger is shown in Figure 2(a). A photograph of the implemented prototype is shown in Figure 2(b).



(a) (b)

Fig. 2 - (a) Basic electric schematic of the battery charger, (b) Battery charger prototype.

Figure 3(a) and Figure 3(b) show some simulation results of the battery charger (boost converter), showing the converter input current (current from the photovoltaic panel) and the output voltage at the battery, respectively.

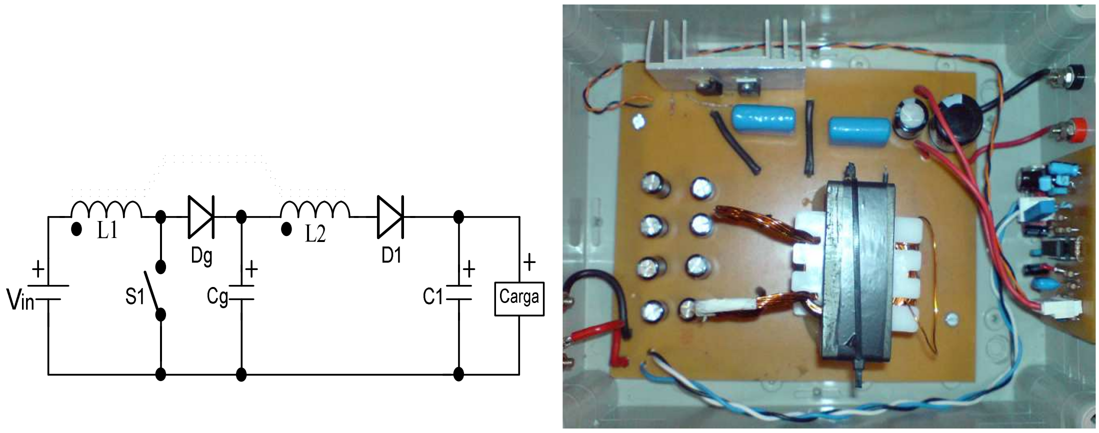


(a) (b)

Fig. 3 - (a) Current from the PV panels (37.5 A); (b) Output voltage (24 V).

3. The Boost Converter

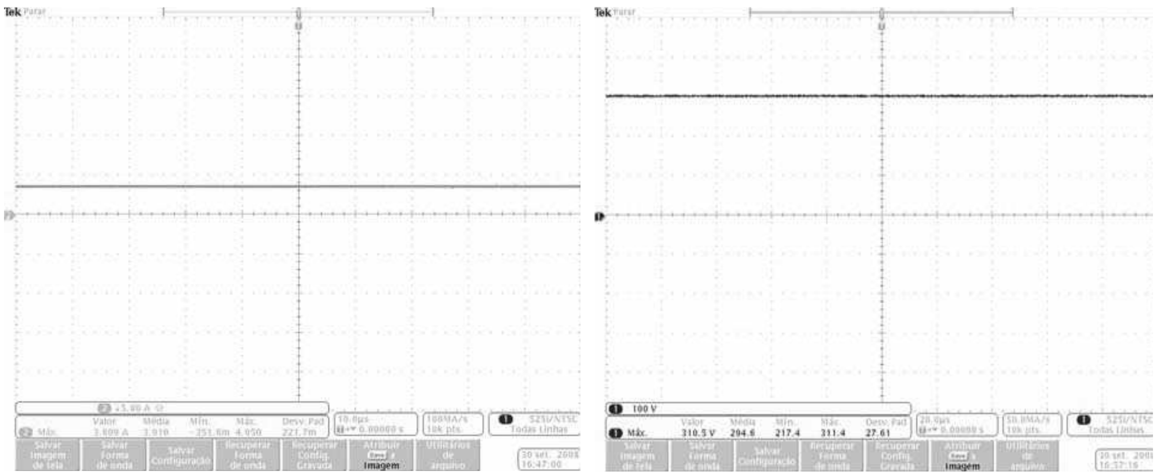
The boost converter has the function to boost the 24 Vcc from the battery bank to 311 Vcc, which is required by the loads. Several topologies of boost converters are presented in the technical literature. However, when a high voltage gain is required (in this case, more than 13 times), most of the topologies are prohibitive, due to switching losses and poor utilization of the power switch (i.e., combination of high current and high voltage). The topology adopted in this work is based on a coupled inductor, what makes possible to reach a high step up voltage without stressing the power switch; this is a key point to achieve high efficiency and robustness, characteristics that are of major importance when processing electric energy for renewable energy sources, such as PV systems. The basic electric circuit schematic of the proposed boost converter is shown in Figure 4(a) and a photo of the implemented prototype is at Figure 4(b).



(a) (b)

Fig. 4 - (a) Electric schematic of the boost converter, (b) Boost converter prototype.

Figure 5(a) and 5(b) show the experimental results for the boost converter input current (current from the battery bank) and the converter output voltage applied to a load of 150 W.



(a) (b)

Fig. 5 - (a) Current from the battery bank(6.25 A); (b) Output voltage at the loads (311 Vcc).

4. Conclusion

The proposed system presents high efficiency and has lower cost when compared with other solar home systems. In addition, its simplicity and robustness make it suitable for applications in rural consumers of low power demand. This is the case of most houses in remote areas in the Northeast of Brazil.

5. References

[1] Júnior, E. M. S.. Sistema Fotovoltaico para Iluminação Pública em Horário de Ponta. Dissertação (Mestrado em Engenharia Elétrica) – GPEC, UFC, Fortaleza, novembro de 2004.

[2] Lee et al.,“Steady-State Analysis of an Interleaved Boost Converter with Coupled Inductors” in Proc. IEEE transactions on industrial electronics, vol. 47, no. 4, august 2000, pp. 787-795.

[3] Martinelli et al., “Coupled inductor boost converter with input and output ripple cancellation”, in IEEE, 1991, pp. 567-572.

[4] Peraça, M. T. Conversores CC-CC Elevadores para Aplicação em Equipamentos de Refrigeração. Dissertação (Mestrado em Engenharia Elétrica) - UFSC, Florianópolis, fevereiro de 2002.

[5] Zhao, Q. Performance Improvement of Power Conversion by Utilizing Coupled Inductors. Dissertação (Mestrado em Engenharia Elétrica) - Faculty of the Virginia Polytechnic Institute and State University, Blacksburg, Virginia, fevereiro de 2003.