MATLAB / Simulink MODEL FOR TRAINING IN RESEARCH AND DESIGN OF SOLAR ALTERNATIVE SOURCES

Stoyan Bozhkov[1], Valeri Mladenov[2]

[1]Department of "Electrical Engineering, Electronics and Automatics" Technical University of Sofia
Bul. "Burgasko chose"№59, Sliven 8800, Bulgaria, e-mail: s_bozhkov@abv.bg
[2]Department Theoretical Electrical Engineering, Technical University of Sofia, 8,
Kliment Ohridski Str., Sofia 1000, Bulgaria, e-mail: valerim@tu-sofia.bg

Abstract. *In this report is submitted an application to set up a model of a photovoltaic source with attached electrical load realized in Matlab/Simulink environment, as part of the learning process. Examines the need to ensure the active personal participation of the students during the training using the tools of computer modeling and simulation variant whereby, the student from a passive observer becomes an active participant in the learning process. Conclusions are made regarding the application of the created electronic model on the quality of training.*

Keywords: *modeling, software, learning process*

1. INTRODUCTION

Wider application of energy from PV renewable energy sources during the last years both globally as well in our country demands a more insightful training to future engineers to design optimal, rational use, implement, and competent to serve such type sources. Limited workload of classes, setting the ever - increasing share of academic material such as hours of self-made along with the traditional methods, the use of computers and technology main support tool in the learning process. Input in the process of learning, Simulation modeling of the studied classes circuits, processes and systems contributes to facilitate and mastering the material studied. Electronic education resources are universal means of providing didactic training in the new information environment, without which the conduct of quality engineering education is unthinkable.

Therefore, through traditional forms and methods of education with the progress of electronic information technologies increasingly successful impose so-called interactive methods for pursuing the high interaction between person and computer systems. The development of computer and information technology in recent years contribute significantly not only to improve the methodology of teaching in technical sciences, but also for a comprehensive rethinking of approaches to teaching [6]. This requires the use more and more new and universal software, the basic meaning of which is undoubtedly the cognitive and motivational.

Study conducted among universities shows that software tools such as Matlab, are becoming more wide application in the education, science and applied science activities developed by students and postgraduates [3]-[5].

Due to its comprehensive, flexible and comfortable to work environment, these products allow for modeling, design and study of objects and systems that are not available in a real learning environment, and non-existent objects. Through the introduction of computer technology in education paves way to more easily accessible and durable learning about the principles of operation of real systems containing multiple components together in a complex interaction. This report is structured as follows:

In the next section presents the basic theoretical dependencies and replacement schemes adopted in the development of a model of a photovoltaic source in MATLAB / Simulink environment.

In the section titled Testing the model are presented numerical and graphical results of the implemented research. Are presented comparative results

In the final section conclusions are displayed and recommendations made.

2. ELABORATION OF MATLAB / Simulink model

To develop a virtual model of a photovoltaic source, implemented in Matlab / Simulink environment by which to follow the process of converting solar energy into electrical energy and explore the production of electricity for the needs of energy management using a single diode replacement scheme [7]. The type of scheme used is shown in fig. №1

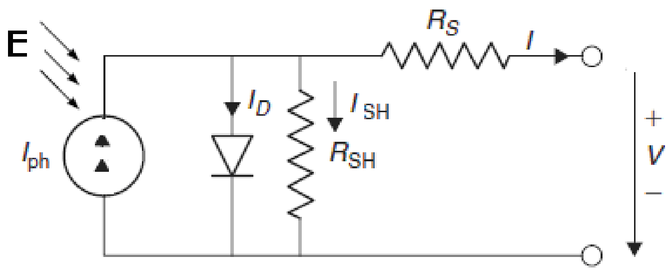

Fig. 1. Single diode replacement scheme

where: I_{ph} is the photo generated current; I_D - is the diode current, so-called current "dark"; R_{SH} - internal diode shunt opening resistance, indicating leakage currents as a result of structural and manufacturing defects of the semiconductor; R_S - consistent resistance representing the resistance of the module. The output current of the model is displayed by Kirchhoff's first law [1], [2]:

$$I = I_{ph} - I_D - I_{SH} \tag{1}$$

To determine the leakage current is applied Kirchhoff's second law, written to the output circuit:

$$IR_S + U - I_{SH}R_{SH} = 0 \tag{2}$$

or

$$I_{SH} = \frac{U + IR_S}{R_{SH}} \tag{3}$$

By substituting (3) into (2) to take account of (4)

$$I_D = I_S\left[\exp\left(\frac{q}{kT_C A}(U+IR)\right)-1\right] \quad (4)$$

for the current source to give the final form (5)

$$I = I_{ph} - I_S\left[\exp\left(\frac{q}{kT_C A}(U+IR)\right)-1\right] - \frac{U+IR_S}{R_{SH}} \quad (5)$$

where:

q – charge – $(=1.6x10^{-19}[\circ C])$; k – Boltzmann constant $(=1.38x10^{-23}[J/K])$; Tc – cell temperature; $[K]$; A – a coefficient dependent on the type of PV technology.

Ignoring the influence of the resistors R_{SH} ($R_{SH}=\infty$) and R_S ($R_S=0$), equation (5) is converted to (6):

$$I = I_{ph} - I_S\left[\exp\left(\frac{qU}{kT_C A}\right)-1\right] \quad (6)$$

Equation (6) applied to photovoltaic array consisting of - N_S series and Np parallel with connected modules is converted to the final presentation (7)

$$I = N_P I_{ph} - N_P I_S\left[\exp\left(\frac{qU}{N_S kT_C A}\right)-1\right] \quad (7)$$

Based on the use of the equations $(1)\div(7)$, taking into account equation (8), representing a thermal mathematical model of photovoltaic source:

$$T_{PV}\left[{}^0C\right] = 0.943T_a + 0.028E - 1.528V_{speed} + 4{,}3 \quad (8)$$

where:

V_{speed} – is the wind speed $[m/s]$; E – solar radiation $[W/m^2]$ was realized model of the photovoltaic source, a general view presented in Fig. (2)

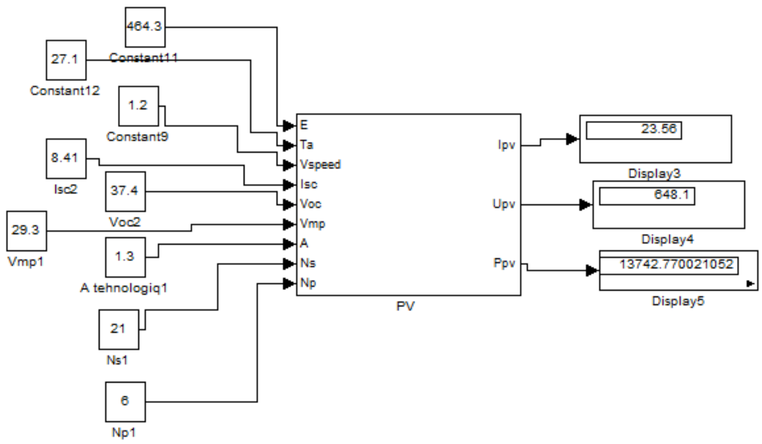

Fig. 2. General view

The type of internal structure is shown in Fig. 3.

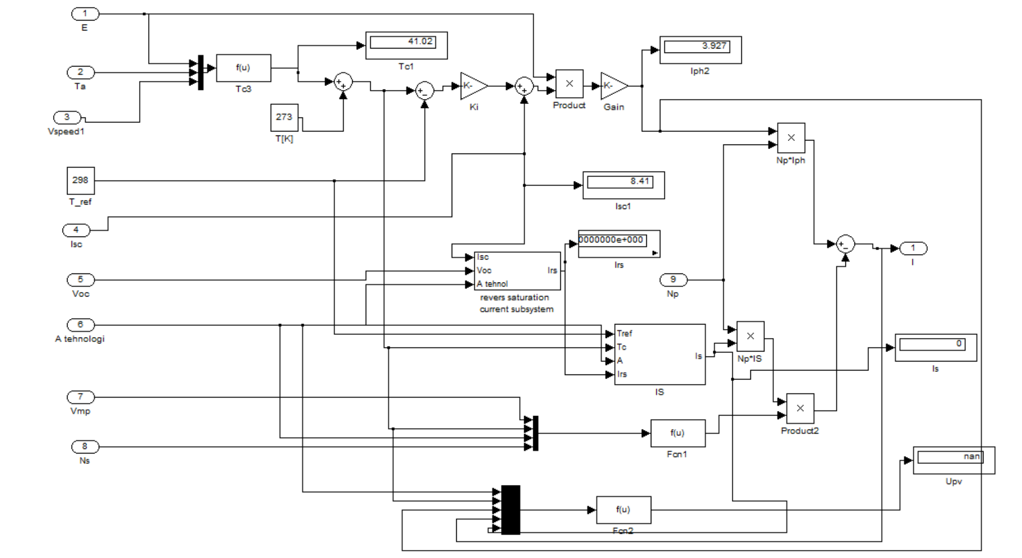

Fig. 3. Internal structure

Presented structure enables the use of model training, in stage of introducing with the principle of operation of photovoltaic sources using the *Display* block to visualize particulars corresponding to each step of basic equations $(1)\div(8)$.

3. TESTING ON MODEL

Efficiency of the model is demonstrated by performing experimental simulation and comparing the results with measurements from a real operating system.

To inputs are used catalog technical parameters of photovoltaic source object of study. These parameters are: short circuit current -I_{SC} $[A]$; voltage at idle -U_{OC} $[V]$; voltage at maximum power - U_{MP} $[V]$, kind of technology of construction of the panel -A.

According the values of the output current, voltage and power, which needs to be achieved to determine the number of sequential (N_S) and the number of parallel(N_P) associated modules.

Before starting the simulation are defined influencing parameters of the environment: solar radiation - E$[W/m^2]$; air temperature T_a $[^oC]$, wind speed -V_{speed} $[m/s]$.

By clicking *Start simulation* of the working window on the toolbox Simulink simulation starts.

Ranging the values of the input parameters of the environment, depending on the climatic operating conditions under which the study is given the opportunity to trace the directly operation of a photovoltaic analyzed system and determine the conditions under which was observed the optimal electrical performance.

For this purpose, with previously assigned input parameters corresponding to the specific weather conditions shown in Table №1, is done modeling of examined photovoltaic system

Table 1. Input parameters

Times of the day and night	**Solar radiation** $[W/m^2]$	**Air temperature** $[^oC]$
07:10:00	106,8	24,5
08:40:00	402	27,1
09:40:00	603,6	27.2
12:40:00	950,4	27,4
14:40:00	882	27,0
15:40:00	759.5	26.7

The data of the modeling can be displayed by measuring tool Display, in numerical form /tabl. 2/ or graphically /Fig. 4/.

Through exporting in Exel provides an opportunity for easy processing and storage of input-output data in a format xls.

Table 2. Numerical results

Time of day and night	Output power **P[W]**
07:10:00	3162.23
08:40:00	11 900.28
09:40:00	17864.11
12:40:00	28109,06
14:40:00	26098,27
15:40:00	22475.85

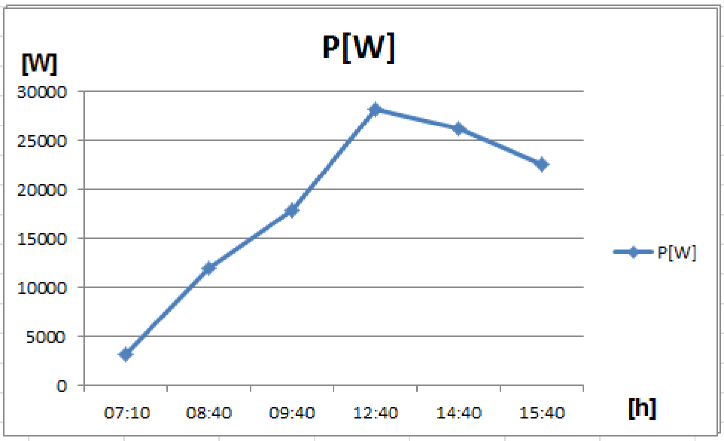

Fig. 4 Graphical representation

For proving working capacity of the model is necessary to make a comparison with a real working station. Comparison is made under identical input influencing parameters. The results obtained in graphical form, are presented in Fig. 5.

The presented method of research and education, by modeling of the behavior of the studied system allows the learner to form a sense that not only it is an object of study, but that actually works with it and experimented. In this way, without fear of any consequences, he can relax and fully develop his imagination and fantasy. Through simulation, with the ways of stimulation of various engineering problem situations expands the horizon of practical and theoretical knowledge and skills which in a real environment certainly leads to more - greater efficiency and speed in decision-making.

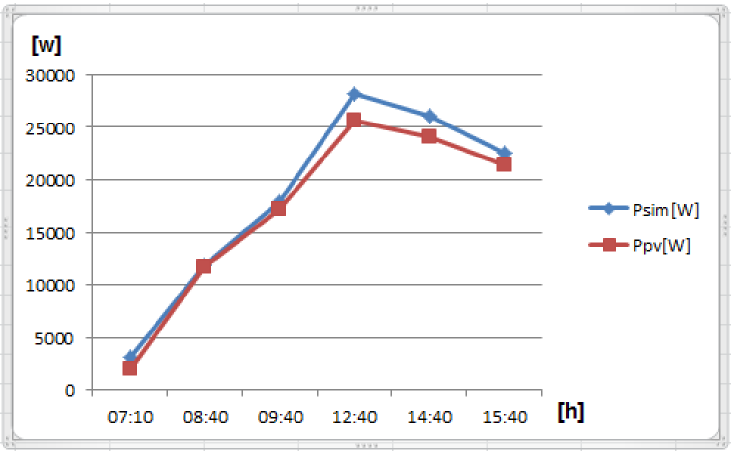

Fig. 5. Comparison between measured and simulated output power

4. CONCLUSIONS

As a result of the use of the model in the learning process can be derived following important conclusions:

- The flexibility of the model allows students to simulate the operation of a photovoltaic studied object at different changes in factors of environment other technology in the production of photovoltaic panels, different single and total output power, diverse connectivity configuration.
- Included in the learning process, MATLAB model, increases the interest and activity of students in the study of modern computer technology and renewable energy.
- By displaying the interim results of the different subsystems involved in the formulation of the model allows for the emphasis and thorough analysis, still in the process of teaching of the processes taking place in the studied PV system.

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