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Simulation and Analysis of MPPT Control with Modified Firefly Algorithm for Photovoltaic System

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Abstract: *This paper presents the simulation and analysis of maximum power point tracking (MPPT) control with modified firefly algorithm (MFA) for photovoltaic (PV) system. The availability of solar energy varies widely with ambient temperature and different atmospheric conditions and hence the maximum power point (MPP) of PV system is not stable. Therefore, a MPPT controller is needed to operate the PV at its MPP. Maximum power tracking methods based on nature inspired algorithm such as MFA is proposed to track the MPP. The proposed method is implemented on a boost DC-DC converter. The result shows that the proposed method can accurately track the MPP and improve the performance of firefly algorithm (FA) in tracking speed for convergence. The effectiveness of the proposed system is provided for PV system by the simulation results and maximum power analysis. The effectiveness of the proposed system is proved with the help of simulation. The simulation is performed in MATLAB/Simulation.*

Keywords: *Photovoltaic Array (PV), Maximum Power Point Tracking (MPPT), DC-DC buck converter, Modified firefly algorithm (AMFA)*

1. INTRODUCTION

The increasing demand for renewable energy has increased significantly over the years because of shortage of fossil fuels and greenhouse effect. Among various types of renewable energy sources, solar energy and wind energy have become very popular and demanding due to advancement in power electronics techniques. Photovoltaic (PV) sources are used today in many applications as they have the advantages of being maintenance and pollution frees [1-6].

The grid-connected PV system can reduce investment outlay because it does not need battery to store energy; it became a hot subject by now. Moreover, the increasing use of power electronic devices and nonlinear loads is known to cause serious problems in electric power systems. Therefore, the technology that combines PV grid-connected generation and active filtering is proposed and develops rapidly. Both of PV grid-connected generation and active filtering need to keep DC bus stable and the key of unified control is generating the uniform current reference accurately [7-9].

The buck–boost converter is a type of DC-to-DC converter that has an output voltage magnitude that is either greater than or less than the input voltage magnitude. Two different topologies are called buck–boost converter. Both of them can produce a range of output voltages, from an output voltage much larger (in absolute magnitude) than the input voltage, down to almost zero. The efficiency of the PV generation depends on maximum power extraction of PV system. Therefore, to maximize the efficiency of the renewable energy system, it is necessary to track the maximum power point of the PV array [10].

The PV array has a single in service point that can supply maximum power to the load. This point is called the maximum power point (MPP). The locus of this point has a nonlinear distinction with solar irradiance and the cell temperature. Thus, in order to operate the PV array at its MPP, the PV system must contain a maximum power point tracking (MPPT) controller. Many MPPT techniques have been reported in the literature. The perturb and observation (P&O) method is an iterative algorithm to track the MPP by measuring the current and voltage of the PV module. This algorithm is easy to implement but the problem of oscillation of operating point around MPP is unavoidable and implementation of PWM control as discussed in [11-12].

The incremental conductance (INC) method presented in [13] is most widely used method. It tracks the MPP by comparing instantaneous conductance to the incremental conductance. The fuzzy logic controllers have the advantages of robustness, simplicity in design and it does not need accurate mathematical model. The selection of parameters and membership function in fuzzy logic is not easy as it needs expert knowledge and experimentation as discussed in [14-16].

X.S. Yang [17], the result show that the superiority of FA over PSO in term of convergence rate and computational burden. In this paper, proposes modified firefly algorithm (MFA) to track the MPP with using DC-DC buck converter. MFA is used to improve FA in tracking speed and tracking efficiency of MPP. The proposed block diagram of MFA-MPPT algorithm is shown in Fig.1.

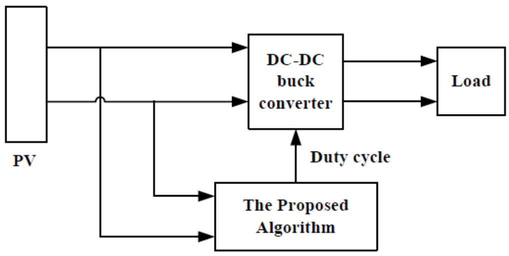

Fig 1: *Proposed block diagram of MFA based MPPT Algorithm.*

2. PV ARRAY MODELING AND SIMULATION

A Photovoltaic (PV) system directly converts solar energy into electrical energy. The basic device of a PV system is the PV cell. Cells may be grouped to form arrays. The voltage and current available at the terminals of a PV device may directly feed small loads such as lighting systems and DC motors or connect to a grid by using proper energy conversion devices. This photovoltaic system consists of main parts such as PV module, charger, battery, inverter and load [18-19]. A Photovoltaic cell is a device used to convert solar radiation directly into electricity. It consists of two or more thin layers of semiconductor material, most commonly silicon. When the silicon is exposed to light, electrical charges are generated. A PV cell is usually represented by an electrical equivalent one-diode model shown in Fig. 2.

In this model, a PV cell is represented by a current source in parallel with a diode and a series resistance, the basic current equation is given in Eq. (1).

$$I=I_{pv,\ cell}-I_{0,\ cell}\{[\exp(qv/akT)]-1\} \qquad (1)$$

Where $I_{pv,\ cell}$ is current generated by the incident light (directly proportional to sun irradiation), $I_{0,\ cell}$ is leakage current of the diode, q is electron charge 1.6021e10-19 C, k is Boltzmann constant, T is Temperature of the PN junction, a is Diode ideality constant is explained in [18-19].

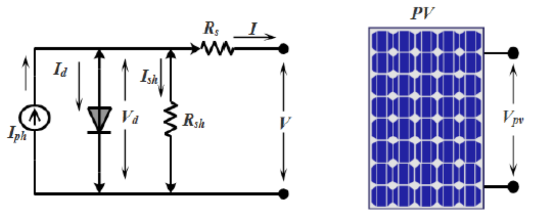

Fig 2: *Equivalent circuit of PV cell.*

The characteristics of PV module are shown by the current versus voltage (I-V) and the power versus voltage (P-V) curves. In the Figs. 3-5, show both I-V and P-V characteristics of PV module at various irradiances and temperatures level.

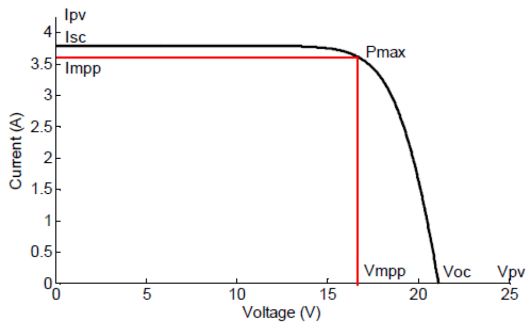

Fig 3: *I-V characteristic of the PV module.*

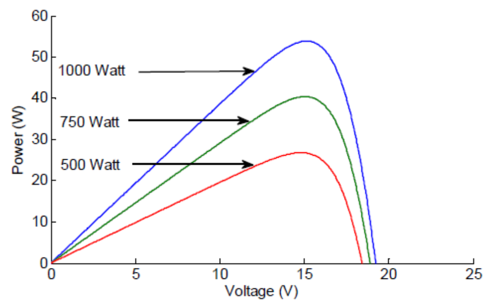

Fig 4: *P-V characteristics at constant temperature and variable irradiance level.*

In the Fig 4 and Fig 5, show that with the increase in irradiance level, the MPP from PV module, also increases. With the increase in temperature level, the MPP decrease in PV characteristic of PV module.

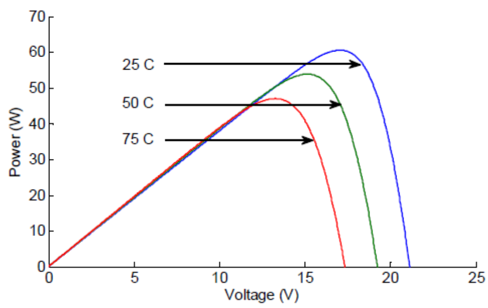

Fig 5: *P-V characteristics at variable temperature and constant irradiance level.*

3. BOOST DC-DC CONVERTER TOPOLOGY

The DC-DC converter to track the MPP of the PV module is buck converter. The input current, voltage and power change continuously under varying irradiance and temperature conditions. Also, the duty cycle is changed continuously in order to track the MPP of the PV module. The boost DC-DC converter topology is shown in Fig.6.

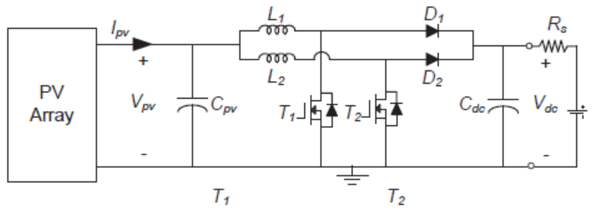

Fig 6: *Proposed boost DC-DC converter topology.*

4. MODIFIED FIREFLY ALGORITHM (MFA) MPPT CONTROL

Xin She Yang at university of Cambridge proposed FA, which is inspired by the movement of fireflies [17]. For simplicity in describing of FA, the three ideas are introduced. The first, all fireflies are unisex so that two fireflies are attracted by each other regardless of their sex.

The second, attractiveness is appropriate to relative brightness, thus the brighter firefly will attract the firefly with lower brighter. The third, landscape of the objective function affects the brightness of a firefly. In maximization problem, the firefly with higher light intensity has higher objective function. Mathematically, the attractiveness can be expressed as follows:

$$\beta(r) = \beta_0 e^{(-\gamma r^m)} \qquad m \geq 1 \tag{2}$$

where, r is distance between two fireflies using Cartesian distance. The distance between the j-th and i-th fireflies is defined with equation as follows:

$$r_{ij} = \left\| X_j - X_i \right\| = \sqrt{\sum_{m=1}^{k} (x_{j,m} - x_{i,m})^2}$$
$$X_j = \left[x_{j,1}, x_{j,2}, x_{j,3} \ldots, x_{j,k} \right]$$
$$X_i = \left[x_{i,1}, x_{i,2}, x_{i,3} \ldots, x_{i,k} \right] \tag{3}$$

The movement of a firefly with lower brightness (Xi) will towards the brighter firefly (Xj) is determined by:

$$X_i = X_i + \beta_0 e^{(-\gamma r^m)} (X_j - X_i) + \alpha \varepsilon_i \tag{4}$$

Where, εj is a random value of Gaussian distribution. The above equation indicates the movements of fireflies consist of three terms such as the current position of the i-th firefly, the movement of the i-th firefly towards to another more attractive firefly, the random movement of the firefly with value from interval [0, 1].

T. Niknam et al proposed modified firefly algorithm (MFA) for solving economic dispatch problems [20]. There are two parameters to be tuned to improve FA in tracking speed and tracking efficiency of MPP. MFA reduces the randomness of fireflies with using the randomization parameter α.

In the MFA process, the simple mutation of the randomization parameter α corresponds changing of iteration. In every iteration, the randomization parameter α is reduced of 0.0001. MFA will increase the tracking efficiency of MPP.

The coefficient β is a function of distance between two fireflies. In this paper, suitable improvement of the coefficient β will guarantee faster convergence. The coefficient β is controlled adaptively to accelerate convergence. The coefficient β is dynamically tuned in the each iteration as follow:

$$\beta^{k+1} = \beta x 2^k \tag{5}$$

where, k is the sequence of iterations

5. IMPLEMENTATION OF MFA TOWARD MPPT FOR PROPOSED SYSTEM

In the fig. 1, show the block diagram of the MFA based MPPT. Here, boost converter as interface between PV module and load. The proposed algorithm controls the DC-DC boost converter operates at the optimum duty cycle corresponding to MPP. The steps of the proposed algorithm toward MPPT are described as follows:

Step 1: initial parameter of the AMFA, namely, β, α and population size N. In this algorithm, the position of the firefly represents duty cycle of DC-DC converter. In this paper, the number of fireflies is chosen as 5.

Step 2: the position of firefly the corresponding PV output power. The brightness of the firefly is obtained from PV output power.

Step 3: the firefly, which has maximum brightness remains in its position whereas the remaining fireflies update their position.

Step 4: the optimization algorithm operates until the last iteration.

6. SIMULATION RESULTS AND DISCUSSION

In order to validate the performance of proposed algorithm, simulation model is developed. The block diagram to track the MPP is shown in fig. 7. The simulation studies are carried out under varying irradiance and temperature conditions. In the fig. 7, show the results of MPPT curves at irradiance level of 1000 W/m2 and temperature level of 500 C. In the case 1, MFA also track the MPP of 53.09 W with 0.72 s. whereas, original FA track the MPP of 52.93 W with 1.03 s.

In the fig. 8, show the results of MPPT curves at irradiance level of 750 W/m2 and temperature level of 250 C. In the case 2, show that the MFA also tracks to the MPP of 44.91 W but the tracking speed is 0.62 s. For the original FA, gets the MPP of 44.17 W with the tracking speed is 1.03 s. In the simulation results, show that the proposed algorithm is superior compared with the original FA in terms of tracking speed because it improves of the coefficient β.

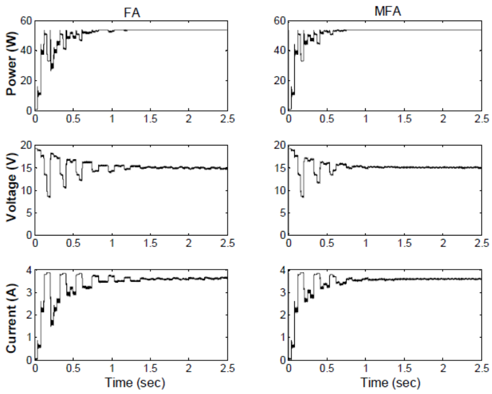

Fig 7: *Simulation of power, voltage and current of the PV during MPPT using FA and MFA for case-1*

The simulation result of the original FA shows the tracking of MPP oscillates because it is influenced by the randomization parameter α. Moreover, the proposed algorithm has good tracking efficiency is compared with maximum available power of the PV module.

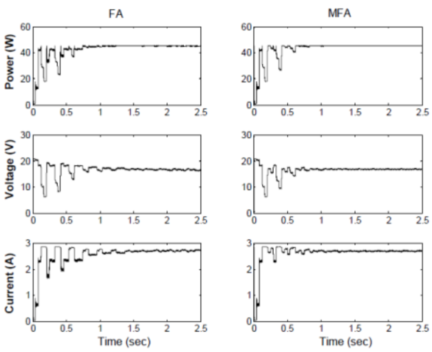

Fig 8: *Simulation of power, voltage and current of the PV during MPPT using FA and MFA for case-2*

7. CONCLUSION

The simulation and analysis of maximum power point tracking (MPPT) control with modified firefly algorithm (MFA) for photovoltaic (PV) system is implemented. The configuration for the proposed system is designed and simulated using MATLAB/Simulink. Due to the importance of PV systems especially in green energy field, this paper introduces an efficient identification method for maximum power point (MPP) function for PV module using MFA algorithm. The proposed MFA algorithm shows good dynamic performance to track the MPP of the PV even under the rapid change of the irradiation and cell temperature. The proposed algorithm improves the original firefly algorithm (FA) to track the MPP with reduce the randomization parameter α and parameter tuning of the coefficient β in each iteration. The simulation results of the proposed algorithm for MPPT are carried out under varying irradiance and temperature conditions. The simulation results demonstrate that the proposed algorithm is superior in terms of tracking speed. The proposed algorithm reduces fluctuation of the original FA in the steady state condition. Moreover, the simulation results also show that the proposed method can accurately track the MPP.

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