Performance and Optimization of MPPT Techniques for Modeling, and Control of Solar PV system

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***Abstract*: today the power sector requirement is increasing continuously and reserve of fossil fuel is limited so we have already moved toward renewable generation. Demand of renewable sources of energy should be our prime focus to mitigate the power requirement. The solar power generation is of the best choice for power generate because it is freely available. Maximum power point tracking (MPPT) techniques is one of the most useful method to get maximum power at any instant of time. Classical MPPT techniques fail to provide an accurate output power thus; optimization of MPPT techniques play an important role in maximization of output power. Considering the dependency on renewable energy uses, this paper, presents various types of optimization to track MPPT techniques implemented on Photovoltaic (PV) system. These techniques applied for solar system is helpful in designing and improving efficiency of the PV system. Due to non linear characteristics of PV array a non-linear controller is most suitable for MPPT applications. The paper, first describe different types of characteristics of solar PV cell used for MPPT technique and followed by different optimization techniques incorporating fazzy, neural network Grey Wolf Optimization (GWO), Simplified Firefly Algorithm (SFA), Enhanced Grey Wolf Optimization (EGWO), Particle Swarm Optimization (PSO), etc have been discussed. Performance has been analyzed based on efficiency, tracking speed, converter used, application and implementation cost etc.**

***Keywords* :** *Maximum Power Point Tracking (MPPT) Photovoltaic (PV), Particle Swarm Optimization (PSO), Simplified Firefly Algorithm (SFA), Buck-Boost converter*

I. INTRODUCTION

Equivalent solar cell circuit with shunt resistance is being created due to slope of I-V characteristics shown in Fig.1. R_{sh}, having very high value of resistance (slope on current line) in same way voltage line slope gives us series resistance R_S having small value of resistance. A single solar cell can produce only 0.6 to 0.7 Volts [1].

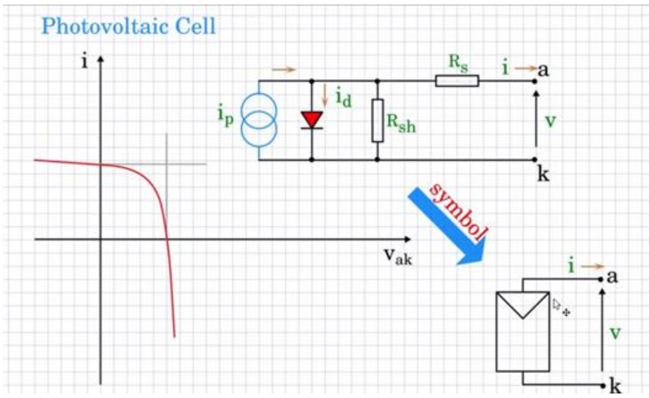

Fig.1. Practical solar cell.

The solar cell characteristics with solar power is shown in figure2, the effect shows that as temperature increases current (I_{SC}) increases but at the same time open circuit voltage decreases by -2.12mV/^{0}K hence powe also decreases. So an optimal design is needed for changing temperature conditions.

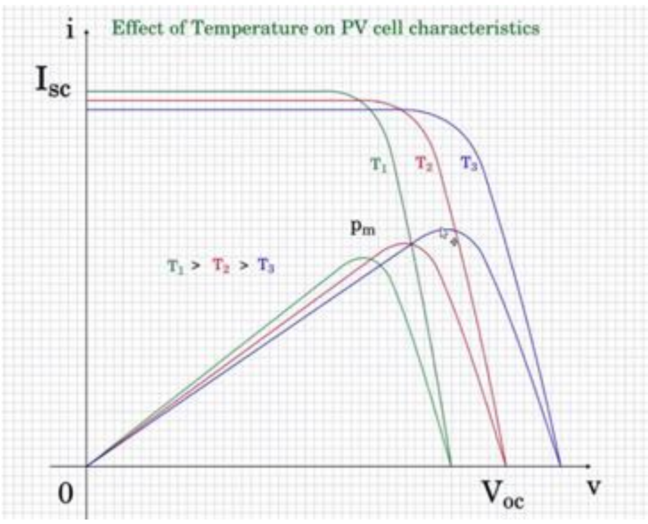

Fig.2. Solar I-V Characteristic with changing temperature along with solar output power.

In designing solar pannel one of the most important parameter is maximum power point tracking as shown in Figure 3. The value of R_T (solar terminal resistance) should remain fixed (so that maximum power can be obtained from the panel) whatever be the value of load resistance R_0, which is possible if a power interface is applied and it is regulated by control input that is duty cycle for Dc-dc converter. Dc-dc converter can include any of the topology such as non-isolated [2]: boost topology, buck topology or buck boost topology. The isolated topology includes-flyback topology, forward topology, push pull topology,

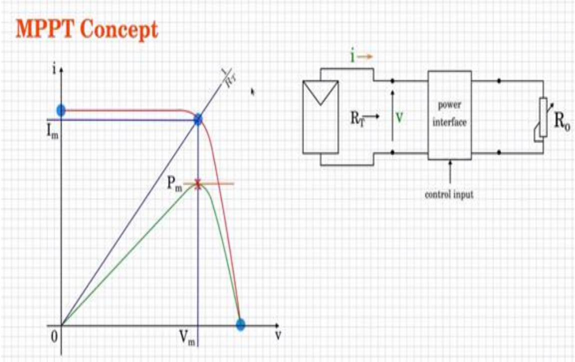

Figure3 MPPT for solar power output.

Half bridge topology, full bridge topology. For all a control signal known as duty cycle is being controlled in such a way that the resistance seen by solar panel remains same whatever load resistance is changing by doing so always Maximum power is obtained from the panel and is being given to the load[3]. To get maximum power different types of algorithms has been given in literature as discussed in section II.

For the solar panel one of the most important factor is fill factor Fig.4. The fill factor decides how much our panel is efficient and it is defined as Fill Factor=V_{mp}. I_{mp}/V_{OC}.I_{OC}. The fill factor for good solar cell should be more than 0.7.[4]

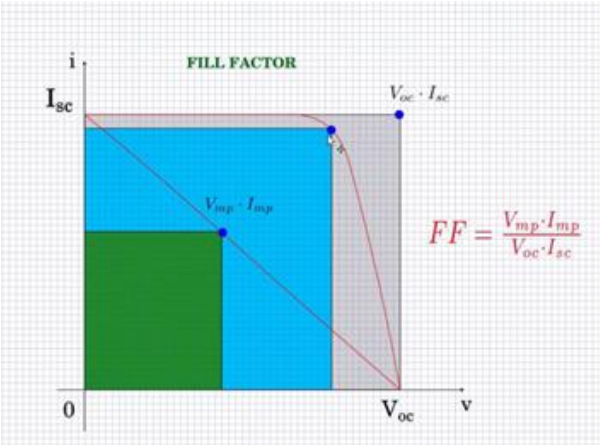

Fig.4. Fillfactor curve of solar PV cell

As a single solar cell can produce voltage only from 0.6 to 0.7volts so solar cells are connected in series and parallel to increase voltage and current rating hence power ratings also. Solar cells are connected in series to form module of increased voltage 35V to 37V [6].
Figure 5 shows solar module connected in parallel.

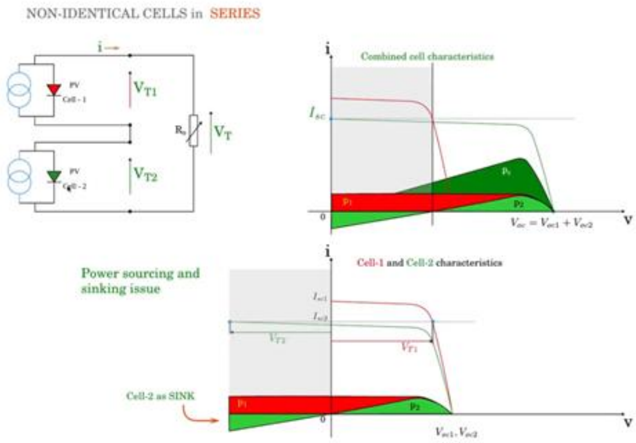

Fig.5.Solar PV cell in series along with Power characteristics

For module of solar PV a bypass diode is highly needed to avoid the power sinking during shading or any one of the faulty panel. Solar cell2 is sinking power To bypass the sinking solar cell 2, a diode has been included[5].
So negative power region is removed by putting a bypassing diode, it is seen from figure 6 that negative power can be removed right of vertical line both cells are giving output but left to vertical line only cell one is sourcing power So now the dark thick line should be operating line of combined solar cell, so by putting bypass diode the efficiency of solar cell can be improved, because the solar cell 2 will not dissipate the power

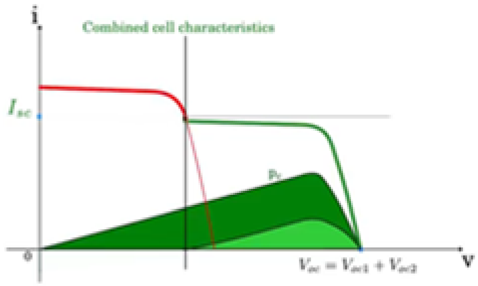

Fig.6. Improving solar efficiency by putting bypass diode

This paper discusses many techniques to extract maximum power from solar PV system. Different converter topologies have been discussed.

Unshaded PV cells act as a source while shaded PV cells acts as a sink under partial shading condition [7-9]. During shading the module behaves like power sink and losses energy hence efficiency is reduced, to avoid this bypass diode is being used as shown in Figure 5.

II. VARIOUS OPTIMIZATION ALGORITHM

Different types of MPPT optimization techniques have been discussed below in details.

Grey Wolf Optimization (GWO)Technique

It is a high level technique approach stimulated by attacking of grey wolves during hunting. The four types of grey wolves techniques found in literature are alpha (α), beta (β), delta (δ) and omega (ω).GWO algorithm is given in figure

7.The hunting mathematics is described by following equations given below:

$$\vec{E} = \left|\vec{C}.\vec{X}_p(t) - \vec{X}_p(t)\right| \qquad (1)$$

$$\vec{X}(t+1) = \vec{X}_p(t) - \vec{F}.\vec{E} \qquad (2)$$

Here t, represent the current iteration; The vectors F and C are related by the following equation:

F=2bXi-b (3)

C=2Yi (4)

Where ‘b’ varies linearly from 2 to 0, and Xi and Yi vector lying between [0,1].

the GWO fitness function has been calculated and is given in equation (6).

$$d_i(k+1) = d_i(k) - F.E \qquad (5)$$

$$R(d_i^k) \geq R(d_i^{k-1}) \qquad (6)$$

Here R is the power, d denotes the duty cycle,

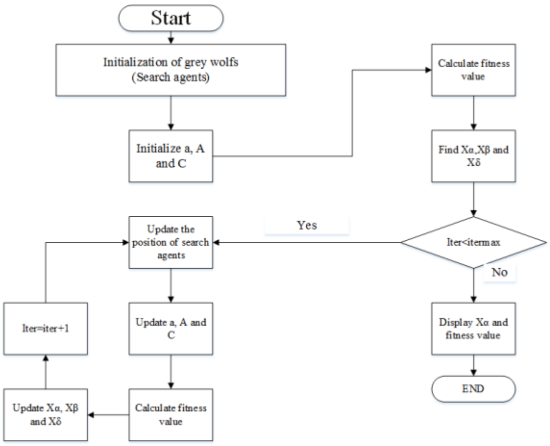

Fig 7 GWO Algorithm for MPPT

Enhanced Grey Wolf Optimization (EGWO)

The EGWO is mainly applied to get maximized power from PV array taking duty ratio as a decision making variable. This techniques uses delta and omega phase elimination process for the search of best solution without disturbing the accuracy of the solution [1].

Ant Colony Optimization (ACO)Technique

This algorithm for MPPT is a probabilistic algorithm used to find the global optimization maximum power point discussed in [20] which, provides solution for non linear related system. Ant colony optimization follows the rule of searching food for ant, the ants provides collective feedback to the large number of ant by giving pheromones to their groups . Large number of ant follow a path where density becomes high, as a result the chance of getting food becomes more. Ultimately ants find a path which is nearest to the food and all ants follow the same path. This method is used for the solar PV system to get the best path to tack maximum power available. For PV system, the duty cycle is being sensed and applied for converter to get the maximum power from PV system [10] .

D. Artificial Bee Colony Optimization (ABC)

It is an optimization tool used to provide path to get places of food where possibility of getting nectar is high. The food position is modified by artificial bees whose aim is to search for nectar. This technique is being applied in solar PV system using boost type dc-dc converter. Dc-dc type converter is connected in between PV system and load. The output power of PV cell is treated as nectar and duty cycle d is treated as decision variable for food point position. The duty cycle calculation is done as follows

$$d_e = d_{min} + rand[0,1](d_{max} - d_{min}) \qquad (8)$$

New $d_e = d_e + \varphi_e(d_e - d_k)$ (9)

Where d_e represents duty cycle, d_{min} and d_{max} range of duty cycle, [1].

F. Particle Swarm Optimization (PSO)

The tracking problem associated with perturb-and-observe (P&O) method for MPPT can be sorted out by using Particle Swarm Optimization (PSO) technique which uses a stochastic mathematical method of, population-that search the behavior of bird flocks . The PSO algorithm method is used to search GMP and time for convergence can also be reduced. Multi junction solar PV system uses Particle Swarm Optimization technique. The PSO provides duty cycle for boost converter to get constant output voltage from boost converter without facing problem of power variation from PV panel [12].

G. Fuzzy Logic Controller (FLC)

Fuzzy logic is an approach based on degree of truth rather than true or false i.e 1,0 this concept was first introduced by Dr Lofti Zadeh in 1960s.Fuzzy logic based controllers are those which provides high accuracy at the maximum power point as compared to conventional controller.Fuzzy logic based controller also regulates the charging states of the batter. Fuzzy logic was assigned two variable X(i) and C X(i) as given below

$$Xi = \frac{P(i) - P(i-1)}{V(i) - V(i-1)} \qquad (14)$$

$$C.Xi = X(i) - X(i-1) \qquad (15)$$

The variables $P(i)$ and $V(i)$ are the Solar PV power and Solar PV panel voltage respectively. X(i) shows the position of operation, and CX(i) give the direction of movement of point of operation.

I. Artificial Neural Network (ANN)

A ANN method of optimization of solar PV system is a apt method to handle non linear characteristics of solar PV system. There is also very high uncertainty of solar irradiation, so ANN finds good approach to handle this uncertainty. 1943, McCulloch, and Pitts, introduced ANN. Because ANN does not require detail information about Solar PV, ANN technique finds good application for non linear system like solar PV system [14].

III. COMPARISION OF VARIOUS OPTIMIZATION MPPT TECHNIQUES AND THEIR CHARACTERISTICS

In this section we will have the comparison of above discussed optimization MPPT techniques on the basis of various parameters such as control strategy, input parameters, output parameters, cost, converter used, efficiency, tracking efficiency, tracking error, partial shading enabled, sensors used and application (stand alone/grid connected). Then we will have the merits and de-merits of the techniques discussed in section 3. Table of comparison and merits and de-merits are given below.

TABLE I. VARIOUS OPTIMIZATION MPPT TECHNIQUES WITH THEIR PERFORMANCE

USED TECHNIQUES	TYPES OF CONTROL	INPUT PARAMETER	NEEDDED VARIABLES SENSOR	OUTPUT	PRICE	METHODS EFFICIENCY	EFFICIENCY	TOPOLOGIES	PLACE OF USE
GWO	BIO-INSPIRED	V_{MP} I_{MP}	V, I	D	H	H	H	DC-DC	SA
ACO	PROBABILISTIC ALGORIT	V_{MP} I_{MP}	V, I	D	L	M	H	DC-DC	SA
ABC	BIO-INSPIRED	V_{MP} I_{MP}	V, I	D	H	L	H	DC-DC	SA
EGWO	BIO-INSPIRED	V_{MP} I_{MP}	V, I	D	H	VH	VH	DC-DC	SA
SFA	BIO-INSPIRED	V_{MP} I_{MP}	V, I	D	LOW	H	H	DC-DC	SA
CS	BIO-INSPIRED	V_{MP} I_{MP}	V, I	D	L	H	H	DC-DC	SA
PSO	BIO-INSPIRED	V_{MP} I_{MP}	V, I	D	L	M	H	DC-DC	SA
FLC	ARTIFICIAL INTELLI	V_{MP} I_{MP}	V, I	D	L	M	M	DC-DC	G
ANN	ARTIFICIAL INTELLI	T, G	T, G	D	H	H	H	DC-DC	G

D= Duty cycle, V= Voltage, I= Current, V_{mp}= Photovoltaic voltage, I_{mp}= Photovoltaic current, T= Temperature, G= solar Irradiance,H-High,M-medium,L-low, VH-very high and SA-stand alone

TABLE II Advantages and dis advantages Optimization Techniques for MPPT

Name of Techniques	Advantages	Dis advantages
GWO	Tracking speed is high,	More complexity,
ACO	Convergence independent of path of travel	Complex calculations, four parameters needs to be optimized at once
EGWO	Highly accurate,	High cost, large search area
SFA	More accurate and convergence	Low effective that of swarm based algorithms
CS	High convergence speed, efficient randomization, robust, fewer tuning parameters,	calculations, is very weak
PSO	Better convergence speed and high accuracy, high efficiency	Computation is, complex, dependency is high
FLC	Good convergence speed and accuracy, low oscillation at MPP	Implementation complexity is high
ANN	Negligible oscillation at MPP, high accuracy, high speed responsibility, good prediction	High cost, complex calculation

(1) conclusion

This paper describes the brief descriptions of the modern optimization MPPT algorithms used for extracting maximum power from PV system under partial shading conditions. All discussed MPPT techniques have been compared based on various factors in this paper has been discussed. Merits and de-merits of the techniques have also been discussed. From the techniques discussed GWO and EGWO found to be most suitable for PV system under PSC. The choice of MPPT technique depends on convergence time, cost, tracking efficiency, efficiency, accuracy and reliability.

References

1. Ilyas, Afshan, PhD Thesis title "Fuzzy Logic Controller for Solar Energy based System"2018 http://hdl.handle.net/10603/236078

2. Kota,Venkata Reddy et al"A novel global MPP tracking scheme based on shading pattern identification using artificial neural networks for photovoltaic power generation during partial shaded condition"IET Renewable Power Generation(2019), 13 (10):1647

3. U. Akram, M. Khalid and S. Shafiq, "Optimal sizing of a wind/solar/battery hybrid grid-connected microgrid system," in IET Renewable Power Generation, vol. 12, no. 1, pp. 72-80, 8 1 2018.

4. A. V. Savkin, M. Khalid and V. G. Agelidis, "A Constrained Monotonic Charging/Discharging Strategy for Optimal Capacity of Battery Energy Storage Supporting Wind Farms," in IEEE Transactions on Sustainable Energy, vol. 7, no. 3, pp. 1224-1231, July 2016.

5. R. P. Venturini, V. V. R. Scarpa, G. Spiazzi and S. Buso, "Analysis of limit cycle oscillations in maximum power point tracking algorithms," 2008 IEEE Power Electronics Specialists Conference, Rhodes, 2008, pp. 378-384.

6. J. M. Carrasco et al., "Power-Electronic Systems for the Grid Integration of Renewable Energy Sources: A Survey," in IEEE Transactions on Industrial Electronics, vol. 53, no. 4, pp. 1002-1016, June 2006.

7. S. Stanzione, C. van Liempd, R. van Schaijk, Y. Naito, F. Yazicioglu and C. Van Hoof, "A High Voltage Self-Biased Integrated DC-DC Buck Converter With Fully Analog MPPT Algorithm for Electrostatic Energy Harvesters," in IEEE Journal of Solid-State Circuits, vol. 48, no. 12, pp. 3002-3010, Dec. 2013

8. G. R. Walker and P. C. Sernia, "Cascaded DC-DC converter connection of photovoltaic modules," in IEEE Transactions on Power Electronics, vol. 19, no. 4, pp. 1130-1139, July 2004.

9. J. Kivimäki, S. Kolesnik, M. Sitbon, T. Suntio and A. Kuperman, "Design Guidelines for Multiloop Perturbative Maximum Power Point Tracking Algorithms," in *IEEE Transactions on Power Electronics*, vol. 33, no. 2, pp. 1284-1293, Feb. 2018.

10. M. A. G. de Brito, L. Galotto, L. P. Sampaio, G. d. A. e Melo and C. A. Canesin, "Evaluation of the Main MPPT Techniques for Photovoltaic Applications," in *IEEE Transactions on Industrial Electronics*, vol. 60, no. 3, pp. 1156-1167, March 2013.

11. R. Jiang, Y. Han and S. Zhang, "Wide-range, high-precision and low-complexity MPPT circuit based on perturb and observe algorithm," in Electronics Letters, vol. 53, no. 16, pp. 1141-1142, 3 8 2017.

12. N. Kumar, I. Hussain, B. Singh and B. K. Panigrahi, "Normal Harmonic Search Algorithm-Based MPPT for Solar PV System and Integrated With Grid Using Reduced Sensor Approach and PNKLMS Algorithm," in IEEE Transactions on Industry Applications, vol. 54, no. 6, pp. 6343-6352, Nov.-Dec. 2018.

13. F. Paz and M. Ordonez, "High-Performance Solar MPPT Using Switching Ripple Identification Based on a Lock-In Amplifier," in IEEE Transactions on Industrial Electronics, vol. 63, no. 6, pp. 3595-3604, June 2016.