

Fuzzy Logic System for Controlling of DC/DC boost converter Developed in MATLAB SIMULINK

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Abstract - In this paper was presented a MATLAB Simulink model of the DC/DC boost converter controlled by the MPPT algorithm of the incremental conductance with the fuzzy logic controller. The model includes the following basic components: a) Photovoltaic system; b) Module that generates the variation of the solar radiation intensity and environmental temperature; c) DC/DC boost converter; d) MPPT algorithm of the incremental conductance with fuzzy logic controller. Following the analysis of the simulation results for the MATLAB Simulink model of the DC/DC boost converter controlled by the MPPT algorithm of the incremental conductance with fuzzy logic controller, it was found that the implementation of this algorithm ensures an optimal operation of the photovoltaic system for a large variation of the intensity of solar radiation and a maximum power transfer from photovoltaic panels to a resistive load.

Key Words: fuzzy logic controller; dc/dc boost converter; MPPT algorithm

1. INTRODUCTION

The conversion of the solar energy into electricity is currently performed at high costs and low efficiency of the photovoltaic systems being used. The maximum power transfer from the solar panels made by the DC/DC boost converter to the load may be obtained through the maximum power point tracking (MPPT) algorithm. The study of the performances of DC/DC voltage converters (Buck-Boost type) with extended voltage has been presented in the paper [1], and of the bidirectional Boost converter in the paper [2]. The follow-up of the maximum power point (MPP) for a photovoltaic system in shading conditions was analyzed in the paper [3]. The implementation of the MPPT algorithm based on the methods: perturb and observe, fuzzy logic controller and adaptive neural fuzzy inference system (ANFIS) has been presented in the paper [4]. The implementation of fuzzy controllers for controlling DC/DC boost converter in the MATLAB-Simulink environment has been presented in the paper [5] for energy management produced by an autonomous Solar PV -Wind hybrid system. The implementation of the MPPT algorithm based on the incremental conductance method has been presented in

paper [6] for a Cuck - type DC/DC converter. The enhancement of the performances of the photovoltaic systems has been obtained through the usage of the MPPT algorithm of the incremental conductance with fuzzy logic controller. The works [7] and [8] have presented the algorithm mentioned above for controlling a DC/DC buck converter. This article presents the implementation of the MPPT algorithm of the incremental conductance with fuzzy logic controller in MATLAB/Simulink for controlling a DC/DC boost converter.

2. DESIGN ELEMENTS OF THE DC/DC BOOST CONVERTER

The electric diagram of a voltage lifting converter supplied from a photovoltaic system is shown at Fig. 1. For designing this type of converter the following design data have been required: minimum input voltage $U_{int_min} = 26$ V.c.c., output voltage $U_{ies} = 50$ V.c.c., intensity of the load current $I_{ies} = 8$ A, switching frequency $F_{SW} = 25000$ Hz, power $P = 400$ W, effectiveness $\eta = 0,95$, the percentage from the output voltage for calculating the ripple voltage is equal to 1. The design elements of the DC/DC Boost converter are: a) The filling factor D for the PWM control signal of the power transistor in the circuit of the voltage lifting converter is determined through the relation:

$$D = \left[1 - \frac{(U_{int_min} * \eta)}{U_{ies}} \right] \% \quad (1)$$

b) The output current is calculated with the relation:

$$I_{ies} = \frac{P}{U_{ies}} \quad (2)$$

c) The value of the input current I_{in} results from the relation: $P = I_{in} U_{in} = I_{ies} U_{ies}$

$$I_{in} = \frac{P}{U_{in}} \quad (3)$$

d) The value of the input current I_{in} will be equal to the current rate in the coil. The ripple current of the inductance L will be equal to 20% of the input current.

$$\Delta I_L = 20\% * I_{in} \quad (4)$$

e) The inductance L is calculated through the relation:

$$L = \frac{U_{int} * D}{\Delta I_L * F_{SW}} \quad (5)$$

f) The value of the ripple voltage ΔU_{ies} will be equal to 1% of the value of the output voltage:

$$\Delta U_{ies} = 0,01 * U_{ies} \quad (6)$$

g) The output capacity C is calculated through the relation:

$$C = \frac{I * D}{F_{SW} * \Delta U_{ies}} \quad (7)$$

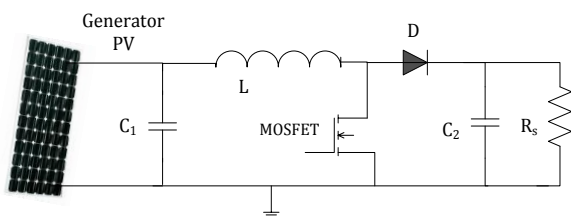


Fig. 1 Block diagram of the boost converter

h) The load resistance is calculated as below:

$$R = \frac{U_{ies}}{I_{ies}} \quad (8)$$

After performing the calculations, the values were obtained: $D = 50,60\%$, $I_{ies} = 8 A$, $I_{in} = 15,38 A$, $\Delta I_L = 3,07 A$, $L = 171,41 * 10^{-6} H$, $\Delta U_{ies} = 0,50 V$, $C = 316,16 * 10^{-6} F$, $R = 6,25 \Omega$

3. MPPT ALGORITHM OF THE INCREMENTAL CONDUCTANCE WITH FUZZY LOGIC CONTROLLER

3.1 MPPT (Maximum Power Point Tracking) Algorithm of the Incremental Conductance

The algorithm of the incremental conductance consists of following up the value of the power derivate in relation to the voltage and settling the result to zero [6].

$$\frac{dP}{dU} = \frac{d(UI)}{dU} = I + U \frac{dI}{dU} = 0 \quad (9)$$

For determining the maximum running point the solution to the above equation needs to be found. If the equation of the power derivate in relation to voltage is made equal to zero, it will result

$$-\frac{I}{U} = \frac{dI}{dU} \quad (10)$$

where: $-\frac{I}{U}$ means the opposite of the instant conductance of the photovoltaic panel, whilst the right side means the incremental conductance, i.e. the modification of the current in relation to voltage (dI/dU). The two amounts

will be equal in absolute sizes at the running of the system in the point of maximum power, $\frac{dI}{dU} = -\frac{I}{U}$. For the running point to be settled at the maximum power point (MPP), the following algorithm will be used: a) from the equation (10) the following set of inequalities will be determined:

$$\frac{dI}{dU} = -\frac{I}{U} \quad \left(\frac{dP}{dU} = 0\right) \quad (11.a)$$

$$\frac{dI}{dU} > -\frac{I}{U} \quad \left(\frac{dP}{dU} > 0\right) \quad (11.b) \quad (11)$$

$$\frac{dI}{dU} < -\frac{I}{U} \quad \left(\frac{dP}{dU} < 0\right) \quad (11.c)$$

b) The equations 11 (b and c) are used for determining to what direction a displacement of the running point has to be done towards MPP. c) The algorithm will repeat until the condition (11.a) is fulfilled. Once MPP is reached, MPPT continues to run until the moment when a change occurs in the current being measured. This change in current is related to the change of the intensity of the solar radiation on the photovoltaic panel. The logic diagram of the iterative algorithm of the incremental conductance is presented at Fig. 2.

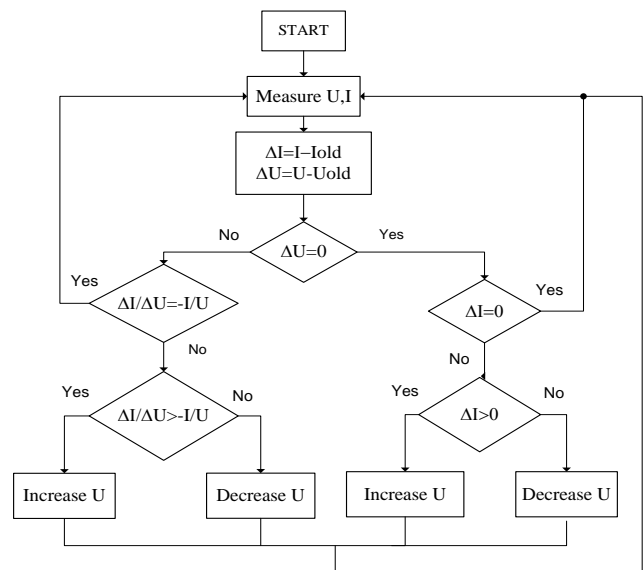


Fig. 2 MPPT Algorithm "Incremental Conductance"

3.2 Implementing in MATLAB Simulink the MPPT Algorithm of the Incremental Conductance with Fuzzy Logic Controller

The photovoltaic system is composed of two photovoltaic panels of type Soltech 1STH-225-P that have the following features: $P_{max} = 224.36 W$, $V_{max} = 29,6 V$, $I_{max} = 7,58 A$. The model in MATLAB Simulink for the DC/DC boost converter of the photovoltaic system where the MPPT algorithm of the incremental conductance with

fuzzy logic controller has been implemented is illustrated at Fig. 3.

as per Fig. 3. The fuzzy logic controller will have two input values: error $E(k)$ and error derivate $dE(k)$, as well as an

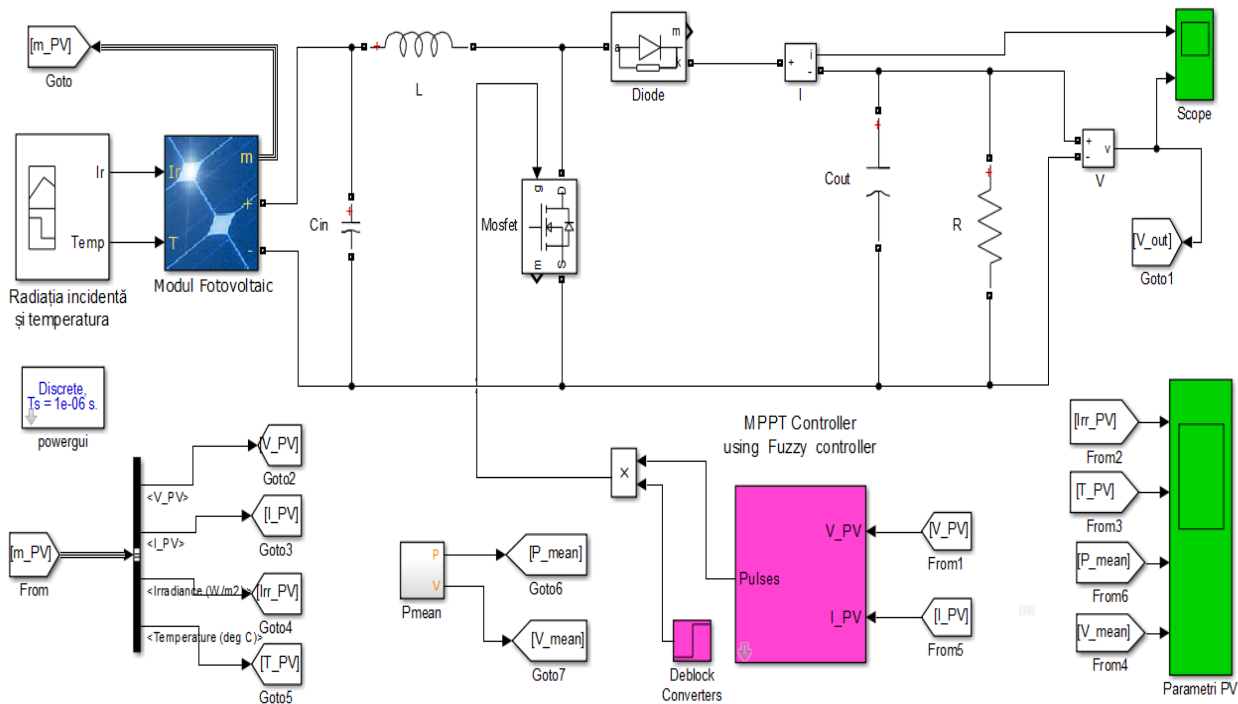


Fig. 3 Model in MATLAB Simulink of the DC-DC boost converter controlled through the MPPT algorithm of the incremental conductance with fuzzy logic controller

The model includes the following basic components:

- Photovoltaic system
- Module that generates the variation of the solar radiation intensity and environmental temperature
- DC/DC boost converter
- MPPT algorithm of the incremental conductance with fuzzy logic controller

For the photovoltaic panels the diagrams $I = f(U)$ and $P = f(U)$ are presented at Fig. 4. From the diagram $P = f(U)$ the coordinates of the maximum power point have been determined, i.e.: $P_{max} = 448.7 W$, $V_{max} = 29,6 V$.

3.3 Synthesis of the Fuzzy Logic Controller in the Structure of the MATLAB Simulink Model

The MATLAB Simulink model allows the measurement of the photovoltaic system parameters: voltage V_{PV} and

current intensity I_{PV} . With the help of these variables the algorithm of the incremental conductance is implemented in MATLAB Simulink, as shown in the diagram at Fig. 2 that belongs to the MPPT controller subsystem using Fuzzy controller

$$E(k) = \frac{\Delta I}{\Delta U} + \frac{I}{U}$$

$$dE(k) = E(k) - E(k - 1) \tag{12}$$

$$\Delta I = I(k) - I(k - 1)$$

$$\Delta U = U(k) - U(k - 1)$$

$$\Delta P = P(k) - P(k - 1)$$

The basis of rules for the fuzzy logic controller is presented at Table 1. This basis of rules has been created into a file with the .fis extension, with the help of the Fuzzy Logic Designer subprogram. The diagram of the incremental conductance algorithm with fuzzy logic controller is presented at Fig. 5.

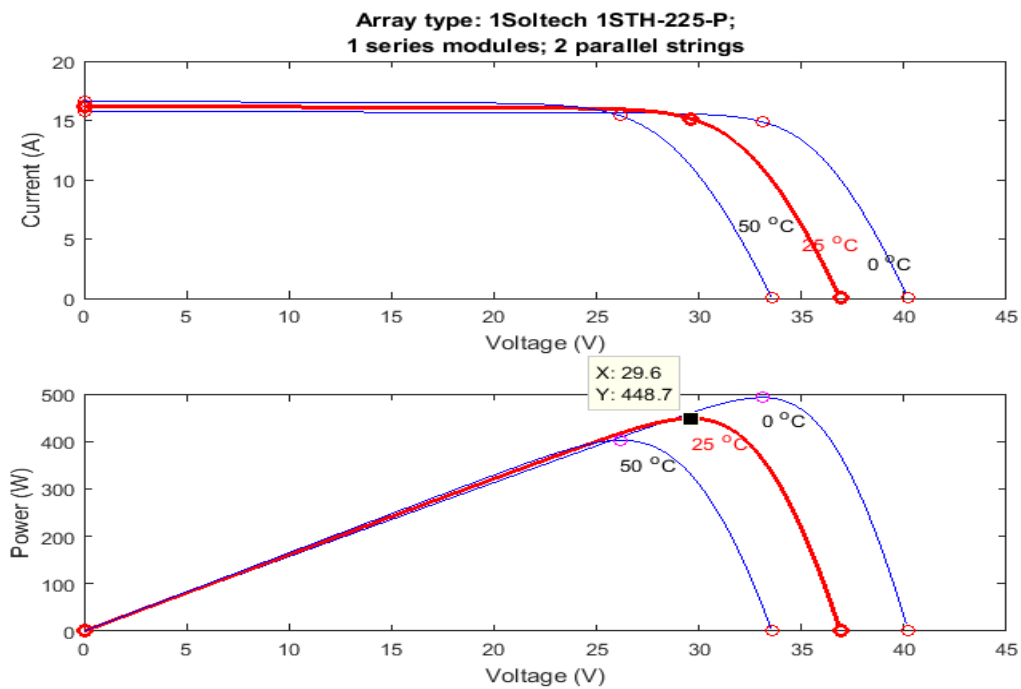


Fig. 4 I-V and P-V diagrams of the photovoltaic system in MATLAB Simulink model

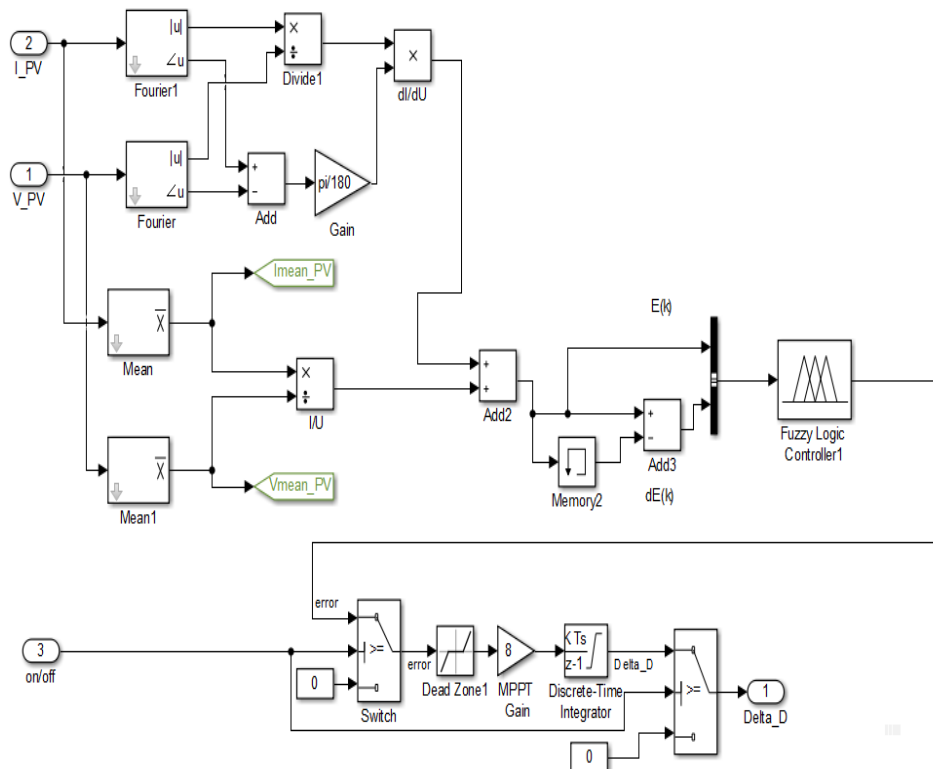


Fig. 5 Diagram of the incremental conductance algorithm with fuzzy logic controller

Table 1 The basis of rules

		E(k)						
		NB	NM	NS	ZE	PS	PM	PB
dE(k)	PB	ZE	PS	PM	PB	PB	PB	PB
	PM	NS	ZE	PS	PM	PB	PB	PB
	PS	NM	NS	ZE	PS	PM	PB	PB
	ZE	NB	NM	NS	ZE	PS	PM	PB
	NS	NB	NB	NM	NS	ZE	PS	PM
	NM	NB	NB	NB	NM	NS	ZE	PS
	NB	NB	NB	NB	NB	NM	NS	ZE

For the input variables the membership functions presented at Fig. 6 have been considered. For the output variable the membership functions presented at Fig. 7 have been considered.

The structure of the fuzzy logic controller is presented at Fig. 8. For de-fuzzifying, the method of the gravity centre has been used. The output signal from the fuzzy logic controller is used for shaping the Delta_D signal used further on into the subsystem for generating the filling factor of the PWM control signal of the power transistor in the structure of the DC/DC boost converter. The subsystem for generating the PWM signal is shown at Fig. 9.

4. EXPERIMENTAL RESULTS

After running the simulation program in MATLAB Simulink for the model presented at Fig. 3 the following results shown in Figures 10 and 11 were obtained. In figure 10 for the variation of the solar radiation intensity from fig. 10.a and the temperature variation from figure 10.b considered as perturbations for the photovoltaic system were obtained the variations of the power provided by the photovoltaic system, (fig. 10.c) and the variation of the voltage of the photovoltaic system (fig. 10.d).

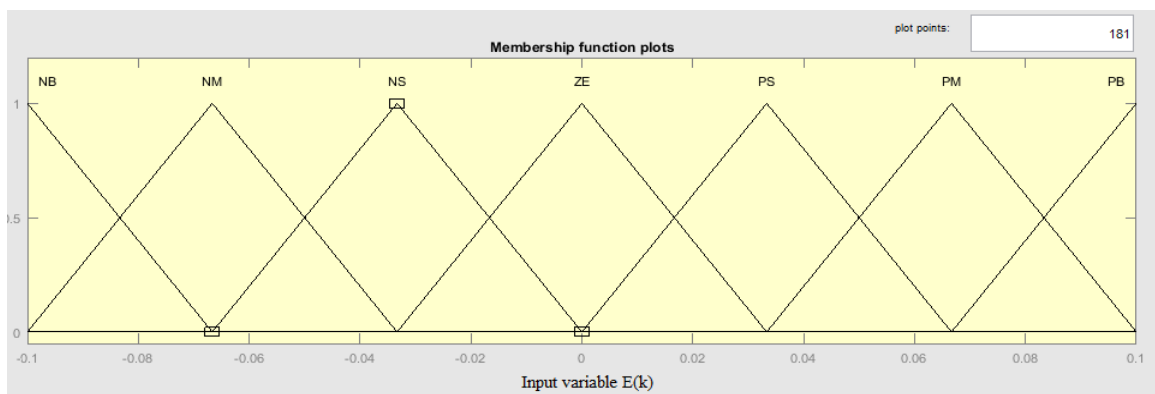


Fig. 6 Membership functions for the input variables E(k) and dE(k)

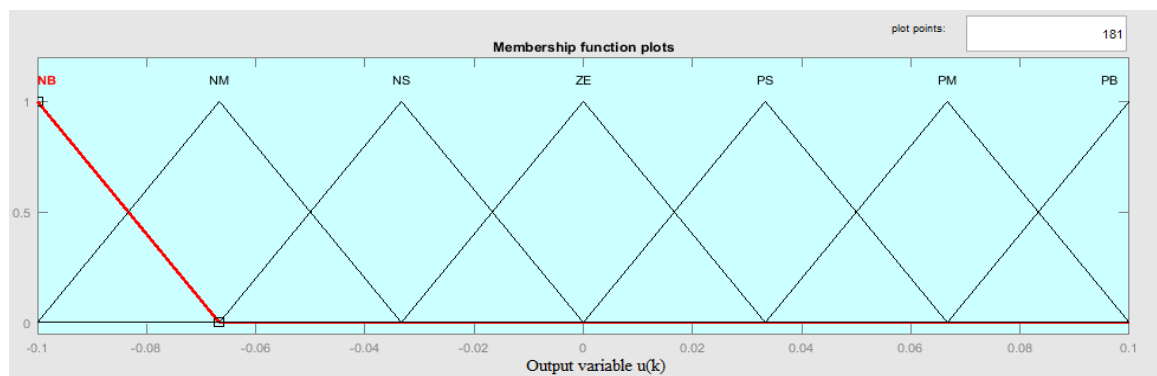


Fig. 7 Membership functions for the output variable u(k)

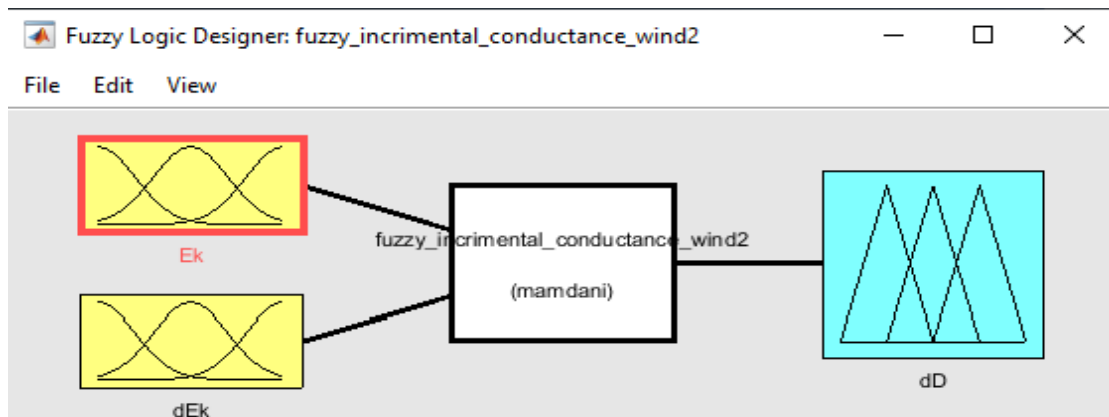


Fig. 8 Structure of the fuzzy logic controller

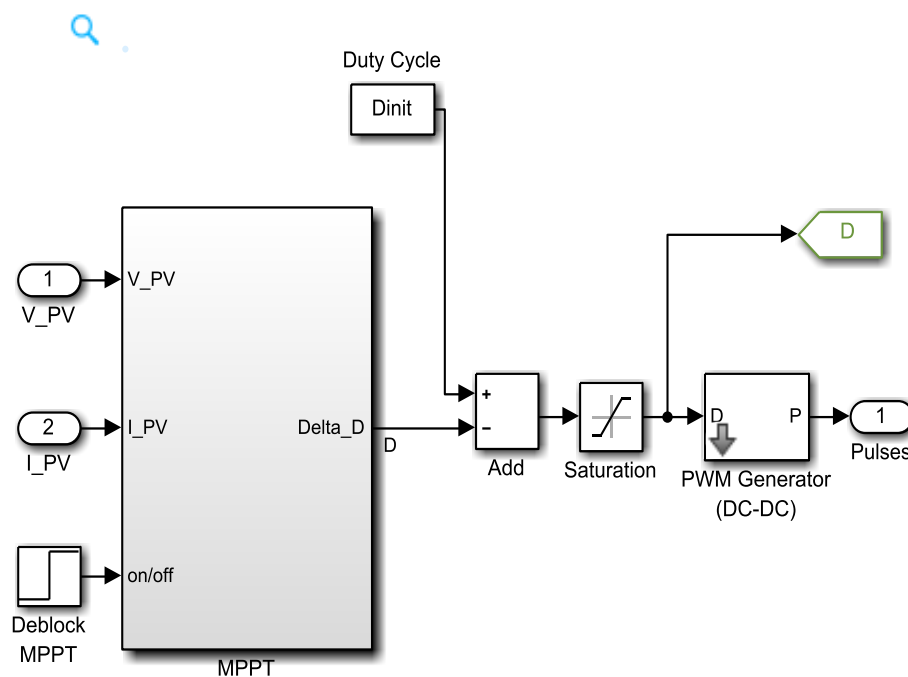


Fig. 9 Subsystem for generating the PWM signal

In Fig. 11 was presented the variations of the current and the voltage on a load of resistive type at the control of the DC/DC boost converter through the MPPT algorithm of incremental conductance with fuzzy logic controller. The values of current and voltage on a resistive load depend on the variation of the intensity of the solar radiation from Fig. 10.a and the temperature variation from Fig. 10.b.

5. CONCLUSIONS

The purpose of this article was to develop a model in MATLAB Simulink for the DC-DC boost converter controlled by the MPPT algorithm of incremental conductance with fuzzy logic controller. The model

contains the following basic components: a) Photovoltaic system; b) Module that generates the variation of the solar radiation intensity and environmental temperature; c) DC/DC boost converter; d) MPPT algorithm of the incremental conductance with fuzzy logic controller. Following the analysis of the simulation results for the MATLAB Simulink model of the DC-DC boost converter controlled by the MPPT algorithm of incremental conductance with fuzzy logic controller, it was found that the implementation of this algorithm ensures optimal operation of the photovoltaic system for a large variation of the intensity of solar radiation and maximum power transfer from photovoltaic panels to a resistive load.

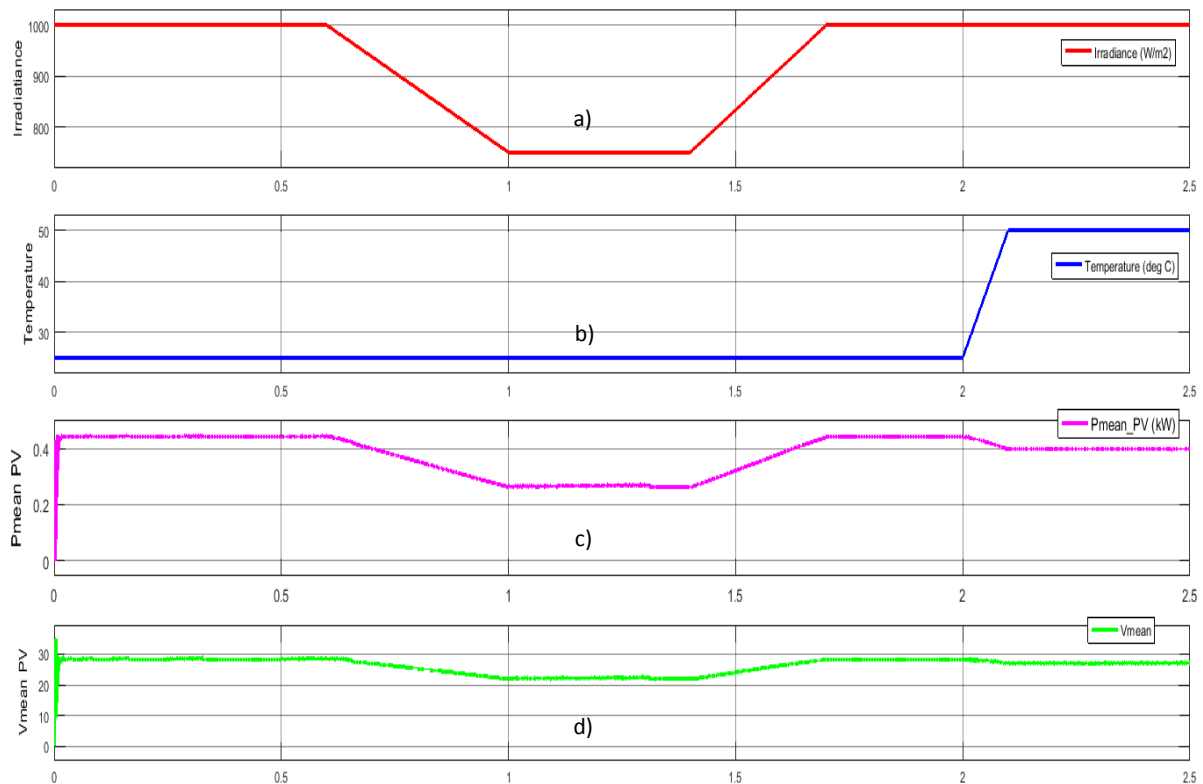


Fig. 10 Variation of the solar intensity - Fig. 10.a; Temperature variation - Fig. 10.b; Variation of power supplied by the photovoltaic - Fig. 10.c; Variation of the photovoltaic system voltage - Fig. 10.d

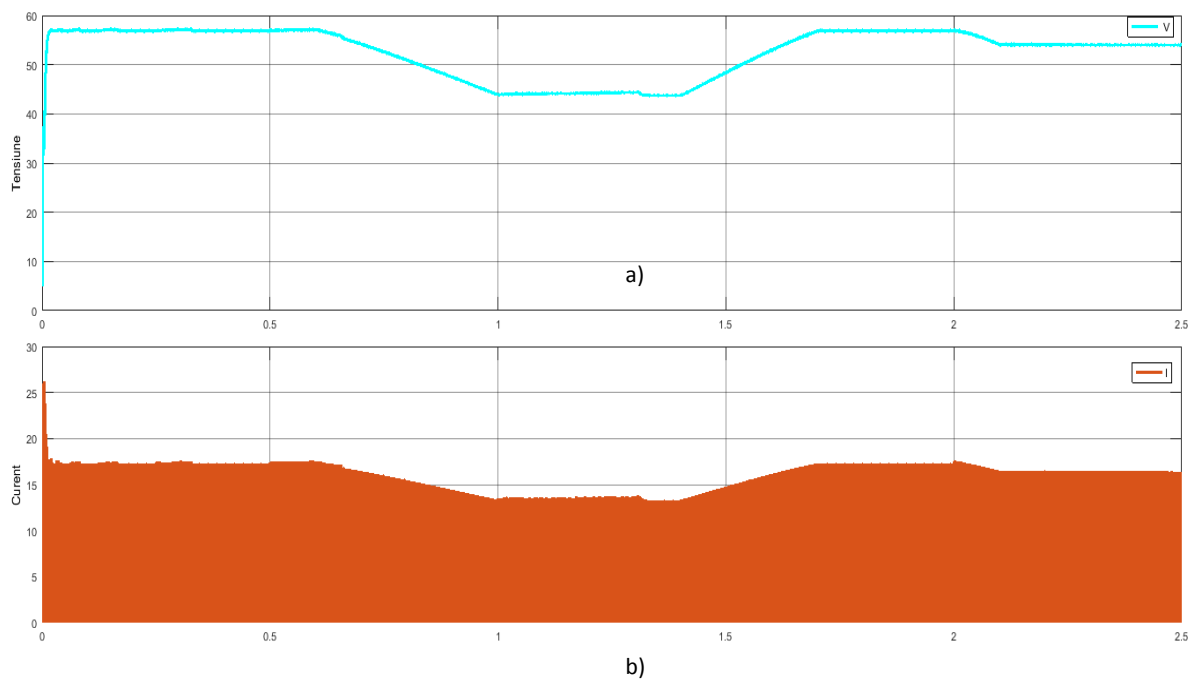


Fig. 11 Variation of the current intensity and voltage on a load of resistive type during the control of the DC/DC boost converter through the MPPT algorithm of the incremental conductance and fuzzy logic controller (Fig. 11.a - voltage variation, Fig. 11.b. - current intensity variation)

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