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New Optimization Approach for Maximizing the Photovoltaic Panel Power Based on Jaya Algorithm and PSO Algorithm

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ABSTRACT

Renewable energy sources are considered as a technological option for generating clean energy. Among them, Photovoltaic (PV) system has received a great attention as it appears to be one of the most promising renewable energy sources, so it is important to operate Photovoltaic (PV) panel at the optimal point to obtain the possible maximum efficiency. This paper presents a new optimization approach in order to maximize the output electrical power of the PV module. The proposed optimization technique is based on an objective function which represents the output power of PV module and some constraints which are either equality or inequality constraints. Parameters identification of photovoltaic (PV) models based on measured current-voltage characteristic curves is significant for the simulation, evaluation, and control of PV systems. To accurately and reliably identify the parameters of different PV models, an improved JAYA (IJAYA) optimization algorithm is proposed in thepaper. In JAYA, a self-adaptive weight is introduced to adjust the tendency of approaching the best solution and avoiding the worst solution at different search stages, which enables the algorithm to approach the promising area at the early stage and implement the local search at the later stage.

Keywords: ***Photovoltaic model, Parameter identification, Optimization problem, JAYA algorithm, PSO algorithm.***

Introduction:

In the last years global warming and energy policies have become a hot topic on the international agenda. Developed countries are trying to reduce their greenhouse gas emissions. Renewable energy sources are considered as a technological option for generating clean energy. Among them, Photovoltaic (PV) system has received a great attention as it appears to be one of the most promising renewable energy sources. Photovoltaic power generation has an important role to play due to the fact that it is a green source. The only emissions associated with PV power generation are those from the production of its components. However, thedevelopment for improving the efficiency of the PV system is still a challenging field of research. To tackle the issues of climate change, global warming, and depletionofclassicalfossilfuels,increasingattentionh asbeenfocusedonthe utilization of renewable energy sources[4]. Solar energy can be generally presented as a promising alternative of inexhaustible and clean sources. Solar energy is converted into electrical energy through photo-voltaic (PV) systems such as solar cell. PV systems usually operate in harsh outdoor environment and their PV arrays are easy to be deteriorated, which greatly affect the solar energy utilization efficiency. Hence, in order to control and optimize PV systems, it is vital to evaluate the actual behavior of PV arrays in operation using accuratemodel based on measured current-voltage data. There are several mathematical models that successfully describe the performance and nonlinear behavior of

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PV systems. The most common and widely adopted models are the singlediode model and double diode model. The accuracy of PV models mainly depends on their model parameters. However, these parameters usually are unavailable and change due to aging, faults, and volatile operating conditions. Hence, the accurate identification for parameters is indispensable to the simulation, evaluation, and control ofPVsystems,andvariousparameteridentificationmethodshavebeen developed over recent years. One can define the optimization as the process that finds values of variables that minimize or maximize the objective function while satisfying the constraints[4]. The optimization problems are centered on three main factors which are:

a. Objective function which is to be minimized or maximized; for example in manufacturing, we want to maximize the profit or minimizecost.
b. A set of unknown or variables that affect on the objective function; or example in manufacturing, the variables are amount of resources used for the timespent.
c. A set of constraints that allows the unknown to take on a certain values but exclude others; for example in manufacturing, one constraint is that all time variables to benon-negative.

Mathematical Model of PV Module:

The solar flux which strikes a collector is resolved to three components; direct-beam radiation that passes in a straight line through the atmosphere to the receiver, diffuse radiation that has been scattered by molecules and aerosols in the atmosphere, and reflected radiation that has bounced off the ground or other surface in front of the collector as shown in Fig. 1.

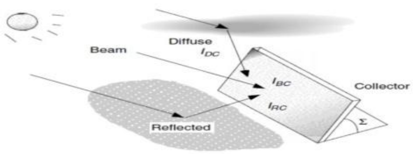

Fig 1: Solar radiation striking a collector, I_C, is a combination of directbeam, I_{BC}, diffusesI_{DC}, and reflected,I_{RC}

The total rate of radiation G_C strikes a collector on a clear day:

$$G_C = G_{BC} + G_{DC} + G_{RC} \quad \text{....(1)}$$

$$Gc = Ae^{-Km}[\cos\beta \cos(\varphi s - \varphi c) \sin\Sigma + \sin\beta\cos\Sigma + C\left(\frac{1+\cos\Sigma}{2}\right) + \rho(\sin\beta + C)\left(\frac{1-\cos\Sigma}{2}\right)] \quad \text{...(2)}$$

$$m = \frac{1}{\sin\beta} \quad \text{...(3)}$$

Where

m: Air mass

β: Altitude angle.

φs: Solar azimuth angle.

φc: PV module azimuth angle (+*ve*for east south and –*ve*for west south).

∑: PV module tilts Angle.

ρ: Reflection factor with range from about 0.8 for fresh snow to about 0.1 for a bituminousand-gravel roof, with a typical default value for ordinary ground or grass taken to be about 0.2.

C: Sky diffuse factor and is given by the following equation [1].

$$C = 0.095 + 0.04\sin[\frac{360}{365}(d-100)] \quad \text{...(4)}$$

A,K are dependent on the day number and can be obtained by the following eqns. [1].

$$A = 1160 + 75\sin[\frac{360}{365}(d-275)] \quad (W/m^2) \quad \text{...(5)}$$

$$K = 0.174 + 0.035\sin[\frac{360}{365}(d-100)] \quad \text{...(6)}$$

Where *d* is the day Number.

A PV cell can be simulated by a real diode in parallel with an ideal current source I_{SC} which depends onimpinging radiation[1]. The generalized equivalent circuit of the PV cell including both series and parallel resistances is shown in Fig. 2

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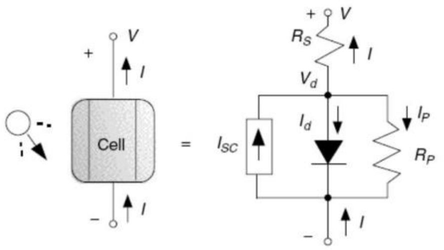

Fig 2: The equivalent circuit for a PV cell

One can derive the following equation for current and voltage in one diode model:

$$Isc = I + Id + Ip \qquad \ldots(7)$$

$$I = Isc - Io\left\{\exp\left[\frac{q(V+I.Rs)}{\eta KbT}\right] - 1\right\} - \left(\frac{V+I.Rs}{Rp}\right) \qquad \ldots(8)$$

$$Io = \frac{Isc}{e^{\frac{qV}{\eta KbT}} - 1} \qquad \ldots(9)$$

The reverse saturation current Io is dependent on the temperature and is given by the following eqn.

$$Io(T) = Io(Tref) * \left(\frac{T}{Tref}\right)^3 * \exp\left(\frac{qE_G}{AK}\left(\frac{1}{T_{ref}} - \frac{1}{T}\right)\right) \qquad \ldots(10)$$

The short circuit current depends on the solar radiation and cell temperature as follows:

$$I_{SC} = \left[I_{SCr} + K_i\left(T - T_{ref}\right)\right] * G_C \qquad \ldots(11)$$

Where

I: Cell output current
I_{SC}: Short Circuit Current
I_0: Reverse diode saturation current
V: Cell output voltage
R_S: Cell series resistance (Ω).
R_P: Cell parallel resistance (Ω).
η: Diode ideality factor.
K_b: Boltzmann constant (1.38e-23).
T: Cell junction temperature (°C).
T_{ref}: The reference temperature of the PV cell
$I_O(T_{ref})$: The cell reverses saturation current at reference temperature
E_G: The band gap of semi conductorused in the cell.
I_{SCr}: The cell short-circuit current at reference temperature and radiation,
Ki : The short circuit current temperature coefficient,
G_C: The solar radiation strikes a tilted module in W/m^2.

The PV module consists of of series cells and of parallel branches as shown in Fig. 3.

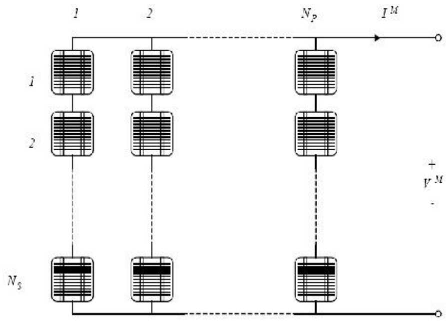

Fig 3: The equivalent circuit for a PV module

The PV module's current I^Munder arbitraryoperating conditions can be described as in asfollows:

$$I^M = N_P Isc - N_P Io\left\{\exp\left[\frac{q\left(\frac{V^M}{N_S} + I^M.R_S^M\right)}{\eta K_b T}\right] - 1\right\} - \left(\frac{\frac{V^M}{N_S} + I^M.R_S^M}{R_P^M}\right) \qquad \ldots(12)$$

$$R_S^M = \frac{N_S}{N_P} R_S \; , \; R_P^M = \frac{N_P}{N_S} R_P \text{ and } V^M = N_S V \qquad \ldots(13)$$

Objective function:

The parameters identification problem of PV models is usually converted into as an optimization problem, and the goal is to minimize the difference between the experimental data and simulated data obtained by estimated parameters. The error function for each pair ofexperimental and simulated current data point is defined by Eqs. (14) for single diode model[4].

$$f(V_L, I_L, X) = I_{PH} - I_{SD}\left\{\exp\left[\frac{q(V+I.Rs)}{\eta KbT}\right] - 1\right\} - \left(\frac{V+I.Rs}{Rp}\right) - I_L \qquad \ldots(14)$$

$$P^M = V^M I^M \qquad \ldots(15)$$

Where $V^M = PV\ module\ voltage$
$I^M = PV\ module\ current$

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JAYA Algorithm:

JAYA algorithm is a new population-based optimization algorithm developed by Rao for solving constrained and unconstrained optimization problems. The conceptual background of JAYA is that one solution obtained for a specific problem should approach to the optimal solution and evade the inferior solution simultaneously. Unlike most other population-based algorithms, JAYA is free from algorithmspecific parameters, and involves only two common parameters like population size and the number of generation. For an objective function $f(\mathbf{x})$ with D dimensional variables ($j = 1,2,\ldots,D$), $x_{i,j}$ is the value of the jth variable for the ith candidate solution, thus $\mathbf{x}_i = (x_{i,1}, x_{i,2},\ldots,x_{i,D})$ is the position of ith candidate solution. The best candidate solutionis

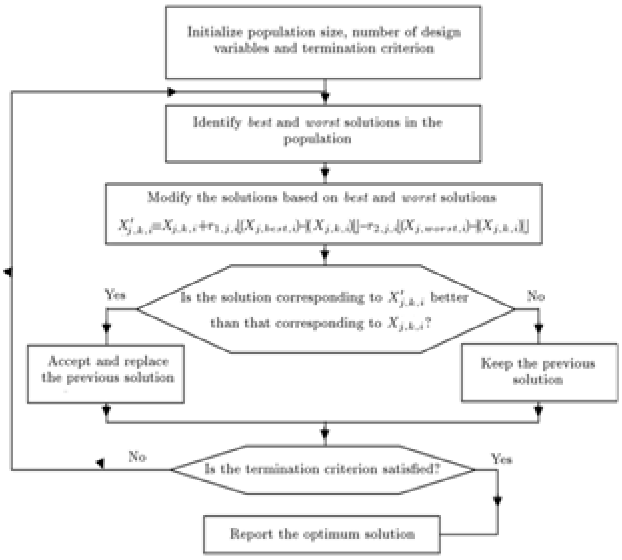

Fig4: Flow chart for JAYA algorithm

$$x_{best} = (x_{best,1}, x_{best,2},\ldots,x_{best,D})$$

It has the best value of $f(\mathbf{x})$ in the current population, while the worst candidate solution is

$$x_{worst} = (x_{worst,1}, x_{worst,2},\ldots,x_{worst,D})$$

It has the worst value of $f(\mathbf{x})$ in the current population. Then, $x_{i\,j}$, is updated using Eq. (16).

$$x'_{i,j} = x_{i,j} + rand1(x_{best,j} - |x_{i,j}|) - rand2(x_{worst,j} - |x_{i,j}|) \quad \ldots(16)$$

where $x_{best,j}$ and $x_{worst,j}$ are the values of the jth variable for the best and worst solutions, respectively. $x'_{i,j}$ is the updated value of $x_{i,j}$, and $|x_{i,j}|$ is the absolute value of $x_{i\,j}$, . $rand1$ and $rand2$ are two uniformly distributed random numbers within [0,1]. In Eq. (16), the term $rand1(x_{best,j} - |x_{i,j}|)$ represents the tendency of the solution attracted by the best solution, and the term $rand2(x_{worst,j} - |x_{i,j}|)$ indicates the tendency of the solution to shun the worst solution. The updated solution $\mathbf{x}'_i = (x'_{i,1}, x'_{i,2},\ldots,x'_{i,D})$ is accepted if it gives a betterfunction value. In the searching process, one solution obtained by JAYA algorithm is moving closer to the best solution and moving away from the worst solution[3]. JAYA algorithm strives to become victory by approaching the best solution and thus it is named as JAYA (a Sanskrit word meaning victory).

5.3 Particle Swarm Optimisation

The Particle Swarm Optimisation (PSO) is a population-based optimisation method first proposed by Kennedy and Eberhart. Some of the attractive features of the PSO include the ease of implementation and the fact that no gradient information is required. It can be used to solve a wide array of different optimisation problems, including most of the problems that can be solved using Genetic Algorithms; some example applications include neural network training and function minimization[10]. A population based optimization technique inspired by social behaviour of bird flocking/roosting or fish schooling.

Numerical Analysis:

The PV module is simulated by Matlab/Simulink toolbox as shown in Fig. 5 and the power voltage characteristics of solar radiation is shown in Fig. 7, also the current voltage characteristics of solar radiation is shown in Fig. 8.

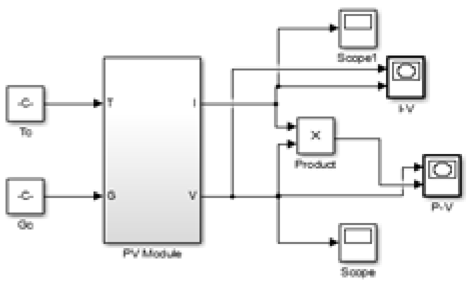

Fig 5: Simulink model of PV module

The detailed configuration of the PV module shown in Fig. 5 is given in Fig. 6. The analysis of the proposed algorithm is performed to measurethe maximum solar power and voltage.

Ki=.0032	q=1.6e-19 c
k=1.38e-23	n=1.3
Eg0=1.1ev	Rs=.221 ohms
Rsh=415.405 ohms	Tn=298
voc=32.9 v	Isc=8.21 A
Ns=32	

Table 1: Design parameters of PV module

These are the values used in the simulation of PV module.

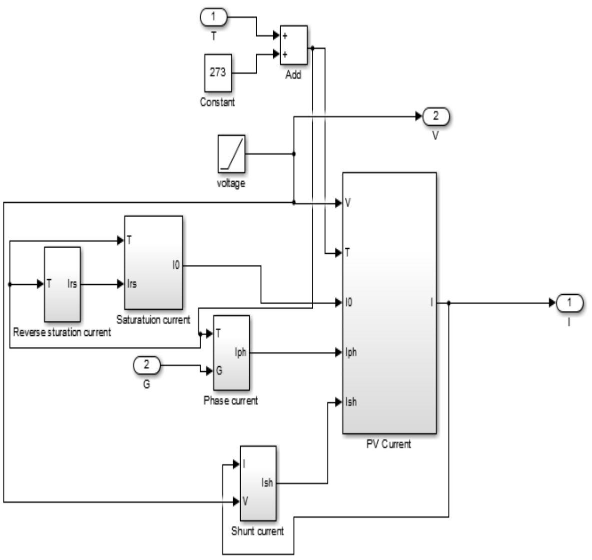

Fig 6: Detailed configuration of PV module

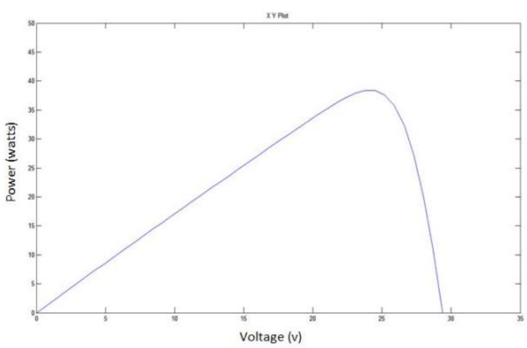

Fig 7: PV module voltage–Power characteristics

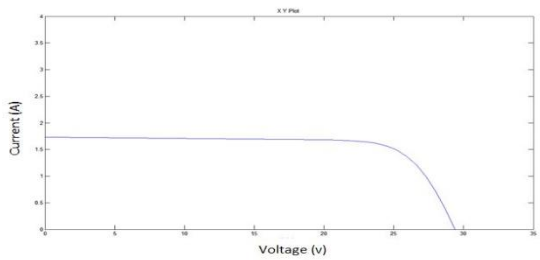

Fig 8: PV module voltage–current characteristics

Results and conclusion:

Optimization of fitness function is done by JAYA algorithm andPSO Algorithm in MATLAB. By giving the constraints for objective function, the optimal values and maximum power for pv module are obtained .and the design parameters for pvmodule used for Jaya implementation are in table 1.which was specified in numerical analysis.At the maximum power point the values of voltage is 24.15v and the current value is 1.6269A.

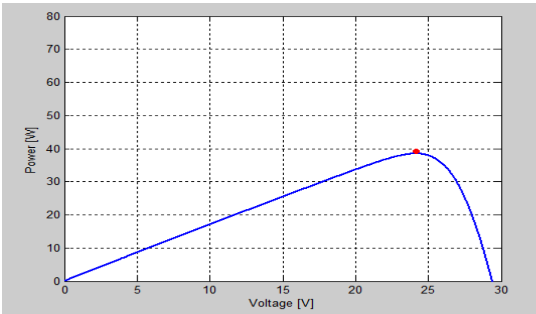

Fig 9.Maximum power point by JAYA algorithm

In The Optimization of PSO Algorithm all the design parameters are same as JAYA algorithm exceptno.of cells. The number of cells are considered in PSO algorithm implementation are 36 and Voc is 21.6v,and Isc=1.5A.

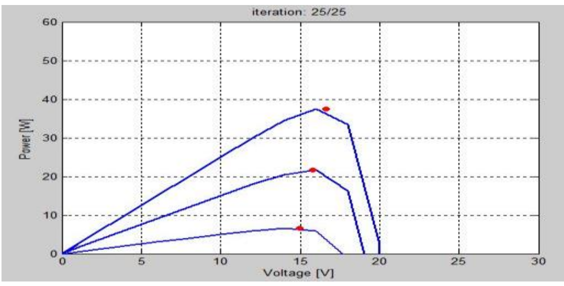

Fig 10. Maximum power point obtained by PSO Algorithm

By comparing the both the results of JAYA algorithm and PSO Algorithm, the convergent time for JAYA algorithm is less compared with the PSO algorithm and in the PSO algorithm finding out the final point for the objective function is somewhat difficult ,but in JAYA the final point approach is very easy.

In the process of running the PSOalgorithm it is difficult to define initial design parametersand it can converge prematurely and be trapped into a local minimum especially with complex problems. ExperimentresultsillustratethatJAYA has the superior performance in terms of accuracy and reliability when comparedwithotherwell-establishedalgorithms.

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