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Estimation of Solar Cell Model Parameter by Hybrid Genetic Algorithm Using MATLAB

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Abstract— **In the present work, an efficient and accurate approach for the estimation of the solar cell parameters using hybrid genetic algorithm from the given voltage-Current data is proposed. Exact estimation of solar cell data is necessary for getting desired accuracy in PV based simulation studies. This paper proposes the hybrid Genetic algorithm, which is based on Genetic Algorithm (GA) and Nelder-Mead (NM) simplex search method. GA-NM is easy to implement in practice as it does not require any initial guess about the parameter values. Proposed approach has the benefits of both Genetic Algorithm and Nelder-Mead simplex method. The simulation results prove the suggested algorithm to be extremely effective and efficient at locating optimal values of the solar cell parameter. MATLAB OPTIMTOOL is used to implement the proposed approach.**

Index Terms— **Hybrid Genetic Algorithm, Solar Cell, Estimation, MATALB**

I. INTRODUCTION

Now days, electricity production by renewable energy sources is encouraged worldwide in many countries and also considered as a strategic objective for the future. Government policies of many countries also support projects that provide potential utilities with access to renewable energy solutions and increase familiarity with renewable energy technologies. Photovoltaic systems become more popular because they can generate electricity on-site where it is needed, avoiding transport losses and contributing to CO_2 emission reductions in urban areas [1-2].

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To explain the non-linear characteristics of the current-voltage (I-V) curve of a solar cell many models were developed [3-5]. A lumped parameter single diode equivalent circuit model is commonly used to simulate the solar cell behavior under different operating conditions. The main key parameters that describe solar cell models behavior are the generated photocurrent, saturation current, series resistance, shunt resistance, and ideality factor. Precise and accurate estimation of these parameters is always required to provide better modeling and accurate performance evaluation of a given PV system [6].

The determination of model parameters plays an important role in solar cell fabrication and design. A detailed knowledge of the cell parameters can be an important way for the control of the solar cell manufacturing process, and may be a mean of finding out the causes of degradation of the performances of panels and photovoltaic systems being produced. This is the reason, that model parameters identification provides a powerful tool in the optimization of solar cell performance [7].

In this paper a hybrid algorithm based on combination of Genetic algorithms and Nelder Mead simplex method is presented for the accurate estimation of solar cell parameters. There are many ways to utilize the idea of hybridizing local search techniques with the genetic algorithm. Here, firstly GA is used to find the optimized values of solar cell parameters and then NM is applied to further, improve the parameters value.

The Nelder-Mead technique generates a new space around the best point obtained from the GA, and search within this space about a better point. The results shown prove the accuracy of the proposed approach.

II. SINGLE DIODE MODEL EQUIVALENT CIRCUIT OF PV CELL

The solar cell can be modeled using an electrical equivalent circuit that contains a current source anti-parallel with a diode, a series resistance and shunt resistance as shown in figure 1

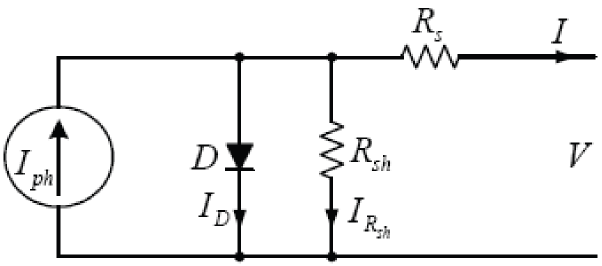

Fig 1: Solar Cell Equivalent Circuit

When the cell is exposed to direct sunlight, a direct current generated which varies with solar irradiance. The current I_D through the anti-parallel diode is largely responsible for producing the non-linear I-V characteristics of the solar cell. The Kirchoff's current law gives the basic equation that characterizes the solar cell I-V relationship, considering the equivalent circuit shown in figure 1

$$I = I_{ph} - I_D - I_{Rsh} \quad (1)$$

Substituting the diode current I_D and I_{sh} by relevant expressions

$$I = I_{ph} - I_D\left(\exp\left(^{(V+IR_s)/(AkT/q)}\right) - 1\right) - (V + I R_s)/R_{sh} \quad (2)$$

Where I and V are the solar cell output current and voltage respectively, *Iph* is the photo-generated current in standard test conditions (STC), I_D is the saturation current in STC, q is the charge of an electron, *A* is the diode quality factor, k is the Boltzmann constant, *T* is the absolute temperature and R_s and R_{sh} are the series and shunt resistances of the solar cell. R_s is the resistance offered by the contacts and the semiconductor material of the solar cell. The shunt resistance R_{sh} is related to the non ideal nature of the p–n junction and the presence of impurities near the edges of the cell that provide a short-circuit path around the junction. In an ideal case R_s would be zero and R_{sh} infinite.

III. Hybrid Genetic Algorithm

An effective optimization technique is that, which has searching ability for global optimum solution and its accuracy. Genetic algorithms can be very powerful to find a global optimum area but are not very fast to solve local optimization problems. Local optimization techniques such as the Nelder-Mead Simplex are quite efficient to find a local optimum very quickly. In recent years, to enhance the global optimization searching ability of genetic algorithm, the genetic algorithm (GA) and the simplex method are being used in hybrid way to get more accurate results for complicated processes [8], [9].

A. Genetic Algorithm

Genetic Algorithms are a particular class of evolutionary algorithms and best used when the objective function is discontinuous, highly nonlinear, stochastic and has unreliable or undefined derivatives. These methods perform a search by evolving a population of candidate solutions through the use of nondeterministic operators and by improving incrementally the individuals forming the population by mechanisms inspired from those of genetics (e.g., crossover and mutation). The separate parts of individuals are known as genes. Each individual is assigned a fitness value, which indicates the quality of the solution the chromosome represents. During the execution of a GA, population is continually replaced by new populations. The new populations are created by crossover and mutation of the existing population. Crossover is seen as the most important operator; it takes two individuals parents and transfers genetic material from parents to new individual's children. An individual's chance of being chosen as a parent is proportional to its fitness. This is done so that the principle of natural selection is mimicked; that is the fittest members of the population are allowed more opportunity to breed in the hope that they will pass their good genetic material to the next population. If this happens enough the population should gradually improve as fitter, and fitter individuals are created. In certain cases, particularly when facing complex optimization problems with numerous local optima, where traditional optimization methods fail to provide efficiently reliable results, Genetic Algorithms can constitute an interesting alternative. Nevertheless, Genetic Algorithms can suffer from excessively slow convergence before providing an accurate solution because of their fundamental requirement of using minimal *a priori* knowledge and not exploiting local information. This kind of "blindness" may prevent them from being really of practical interest for a lot of applications [10, 11].

B. The Nelder-Mead Algorithm

The Nelder–Mead simplex algorithm is a derivative free classical powerful local descent

algorithm. The algorithm uses a geometric construct, called
simplex consisting in, n-dimensions, of (n +1) points. If any point of a simplex is taken as the origin, the other (n) points define vector directions that span the n-dimension vector space. If we randomly draw as initial starting point, then we generate the other (n) points through a sequence of elementary geometric transformations, the initial simplex moves, expands or contracts. To select the appropriate transformation, the method only uses the values of the function to be optimized at the vertices of the simplex considered. After each transformation, the current worst vertex is replaced by a better one. Due to its simplicity and robustness, the Nelder-Mead method is much more efficient than alternative traditional methods [11].

C. Hybrid GA-NM Algorithm

The main idea behind hybrid GA-NM algorithm is to combine the advantages of each algorithm in a way to avoid their disadvantages. There are many methods to utilize the idea of hybridizing local search techniques with the genetic algorithm. In this paper we use the idea, where the GA generates the solutions for the new population and then the Nelder-Mead technique is used to improve the best solution which exists in the new population. This approach introduces two concepts of exploration and exploitation. In an exploration phase, the GA covers the whole search space, and detects a good area. The exploitation phase is then performed inside this good area by using the Nelder–Mead technique. Applying the Nelder–Mead search enhance the exploitation process, and accelerate the GA procedure [10].

IV. Simulation Results

To estimate the solar cell model parameters a hybrid Genetic algorithm-Nelder Mead technique is used.

Figure 2 shows the deviation in I-V characteristics obtained from GA based model parameter and actual data. Solar cell parameters values obtained from GA is shown in table I, these values are used as initial guess for NM method, because it needs initial guess for the optimization. The accuracy of the estimation highly depends upon the initial values in NM.

Figure 3 shows the perfect match between the I-V characteristic obtained from actual data and hybrid GA-NM based model parameter values. This validates the success of the proposed approach.

TABLE I

S. No.	*Parameter*	*GA*	*GA-NM*
1	***Photo-generated Current (I_{ph})***	***3.7***	***3.70248***
2	***Diode Saturation Current (I_D)***	***$3.01 * 10^{-7}$***	***$3.15869 * 10^{-7}$***
3	***Diode Quality Factor (A)***	***1.6***	***1.49989***
4	***Series Resistance (Rs)***	***0.005***	***0.00515132***
5	***Shunt Resistance (R_{sh})***	***10***	***10.2084***

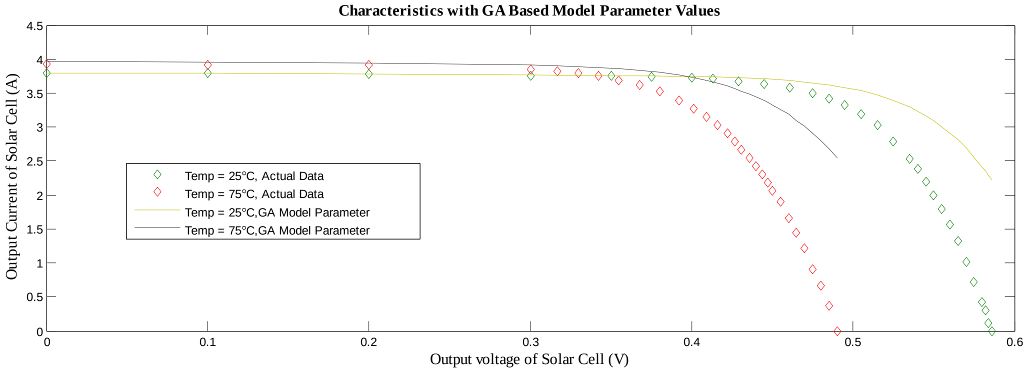

Fig 2: I-V Characteristics Using Actual Data and GA Estimated Results

I.

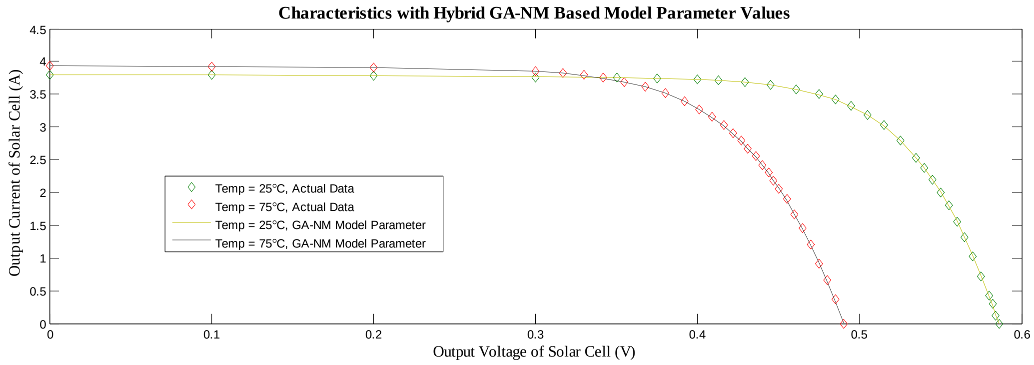

Fig 3: I-V Characteristics Using Actual Data and GA-NM Estimated Results

V. CONCLUSION

The proposed technique based on hybrid GA-NM is used to estimate the optimum values of solar cell model parameters. From simulations results, it has been demonstrated that applying the hybrid algorithm yields to optimum values with good accuracy, since the hybrid GA-NM algorithm exploits the higher ability of the GA in global search and the efficiency of NM in local search.

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Biography

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