SOME ASPECTS ABOUT IMPLEMENTING OF AN EMULATOR FOR THE PHOTOVOLTAIC PANEL

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Abstract: *This paper presents the design and implementation of an emulator for a Photovoltaic (PV) panel. PV emulator should behave, in terms of the output power delivered, similar to a PV panel. The usefulness of this emulator is that it will work in lab, regardless of weather conditions, for some imposed environmental conditions (like temperature, solar irradiation etc.). The proposed system consists of a DC-DC converter designed using a Buck-type converter operating almost as a Current Controlled Source (CCS) by a simple control algorithm.*

1. INTRODUCTION

The main PV uses is the transformation of solar radiation into electricity via the photoelectric process.

The solar cell can not be treated as any other traditional power source for generating DC power because of its impedance and specific electrical characteristics. The electrical static characteristics are not similar with of those given by a source of constant voltage or constant current. Now, we can note that the solar energy conversion efficiency is low (usually, under of 12%) [1,2,3], but there are technological solutions for its increase. This low yield and the relatively high costs of photovoltaic panels have determined at the designers' level the problem of using of the maximum available power from the PV generator. Generally, the maximum is achieved by providing a good adaptation between PV generator and associated consumer via a power converter. The best adaptation with a DC load is accomplished by using a DC-DC power converter that operates at the Maximum Power Point (MPP) of the PV characteristic (power vs. current) [4,5]. The objective of this paper is to develop a circuit to emulate a photovoltaic panel using a buck DC – DC converter controlled as a current source [6].

2. HARDWARE CONSIDERATION

Photovoltaic panel that will be emulated has the following parameters:

- Vout = 4 V;
- Iout_max = 1A.

It is noted that temperature variations are not taken into account in designing the emulator. This will be the subject of next paper.

Photovoltaic emulator has been designed according to the block diagram see in Fig.1

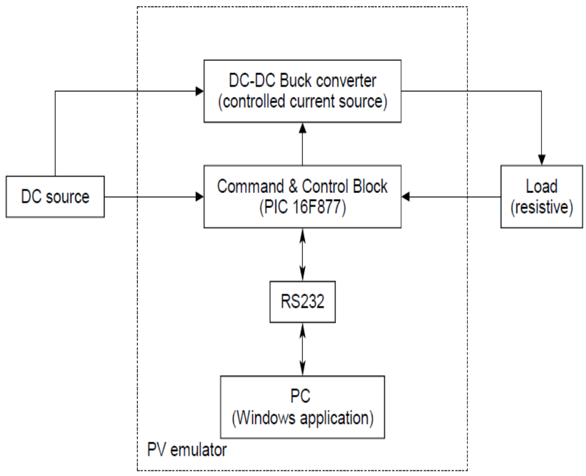

Fig. 1. Block diagram of the photovoltaic panel emulator

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The emulator is powered from a DC voltage source (Vcc=15 V) and controlled load (R_L) is of resistive type. The behavior of the PV emulator is almost as a CCS operating. The CCS is implemented using a buck converter and its command and control is done with a PIC 16F877 microcontroller.

Fig. 2 shows the detailed electrical scheme for the implemented PV emulator.

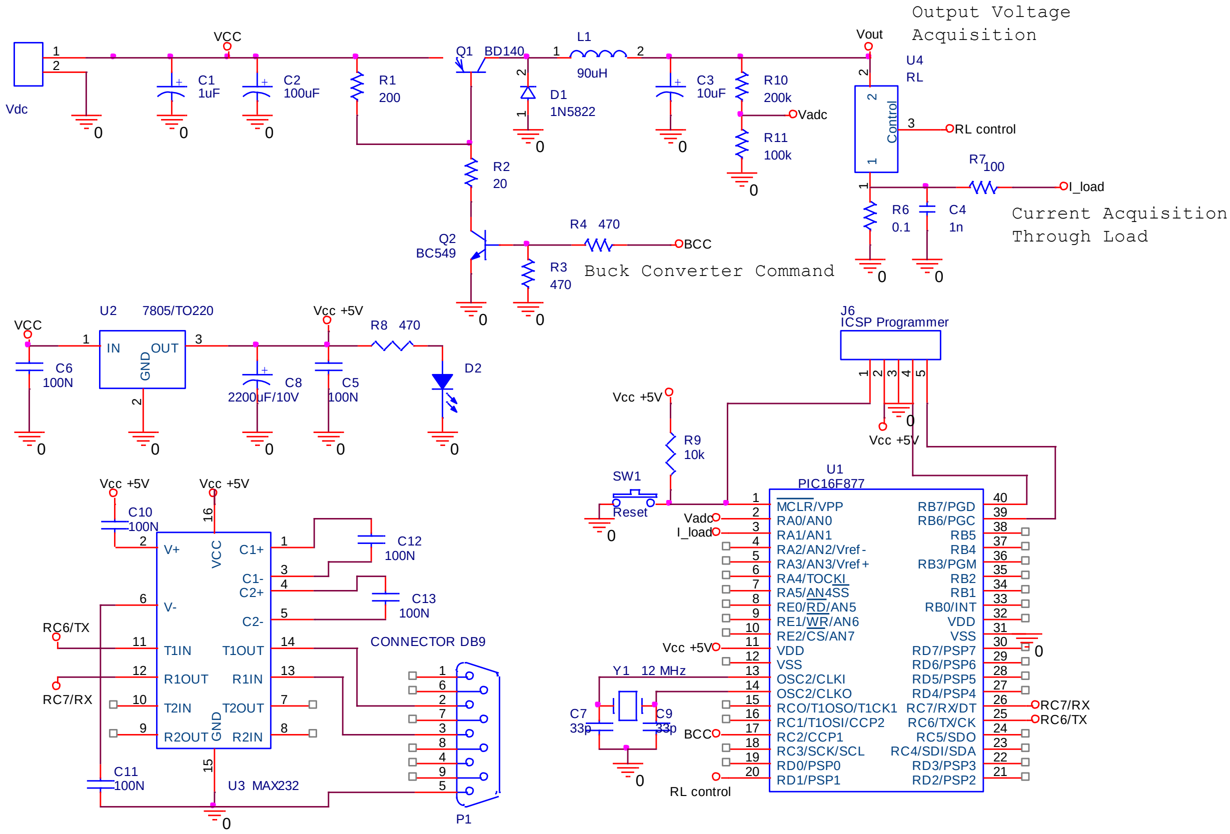

Fig. 2. The electric scheme of the implemented photovoltaic panel emulator

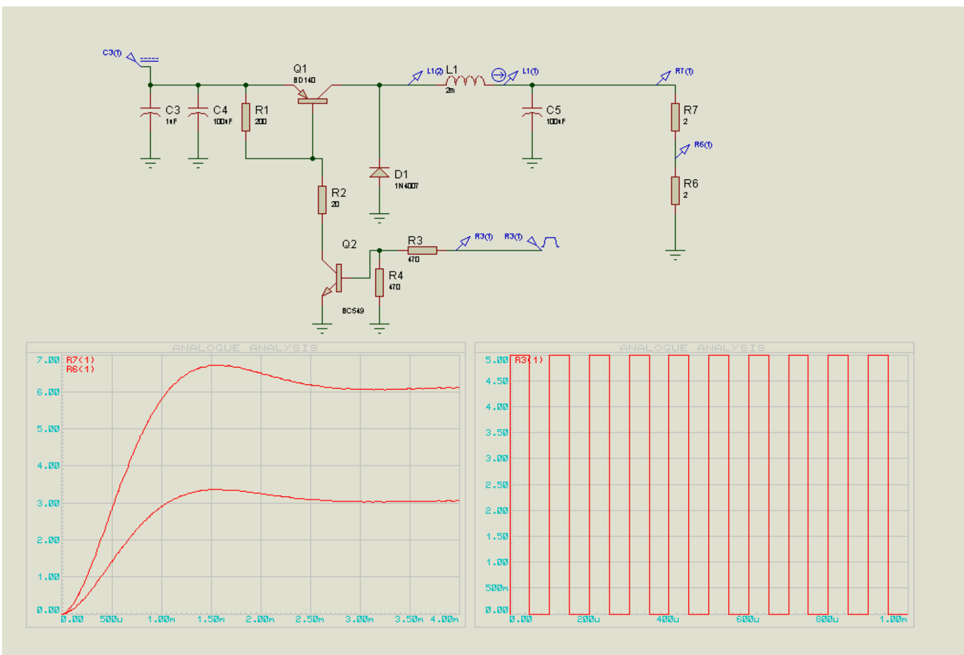

Fig. 3. Buck converter simulation (f = 10 kHz and D = 63%)

The PIC 16F877 microcontroller acquires on the RA0 and RA1 pins, configured as input for the internal Analog to Digital Converter (ADC), the information about the buck converter operation (the output voltage and current). The microcontroller is powered from the same DC voltage source via a voltage stabilizer type LM7805.

PWM control signal for buck converter is generated on pin RC2. This pin is configured by software as PWM signal pin.

Depending on the input voltage and the load current, the microcontroller decides to change the duty cycle (D) of PWM signal in order to obtain the PV characteristic proposed.

The communication between computer and emulator is of serial type using the MAX232 circuit. Using a Windows application, the data are exchanged through this interface in order to reprogram the operation of the PV emulator.
To design the buck converter were taken into account the relations shown in Table 1 [7]:

Table 1: Relationships for the designing of the buck converter parameters

Calculation of inductance	**L = ((Vin – Vout) • (D / f)) / Iripple**	**90uH**
Calculation of the output capacitor	**C = (ΔI • ΔT) / (ΔV - (ΔI • ESR))**	**10uF**
Diode Selection	**I_D = (1-D) • I_{out}**	**1N5820 (20V, 3A)**
Selection of switching element	**Vin=12V, I_{out}=1 A, D = 0.33, f = 10 KHz.**	**BD140**
Buck converter efficiency	**Output power: 4 W (4V/ 1A) Transistor losses: 0.2 W Diode losses: 0.3 W Inductance losses: 0.15 W Capacitor losses: 0.01 W Total loss: 0.66 W**	**86%**

3. SOFTWARE CONSIDERATION

A simulation of buck converter operation is made using different parameters for the PWM switching command (see Fig. 3, where f = 10 kHz and D = 63%). The same shape has been obtained for the control signal acquired.

The output voltage variation depends in a simplified manner by the input voltage and duty cycle as is mentioned in the below relation [7]:

$$Vout/Vin \cong D$$

The voltage ratio depends also by the other parameters. Consequently, the relation of output/input ratio is more complex, depending by parameters of power devices and passive components [8].

For the active and passive components used in implementation of buck converter, the experimental results are shown in Table 3, where Vadc is the divided voltage by the resistive divider R10 and R11. Vadc is the input voltage on pin AN0 for the internal ADC of the microcontroller.

Table 3: Parameters for control signals

Vout [V]	Iout [A]	R_L [Ω]	D [%]	Vadc [V]
6	1	6	52	2
7	1	7	59	2.33
8	1	8	65	2.66
9	1	9	72	3
10	1	10	78	3.33
10,5	0,75	14	78	3.5
11	0,5	22	78	3.66
11,5	0,25	46	78	3.83
12	0,1	120	80	4

A more simplified or complex control are proposed to be implemented for the emulator of energy source type PV and Fuel Cell [9,10,11]
Usually, the engineering design problems require both experiment and simulations to implement the best model for a complex system. Consequently, the construction of an approximative model of real system is necessary sometime. This model can mimic the behaviour of the real system. This approach is known as ‘‘behavioural modelling’’ or ‘‘blackbox modelling’’, and is used in control of proposed PV emulator, that is constructed using the input experimental dataset and a approach of interpolation for data from the look up table. It is obviously that control of PV emulator causes the whole emulator’s behavior.

Control program was developed and built into the PIC microcontroller and the flow chart of the microcontroller program is presented in Fig. 4. In the look up table are stored the data corresponding to the PWM patterns for command at different temperatures (T) and solar global irradiations (G) of the PV panel. In the memory can be also stored the data sheet information regarding the PV panel that is emulated.

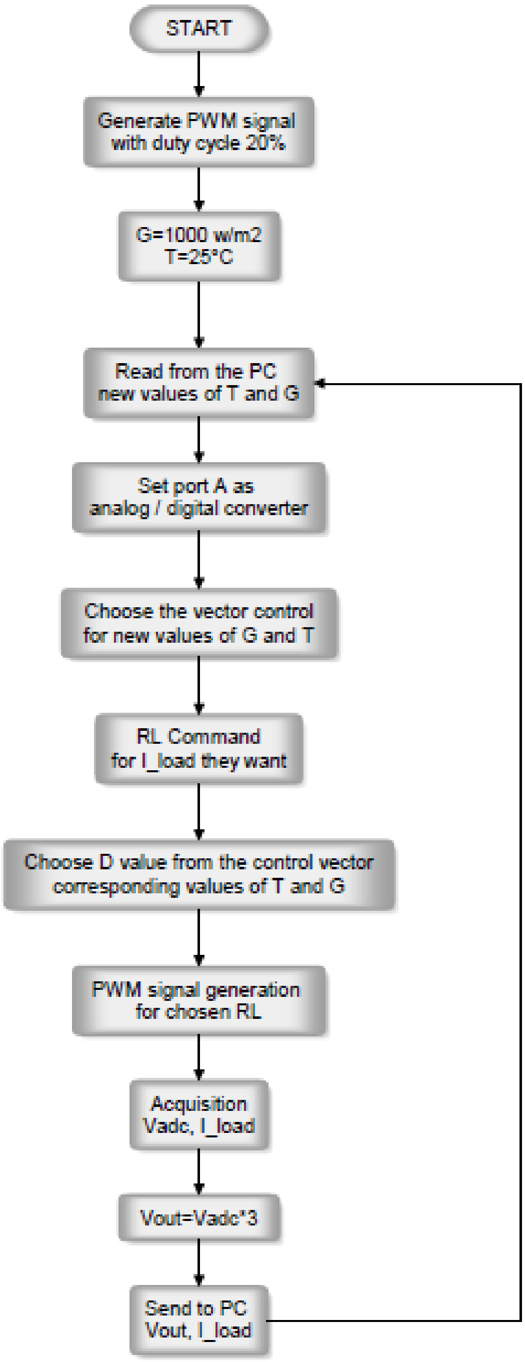

Fig. 4. The flow chart of the microcontroller program

A simplified I-V characteristic is considered for the PV emulator: below the knee voltage the current is almost constant; after this value, up to open-voltage value, the current decreases linearly to zero. Consequently, a simple control algorithm results and the dimension of the look up table is low. As it is mentioned before, the data for the look up table is completed only by considering of the different solar global irradiations (G). Also, the shadow effect [11] isn't yet implemented.

This knee voltage for emulated PV panel was chosen at 10 V, and the constant value of output current is set to 1A. The MPP is at about 10 W and 1 A. The resulting static characteristic (Iout vs. Vout) for the implemented emulator is shown in Fig. 5:

Between the data inserted in the look up table the control algorithm uses an interpolated value of those given data. If the PV emulator is coupled to a dynamical load, than the control loop must to assure the control of load for different operating modes in order to draw the static characteristic of the PV emulator or to operate the PV emulator at MPP (see Fig. 6).

It is know that PV panel must be operated at MPP for high energy efficiency. But also it is demonstrated that only the buck–boost DC/DC converter is able to manage the facility to track the PV MPP in all load and environmental conditions (connected load, PV panel temperature and solar global irradiation) [12]. So, the next step in evaluation of this PV emulator will be that of using as load a DC-DC converter with a MPP tracking control. In such of experiment, the dynamical behaviour of the PV emulator will be observed and evaluated.

4. CONCLUSION

Using experimental data and simulation results it was implemented a hardware emulator based on buck DC-DC converter, whose characteristics approximate a type of photovoltaic panel available in lab. By changing the design parameters and by redesigning the DC-DC converter at the new level of power required, it can be emulate any type of PV panel.

The tests were performed for static load or with a slow dynamic. Experiments with this emulator have produced results almost similar to real ones performed in the lab.

The advantage of this PV emulator is its simplicity in implementation regarding the control algorithm, in comparison with other proposed control algorithms.

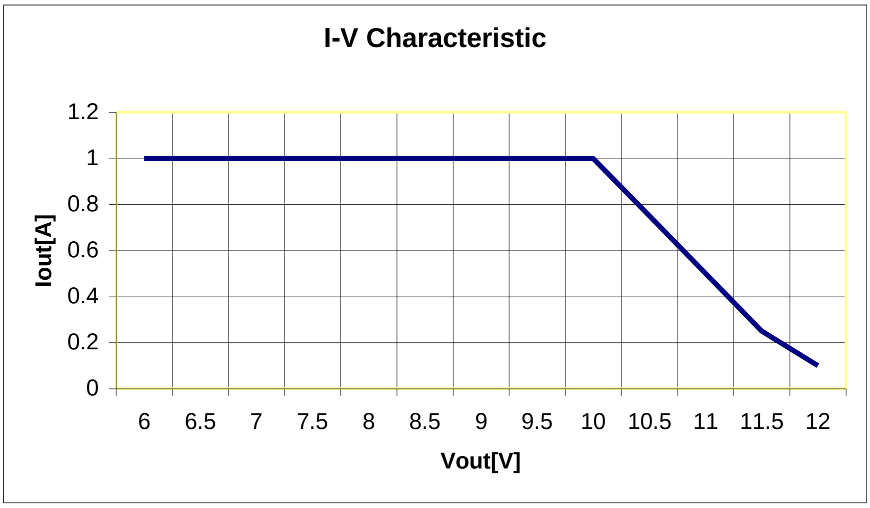

Fig. 5. Static operating characteristic of the implemented PV emulator

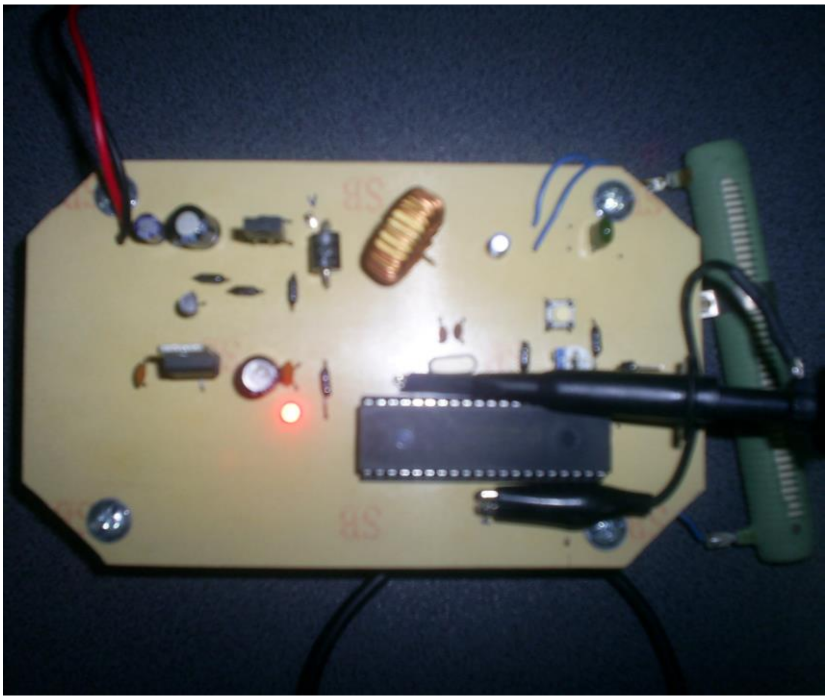

Fig. 6. Emulator for a photovoltaic panel

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