High Gain DC-DC Converter Applied to Photovoltaic System with New Proposed to MPPT Search.

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Abstract. **This paper presents the development of a high gain Boost converter applied to photovoltaic (PV) system. This converter raises its input voltage and injects its output current at a constant 311 Vdc bus, using the maximum power point tracking (MPPT). The new proposal seeks the MPPT is to connect each module a converter for a high gain greater accuracy in finding the point of maximum power. The converter will work with input voltage of 17.4 Vdc, output voltage of 311 Vdc and power of 100 W.**
Keywords: High gain converter, MPPT, photovoltaic system.

I. Introduction

With the need for diversification of global energy matrix, today, there are several relevant researches on photovoltaic systems. The great challenge of this research is to transform one type of generating enough electricity costly something that is economically viable to all communities in the world.

One method to achieve this reduction in the cost of the photovoltaic system (installation, generation and marketing) is to increase its efficiency. It's possible buying a photovoltaic panel with an efficiency of yield 20%.

One way to increase this efficiency is to improve the search of maximum power point. There are many researches who are looking to accomplish this improvement through complex algorithms and intelligent. In this paper we propose the search for the point of maximum power, using a traditional algorithm, each photovoltaic module in order to obtain better accuracy.

The increased efficiency can be seen when considering the following hypothesis: it is supposed a set of 10 photovoltaic modules connected in parallel to a single converter that searches the MPPT.

If 5 of these modules are shaded, the MPPT will lose its effectiveness, because the maximum power point average will move, even if the MPPT take that into consideration, the point cannot be found with precision.

Assuming now 10 photovoltaic modules that are connected each to a converter that performs the search for maximum power. If 5 of these modules are shaded, the efficiency of search the MPPT of others will not decrease because, this shading, not interfere with the search of maximum power point of others modules that continue to function normally.

Another challenge faced in this project was to raise the input voltage of a panel of Kyocera Company of power equal the 65 W (17.4 Vdc) to an output voltage equal to 311Vdc.

II. Topology Selection

The literature divides the DC / DC converters into two major groups: isolated converters and non-isolated converters. This work was chosen using the type non-isolated converters.

There are several basic topologies of non-isolated converters as: Boost classic, modified Boost, Boost, high-gain, cascading Boost, Boost interleaved, interleaved High Gain Boost, Buck-Boost classic, modified Buck-Boost, Buck-Boost High gain, Cuk, Sepic, Zeta, among others [1], [2].

Boost conventional topologies, besides failing to provide a large increase in voltage, its operation have hindered due to high ripple current in the power switch and the output diode; the high voltages on the power switch, which are normally equal the output voltage of the converter and the switching losses, because usually the frequency used for switching the switches is very high [3].

After conducting analysis of some converters, the team chose to use the high gain Boost converter with a coupling inductor proposed by [4]. The Figure 1 shows the high gain Boost converter chosen.

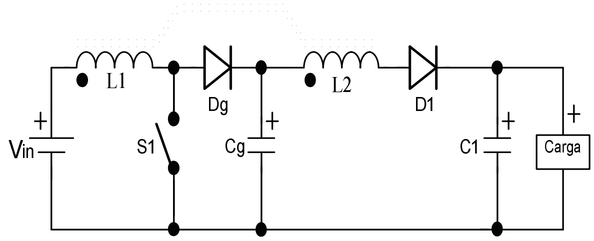

Fig. 1. High gain boost converter with clamped circuit.

In the simulation of this circuit was observed that due to a low value of input voltage (17.4 Vdc) the value of peak voltage across the diode D_1 was very high (approximately 800 Vdc). Noting this fact and considering that the study's goal is to create a modular solution for photovoltaic systems, low cost, ruled out the use of diodes of 1000 Vdc, for they are difficult to access and are priced high.

To solve this problem was made a change in topology proposed by [4]. Since the problem of converter from Figure 1, was the high voltage on the terminals of the diode (diode D_1) was added over a block of components (inductor, diode and capacitor) in the circuit.

This block has exactly the same values of the components of their concatenated block and aims to share the work with his twin block. The new circuit can be seen in Figure 2. The new block is between the dotted lines [5].

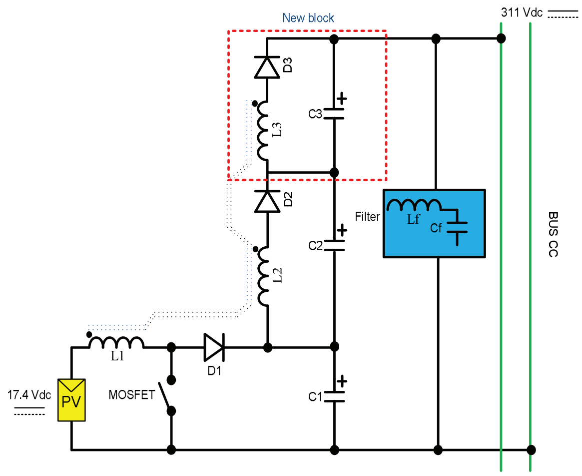

Fig. 2. High gain boost converter proposed.

III. The Proposed Converter

During the achievements of the initial tests with the converter of Figure 2, we observed that the circuit when working in continuous conduction mode provided a great resonance between the inductor L_1 and the capacitor C_1.

This occurred because the inductor L_1, not fully discharged its stored energy, characteristic of the continuous conduction mode, with this, the remaining energy went into resonance with the capacitance of the capacitor C_1 making the converter works the wrong way.

To solve this problem, we chose to work in discontinuous conduction mode, so, it was possible to ensure that the inductor L_1 fully discharge its energy. The Figures 3 (a), (b) e (c) shows the operation steps of the converter proposed.

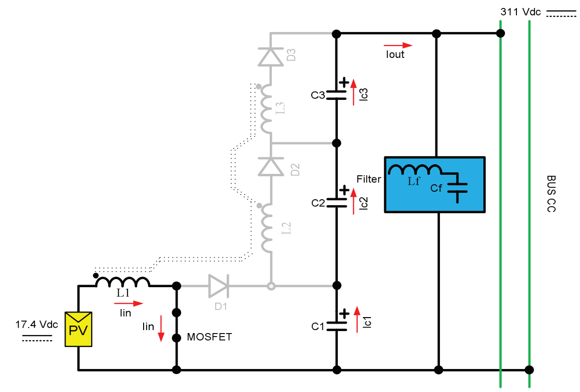

Fig. 3(a). First step.

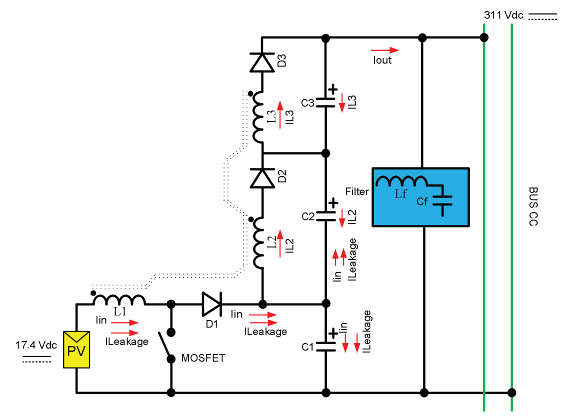

Fig. 3(b). Second step.

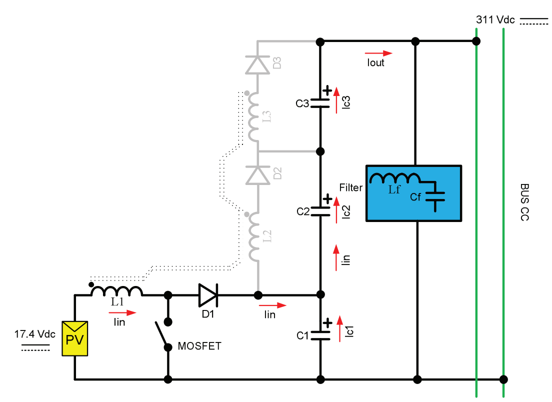

Fig. 3(c). Third step.

The Figure 3 (a) shows the inductor L_1 loading by power supplied from the photovoltaic panel. In this stage the capacitors C_1, C_2 and C_3 provide power to the DC bus. The output filter is designed to transform the output's high-gain converter in current.

The Figure 3 (b) shows the inductor L_1 reflecting its energy to the inductor L_2 and L_3. In this stage the inductor L_1, even fully discharged, continues to send a little energy with the photovoltaic panel to the capacitor C_1. This is because there is a leakage inductance inherent to the inductor L_1 that stores energy during the first stage and discharges during this stage. It can also be seen that I_{in}, I_{L2} and I_{L3} charge the output capacitors, thus maintaining tension in the value of 311 Vdc. Even the capacitors being charged, they contribute to the output current, because its load is very fast.

The Figure 3 (c) shows the third stage. This stage is quite similar to the first. What sets it apart is that all inductors are discharged, as shown in Figure 4. At the moment the capacitors C_1, C_2 and C_3 along with the input source, provide energy to the DC bus, maintaining the stable. The Figure 4 shows the main waveforms of the converter studied.

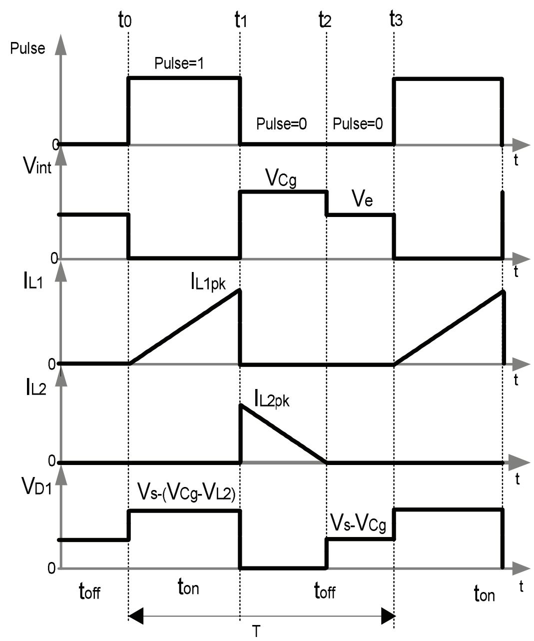

Fig. 4. Main waveforms of the converter studied.

In the Figure above is possible identify which are the theoretical values of each stage of operation. Can be see the operation in discontinuous conduction mode by analysing the waveform of the inductor L_1 and the three stages of operation of the converter, as described above by analysing the waveforms of voltage across the diode D_3.

In Table I are shown the considerations adopted for the calculation of the components.

Table I – Considerations Adopted

Variable	Value	Description
V_{emin}	10 V	Minimum input voltage
V_e	17	Nominal input voltage
V_s	311 V	Output voltage
D_{max}	0.5	Maximum duty cycle
$D_{nominal}$	0.29	Nominal duty cycle
T	20µs	Period
Pot_s	100 W	Output power
td	10,12µs	Discharge time
N_2	29xN_1	Number of turn of the secondary

Shown below are the main equations of the converter. It is important to remember that L_1 and L_2 have been dimensioned in critical conduction mode and the others variables have been designed in discontinuous conduction mode [6].

$$L_1 = \frac{V_{e\min} \cdot T}{2 \cdot Pot_s} \cdot \left[V_{e\min} \cdot D^2 + \frac{N_1^2 \cdot (1-D)^2}{(N_1+N_2)^2} \cdot (V_s - V_{e\min}) \right] \quad (1)$$

$$L_2 = \left(\frac{N_2 + N_1}{N_1} \right)^2 \cdot L_1 \quad (2)$$

$$I_{L1_{pico}\,MCD} = \frac{V_e \cdot D_{\text{nominal}} \cdot T}{L_1} \quad (3)$$

$$I_{L2_{pico}\,MCD} = \frac{(V_s - V_e) \cdot td}{L_2} \quad (4)$$

Where,

L_1 – Primary inductance
L_2 – Secondary inductance
$I_{L1picoMCD}$ – Output power
$I_{L2picoMCD}$ – Duty cycle

IV. Experimental Results

The following will show the main waveforms of the high gain DC / DC converter. All waveforms were taken with the converter injecting current on the dc bus. The Figure 5 show the prototype implemented in laboratory.

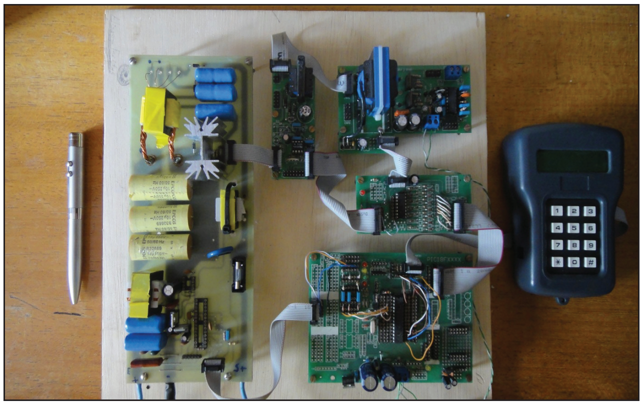

Fig. 5. The prototype implemented in laboratory.

The Figure 6 shows the waveform of the input voltage, input current and input power in the converter.

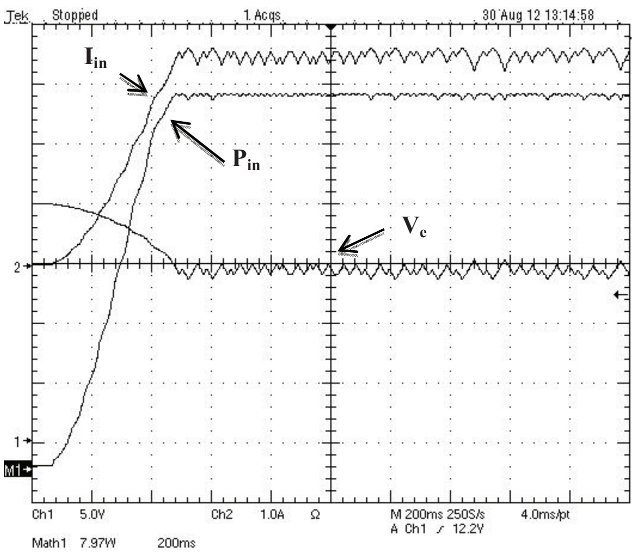

Fig. 6. Input voltage (Ch1 – 5 V/div), input current (Ch2 – 1 A /div) e input power (M1 – 8 W/div).

In the Figure 6 was obtained when the MPPT begins to enter into operation. It may be noted that the waveforms of the input current and input voltage with their values are close to the nominal. The value of input power found by multiplying the values of voltage and current input to the oscilloscope. In Figure note also that the MPPT was performed by the control circuit fairly quickly, reaching a result higher than expected by the working group.

The Figure 7 shows the current through the inductor L1 and L2.

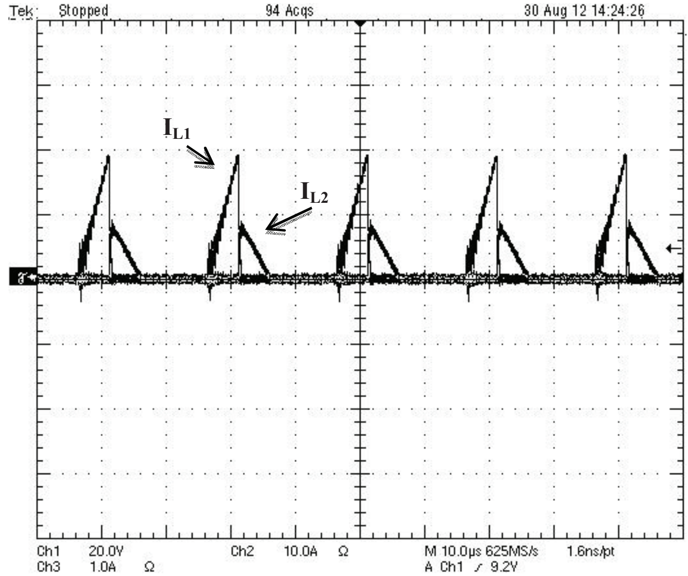

Fig. 7. Current through the inductor L1 (Ch2 – 10 A/div) and current through the inductor L2 (Ch3 – 1 A/div).

The waveforms of current through L_1 and L_2 clearly show the complete discharge of the inductor, characterized discontinuous conduction mode (DCM) proposed in this work.

The Figure 8 shows the output voltage and outputt current

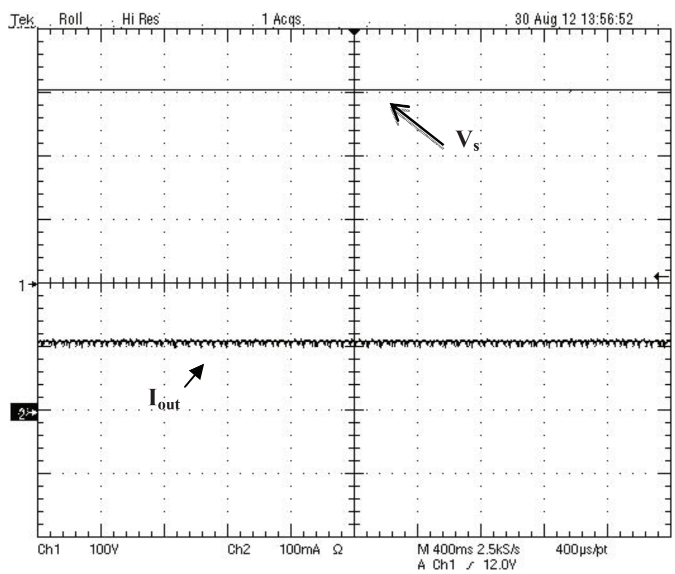

Fig. 8. Output voltage (Ch1 – 100 V/div) e output current (Ch2 – 100m A/div).

In Figure 8 it is noted that the ripples in the waveforms of output current and output voltage is practically zero, indicating that the output filter has obtained the desired result. Importantly, the filter 6 mH was built to make the output of the high gain converter with characteristics of current source.

The Figure 9 shows efficiency curve of the prototype implemented in laboratory.

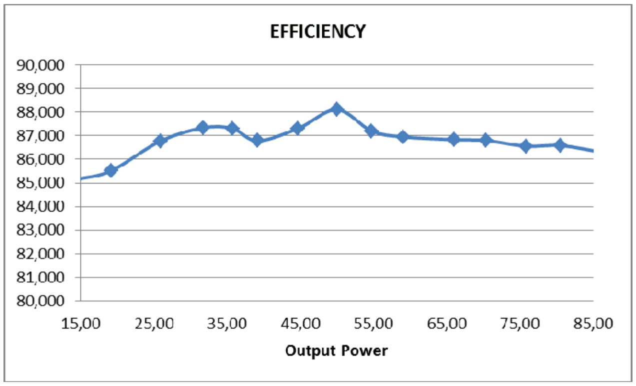

Fig. 9. Curve the efficiency of the prototype.

The Figure 9 shows the curve of converter efficiency studied, where the mean value was equal to 87%. This value was relatively low due to the high value of the switching frequency used in the circuit (50kHz) and high peak values of current in the switch, these two values being characteristic of the functioning of the converter.

Another feature that influence the efficiency value was high magnetic dispersion caused by the use of a magnetic core of the type EE.

V. Conclusion

This work aimed to develop a high gain DC / DC converter applied to a photovoltaic system. The converter was proposed as major characteristics, operation in discontinuous conduction mode, and searches the maximum power point of a photovoltaic module on only.

The prototype has proven robust, good efficiency and low cost, characteristics required for a converter applied to renewable energy sources. The performance of the prototype in finding the point of maximum power exceeded the expectations of the author, showing that a very simple algorithm can be extremely reliable when it chooses the setting for a converter module.

Finally, we suggest for future work, the development of a study in which the prototype implementation is that through the use of toroidal cores. Thus, the magnetic dispersions caused by oscillation of EE type core would be damped by increasing the efficiency of the converter.

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