Experimental estimation of Solar Stratospheric Platform power station equivalent chart parameters

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Abstract. An analytical model is offers and the experimental estimation of parameters of stratospheric UAV Solar power station equivalent chart is executed. Solar power station is realized on single-crystal photocells MaxeonC60 by SunPower company. Round the maximum power point the analytical model of photocells is modified for reduction of error from the obtained experimental data. The specified model allows to optimize the flight modes of sunny stratospheric platform with exactness sufficient for the practical use.

The development of Solar-Powered High-Altitude Unmanned Aerial Vehicles [1], [2] results in future to stratospheric carriers of communication and monitoring equipment. In comparison to communication satellites Solar-Powered Stratospheric Pseudo-Satellites (SSP) have such advantages as a low cost infrastructure of exploitation and manoeuvring possibility inside national air space.

For steady exploitation of SSP it is necessary to provide three fundamental energy armed conditions:

- takeoff and reaching of stratospheric altitude within the limits of light day,
- holding the height within the limits of distinguished air space during a sunset-to-sunrise;
- holding of SSP within the limits of the specified territory in a stratospheric speeds of the air masses transfer.

While solar energy is a basic and only renewal energy source, research and optimization of onboard solar power plant parameters are an actual task.

At the present work an analytical model offers and the experimental estimation of parameters of equivalent chart of SSP "Crocus" Solar power station [3] is executed. Solar power station is realized on Maxeon C60 single-crystal photocells by SunPower company. The dimension of any photosell is 125x125 mm. High efficiency (up to 24%) arrived at in them due to the one-sided location of current collecting tires and guided law of alloying in photodiodes p-n- transitions [4].

Typical equivalent chart of Solar photocell (figure 1) [5], [6] includes the source of photocurrent I_p, which is proportional to the spectrum-diffused luminosity of photocell $E(\lambda)$ and p-n transition with a current I_d, that represents dynamic allocation of charge carriers inside the volume of transition. In addition, shunt resistance of photocell R_p and successive resistance R_s are included in an equivalent chart [4].

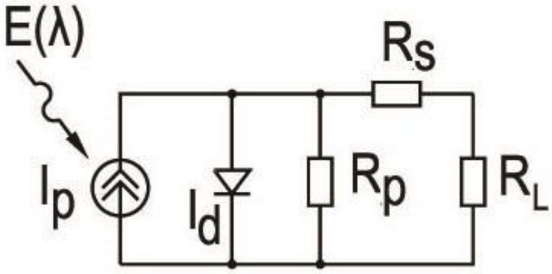

Figure 1. Typical equivalent chart of Solar photovoltaic cell.

Photocell Volt-ampere description links a current I and voltage U on external loading resistance R_L:

$$I = I_p - I_h\{EXP(\frac{U}{A \cdot k \cdot T}) - 1\} - \frac{U}{R_p}, \tag{1}$$

where

$$I_p = \int_{(\lambda)} E(\lambda) \cdot \vartheta(\lambda) d\lambda, \tag{2}$$

λ is wavelength of photocell radiation, $E(\lambda)$ is spectrum distribution jf radiation, $\vartheta(\lambda)$ is photocell spectrum sencitivity, I_h is reverce current of heated p-n junction, k is Boltzmann constant, T is absolute temperature, A is dimensionless factor, which depends on admixture atoms concentration gradient inside p-n junction.

For the experimental measuring of values R_p, R_s and parameters I_h, A of photocell equivalent chart, we will take advantage of the methodology based on research dark and light volt-ampere descriptions of p - n transition of photocell [5]. The parameters of equivalent chart of substitution are driven to the table.1.

The measuring of volt-ampere description were executed with photovoltaic elements battery, carried by the experimental section of the wing cantilever (figures 2, 3) for SSP "Crocus" [2].

Figure 2. Solar cells battery at the surface of experimental section of the wing.

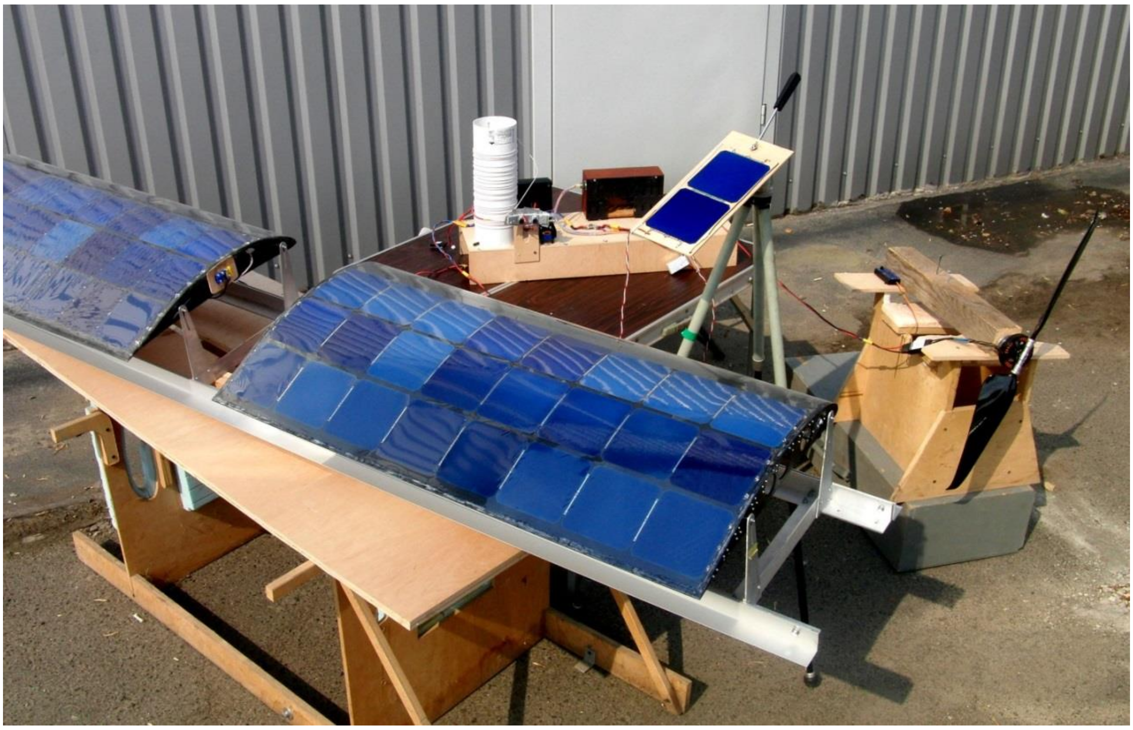

Figure 3. Experimental measuring setting of SSP "Crocus" power station parameters.

Table.1. Parameters of equivalent chart of substituting for the SunPower 60 photocell, measured on methodology [5].

R_p	R_s	I_h	A
8,5 Ohm	0,012 Ohm	0,075 A	6

A classic formula (1) does not take into account influence to volume charge of p - n junction from electric field of current collecting tires. The volt-ampere description got at a design in area of maximum power point substantially differs in a due form from the real [5, fig.4]. At the high coincidence in area of modes of short circuit and idling, near-by the point of maximal power, a model gives a substantial error: to 30%.

An influence of current collecting tires potential on p - n junction behavior near the maximal power shows up as complementary non-linearity of volt-ampere description and can be taken into account by dependence of parameter A on distribution between drift and diffusive constituents of junction current. As a result, volt-ampere description can be described by dependence:

$$I = I_p - I_h\{[EXP(\frac{U}{A \cdot k \cdot T}) - 1]^{\alpha}\} - \frac{U}{R_p}, \quad (3)$$

where parameter α for silicon chip equal to 2,0…2,3.

For the division of variables I, U in (3) it is comfortably to use the numeral method of progressive approximations. The equivalent chart of substituting for a photocell can be presented as a photocurrent's divizor on linear and nonlinear constituents, where a q-point of the system is on crossing of volt-ampere descriptions of branches (figure 3). For the different cases of photocurrent distribution between linear and nonlinear branches ($U2 > U_{dp}$ and $U2 < U_{dp}$) the direction and sequence of progressive approximations iterations are opposite. At the maximum power point equality of voltages takes place at the hypothetical photocurrent follow separately on linear and nonlinear branches ($U2 = U_{dp}$).

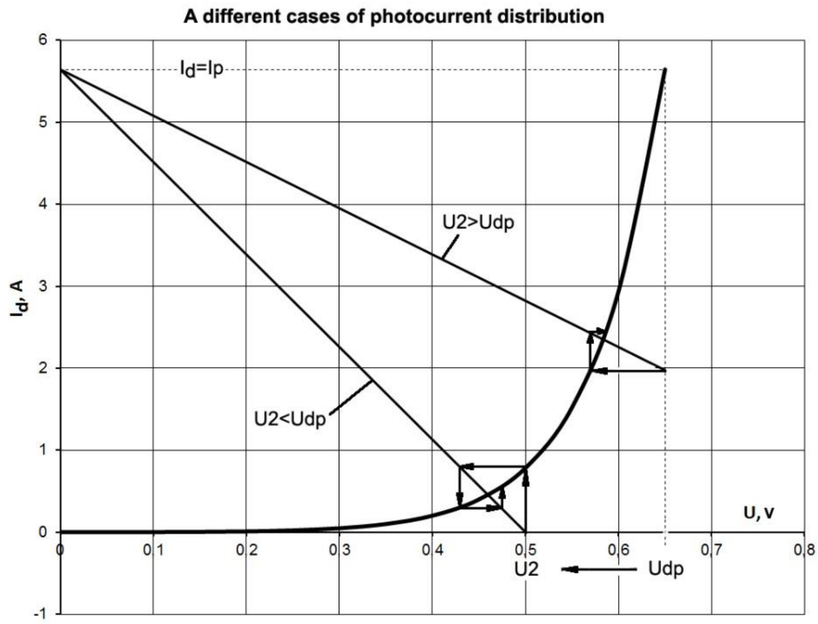

Figure 3. Iteration decision of nonlinear equalization (3).

Experimentally measured and designed by (3) descriptions of photocell are combined on fig.4 with passport volt-ampere description of photocell from a producer, given at integral power of irradiation 1000 W/m2. The designed volt-ampere description of photocell is expected concordantly (3) at a value α =2,0.

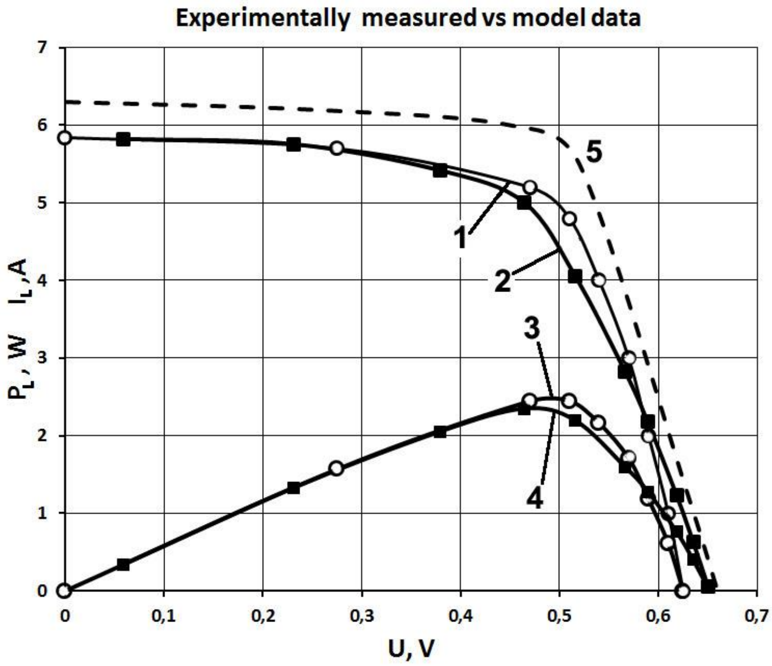

Figure 4. Experimentally measured and predicted by (3) descriptions of SunPower Maxeon C60 photocells. 1 – experimentally measured photosell current, 2 – modeled by (3) photocell current, 3 - experimentally measured photosell output power, 4 – modeled photosell output power, 5 - description of photocell from a producer, given at integral power of irradiation 1000 W/m2.

Specified concordantly (3) the volt-ampere description model of SunPower Maxeon C60 photocells is well comports with experimental data, an error on power in area of point of maximal power does not exceed 8%. Application in the model (3) of expression (2) for a photocurrent taking into account the spectral closeness of irradiation on a different height and at the different angular height of a Sun allows to investigate and optimize the flight modes of SSP with exactness sufficient for practical aims.

References

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