MAXIMUM POWER POINT TRACKER USING GENETIC FUZZY CONTROLLER FOR PHOTOVOLTAIC GRID CONNECTED ARRAY

N.TKOUTI(1), A.MOUSSI(2)

(1,2)Electrical engineering department University of Biskra, Algeria
tkoutinacira_basmala@yahoo.fr(1), moussi_am@hotmail.com(2)

ABSTRACT

paper presents a fuzzy logic controller (FLC) used as a maximum power point tracker(MPPT) of a line commutated inverter in a photovoltaic (PV) grid connected system, under variable irradiance conditions. The purpose is to find the relationship between the maximum power point (MPP) and weather parameters and track the MPP and transferring the maximum power to utility grid. The design of control rules were found by genetic algorithms (GAs) to modulate the firing angle of the inverter for tracking the MPP. Simulation results prove the superior tracking efficiency of the fuzzy controller optimized under variable parameters.

KEYWORDS: Fuzzy Controller, Genetic Algorithm, Grid Connection, Maximum Power Point Tracking, Photovoltaic Energy. Weather conditions.

1 INTRODUCTION

As the world energy demand will increase up to 53% by 2035, the usage of renewable energy has been steadily increasing over the past few years to help solving acute problems of energy and environmental concerns especially global worming[1].Among the available renewable sources, solar energy is one of the most promising nowadays. The international energy agency (IEA) estimates that by 2050, photovoltaics (PV) will provide around 11% of global electricity production and would avoid 2.3 Gt of CO_2 emissions per year [2]. Solar arrays used to convert sunlight into electricity (photovoltaic or PV arrays) scale every well from very small sizes for calculators to very large sizes used in centralized power plants. Another benefit of solar energy is that the PV arrays contain no moving parts and can last several decades before needing to be replaced [3].

In the other hand PV generation systems have two major problems, the conversion efficiency of electric power generation is very low (from 12% in ordinary units up to a maximum of 42.8% in very special setups), especially under low irradiation conditions, and the amount of electric power generated by solar arrays depends on many extrinsic factors, such as isolation (incident solar radiation) levels, temperature, ageing and load conditions [4].In this environment, maximum power point tracking (MPPT) controllers are becoming an essential element in PV systems.

Many tracking control strategies have been proposed among them constant voltage method [5] perturb and observe (P&O) method [6], the incremental conductance method [7] etc. The P&O MPPT algorithm is mostly used, it is relatively simple to implement, but it cannot track the MPP when the irradiance changes rapidly; and it oscillates around the MPP instead of directly tracking it. All these conventional strategies cannot track the MPP in fast changing of environmental conditions.

In [8] the FLC improves tracking performance when compared with the conventional method P&O, then the FLC is compared to the optimized fuzzy logic MPPT controller, this OFLC showed much better performances and robustness. It has not only improved the response time in the transitional state but has also reduced considerably the fluctuations in the steady state under different temperature and irradiance conditions.

The emphasis of this paper is concerned with the design of an advanced maximum power tracking controller which is achieved by implementation of genetic fuzzy control techniques. The genetic algorithm scheme is adopted to extract the best fuzzy rules of the FLC for a power grid connected system for any variation of the solar radiation at a constant temperature.

The paper is organized as follows: in section 2 a brief description of the photovoltaic grid connected system. Section 3 presents the FLC used to control the line commutated inverter and the application of the genetic algorithm to tune the FLC. Section 4 presents the results obtained when applying the genetic FLC.

2 SYSTEM DESCRIPTION

The power conversion scheme used in the present work is shown in Fig.1.

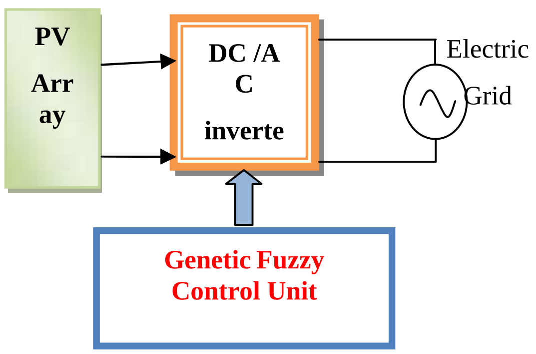

Figure 1: schematic diagram of the solar power plant

The photovoltaic array is connected to the electric utility via a dc link line-commutated inverter. The system is controlled by a FLC automatically designed by means of a genetic algorithm (GA) inspite of disturbances such as changes in the solar radiation level (caused by clouds).The objective of the control system is to maintain the maximum power at the output of the inverter. For a given solar radiation level and temperature the power versus voltage characteristics is shown in fig. 2. It is seen that there is a particular operating point at which the output power is maximum.

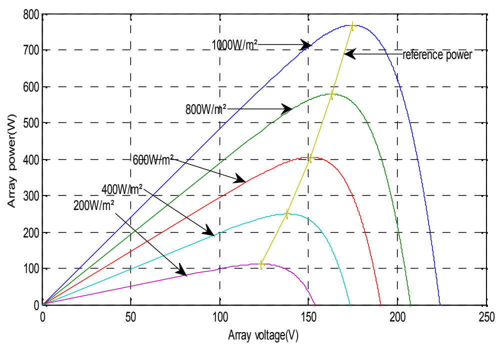

Figure 2: Power voltage characteristics of the PV array at T=25 °C at different solar radiation levels

The I-V characteristic of the PV array can be represented by the following nonlinear equation [9, 10, 11, 12, 13]:

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

Where:

I PV array output current,

Rsh PV array equivalent shunt resistance,

Isc PV array short circuit current.

Io PV array reverse saturation current.

Rs PV array series resistance .

Vth PV array thermal voltage.

The parameters of the PV array which identify equation (1) are related to the parameters of the solar panel as follow :

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

$$I_o = N_p I_o\ \text{panel} \tag{3}$$

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

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

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

The thermal voltage Vth and the reverse saturation current Io is successively identified by:

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

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

To adapt equation (1) for other levels of solar radiation and temperature we can utilize the SANDSTROM model. This model translates the reference point (Iref, Vref) to a new point (I, V) via equations (9) to (13):

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

$$\Delta I = \sim (S/S_{ref})\Delta T + (S/S_{ref} - 1)I_{sc} \tag{10}$$

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

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

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

The maximum power operating point in Fig.2 is determined for different solar radiation levels S using least square method. It is represented by the following polynomial, assuming constant cell temperature (25co).

$$P_{ref} = 0.0002 S^2 + 0.5633 S - 9.6795 \tag{14}$$

3 GENETIC FUZZY SYSTEM

3.1 FLC Design

An incremental fuzzy logic controller, is proposed to the solar power plant. The error E is defined as the difference between the reference power delivered by the PV array Pref and the output power of the inverter Pout. The error and its increment ΔE are considered to be the inputs for the fuzzy controller and the output variable $\Delta\sim$ is the increment to the control signal.

The complete control scheme is depicted in Fig. 3

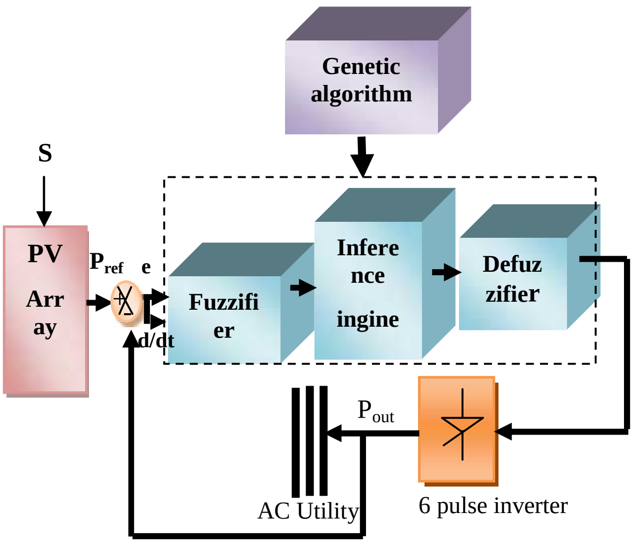

Figure 3: Control scheme for the photovoltaic power plant

Error $E(K) = P_{ref}(K) - P_{out}(K)$ (15)

Cange of error $\Delta E(k) = E(k) - E(k-1)]$ (16)

Change of control signal $\Delta\sim(k) = \sim(k) - \sim(k-1)$ (17)

K: Time instant

The membership functions used in the present paper are assigned using the following 7 basic fuzzy subsets.

Where N, Z, P, NB, NM, NS, ZE, PS, PM, PB are : Negative, Zero, Positive, Negative Big, Negative Medium, Negative Small, Zero, Positive Small, Positive Medium, Positive Big.

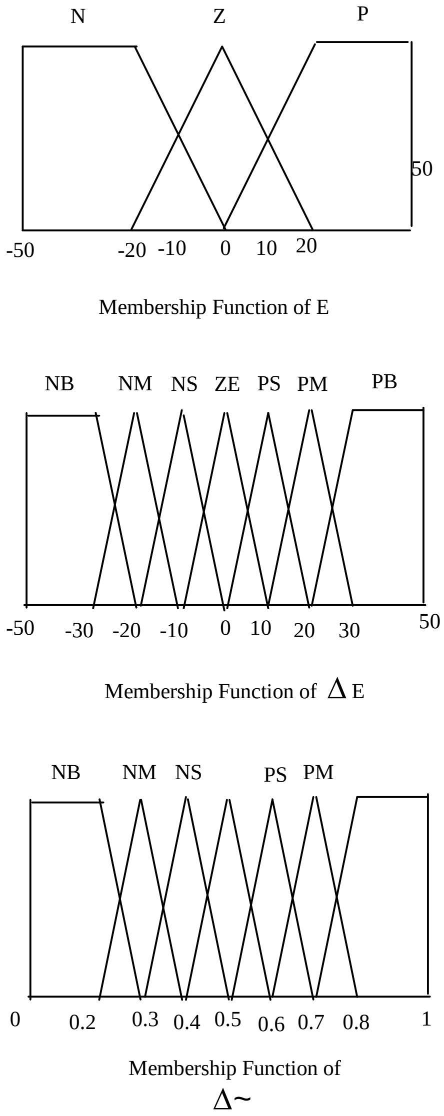

Figure 4: Membership function of $\Delta\sim$

3.2 Design procedure

This section attempts to describe the genetic fuzzy rule base generating process used here, with membership functions previously defined.

3.2.1 coding of fuzzy rule base

The rules are coded by integer numbers that represent the index of fuzzy sets (from 1 to 7) that appear in the consequent part of the rule.

The chromosome that represents this fuzzy rule set has a size of 21 and it is shown in Fig. 5.

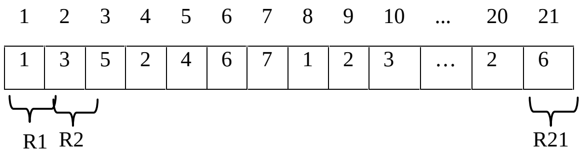

Figure 5: Coding of fuzzy rule bases

3.2.2 Initial population

The initial population is randomly generated. It is formed by a limited set of chromosomes encoded as indicated previously, and then it will be evolved by modifying some selected chromosomes by crossover and mutation.

3.2.3 Fitness function

The fitness function is defined by the best fuzzy rule base which gives the minimum value of error E.

$$E = fitness(e, \Delta e) = eval(FLC) \tag{18}$$

3.2.4 Genetic operators

We have utilized in this work: one point crossover, standard mutation and elitist selection.

3.2.5 Stopping condition

In this work we have used the maximum number of generations as the stopping condition.

4 RESULTS AND DISCUSSION

In our case we have taken for any solar radiation a table of rule base, for example for S=100W/m², we have:

Table 1: final rule base in tabular form for solar radiation S=100W/m².

E

ΔE	N	Z	P
NG	ZE	PG	NM
NM	NG	PM	PG
NP	ZE	NG	NG
ZE	NP	NG	NG
PP	NP	ZE	ZE
PM	ZE	ZE	PG
PG	NP	PP	NG

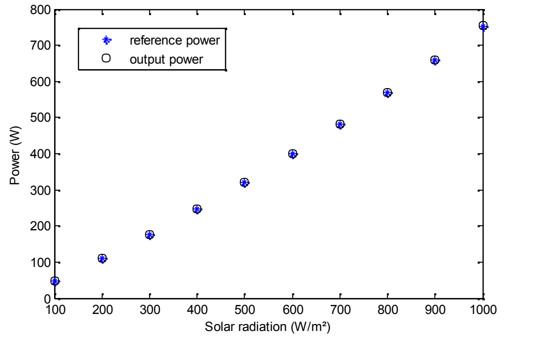

Figure 6: Comparison between reference power and the output power.

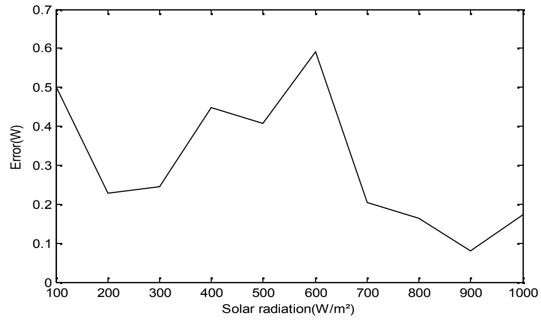

Figure 7: Error between Pref and Pout

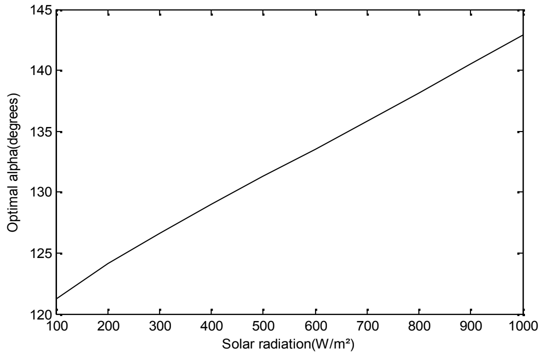

Figure 8: Optimal firing angle alpha

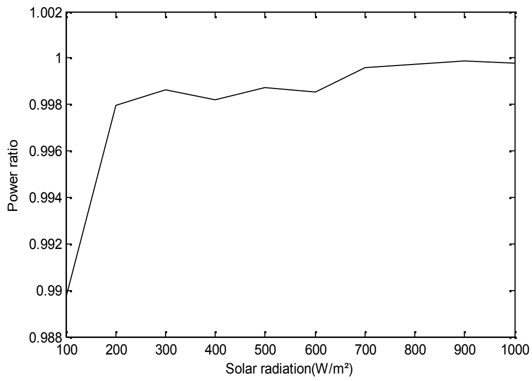

Figure 9: Power ratio

- Test of robustness:

$$P_{ref} = -0.0019T^2 - 2.5465T + 832.6288 \tag{19}$$

For any temperature a table of rule base, for example for

T=25°C we have the following table:

Table 2: final rule base in tabular form for a temperature T=25°C

e Δ e	N	Z	P
NG	PG	ZE	PM
NM	PP	NP	ZE
NP	NP	PG	NG
ZE	PM	PP	NM
PP	ZE	NP	NM
PM	ZE	NP	ZE
PG	NG	ZE	NG

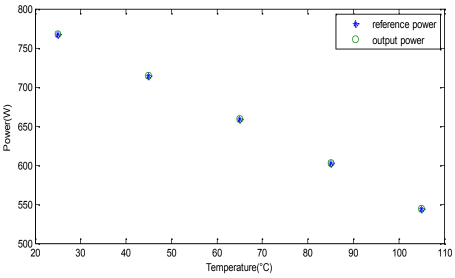

Figure 10: Comparison between reference power and output one

The photovoltaic system has been simulated on a PC using the Matlab software and its toolbox packages.

In fig. 6 it is clear that the two profiles, Pref and Pout are very close which insure the complete utilization of the available photovoltaic energy. Fig. 7 shows the tracking error it is very low. Fig. 8 shows the optimal firing angle as a function of the solar radiation it is in the interval [95 165]. Fig.9 shows the system efficiency which can be evaluated by calculating the power ratio a between the output power and the reference one, it represents the maximum power that can be generated at the output of the inverter under given conditions, it is given as follows:

$$a = \frac{\sum P_{out}}{\sum P_{ref}} \times 100(\%) \qquad (20)$$

The power ratio is evaluated a =99.99% we have neglected the losses of energy caused by commutation process.

In fig 10 a satisfied result is obtained for any change of temperature with a power ratio a = 99.96% witch improves the robustness of the OFLC.

The genetic fuzzy controller led to high performance with fast response and robust control.

5 CONCLUSIONS

In this paper, optimized fuzzy logic controller (OFLC) is introduced to improve the efficiency of PV systems under variation irradiance and temperature conditions. Genetic algorithms were used to obtain the best rule bases as it is complicated to be achieved by the designer for any variation of solar radiation at a constant temperature. Simulation results prove that the using of the proposed OFLC lead to inject the maximum PV power into the electric grid with satisfactory performance (robustness, tracking speed, small oscillations) which gives a simple FLC structure with low cost.

In the future we will take the variation of solar radiation and temperature in the same time.

Appendix

PV solar panel used in this study is the AEG-40 type which has the characteristics for 1000W/m²and 25°c as follow:

Open circuit voltage = 22.4V,

Optimum current = 2.2A,

Optimum voltage = 17.45V,

Series resistance = 0.45 Ω,

Maximum power = 38.4W,

Short circuit current = 2.41A.

REFERENCES

[1] M.Fadaee[*], M.A.M. Radzi Multi-objective optimization of stand-alone hybrid renewable energy system by using evolutionary algorithms: A review Renewable and sustainable Energy Reviews 16(2012), pp: 3364-3369.

[2] A. Bouilota[a] , A.Millit[a, b, *], S. A. Kalogirou[c] New MPPT method for stand alone photovoltaic systems operating under partially shaded conditions. Energy 55 (2013): 1172-1185.

[3] Ganesh Kumar Venayagamoorthy*, Richard L. Welch Energy dispatch controllers for a photovoltaic system. Engineering Applications of Artificial Intelligence 23(2010): 249-261.

[4] A. Messaia, A.Mellitb,*,1, A.GuessoumC, S.A. Kalogiroud Maximum power point tracking using a GA optimized fuzzy logic controller and its FPGA implementation. Solar Energy 85(2011): 265-277.

[5] W. Swiegers and J. Enslin An Integrated Maximum Power Point Tracker for Photovoltaic Panels. Proceedings of IEEE International Symposium on Industrial Electronic1998, Vol. 1, 1998: 40-44.

[6] Trishan Esram, and Patrick L. Chapman Comparison of Photovoltaic Array Maximum Power Point Tracking Techniques. IEEE Transactions on Energy Conversion, vol. 22, No. 2: 439-449, June 2007.

[7] A. Brambilla New Approach to Photovoltaic Arrays

Maximum Power Point Tracking. Proceeding of 30th IEEE Power Electronics Specialists Conference, Vol. 2, 1998: 632-637.

[8] C.Larbes, S.M.Ait Cheikh, T.Obeidi, A.Zerguerras Genetic Algorithms Optimized Fuzzy Logic Control for the Maximum Power Point Tracking in Photovoltaic System. Renewable Energy 34 (2009) :2093-2100.

[9] Anastasios I. Dounis*, Panagiotis Kofinas, Constantine Alafodimos, Dimitrios Tseles Adaptive fuzzy gain scheduling PID controller for maximum power point tracking of photovoltaic system. Renewable energy 60(2013): 202-214

[10] Shawu Lia,b, Xianwen Gaoa,*, Lina Wanga, Sanjun Liub A novel maximum power point tracking control method with variable weather parameters for photovoltaic systems. Solar energy 97(2013) : 529-536.

[11] M.U. Siddiquia,*, M. Abidob Parameter estimation for five-and seven-parameter photovoltaic electrical models using evolutionary algorithms. Applied soft computing 13(2013): 4608-4621.

[12] A.Terki*, A.Moussi, A.Betka, N.Terki An improved efficiency of fuzzy logic control of PMBLDC for PV pumping system Applied mathematical modeling 36(2012) 934-944.

[13] A. Betka*, A. Attali, Optimization of a photovoltaic pumping system based on the optimal control theory, Sol. Energ. 84 (2010) 1273–1283.