

DC-DC high gain converter applied to renewable energy 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. The converter was designed to be connected directly to the photovoltaic panel and perform the search for the maximum power point (MPPT). The new proposal seeks the MPPT is to connect each panel a converter for a high gain greater accuracy in finding the point of maximum power. The converter will work with input voltage of 17.7 Vdc, output voltage of 311 Vdc and power of 200 W.

Key words

High gain converter, MPPT, photovoltaic system.

1. 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 panel 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 panels connected in parallel to a single converter that searches the MPPT.

If 5 of these panels 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 panels that are connected each to a converter that performs the search for maximum power. If 5 of these panels 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 panels 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 135 W (17.7Vdc) to an output voltage equal to 311Vdc. This value of output voltage was chosen, because, it is intended to link all the converters to a single dc bus using this bus to supply energy the many home. Researches show that with the advancement of electronics is possible to supply a residence, almost that complete, by energy DC [1].

2. Topology Selection

Considering the cost of the electricity produced from PV conversion, it is mandatory the search for efficient converters. In relation to the efficiency of dc-dc converters, the non-isolated can be more efficient than the

isolated ones. The literature about non-isolated dc-dc converters presents some topologies as: classical boost, modified boost, high gain boost, cascade, interleaved boost, high gain interleaved boost and classic boost converter [2].

As discussed earlier, the boost converter requires a gain of approximately 17.5 of voltage. To gain this level, the classical converters are not suitable due to the fact that the switches operate, with high current in the input and with high voltage on the output [3]. These are unfavorable, on the practical implementation and of efficiency.

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.

The simulation of this circuit was performed in the PSIM software. It was observed that due to a low value of input voltage (17.7 VDC) the value of peak voltage across the diode D1 was very high (approximately 800 V). 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 volts, 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 D1) 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.



Fig. 2. High gain boost converter proposed.

3. 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 L1 and the capacitor C1. This occurred because the inductor L1, 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 C1 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 L1 fully discharge its energy. The Figures 3 (a), (b) e (c) shows the operation steps of the converter proposed.





Fig. 3(c). Third step.

The Figure 3 (a) shows the inductor L1 loading by power supplied from the photovoltaic panel. In this stage the capacitors C1, C2 and C3 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 L1 reflecting its energy to the inductor L2 and L3. In this stage the inductor L1, even fully discharged, continues to send a little energy with the photovoltaic panel to the capacitor C1. This is because there is a leakage inductance inherent to the inductor L1 that stores energy during the first stage and discharges during this stage. It can also be seen that lin, IL2 and IL3 charge the output capacitors, thus maintaining tension in the value of 311Vdc. 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 C1, C2 and C3 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 L1 and the three stages of operation of the converter, as described above by analysing the waveforms of voltage across the diode D3.

Shown below are the main equations of the converter. It is important to remember that the converter has been designed in discontinuous conduction mode (DCM).

$$Iout = \frac{Vin^2 \cdot D^2}{2 \cdot L_1 \cdot f \cdot (Vout - Vin)}$$
(1)

$$L_{1} = \frac{Vin^{2} \cdot D^{2} \cdot Vout}{2 \cdot Pout \cdot f \cdot (Vout - Vin)}$$
(2)

$$Ipk = \frac{Vin _\min \cdot D\max}{L_1 \cdot f}$$
(3)

Where,

Iout – Output current Vin - Input voltage Vout – Output voltage L1 – Primary inductance L2 – Secondary inductance Pout – Output power D – Duty cycle f – Frequency

In Table I are shown the considerations adopted for the calculation of the components. To facilitate the initial calculations, the sizing was performed using the BCM.

Table I - Considerations Adopted

Variable	Value
Vin_min	10 V
Vout_min	300 V
Dmax	0.5
f	50k
Pout	200 W

4. Simulation Results

This topic will show the waveforms obtained by simulation in PSIM software, using the library of the physical model of the photovoltaic panel. The Figure 5 shows the circuit simulated.



Fig. 5. The circuit simulated.

Using the physical model of a photovoltaic panel was able to simulate the behavior of converter with high-precision. With this new library has been traced the curve of the panel that will be used. Note that to prove that the MPPT was functioning properly, a source with two levels (Step Voltage Source) was used to simulate a variation in solar radiation. The values used were 800 and 1000. The value used to simulate the temperature was 25 ° C.

The Figure 6 shows the waveform of the photovoltaic panel used in the simulation.



Fig. 6. The waveform of the photovoltaic panel.

The Figure above shows the graphic current versus voltage of photovoltaic panel. When the voltage is zero has the value of short circuit current of the panel (8.37 A). When the current is zero has the value of open-circuit (22.1 V). The panel simulated was KD135SX Kyocera.

The Figure 7 shows the current through the inductor L1 and L3.



Fig. 7. Current through the inductor L1 (red) and L3 (blue).

In the Figure above can see that the value of current flowing through the inductor L1 is quite high, approximately 60 A. This current peak is a normal feature in discontinuous conduction mode. The peak value of current flowing through the inductor L3 is approximately 2.2 A.

The Figure 8 shows the voltages on the terminals L3, C3 and D3.



Fig. 8. The voltages on the terminals of L3 (pink), C3 (green) and D3 (blue).

In Figure above is shown the three stages of operation. In the first stage, there is a voltage across the terminals of the diode D3 equal to 369 V. This value is result from the sum between the voltage of the capacitor C3 and the voltage about the terminals of the inductor L3. In the second stage, the value the voltage of D3 is equal to zero, because the voltage values about the terminals of L3 and C3 are opposite and equal. In the third and final stage, the value of voltage on D3 is equal to 141 V, same value of voltage about o capacitor C3.

The Figure 9 shows the voltage across the terminals of the power switch



Vin (green) and VMosfet (red).

In Figure above is shown the three stages of operation. In the first stage there is a voltage across the terminals of the power switch equal to 28 V. This value is result from the sum between the voltage of the input source Vin and the voltage about the terminals of the inductor L1. In the second stage, the value of voltage on power switch is equal to 17.7 V, same value of voltage in the input source. In the third and final stage, the value the voltage of power switch is equal to zero, because the voltage values about the terminals of VL1 and Vin are opposite and equal.

Several difficulties were encountered in achieving a reliable MPPT. In previous versions, the software PSIM could not record the previous value of the variables, thus the comparison of the calculation algorithm of the MPPT within the block was affected. To solve these problems the authors used a block buffer to perform the delay and the recording of the previous value, using it to compare with the current value [5]. In newer versions, PSIM provides

that the author use the command STATIC + type of variable. This command does not let the previous variable be reset when the program restart, being compared. The block ZOH (Zero Order Hold) is used to acquire a sample of the monitored signal. The ZOH was necessary for the proper functioning of this algorithm, but we cannot say that its use is obligatory when using the current and voltage sensor.

Another parameter discussed in detail among the authors, was the increment value. Algorithm in this paper, the duty cycle was the variable increased. Evaluating tests by [6] it was observed that high increments (step = 1) were not accurate and that very low increments (step = 0.005) meant that the algorithm did not come in convergence. For a frequency equal to the value of 100 was used for the increment of 0.01, obtaining satisfactory results. It was noted that no multiple increases of the frequency caused errors in the program.

Figure 10 shows the curve of input power following the curve of theoretical maximum power panel



Fig. 10. Input Power (blue) and Output Power (blue).

In the Figure above is noticed that the curve of input power (blue curve) follows the same route of theoretical maximum power panel (red curve). The difference between the two curves is minimal. To further increase the accuracy of the MPPT algorithm is advised that the comparison between the duty cycle and the triangular wave is made internally to the block of the MPPT.

5. Conclusion

The converter has proved an excellent choice for the purpose of this project. The choice of discontinuous conduction mode proved to be correct, because the equating the converter, which in continuous conduction mode proved to be very difficult, was easier. The PSIM software has proven to be an excellent tool for the simulation of digital control in power converters. The goal of designing a compact converter has been reached.

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