A Review On different MPPT techniques implemented in Solar PV System

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Abstract— **Due to increasing demand of power and scarcity in non-renewable energy sources, solar energy has become a burning topic of discussion for generating electricity and it also generates electricity without harming the environment. But the only point of concern is the efficiency of solar energy and it is about 25-30% which makes the harvesting more costlier. So to extract maximum power from the PV panel MPPT controller plays a major key role. We know that there are various parameters that effect the panel output such as temperature, solar irradiance, partial shading etc. which makes it difficult to track the MPP all the time. So to overcome this problem various MPPT algorithm has been proposed and well implemented and this algorithm also has their own advantage and disadvantage. So in this review paper we have discussed some of the algorithms current issues and their respective merit which also gives us clear path for future works for attaining better efficiency.**

Keywords—Solar energy; MPPT; Techniques; non-renewable; PV characteristics.

I. INTRODUCTION

As the number of population increasing day by day, there is also increase in demand of electricity which leads to the scarcity of non-renewable energy sources and also as we know the usage of these non-renewable energy sources increases the amount of carbon content in the atmosphere. To avoid the extreme paucity of non-renewable resources, the power sector shifted its focus towards the renewable energy sources such as sun, wind, biogas etc. and these sources are readily available which can easily fulfill the necessary power demand. But as we know everything comes with a price so here the price is the efficiency. The efficiency from these renewable sources are quite low and to increase these efficiency a lots of researches are going on. Among all these renewable energy sources, solar energy has drawn maximum attention in electricity generation. Due to its simplicity its playing a pivotal role in electricity generation nowadays. Earlier the cost of PV panel is higher and also the efficiency was quite low but in recent years various scientific researches have been going through which certainly somewhat decreases the cost and also increases its efficiency, upto some extent. The working and output of solar PV panel is truly depend on the material of the cell. The other factor such as temperature, irradiance etc. also plays a pivotal role in the performance of solar PV panel. The maximum efficiency of commercial cell is around 16-20% only [1, 2].To increase these efficiency various researches are going on material of cell, grid efficiency and extraction of maximum power from solar panel. Also in recent there is huge advancement going in the field of power electronics which in turn also helps in increase in efficiency of solar panel.

The performance of a PV cell largely depends on quality of cell material such as absorption capacity and reflectance of the surface. The operating condition like solar irradiance level, incident angle, temperature and load current plays a big role in dictating the performance of PV array output voltage, current and power delivery. Among all these area of scope of improvement, the most interesting field of work in nowadays is extracting maximum output from PV panel. As its output hugely depends on the irradiation level and temperature. So it is very important to ensure that the conversion system works close to the maximum point so that efficiency get increased. To do this Maximum Power Point Tracking device is required which helps in achieving and delivering maximum power at the output of the panel in spite of different weather condition prevailing. . MPPT are used for operating PV array at the point of maximum power irrespective of irradiance, temperature and load current variation. In literature, different MPPT techniques have been proposed but their suitability largely depends on factors like the end application, dynamic of irradiance, design simplicity, convergence speed, hardware implementation and the cost. Several MPPT algorithm are proposed and shown their potentiality to derive maximum power efficiently but all these algorithm suffer from various drawback such as slow tracking, oscillation at MPP, complexity etc all these drawback leads to the reduction in efficiency. The various MPPT methods are Perturb and observation, Inc. Conductance, PSO etc.[5-33].

II. MODELLING OF PV MODEL

A solar PV panel is consist of several solar cell which are best known as the basic unit of any PV panel. The cells are either connected in series or parallel as per requirement. Parallel connections leads to increase in current in the array whereas the series connection is responsible for increase in voltage. An universal PV model is shown in Fig 1. which is also known as Single diode model. The circuit consist of 5 parameters. The current source i.e. the cell (I_{ph}) is connected in series with a resistance R_S and a shunt resistance R_{Sh} which is due to leakage current and a parallel connected exponential diode (D)

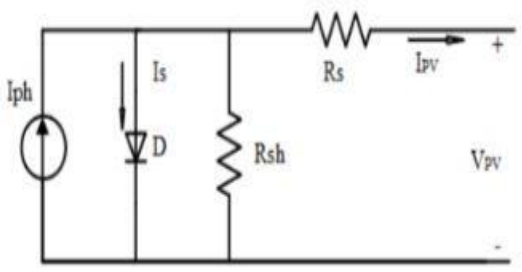

Fig 1.Basic PV cell circuit.

The PV cell output current can be written as

$$I_{pv} = I_{PH} - I_D \left(e^{q\left(V_{pv} + I_{pv} * R_S\right)/nkT} - 1 \right) - \left(V_{pv} + I_{pv} * R_s \Big/ R_{sh} \right)$$

Where:

I_{PH} = solar induced current

I_D =Diode current

q = Electron Charge

K = Boltzmann Constant

n= Ideality factor

T = Temperature

The induced current is totally depends upon irradiation leval and the working temperature which can be expressed as;

$$I_{PH} = I_{SC} + C_i(T_c - T_r) * \frac{I_r}{1000}$$

I_{SC}= Short circuit current

C_i= cell short circuit co-efficient

T_c , T_r=cell working and reference temperature

I_r= irradiance level covering the surface area.

The characteristics diagram of I-V and P-V are shown in fig 2(a) and 2(b) at constant insolation and different temperatures and different insolation and const. temperature resp.

III. MPPT TECHNIQUES

Maximum Power Point tracking control methodology actually enhance the performance of solar panels by extracting maximum capable power from the pv modules irrespective of insolation and temperature at a particular instant of time. There are number of methods that are being proposed for harvesting maximum power through MPPT, but among them only a few methods holds their position such as Inc. Conductance[5-8], Perturb and Observation[9-11], Particle Swarm Optimization[14-20], Ant Colony Optimization, Genetic algorithm etc.

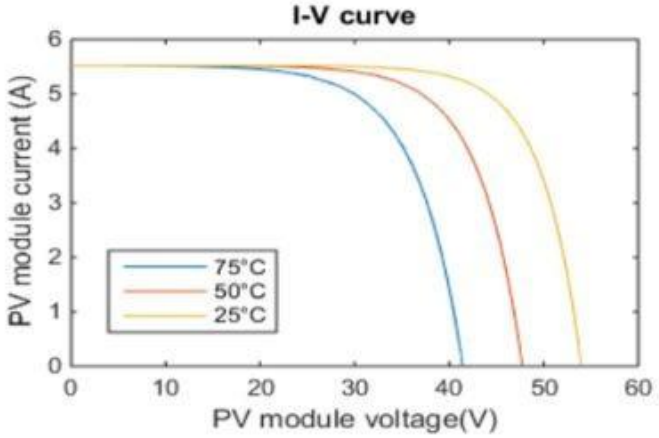

Fig.2(a).I-V curve for different cell temperature

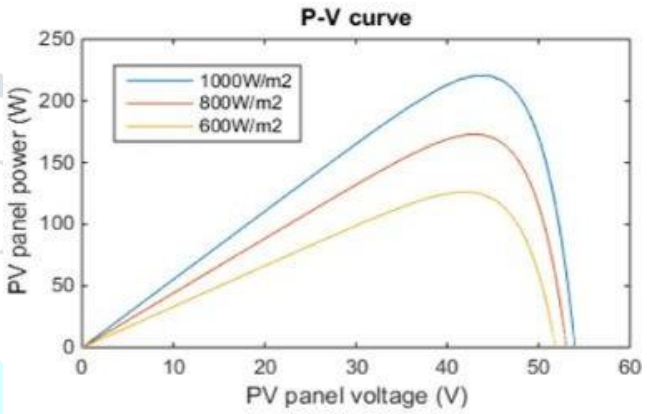

Fig. 2(b). P-V curve at different insolation

A. Perturb and Observation Method

This is the most popular algorithm used in MPPT. This operates by continuously changing the operating point of PV panel and observe the change in output power and then determines the next variation which leads to MPP. In P&O algorithm the reference value may me terminal voltage, output current or duty cycle of the converter. When the harvested power from the array increases, then the operating point will move towards the MPP which suits to further increase in reference voltage or current. But if the output value of power decreases which suggest that the operating point is moving away from MPP which indicates to decrease the reference voltage or current. The major drawback that P & O method suffers from is oscillation around the maximum operating point which leads to unnecessary wastage of energy which in turn impacts the efficiency. So to rectify this problem a number of improvements on the P&O algorithm have been applied. Liu et al. [15] have provided a solution which reduce these power fluctuation caused by P&O algorithm. In this he proposed to measure incremental change in power i.e. ΔP. If ΔP is positive which gives a space to increment ΔV that means operating point is approaching towards the MPP. And the

same is reversed if ΔP is negative, ΔV should get decreased. The flow chart for P&O is shown in Fig 3.

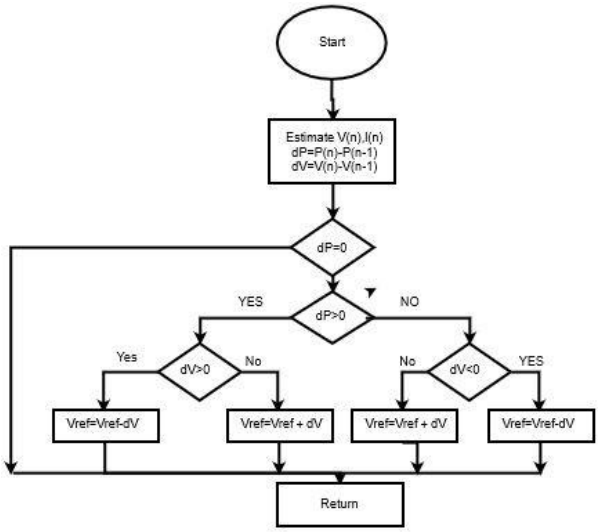

Fig. 3.Flowchart of P&O Method.

GAGA Ahmed et al. [20] also proposed a solution, based on the measurement of irradiance and temperature the maximum power is being calculated .After calculation the classical P&O method comes into play. After execution of each cycle the difference between actual power and the estimated power is being calculated. If the difference between the two is zero then we can say that we achieve the maximum power point and achieved the optimal duty cycle. This value is taken as the control signal for converter until the next variation of maximum power that PV can provide. At the result it is seen that the efficiency of the classical P&O method is improved by using this enhanced method .Al-Amoudi and Zhang [27] have presented a variable step size incrementation method but it is not a feasible solution as the step does able to vary with real time changes.

Petrone et al. [24] proposed a multivariable P&O technique, though the method does well in its performance but the presence of multiple variable leads to the controlling of number of variable which in turn increases the complexity in the performance. Suganya and Carolin Mabel [31] have designed and analysed a PV system based on P&O technique to extract the maximum power by continuously chasing the MPP. The model improved the efficiency under constant irradiation condition. Radwan and Orabi [32] in their proposed paper also tried to get the dynamic behaviour of the PV system by optimizing the parameters of P&O algorithm. But they also observed sa me drawback regarding oscillation around MPP. Wang et al. [35] proposed a PV model based on mathematical modelling of the PV array on the basis of P&O method. Kwan and Wu [37] also proposed a P&O based Lock on Mechanism algorithm in order to reduce the oscillation at the point of MPP. The aim of this LOM is to adjust the perturbation size on the basis of weather the operating point is at MPP or not by applying the lock on mechanism on the input reference voltage of P&O method.

B. Incremental Conductance Method

This technique utilizes the method of tracing the slope of a PV curve of solar array to get the MPP. It states that a small change in power w.r.t to small change in voltage is equalizes to zero at the point of MPP. It also signifies that if the operating point lies on the left side of MPP in slope then it is positive and vice versa on the basis of its position incrimination and decrementation of factors can be applied in next possible iteration step. This adaptive capability in voltage change step makes the algorithm to trace easily the change in environmental condition. As a result of which more power can be harvested from panel and thus efficiency get increased.[4-9].The basic rules of MPP can be summarized as:

$\frac{dP}{dV} = 0$, at MPP

$\frac{dP}{dV} > 0$,to the left of MPP

$\frac{dP}{dV} < 0$,to the right of MPP.

In other words it compares the static conductance with instantaneous conductance and utilizing these two factors the algorithm locates the point of MPP. The flowchart is shown in Fig.4

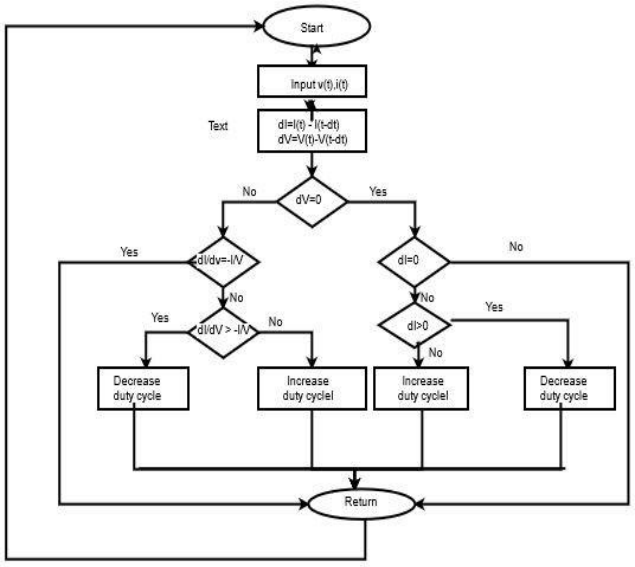

Fig. 4.Flowchart of Inc.Conductance Method.

Inc. Conductance actually operates best for rapidly changing atmospheric condition [38].Because of high accuracy in speed control and sampling results in complexity in structure which makes it costlier to implement. Generally this method is used along with hill climbing algorithm but the most crucial drawback that it suffers from is that as the speed increases, the step size also gets increased and further it may lose direction under rapidly changing atmospheric condition.The tracking speed of the MPPT controller is enhanced by applying INC. algorithm using variable stepsize [8]. Incremental Conductance basically determines the direction of radiation change and with respect to that it

changes the voltage and also finds MPP. This eliminated the oscillation problem around steady state. Incremental Conductance is determined to attain MPP under disturbed environmental condition. However the cost and complexity of Incremental conductance is high. Another drawback is the change of speed w.r.t. step size of error.To maintain the tracking speed and MPP the major difficulty is to determine the voltage step size. So this paper represent an improved version of Inc. algorithm which uses variable step size to estimate the commutation between the dynamic and steady state oscillation w.r.t step size and in this way this algorithm overcome the oscillation problem suffered by P&O method otherwise under uniform insolation both the algorithm have same efficiency [10,11].

Murtaza et al.[13] has generally compared four MPPT method and analyse the result of each of them in both steady state and dynamic atmospheric condition. It is seen that Inc. Conductance stands out to be better among all of them in terms of efficiency but it is also found that the method is too complex to easily implement. Adly et al. [41] also implemented the Inc.Conductance along with DC-DC converter as a isolation stage and it is found that 15% of energy loss can be saved. Keyrouz and Georges [43] have also proposed a multidimensional MPPT by using a hybrid algorithm under dynamic condition. Al Nabulasi et al.[45] also proposed a Hill climbing along with Inc. Conductance for locating MPP to harvest maximum power from the PV panel. Here the duty cycle are provided to the DC-DC converter and then to the load. But then here also oscillation around the MPP occurs and leads to power loss. Ratna Ika Putri et al.[46] also presented a paper which control the duty cycle of DC-DC boost converter using Inc. Conductance and compares it P&O method which shows the efficiency of Inc.Conductance is higher during variable atmospheric condition.

C. Particle Swarm Optimization Method

This is the most advanced algorithm used now a day in order to eliminate the drawbacks suffered by above two methods such as steady state oscillation and reduced tracking speed of MPP. This algorithm is inspired from the pattern made by flock of birds during flying in the sky.In this method firstly some particles are initialized randomly in space having different velocities and positions. The random values get updated based on previous best values, new local best value and global best value. The search for optimized value continues until and unless termination criterion is reached.PSO particles position is calculated by using following formula

$$x_i^{t+1} = cx_i^t + z_1 rand()\left(P_{best_i}{}^t - a_i^t\right) + z_2 rand()\left(G_{best_i}{}^t - a_i^t\right)$$

and

$$a_i^{t+1} = a_i^t + v_i^{t+i}$$

x_i^{t+1} is the particle velocity.

a_i^{t+1} is the current position of the particle

a_i^t is the previous position of the particle

c is weighing factor

z_1, z_2 are the learning co-efficient

rand() is the random value generated

$P_{best_i}{}^t$ is the local best

$G_{best_i}{}^t$ is the global best.

According to this algorithm there will be almost zero oscillation at the point of maximum power. This algorithm actually has the capability to differentiate between global maxima and local maxima in the PV graph. This capability of PSO makes it a superior algorithm during rapid environmental changing condition and partial shading condition. The PSO has garned more popularity because of its simple structure, ease of implementation and fast tracking speed. It can easily locate the position of MPP at any environmental condition. Further more as the search space area gets reduced in PSO which in turn decreases the convergence time. The flow chart for PSO is shown in fig 5.

Kashif Ishaque et al.[53] have presented a paper which deals with proper initialization of duty cycle which results in reduced convergence time to get MPP. The initialization of duty cycles are done in two phases. Firstly, the increment or decrement of previous duty cycles must be multiplied by a linear factor K. Secondly at MPP all the particles are approximately at same position with zero velocity. Rini et al.[57] also presented a paper which tried to overcome the serious problem i.e proper selection of duty cycle because without proper selection it will effect the efficiency. For example if the initialization of duty cycles are not within proper limits then the algorithm will take more iteration to get MPP which in turn increases the time for finding optimal solution. Hence initial duty cycle must be confined in proper limits for faster convergence. So this paper address the proper initialization of duty cycles d1,d2,d3 and hence it is called modified PSO. Applying the reflective impedance method the upper and lower bounds duty cycles d1 &d3 are initialized and d2 is initialized by using following equation(d1=1-√R(in)/R0).R(in))is the internal resistance and R0 is the equivalent load resistance.

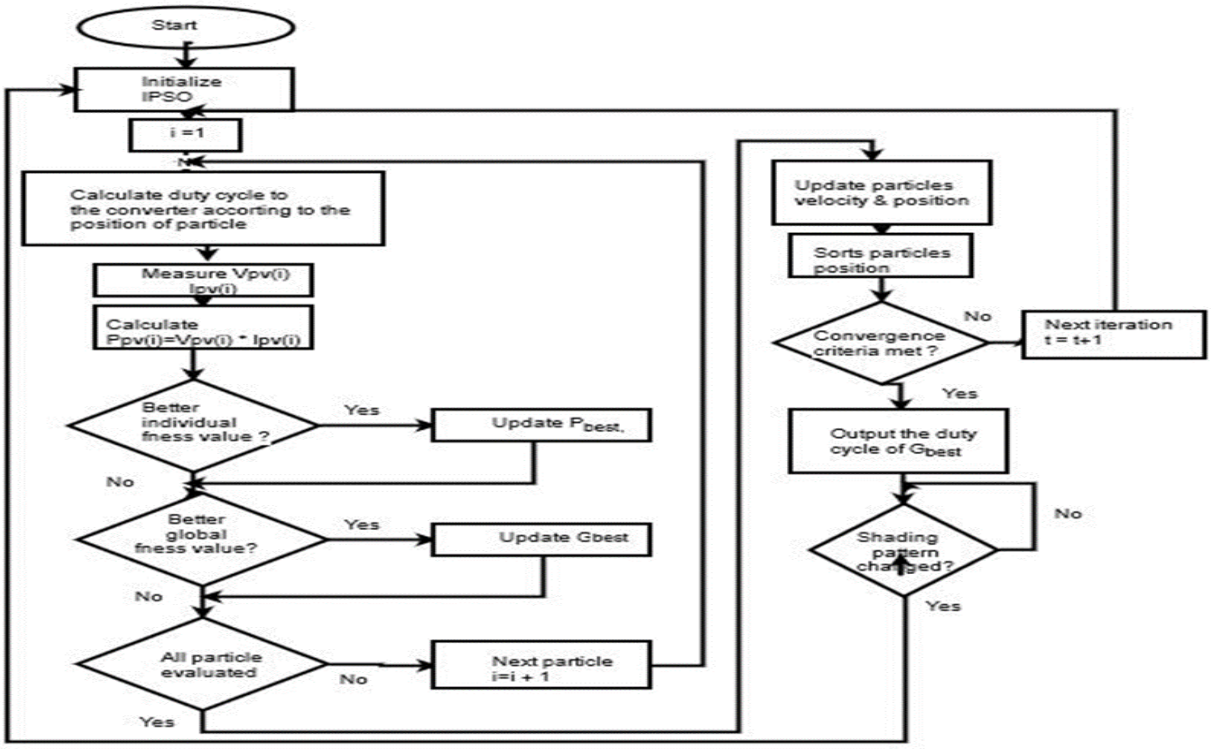

Fig. 5. Flowchart of PSO algorithm

Ramadan et al.[59] in his paper compares other conventional method with PSO .For proper evaluation this method implemented with DC-DC cuk converter and the simulation result presented confirms that PSO is more superior in terms of tracking speed, efficiency and ease of implementation but the only barrier is the perfect selection of parameters because this wiil greatly impact the optimization efficiency. M.Abdulkadir et al.[60] proposed an improved version of PSO. It actually modified the linear decreasing of weighing factor, cognitive and social parameter. The proposed version can overcome the drawback and increased the rate of convergence of the IPSO method. This method easily locate the MPP at both uniform irradiance and non-uniform one. This method is also used with other conventional method as K.Sundareswaran et al.[9] proposed a such topology which combines the advantage of both PSO & P&O method, as a result it is seen that efficiency is increased.

D. Open Circuit Voltage Method

:It is the simplest method [48-51] of all it works on the fact that under any circumstances the open circuit voltage is always linearly proportional to the voltage at which MPP is located which is satisfied by the equation:

$$V_{MPP} \approx C * V_{(OC)}$$

The principle idea of this method is that the open circuit voltage is always close to the voltage at which maximum power is obtained with 2-5% of tolerance. In this method, the MPPT system temporarily sets the array current to zero and is set around 76% of the measured voltage and is kept in hold circuit until the next sampling instant.[47,52].This process is repeated until MPP is achieved. Though the method is simple and can be easily implement but it suffers from two major drawback. Firstly, frequent switching off of load to measure open circuit voltage and secondly exact MPP cannot be determined

E. Short Circuit Method

The short circuit method is similar to that of constant voltage method. In this method the Short circuit current is proportional to the current at MPP under various irradiation level.

$$I_{mpp} = kI_{sc}$$

The above equation signifies that the current at MPP can be determined instantaneously by deriving the I(sc) and then providing command to the MPPT system that I(ref)=I(MPP) to a power converter. One implementation is required to monitor PV panels to measure short circuit current and another implantation is to short the pv panels for a short duration of time to get the short circuit current I(sc).[71]

F. Fuzzy logic based Controller

Fuzzy logic control is a convenient way to map an input space to output space. Fuzzy logic uses fuzzy set theory, in which a variable is a member of one or more sets, with a specified degree of membership. It consist of three specified blocks namely fuzzification, inference and defuzzification. In

order to overcome nonlinearity characteristics of PV cell fuzzy logic control implemented, the duty cycle for the converter is calculated based on fuzzy logic control algorithm. The core principle of this algorithm is to drive the operating point towards MPP .The most desirable quality that is possess is its robustness and fast response towards any change in atomospheric condition.The flow chart is shown in Fig. 6.

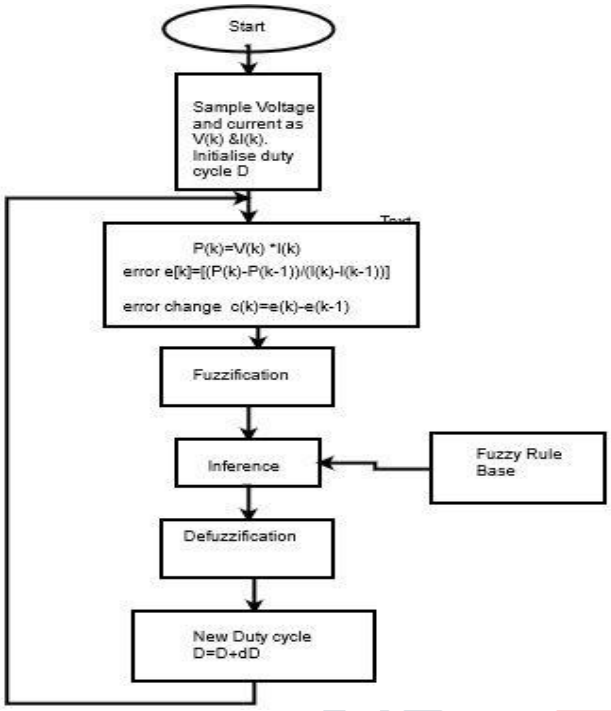

Fig. 6.Flowchart of FMPPT

R.Mahalaxmi et al.[63] have presented a fuzzy logic based controller along with its hardware. The proposed method aimed to change the duty cycle by sensing the change in atmospheric condition. The result shows that it trace the MPP in reduced time and with less fluctuation in comparison to other method. Narendiren et al.[64] also compare the fuzzy based controller with P&O method and simulation result shows that it is far more superior than P&O method. Adly et al. [41] also compared Inc. Conductance method with fuzzy MPPT under dynamic weather condition. Hossain et al.[65] also proposed a method to overcome fluctuation due to non-linear characteristics of PV panel under dynamic weather condition. The duty cycle provided to the DC-DC converter is by using fuzzy logic based control algorithm which can easily trace the MPP under variable insolation and temperature condition. Hadjammar and Bouchafaa[67] have also presented a fuzzy based MPPT which extract maximum power from panel and then provide it to the 3-level neutral point clamped VSI , which gives output with low harmonic distortion and low switching frequencies. Chin et al.[68] also proposed a paper to overcome the low accuracy of P&O method by implementing Fuzzy based MPPT which shows that it reduced the convergence time also reduced the settling time as compared to the P&O and other conventional technique.

Ammar Ghalib Al-Gizi, and Sarab Jwaid Al-Chlaihawi [70] in their paper compared three techniques namely FLC,P&O and Inc. Conductance on the basis of their tracking speed ,accuracy and steady state stability. It is analyzed that FLC provides better performance during both steady and transient state compares to other and also it shows high tracing speed and accuracy.

IV. Conclusion

Due to ongoing scarcity in non-renewable sources people are greatly focusing on renewable sources specially towards solar energy and it is also essential to reduce the environmental problems. But the most important drawback that solar energy suffering from is its efficiency and due to this, it is costlier in compare to non-renewable energy. To make solar energy as a domestic generation of power many researches are going on the algorithms of MPPT. There are many algorithm present for MPPT which are used according to their requirement. This review has included most of the dominant algorithm along with some hybrid algorithm.

It is observed that P&O method is the most simplest one but it has an oscillation problem around MPP. To overcome this oscillation Inc. Conductance comes into play and it shows a better efficiency during rapidly changing atmospheric condition and also the oscillation problem is reduced. But due to the complexity of structure this algorithm is not easy to implement. Then comes the PSO which is one intelligent technique it works greatly during dynamic weather condition as it can easily track the MPP and does not lose its track and also has fast tracking speed. To boost up the efficiency more fuzzy logic are used in present days as this method has all the capabilities to boost the efficiency.

PSO seems to be more promising and accurate of all providing high efficiency. Inc. Conductance MPPT algorithm seem to be the most prone to find the MPP during rapid change in atmospheric condition at expense of complexity and cost of the system. Conversely the P&O method though it is the most simple of all still it possess some intrinsic limitation such as oscillation around MPP, slow speed response and tracking in wrong direction during atmospheric change.

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