

MPPT Controller Design Using Fuzzy-BBBC Method

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Abstract

Maximum power point tracking is considered to be an efficiency improving method applicable to the solar arrays. In this paper, Fuzzy-Big Bang-Big Crunch algorithm is applied in tracking of maximum power point. Simulation has been done in both MATLAB software where comparison made between Fuzzy-Big Bang and Fuzzy algorithm-alone. It has shown that in various temperatures and irradiances, optimized duty cycle achieved by proposed method is closer than fuzzy logic method to the values previously expressed in the referred source. Using those calculated values, the maximum error in Fuzzy-Big Bang method is only 0.0028 where fuzzy logic shows 0.0088. That is, the maximum error is reduced by 6.67% also efficiency of the system with Fuzzy-Big Bang algorithm is 5% improved in comparison with the Fuzzy method. The tracking system will quickly adapt itself even in rapidly environmental changes.

Keywords: MPPT, Fuzzy, BB-BC, Fuzzy-BBBC, PV.

1. Introduction

An appropriate controller is a vital requirement in any photovoltaic system to control or monitor various outputs including maximum power point tracking (MPPT) [1]. There are few well-known techniques of MPPT such as Perturb and Observe (P&O), constant voltage, neural network algorithms, Model Predictive Control (MPC) and Genetic algorithm [2]. Among these methods, the fuzzy controller proved certain advantages over the others. These advantages include: working with linguistic variable, rapid communication with other components and simplification in system design. Fuzzy controllers due to have the ability to track the path of maximum power, with no need extra sensor to measure irradiation and temperature intensity are highly regarded [3].

Further more, the Big Bang-Big Crunch (BB-BC) algorithm is an intelligent algorithm introduced by Eksin and Erol in 2006 exhibits high convergence speed. From the point of view the initial population creation, the algorithm in two phases (Big Bang phase and Big Crunch phase) has similar function as genetic algorithm and Particle Swarm Optimization (PSO) [4, 5].

The application of BB-BC algorithm has been carefully investigated in order to reduce maximum error and thus optimize fuzzy algorithm.

In this paper, at first the solar cell and the SEPIC converter are reviewed, next the Fuzzy logic control method is studied, then the BB-BC algorithm is applied to optimize the membership functions and is simulated by MATLAB software, and finally, comparison and conclusion are made.

2. Solar cell

A photovoltaic module is consisted of many series-parallel connected solar cells. As it shown in Fig. 1; a current source, a diode and two resistors are modeled a single-diode solar cell [6].

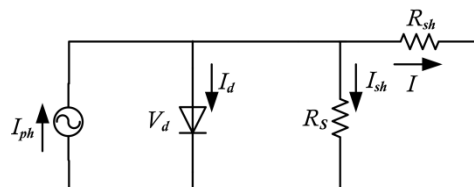


Fig. 1 single-diode solar cell model.

The characteristic equation of photovoltaic cell is given by Eq. (1-3) [6]:

$$I = I_{lg} - I_{os} \times \left[\exp \left\{ q \times \frac{V + I \times R_s}{A \times K \times T} \right\} - 1 \right] - \frac{V + I \times R_s}{R_{sh}} \quad (1)$$

Where

$$I_{os} = I_{or} \times \left(\frac{T}{T_r} \right)^3 \times \left[\exp \left(q \times E_{go} \times \frac{1}{T_r} - \frac{1}{T} \right) \right] \quad (2)$$

$$I_{lg} = (I_{scr} + K_i \times (T - 25)) \times \lambda \quad (3)$$

I & V : Cell output current and voltage; I_{lg} : Light-generated current; I_{os} : Cell reverse saturation current; R_{sh} : Shunt resistance; R_s : Series resistance; A : Ideality factor; K : Boltzmann's constant which is $1.38 \times 10^{-19} \text{ J/}^\circ\text{K}$; T : Cell temperature ($^\circ\text{K}$); T_r : Reference temperature; E_{go} : Band gap for silicon; I_{scr} : Short circuit current at 25°C ; K_i : Short circuit current temperature coefficient at I_{scr} ; λ : Solar irradiation in W/m^2 ;

It is observed that a solar module is related to the number of series-parallel cells; the result is shown that the current variations depend on series resistance more than the shunt resistance [7].

In Fig. 2, the P-V and I-V curves for solar cells are. As is seen, operating cell operates at low currents like a constant voltage source. It also operates at low voltages like a constant current source.

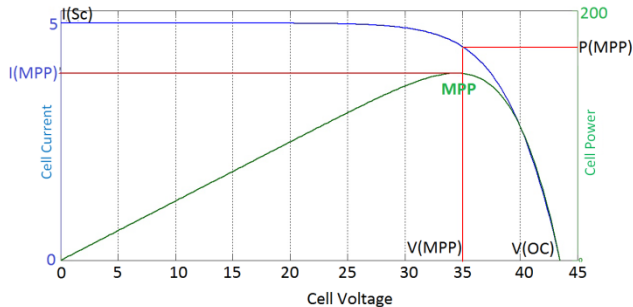


Fig. 2 P-V, I-V diagram solar cell at a given temperature and irradiance.

In Fig. 2, by using the above equation and the bp-sx150s model of panel; the power - voltage characteristic can be earned. The parameters of the panel, is given in Table 1, [8].

3. SEPIC converter

SEPIC converter is a DC-DC converter which in this converter the electric potential (voltage) in output can be greater than, less than or equal to input voltage.

Table 1: The presented parameters of bp-sx150s panel by the manufacturer

Electrical characteristics	
Maximum power (Pmax)	150W
Voltage at Pmax (Vmp)	34.5V
Current at Pmax (Imp)	4.35A
Open-circuit voltage (Voc)	43.5V
Short-circuit current (Isc)	4.75A
Temperature coefficient of Isc	0.065+0.015%
Temperature coefficient of Voc	-160+20mV/c
Temperature coefficient of power	-0.5+0.05%/c
NOCT	47+2°C

SEPIC output is controlled by duty cycle of the control transistor. SEPIC is similar to the Buck-Boost converter. The SEPIC converter schematic is shown in Fig. 3 [9].

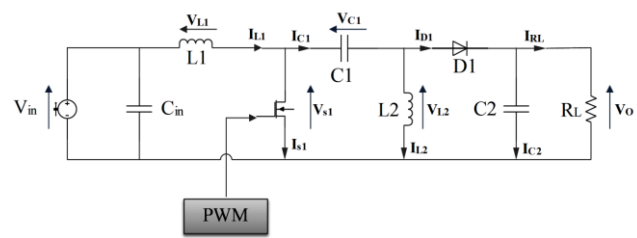


Fig. 3 SEPIC converter schematic.

To gain new membership functions, using the fuzzy membership functions, the duty cycle is calculated and by putting it in the SEPIC converter equations, I and V values can be calculated by Eq. (4, 5) [10].

$$V_s = \frac{D}{1-D} V_o \quad (4)$$

$$I_s = \frac{D}{1-D} I_o \quad (5)$$

Where V_o is the output voltage, V_s is the input voltage, I_s is the input current, I_o is the output current and D is the duty cycle.

4. FUZZY

Fuzzy logic is a drastic control method which uses member functions and rule table to determine the next operating point, relying on knowledge of expert. The flow chart of fuzzy algorithm is depicted in Fig. 4.

Fuzzy logic is a multi-valued logic which is based on fuzzy set theory. Fuzzy sets are defined by membership functions. Membership functions of the fuzzy algorithm

include several inputs and one output. In this paper, temperature and irradiation of the sun are considered as inputs and optimized duty cycle as output, which are defined in four ranges Small, Means, Large and Very Large. The membership degree is expressed using the Eq. (6-8).

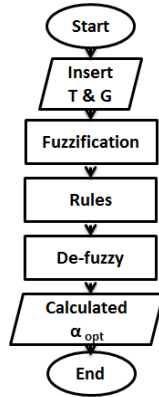


Fig. 4 Flow chart of fuzzy algorithm.

Irradiation (G) variation are intended in a range between [0 1300] [11].

$$\mu_{Ai}(X_{oi}) = \begin{cases} 1 - \frac{|X - X_{oi}|}{\mathcal{E}_{X_{oi}}} & \text{if } |X - X_{oi}| < \mathcal{E}_{X_{oi}} \\ 0, & \text{otherwise} \end{cases} \quad (6)$$

$\mu_{Ai}(X_{oi})$ is the membership degree of the irradiation function at specified point X_{oi} .

The temperature (T) range is between [10 52] [11].

$$\mu_{Bj}(Y_{oj}) = \begin{cases} 1 - \frac{|Y - Y_{oj}|}{\mathcal{E}_{Y_{oj}}} & \text{if } |Y - Y_{oj}| < \mathcal{E}_{Y_{oj}} \\ 0, & \text{otherwise} \end{cases} \quad (7)$$

$\mu_{Bj}(Y_{oj})$ is the membership degree of the temperature function at specified point Y_{oj} .

The optimized duty cycle (α_{opt}) varies in the range between [0.3 0.55] [11].

$$\mu_{Ck}(Z_{ok}) = \begin{cases} 1 - \frac{|Z - Z_{ok}|}{\mathcal{E}_{Z_{ok}}} & \text{if } |Z - Z_{ok}| < \mathcal{E}_{Z_{ok}} \\ 0, & \text{otherwise} \end{cases} \quad (8)$$

$\mu_{Ck}(Z_{ok})$ is the membership degree of the optimized duty cycle function at specified point Z_{ok} .

Using expressed fuzzy logic equations, membership functions are defined (Fig. 5). Control rules in this paper are extracted from Mamdani method and are presented in Table 2 [11].

A new membership function is gotten by using the fuzzy membership. In this case, the duty cycle is calculated then it is put in the equations (4, 5) of SEPIC converter.

The value of I and V are calculated. They are compared with the value that obtained from the panel then the maximum error is gotten.

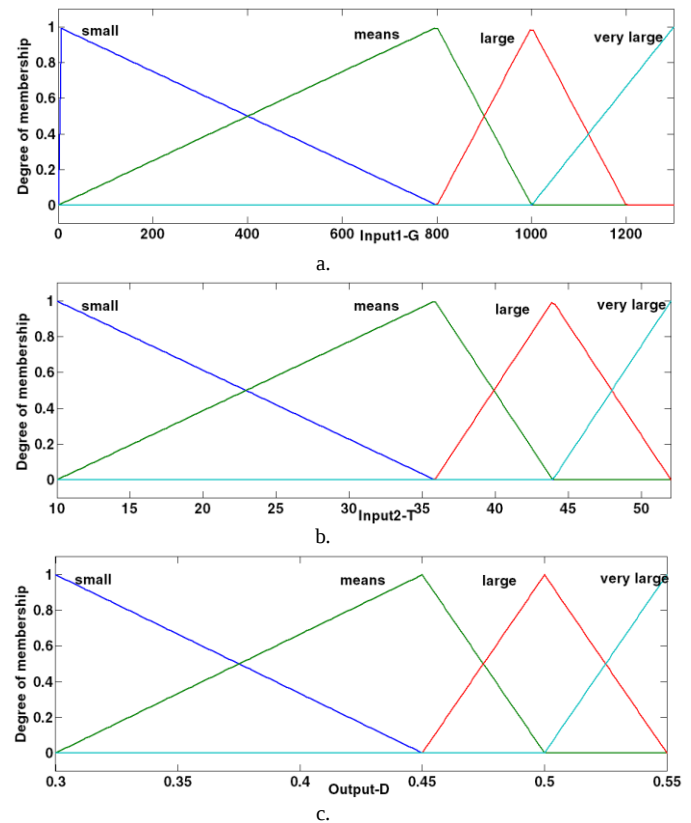


Fig. 5 Membership functions a. irradiation G b. temperature T c. optimum duty cycle.

Table 2: Control rules by Mamdani

$T(^{\circ}C)$	$G(W/m^2)$			
	Small	Means	Large	V-Large
Means	Means	Means	Large	Small
Large	Means	Large	Large	V-Large
V-Large	Small	Means	V-Large	V-Large

5. The proposed MPPT algorithm based on Fuzzy-BB BC

A new membership function is gotten by using the fuzzy membership. In this case, the duty cycle is calculated, after that; using the equations 4 and 5, the values of I and V are obtained. They are compared with the values obtained from the panel, thereby the maximum error is achieved.

The initial population is generated in next step, Where the population is randomly and uniformly spreading over the entire search space.

In this paper, Fitness function is calculated by Eq. (9) [4]:

$$f_{sphere}(\vec{X}) = \sum_{i=1}^n X_i^2 \quad (9)$$

After calculating this function, called Big Bang phase; in this step, the population is randomly and uniformly spread over the space. The number of member is 100 for each function. Next step is Big Crunch which calculated by Eq. (10) [4]:

$$\vec{X}^c = \frac{\sum_{i=1}^N \frac{1}{f_i} \vec{x}_i}{\frac{1}{f_i}} \quad (10)$$

X_i is a point in N -dimensional space, f_i is fitness function, and N is the number of particles.

After Big Crunch phase, the new position of each particle is obtained by Eq. (11) [4]:

$$X_j^{new} = X_j^c + (X_{max} - X_{min}) \times r \times \frac{1}{K} \quad (11)$$

X_j is j -th component of central mass, X_{min} and X_{max} are the upper and lower of the X variable, r is a normally distributed random number, and K is the iteration number.

The new function, Fuzzy-Big Bang-Big Crunch is obtained by replacing member in fuzzy function.

Again the error is calculated, unless the error is suitable, the procedure repeat and the fitness function is calculated.

Flowchart of the Fuzzy-BBBC algorithm is shown on Fig. 6.

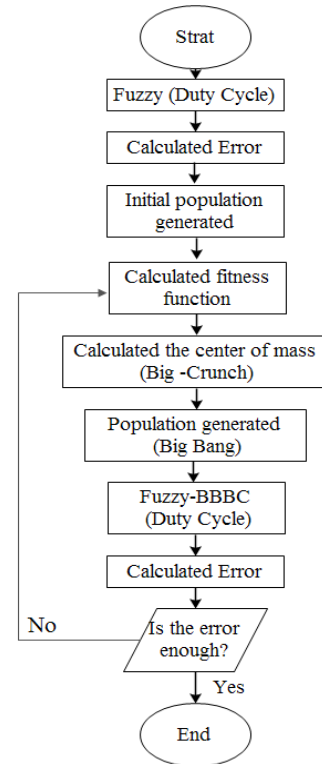


Fig. 6 Fuzzy-BBBC algorithm flowchart.

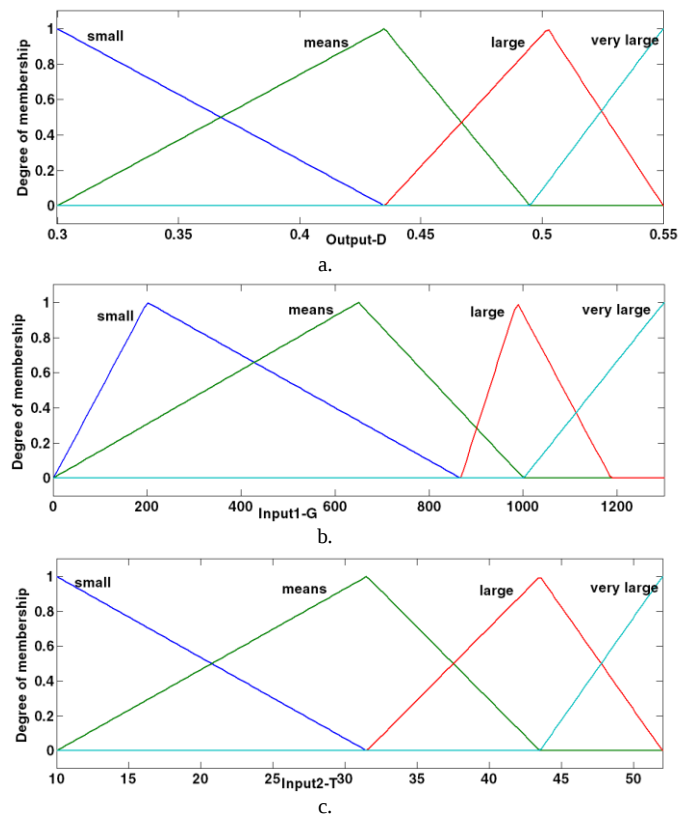


Fig. 7 Optimized membership functions a. irradiation G b. temperature T c. optimum duty cycle.

5.1 Improved Function due to BBBC

Membership function is fuzzy system which is presented; dose not allows bring the best result. So it is tried to improve the result of fuzzy algorithm by using the BB-BC algorithm. Improved membership function by using flowchart (f_i) is on Fig. 7.

6. MATLAB Simulation

To evaluate the performance, the system block diagram (Fig. 8) is simulated in two different situations.

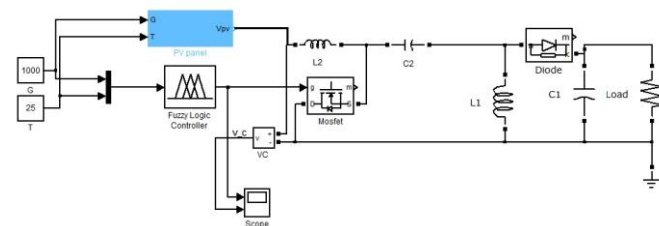


Fig. 8 The system block diagram.

As in first case, temperature is fixed at 25°C and the irradiation will change as shown in Fig. 9a. Fig. 9b shows the obtained optimized duty cycle for Fuzzy-Big Bang and Fuzzy methods. Then, the irradiation is fixed at 1000 W/m² and the temperature will vary as shown in Fig. 10a. The α_{opt} of this case is shown in Fig. 10b for both algorithms.

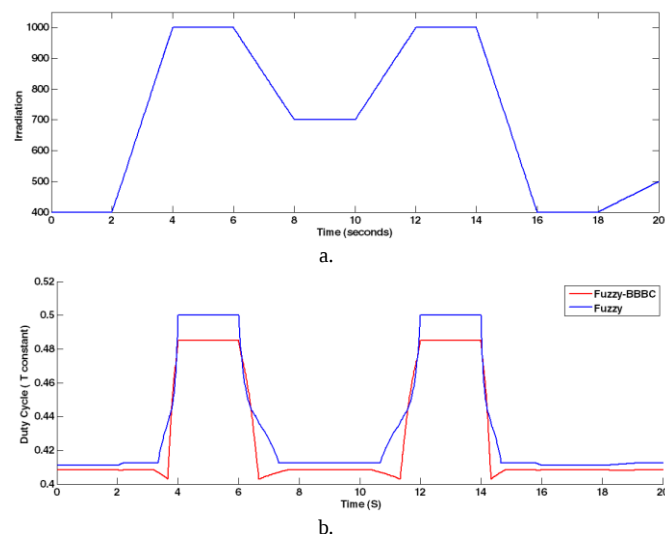


Fig. 9 At 25(°C) fixed temperature a. Applied irradiation (G) signal b. Obtained optimized Duty cycle.

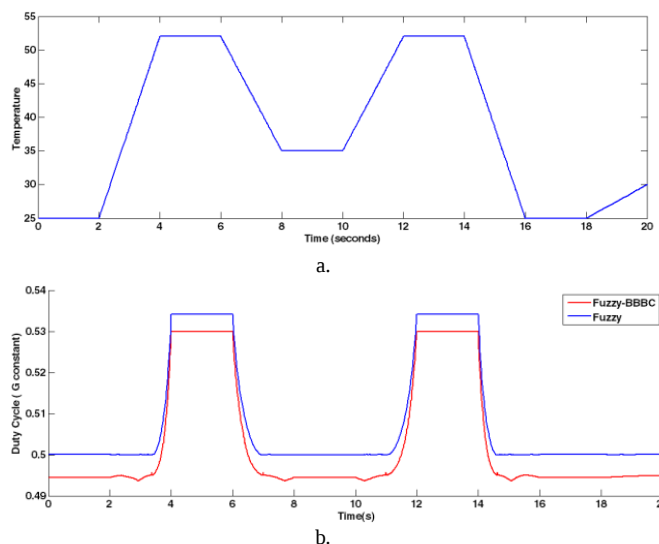


Fig. 10 At 1000 W/m² fixed irradiation a. Applied temperature (T) signal b. Obtained optimized Duty cycle.

7. Conclusions

In this paper, the fuzzy-BBBC and Fuzzy algorithm were simulated.

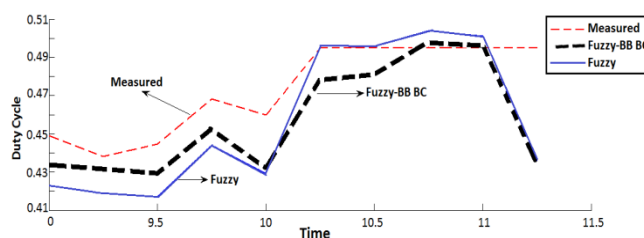


Fig. 11 Calculated and Compare MPP results.

As depicted in Fig. 11, the maximum power point is calculated in variation of temperature and irradiation. The result indicated, the duty cycle which is obtain from Fuzzy-BBBC cause of being closer to the results of the measured has priority than the Fuzzy method. The MPP error is reduced 0.006 in Fuzzy-BBBC.

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