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AC SOURCE BASED ON SOLAR CELLS

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Abstract: This paper deals with the design of low power solar source. The power solar source consists of battery, electronic part and a solar module that uses solar cells.

Keywords: Solar cells, solar module, simulation, PSpice.

1 Introduction

The basic condition for designing of solar power unit consists in nominal parameters defining of such unit, which are depending on operational parameters. If basic asked conditions for functionality of solar cells are fulfilled, such as lighting intensity, time duration of lighting, wave-length, temperature, operational and safeguard conditions, then the basic output parameters is possible to provide.

2 Basic parts of solar source

Solar source is possible to divide to three basic parts from the point of view of its realisation. These parts are created by solar module, battery and control electronics. All solar module is created by serial and parallel connections of individual elementary solar cells. Battery as accumulator of electric energy must fulfil certain basic requirements, which are represented by the voltage value and its stability, asked number of recharging cycles, weight and

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dimension, lifetime and capacity. Control electronics should involve also the guard diode, voltage regulator, safe guard circuits against battery discharge or overcharge, of battery, power peak regulator and for AC sources an inverter, too.

2.1 Solar modul design

Solar module is created by solar cells utilising P-N junction. At first we will analyse P-N junction situated in dark place. Let the absolute current values created by electrons and holes are I_n^N and I_p^N for current flows from N side and I_p^P and I_p^P for current flows from P side. For equilibrium state is valid following system of equations:

$$-I_n^N + I_p^N + I_n^P - I_p^P = 0 \quad (1) \qquad -I_n^N + I_p^N = 0 \quad (2) \qquad I_n^P - I_p^P = 0 \quad (3)$$

The influence of illumination will be proving by enlargement of carrier minority concentration. The current I_f flowing by P-N junction will be rising. The Fermi´s surface will be cleaved on two quasi-surfaces for electrons and holes after illumination. Its difference φ is corresponding to the voltage $U_f = \frac{\varphi}{e}$, which came into existence as result of illumination. Current flowing by P-N junction is equal to zero in stationary state:

$$I_f - I_n^N + I_p^N + I_n^P - I_p^P = 0 \qquad (4)$$

The currents of majority carriers I_n^N, I_p^P will be changed after illumination in due to mutual change of energetic surfaces and changes of potential barrier levels:

$$I_n^N = I_n^P \exp\left(\frac{\varphi}{kT}\right) \quad (5) \qquad I_p^P = I_p^N \exp\left(\frac{\varphi}{kT}\right) \quad (6)$$

By equations (4), (5) a (6) and after modification we can obtain:

$$I_f - \mathrm{I_s}\left[\exp\left(\frac{\varphi}{kT}\right) - 1\right] = 0 \qquad (7)$$

For photoelectromotorical force is valid:

$$U_f = \frac{\varphi}{e} = \frac{kT}{e}\ln\left(\frac{I_f}{I_s} + 1\right) \qquad (8)$$

If P-N junction will be connected to the circuit flowing by current I, then we will obtaining by equations (7), (8) following dependencies:

$$I_f = I + \mathrm{I_s}\left[\exp\left(\frac{\varphi}{kT}\right) - 1\right] \quad (9) \qquad U_f = \frac{kT}{e}\ln\left(\frac{I_f - I}{I_s} + 1\right) \quad (10)$$

If the P-N junction is connected to the resistive load with value $R = \frac{U_f}{I}$, then the equation (9) has form:

$$I_f = \frac{U_f}{R} + \mathrm{I_s}\left[\exp\left(\frac{\varphi}{kT}\right) - 1\right] \qquad (11)$$

For small external resistors or for connection to short when is valid that

$I >> I_s\left[\exp\left(\frac{\varphi}{kT}\right)-1\right]$ we can say that $I_f \approx I$. For great external resistors or open connection when $I \to 0$ we can say that $I_f = I_s\left[\exp\left(\frac{\varphi}{kT}\right)-1\right]$.

In the case that to the P-N junction is also connected the voltage source with voltage value U we can obtain:

$$I_f = \frac{U_f - U}{R} + I_s\left[\exp\left(\frac{\varphi}{kT}\right)-1\right] \qquad (12)$$

For power of the solar cell is valid that $P = UI$.

For maximal power is given equation:

$$\frac{d(UI)}{dU} = I_k - I_s + I_s\frac{e}{kT}\exp\frac{eU_m}{kT} = 0 \qquad (13)$$

Voltage across the output terminals without the load is possible to write:

$$U_0 = \frac{kT}{e}\ln\left(\frac{I_k}{I_s}+1\right) \qquad (14)$$

Only in the case if the basic asked conditions for functionality of the solar source are fulfilled (such as for example the magnitude of lighting intensity, time interval of lighting, wave-length of lighting source), only then one can to guarantee the basic output parameters of solar source (such as for example maximal output current and voltage, maximal power P_m, serial resistance R_s, parallel conductance G_s saturation factor F_F). Solar cell equivalent scheme is shown on Fig. 1. On Fig. 2 is pictured the load characteristic of solar cell.

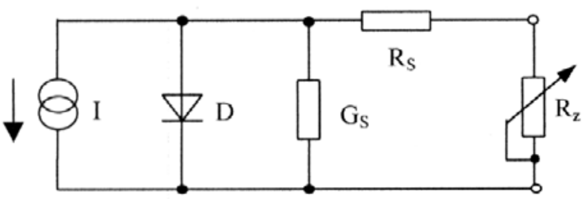

Fig. 1 Solar cell equivalent scheme

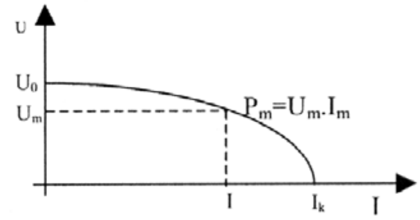

Fig. 2 Load characteristic of solar cell.

Measured load characteristic is drawn in Fig. 3 for lighting intensity 5000 lux.

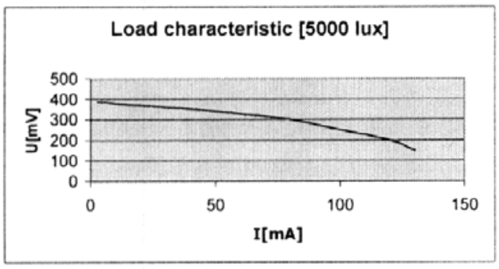

Fig. 3 Load characteristic of solar cell of using intensity of 5000 lux.

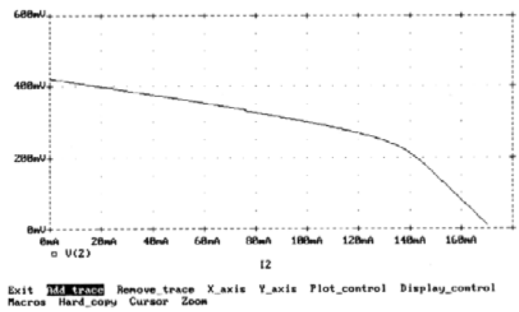

Fig. 4 Simulation characteristic of solar cell using PSpice.

On the basis of real measuring of solar cell load characteristic and by performed mathematical analysis is possible to make computer simulation of solar cell functionality. Simulation of solar cell investigated by us was performed in PSPICE program. Solar cell load characteristic obtained by simulation is shown in Fig.4.

2.2 Controlling part

Controlling part must be designed by inverter, which is changing DC voltage from battery on AC voltage. Two stage DC impulse convertor realised by transistors T1, T2 and impulse transformer TR was used. Transistors are controlled by pulse width modulation (PWM). Filter serves for filtering of higher harmonics of secondary transformer non-harmonics voltage. Controlling part scheme based on PWM is shown in Fig. 5.

The voltages across the switching transistors T1 and T2 are drawn on Fig. 6. Filtered output voltage on secondary transformer windings is shown on Fig. 7.

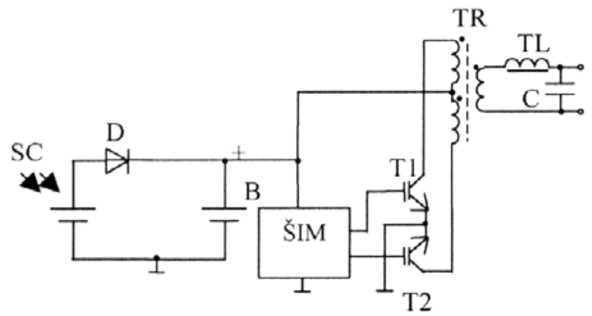

Fig. 5 Basic scheme of power source using PWM.

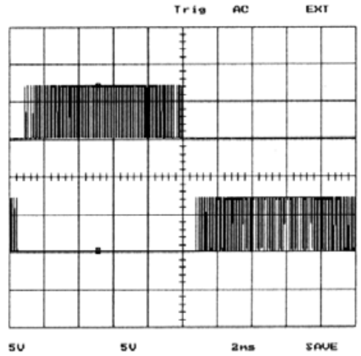

Fig. 6 The shape of signal on the collectors of the T1 and T2, the zero level of the first signal is 5V, the zero level of the second signal is –10V.

3 Conclusion

The main advantage of the solar source is its mobility and disadvantage is its sensitivity on weather. Despite of this fact such sources is possible to utilise for feeding of mobile phones, transportable printers and etc.

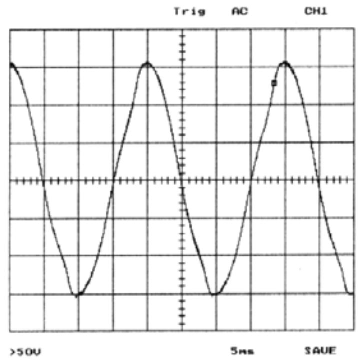

Fig. 7 Design of the signal on the secondary coil behind LC Filter.

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