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A Model Based Maximum Power Point Tracking for PV Panels using Genetic Algorithm

Lini T Koshy, Rini Jones S.B

Abstract*— This paper presents a genetic algorithm (GA) based technique in Model Based (MB) maximum power point tracking (MPPT) controller for photo voltaic (PV) system. Maximum power point tracking is the main solution to reduce the power loss in the photo voltaic system when temperature and solar irradiance variation occurs. The PV system has an operating point that can supply maximum power to the load. The point that gathers the power called the maximum-power point (MPP). A model-based MPPT offers a better dynamic performance, because it is relatively easy to obtain an accurate model of a single PV panel, thus predicting the maximum power point voltage for given environmental conditions. Experiments reveal that the existing MB MPPT gives improved tracking error but minimum power extraction. To overcome this disadvantage an optimization algorithm called Genetic Algorithm based MB MPPT is presented. The proposed GA based MB MPPT can reduce the tracking error as well as maximum power is extracted as compared to the existing MB MPPT.

***Index Terms*—. Energy efficiency, Genetic Algorithm (GA), Modeling, Maximum Power Point Tracking (MPPT), Parameter estimation, Photo Voltaic (PV) system**

I. INTRODUCTION

Photovoltaic energy is a sort of solar energy that is available in almost all parts of the world and has the least maintenance since it attracts researchers toward this kind of clean and renewable energy. Despite abundant advantages, PV module has low energy conversion efficiency [1]. To overcome the problem, maximum power point tracking technique is necessary [1]. The sunlight intensity is time variant and sometimes changes rapidly in a day, because of this, the optimum operation point of PV module moves from one curve to another. So the maximum power point tracker must track the maximum point as rapidly as possible in order to alleviate the oscillation of output power of PV module [1]. The cost effectiveness of a PV plant for given environmental conditions basically depends on two aspects. The first is the technology employed to build the PV cells; the second is the configuration and the control algorithms implemented in the switch mode power converters in which the PV panels are connected to. It is well known that the low-frequency behavior of an array of PV modules can be represented by a current–voltage characteristic, while the dynamics can be neglected in most of the applications. Its shape essentially depends on the temperature and on the solar irradiance. For given environmental conditions, there is an operating point on the *V–I* characteristics, called Maximum Power Point (MPP), where maximum power output is achieved, hence the efficiency is optimized. However, if each PV panel was connected to its own power converter hence known as Module

Integrated Converter (MIC) controller, it would be possible to further enhance the system efficiency. In fact, the panel level Maximum Power Point Tracker (MPPT) control allows a huge reduction of the losses because of the mismatch between panels, which can be serious in partially shaded conditions. Several MPPT algorithms can be implemented in MICs. In general, they perform very similar in quasi-stationary environmental conditions. The most significant differences among them, however, lie in their dynamic behavior, which becomes evident in rapidly changing conditions. Model-Based (MB) MPPT techniques seemed to be very attractive for MIC applications. It is easy to accurately model the behavior of a single panel with respect to an array of modules. They offer an interesting dynamic performance, but the conventional implementations need an expensive high precision pyranometer. To overcome this problem, the authors have proposed a novel MB MPPT algorithm, which requires a pyranometer just during the identification of the relevant parameters in the panel but not during its operation [3]. Starting from the assumption that a MB MPPT for MIC applications requires an efficient yet accurate model of PV panel, Cristaldi *et al.* [4], have also presented a new single diode model whose parameters can be more easily estimated

with respect to conventional ones.

The existing MB MPPT gives improved tracking error but the power extraction is minimum and also it is noise sensitive. The proposed system is more efficient than the existing system which helps for the extraction of maximum power and to reduce the tracking error.

The outline of this paper is organized as follows. The next section briefly explains the characteristics of photo voltaic system, while section III discusses about Model Based maximum power point tracking in photo voltaic panels .While section IV and V discuss about estimation of panel parameters and proposed genetic algorithm based MB MPPT respectively. While section VI is the comparison between the existing MB MPPT and the proposed Genetic Algorithm based MPPT (GA based MB MPPT).Finally section VII conclude this paper.

II. PHOTO VOLTAIC SYSTEMS

A photovoltaic system normally consists of photovoltaic array is comprise a few numbers to a few hundreds of modules. The sun pointed to PV array and the charge controller will regulate the power. Then the power will stored at the battery bank that consisting of deep cycle batteries. Lastly, the inverter will convert the dc power from array into ac power.

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The Daily energy output From PV array will vary depending on its size, orientation and location, season of the year and the daily weather conditions. Energy storage is required for the power when sun is not shining. Battery sizing depends on the application, the daily solar radiation, the total load, peak load and the number of days which storage required.

The charge controller is placed between the PV array and the storage battery to prevent the battery from being damaged either due to overcharging or over-discharging to enhance its life. The power from the PV system is dc and most electrical appliances work on ac. The inverter is used to convert 12 volts or 24 volts dc power into 220 volts or 110 volts ac power that usually used in electrical appliances. Figure 1 shows the elements in PV system.

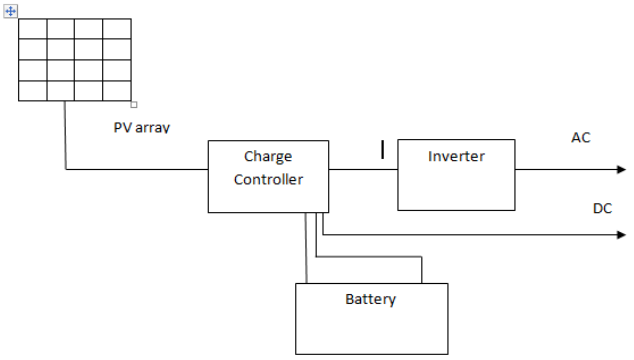

Fig 1: Elements of PV system

(A) Photo Voltaic Cell Modelling

One of the most widely used is the single diode model, which, in many applications, represents a good compromise between accuracy and simplicity. Modeling is basic tool of the real system simulation. For modeling, it is necessary to analyze the influence of different factors on the photovoltaic cells and to take in consideration the characteristics given by the producers. The mathematical models for photovoltaic cells are based on the theoretical equations that describe the operation of the photovoltaic cells and can be developed using the equivalent circuit of the photovoltaic cells

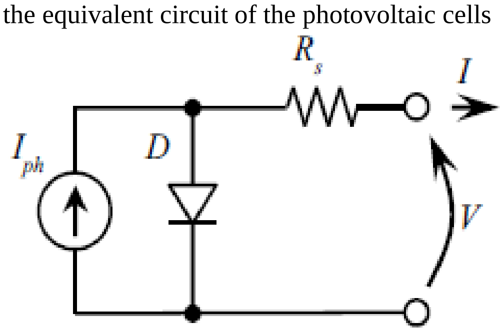

Fig 2: Single diode equivalent circuit.

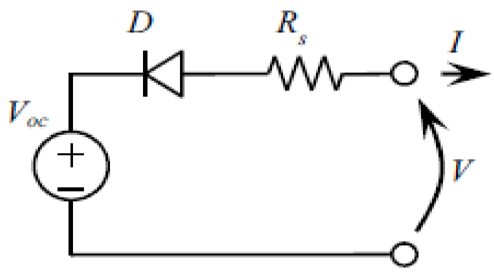

Fig 3. Equivalent electric circuit of single diode model.

Where *V* and *I* are the panel voltage and current, *Iph* is the photocurrent, *Is* is the reverse saturation current, and *VT* is the thermal voltage. Finally, *Rs* and Gsh are the series resistance and the shunt conductance, respectively. Often *Gsh* is supposed to be zero, because it does not produce relevant effects around MPP, where the PV module is supposed to operate.

$$I = Iph - Is(e^{\frac{V+RsI}{VT}} - 1) - Gsh(V + RsI) \dots\dots\dots (1)$$

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A good match with the actual *V–I* characteristic can be anyway reached by opportunely tuning the thermal voltage and series resistance [16], [18]. On the contrary, *Rs* cannot be usually neglected because small variations may significantly affect the *V –I* curve around the MPP [16], [18]. The equation of the single diode model with zero-shunt conductance (Fig. 2) can be written as follows:

$$V = V_T \ln\left(1 + \frac{Iph - I}{Is}\right) - RsI \dots\dots\dots (2)$$

The open-circuit voltage *Voc* is considerably higher than the thermal voltage, so it is possible to assume that *eVoc/VT* - 1 [4]. These assumptions lead to the following approximate expression of the panel voltage:

$$V = Voc + V_T \ln\left(1 - \frac{I}{Iph}\right) - RsI \dots\dots\dots (3)$$

Equation (3) is a simple model for PV modules, which practically has the same behavior of the conventional single exponential formulation. It can be represented with the equivalent circuit shown in Fig. 3. The diode is characterized by the thermal voltage *VT* and the reverse saturation current equal to the photocurrent *Iph*. Equation (3) provides an approximate expression of the whole *V –I* curve for given environmental conditions. It is very important to point out that the parameters are affected by the solar radiation intensity *G* and by the cell temperature *Tc*, which are supposed to be uniform on the module. Literature [18] reports an approximate expression of these dependencies.

$$Iph(G,Tc) = Ipho\frac{G}{G0}[1 + \alpha(Tc - Tco)] \dots\dots (4)$$

$$Voc(G,Tc) = Voc0[1 + \beta(Tc - Tco)] + V_T \ln\left(\frac{G}{Go}\right) \dots\dots (5)$$

$$V_T(Tc) = Vto\frac{Tc}{Tco} \dots\dots (6)$$

where I_{ph}, V_{oc}, and V_T are the values of the parameters when the solar radiation and the cell temperature are equal to *G* and T_c, respectively. α and β are the thermal coefficients. I_{ph0}, V_{oc0}, and V_{T0} are the photocurrent, the open-circuit voltage, and the thermal voltage when the solar radiation intensity is equal to G_0 and the temperature is T_{c0}.

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Finally, it is important to note that the series resistance R_S is weakly dependent on the environmental conditions, therefore it can be considered as a constant .

III. MODEL BASED MAXIMUM POWER POINT TRACKING IN PV PANELS

A typical solar panel converts only 30 to 40 percent of the incident solar irradiation into electrical energy. Maximum power point tracking technique is used to improve the efficiency of the solar panel. According to Maximum Power Transfer theorem, the power output of a circuit is maximum when the Thevenin impedance of the circuit (source impedance) matches with the load impedance. Hence our problem of tracking the maximum power point reduces to an impedance matching problem. In the source side we are using a boost convertor connected to a solar panel in order to enhance the output voltage so that it can be used for different applications like motor load. By changing the duty cycle of the boost converter appropriately we can match the source impedance with that of the load impedance.
The parameters are known for a given solar cell, the solar cell current and voltage could be calculated from measurements of the light incident on and temperature of the solar cell. The maximum power voltage could then be calculated directly, and the PV array operating voltage could be simply set equal to VMPP. Such an algorithm is commonly called a model-based MPPT algorithm. There are different techniques used to track the maximum power point.

IV. ESTIMATION OF PV PANEL PARAMETERS

The main advantage of this model becomes evident when its four parameters (*Voc*, *Iph*, V_T, and *Rs)* have to be evaluated. *Voc* can be directly measured, whereas in most of the cases, *Iph* can be assumed to be equal to the short-circuit current *Isc*. The identification of the other parameters requires two equations. Because the PV panel is supposed to operate around its MPP, the model shall be particularly accurate near it. Therefore, a first equation can be found by imposing that the *V –I* characteristic of the model includes the MPP of the panel, defined by the voltage *Vmp* and by the current *Imp*. The second equation shall guarantee that this point is a maximum, which is equating to zero the derivative of the electrical power. The following system of equations can be written down:

$$V_T = \frac{(2Vmp - Voc)(Isc - Imp)}{Imp + (Isc - Imp)\ln\left(1 - \frac{Imp}{Isc}\right)} \ldots\ldots(7)$$

$$Rs = \frac{Vmp}{Imp} - \frac{(2Vmp - Voc)}{Imp + (Isc - Imp)\ln\left(1 - \frac{Imp}{Isc}\right)} \ldots\ldots(8)$$

The cell temperature is measured for a given environmental temperature ΔTe. It is very difficult to obtain an accurate evaluation of the cell temperature starting from the measurement of *Te*. So Tp is expressed in terms of Tc. In particular, it is much less affected by the wind speed and the thermal transients. The coefficient k_T can be introduced to write down the following equation:

$$Tc = Tp + k\Delta_T G \ldots\ldots\ldots\ldots(9)$$

The previous equation can be rewritten ad a linear combinations of unknown parameters.

$$Isc(G,Tp) = G(Ksc1 + Ksc2T_p) \ldots\ldots\ldots\ldots\ldots(10)$$

$$Voc(G,Tp) = Koc1 + Koc2Tp + Koc3G +$$

$$+Koc4Tp\ln(G) \ldots\ldots\ldots\ldots\ldots\ldots(11)$$

$$V_T(G,Tp) = KT1Tp + KT2G \ldots\ldots\ldots(12)$$

V. PROPOSED SYSTEM

The genetic algorithms are based on concepts of evolutionary theory, and provide an effective way of searching a large and complex solution space to give close to optimal solutions much faster than random trial-and-error methods. They are also generally more effective at avoiding local minima than differentiation-based approaches. The basic mechanism of a GA can be simply described as follows [3]: These are computational models that mimic natural evolution in their design and implementation; i.e. they are based on survival of the fittest. GAs differ from conventional search techniques in that they operate on a coded parameter set of the solution, are global in their search, make use of a cost function that does not involve derivatives and finally employ pseudo-probabilistic rules and not deterministic ones. Genetic algorithms have been used in recent years in solving optimization problems in science and engineering applications. Implementation of GA involves making the following preliminary decisions.

(1). Solution encoding. This involves coding a possible solution (individual) as a string of variables using some alphabet, e.g. binary *{*0, 1*}*. Individuals are likened to *chromosomes* and variables to *genes*. A chromosome (solution) is composed of several genes (variables).

(2) Evaluation function. This determines the fitness score attached to each chromosome (solution). The higher this score, the greater is the chance of an individual (solution) being selected for reproduction.

(3) Initial population generation. Generation of the initial population (set of possible solutions) can be random or from known approximate solution(s).

(4) Selection criterion. Methods of selecting individuals for reproduction are numerous and include roulette wheel sampling, stochastic universal sampling, tournament selection, elitism, sigma scaling, rank selection etc.

(5) Recombination/reproduction. This is achieved through tw o genetic operators, namely crossover and mutation. A number of variations of crossover are in use such as single-point, multi-point or uniform crossover. In single-point crossover where binary encoding is used, a locus (bit location) is randomly chosen. Bits after that locus are exchanged between two chromosomes to create two offspring (new solutions). Mutation on the other hand involves randomly flipping some of the bits in a string (chromosome). A very small probability is usually attached to occurrence of mutation at each bit location (e.g. 0.001). This operation is performed to ensure that new areas of the solution are explored.

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(6) Termination Criteria. The algorithm can be terminate if the maximum number of generations (iterations) is achieved, or convergence of the solution is attained (i.e. all solutions yield the same fitness value or differ by less than a specified tolerance).

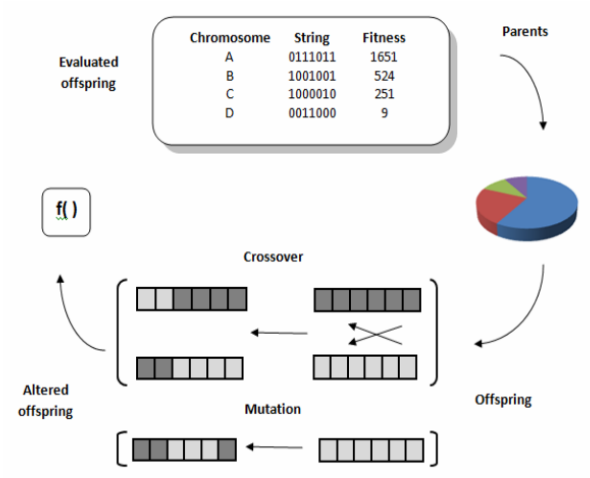

Fig 4: Basic Mechanism of Genetic Algorithm

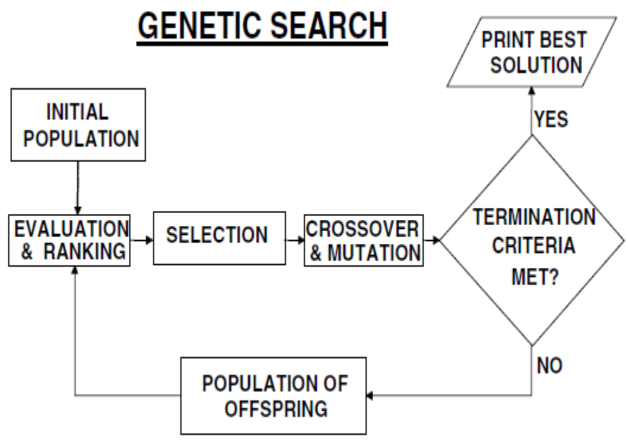

Fig 5: Flow chart of GA

By using the Genetic algorithm the solar cell parameters can be optimized. The optimized value of (Ksc1, Ksc2, Koc1, Koc2,Koc3,Koc4,KT1 and KT2) gives the maximum power. Also noise present in the temperature sensor is removed by adding a sensor wavelet filter.

GA PROPERTY	Value/Method
POPULATION SIZE	8
MAXIMUM NUMBER OF GENERATIONS	25
PERFORMANCE INDEX/FITNESS FUNCTION	MAXIMUM MPP POWER
SELECTION METHOD	ROULETTE SELECTION
CROSSOVER METHOD	ARITHMETIC
CROSSOVER PROBABILITY	0.8
MUTATION METHOD	ADD/SUBSTITUTION METHOD
MUTATION PROBABILITY	0.2

Table 1: Genetic Algorithm Parameter values for solar cell parameter estimation

VI. EXPERIMENTAL RESULTS

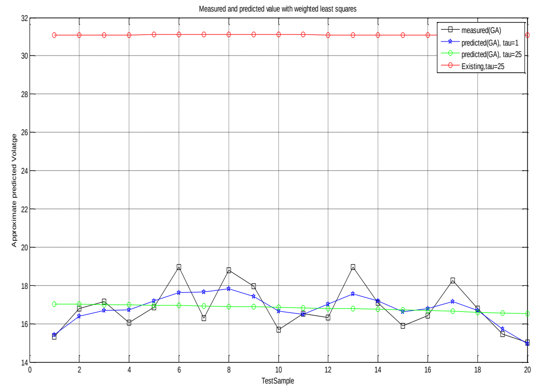

Fig 6: Comparison between measured and estimated MPP voltage

By using GA based MB MPPT the voltage is maximum and for MB MPPT the voltage is minimum.

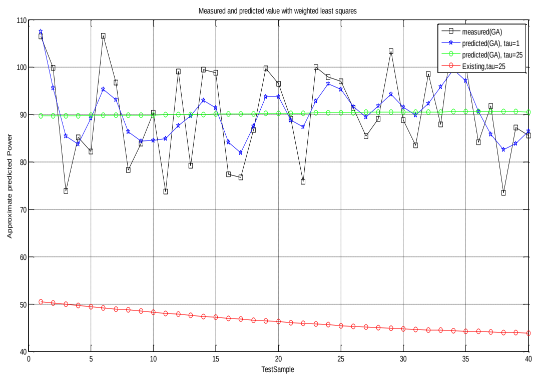

Fig 7: Comparison between measured and the predicted MPP power

The power is maximum for GA based MB MPPT and for MB MPPT the power is minimum.

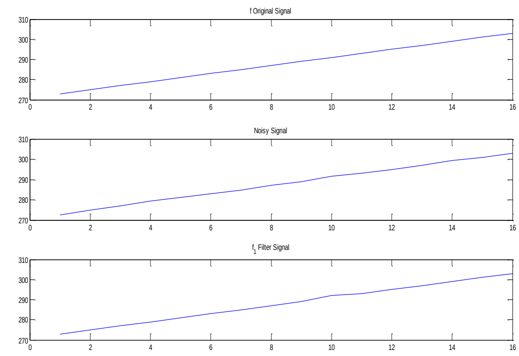

Fig 8: Sensor Wavelet Filter removes the noise present in the Temperature sensor

The wavelet filter is used for removing the noise in temperature sensor

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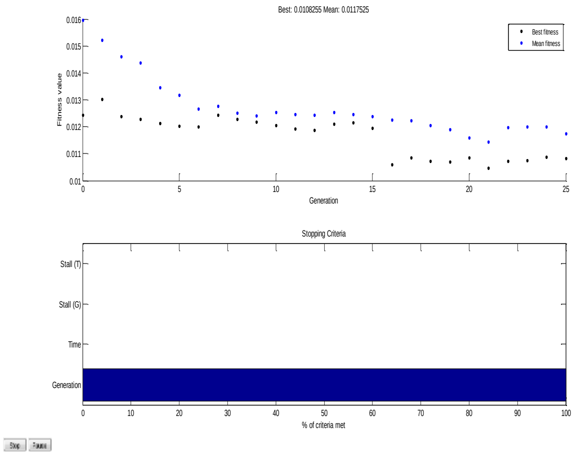

Fig 9: Best Fitted Value using Genetic Algorithm

VII. COMPARISON

Maximum power point tracker has a significant rule in PV systems because of low efficiency of PV modules, crisis of energy and incremental cost of fossil fuel. In this paper an intelligent maximum power point tracking technique for photovoltaic system is used to obtain the maximum available power. The GA based MB MPPT extracts maximum voltage from the PV module shown in fig 6.Maximum power obtained from the PV module is shown in fig 7.The noise present in the temperature sensors removed by adding a sensor wavelet filter. The graph is shown in fig 8.Fig 9 shows the best fitted value of genetic algorithm.

PARAMETER	MB MPPT	GA MB MPPT
MPP VOLTAGE (tau=25)	31V	17V
MPP POWER (tau=25)	50W	90W

Table 2: Comparison between MB MPPT and GA based MB MPPT

VIII. CONCLUSION

A technique for improving the accuracy of the extracted values of solar cell parameters is developed. It is based on formulating the parameter extraction problem as a search and optimization one. Since determination of the search range is of importance in applying this technique, one of the known extraction methods is to be used to determine approximate values for the solar cell parameters. The PV panel parameters are optimized to get the maximum power. The solar panel is noise insensitive in the presence of sensor wavelet filter and also tracking error is improved by using this method.

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REFERENCES

1. Loredana Cristaldi and Marco Rossi "An Improved Model-Based Maximum Power Point Tracker for Photovoltaic Panels"Ieee Trans. Instrumentation and Measurement, Vol. 63, no. 1, January2014.
2. S. C. T. a. A. C.Larbes, "Genetic algorithms optimized fuzzy logic control for the maximum power point tracking in photovoltaic system," Algeria, 2009.
3. Joseph A Jervase, Hadj Bourdoucen and Ali Al- Lawati "Solar cell parameter extraction using genetic algorithms" Published 9 October 2001.
4. S.Mallika, R.Saravanakumar "Genetics Algorithm Based MPPT Controller for Photo Voltaic System" International Electrical Engineering Journal (IEEJ) Vol. 4 (2013) No. 4, pp. 1159-1164.
5. J K Maaherchandani,Chitranjan Agarwal,Mukesh Sahi "Estimation of Solar Cell Model Parameter by Hybrid Genetic Algorithm Using MATLAB" International Journal of Advanced Research in Computer Engineering &Technology(IJARCET)Vol .1,Issue 6,August 2012.

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