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Management system of charging ultracapacitors from a photovoltaic module – computer research

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ABSTRACT

In this work, the system of charging ultracapacitors with a constant current and voltage limit are tested. The specify is that the current through the inductance of the boost converter is monitored. Through a computer simulation, the process of the initial charge and in a buffer mode with load are tested. The simulation study is made through PSIM software. Graphics from computer simulation with and without load are included.

Keywords: ultracapacitor, boost converter, charging, constant current.

INTRODUCTION

The capacitors are with a double layer - Double-Layer Capacitor. It is used for energy storage based on an electrostatic principle, and are offered by a big number of firms with different names – Ultracapacitor, Supercapacitor, Goldcapacitor, Energycapacitor. They are applied in the electrical transport and in the systems for energy conversion from renewable sources. There are existed two methods for their charging – with a constant current and with a constant power [1]. In [2] charging with a constant current for indentifying the parameters of 150 F and 350 F ultracapacitors is described.

In the current work, a test through a computer simulation of a closed loop system for automatic regulation of the charge of ultracapacitors with a constant current and the limit voltage is tested. The system contains a photovoltaic module, boost converter, and a managing system. In this system the current through the inductance of the boost converter is monitored, which is connected to the output current [3], and not the output current directly. This systems is tested with an ultracapacitor charge and when operating in a buffer mode with load. Monitoring the current through the inductance of the boost converter is used in [4] too, without clarifying the system's structure for automatic regulation. To represent

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the ultracapacitors, different models are used [5]. In the current article, a condensator model is used, two resistors, and an inductance, the values of which can easily be received from the firm data.

COMPUTER SIMULATION

The computer simulation is made with the program product PSIM. In Fig. 1 is shown the simulation scheme for the initial charging. The current through the inductance L1 is compared to a setpoint, and the difference determines the input signal of the PI-regulator for the maximum charging current. The output signals of both regulators are limited to a minimum and a maximum so that after the schemes for limitation, the signals are changed in the diapason of the sawtooth voltage of the inverting input of the comparator. For the purpose of simulation, the sawtooth voltage is changed from 0 V to 5 V. This sawtooth voltage is compared to the minimal signal of the regulators. In this way, the duty cycle of control pulses of the transistor IGBT1 of the boost converter is determined.

The data entered for the photovoltaic module in the model of PSIM, corresponds to Sharp NQR256A and are [6]: open-circuit voltage $U_{OC} = 32.49\ V$ short-circuit current $I_{SC} = 9.95\ A$, maximum power point voltage $U_{MPP} = 27.53\ V$, maximum power point current $I_{MPP} = 9.3\ A$, maximum power $P_{MPP} = U_{MPP}.I_{MPP} = 256\ W$. The data complies with the following conditions of the environment [1]: light power 800$\frac{W}{m^2}$, wind speed - $1\ \frac{m}{s}$, environmental temperature 20°C, cell temperature 49,9°C.

The module of the ultracapacitor is made up of the elements L2, R2, C3, R3. The data entered for the values of these elements correspond to ultracapacitor Maxwell BMOD0083 PO48 B01 and they are [7]: nominal capacity – C3 = 83 F, 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 $L2 = 1\mu H$ of corresponding to the conclusions and the connector cables.

With the simulation the frequency point of

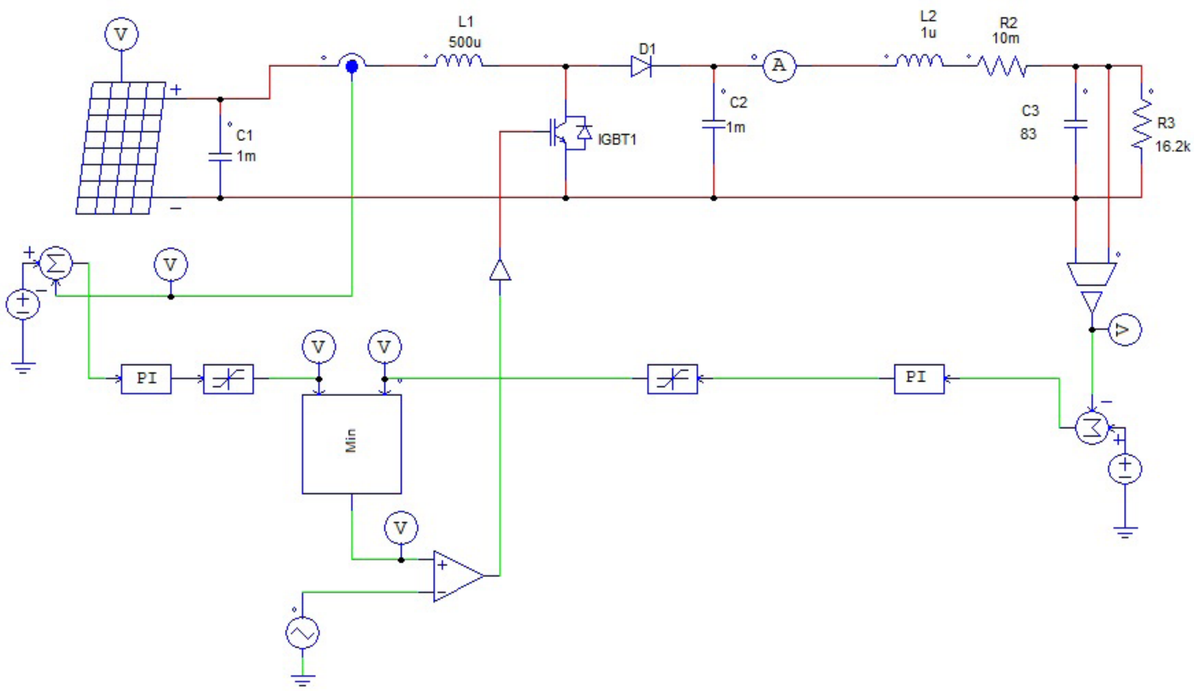

Fig. 1. Computer simulation scheme for initial charging.

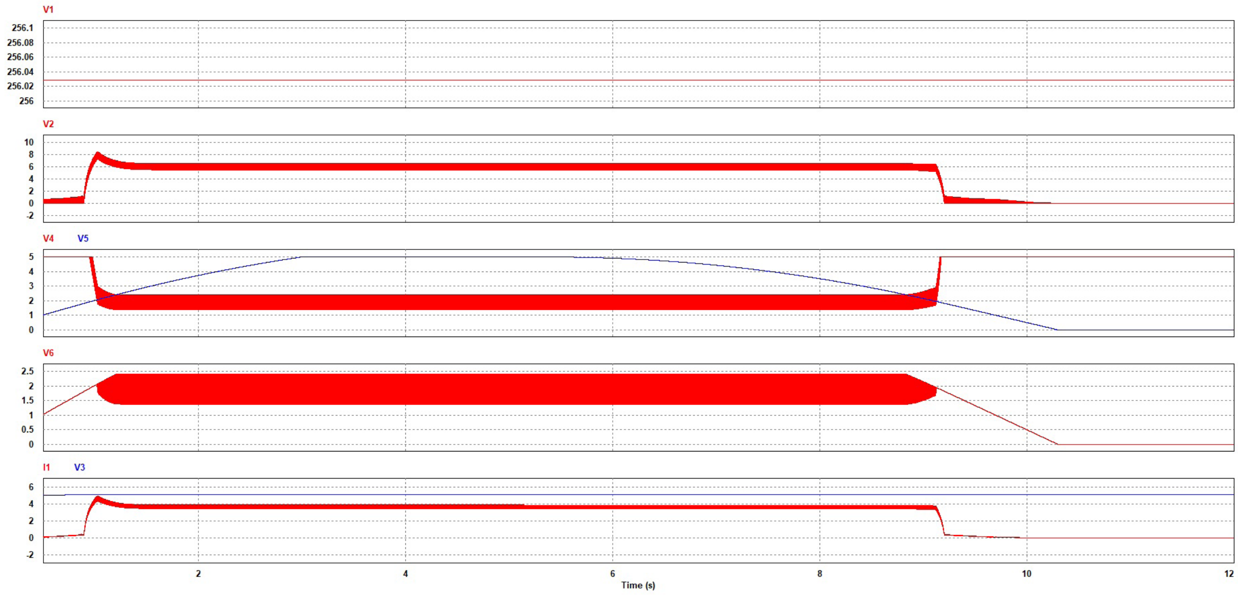

Fig. 2. Results from the computer simulation with an initial charging.

the sawtooth currency for the inverting input of the comparator, equal to $20\ kHz$, which the boost converter works with.

The ultracapacitor is with a big capacity and if it is fully discharged, the charging time will be longer. That is why the last stage of the charge is tested, so that how the two regulators work can be seen. A starting voltage value of the ultracapacitor of 50.8 V is specified and voltage limiting of 51 V, equal to the maximum limit.

The results from the simulation are shown in Fig. 2. From top to bottom are arranged: V1 – maximum power of the module in the point of the maximum power; V2 – current through the inductor L1; V4, V5 – outputs after the schemes for the regulator limits of current and voltage; V6 – voltage of the upper input of the comparator, which determines the duty cicle of the transistor IGBT1; I1, V3 - respectively, current for the ultracapacitor's charge and voltage in the scheme's output for its voltage measurement. The coefficient of the transmission of this scheme is inserted to be equal to 0.1.

With the simulation the set average current through the inductance L1 is equal to 6 A. It is working the first regulator for charging current of the ultracapacitor, which can be seen from the second chart top to bottom – V2. In this case the average charge current of the ultracapacitors is about 4 A, that is seen from the last chart – I1.

The system starts to work with a minimum duty cicle of the control pulses of the transistors. This happens because the current through the inductance is smaller than the set one, and the signal in the output of the first regulator V4 is bigger than the one in the output V5 of the regulator for the output voltage. When the signal V5 becomes bigger than V4, determinative is the regulator for the charging current. This happens approximately after 1s from the beginning of the simulation. After that approximately to the 9-th second a constant charging current of the capacitor is maintained. Since its voltage reaches the set maximum value, the signal in the output of the voltage regulator becomes determinative. Then V5 approximately after the 9-th second becomes smaller than V4. The duty cicle of the control pulses of the transistor IGBT1 is determined by the signal V6, which initially tracks V5, after that V4, and approximately after the 9-th second, V5 again. A little bit after the 10-th second, the boost converter stops working, i.e. the current through the inductance is 0 (V2 is equal to 0). The system maintains this state, while the voltage of the ultracapacitor decreases. This happens as a result of self-discharge through the parallel resistor R3

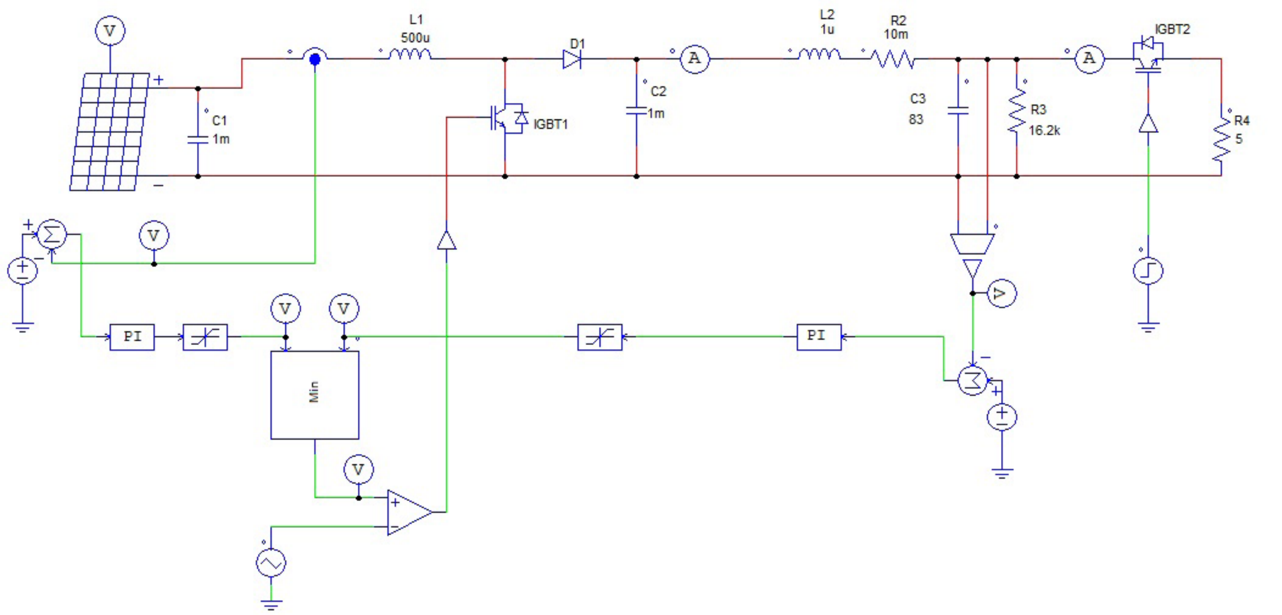

Fig. 3. Scheme for computer simulation when connecting the consumer to the charged ultracapacitor.

or as a result of connecting the consumer to the ultracapacitor. The research shows that the time of the transition process to establishing the charging current of the ultracapacitor is smaller than 0.5 s, and the delay after starting is less than 1s. The ultracapacitor is charged with good accuracy – voltage in the end of the process is 51.07 V.

Operation of the system in buffer mode when connecting the consumer to the charged ultracapacitor is examined wih the scheme shown in Fig. 3. The additional transistor IGBT2 is turned on in the 12-th second after the start of the simulation and the ultracapacitor is loaded with the resistor R4.

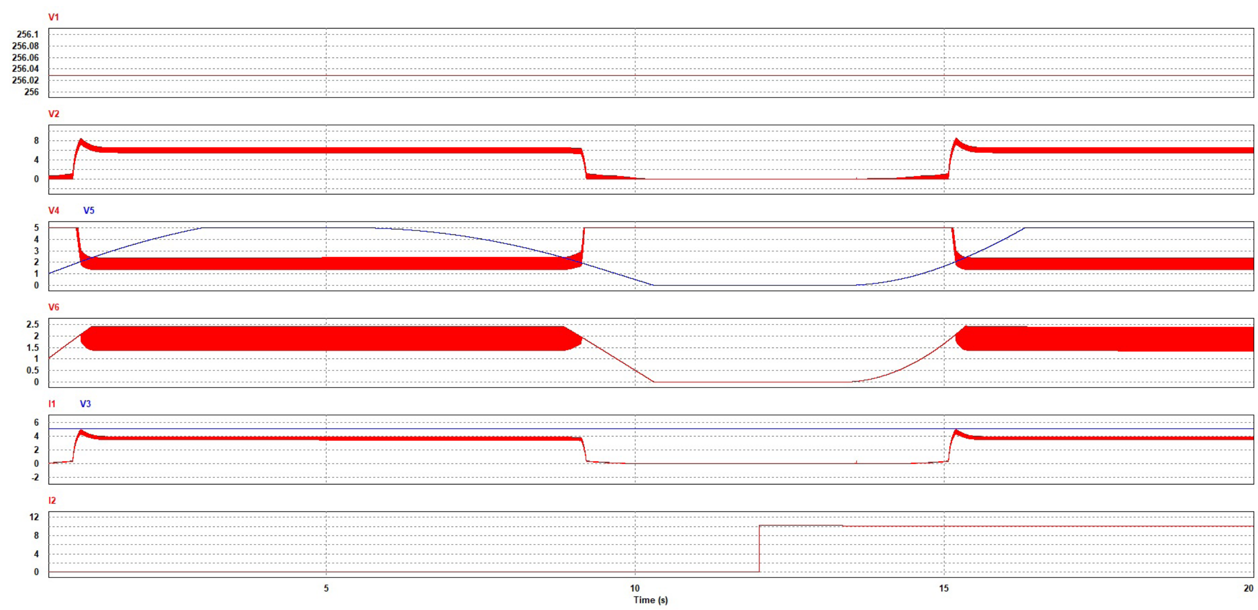

Fig. 4. Results from the computer simulation when connecting the consumer to the ultracapacitor.

The results from the simulation are shown in Fig. 4. They are arranged as in Fig. 2, and at the top bottom is shown the current I2 through the load R4. Approximately after the 15-th second, the boost converter starts working again, and the charging current is maintained at a set value around 4A – I1. The ultra capacitor is in buffer mode, and its discharge current is around 10 A - I2.

The results from the test show that the time of the transitional process to the establishing of the charging current of the ultracapacitor is less than 0.5 s, and the delay after turning on the load of 5 Ω - around 3 s. This delay will be different based on the load of the value, since with a different speed will decrease the voltage of the ultracapacitor. On this will depend the action of the regulators in the system for automatic regulation.

CONCLUSIONS

The results from the test through a computer simulation show a stable operation of the system for automatic regulation for charge of ultracapacitors with constant current and a voltage limit in two regimes: initial charging and work in a buffer mode with load.

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