Comparison between ideal and estimated pv parameters using evolutionary algorithms to save the economic costs

Rahmani, Javad and Sadeghian, Ehsan and Dolatiary, Soheil

Department of Islamic Azad University, Science And Research BranchTehran, Iran, Islamic Azad University Central Tehran Branch college, Tehran, Iran, Islamic Azad University Central Tehran Branch college, Tehran, Iran

October 2018

Comparison between Ideal and Estimated PV Parameters Using Evolutionary Algorithms to Save the Economic Costs

Javad Rahmani [1], Ehsan Sadeghian [2], Soheil Dolatiary[3]

[1]Graduate Student of Digital electronics Engineering, Department of Islamic Azad University, Science And Research BranchTehran, Iran

[2,3]Graduate tudent of Electrical engineering, Islamic Azad University Central Tehran Branch college, Tehran, Iran

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Abstract – *Micro grids are now emerging from lab modules sites into commercial markets, driven by technological improvements, falling costs, a proven track record, and growing recognition of their benefits. Their main contribution is to improve reliability and resilience of electrical grids, to manage the addition of distributed clean energy resources like wind and solar photovoltaic (PV) generation to reduce fossil fuel emissions, and to provide electricity in areas not served by centralized electrical infrastructure. In between, the popularity of photovoltaic panel is not deniable. In this paper, the ideal and practical electrical model of PV is being discussed. Due to significant role of the PV parameters, they are assessed by several heuristic methods and the results are compared. Hence an optimal method for parameter estimation is discussed that can be used in micro grid simulations to reach to an optimal quiescent working condition.*

***Key Words*: Micro grid, power system, PV panel, heuristic optimization**

1.INTRODUCTION

Over 99.9 per cent of Earth's energy comes from the sun .In addition to sunlight reaching the earth's surface, the sun is the source of all wind, hydro, and wave energy as well as biomass and fossil fuels which originated from organic matter and represents stored solar energy collected by photosynthesis over many millions of years [1, 2]. Enough direct sunlight reaches the earth to supply all of humankind's energy needs many times over [3, 4]. For example, the yearly direct normal irradiation (DNI) component of solar energy from just the Northern Cape Province of South Africa is equivalent to more than six times the worldwide annual energy consumption [5, 6]. The necessity of energy management in a multi generation source network to ensure a reliable and continuous power supply, accelerates the integration of intermittent renewable energy resources in power grid [7, 8]. By associating a variety of distributed energy sources and loads in a power grid these issues are addressed in microgrd concept with ability of islanding operation with the main grid [9, 10]. Economic, environmental, and electricity supply quality and reliability are impacted by deployments of micro grids. Reducing carbon dioxide emissions related to energy generation, guaranteeing a low cost of energy, and maintaining high continuity and/or quality of electric supply are drivers of coordination strategies in controllable local grids [7, 11, 12].

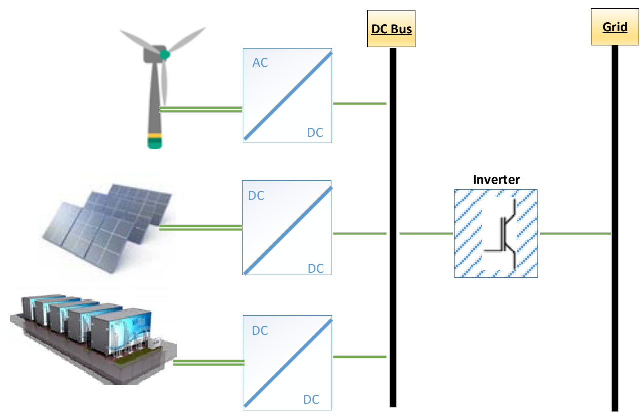

Fig. 1. Micro grid and renewable resources

Many analysts predict that, by the end of this decade, distributed network energy costs will be competitive with other conventional forms of generating electricity [13]. Government assistance can also contribute to the growth of this procedure. Perhaps at first, it would seem that the cost of generating electricity by solar power is more than conventional, but policymakers will slowly conclude that burning fossil fuels makes significant social costs, including environmental pollution-related ones. How much the use of the solar energy system can be welcomed by homeowners depends on factors such as initial costs, maintenance costs, government grants, electricity costs, and the price of sales of surplus electricity [14, 15]. The ability to isolate the grid from the main network also increases cybersecurity. The reason is when an incident occurs, for any reason, micro grid can limit its consequences [16, 17]. If there is no physical damage, a grid can continue to operate as long as it has access to the energy source (fossil fuels, sun, or wind). In the end, considering economic issues and technology regulations, it is possible to expand the distribution network by using a series of adjacent grids [18, 19]. They share energy close together with each other and the main grid, in addition to maximizing the level of access, minimize the cost of generating electricity [20]. In the adjacent trenches that are also set up and operated by the private sector, large power plants can, in lieu of providing electricity to each consumer, if necessary, the power required by a grid or in case of emergency multi-grid connections. Hence, they can provide part of the electricity required by the global network [21, 22]. However, the dilute nature of sunlight reaching earth makes it relatively difficult to capture and convert into usable power. There are two methods commonly used to harvest solar energy for electricity. PV cells use semiconductors to directly convert light into electricity while solar thermal systems convert sunlight into thermal energy to generate electricity by means of a heat engine in much the same way as conventional power plants do. This happens by usage of focusing optics and solar tracking mechanisms to concentrate sunlight for producing high temperature thermal energy. Fig.1 shows a classification diagram of solar power in which a distinction is made between PV and solar thermal systems [23].

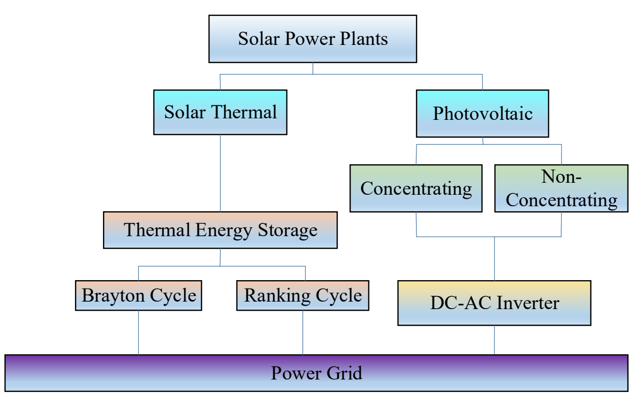

Fig. 2 Classification diagram of solar power

The initial cost to make PVs is still high due to their low returns, but with the increasing progression of semiconductor technology, their initial prices are decreasing and their returns are increasing. In between different methods of optimization helped the grid operators to exploit the maximum benefit of the currently installed PVs. For example, a new method for application in communication circuit system is proposed in [24-26] that it causes increasing the efficiency, PAE, output power and gain in which the author discusses about switching class of E-J and switching class of AB-J respectively. Application of neural network in power engineering as well as other branches of science is well established as in [27, 28] neural networks based models were successfully applied in external radiotherapy to track the dynamic of respiratory system in order to target tumors with high accuracy and prevent side effects of extra radiation. [29, 30] represents a framework for automatic segmentation of medical images of different kinds of tumors using adaptive neuro-fuzzy inference system. An Adaptive controller based on model reference control is designed for tracking control of manipulator of arm robots. Robust controller is used in [31, 32] to control nonlinear systems. In case of robotics, In [33, 34] a sliding mode controller is designed for spherical mobile robot t. A grid resilient framework is utilized in [35-37] to enhance the system outage recovery faced by extreme emergencies. Dealing with a lot of parameters, in [38, 39] new methods to reduce the dynamic model of power system is proposed. Resilient cyber method to defend against attacks id discussed in [40].The implemented optimizing engine helps rapid recovery of the power grid outage in case of loss of generators and is able to track the desired trajectory and remain stability of the micro grid [21, 41]. In this research, the parameters of the single-dihedral photovoltaic panel model (5 parameters) and two diode (7 parameters) are estimated using various meta-optimization optimization algorithms. The photovoltaic panel is characterized by experiments conducted at the Renewable Energy Laboratory of the University of Industrial Engineering and Advanced Technology, Then using the practical results, the problem of estimating the parameters in order to reduce the squared error has become a minimization problem and been solved with various optimization algorithms [42, 43]. In addition, the model obtained from the experiments is compared with the model derived from the panel data sheet. For this purpose, the photovoltaic panel model obtained from the panel data sheet is also obtained in standard conditions. In the end, the two models are compared with each other.

1.1 PHOTOVOLTAIC PANEL MODELING

Photovoltaic panels can be modeled in two ways

A. Ideal single diode photovoltaic panel

$$I = I_{pv,cell} - I_{0,cell}[\exp(\frac{qV}{akT}) - 1] \quad (1)$$

This equation depends on the radiation perpendicular to the panel surface and panel temperature and the photovoltaic panels used.

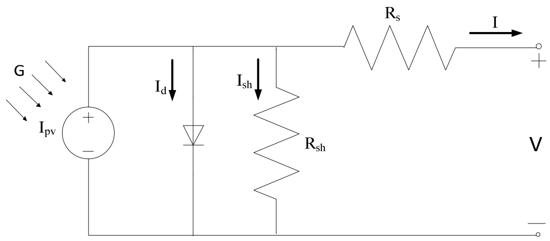

Fig. 3 Electrical Photovoltaic Model

The constants $I_{pv,cell}$ stands for the flow generated by the collision light (directly related to the received radiation), $I_{0,cell}$ reverse saturation current or diode leakage current, q electron charge, K is Boltzmann's constant, T bond temperature and an is ideal constant of diode respectively [44, 45].

A. Practical photovoltaic panel modeling

The practical characteristics of the photovoltaic panel by (1) do not adequately describe the features of the experimental photovoltaic panel [46, 47]. In order to express the practical characteristics of the photovoltaic panel, the addition of other components requires equation (2). The experimental model of the photovoltaic panel is as follows:

$$I = I_{pv} - I_0[\exp(\frac{V + R_s I}{V_t a}) - 1] - \frac{V + R_s I}{R_p} \quad (2)$$

In which I_{pv} is photovoltaic current ,I_0 diode saturation current ,T temperature of photovoltaic panel, N_s number of cell series, N_p the number of parallel cells, R_s series equivalent resistance, R_p parallel equivalent resistance and a is the ideal coefficient of the panel. The photovoltaic and diode saturation flows are calculated according to the number of series and parallel cells in the panel using the following formulas:

$$I_{pv} = (I_{pv,cell}) \times (N_p) \quad (3)$$

$$I_0 = (I_{0,cell}) \times (N_p) \quad (4)$$

With the photovoltaic panel temperature and the number of series cells present in the panel, the photovoltaic panel temperature is obtained [48]. Therefore, (2) has five unknown parameters. These parameters are the photovoltaic current, the diode saturation current, the equivalent series resistance, the equivalent parallel resistance, and the ideal coefficient of the panel [49]. All of these five parameters depend on the environmental factors affecting the panel, which are the most important factors of radiation and temperature [50, 51].

B. Two diode photovoltaic panel

By adding a diode to a single-dihedral photovoltaic panel model, a two-dihedral photovoltaic panel model (Fig. 3) is obtained [52, 53]. This model involves the effect of the open-ended loss in the space between the two links by adding an additional diode in the flow relation. This model increases the accuracy considerably, but also makes the calculation even more complicated. The equivalent circuit of the photovoltaic panel of the two diode is in Fig.3.

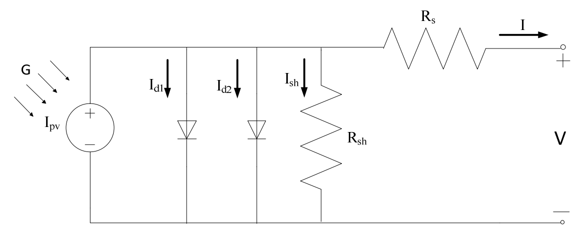

Figure. 4. Two diode photo voltaic cell model

$$I = I_{pv} - I_{01}[\exp(\frac{V + R_s I}{V_t a_1}) - 1] - I_{02}[\exp(\frac{V + R_s I}{V_t a_2}) - 1] - \frac{V + R_s I}{R_p} \quad (5)$$

In which I_0 is diode saturation current , V_t temperature of photovoltaic panel, N_s number of series cells, N_p the number of parallel cells, R_s series equivalent resistance, R_p parallel equivalent resistance and a is the ideal coefficient of the diodes is. In this equation, as the single-diode model with the photovoltaic panel temperature and the number of series cells in the panel and, the temperature of the photovoltaic panel can be obtained, but still, seven parameters are unknown. These parameters are the photovoltaic current, the diodes saturation current, the equivalent series resistance, the equivalent parallel resistance, and the ideal coefficients of the diodes respectively.

2. IMPROVEMENT OF PHOTOVOLTAIC PANEL MODEL

The model presented in the previous section for the radiation, the specified temperature is obtained, and the five parameters in that model are stable: the three parameters, namely series and parallel resistors, and the coefficient of the ideality of the diodes in the panel [54]. Two other parameters, are the photovoltaic flow of the panel and the saturation current, are modified by the use of (3) and (4). In these formulas, the photovoltaic panels are mainly effective from radiation and effective saturation flow from the panel temperature. This model does not respond appropriately to different solar conditions and temperatures, while changing at least four parameters of the five parameters are expected by different weather conditions [55, 56].

In this paper, an analytical model of a photovoltaic panel that is capable of representing the characteristics of the photovoltaic panel characteristic for different weather conditions has been used. Equivalent circuit parameters are obtained by solving a set of equations using the information in the panel data sheet under standard conditions and with the test and error method [57]. The superiority of this method is not using a particular method to solve the equation or using optimization algorithms, which makes it easier to implement this model in control devices such as microcontrollers. Also, by using the test and error method and the lack of use of approximation in equations, the more accurate answers are obtained, which is another advantage of this method.

The failure of this method is to create a new equation for the equivalent photovoltaic panel in a different condition than standard conditions [55, 58]. In the sense of the equation used in standard conditions, the equation of ordinary photovoltaic panel is adapted. In addition, the use of panel data values in standard conditions, which rarely happens, reduces the accuracy of the model. In any case, it is possible to use this model for different weather conditions on other models. The proposed model of the photovoltaic panel is represented by the following equation [21, 59]:

$$I(\alpha_G, T) = \alpha_G I_{pv}(T) - I_o(\alpha_G, T)(e^{(\alpha_G[V+K(T-T_{ref})]+IR_s)/\alpha_G nT} - 1) - \frac{\alpha_G[V+K(T-T_{ref})]+IR_s}{R_{sh}} \quad (6)$$

In this equation, radiation (G) is entered using the following equation:

$$\alpha_G = \frac{G}{G_{ref}} \quad (7)$$

In which G_{ref} the radiation in standard conditions is 1000 watts per square meter($\frac{W}{m^2}$). The I_{pv} in (6) is obtained by the following formula:

$$I_{pv} = (I_{pv,n} + K_I \Delta T) \quad (8)$$

Therefore, the photovoltaic flow is equal to the previous formula and the other parameters obtained are different. K is a temperature coefficient that is an additional parameter than the previous formula. In this formula, series and parallel resistors are taken for each radiation and constant temperature [52].

In the previous chapter, the parameters were obtained by numerical methods [60, 61]. In this section, the parameters are obtained by an adaptive test and error method. This method is more suitable than other methods because of the lack of numerical methods and approximations [62]. In this method, the data of three points of short circuit, open circuit and maximum power, as well as the characteristic slope of the current voltage at short points and open circuit are used [46].

A. Calculating Parameters

In the method used the values of short circuit and open circuit and maximum power in the data sheet of the photovoltaic panel and the curve slope of the voltage characteristic of the short circuit and open circuit obtained from [40] are used.

• Short circuit point $V = 0, I = I_{sc,ref}$

$$I_{sc,ref} = I_{L,ref} - I_{o,ref}(e^{I_{sc,ref}R_s/nT_{ref}} - 1) - \frac{I_{sc,ref}R_s}{R_{sh}} \quad (10)$$

• Short circuit slope point

$$\left.\frac{dI}{dV}\right|_{\substack{V=0\\ I=I_{sc,ref}}} = -\frac{(I_{o,ref}/nT_{ref})e^{I_{sc,ref}R_s/nT_{ref}} + 1/R_{sh}}{1+R_s((I_{o,ref}/nT_{ref})e^{I_{sc,ref}R_s/nT_{ref}} + 1/R_{sh})} = -\frac{1}{R_{sho}} \quad (11)$$

• Open circuit point

$V = V_{oc,ref}, I = 0$

$$0 = I_{L,ref} - I_{o,ref}(e^{V_{oc,ref}/nT_{ref}} - 1) - \frac{V_{oc,ref}}{R_{sh}} \quad (12)$$

• Open circuit gradient

$$\left.\frac{dI}{dV}\right|_{\substack{V=V_{oc,ref}\\ I=0}} = -\frac{(I_{o,ref}/nT_{ref})e^{V_{oc,ref}/nT_{ref}} + 1/R_{sh}}{1+R_s((I_{o,ref}/nT_{ref})e^{V_{oc,ref}/nT_{ref}} + 1/R_{sh})} = -\frac{1}{R_{so}}$$

Maximum power point ($V = V_{mp,ref}, I = I_{mp,ref}$) (13)

$$I_{mp,ref} = I_{L,ref} - I_{o,ref}(e^{(V_{mp,ref}+I_{mp,ref}R_s/nT_{ref})} - 1) - \frac{V_{mp,ref}+I_{mp,ref}R_s}{R_{sh}}$$

The formulas obtained from these parameters are approximated. Therefore, in this paper, these methods are directly used in the test and error method based on the change of n and R_s parameters [54].

I. PARAMETER ESTIMATION ALGORITHM

The following algorithm is used to estimate the parameters:

1. Determine the initial values of the parameters n and R_s
2. Insert values $I_{L,ref}$ and R_{sh} using:

   $I_{L,ref} = I_{sc,ref}$

   $R_{sh} = R_{sho}$

3. Calculation I_0 using (4).
4. n is calculated using (6) and is compared with the amount specified in step (1).
5. The steps 3 and 4 are repeated to obtain the n value according to the desired accuracy.
6. R_s is calculated based on n from (7), is compared with assumed value, and will change.
7. Steps 3,4 and 5 will be repeated.

R_s Re-calculated by (7) and compared to the previous value and changed accordingly.

This process continues to reach the correct value. In this way, the system is solved by not simplifying any equations in a non-approximate form. Very simple programs that can be used to estimate these parameters in various control methods implement this process [63]. Matlab software has been used to run the algorithm. The results obtained by this method provide accurate and high-speed results. But the use of the initial values in the photovoltaic panel data sheet due to non-experimental information reduces the accuracy of the model. The parameters calculated for the regular commercial solar panel which are specified in the standard conditions are depicted in Table 1.

Table -1: Parameters calculated for the solar panel under standard conditions

R_{sh}	R_s	n	I_o	I_{pv}
131.7225(Ω)	0.27742(Ω)	0.002438(Ω)	3.7e-11(A)	5.311(A)

The only remaining unobstructed parameter K is the temperature coefficient obtained by the curve values of the voltage characteristic current in the panel data sheet. This coefficient is used to move the curve of the voltage characteristic curve to better position the curves.For a favorable temperature T^* different than T_{ref}, this parameter is obtained from the following equation [57, 64]:

$$K = \frac{V_{mp} - V_{mp}^*}{I_{mp}^*(T^* - T_{ref})} \tag{14}$$

Which V_{mp}^* voltage and I_{mp}^* current at optimal temperatures are presented in the panel data sheet. It is more appropriate to use radiation data of 1000 watts per square meter and a temperature of 75 degrees that is present in the data sheet of the curve of the current voltage curve. To do this, you can turn curve information into numbers using the Plot digitizer software [65, 66].

3. VALIDATION OF THE MODEL

This chapter uses the Newton algorithm to validate the previous chapter. Due to the complexity of the formula, the speed of the Newton algorithm decreases, but it still has the right precision. For radiation of 1000 W / m2 and at 25 ° C, the curve of the characteristic current-voltage and voltage-power characteristics of the panel in standard conditions, are shown in Fig .5 and Fig.6 respectively. As can be seen, the results for a given temperature and radiation are not quite as good as the results of the previous chapter, and the curves are somewhat biased [46, 67]. However, being able to operate in different environmental conditions is very suitable, in contrast to which low accuracy can be neglected. It should be noted, however, that the use of panel data information is one of the factors reducing model accuracy.

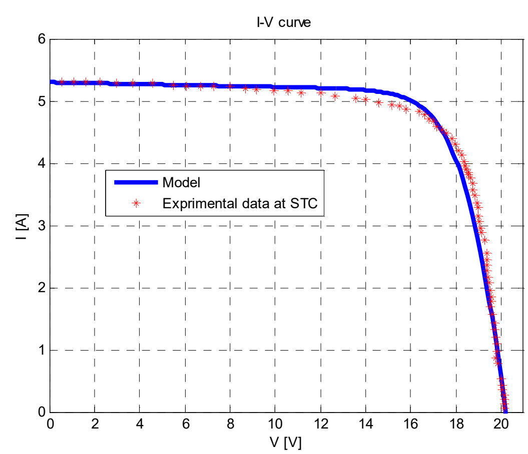

Chart -1: Comparision between current-voltage characteristics with ideal and optimized parameters

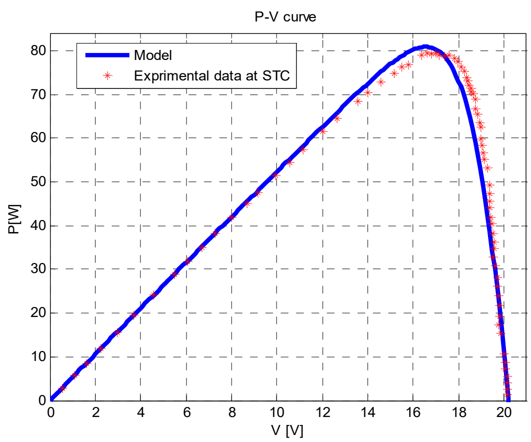

Chart -2: Comparison between power-voltage characteristics with ideal and optimized parameters

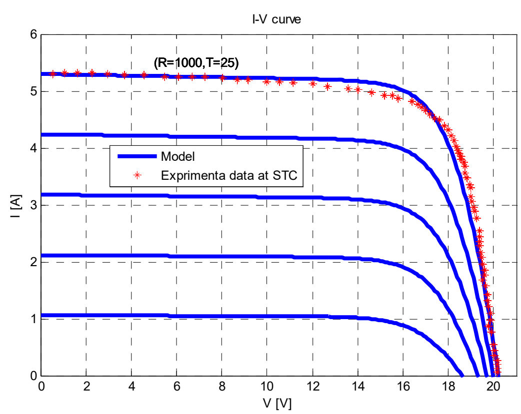

Chart -3: Comparison of with ideal and optimized voltage-current profiles in different weather conditions

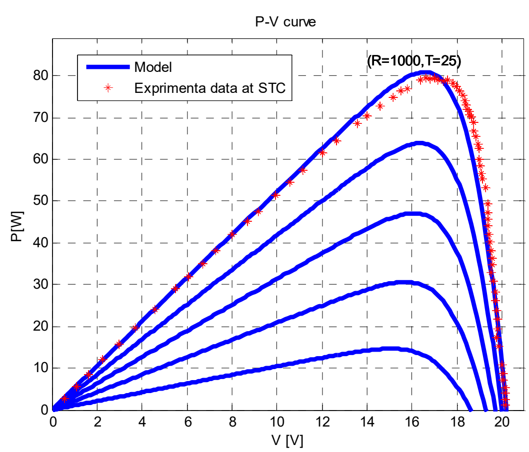

Chart -3: Comparison of with ideal and optimized voltage-power profiles in different weather conditions

Modeling and Validation for different conditions are performed in Fig.7 and Fig.8. It is obvious that the resulting optimized model is accurate with proper accuracy for different atmospheric conditions. Hence, with the slightest neglect of precision, we can use the model for different atmospheric conditions and different radiation and temperatures.

4. CONCLUSIONS

The costs of solar photovoltaic generation are rapidly reducing, to the point that they are closing in on cost parity with traditional electricity sources. Due to high penetration of PV panels having an accurate electrical model of it is necessary for micro grid simulation. Though first ideal mathematical model of a PV is discussed and then based on multiple heuristic methods, the optimized parameters are calculated. The proposed model for the photovoltaic panel has been improved and is capable of modeling a photovoltaic panel in different radiation and temperatures, and provides a good performance for designers and planners of photovoltaic systems. The model presented for different atmospheric conditions is used and validated for information obtained from field experiments, which results in the acceptable accuracy of this model.

ACKNOWLEDGEMENT (Optional)

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