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Control of a DC/DC Buck Converter by Fuzzy Logic of a Pumping Solar System

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Abstract

The exploitation of the solar energy is very significant for Algeria (a very sunny country). Moreover the dryness phenomenon in this country imposes more and more the use of pumping plants. In our work, we propose a technique for the identification of the Maximum Power Point (MPP) based on fuzzy logic. This method is used to generate the cyclic ratio to operate the switcher within the maximum power of a photovoltaic array (PV). For simulation purpose we made a complete modeling of the entire system. The system carried out consists of a photovoltaic generator supplying, through a DC converter, a direct current (DC) engine coupled to a centrifugal pump. Our experimental bench consists of two principal units. A DC converter module composed of IGBT power transistors. And a processing module connected to a PC serial port, handling the input signals delivered by photovoltaic generator and controlling the power unit. The obtained experimental results show on the one hand the utility of the fuzzy controller for the optimization of the system, and on the other hand the match with the results of simulation which is very satisfactory.

Keywords: *Pumping, Fuzzy Logic, MPPT, Photovoltaic array, Cyclic Ratio, DC Converter.*

1. Introduction

The PV arrays represent a system providing a non-linear power. It's requires a real time identification and the tracking of the maximum operation point. This maximum power point varies largely in time according to the climatic conditions such as the sunning and the temperature. The simulation of the system (figure 1) was carried out in [1]. The purpose was to determine a model of the maximum power tracker device relating to the events, where which the regulator must react, i.e. the change of sunning, and relating to the events, where which the regulator must produce, i.e. the variation of the cyclic ratio. Several MPPT were carried out and implemented on microprocessors and micro-controllers by using various control strategies [2]. In our work, we propose a method of the MPP identification based on fuzzy logic. Who will be used to generate the cyclic ratio to operate the DC converter on the maximum power of the PV arrays

I. Followed process

I.1. Presentation of the simulated system

The bloc diagram of the maximum power point tracking system is composed of a PV arrays, a DC converter and a load represented by an engine coupled to a pump. The point of optimum power is controlled by the cyclic ratio generated by the fuzzy controller whose the inputs are the voltage and the current of the PV arrays (figure 1).

Before synthesis of control law, it is necessary to analyze the process to check and establish a suitable model. Regarding the Photovoltaic array, we considered an input, current and two voltage vectors measured experimentally (I1, V1) to specific climatic conditions of operation, sunshine and temperature, respectively.

The characteristic (I1, V1) obtained practically does not operate at nominal power point optimum for our office, hence the need for sizing of a Photovoltaic array.

The characteristic size of the simulation was to multiply currents and voltages recorded by the characteristic coefficients Ki (constant current) and Kv (constant voltage) properly chosen. The translation of formulas (1), (2) would provide the characteristic temperature T2 and E2 sunshine, from a typical reference found practically at the temperature T1 and E1 sunshine.

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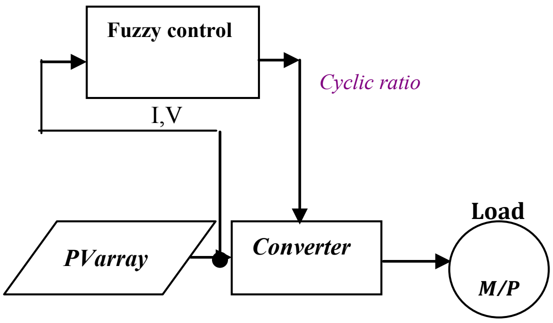


Fig. 1. Bloc diagram of the MPP

$$I_2 = I_1 + I_{cc}(E_2/E_1 - 1) + \alpha(T_2 - T_1) \qquad (1)$$

$$V_2 = V_1 + \beta(T_2 - T_1) - R_s(I_2 - I_1) - kI_2(T_2 - T_1) \qquad (2)$$

With :

α = 1.6e-3
β = -7.8e-2
Rs = 0.4*5 *Ω*
K = 5.5e-3

(I_1, V1) characteristic *to* E1=60% *and* T1=30°C
The load used is a DC motor connected to a centrifugal pump, the engine type dc permanent magnet.
His model is defined by the following two equations:

1. The equation of the electrical circuit induces.

$$V_a = R_a I_a + k\emptyset\Omega + L_a \frac{dI_a}{dt} \qquad (3)$$

2. The mechanical equation

$$k\emptyset I = (A + B\Omega) + J\frac{d\Omega}{dt} + C_c \qquad (4)$$

These parameters are determined from information recorded on the motor nameplate or from practical tests made on the engine. The values of the plate are given for nominal operating conditions:

- **V_a**=180 V
- **I_a**=4.9 A
- **Ω**=1750 r/mn

The electromotive force cons :

$$e = \frac{p}{a} N n \emptyset \qquad (5)$$

N: is the number of conductors,
n: rotational speed of the motor shaft (r / s)
Φ: the flow from a pole
a: has the number of pair of voice coil (voice coil: the circuits that are parallel to the armature brushes).
P: the number of pole pairs.
The constant tension is expressed by K

$$k = N\frac{p}{2\pi a} \qquad (6)$$

We have:

$$e = k\emptyset\omega \qquad (7)$$

The useful power:

$$P_u = C\Omega \qquad (8)$$

- The magnetic torque:

$$C = k\emptyset I \qquad (9)$$

The pump is used centrifugal type. Its torque is a function of speed Ω, and is expressed by equation (10).

$$C_c = a + b\Omega^n \qquad (10)$$

The moment of inertia is approximated to $J_P = 5 \times J_m$, where J_m is the moment of inertia of the engine.

The parameters a, b and n must be chosen so that at the rated speed, or : $\Omega{=}\Omega_n$ and the torque of the pump is equal to the nominal torque C_{mN} .

Where :

$$C_c(\Omega = \Omega_n) = C_{mN} \qquad (11)$$

$$C_{mN} = K_{mN}\Omega_N = 6Nm \qquad (12)$$

The converter used is a step down converter, the model is defined by:

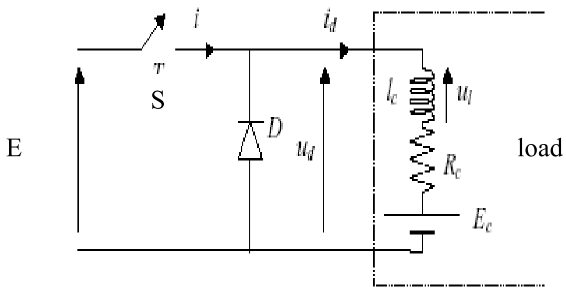


Fig. 2. diagram of the buck converter

It symbolizes our converter by the interruption S.
first case:
0<t<Ton : The switch S is closed, it is given by the following equation :

$$E = R_L i_L + L\frac{di_L}{dt} = V_L(t) \qquad (13)$$

Second case:
Ton <t<T : The switch S is open, it is given by the following equation :

$$R_L i_L + L\frac{di_L}{dt} = V_L(t) = 0 \qquad (14)$$

$$V_{Lmoy} = \frac{1}{T}\int_0^{Ton} V_L(t)\,dt \qquad (15)$$

$$V_{Lmoy} = E\frac{T_{on}}{T} = E\alpha \qquad (16)$$

In our work, E is the voltage of PV array.

α : The cyclic ratio or hash rate ranging from 0 to 1 frequencies of the converter was set at 20 KHz.
The variation in cyclic ratio will be such that V_{Lmoy} equal to the optimum voltage Vopt of PV arrays.

2. Structure of the Developed Setup

The system consists of a photovoltaic generator supplying a DC engine coupled to a centrifugal pump, through an electronic power converter

Allowing the tracking of the optimum operation point. The developed controller is a micro controller based board connected to a PC through the serial port for monitoring purpose figure (3).

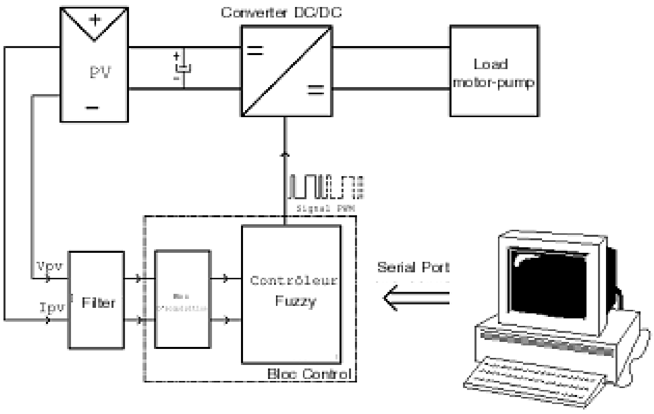


Fig. 3. Test bench set up

3. Control Strategies

3.1 Traditional Technique

This method allows the optimal point tracking of a PV arrays by studying the difference in power between two points of characteristic I-V of PV arrays [6]. We carried out simulation tests, whose results obtained, are presented in the figures below. The figures (4.a) and (4.b) show the variation of the operation power during the tracking regarding a small step and a large step.

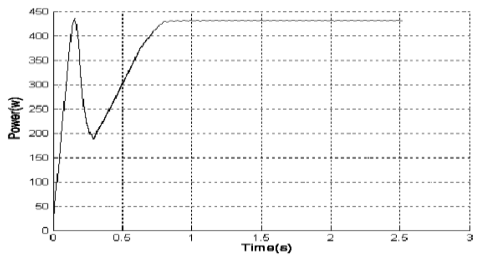


Fig. 4.a. Small step tracking

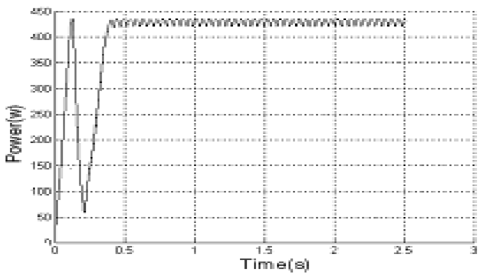


Fig. 4.b. Large step tracking

According to figure 3, we can deduce that for a large tracking step, the response time of the system decreases and the oscillations in static mode increase. In the case of a small tracking step, the response time increases and the oscillations of the power around the optimal point decrease. To improve this tracking a variable step using a fuzzy logic control technique is adopted.

3.2 Fuzzy Control by the dP/dI Variation

This method is based on a ratio calculation between a power variation and a current variation. The block diagram of the regulator is as follows: figure (5)

Where:

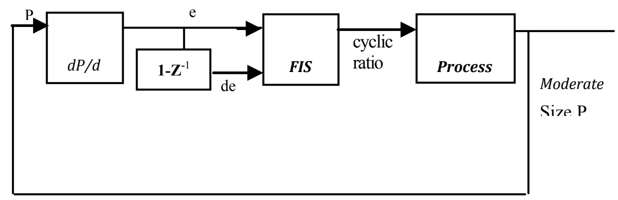


Fig.5. Structure of the fuzzy logic control

$$e = dP/dI = (P(k) - P(k-l)) \ / \ (I(k) - I(k-l)) \quad (17)$$

$$de = e(k) - e(k-l) \quad (18)$$

P: measured power on the PVG.

For the inputs variables, the error and its derivative, we chose five subsets of triangular forms being spread out over the [-1,1] interval. Figure (6)

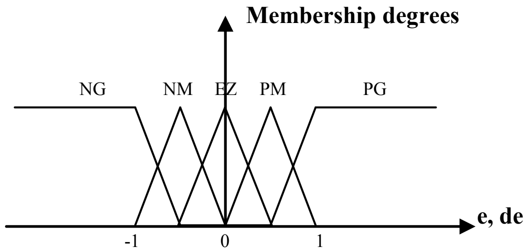


Fig. 6. Membership functions

However the output variable, which is the result of a deduction between the two input values, representing in our controller the cyclic ratio, the room values are spread out between -0.25 and +0.5, with seven subsets for more precision [4]. Figure (7)

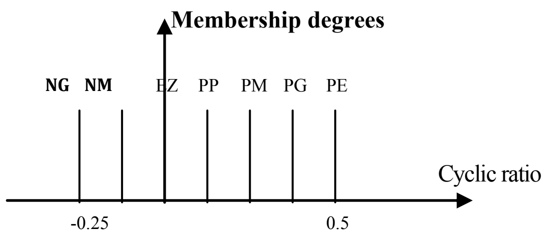


Fig. 7. Fuzzy singletons of the output

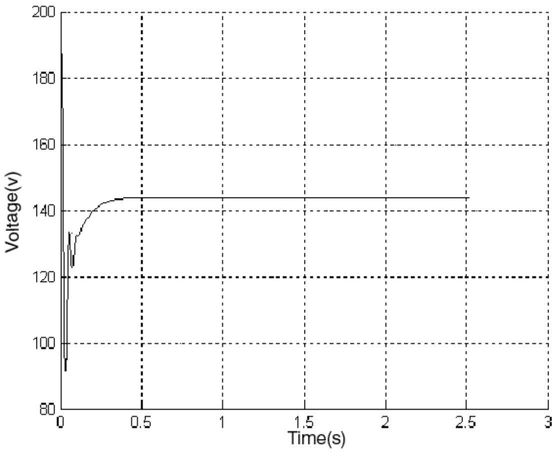
In our regulation, we use the SEGENO logic [4] whose rule is:" IF the error is PM AND derivative is NG THEN the cyclic ratio is NG ".

Were { NL: Negative large, NA: Negative Average, AZ : Approximately Zero, PA: Positive Average, PL: Positive Large } is the total of the subsets [2] . The table below gather the whole fuzzy rules .

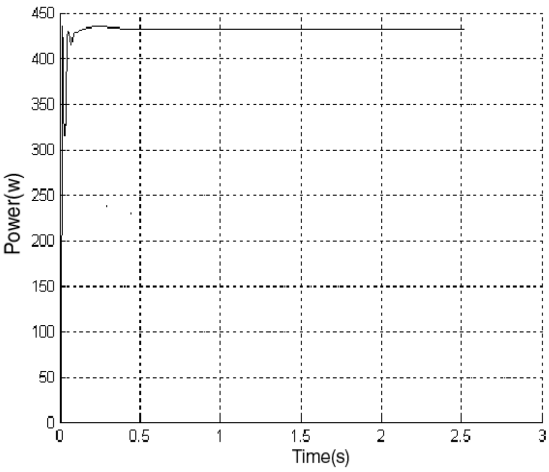
Table 1. Fuzzy rules

e / *de*	*NG*	*NM*	*EZ*	*PM*	*PG*
NG	PG	PP	EZ	NG	NG
NM	PG	PP	EZ	NG	NG
EZ	PE	PM	EZ	NG	NG
PM	PE	PM	PP	NM	NM
PG	PE	PM	PP	NM	NM

The results of the simulation of this fuzzy method are represented through figure (8)



(a)



(b)

Fig. 8. Simulation results: (a) optimal operation power, (b): optimal operation voltage

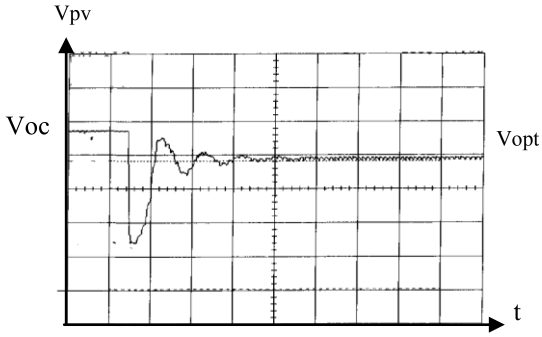


Fig. 9. Optimal operation voltage

To highlight this technique we carried out an experimental t**est** with an initial cyclic ratio of 0.7. The obtained results are indicated in figure (9). Figures (10) show the shape of the current of the PV arrays and the load following an increase in the cyclic ratio. It is noticed that to provide current to the load, we should increase the cyclic ratio, which mean that we should not boost the current beyond the optimal current. More the cyclic ratio increases more the current of charge and discharge of the engine decreases.

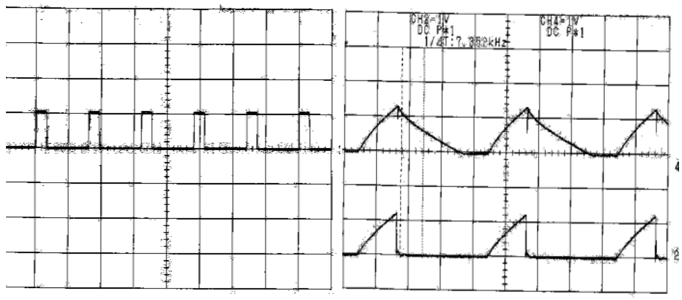


Fig. 10.a. Engine current, PV arrays current for alpha=10%

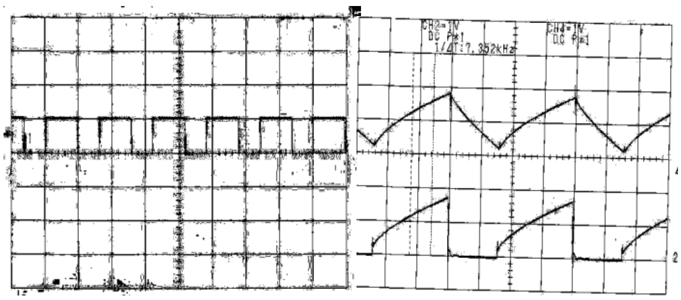


Fig.10.b. Engine current, PV arrays current for alpha=50%

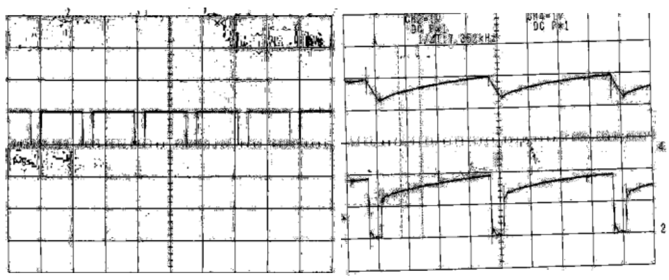


Fig.10,c. Engine current, PV arrays current for alpha=80%

4. Conclusion

With the aim of optimizing the efficiency of photovoltaic generators, by making them working with their maximum power, our contribution efforts are fixed on the development of a linguistic tracking system based on fuzzy logic, ensuring a good adaptation of the load. One of the specificity of the fuzzy regulator proposed is that it does not require a preliminary knowledge of the sunning or the optimum power since the slope dP/dI at the point of operation is only function of this point position compared to the optimal operation point.

We noted that in addition to the optimum power tracking the regulator also allows the optimization of the response time and the reduction of the power oscillations around the optimal point. The obtained experimental results show on the one hand the usefulness of the existence of the fuzzy controller to the system optimization, and on the other hand the match with the simulation results what is very satisfactory.

Technological advances always renovated in the field of power electronics, static converters are gradually their types and modes of change orders and develop new technologies more efficient in quality and response time. We are currently designing a new structure Superbuck step down choppers whose literature is still limited, operating mode CCM (continuous conduction mode) [5], commanded by the PCM (Peak Current Mode).

In conclusion, we can classify this work as a contribution to the integration of Soft-Computing and the artificial intelligence in the field of the exploitation of the energies to improve the performances and to make of them discover the new techniques.

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