A Water Pumping Photovoltaic Powered System Based on a Merged DC-DC Sepic-Cuk Converter

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Abstract - This paper has the purpose to present a non-isolated dual output *DC-DC* converter for a water pumping photovoltaic powered system. The proposed topology is based in the integration of a traditional *Sepic* and *Cuk* converters but requires only a single power semiconductor switch. It is characterized by an extension of the voltage static gain when compared with the classical boost topology and by a reduced voltage stress across the power switch and diodes. The system will be implemented through a classical *MPPT* algorithm that will control the proposed *DC-DC* converter. Several simulation and experimental results are also presented in order to confirm the characteristics of the proposed power converter and global water pumping systems.

Keywords- *DC-DC* converter; *Sepic* converter; *Cuk* converter; Water pump; Photovoltaic panel.

1. Introduction

In the actual context solar energy for water pumping is a promising alternative to conventional electricity and diesel based pumping systems or in remote areas where no electricity supply is available [1,2]. The use of the photovoltaic (*PV*) as the power source for pumping water is considered as one of the most promising areas of *PV* application, especially in agricultural in remote areas since allows generating electricity directly from solar radiation (sunlight) for power irrigation watering systems and livestock. The advantages of using water pumps powered by photovoltaic systems include low maintenance, ease of installation, reliability and the matching between the powers generated and the water usage needs. In addition, water tanks can be used instead of batteries in photovoltaic pumping systems. The disadvantages for using water pumping by solar energy are the very low *PV* cell conversion efficiency and dependence on several factors such as the solar radiation, the ambient temperature. Another aspect is that is required a *DC-DC* converter with a high voltage gain. In this way, several solutions have been proposed, but with limited voltage gain or high number of power switches [3,4].

This, work proposes a new *DC-DC* converter based on a merged *Sepic-Cuk* topologies. However, it only uses a single switch with a reduced blocking voltage. The proposed system will be supported by simulation and experimental results.

2. Proposed System

The proposed system consists of a *PV* array, a *DC-DC* converter, a *DC-AC* converter and a centrifugal pump driven by single-phase induction motor (*SPIM*), Figure 1. The *DC-DC* converter is controlled in order to ensure the maximum power of the *PV* array. For the maximum power point tracking (*MPPT*) algorithm is used the classical perturb and observe. In order to control the flow of the centrifugal pump, from the power available in the *PV* array, it is used a speed controller.

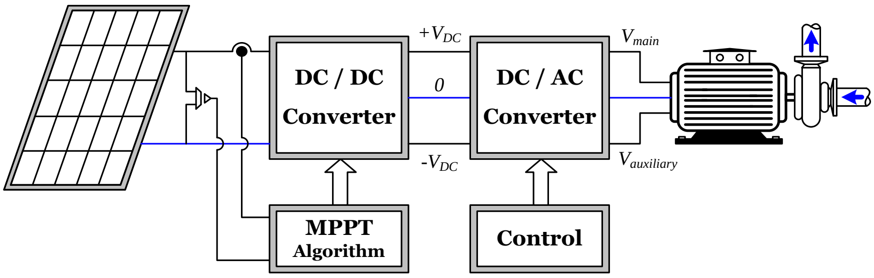


Figure 1. Photovoltaic Water Pumping Global System

The proposed *DC-DC* converter is the combination of the *Sepic* and *Cuk* converters [5,6], where both converters have same voltage conversion ratio (V_0/V_i) with opposite polarity and have same number of active and passive elements. There is only one semiconductor switch in order to control both configurations, therefore there is no need of synchronization with other switches. This combination of the converters is able to create same output voltage with opposite polarity, where the medium terminal is connected to medium point of the single phase induction motor (Figure 2). The *PV* panel is connected to the medium point of the motor windings for reduce the common-mode voltage generated by both *DC-DC* converter and *DC-AC* inverter, so the leakage current flowing by *PV* system (blue line in Figure 2).

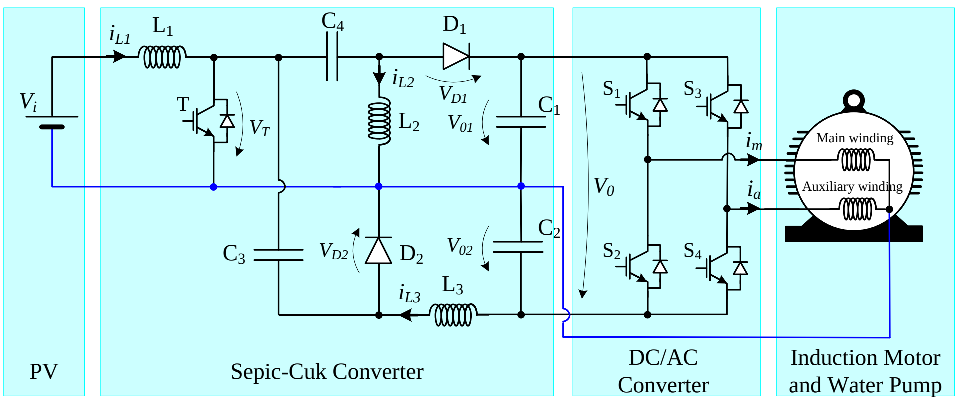
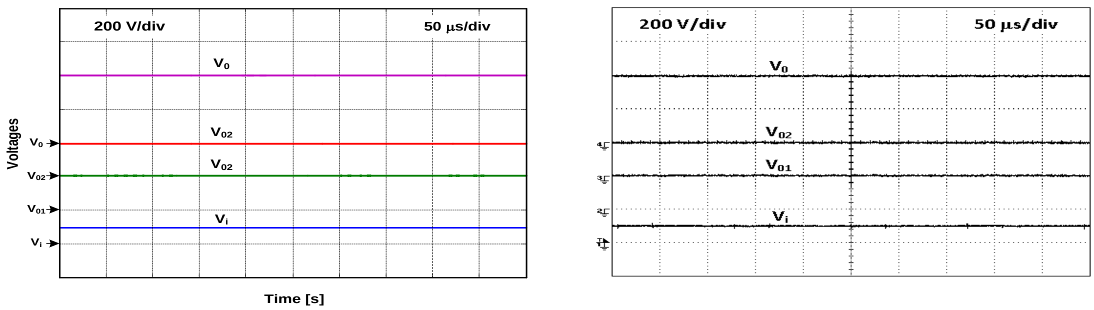


Figure 2. Schematic of Proposed Topology.

3. Simulation and Experimental Results

The proposed topology was simulated using *MATLAB/Simulink* software and experimental results obtained from the experimental tests realized through the developed prototype, in order to validation of the proposed topology. The converter operation was simulated at V_i = 96 V (photovoltaic panel voltage) → V_0 = 400 V, $L_1 = L_2 = L_2$ = 1 mH, $C_1 = C_2$ = 150 μF, $C_1 = C_2$ = 20 μF, a switching frequency of f_S = 20 kHz and duty cycle D = 0.7.

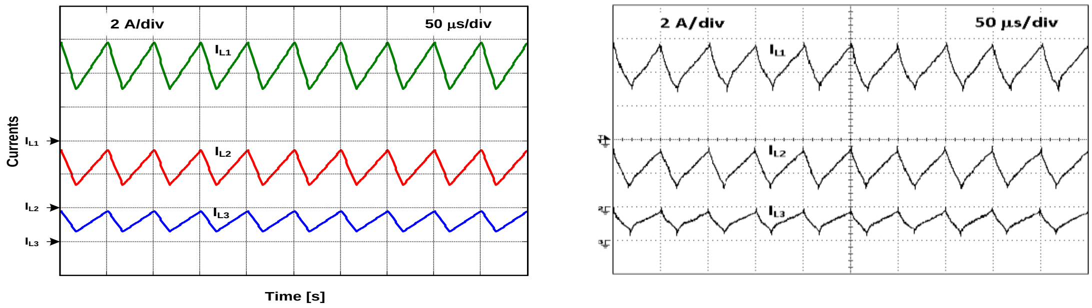
In Figure 3 it can be seen the steady-state waveforms of the input voltage (V_i), capacitor voltages (V_{01} and V_{02}) and the converter output voltage (V_0). In accordance with the defined duty cycle 0.7, this figure shows that the relationship between the input and output voltage is approximately 4 ($V_0/V_i = 4$). Besides that, it is possible to confirm that the voltages of the output capacitors are practically equal and half of the total output voltage ($V_{01} = V_{02} = V_0/2$).



(a) **(b)**

Figure 3. Input, capacitors and output voltages V_i, V_{01}, V_{02} and V_0: a) Simulation and b) Experimental results.

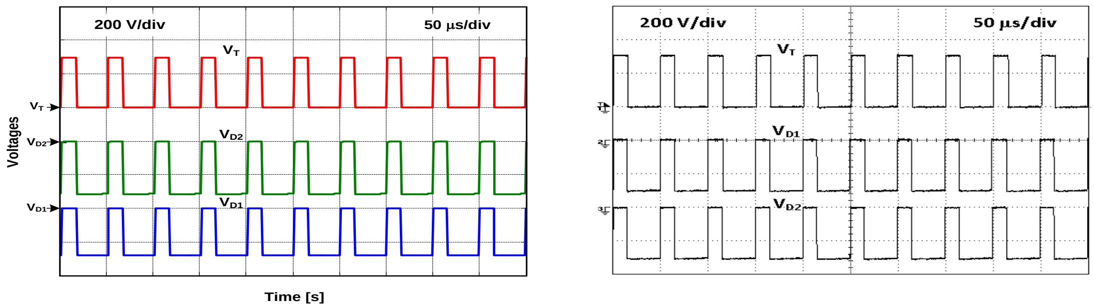
The waveforms input current (in the inductor L_1) and inductor currents L_2 and L_3 are presented in Figure 4. From these waveforms obtained from the simulation and experimental test, is possible to confirm the continuous input current of the power converter.



(a) **(b)**

Figure 4. Inductor currents i_{L1}, i_{L2} and i_{L3}: a) Simulation and b) Experimental results.

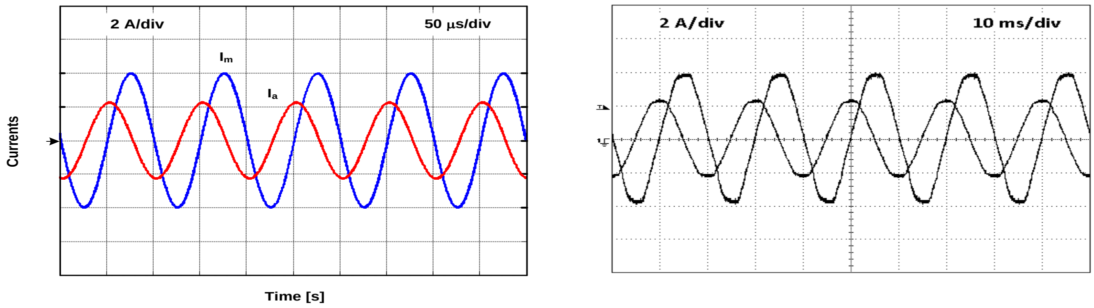
The voltages across the power semiconductors (V_T, V_{D1} and V_{D2}) can be seen in Figure 5 where is presented the waveforms that were obtained through the simulation and experimental test. Through the analysis of these waveforms is possible to see that the voltage across them is lower than the output voltage, being half of the total output voltage.



(a) **(b)**

Figure 5. Voltage across the switch and diodes: V_T, V_{D1} and V_{D2}: a) Simulation and b) Experimental results.

The centrifugal pump is coupled to a single-phase (two phases) induction motor. The main and auxiliary currents in single-phase induction motor/pumping (i_m and i_a) are presented in Figure 6. From these waveforms obtained from the simulation and experimental test, it is possible to confirm approximately 90º phase shift between the currents for to ensure the maximum motor torque.



(a) (b)

Figure 6. Motor currents i_m and i_a: a) Simulation and b) Experimental results.

4. Conclusion

A new non-isolated *Sepic-Cuk* converter (*DC-DC*) suitable for water pumping was presented in this paper. The proposed converter presents high voltage gain characteristic and dual output voltage. This converter has a single active power switch, therefore, assure the drive simplicity offered by a ground referenced single switch. Furthermore, this converter presents continuous input and output current. The performance of the proposed converter was tested and verified through several computer simulations and experimental results using a laboratorial prototype built for this purpose.

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