Stand for Testing of Bi – Directional Converters in Photovoltaic Systems

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Abstract – **The purpose of this paperwork is to present a developed an experimental stand for testing different kinds of bi – directional circuits, providing a work of a supercapacitors in renewable energy systems – photovoltaic systems. A simulation model has been created of the studied bi – directional converter. During combined operation between a supercapacitor and a battery there are mainly two kinds of wiring methods. In the first method the battery is working in buffer mode and the supercapacitor is connected to the bi – directional converter. The second method is when the supercapacitor is working in buffer mode and the battery is connected to the bi – directional converter [1, 5]. In this paperwork a renewable energy system build in the first method is studied. For testing different circuit kinds of bi – directional converters in photovoltaic systems, an experimental stand, described in this work, has been created. The information measuring system is realized by the softwer LabView. In the document a comparison between the simulation and experimental results has been made.**

Keywords – **Battery, Bi – Directional converter, Labview, PV system, Supercapacitor**

I. Introduction

The main components of an off-grid photovoltaic systems are: controller – it is used manly for the right distribution of the energy, obtained from the PV panel; charging of the batteries and ensuring appropriately voltage for the load. Adding a supercapacitor to this kind of system leads to expanding the exploitation term of the batteries, because the charging/discharging cycles are reduced at the expense of charging/discharging the supercapacitor [3, 6]. In the work the tested bi – directional converter is described. For its testing a simulation and an experimental model has been created. For the controlling of the energy conversion and the gathering of data in the system, a virtual instrument is created in LabView [7, 8]. Displaying the process in the PV system is achieved by the help of a suitable graphical interface (front panel of the virtual instrument).

The stages of work of the system can be changed by algorithm, realized by the block diagram of the virtual instrument. The developed stand and model allows testing other kinds of bi – directional converters and their working regimes in the system for storage and energy conversion.

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II. Block Diagram of the Stand for Testing Bi – Directional Converters

On figure 1 the block diagram of the stand for testing bi – directional circuits is shown.

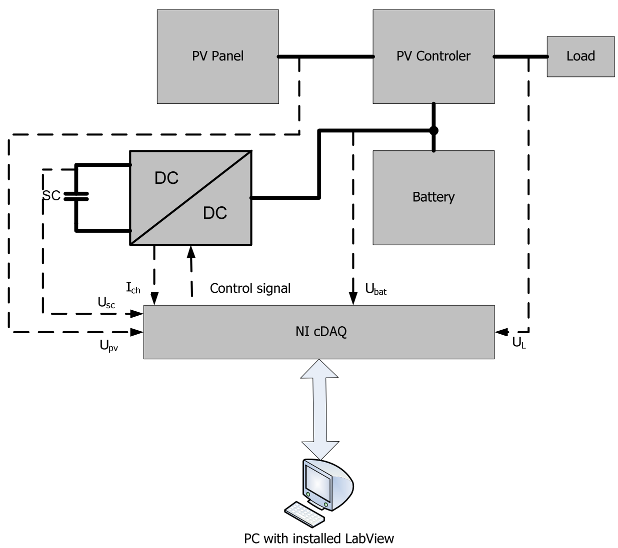

Fig.1. Block diagram of the stand for testing

The system is made of the following blocks:

- PV Panel – this is the photovoltaic panel, which is the energy source in the system;
- PV Controller – it is used for distribution of the energy obtained from the PV panel (in normal mode it ensures the power supply of the load and the charge of the battery; in moment of low energy from the panel, the normal power supplying of the load is ensured from the PV panel and the battery simultaneously. In the moment of no energy from the PV panel, the power supply is ensured by the battery.);
- DC-DC – bi – directional converter which charges the supercapacitor and ensure the combine work with the battery;
- Battery – element for energy storage in which the most of the energy in the system is stored;
- Load;
- Chassis NIcDAQ for controlling of the converters by TTL outputs and measuring by ADC;
- LabView – software in which the virtual instruments for managing the hardware are created.

According of the value of the measured parameters and the accomplishment of terms from the algorithm, the control system created control commands and sends them to the bi – directional converter by the module cDAQ.

The measured parameters are:

- U_{sc} – voltage over the supercapacitor;
- U_{pv} – voltage from the PV panel;
- U_{bat} – Voltage of the battery;
- U_L – Voltage over the load ;
- I_{charge} – Charging current.

The measured values and the generated control pulses are displayed on the front panel of the virtual instrument. By reaching a predetermined value of the voltage over the supercapacitor, the control system generates a control signal, which stops the charge of the supercapacitor. When the voltage decrease under another predetermined value, a control pulse is generated and the charging of the supercapacitor starts again.

III. Developing of a Virtual Instrument

On figure 2 the front panel of the virtual instrument is shown.

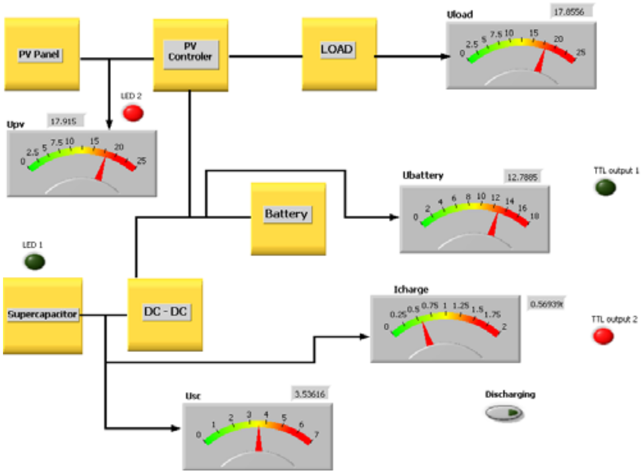

Fig. 2. Front panel of the virtual instrument – control system

On the front panel are shown the measured parameters, described above.

The leds LED1, LED2, TTL output 1 and TTL output 2 are for:

- LED 1 – turns on when the supercapacitor is charged to the predetermined value of the voltage;
- LED 2 – turns on when the output voltage of the PV panel is over a predetermined value (for example over 14V);
- TTL output 1 – turns on when the charging stage is stopped;
- TTL output 2 – turns on when the discharging of the supercapacitor is started.

On figure 3 is shown the block diagram of the virtual instrument.

The functions of the blocks 1 to 7 are:

Block 1 – this is an input device, which is an ADC (analog to digital converter), connected to the chassis cDAQ. It collects the data – the measured voltage over the different components of the PV system (controller, battery, supercapacitor, load and the current sensor from the bi – directional converter).

Block 2 – this is a comparator which compares the measured instantaneous value of the voltage over the supercapacitor and one predetermined minimum and maximum charge value. If the measured value reaches the maximum predetermined value in the output of the comparator we get logical 1 and this is the term for stopping the charge of the supercapacitor.

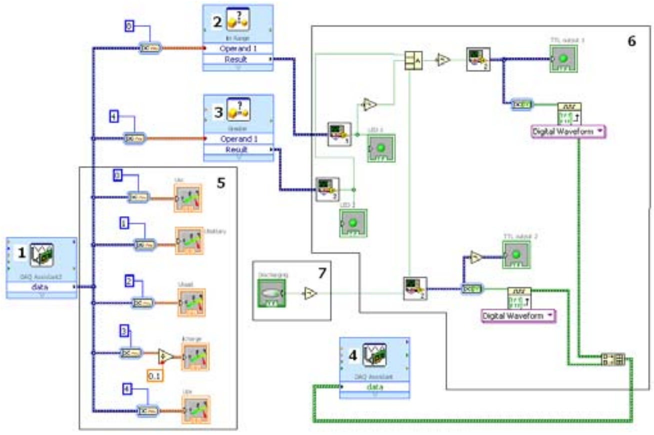

Fig. 3. Block diagram of the virtual instrument.

Block 3 – this is a comparator which compares the voltage on the output of the PV panel with one predetermined value of the voltage. If the measured voltage is bigger than the predetermined value, in the output we get a logical 1. If it is below this predetermined value in the output we get logical 0.

Block 4 – this is the graphical representation of a module with TTL outputs. TTL output 1 manages the bi – directional converter to work in charge mode, for charging the supercapacitor.

Block 5 – graphical indicators of the scales of the voltmeters, which are displaying the measured voltages in different control points of the system.

Block 6 - logical circuit for execution of the predetermined programmed working regime of the system. Parts of the program are made as subvi – es, for executions of uniform functions.

Block 7 – it is a virtual button, by which pressing the discharging of the supercapacitor is activated.

The working principle of the stand is the following. The system by the help of the virtual instrument nonstop controls the voltages in the determined control points. The system is used for automatic management of the charging process of the supercapacitor. In the presented version of the algorithm of the virtual instrument, the discharge of the supercapacitor is manually accomplished. Some of the possible working stages of work of the system are:

Stage 1 – charge of the supercapacitor: the charging is only executed when the voltage over the supercapacitor is under a predetermined value and the voltage in the output of the PV panel is over than the minimum value of the voltage of the photovoltaic, which allows the work of the photovoltaic (for example over 14 V). When this is accomplished a control pulse is generated from the TTL output 1 and the converter starts the charge of the supercapacitor.

Stage 2 – stopping of the charge: the stopping of the charge of the supercapacitor occurs when its voltage is in the determined range. When the voltage is in this range, the system generates a control signal from the TTL output 1 which stops the charging. The prohibition for charging may occurs when the supercapacitor is discharge and must be charged, but the voltage in the output of the PV panel is lower than 14V. This is made for purpose, because so the battery can be discharged by the supercapacitor.

Stage 3 – discharging of the supercapacitor: the discharge of the supercapacitor starts manually, by pressing the virtual button. The stop of the discharge is by pressing again the virtual button. The algorithm is so made that it can not allow the possibility for simultaneous activation of both regimes – charging/discharging of the supercapacitor.

IV. Studied Circuit of the Bi – Directional Converter

On figure 4 is shown the block diagram of the studied bi – directional converter.

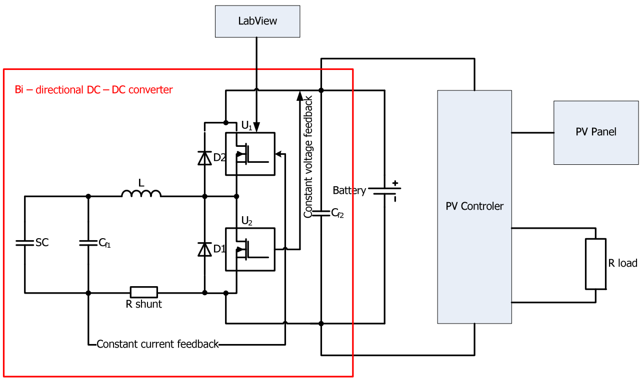

Fig. 4. Block diagram of the studied bi – directional converter

The bi – directional converter is made of two specialized integrated circuits of DC – DC switching converters.

The buck converter, which charges the supercapacitor, is made of the converter U_1 inductor L, filter capacitors C_{f1} and C_{f2} and the diode D_1. The circuit is designed to charge with constant current.

The boost converter is made of the converter U_2, inductor L, filter capacitors C_{f1} and C_{f2}, diode D_2. The circuit is design to work in constant voltage mode [1, 2, 4].

The managing of the working regime (charging or discharging of the supercapacitor) is set by the virtual instrument, developed with LabView.

The created working algorithm of the virtual instrument allows easy modifying and testing different working stages of the developed converter. It is very easy to connect other converter circuits, to this system, managed by the virtual instrument and searching for optimal regimes of combine work between supercaspacitors and photovoltaic systems.

V. Simulation and Experimental Results

On figure 5 are shown the results of the simulation studies with the software LTSpice of the work of the bi – directional converter in the stage of charging the supercapacitor (the serial RLC equivalent model of supercapacitor is used). The simulations are made with a value of the supercapacitor less than the value of the studied supercapacitor. Thus the supercapacitor charges quicker.

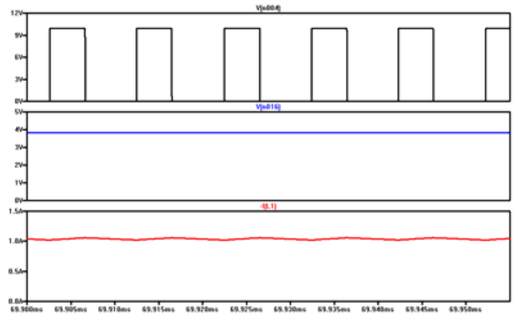

Fig. 5. Simulation results of the work of the converter in charging mode.

From up to down are: Voltage over the diode D_1 – V (004); Voltage over the supercapacitor – V (N016); current trough the inductor L – I (L).

On figure 6 are shown the results from the simulation study of the converter in discharging mode (work of the boost converter)

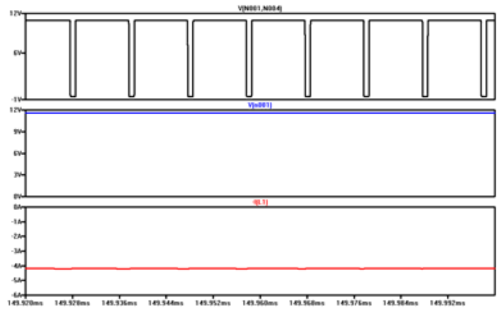

Fig. 6. Simulation results of the work of the converter in discharging mode

From up to down are: voltage over the diode D_2 - V(N001;004); voltage over the load товара V(N001); current trough the inductor L – I (L).

On figure 7, 8 and 9 are shown the experimental measurements with oscilloscope of the converter in charging mode – charging the supercapacitor with value of 33 F. Are shown: voltage over the diode D_1 voltage over the supercapacitor and current though the inductor L

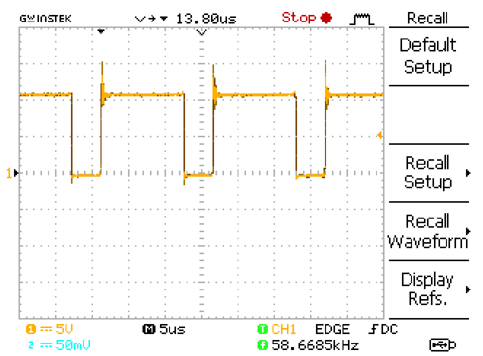

Fig. 7. Experimental results in charging mode.

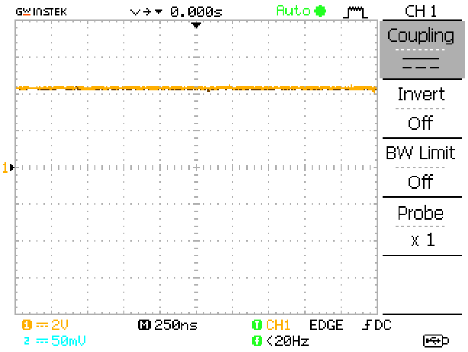

Fig. 8. Experimental results in charging mode.

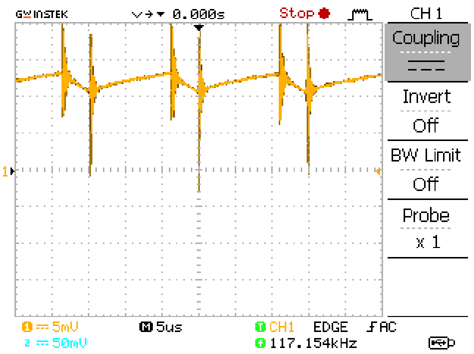

Fig. 9. Experimental results in charging mode.

On figures 10, 11 and 12 are shown the experimental measurements with oscilloscope of the converter in discharge mode – discharging the supercapacitor. Are shown: voltage over the diode D_2, voltage over the load, current trough the inductor L.

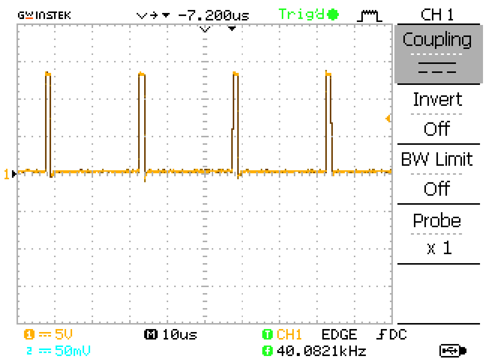

Fig. 10. Experimental results in discharging mode.

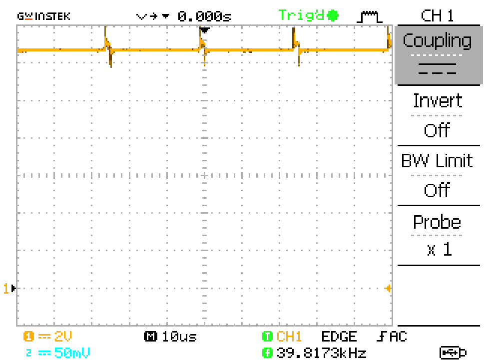

Fig. 11. Experimental results in discharging mode.

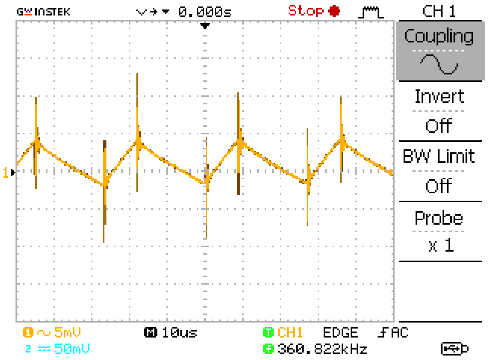

Fig. 12. Experimental results in discharging mode.

VI. Conclusion

A universal stand for testing the combine work of a supercapacitor and battery in photovoltaic power supply system. The stand allows flexible programming of the working regimes of the converters on the system. We can use different kinds of converters for searching of an optimal circuits and decisions for a system by different choices. User friendly graphical interface facilitates the displaying of the process in the system and track the pros and cons of the tested circuits and systems. Adding PV simulator to the stand will allow testing the system at any time in the day and imitating of different weather conditions.

The comparison between the experimental and the simulation results, part of them are shown from fig. 5 to fig. 13, shown sufficient accuracy for the engineering methodology.

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References

[1] Iv. Nedyalkov „ Simulation study of a Bi – directional DC – DC Converter Allowing a Combining Work Between a Supercapaitor and a Battery”, XII National Conference with International Participation "Electronica 2014" May 15, 2014 National Science and Technical Centre p. 350 – 356.

[2] M. CHALCZUK, L. RZESIAK, B.UFNALSKI “A Lithium Battery and Ultracapacitor Hybrid Energy Source for an Urban Electric Vehicle”

[3] M.Glavin, W. Hurley “Optimisation of a Photovoltaic Battery Ultracapacitor Hybrid Energy Storage System”, Solar Energy 86 (2012) 3009–3020

[4] Dr. J. Miller, , M. Prummer and Dr. A. Schneuwly “ Power Electronic Interface for an Ultracapacitor as the Power Buffer in a Hybrid Electric Energy Storage System”, WHITE PAPER, Maxel Technologies

[5] P. Caratozzolo, M. Serra, and J. Riera, "Energy management strategies for hybrid electric vehicles," presented at IEEE Electric Machines and Drives Conference, IEMDC'03, 2003.

[6] Ian C. Smith “Benefits of Battery – Ultracapacitor Hybrid Energy Storage System”, fulfillment of the requirements for the degree of Master of Science in Electrical Engineering at the Massachusetts Institute of Technology, June 2012

[7] http://www.ni.com

[8] http://www.metrisys.bg