A BBO Based MPPT Technique for Solar Sub-System

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Abstract: The conventional energy resources are exhausting rapidly to meet the ever increasing demand of exponentially rising global population. In this present scenario researchers are finding out the way to slow down the quick depletion of earth energy and this effort has opened up the era of green energy or non-conventional energy or renewable energy. There are various types of renewable source of energy like wind energy, solar energy, tidal energy etc. Among these non-conventional energy resources the Sun is the foremost resource of the renewable energies. Solar energy has become popular across the world from rural area to country side because it is abundant in nature, requires little maintenance, and causes no noise and pollution. There are various ways to convert solar energy into electric energy such as solar thermal, solar pond, photovoltaic effect. Solar cell is a device which converts solar energy into electric energy using photovoltaic effect and it is represented by a current source in parallel with a diode. Assemble of photovoltaic cell construct the solar module. Although solar cell was expensive at the beginning, it is considered that solar power systems can compete with the fossil fuel systems due to the development of the semiconductor technology and manufacturing process. The installation cost of solar system is high. Moreover the power-voltage characteristic is non-linear in nature and drifts with temperature, irradiation, building material of solar cell and delivers maximum power output at a specific operating point called maximum power point. So under this fast varying operating condition a fast converging Maximum Power Point Tracking Technique (MPPT) is required to ensure minimum power losses. Till date a number of MPPT has been proposed and implemented to optimize the cost of generation of solar electricity. These MPPT techniques vary in terms of implementation complexity, speed of operation, convergence under abrupt atmospheric condition, efficiency or accuracy. In this paper Biogeography Based Optimization algorithm has been simulated to obtain Maximum Power Point on PV characteristic.

Keywords: Maximum power point tracking; solar; biogeography based optimization (BBO).

1 INTRODUCTION

The exponential growth of civilized population worldwide has reinforced the rapidly increased need of electricity depleting the energy resources. In this alarming scenario research efforts are moving towards renewable energy to solve the energy crisis. As these non-conventional energies are abundant in nature, sustainable, enduring and unpolluted these are becoming popular alternative to the fossil fuel energies worldwide [1]. Renewable energy provides 21.7% of electricity generation globally as reported in 2013 [2]. Out of

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these sources, solar energy is used to generate heat, light and electricity. Main utilization of Solar Cell is to provide electricity. As the solar electricity is costly researchers are finding out the way to cut down the cost. One feasible solution is to extract maximum power from solar cell because Solar cell has a single operating point which results in maximum power output and varies with solar irradiation, cell temperature and other parameters [3]-[6]. To optimize the nonlinear characteristic there are different techniques. They can be categorized as follows:

Look up table – MPP is calculated for each probable condition and they are stored in memory but due to non-linear and time varying characteristics of solar cell make it challenging to record and accumulate them for all operating conditions [7].

Computation method such as MPPT based on Voltage and Current. In these computation methods non-linear Voltage-Current characteristic of PV panel is represented using mathematical equations or numerical approximations. Maximum power point voltages for different load condition are computed as a function of open circuit voltage or short circuit current of corresponding solar cell eliminating the reference cell which results in less expensive and more efficient, reliable PV system [8].

Perturb and observe method- It is carried out by perturbation of duty cycle of power converter [9] and Perturb and Observe (P&O) method involves perturbation of operating voltage [10]. There are different techniques to implement P&O method using DSP [11], Microcontroller [12], or FPGA [13], [14]. Though the algorithm offers simple implementation, it has to make a trade-off between tracking speed and oscillation e. g. Small perturbation reduces oscillation but affects the tracking speed. During fast fluctuating insolation the algorithm fails to direct to true Maximum Power Point. Several modifications have been made but those are not so much effective in challenging conditions like Partial Shading [15]. In Partial Shading condition as there are multiple peaks (global peak, local peak) P&O fails here.

Incremental Conductance algorithm- Based on the fact that slope of power curve of PV array is zero MPP, the left of MPP it is positive and negative on the right [16]. Although IC does not loose tracking direction like P&O, during rapid fluctuating environmental conditions its tracking speed significantly reduces [17].

Hill Climbing method is also named as direct control method [18]. Though it is similar to P&O, it works by perturbing voltage or current and direct updating of the duty cycle of the controller eliminating the need of PI or hysteresis controllers.
Evolutionary algorithm handles the non-linear objective functions [19]. Two main characteristics of these algorithms are exploration and exploitation [20]. Exploration is the characteristic to search the whole problem space whereas exploitation is the ability of convergence to best solution. Hence the EA are capable of solving finite set of problems i.e. these algorithms can solve some problems better some problems worse than other.

Among all Evolutionary Algorithm methods, Particle Swarm based Optimization (PSO) is highly effective because of its simplicity in structure, ease of implementation and faster computation capability [21, 22]. As it is a search optimization it can locate MPP at any environmental condition. Many research works have been done on PSO.

A heuristic Evolutionary Algorithm, Gravitational Search Algorithm was first coined by Rashedi, Nezamabadi-pour and Saryazdi in 2009 [23]. Then a modified GSA has been proposed by Han in 2012. Mirjalili and Hashim projected Hybrid PSOGSA for function optimization and Binod Shaw further added an opposition based GSA [24, 25]. An Improved GSA based on neighbour search has been investigated by Wang [26].

Another important EA is Biogeoghaphy Based Optimization. This algorithm is coined from the science of Biogeography, introduced by the work of Alfred Wallece and Charles Darwin [27, 28]. Robert Mac Arthur and Edward Wilson published their work in 1967- “The Theory of Island Biogeography” containing mathematical model of Biogeography. Mathematical model of Biogeography describes how species migrate from one island to other, how they expands or extinguish. Each habitat is categorised in terms of HSI (Habitat Suitability Index). Habitats with low HSI have small number of species having high immigration rate. Whereas habitats with high HSI have large number of species having low immigration rate and the species become static than low HSI habitats. If species immigrate to low HSI habitat the HSI increases else it remains low causing extinction and further immigration. For a problem a candidate solution is there. A good solution represents high HSI habitats & Poor solution is equivalent to low HSI habitats. Good solution resist any change but shares features with poor solution while poor solution accepts lot of changes, updates from good solution [29].

BBO is similar to other biological algorithms like GA and PSO. GA solutions 'die' at the end of each generation but PSO and BBO solutions survive forever. PSO solution tends to clump together in same group while GA and BBO do not inclined to cluster.

2 PV- SYSTEM DESCRIPTIONS

A stand-alone solar system works in following way. Voltage and current output are measured and then fed to MPPT controller which drives the DC/DC converter.

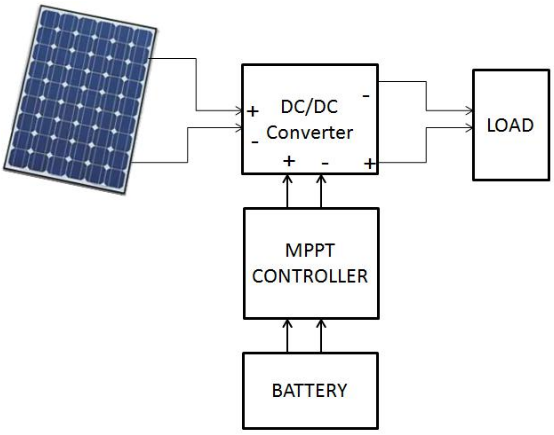

Fig. 1. Block diagram of PV system.

3 PHOTOVOLTAIC ARRAY

Solar cell is represented by an equivalent circuit consisting of a diode, photo-generated current source, series and shunt resistors. A PV array is composed of multiple PV modules by Ns×Np connection where Ns is the series configuration and Np is the parallel configuration. Neglecting the internal series and shunt resistances current output of PV array is given by following eqn.

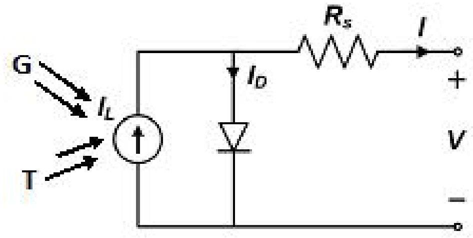

Fig. 2. Equivalent circuit of 1-diode solar cell

$$i_{pv} = N_p I_{ph} - N_p I_{rs}\left(e^{K_{pv}V_{pv}/N_s} - 1\right) \tag{1}$$

Photo-generated current I_{ph} is given by eqn.

$$I_{ph} = \left(I_{sc} + K_I\left(T - T_r\right)\right)\frac{\lambda}{100} \tag{2}$$

Reverse saturation current I_{rs} is given by eqn.

$$I_{rs} = I_{rr}\left(\frac{T}{T_r}\right)^3 e^{qE_{gp}\left(\left(\frac{1}{T_r}-\frac{1}{T}\right)\right)/pk} \tag{3}$$

Where, C=1.1×1; K=1.3805

T=Cell Temperature

For ideal p-n junction diode characteristic factor is p (1 to 5)

K_I = short circuit current temperature coefficient = 2.06mA/◦C

Open circuit voltage, Voc=21.7V

Short circuit current, Isc=4.8A

4 MPPT USING BBO

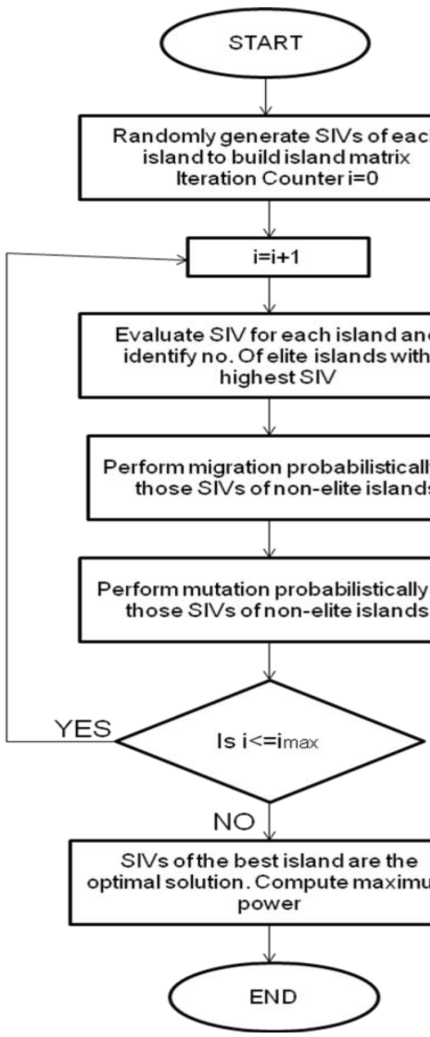

Fig. 3. Flow chart of BBO.

Based on the science of bio-geography, Bio-geography Based Optimization (BBO) is an evolutionary algorithm (EA) that optimizes a multidimensional real valued function stochastically and iteratively improving candidate solution with respect to a given measure of fitness function.

Mathematical model of biogeography describe evolution, migration, extinction of species between islands or habitats which are characterized by Habitat Suitability Index (HSI). Variables that characterize habitability are known as Suitability Index Variable (SIV).

As the habitats with high HSI are friendlier to live they host large number of species. Hence these habitats have large probability of emigration (high emigration rate, 'μ') and small probability of immigration (low immigration rate, 'λ') as they are already saturated with species.

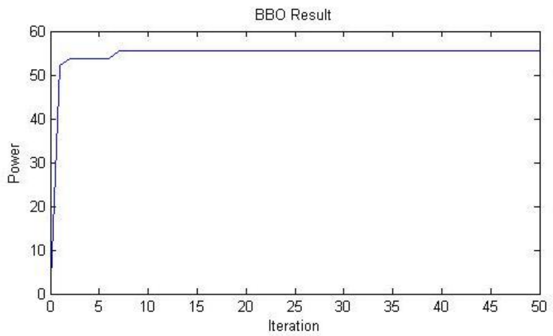

Fig. 4. Power characteristic of solar panel obtained by BBO.

4.1 Migration

Migration is a probabilistic operator which improves HSI of poor habitats by sharing information from good habitats. If a habitat is selected for immigration then based on emigration rate μ_J emigrating habitat H_J is found. Values of SIVs are copied from H_J to H_I randomly for migration.

4.2 Mutation

There is a process called Mutation in BBO, where Habitat's HSI changes suddenly due to some adverse situation or for improvement. Very high or very low HSI are not suitable for Mutation whereas medium HSI solutions have better opportunity to generate better solution by mutation.

To simplify it is assumed a linear relationship between HSI or population and immigration, emigration rates.

$\lambda_{max} = \mu_{max}$ i.e E=I

For K_{th} variable immigration rate λ_k and emigration rate μ_k are given by following equation.

$$\mu_k = E.\frac{HSI_K}{HSI_{\max} - HSI_{\min}} \tag{4}$$

$$\lambda_k = I\left(1 - \frac{HSI_K}{HSI_{\max} - HSI_{\min}}\right) \tag{5}$$

4.3 Application of BBO for MPPT Method

Output power of solar array is optimized using BBO. When an SIV is selected for emigration to immigrant Island, it will emigrate if new immigrated solution has cost or fitness less than the solution without accepting the emigrated solution otherwise immigration will be rejected.

Initialize Parameters
Generation Count Limit=50
Population Size=10
Problem dimension=1
Mutation Probability=0.01
Elitism parameter=2

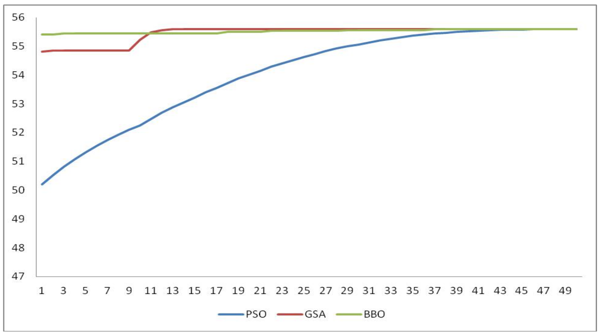

Fig. 5. Comparative power characteristics of solar panel obtained by different EA.

5 RESULTS AND DISCUSSION

BBO algorithm has been simulated in MATLAB environment to obtain Maximum Power Point and other Evolutionary Algorithms e.g. GSA & PSO are also implemented to evaluate the comparative result for obtaining the Maximum Power Point. Results show that convergence of power characteristic using BBO is fastest among the three Evolutionary Algorithms for the present MPPT problem. While using GSA oscillation in output get reduced by a comparable amount than PSO and for BBO oscillation is minimum. Fig. 4 depicts the Power vs. time plot for MPPT using BBO and Fig.5 depicts the comparative study of power characteristics where result shows lesser oscillation using BBO than GSA than PSO techniques while obtaining MPPT of the solar cell, described here.

6 CONCLUSION

In this paper, BBO is used to track the MPP of a PV system. MPP is also obtained by other two EA techniques- PSO and GSA. The results indicate that the proposed controller using BBO outperforms the other EA techniques and gives a number of advantages: 1) faster tracking speed, 2) zero oscillation at MPP.

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