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Artificial Rabbits Optimization Algorithm for PV Cell Parameter Extraction

Vimalakeerthy Devadoss[1], Mohana Sundaram.K[2], Annamalai Muthu[3], Periasamy Selvaraju[4]

[1]Lecturer, University of Technology and Applied Sciences, Nizwa, Sultanate of Oman. Email: vimalakeerthy.devadoss@utas.edu.om

[2]Professor, Department of EEE, KPR Institute of Engineering and Technology, Coimbatore, India. Email: mohanasundaram.k@kpriet.ac.in

[3]Lecturer, Electrical Section, Engineering Department, University of Technology and Applied Science – Nizwa, Oman. Email: annamalai.muthu@utas.edu.om

[4]Professor of Computer Science and Engineering, Saveetha School of Engineering, Saveetha Institute of Medical and Technological Sciences (SIMATS), Thandalam, Chennai-602105) India.

Email: pselvar@yahoo.com

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Abstract:

Solar energy is available in abundance and the energy obtained from solar is economical. The accurate Modelling of solar module is however more important before its installation. The manufacturers of Solar Panel would provide only few parameters in datasheet that which is not enough for modeling. Metaheuristics algorithms was applied and to obtain those few parameters of module. Artificial rabbits optimization has been applied to obtain the unknown parameters in 250Wp SVL0250P photovoltaic module at varying temperature and irradiance. A performance comparison is made with flower pollination, Jaya algorithm and it is found that Artificial rabbits optimization provides excellent results with respect to precision and convergence.

Keywords: Artificial rabbits optimization, Irradiance, Photo-Voltaic (PV), FPA, Jaya Algorithm.

Introduction

Global warming driven by rise in greenhouse gases such as methane, and nitrous oxide, carbon di oxide in atmosphere, are high owing to the combustion of fossil fuel such as coal to produce electricity which alarms threat to entire country and its critical problem to be addressed urgently. As alternate renewable energy sources produces electricity without the use of fossil fuel are harmless. Compare with the various renewable energy sources, energy obtained from solar is non polluting and clean energy with less maintenance [1]. Photovoltaic (PV) represents one of the most significant advancements in solar power generation.

The exact modeling of PV modules is essential for PV characterization, fault detection, MPPT, and efficiency and it should be done before installation part. The equivalent circuit models can be useful in simulating input and output characteristics for Photovoltaic systems. Various analytical and optimization methods were applied to achieve optimal parameters of PV systems. The analytical method is based on the peculiar spots on the current-voltage (I-V) curve whereas the I-V curve varies in different conditions and it will produce a large data error.

The optimization approaches adhere to the principle of fitting the I-V curve in a way that minimizes errors between the simulated and measured data, resulting in a more accurate and dependable solution.

The parameters given in the datasheet of solar module are limited. The parameters: series resistance (Rs), Shunt Resistance (Rsh), diode saturation current(Io), Photogenerated current(Ipv), and factor (a) not in the datasheets[2-5].

GS and NR methods were used initially used to find the unknown parameters but while solving objective function, they are sensitive to initial conditions and iterations to obtain the fitness function is also high[6-10]. Optimization approaches such as particle swarm optimization, and genetic algorithm was already applied to determine the unknown parameters [11-19]. Nevertheless, in literature, Artificial rabbits optimization have not been used. Thus, ARO is applied to parameter identification of PV models. Further, the results are compared with another metaheuristic algorithm.

2. PV Cell Mathematical Modelling

The single diode model has been analyzed depicted in the fig1.

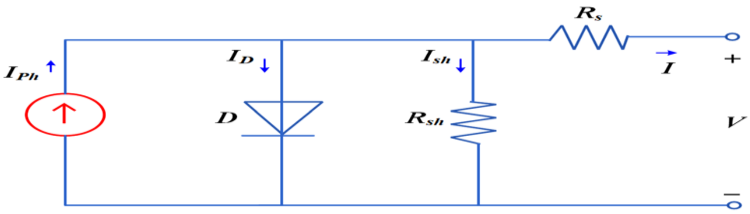


Figure 1. Single diode model

The MATLAB Modelling of PV Cell is shown in figure 2. The commercially available solar model has series and parallel resistance that are connected parallel to the diode. Rs represent the structural resistance of the device, Rp represents the loss in the device due to leakage current through resistive path [7] in parallel.

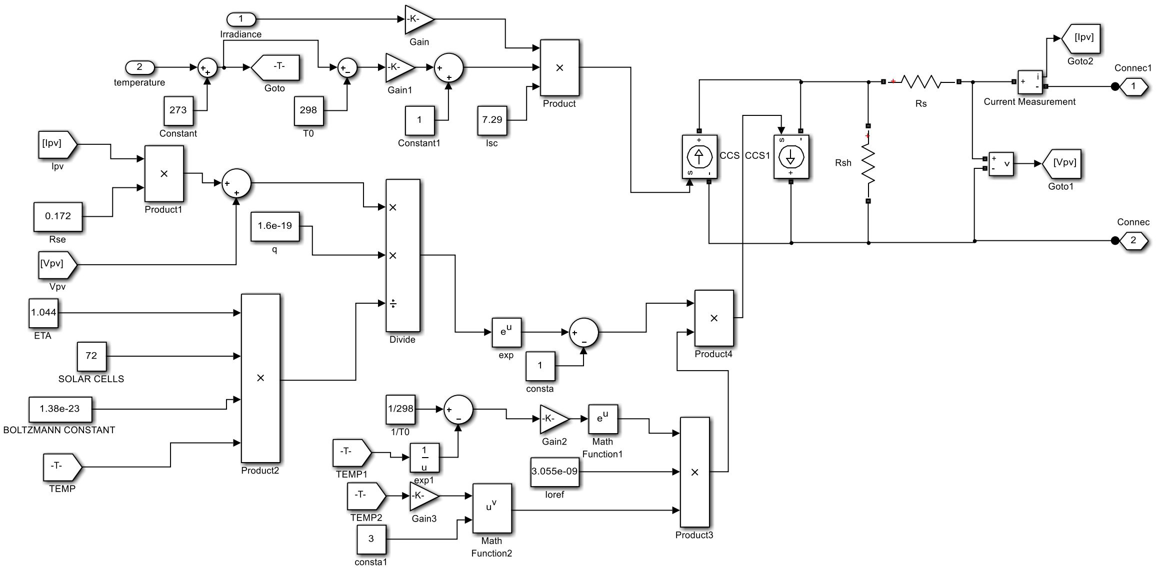


Figure 2. Mathematical Modelling of PV Cell

The current is given by:

$$I = I_{PV} - I_D - \frac{V_D}{R_P} \tag{1}$$

The current equation of diode is represented as

$$I_D = I_0(exp\left(\frac{V_D}{\alpha V_t}\right) - 1) \tag{2}$$

I_0 is saturation current of diode, V_t thermal voltage can be written as

$$V_t = N_s kT/q \tag{3}$$

Where *k* represents Boltzmann constant, *T* represents temperature in Kelvin, *q* represents electron charge and *Ns* indicate the series connected solar cells.

The PV Module equation of current [6]-[9] is given as:

$$I = I_{PV} - I_0[\exp\left(\frac{V+R_S I}{V_t a}\right) - 1] - (V + R_S I)/R_P \tag{4}$$

Hence, these five parameters such as I_{PV}, *Rp*, *Rs*, *a*, I_0 in the PV Module are unknown and is mandatory for accurate solar cell modelling.

To reduce intricacy, the suggested work calculates 'I_{PV}', 'I_0' is analytically. The 'a' is chosen randomly between 1 to 2 depends on the other parameters of the solar module [24]-[25]. The remaining two parameters of 'R_S', 'R_P' are calculated using optimization approaches. It is discovered that these parameters are modified with regard to irradiance and temperature and then adjusted to an optimum point that is based on the minimal error between computed and actual power.

The Photo generated current of PV Module [7] is given by

$$I_{PV} = (I_{SC} + k_i dT) * {}^{G}/_{G_n} \tag{5}$$

Where G & G_n represents actual solar irradiance and irradiance at STC. The Magnitude of I_0 is based on the I_{PV} and Voc [8].

$$I_0 = I_{PV}/\exp\left(\frac{(V_{OC}+k_v dT)*V_t}{a}\right) - 1 \tag{6}$$

The voltage obtained from Solar module is V_{mp}, and current is I_{mp} When PV curve is at maximum power point (MPP). Further, at this point, the differentiation of power as function of voltage becomes zero [8]. In this circumstance, the unknown parameters are extracted in this study.

$$\frac{dP}{dV} = 0 \tag{7}$$

$$\frac{d(V*I)}{dV} = V\left(\frac{dI}{dV}\right) + I \tag{8}$$

$$\frac{dI}{dV} + \left(\frac{I}{V}\right) = 0 \tag{9}$$

$$\left|\left(\frac{dI}{dV}\right)\right|_{(Vmp,Imp)} = (I_0\psi \exp\{\psi(V_{mp} + I_{mp}R_S)\} - Z_P\Big)/(1 + I_0\psi R_S \exp\{\psi(V_{mp} + I_{mp}R_S)\} - Z_P R_S \tag{10}$$

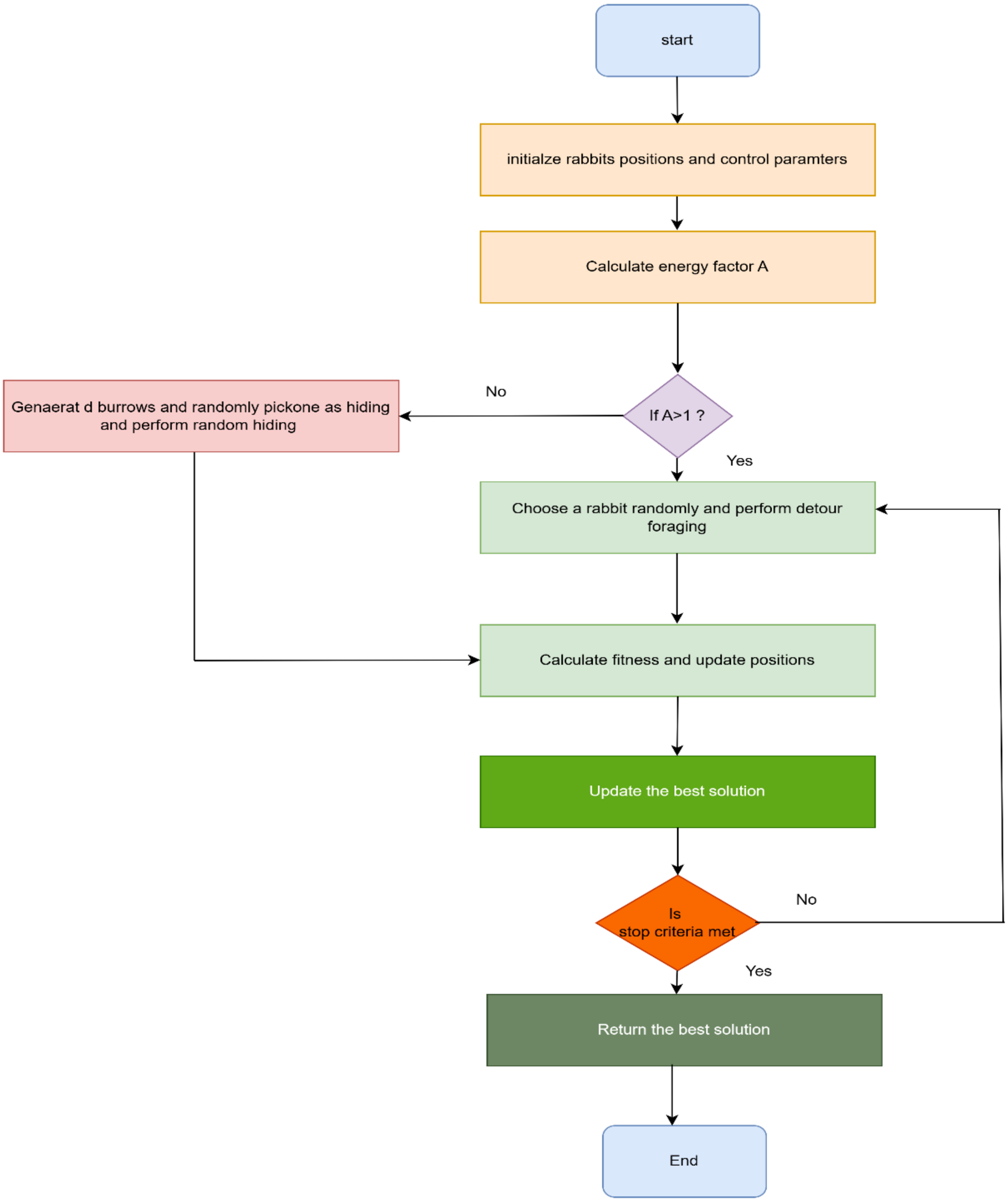
Where $Z_P=1/R_P$, $\psi=1/aV_t$

$$J = |\left(\frac{dI}{dV}\right)|_{Vmp,Imp} + \left(\frac{I_{mp}}{V_{mp}}\right) \tag{11}$$

The measured solution is achieved when the fitness function (J) approaches zero[8].

Artificial rabbits optimization Algorithm based solar cell Extraction:

ARO is originated from the survival strategies of rabbits in nature The ARO has three phases, namely exploration (detour foraging), exploitation (random hiding) and balancing exploration and exploitation (energy shrink). The flow chart is given below.



Result analysis:

A 250 Watts SVL 0250P datasheet was taken and it provides the values of OC voltage, SC current, maximum power point current, k_v, k_i. The parameters that are unknown such as Ipv, $I_{0,}$ Rs, a, Rp. The Ipv, $I_{0,}$ are calculated analytically and Rs and Rp are accurately measured using ARO, JA, FPA.

The value of Rs is selected arbitrarily between [0 to 2] and initial boundary limit for Rp between 50 to 500. The measured Rs and Rp values using ARO, Jaya Algorithm, and FPO for different environmental conditions is shown below.

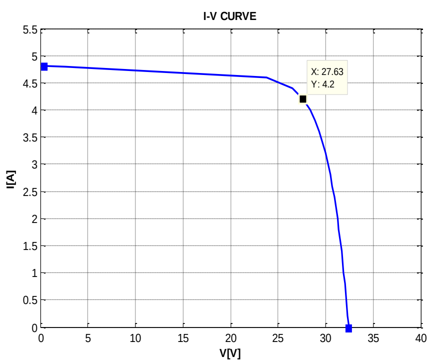
Table 1. Solar module unknown parameters measured with ARO, JA, and FPO for different Temperature (T) and Irradiance (G)

Parameters	**SVL 0250P**		
	FPO	**JA**	**ARO**
T=25^{0}C & G=1000W/m^2			
Rs(Ω)	0.91778	0.916811	0.814
Rp(Ω)	63.254	50.0028	221.62
T=47.4^{0}C & G=525W/m^2			
Rs(Ω)	0.341673	0.772148	1.3489
Rp(Ω)	123.46722	50.00964	131.4698
T=45.9^{0}C & G=368W/m^2			
Rs(Ω)	1.92697	1.485236	1.4589
Rp(Ω)	82.63984	50	322.8952

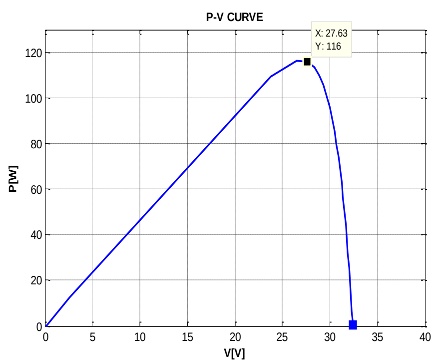
From the observation of table, it is seen that magnitude of Rs is very small and magnitude of Rp is high. According to which, smaller value of Rs and higher value of Rp moves the P-V curve towards MPP. Accordingly, a lower value of Rs and a higher value of Rp shift the PV curve towards MPP.

Figure 3 (a-d) shows the simulation results of I vs V and P vs V Characteristics of 250Wp PV module for two environmental conditions such as STC, T=47.4^{0}C & G=525W/m^2, and T=45.9^{0}C & G=368W/m^2.

(a)



(b)



(c) (d)

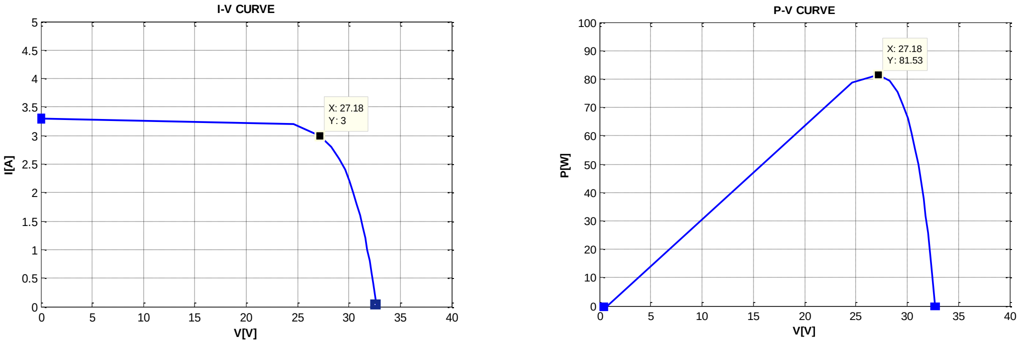


Figure 3. (**a&b**) I vs V & P vs V characteristics for G=525W/m^2 and T=47.4^{0}C ,(**c&d**) I vs V & P vsV characteristics for G= 368W/m^2 and T =45.9^{0}C

With the obtained results, we can identify that at T=47.4^{0}C & G=525W/m^2, the voltage(mpp) and current(mpp) are 26.53 V and 4.1A. With T=45.9^{0}C & G=368W/m^2, the voltage(mpp) and current(mpp) are 26.18 V and 3A. The figures clearly indicate the variation of significant PV parameters i.e., Voc, Isc, MPP voltage and current based on irradiance, temperature.

The figure 4 shows the fitness of various algorithms such as ARO, JA and FPO.

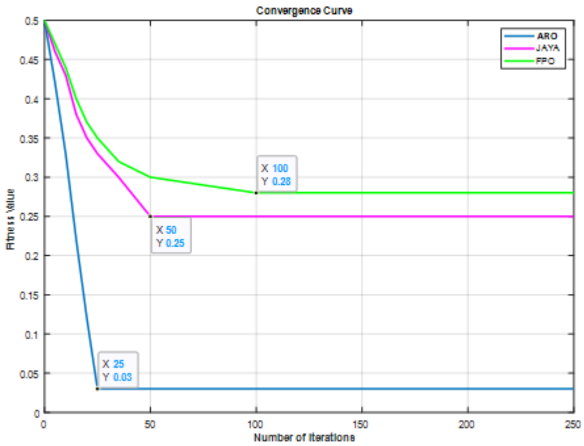


Figure 4. Convergence Curve Comparison of ARO, JA and FPA

With the study of convergence, it can be observed that convergence rate of (ARO) is fast compared to JA and FPA. The ARO has been converged at thirtieth iteration, JA at 160th iteration, and FPO at 180th iteration.

ARO, JA, and FPO performance comparison has been depicted in the table 2.

Table 2. Comparison of ARO, JA, and FPA.

Technical criteria	FPO	JA	ARO
Solution Accuracy	Low	Medium	High
Convergence Speed	Medium	Medium	High
Computational Complexity	High	Medium	Low

With the above table, one can conclude that, it displays that ARO had the best convergence performance proved to be an appropriate optimization technique for PV module unknown parameters extraction in terms of solution accuracy, Convergence speed, and computational complexity.

5. Conclusion

ARO has been implemented to measure the PV model parameters, Rs and Rp accurately without sub-optimal traps. These parameters have been extracted with a fitness function of differentiation of power with respect to voltage at maximum power point. The detailed study of ARO is presented in this paper.

The ARO Algorithm is validated in following ways

i. The SVL0 250P PV Module electrical characteristics using MATLAB/SIMULINK model measured for different environmental conditions using ARO and its variants are compared to FPA, and JA.
ii. Convergence figure has been plotted for ARO, JA and FPA and iteration found to be less in ARO.
iii. Computation complexity is less in ARO compared with JA and FPA.

Hence, ARO Algorithm is best with fast computation for extraction of SVL0 250P Module.

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