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Optimization of the Collecting Grid Front Side of a Photovoltaic Cell Dedicated to the RF Transmission

Chokri Baccouch, Dhaou Bouchouicha, Hedi Sakli*, and Taoufik Aguili
National Engineering School of Tunis, Tunis El Manar University, B.P. 37, Le Belvédère, 1002
SYS'COM Laboratory
Tunis, Tunisia.
email: chokri.baccouch13@gmail.com
bouchouicha.dhaou@gmail.com
*saklihedi12@gmail.com
taoufik.aguili@enit.rnu.tn

Abstract*—This work presents a geometrical parameters optimization of a collecting grid of a photovoltaic cell dedicated to a radiofrequency transmission. The optimal value of the fingers width is obtained for a minimum loss. A mathematical model is presented to determine the conduction rate as well as that of a shade.

***Keywords*— Photovoltaic cells, Collecting grid optimization, Collected electrical power, Optical and electrical loss.**

I. Introduction

In the absence of transparent semi-conductor materials and sufficiently conductive ones, we are practically led to collect the carriers on a metal grid that only uses a very small portion of the metal surface of the photovoltaic cell. The role of this grid is to reduce the resistance series of the diffused layer and bring the current as directly as possible to the contact to assure the connection between the unitary cells. [1].

The problem is divided into two main parts, the first being the choice of the grid structure; however there is no general mathematic method for predicting the best form. Although Napoli and al. [2] showed that a cross-structure of grid lines is always less efficient than the straight-line structure [3]. The second is to optimize the chosen structure so that the width and thickness of the grid lines cause the minimal loss of the power or improve the output power.

In this paper, we are going to study the optimization of the collecting grid, front side of the photovoltaic cell. Our study will focus in the width of metallic lines and the height of these latter which will be chosen so that the losses (losses due to horizontal power in the transmitter, conduction losses in the metallic fingers, losses due to shading created by the grid) of power produced by the voltage drop is minimal.

II. Optimization of the Geometry of the Grid Front Side

There are three sources of losses due to the resistance series: resistance of the emissive layer, resistance of the grid and resistance of the contact metal/semi-conductor [4, 5]. The shading of the grid also contributes to the loss of power. The various contributions of resistance of a photovoltaic cell are shown in figure 1 [6].

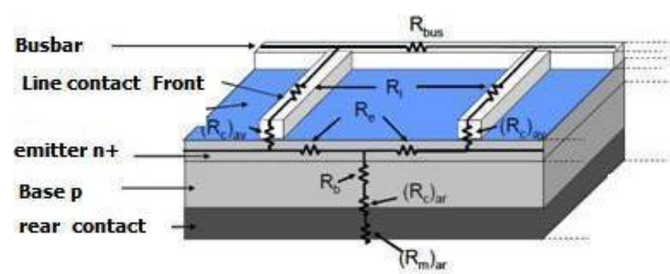

Fig. 1. Shematic representation of the different contributions of resistance of a photovoltaic cell [6].

The linear grid structure in the figure 2 is the simplest and represents the basis of calculating for the most complicated structures. The unitary cell (Fig. 3) has a width $d/2$ and a length l.

The optimization of the geometry of the grid on its front side of the photovoltaic cell requires a detailed analysis of the optical and electrical losses caused by this grid. The total loss of a photovoltaic cell comprising a collector and n fingers on each side of the latter is given by [6]:

$$P_t = P_e + P_{gav} + P_{busav} + P_{cav} + P_b + P_F \qquad (1)$$

with

P_e : Power dissipated in the transmitter

P_{gav} : Power dissipated in the front grid

P_{busav} : Power dissipated in the front bus

P_{cav} : Power dissipated in the front contact

P_b : Power dissipated in the base

P_F : loss related to the shade rate.

We seek to reduce the total loss. Therfore we maximize the collected electric power and that for a width w to be determined a finger of the grid.

The rear face being entirely metallized, considering that the associated resistance is insignificant compared to other contributions (transmitterr, front grid…). In a solar cell, ohmic losses are associated with the current flow through the

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resistance of the metalic grid, the metal-semi-conductor resistance, the substrate resistance and the transmitter region.

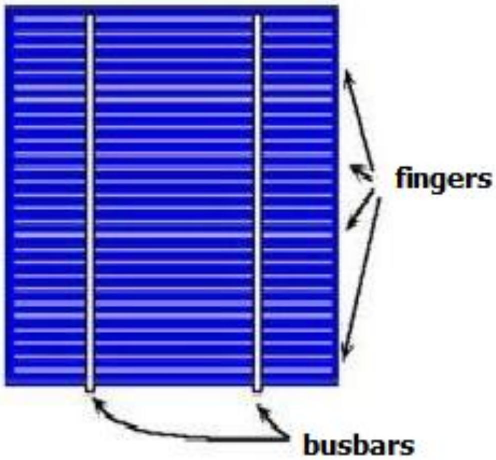

Fig. 2. Shematic representation of a photovoltaic cell to be studied.

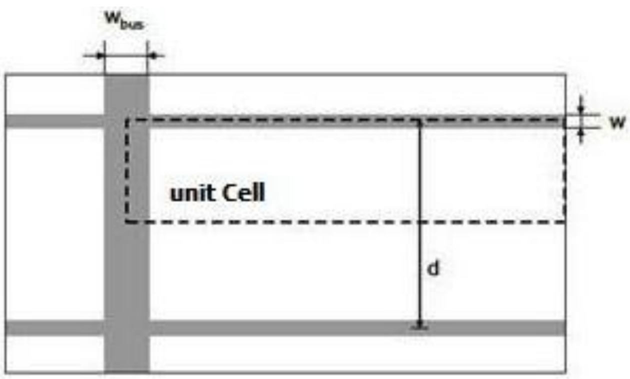

Fig. 3. Layout of the unitary cell used for calculating the resistive losses in the case of a metalic grid . comb form front side of a photovoltaic cell

The power dissipated in the transmitter is given by

$$P_e = J^2 R_e L^4 \tag{2}$$

with

$$R_e = \frac{R_{se} d^2}{12 L^2} \tag{3}$$

$$R_{se} = \frac{\rho_e}{e} \tag{4}$$

R_e : transmitter resistance (Ω).

R_{se} : transmitter layer resistance $(\Omega/\square)$.

d : distance between two fingers.

L : side of the square cell.

J : surface density of the current.

e : thickness of the transmitter.

ρ_e : transmitter resistivity $(\Omega.cm)$.

The power dissipated in the base is given by

$$P_b = J^2 R_b L^4 \tag{5}$$

with

$$R_b = \frac{\rho_b w_b}{L^2} \tag{6}$$

R_b : resistance of the base (Ω).

ρ_b : base resistivity $(\Omega.cm)$.

w_b : thickness of the base (cm).

The power dissipated in the front side of the grid is given by

$$P_{gav} = J^2 R_{gav} L^4 \tag{7}$$

with

$$R_{gav} = \frac{d}{48} \frac{R_m}{w} \tag{8}$$

$$R_m = \frac{\rho_m}{h} \tag{9}$$

R_{gav} : resistance of the front grid (Ω).

R_m : resistance of the metal (Ω).

ρ_m : metal resistivity $(\Omega.cm)$.

w : finger width (cm).

h : metal thickness (cm).

The power dissipated in the busbars is

$$P_{bus} = J^2 R_{bus} L^4 \tag{10}$$

with

$$R_{bus} = \frac{r_{bus} d^2}{12 L w_{bus}} \left(\frac{L^2}{2m^2 d^2} + 3\frac{L}{2md} + 1 \right) \tag{11}$$

$$r_{bus} = \frac{\rho_m}{h_{bus}} \tag{12}$$

R_{bus} : resistance of the collecting line (busbar) (Ω).

w_{bus} : width of busbar.

m : number of weld points on the current-collecting lines.

The power dissipated in the contact resistance is

$$P_{cav} = J^2 R_{cav} L^4 \tag{13}$$

with

$$R_{cav} = \frac{d}{2L^2} L_T R_{se} \coth\left(\frac{w}{2L_T} \right) \tag{14}$$

$$L_T = \sqrt{\frac{\rho_c}{R_{se}}} \tag{15}$$

R_{cav} : resistance of front contact (Ω).

L_T : current density transfer length (cm).

ρ_c : contact resistivity front side $\left(\Omega.cm^2\right)$. .

Losses out of shadow effect (or optical losses) are caused by the presence of metal on the top surface of the solar cell which prevents light from penetrating. We define the overlap rate F, also called the rate of shade, as the ratio between the top surface of the metal grid and the total surface of the cell [6].

$$F = \frac{S_{rav}}{L^2} = \left(w + \frac{2w_{bus}(d-w)}{L} \right) \cdot \frac{1}{d} \qquad (16)$$

It is clear that the hidden area is proportional to the distance between the fingers of the grid. The closer these latter are, the larger the surface of the metal grid is, therefore the surface exposed to the light fades.

The power dissipated due to optical losses is

$$P_F = F.I_m.V_m \qquad (17)$$

with

I_m : the current supplied by the cell intensity.

V_m : the voltage supplied by the cell.

The power collected by the cell is therefore

$$P_{col} = P_{ecl} - P_t \qquad (18)$$

with

P_{ecl} : power cell lighting.

P_t : Total power dissipated due to resistive losses and shadow levels.

III. Results and Discussions

In addition to maximize absorption and minimize recombination, the final condition required to design a high performance of a solar cell is to minimize its parasitic resistive losses, hence the conduction rate which is the relationship between the total power Pr lost by the joule effect to the power supplied without loss, therefore from an optical point of view, the coverage rate or the shade rate must be low because the hidden surface by metallization is inactive. Thus, there is a compromise between these two situations, which tend to improve the energy conversion efficiency.

The base substrates used are generally in multicrystalline silicium. Useful parameters for the calculation of the various resistive and optical input from the standard cell serigraphed in front are given in Table I. The rear face of the cell is assumed solid plate metallized with aluminum deposited by serigraphy.

TABLE IParameters used for the simulation of the calculation of the total losses of the photovoltaic cell on the front of the figure 2 [6].

Symbole	Description	Valeurs
L	side of the square cell	$12.5\ cm$
d	distance between two fingers	$0.25\ cm$
J	surface density of the current	$0.03\ A.cm^{-2}$
R_{se}	transmitter layer resistance	$40\ \Omega/\square$
ρ_b	base resistivity	$0.6\ \Omega.cm$
w_b	thickness of the base	$2\ 10^{-2}\ cm$
ρ_m	metal resistivity	$3.9\ 10^{-6}\ \Omega.cm$
h	metal thickness	$1.5\ 10^{-3}\ cm$
w_{bus}	Width of busbar	$0.2\ cm$
m	number of weld points on the current-collecting lines	10
ρ_c	contact resistivity front side	$10^{-3}\ \Omega.cm^2$
V_m	the voltage supplied by the cell	$0.5\ V$
p	number of busbars in front	2

Figure 4 shows the variation of the power according to the width w of a finger. We note that the maximum of the received power is $21\ W$, for a lighting power of $P_{ecl} = 1300\ W/m^2$ and which corresponds to a width of a finger equal to $60\ \mu m$. This value of the finger width will be useful for the antenna patch conception on silicon dedicated to the radiofrequency transmission.

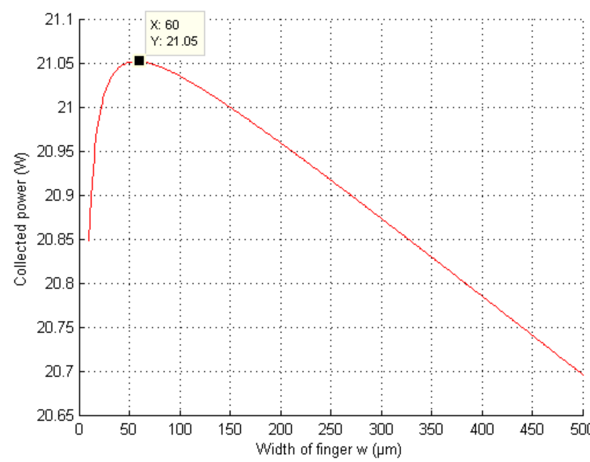

Fig. 4. Variation of the power collected by finger width function.

IV. Conclusion

In this paper, we studied the optimization of the collecting grid, front side of a photovoltaic cell dedicated to the RF transmission using the antenna patch on silicon. This optimization therefore requires the right choice of the geometry of the grid and its manufacturing material.

We chose a compromise between the optical losses and conduction losses to derive the geometrical dimensions of the optimized collecting grid which will give the maximum productivity of the cell.

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