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Charging of Ultracapacitor with Cuk-converter in Constant Power Mode – Computer Investigation

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ABSTRACT

Here is presented a study through computer simulation of Cuk-converter for charging an ultracapacitor, operating at constant power consumption from the input voltage source. In the article is described a structure of the automatic control system, performing the charging process, when operating the Cuk converter as step-up and step-down.

Keywords: ultracapacitor, Cuk-converter, constant power, computer investigation.

INTRODUCTION

When charging energy storage elements, such as rechargeable batteries and ultracapacitors, different charging process algorithms are known. For example, for Maxwell ultracapacitors, it is recommended to charge with constant power [1, 2]. The results of charging with constant current are presented in [3, 4]. The authors of the present work show the results of charging an ultracapacitor from a photovoltaic module and when charging an accumulator battery without monitoring the maximum power point [5, 6]. The effect of a filter capacitor, which could also be an ultracapacitor, on voltage source inverters, is discussed in [7, 8].

This article examines the operation of a Cuk-converter when charging an ultracapacitor with constant power consumption from the input voltage source. This source may be, for example, a photovoltaic panel system operating at the maximum power point. For this purpose, Sharp NU-RC300 panels are selected [9]. When connecting two panels in parallel, one of the points of maximum power corresponds to the voltage $\approx 25\,V$ and current $\approx 20\,A$ at a density of luminous flux 800 W m^{-2}. When connecting the two panels in series, one of the points of maximum power corresponds to the voltage $\approx 75\,V$ and current $\approx 6.67\,A$ at the density of the luminous flux 800 W m^{-2}.

COMPUTER INVESTIGATION

The computer simulation researches are done with the PSIM program. Fig. 1 shows the circuit for the operation of step-up converter at the first point of maximum power 500 W corresponding to a voltage of 25 V and a current of 20 A. The

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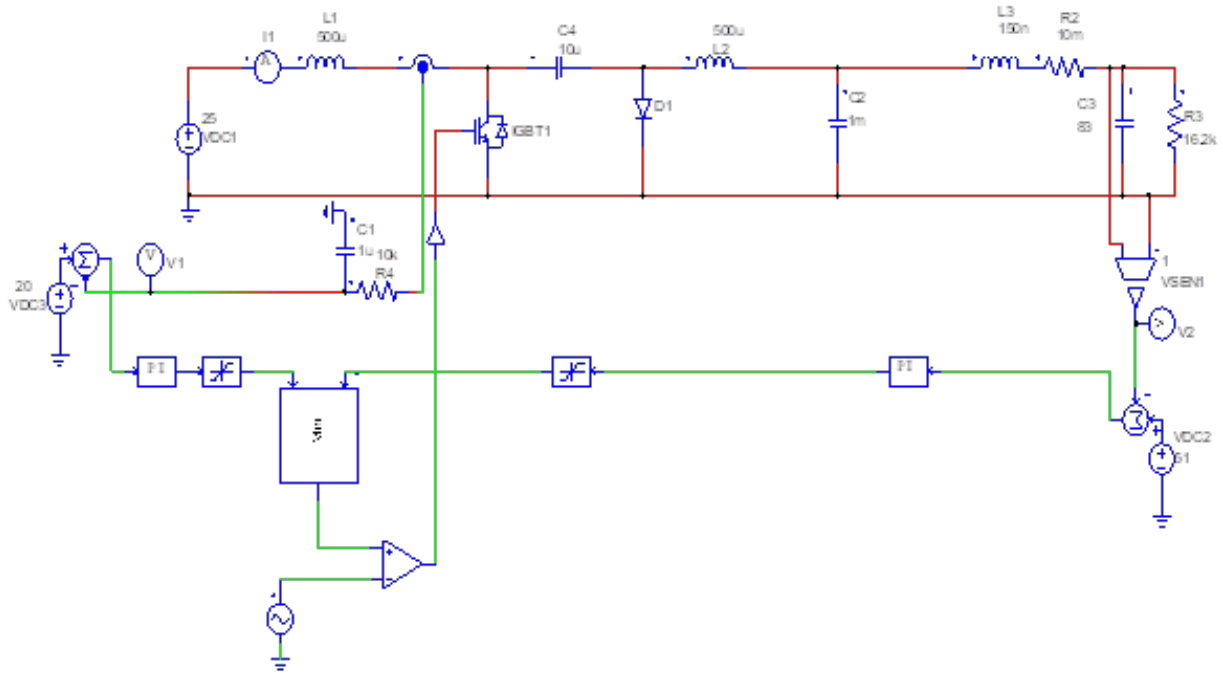

Fig. 1. Circuit for testing step-up converter: input voltage 25 V, input current 20 A, input power 500 W.

power circuit contains the following elements - inductances L1 and L2, capacitors C2 and C4, transistor IGBT1 and diode D1. The equivalent circuit of the ultracapacitor is composed of the elements L3, R2 C3 and R3. They refer to the Maxwell BMOD0083 PO48 B01 ultracapacitor and are [10]: Nominal capacity – $C3$ = 83F, nominal voltage 48 V, absolute maximum voltage 51 V, series resistance $R2 = 10\ m\Omega$. Value of the parallel resistor $R3 = 16.2\ k\Omega$ corresponds to the given nominal leakage circuit current $3\ mA$, a specified small series inductance $L3 = 150\ nH$ of corresponding to the conclusions and the connector cables.

The value of the input current is monitored by a current transformer and after filtration through R4 and C1 is compared with the reference VDC3. The output voltage from the comparator is an input value for a proportional-integral controller PI. A limitation for the output voltage of the regulator is planned, the signal of which is transmitted to the left input for the circuit of the priority block at minimum - Min. On the right-hand input for the circuit, there is a signal, after limitation, from a second proportional-integral controller PI for the value of the output voltage of the ultracapacitor. It is monitored by an isolating amplifier VSEN1 and is compared to the reference VDC2, equal to the maximum charging voltage of 51 V. The output signal of the priority block is compared by a comparator with that of a ramp-shaped voltage generator. Thus a pulse-width modulated signal for transistor control from the IGBT1 power circuit is obtained. The automatic control system thus presented, implements charging of the ultracapacitor with DC current with voltage limitation.

Fig. 2 presents the obtained results. They show that the automatic control system keeps the input current of the converter constant during the charging. At the end of this process, the system limits the charging voltage to the set maximum value. The duration of the process is about 43 s at an initial voltage of the ultracapacitor 46 V.

Fig. 3 shows the operation scheme of step-down converter at the second point of maximum

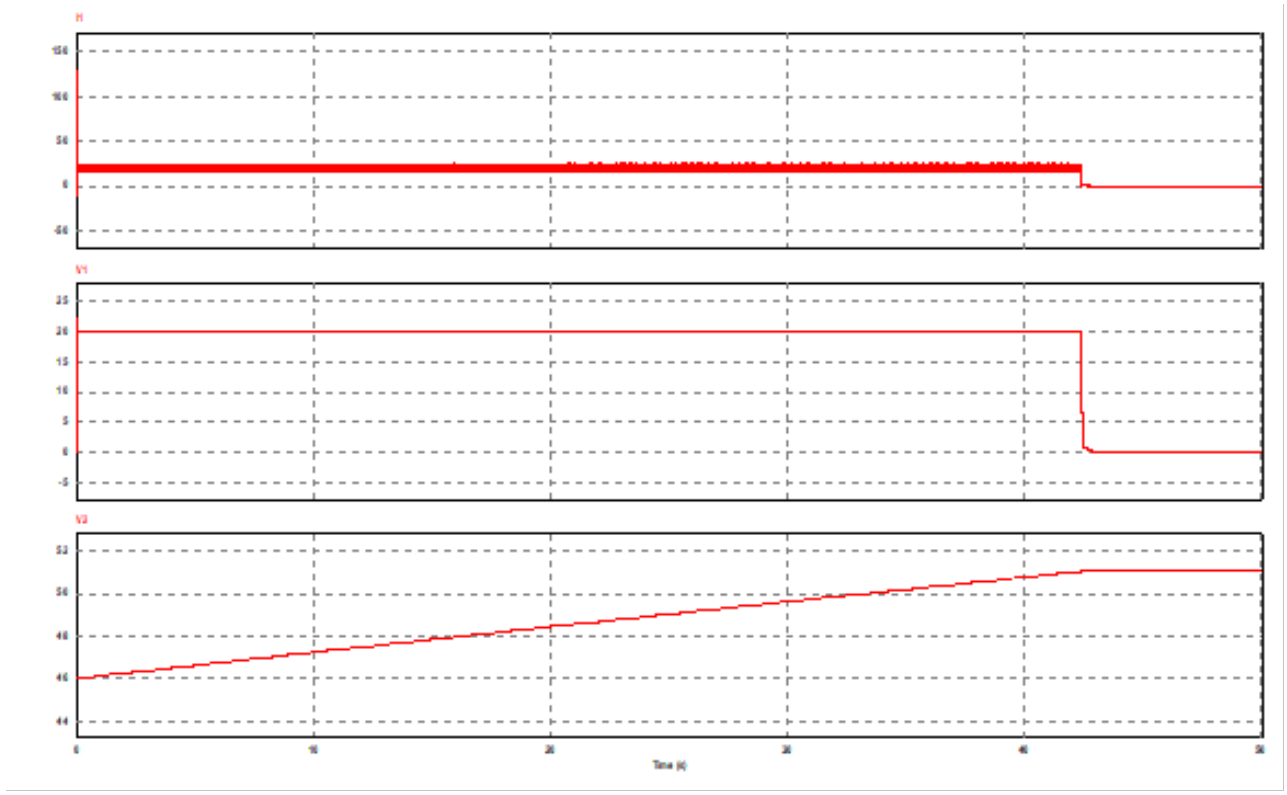

Fig. 2. Results of the computer simulation when the converter is step-up at the first point of maximum power, input voltage 25 V, input current 20 A: I1 - current through inductance L1; V1 - voltage after filter; V2 - voltage of the ultracapacitor.

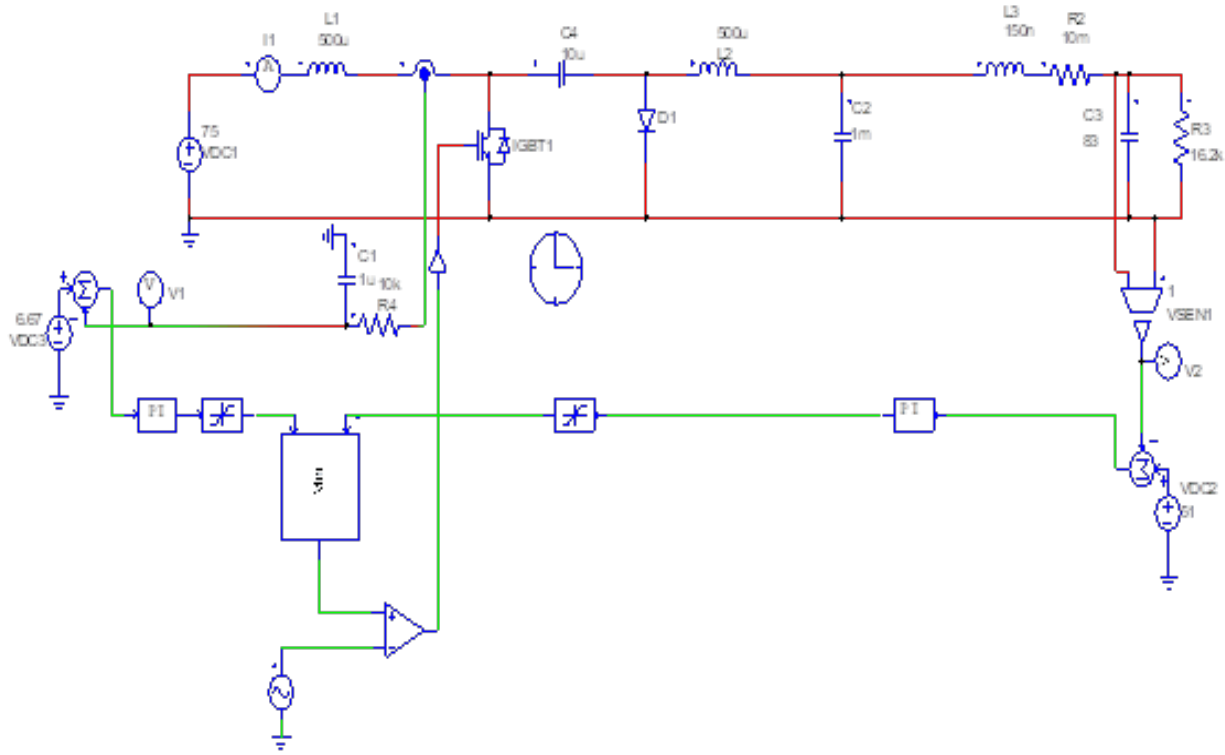

Fig. 3. Circuit for testing step-down converter - input voltage 75 V, input current 6.67 A, input power 500 W.

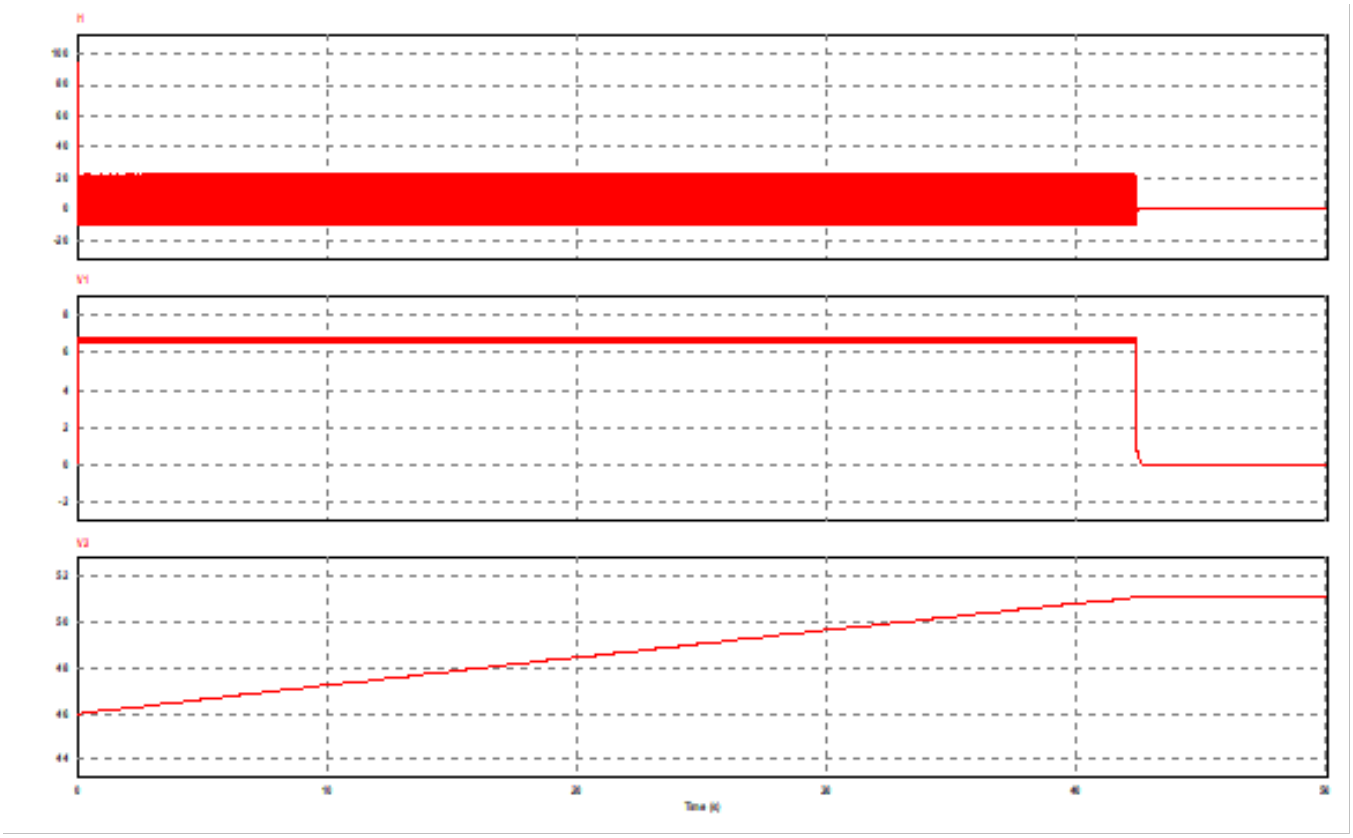

Fig. 4. Results of the computer simulation at operation of step-down converter in the second point of maximum power - input voltage 75 V, input current 6.67 A: I1 current through inductance L1; V1 - voltage after filter; V2 - voltage of the ultracapacitor.

power 500 W, corresponding to a voltage of 75 V and current of 6.67 A. Compared to the scheme in Fig. 1, the value of the input voltage VDC1 and the current reference VDC3 have been changed.

The obtained results in this case are presented in Fig. 4. The automatic control system maintains a current value of 6.67 A during the charging process, whose duration is again 43 s at an initial voltage of the ultracapacitor 46 V. In both cases, the charging process has the same duration, because it is implemented with the same power.

From these results, the following conclusions can be made: The proposed converter would work effectively as a step-up one when connecting in parallel the photovoltaic panels, mentioned in the beginning. The same converter would work effectively as a step-down one when connecting the same panels in series as well. Of course, the reference for the current value VDC3 must be obtained from the system for monitoring the maximum power point - MPPT, and will correspond to the maximum power from the panels in the specific conditions.

CONCLUSIONS

The obtained results from the computer simulation confirm the efficiency of the operation of the offered structure of an automatic control system when charging the ultracapacitor with constant current and voltage limitation. They also confirm the operation of the Cuk-converter, driven by the studied algorithm in step-up and step-down mode, and consuming constant power from the input voltage source.

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