ISSN 0735-2727, Radioelectronics and Communications Systems, 2009, Vol. 52, No. 1, pp. 16–23. © Allerton Press, Inc., 2009.
Original Russian Text © E.Ya. Shvets, S.L. Khrypko, E.I. Zubko, 2009, published in Izv. Vyssh. Uchebn. Zaved., Radioelektron., 2009, Vol. 52, No. 1, pp. 26–36.

Investigation of Methods Used in Calculations of Solar Cell Parameters

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Received in final form April 14, 2008

Abstract—Analytical expressions have been obtained for extracting the electrical parameters and characteristics of solar cells, including series and shunt resistances, and the saturation current. The method of Lagrange multipliers was used for computing the shape factor of the current–voltage characteristic (CVC) of solar cell. The calculation results demonstrated a satisfactory agreement with experimental data.

DOI: 10.3103/S0735272709010038

INTRODUCTION

For more than 25 years silicon has been a dominant material for production of solar cells [1, 2] and may remain the basic material for solar cells, if the price and efficiency will be matched. [3]. The efficiency depends on a number of factors: the presence of series and shunt resistances; absorption of light in the surface layer; recombination of charge carriers in the volume of semiconductor or the area of spatial charge; heating in the presence of excessive photon energy; through passage of photons, etc. The series and shunt resistances are among the parameters that significantly affect the efficiency [4–6]. The knowledge of these parameters is important for monitoring the quality and estimating the degree of perfection of solar cells. There are different theoretical methods for evaluating the series resistance (R_s), shunt resistance (R_{sh}), saturation current (I_s), quality factor (n), and the shape factor of CVC (FF) [7–31]. The following requirements are imposed on these methods: maximum agreement with experimental results, simplicity, accuracy, validity, and the minimum additional information regarding the other numerical parameters. They are based on the analysis of the measured illuminated and dark CVC, application of the parameter approximation using numerical methods, obtaining the parameters on the basis of the description of nonlinear electric model of the solar cell.

OBJECTIVE OF THE STUDY

The purpose of this study consists in the development of direct analytical method for obtaining such parameters as R_s, R_{sh}, I_s and the method of Lagrange multipliers in determining the CVC shape factor of solar cells.

SOLUTION OF EQUATIONS AND THEIR EXPERIMENTAL VERIFICATION

The illuminated CVC of solar cell in accordance with the single-diode model of solar cell (Fig. 1) can be characterized by the following expression [32]:

$$I = I_{ph} - I_s\left[\exp\left(\frac{U + IR_s}{n\varphi_T}\right) - 1\right] - \frac{U + IR_s}{R_{sh}}, \quad (1)$$

where I is the current passing through the load; I_{ph} is the light current; $\varphi_T = kT / e$ is the thermal potential; T is temperature; e is the electron charge; U is voltage.

The equivalent electric circuit of solar cell and the general view of solar cell CVC for an idealized case are displayed in Figs. 1 and 2, respectively.