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Estimate The Parameters of Photovoltaic Module by FODPSO

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***Abstract*— Improving the Mathematical Modeling of photovoltaic module has been done by an accurate estimation parameters algorithm. The Fractional Order Darwinian Particle Swarm Optimization (FODPSO) has been used for estimation photovoltaic module parameters. The photovoltaic modules are described using double diodes model (DDM). The algorithms are performed on two different poly crystalline Silicon photovoltaic modules to approximate their optimum parameters of double diode model at different environmental condition. Results of FODPSO are accomplished by achieving the Minimum Root Mean Square Error (RMSE) and minimum Summation of the Individual Absolute Error (SIAE).**

Keywords*— Photovoltaic; Algorithm; Fractional Order Darwinian Particle Swarm Optimization (FODPSO); Model

1. INTRODUCTION

Solar PV demand is spreading and expanding as it becomes the most economical choice for energy generation in an increasing amount of markets for residential and commercial applications and progressively for utility projects even without the internal expenses of fossil fuels being taken into account [1]. Due to the variability in PV cell types used in many solar panel applications such as multiple terrestrial applications, space applications and electrical power supply units for electronic devices, power satellites and other communications equipment, precise PV modeling is required. Precise PV modeling enables highly accurate cell quality control and efficiency assessment, thus allowing comprehensive study, evaluation of PV system performance before being installed within the different applications [2]. The characteristic of the photovoltaic power generation is non-linear influenced by external effects such as environmental conditions such as light intensity and temperature, and load properties [3]. Accordingly, the main challenge is that a precise photovoltaic model can only be done by optimal estimation electrical parameters [4]. From the literature review there are many techniques to estimate the parameters, among which are the iterative algorithms and/or the non-iterative algorithms with its complexity, dependence on initial conditions, and long time for parameter estimation [5]. Other algorithms such as Harmony Search (HS) [6], Cuckoo Search (CS) [7], Simulated Annealing (SA) [8] and Pattern Search (PS) [9].which are found to be not sufficient [10]. Proposed heuristic procedure is applied to identify the PV model parameters. The algorithm named Fractional Order Darwinian Particle Swarm Optimization (FODPSO) is essentially a Particle Swarm Optimization (PSO) algorithm enhanced by fractional order calculus [11-12]. To identify the superiority of the FODPSO algorithm, experimental actual measurements have been used for two different poly crystalline Silicon modules at different conditions in indoor conditions, Indoor conditions mean the sun is simulated by PVCT sun simulator that is manufacture by HALAM where we can control the environmental condition, From the comparative study this algorithm achieves accurate results at minimum Root Mean Square Error (RMSE).

2. EXTRACTING DOUBLE DIODES MODEL PARAMETERS METHOD

To estimate the electrical photovoltaic parameters of the, the double diodes model (DDM) that is used to describe the characteristic of the module as shown in fig. 1. The double diode model estimations parameters are the photovoltaic generated current (I_{ph}), the first diode reverse saturation current (I_{o1}) with ideality factor (a_1), the second diode reverse saturation current (I_{o2}) with ideality factor (a_2), and the shunt and series resistances (R_{sh}, R_s) where are described by equation (1).

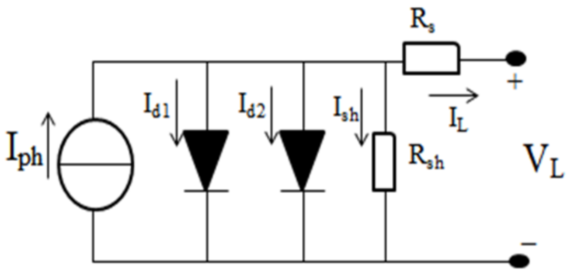

Fig- 1: double diodes model

$$I_L = I_{ph} - I_{01} *[e^{(\frac{q(V_L+I_L R_s)}{a_1 kT})} - 1] - I_{02} *[e^{(\frac{q(V_L+I_L R_s)}{a_2 kT})} - 1] - \frac{(V_L+I_L R_s)}{R_{sh}} \quad (1)$$

Where I_L is the load current, V_L is the terminal voltage, the electronic charge (q), Boltzmann's constant (k=1.3806503·10^{-23} J/K) and is the cell absolute temperature (T in Kelvin).

FODPSO algorithms have been identified by the particles (X) and the velocity (V) of its particles [11]. The particles of FODPSO algorithms for parameters' estimation are defined for the double diodes model with the solution vector, P = (Rs, Rsh,

Io_1, Io_2, a1, a2, I_{ph}) and L (V_L, I_L, X) which is the error function that is defined as the variance between the probable current and the measured current. The double diodes model error is stated in equations (2) and The Root Mean Square Error (RMSE) is the optimized function of the error function equation (3). While, the summation of the individual absolute error (SIAE) that is termed in equations (4) Where K is the number of measured.

$$\text{L (VL, IL, X)} = I_{ph} - I_{o1}[e^{\left(\frac{q(V_L+I_LR_s)}{a_1kT}\right)} - 1] - I_{o2}\,[e^{\left(\frac{q(V_L+I_LR_s)}{a_2kT}\right)} - 1] - \frac{(V_L+I_L R_s)}{R_{sh}} - I_L \quad (2)$$

$$\text{RMSE}=\sqrt{\frac{1}{K}\sum_{I=1}^{K}(\text{L (VL,IL,X)})^2} \quad (3)$$

$$\text{SIAE} = \sum_{1}^{K} |\text{ L (VL,IL,X)}| \quad (4)$$

And the velocity of these particles is defined by equation (5) for FODPSO algorithm and also the particles are update by equation (6).

$$V_{t+1} = \alpha V_t + \frac{1}{2}\alpha V_{t-1} + \frac{1}{6}\alpha(1-\alpha)V_{t-2} + \frac{1}{24}\alpha(1-\alpha)(2-\alpha)V_{t-3} + C_1 * rand(P - X_T) + C_2 * rand(G - X_T) \quad (5)$$

$$X_{t+1} = X_t + V_{t+1} \quad (6)$$

Where, w: weight, t: iteration, C1&C2: knowledge factors, P: best owner position particle, G: best overall position swarm α : the order of the derivative

The main advantage obtained from the FODPSO algorithm, is that the FODPSO algorithm allows additional degree of freedom to change the position velocity by changing the order of the derivative (α). In this new application, the value of (α) is selected to be 0.1 or 0.2. If α value is close to be integer number the algorithm will be fail but for the fraction number the algorithm will be perfect

3. THE RESULTS

Two modules are used to validate the FODPSO algorithm by extracting the optimum double diodes model parameters for these modules, the two modules are multi – crystalline type and consist of 60 solar cells. Its type and its characteristics are list on table 1. The measurements have been done indoor in laboratory at different operating condition by using PVCT sun simulator that is manufacture by HALAM.

TABLE I. THE CHARACTERISTICS OF TWO MODULES

characteristics	Module 1	Module 2
type	ARECO 275 WP	NEMO® 2.0 60 P265 21
P_{MPP} (maximum power)	275W	265W
V_{OC} (open circuit voltage)	38V	37.7V
I_{SC} (short circuit current)	9.6A	9.19A
V_{MPP} (voltage at maximum power)	30.22V	30.9V
I_{MPP} (current at maximum power)	9.1A	------

A. *Case study 1 (Module 1)*

FODPSO and PSO are used to predict best double diodes model parameters under different conditions (200 W / m^2, 25^o C), (800 W / m^2, 20^o C) and (1000 W / m^2, 25°C) for module 1. Table 2 shows the parameters for the double diodes model along with the root mean square error (RMSE) for FODPSO.

TABLE II. OPTIMUM PARAMETERS OF DOUBLE DIODES MODEL FOR MODULE 1 BY FODPSO AT THREE DIFFERENT ENVIRONMENTAL CONDITIONS

parameters	(200 W / m^2, 25^o C),	(800 W / m^2, 20^o C)	(1000 W / m^2, 25°C)
$R_{s(\Omega)}$	0.3098634	0.2310514	0.2465738
$R_{sh(\Omega)}$	2037.2545	801.88759	494.04329
I_{o1} (μA)	0.00081545	5.38568E-8	4.7984E-5
I_{o2} (μA)	7.6856E-6	3.57584E-4	0.0011959
a_1	64.321362	52.403093	57.585175
a_2	58.096349	63.978006	71.76842
I_{PH} (A)	1.8199929	7.1905376	8.9986232
RMSE	0.0172914	0.0295874	0.0306767
SIAE	2.95175167	5.1437546	8.426457

In order to validate the correctness of the results, the current (I_L) has been calculated by replacing probable parameters for double diodes models and the measured current has been plotted for module 1 as presented in fig. 2 for FODPSO algorithms

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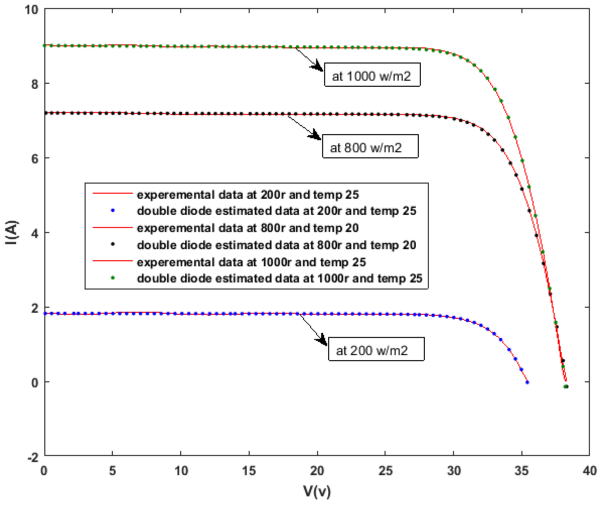

Fig-2: I-V curves of double diodes model of module 1 by FODPSO algorithm

As shown in fig. 2; the real measuring and estimated current are almost the same and it can be observed that FODPSO technique's optimum parameters are very close to the curves of measured data in the complete range so the superiority of FODPSO is achieved.

B. Case study 2 (module 2)

FODPSO has been applied for the extracting the optimum double diodes model parameters for this module 2 at different condition (1000 W/m2, 30o C) and (1000 W/m2, 35o C) , (800 W/m2, 25o C) ,(800 W/m2, 30o C) and (200 W/m2, 25o C). Table 3 shows that the parameters for the double diodes model along with RMSE for the FODPSO technique at environmental condition.

The calculated output current and the measured current with voltage are plotted for module 2 as presented in fig. 3 and 4 for FODPSO at different environmental condition. It can be experimental that the optimum parameters by FODPSO are very precise as the calculated current and measured current are same equal in this entire condition.

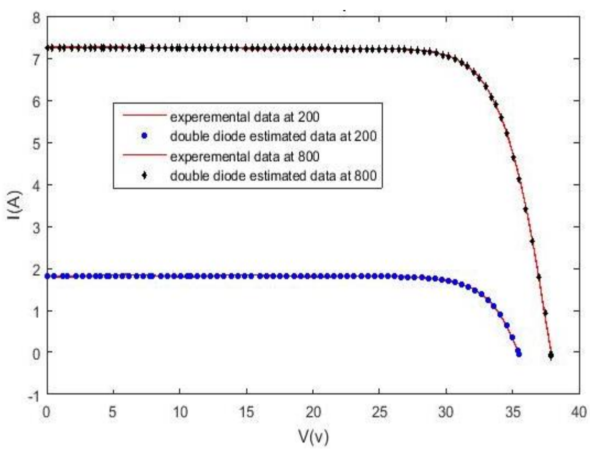

Fig-3: I-V curves of double diodes model of module 2 for FODPSO algorithm at conditions (25^{O}C and 200,800 W/m^2)

TABLE III. THE PROBABLE PARAMETERS OF DOUBLE DIODES MODEL OF MODULE 2 BY FODPSO AT DIFFERENT ENVIRONMENTAL CONDITIONS

Items	1000 W/m^2 , 30^o C)	1000 W/m^2 , 35^o C)	800 W/m^2 , 25^o C)	800 W/m^2 , 30^o C)	200 W/m^2 , 25^o C)
$R_{s(\Omega)}$	0.2466059	0.2376548	0.242952	0.229306	0.2531381
$R_{sh(\Omega)}$	702.85243	582.71906	1708.7798	895.79635	2579.3565
I_{o1} (μA)	0.0128251	0.0012212	0.0001969	0.0031859	0.0001395
I_{o2} (μA)	7.9699E-5	0.0024334	0.0011971	6.1673E-5	0.0083176
a_1	76.781079	61.685219	61.227175	67.61926	60.566722
a_2	56.977966	72.596408	70.565786	58.671698	75.62327
I_{PH} (A)	9.1034785	9.1084515	7.2429776	7.2846397	1.8245432
RMSE	0.0333552	0.030204	0.0330785	0.030644	0.014266
SIAE	8.634343	7.699235	4.675939	4.89295	2.5078704

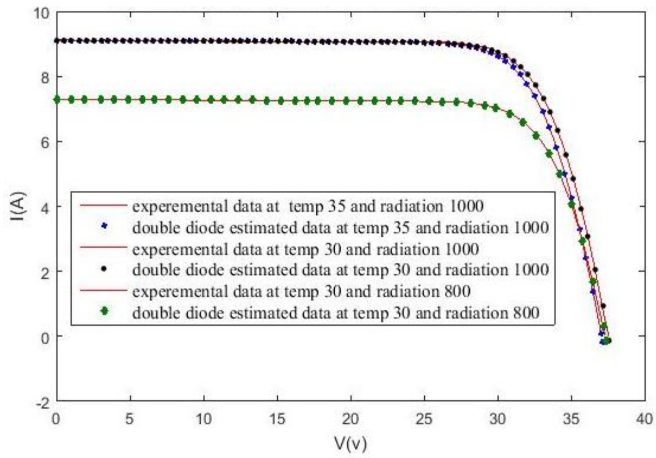

Fig-4: I-V curves of double diode model of module 2 for FODPSO algorithm at irradiances (800, 1000 W/m^2) for different temperature

4. CONCLUSION

The Fractional Order Darwinian Particle Swarm Optimization (FODPSO) has been applied to extract the parameters of solar PV modules. The algorithm has been implemented on two photovoltaic modules to approximate their best parameters of double diodes models at different environmental condition. From the results of FODPSO algorithm it is achieved the optimal parameters of photovoltaic model by using Minimum Root Mean Square Error (RMSE) and minimum Summation of the Individual Absolute Error (SIAE), This algorithm is able to estimate the optimum parameters at all ranges of environmental conditions (irradiance and temperature), FODPSO has achieved excellent balance between simplicity in calculation and accuracy due to its flexibility in control through the change of velocity. The modification of FODPSO has less number of control parameters, it only need to adjust (α) fraction factor but the other algorithm need to regulate some number of factors.

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