Artificial Intelligence Based MPPT techniques for Solar PV System: A Review

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Abstract: A solar photovoltaic (PV) power generation system (SPPGS) is be important as energy sources because its benefits. In the large SPPGS, the partial shaded condition (PSC) is occurs and its effect is highly decrease efficiency of SPPGS. Under PSC, the multiple peaks in P-V characteristics, that condition conventional maximum power point tracking (MPPT) techniques not able to achieve maximum power point (MPP) in such a case. The artificial intelligence (AI) based MPPT (AI-MPPT) methods are faster, reliable in performance and improve the efficiency of SPPGS. In this paper different AI based MPPT techniques are review and compare different techniques on the bases of tracking speed or time, oscillation, efficiency and limitation**.**

***Keywords*— Maximum power point tracking, artificial intelligence , Particle swarm optimization, Ant- colony optimization, Artificial neural network , Fuzzy logic control.**

I. INTRODUCTION

Nowadays in the energy demand is ever increasing. Energy generated by the fossil fuel is produce carbon- dioxide and other gases that are harmful for the environment, the renewable energy sources are more favourable option in generation energy to fulfil demand [1-2]. In renewable energy solar energy is most important energy source. In SPPGS the high investment cost and widely drawback is not available for the all-time. The output characteristics of the PV panels are influenced by the different external factors like irradiation, temperature and PSC [2]. The MPP of the PV panel are influence by the external factors. Therefore, MPPT is the very important for the efficiency improvement of the SPPGS [2].

The perturbation & observation (P&O), hill climbing, incremental conductance techniques are the most popular conventional MPPT techniques. When SPPSC is under PSC, the P-V characteristics have been multiple peaks. Mainly two types of peaks global maximum power point (GMPP) and local maximum power point (LMPPS). In that condition general MPPT techniques are not able to track or achieve MPP [3].

There are commonly used AI-MPPT techniques are artificial neural network (ANN), Particle swarm optimization (PSO), Ant colony optimization (ACO), Genetic Algorithm (GA). These techniques are able to track MPP in PSC and different environment condition. AI-MPPT are learn from the past experiences so they have start tracking from the last MPP, so they have achieve MPP quickly that's why the tracking speed is high.The main benefits are tracking speed, less oscillation around MPP. But these techniques algorithms complexity and implementation cost is high compare to conventional techniques [1-2].

II. SYSTEM CONFIGURATION

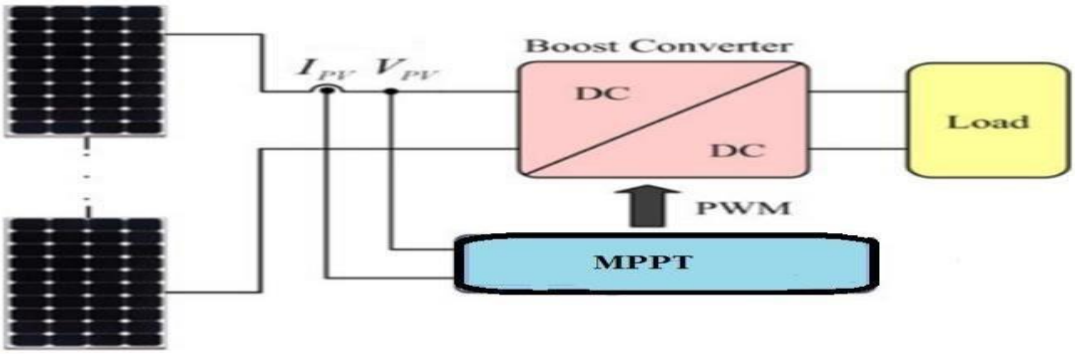

Fig.1 System configuration [6]

Fig.1 shows the block diagram or system configuration of the basic SPPGS. Solar PV arrays are connected in series with the DC to DC converter means the boost converter for the step-up or step-down the voltage. Boost converter switching device work on the gate signal and that gate signal provided by the MPPT. If the boost converter operate without MPPT the output of the boost convert

are vary because the PV arrays output is change in sum condition. MPPT get reference from the PV output and create gate signal so the boost converter duty cycle will be change as per the condition or requirement [6-7].

III. Different AI based MPPT techniques.

This section describes different AI-MPPT techniques and algorithms in detail. Different AI-MPPT techniques as follow [1-2]

- Artificial neural network (ANN)
- Particle swarm optimization (PSO)
- Fuzzy logic control (FLC)
- Ant colony optimization(ACO)

A. Artificial neural network

In fig.2 there are three layers input layer (IL), hidden layer (HL) and output layer (OL). Input variables are select on the bases of PV system parameters such as a short circuit current (I_{PV}), open circuit voltage (V_{PV}) and other external factors. These variables (V_{PV}, I_{PV}) are applied in the input layer.Input variables are processed in hidden layer and provide the accepted signals in output layer [3].

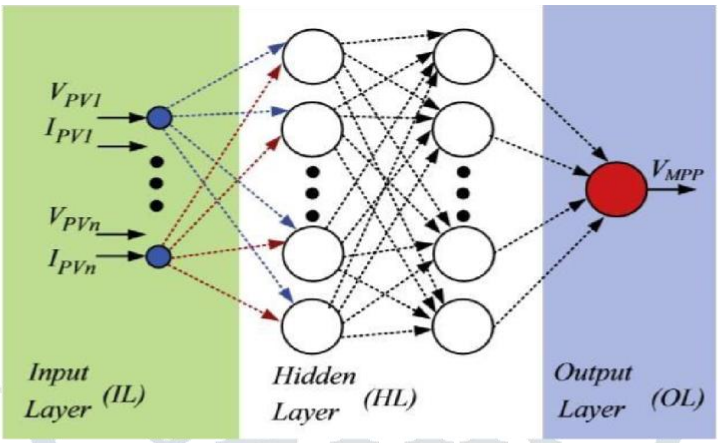

Fig.2 Multilayer feed-forward neural network [4]

ANN based MPPT accuracy and capability are depends on the algorithm in hidden layer and training process. Sum months are required for training procedure for the improvement the functionality in the different different environmental conditions [4].

To observe MPP with precision &accuracy, the neurons associated weights should be obtain by the intensive and comprehensive training process. Theses process time neurons weight are depends on SPPGS input output relation are targeted. Therefore, trained ANN for SPPGS so they are work properly for this system but change the specification of PV arrays that condition they not work properly. Normally the output variables are signal by the operating point approach the MPP region. Th e most common signals for the boost are the converter duty cycle [3-5].

B. Particle swarm optimization

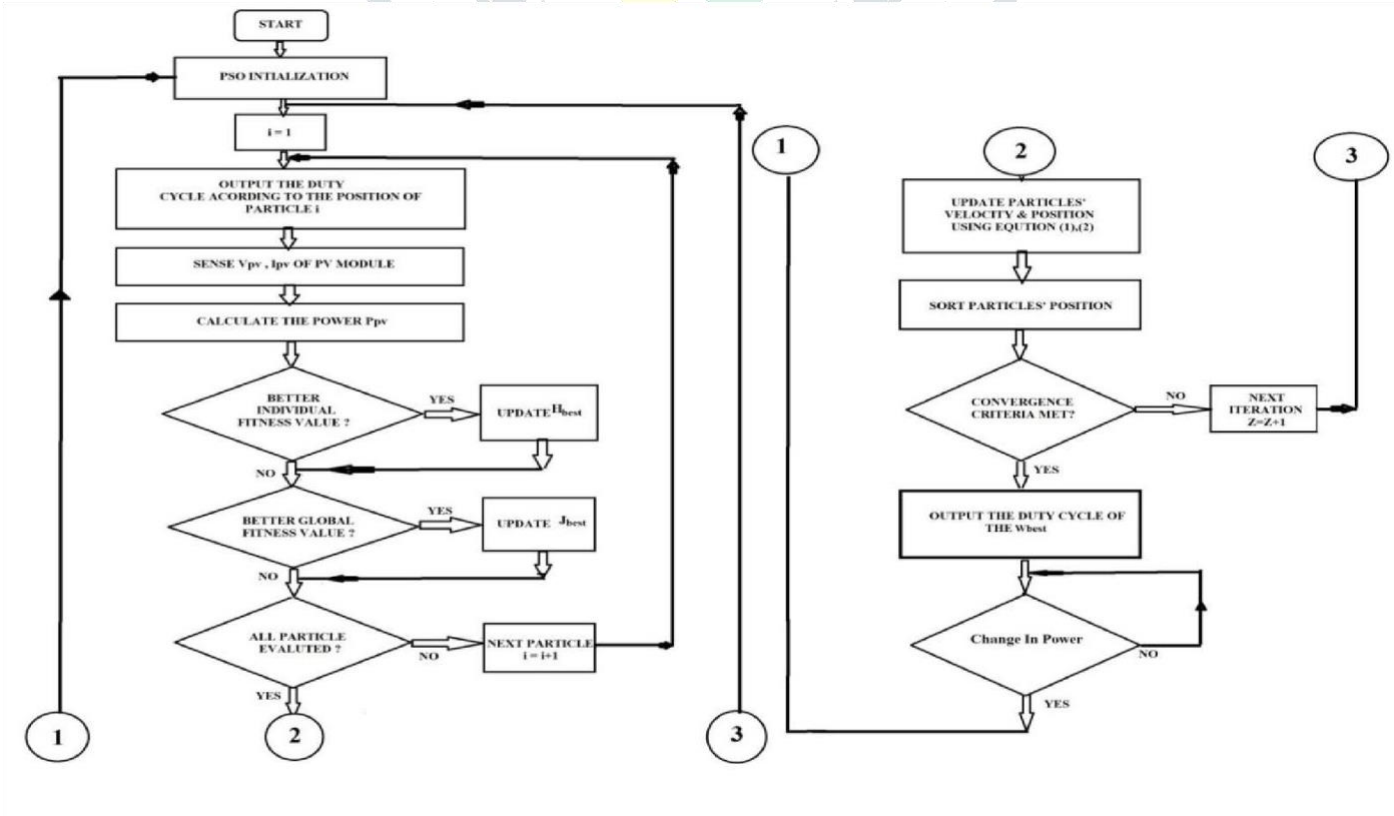

Fig.3 Multilayer feed-forward neural network [21]

In 1995 Eberhart and kennedy introduce PSO algorithm base on swarm intelligence optimization, they inspired by the social behaviour of swarm birds. It is the optimization algorithm or dealing with global optimization algorithm for problems on which a surface in n-dimensional space represents a best solution. In this algorithm, agents are used, and each agents exchange information they achieve in respectively search process [1,6-8]. The standard PSO method can be defined using these equations [23]: $r_i(M$ 1) $wr_i(M)$ $p_1o_{1.}(H_{best,i}\,y_i(M))$ $p_2o_2.(J_{best}\,y_i(M))$ (1)

$y_i(M+1) = y_i(M) + r_i(M+1)$ (2)

$i = 1,2,3.....N$ where, r_i is the velocity of the particle i ; M is the iteration value, w is the iteration weight, p_1 and p_2 are random variables, y_i is the position of particle i. $H_{best,i}$ is used to store the best position that the achieve by the i^{th} particle, and all particles best

value store in J_{best}[9-10].

Fig.(3) Shows the PSO based MPPT technique flow chart, the first stage is define the parameter on the bases of duty cycle of boost convert and the fitness value of the generated power from the PV arrays. Then calculate the power generated from the PV arrays and particle finds the better individual value or individual best value, if they found individual best value they update $H_{best,i}$[26]. Then, select the particle with the best fitness value compare to all particles as know the J_{best}.After all the particles are consider then update the velocity and position of the particles [9]. If the all particles are not evaluated then update the value of i particle [22].

The selection of the weight of the iteration value will be selected such that the effect of $r_i(M)$ during the execution of the PSO algorithm. The J_{best} value is defining the MPP point in the output P-V characteristic; on the bases of algorithm create the signal for the DC-DC converter duty cycle [1, 11].

C. Fuzzy Logy control

FLC is the most commonly used techniques because its multi rule based characteristics. In the FLC exact mathematical modelling and technical quantities are not required for the controller. The variables manage by the non- numerical and linguistic actual values. In this technique optimization, everything is selected according to the degree; exact reasoning is change by the approximate reasoning, and the final decision base on estimated value [1,12].

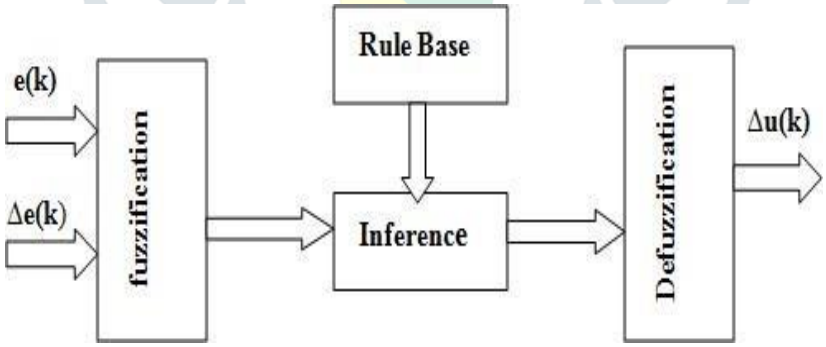

Fig.4 Block diagram of FLC [12]

The FLC comprise in three steps fuzzification, inference rule base and defuzzification. Fig Block diagram shows these techniques. The input variable of the fuzzification but thease variables are generally know as a error 'e(k)' and variation in error (Δe(k)). The main work of fuzzi-fication is using membership function converts crips value to linguistics value. The triangular [25-26] membership is highly popular show in fig. And table 1.

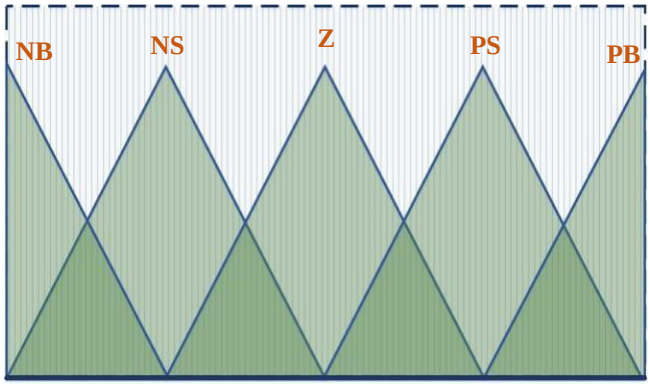

Fig.5 Membership function [1]

Table.3.1: **Rule table of FLC [15]**

$\Delta P_{pv}\Delta I_{pv}$	P	Z	N
PB	PB	PB	NB
PM	PM	PM	NM
PS	PS	PS	NS
ZZ	PS	ZZ	NS
NS	NS	NS	PS
NM	NM	NM	PM
NB	NB	NB	PB

Output variables are control according to rule inference engine. Using a rule base table themembership function base inference engine applies rules. In defuzzification convert output linguistic to relevant crisp & numerical value [14].
In MPPT application input variable calculate using this equations:

$$(e(t))^{\cdot} = \frac{\Delta p(t)}{\Delta V(t)} = \frac{P(t)-P(t-1)}{V(t)-V(t-1)} \quad (3)$$

$$\Delta e(t) = e(t)- e(t-1) \quad (4)$$

In FLCP(t) power value and V(t) voltage value are the operating point, respective; t is the sampling time; next step of the operation direction of the operating point define by the Δe(t), and position e(t) of the operating point in the P-V

locus that are the MPP [13-15].

In next stage, the fuzzy rules are mentioned in Tabel.1 are used to determine the MPP based on "THEN Changes applied AND power increased THEN- continue the direction" to define the DC-DC converter requierd change in operating cycle. Fuzzy value Output of the rule base section is convertes in to non-fuzzy value by the defuzzification. The centroid method is only used to define the requried duty cycle variation as per the output of the FLC based MPPT [12-15].

D. Ant colony optimization (ACO)

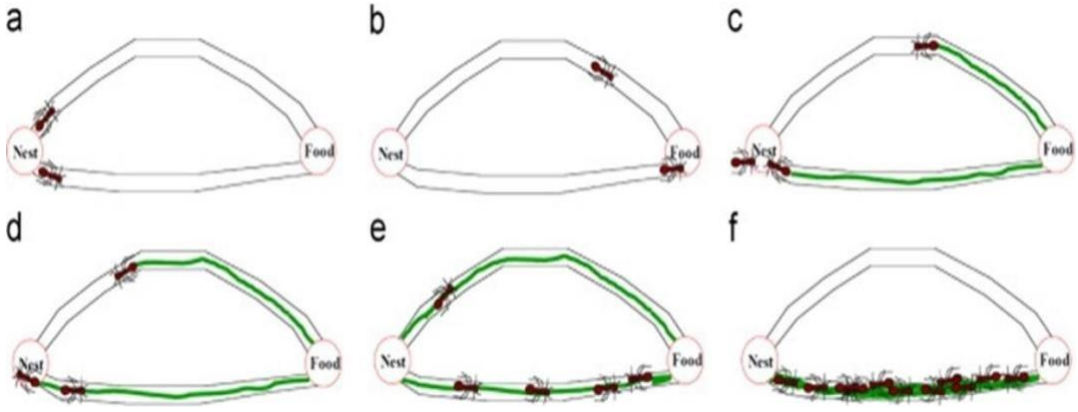

Fig.6 Behavior of Ants [1]

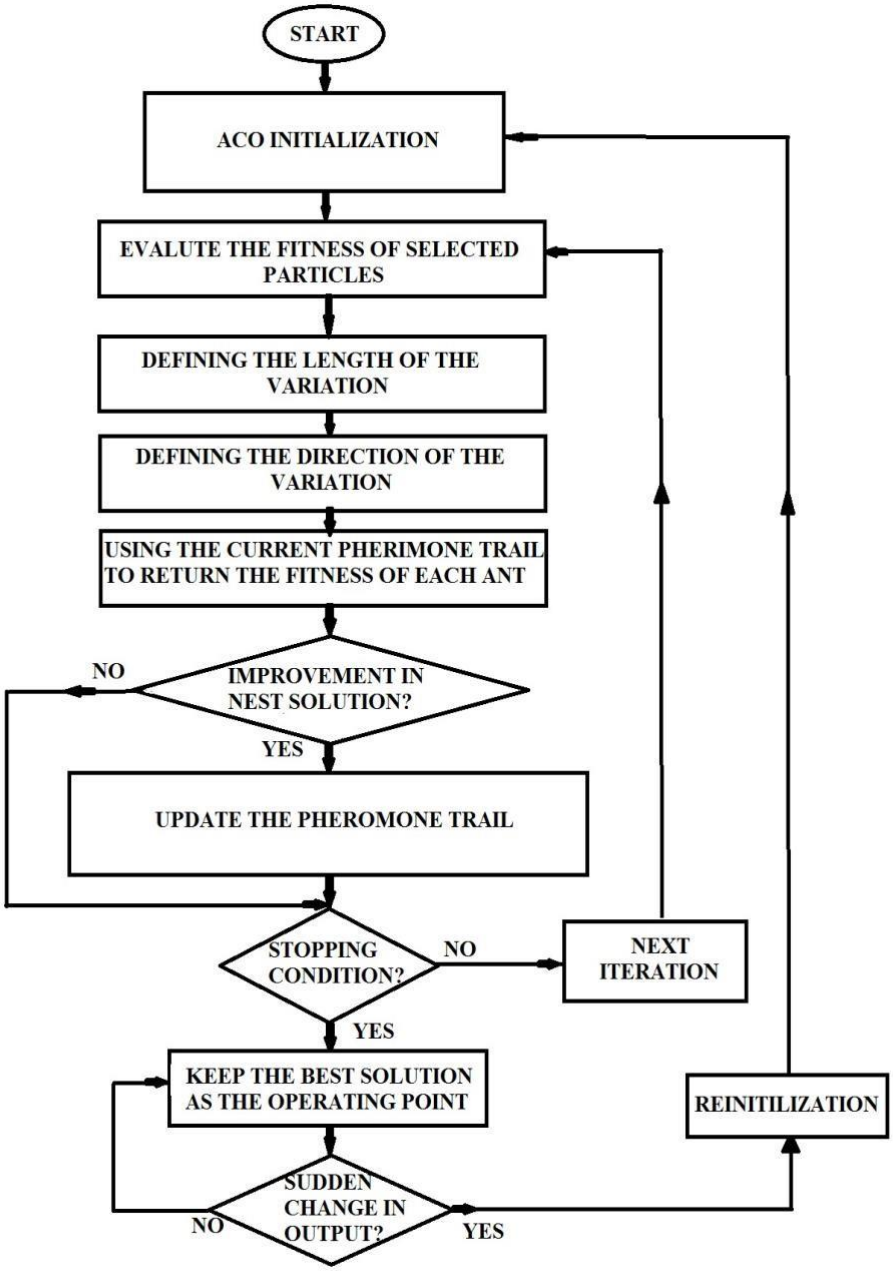

Fig.7 ACO based MPPT flow chart [1]

In the ACO based MPPT each locations are represent the voltage value of PV arrays. F(x) objective function is the best fitness value of each ant and is evaluated according to voltage value. Assuming the n ants participate, the following eq.(5) show the l^{th}iteration in location matrix [18-20].

$$X_l^i = \lceil X_l^1, X_l^2, \ldots, X_l^N \rceil \quad (5)$$

The ACO algorithm was fast tracking in normal and PSC condition. Hardware implementation complexity and cost is less compare to the ANN and FLC algorithm [20].

IV. Comparison of MPPT techniques

Table 4.1: Comparison of different MPPT techniques

Criteria	ANN	FLC	PSO	ACO
Convergence speed	Medium	Medium	High	High
System Independency	Low	Low	More	More
MPP track under PSC	Slow	Slow	Fast	Fast
MPP track under normal condition	Fast	Fast	Very fast	Very fast
Efficiency	Less	Less	More	More
AI based algorithm complexity	Easy	Easy	Easy	Medium
Hardware Implementation complexity & cost	More	More	normal	normal
Periodic tuning	Required	Required	Not required	Not required

Oscillation around MPP	Very-low	Very-low	Very-low	Very-low
Initial design Dependency	More	More	Low	Medium

V. CONCLUSION

In this paper reviewed on the AI based MPPT techniques or algorithms, such as FLC, PSO, ANN, and ACO. The concept and structure of each method of tracking maximum power point in various endearment conditions. The final- evolution is the carried out evaluate the tracking GMPP in PSC condition, complexity, cost, system independency, efficiency, oscillation and periodic tuning. The comparison conducted according to the algorithms or techniques concept, as per the studies were perform on different system and condition.

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