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INVESTIGATION OF THE DYNAMIC PROPERTIES OF SOLAR BATTERIES

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Abstract: The investigation of the dynamic properties of solar batteries (SB) at the changes of loading resistance is described in this article. The results of research are illustrated by the oscillograms, which show the presence of inertia properties of SBs.

Key words: Maximum Power Point Tracking (MPPT), Solar Battery (SB), solar elements, computer model.

1. Introduction

The new algorithm of extreme control system is presented in previous work [4]. The exact computer model of controlled object is needed for the effective investigation of its work. Therefore, the purpose of the work is verification of presence dynamic properties of solar batteries (or photovoltaic elements – PV). This task is set for subsequent authentication of their parameters and creation of their mathematical model.

The investigation of dynamic properties was carried out on a stand with single-crystal SB, however this results can be spread over other types of batteries. The account of dynamics solar batteries (or PV) enables to promote efficiency of new developments. It can draw on research results for creation of mathematical and computer models of SB, which are intended for application on the stage of design.

2. Actuality

Development of alternative energy sources in Ukraine is in the embryonal stage; however we have quite good potential for development of sun energy. There is the own production of high-efficiency silicon PV (sun batteries) with coefficient of efficiency to 20 % in Ukraine nowadays. The advantages of using sun batteries are:

1. autonomy;
2. high reliability;
3. cost cutting on a hot water-supply and heating to 85% because sun energy is free of charge;
4. the economy of organic fuel (fuel oil, oil, gas);
5. reduction of carbon dioxide emissions;
6. popularity and inexhaustibility of a source;
7. absence of intermediate phases of transformation of energy;
8. semiconductor solar batteries have a very important advantage – longevity, the service required is minimum, and any special knowledge or skills are not required for it;
9. in theory SB are harmless for environment (because of the ecologically clean energy source) and human beings (technical safety meets world standards);
10. using sun energy by a population and industry positively influences the power safety of Ukraine.

The disadvantages of sun batteries are a permanent dependence on local conditions, time of day and year, relatively high cost, low efficiency, and sensitivity to mechanical damage.

To improve the efficiency of a solar cell the tracking the point of maximum power (MPPT – *Maximum Power Point Tracking*) is introduced into the system. Tracking the maximum power point is usually an integral part of the photovoltaic system, because for this purpose many methods of searching the maximum power point have been developed and implemented, as well as differing complexity, required sensors, work speed, cost, efficiency, popularity and others.

3. Purpose of work

A new algorithm of searching an extreme was implemented for the MPPT [4]. It is necessary to have the computer model of the object – i.e., solar battery – to test the performance of the proposed method using computer simulation. The computer models of single diode SB [1] are widely introduced in literature. A double exponential model [2] and other models [3] are not so popular. However, none of these models takes into account dynamic characteristics of solar cells, which are defined by internal panel capacity.

Previous investigations have shown that this capacity is sufficiently large and requires the consideration of SB inertia as a controlled object. As shown by experiments, dynamic properties of solar panel depend on the internal resistance and internal capacity of a panel. It should be noticed that the majority of MPPT algorithms does not foresee the presence of inertia in an energy source, so that this issue needs further studying.

Thus, the aim of the conducted research is to study the dynamic characteristics (inertia) of a SB as an object of control.

4. Investigations

The main idea of the conducted research is to identify the dynamic properties of the photovoltaic cell or solar battery in the modes of a changing load. The output coordinates (current and voltage) will show the presence the appropriate changes in the case of such properties, which can determine

the behavior of the object and identify it as a dynamic object. The perturbation change of loading takes place by connecting the corresponding resistance (R_{load}) to the output of SB using a semiconductor power switch.

The block diagram of the experiment is shown in Fig. 1. The light source for solar panel is an adjustable "solar simulator" – a halogen bulb with a voltage regulator. The investigated object in the first approximation is presented as an RC-circuit (where C_{int} , R_{int} are parameters of substitution circuit), the load is purely active. Generator of rectangular pulses (PWM duty cycle 50 %), which is realized on a microcontroller ATmega 8, controls an on/off power switch transistor.

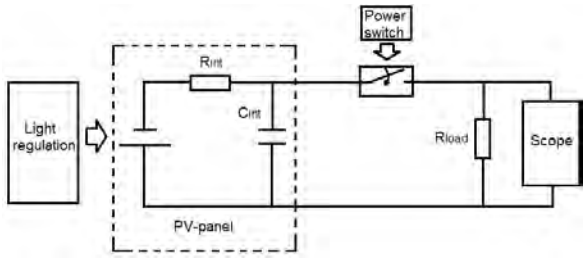

Fig. 1. The block diagram of the experiment.

The investigation of the mode of step change of loading were conducted for three different values of illumination, which provide the value of electromotive force of sun battery E_0, accordingly, 14 V, 12.4 V and 10.5 V. The resulting value of the output voltage under the load U_{load} and resistance value R_{load} = 10.2 ohms constituted, respectively, 6.0 V, 3.55 V and 1.6 V.

SB internal resistance R_{int} is calculated on the measured data by the equation

$$R_{\text{int}} = R_{load} \frac{E_0 - U_{load}}{U_{load}}.$$

5. Results of the research

The experimental output voltage waveforms of SB are shown on Fig. 2–4 for different values of illumination. The results of mathematical processing of are presented in Table 1, where the results of calculations the parameters of the used circuit solar cell are described for different values of illumination.

For the first model approximation presented as an RC-circuit the analytic time-dependence expression of output voltage versus loading is:

$$U_{out}(t) = E_0 \cdot \frac{R_{load} + R_{\text{int}} \cdot e^{-t/T_{\text{int}}}}{R_{load} + R_{\text{int}}}.$$

The experiments showed that the time constant of SB, T_{int} , is practically unchanged for the different values of illumination and makes approximately $T_{int} \approx 3$ μs, while the internal resistance of SB, as it is evident from a Table 1, varies significantly depending on the level of illumination.

Table 1

The results of treatment of researches

Values of illumination	E_0	U_{load}	R_{int}	T_{int} , μs
max	14	6	14	≈3
med	12.4	3.55	26	≈3
min	10.5	1.6	58	≈3

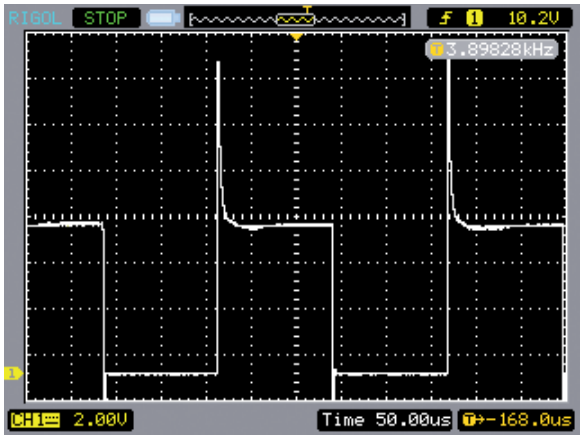

Fig. 2. An oscillogram of SB voltage at maximal illumination.

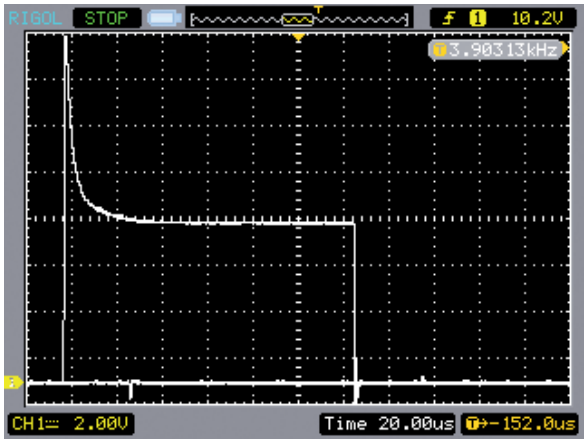

Fig. 3. An oscillogram of SB voltage at middle illuminati on (increased).

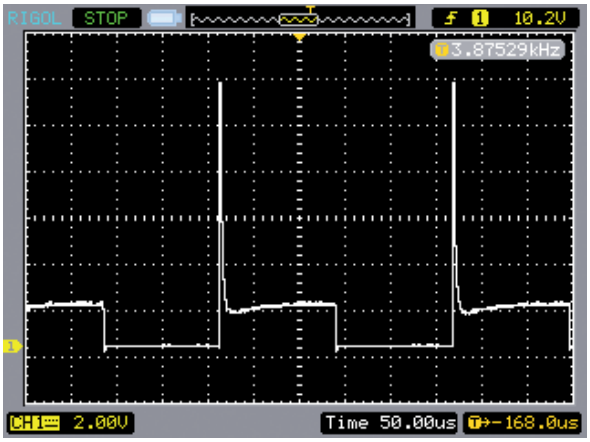

Fig. 4. An oscillogram of SB voltage at minimum illumination.

The research has also shown a nonlinear change of internal resistance of SB when illumination is changed (see Table 1).

5. Conclusions

The conducted research has shown that there exists a substantial internal capacity of solar cells. Their inertia is not considered by any mathematical or computer models. The authentication of the parameters of dynamic properties of the explored system testifies its accordance to the one real pole that lets us describe photovoltaic cells and solar batteries as the inertial block of the first order at the computer simulation of the MPPT algorithm.

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ДОСЛІДЖЕННЯ ДИНАМІЧНИХ ВЛАСТИВОСТЕЙ СОНЯЧНИХ БАТАРЕЙ

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Описано дослідження динамічних властивостей сонячної батареї за зміни навантаження. Результати роботи проілюстровано осцилограмами експериментів, які свідчать про наявність інерційних властивостей сонячних батарей.

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