OPTIMISATION OF THE PHOTOVOLTAIC GRID CONNECTED SYSTEM USING FUZZY LOGIC CONTROL

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ABSTRACT

This paper presents a maximum power point tracker (MPPT) using fuzzy logic for a PV grid connected system. Since the PV array characteristic is hardly nonlinear, conventional control technics could be inefficient for an optimal use of these systems. Knowing that PV systems are still very expensive, therefore a fuzzy logic controller is proposed to ensure the transfer of the maximam power to the utility grid system. This method has proved its effeciency and robustness inspite of climatic conditions variations.

KEYWORDS: Fuzzy Controller, Grid Connection, Maximum Power Point Tracking, Photovoltaïc Energy.

1 INTRODUCTION

The conventional energy sources, obtained from our environment, tend to exhaust with relative rapidity due to its irrational utilization by the huminity. Renewable energy offers a promising alternative source. Solar energy seems to be most attractive nowadays. The quantity of energy from the sun, that arrives on the earth surface in a day is ten times more than the total energy consumed by all people of our planet during a year [5]. Through the photovoltaic effect the energy contained in the sun light can be converted directly into electrical energy. This method of energy conversion presents somme advantages, such as simplicity, modular consruction, flexibility on utilization, high reliability and low maintenance. In addition, the photovoltaic systems represent a silent, sure, no polluant and renewable source of electric energy. Because of the low effeciency of the solar cell, which is not higher than 20%, the high initial price of the PV installation and the nonlinearity of the I-V, P-V characteristics, the optimal use of such system is important to improve the global conversion effeciency. This operation is known as “Maximum Power Point Tracker” MPPT. In this context the present paper treats the optimisation of a grid connected photovoltaic system using fuzzy logic.

The purpose of the present work is to develop a fuzzy controller to control a DC/AC inverter that forces the phovoltaic array to deliver its maximal power for any value of solar insolation rapidly and precisely without the need to the exact mathematical model of the system. Only the case of constant temperature is considered in this study for seek of simplicity.

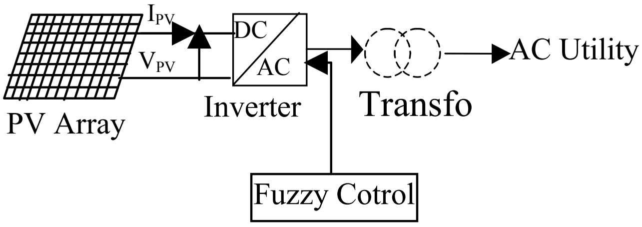


Figure 1 : Photovoltaic system block diagram

2 MODELING OF PV LINE-COMMUTATED INVERTER SCHEME

The power conversion scheme used in the present work is shown in Fig.1. The photovoltaic array is connected to the electric utility via a dc link line-commutated inverter. The PV array transforms the sun light energy directly into electrical energy. Fig.2, shows the typical output Current-Voltage and Power-Voltage characteristics of the PV array. The P-V output characteristics of the PV array show peak power points with solar insolation as a parameter.

The I-V characteristic of the PV array can be represented by the following nonlinear equation [2, 4]:

$$I = I_{sc} - I_o[\exp(\frac{(V + R_s I)}{V_{th}}) - 1] - \frac{(V + R_s I)}{R_{sh}} \quad (1)$$

Where :

I PV array output current,

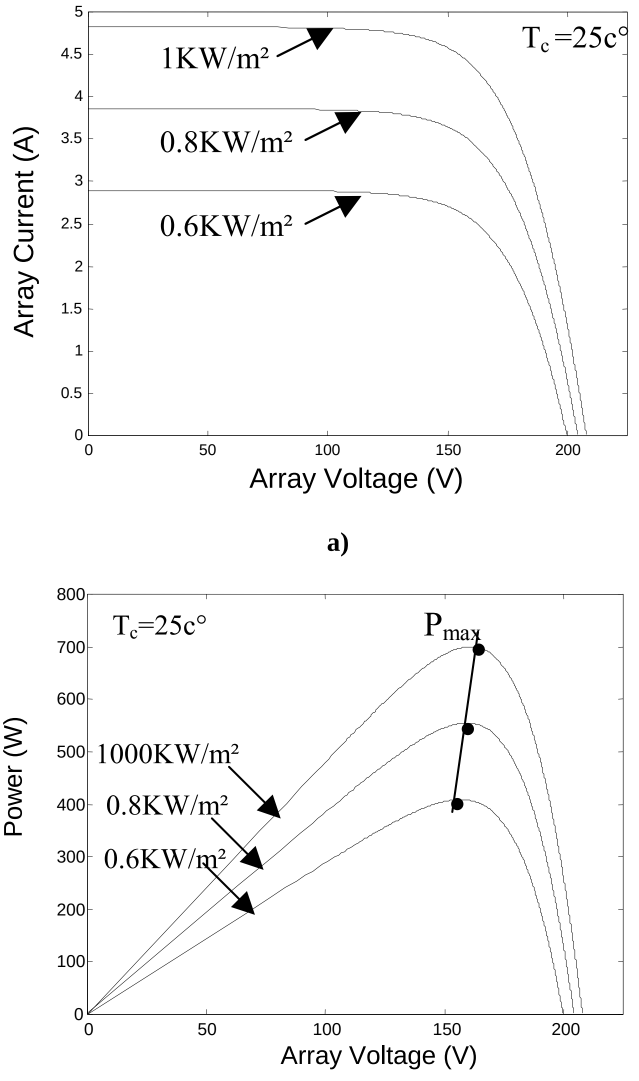
R_{sh} PV array equivalent shunt resistance,

I_{sc} PV array short circuit current,

I_o PV array reverse saturation current,

R_s PV array series resistance,

V_{th} PV array thermic voltage.



a)

b)

Figure 2 : Charactéristics a) current-voltage b) power-voltage.

The pararneters of the PV array which identify equation (1) are related to the pararneters of the solar panel as follow [8]:

$$I_{sc}=N_p I_{sc\,\text{panel}} \tag{2}$$

$$I_o=N_p I_{o\,\text{panel}} \tag{3}$$

$$V_{th}=N_s V_{th\,\text{panel}} \tag{4}$$

$$R_s=\frac{N_s}{N_p}R_{s\,\text{panel}} \tag{5}$$

$$R_{sh}=\frac{N_s}{N_p}R_{sh\,\text{panel}} \tag{6}$$

The thermic voltage V_{th} and the reverse saturation current I_o are successively identified by [2, 6] :

$$V_{th}=\frac{(V_{op}+R_s I_{op}-V_{oc})}{\log(1-\frac{I_{op}}{I_{sc}})} \tag{7}$$

$$I_o=(I_{sc}-I_{op})\exp(-\frac{(V_{op}+R_s I_{op})}{V_{th}}) \tag{8}$$

To adapt equation (1) for other levels of solar insolation and temperature we can utilize the SANDSTROM model [6]. This model translates the reference point (I_{ref}, V_{ref}) to a new point (I, V) via equations (9) to (13) :

$$\Delta T=T-Tref \tag{9}$$

$$\Delta I=\alpha(E/E_{ref})\Delta T+(E/E_{ref}-1)I_{sc} \tag{10}$$

$$\Delta V=-\beta\Delta T-R_s\Delta I \tag{11}$$

$$V=V_{ref}+\Delta V \tag{12}$$

$$I=I_{ref}+\Delta I \tag{13}$$

The maximum power operating point in Fig.2 is determined for different solar insolation levels E using least square method. It is represented by a second order polynom, assuming constant cell temperature.

$$P_{ref}=-78.0549+0.9003E-0.0001E^2 \tag{14}$$

The output power of the PV array is given as :

$$P_{PV}=V_{PV}\cdot I_{PV} \tag{15}$$

3 FUZZY CONTROL

The development of fuzzy sets theory and algorithms makes it possible to build a control system based on a verry general kind of inexact information. In the present study, we have chosen a fuzzy controller which has two input variables which are power error PE and its change CPE and one output variable used to adjust the line-commutated inverter firing angle α_I [3, 7].

$$PE(K)=ge[\frac{(p_{ref}(K)-P_{pv}(K))}{P^*_{ref}}] \tag{16}$$

K : Time instation.

P^*_{ref} :Maximum available power of the PV array at

E= 1000W/m².

It will be normalised in the interval [-0.14, 1].

$$CPE(k) = gde[PE(k) - PE(k-1)] \tag{17}$$

It will be normalised in the interval [-11,1].

$$\Delta\alpha(k) = \alpha(k) - \alpha(k-1) \tag{18}$$

It will be normalised in the interval [0,1].

The membership functions used in the present paper are assigned using the following 9 basic fuzzy subsets.

1) error

NB = (-0.14 -0.12 -0.11 -0.1)
NM = (-0.1 -0.09 -0.08 -0.07)
NS = (-0.07 -0.06 -0.05 -0.04)
NZ = (-0.04 -0.03 -0.02 -0.009)
ZE = (-0.009 -0.006 -0.004 0)
PZ = (0 0.004 0.09 0.1)
PS = (0.1 0.2 0.3 0.4)
PM = (0.4 0.5 0.55 0.6)
PB = (0.6 0.7 0.8 1)

2) Error change

NB = (-11 -10.999 -10.7 -1.05)
NM = (-1.05 -0.02 -0.005 -0.002)
NS = (-0.002 -0.0015 -0.001 0)
NZ = (0 0.1 0.15 0.2)
ZE = (0.2 0.25 0.3 0.35)
PZ = (0.35 0.4 0.45 0.55)
PS =(0.55 0.58 0.6 0.65)
PM =(0.65 0.7 0.77 0.8)
PB = (0.8 0.85 0.95 1)

3) Control signal

NB =(0 0.001 0.005 0.009)
NM = (0.005 0.009 0.02 0.03)
NS = (0.02 0.03 0.05 0.07)
NZ = (0.05 0.07 0.1 0.2)
ZE = (0.1 0.2 0.28 0.3)
PZ = (0.28 0.3 0.35 0.4)
PS = (0.35 0.4 0.45 0.5)
PM = (0.45 0.5 0.6 0.65)
PB = (0.6 0.65 0.8 1)

The signals NB, NM, NS, NZ, ZE, PZ, PS, PM, PB mean successively negative big, negative medium, negative small, negative zero, zero, positive zero, positive small, positive medium and positive big.

4 RESULTS AND DISCUSSION

The simulation have been done on a simplified model of a grid connected photovoltaic array via a dc link line-commutated inverter. The system efficiency can be evaluated by calculating the power ratio λ between the output power and the reference power which represents the maximum power that can be generated under given conditions which is given as [1] :

$$\lambda = \frac{\sum P_{sor}}{\sum P_{ref}} * 100(\%) \tag{19}$$

A. 1st Case : 17 rules

17 rule base utilized in this application to decide the final control action. The rules are given as follows :

1) If (PE is NB and CPE is (from NS to PB)) then $\Delta\alpha$ is PB.

2) If (PE is (from NB to NM) and CPE is NS) then $\Delta\alpha$ is PM.

3) If (PE is NP and CPE and(from NZ to PS)) then $\Delta\alpha$ is PM.

4) If (PE is NZ and CPE and (from PM to PG))then $\Delta\alpha$ is PM.

5) If (PE is NZ and CPE and (from NG to NM)) then $\Delta\alpha$ is NM.

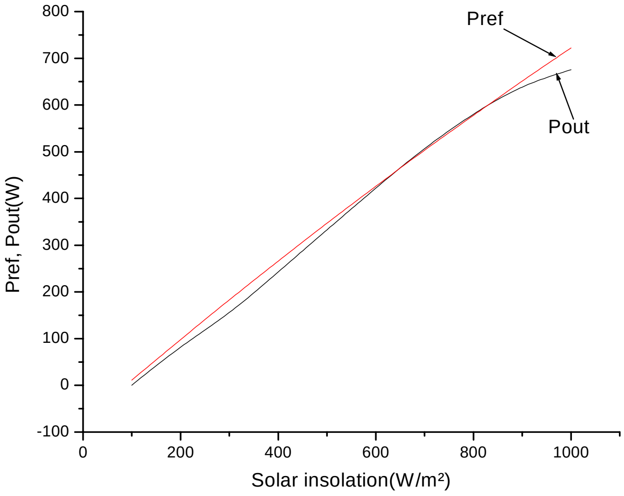


Figure 3 : Comparison between reference power and the output power.

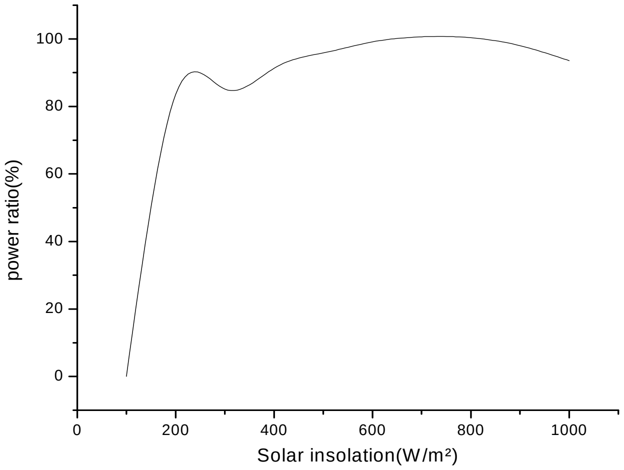


Figure 4 : Power ratio.

After the analysis of Fig.3-4, the most important remarks are :

Its clear that the output power P_{out} and the reference power P_{ref} are similar. This assures the complete use of availble solar energy. The power ratio take a low value at the beginning, which is due to the choice of the initial conditions with α=90°, that is to say there is no output power obtained at start-up. It is evaluated approximately to 96% which translates the efficiency of the fuzzy controller. The system for 17 rules can be applied in the medium insolation areas.

B. 2^{end} Case : 18 rules

1) If (PE is NG and CPE is (from NP to PG)) then $\Delta\alpha$ is PG.

2) If (PE is (from NG to NM) and CPE is NP) then $\Delta\alpha$ is PM

3) If (PE is NP and CPE is (from NZ to PS)) then $\Delta\alpha$ is PM

4) If (PE is NZ and CPE is (from PM to PB)) then $\Delta\alpha$ is PM

5) If (PE is NZ and CPE is (from NG to NM)) then $\Delta\alpha$ is NM

6) If (PE is NZ and CPE is NZ) then $\Delta\alpha$ is NZ

In this case, the power ratio was evaluated λ =*94.92%.*

We can interpretate the system of 18 rules Fig. 5-6, in the same maner as the system of 17 rules but in this case we remark that for high values of solar insolation the two curves P_{ref} and P_{out} are similar. The power ratio is approximately to 95%, this case is preferable in high insolation ereas.

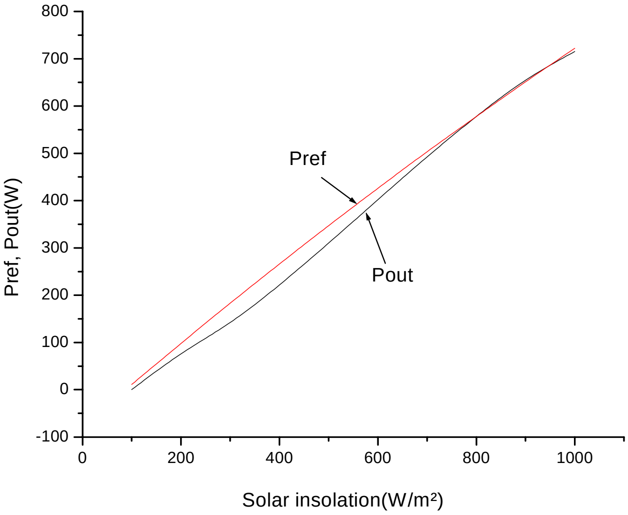


Figure 5 : Comparison between reference power and the output power.

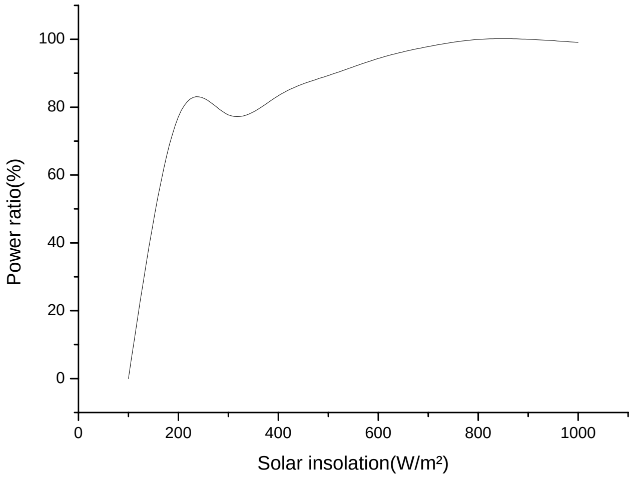


Figure 6 : Power ratio.

5 CONCLUSIONS

The proposed system has been controled using a fuzzy logic controller to track the maximum power availble at the output the PV array regardless of solar insolation. The maximum power is transfered to the utility via a line-commutated inverter. The fuzzy control gave an acceptable results for the two cases :

For 17 rules, the simulation results where very good for the medium values of solar insolation.

For 18 rules, this case is preferable for high values of solar insolation. We notify that this study was considered for constant temperature.

These two systems can be applied for all values of solar insolation because the power ratio is high for the two cases. Due to its natural robustness, fuzzy controller is naturally suited for this type of application where an exact model is impossible to achieve.

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APPONDIX

PV solar panels used in this study are the AEG-40 type which has the characteristics for 1000(w/m²) and 25^0c as follow:

Maximum power = 38.4W.
Short-circuit current = 2.41A.
Open circuit voltage = 22.4V.
Optimum current = 2.2A.
Optimum voltage = 17.45V.
Series resistance = 0.45Ω.