A Review of Control Techniques in MPPT for Solar Power System used to Monitor and Power Management

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Abstract— the purpose of this review is to study various control techniques used to control solar power generation as to optimize and track maximum power from solar radiations. Now a day researchers are focused on both the aspects that to optimize the power as compared to demand and to track maximum energy from solar radiations. Fuzzy logic controllers (FLC), PID, Artificial Neural Network (ANN), perturb and observe, feedback voltage, incremental conductance, Multiagent –System (MAS) are few techniques. Among these techniques FLC and MPPT are most attracting techniques for solar power system. In this paper the purpose and conditions to use these is reviewed and summered to understand optimization and purpose of using control techniques in non-conventional sources to generate electricity.

Key words: Solar Power, Non-Conventional, Fuzzy Logic Controllers, Perturb and Observe, Feedback Voltage, Incremental Conductance, PID, Artificial Neural Network, Multiagent –System

I. Introduction

Now a day the demand of electrical power is increasing exponentially. To fulfill this demand various power resources are used, which are classified into two major types as conventional and non-conventional. Non- conventional energy sources further listed as solar energy, wind power, bio-fuels, geothermal, tidal energy, hydro power etc. Total power installed in India is 308834.28 MW (approx), from which 45916.95 MW is generated from non-renewable sources (NRS), it is 14.86% of whole generation. Power generated from solar energy from this is 8513.23 MW which is again 18.54 % of total NRS upto November 2016[1]. Solar and wind energy are major resources in this era. To obtain maximum energy from these resources is important aspect to be considered. Researchers are working to find out the new techniques to obtain optimized process and utilize maximum energy from these incredible resources[1].

The techniques introduced by various authors in solar energy are reviewed in this paper and concluded to understand the need of particular technique at appropriate system. The most applicable techniques are FLC, MPPT, PID and ANN. FLC, MPPT and PID controllers are used to control as well as optimize the power generation by solar energy. These techniques can be implemented as per requirement and conditions of getting output. For power storage, batteries are used and for battery management system these techniques frequently used with control systems.

Understanding of appropriate technique for particular system is very important to gain maximum output from running system. For this understanding a description of these techniques is elaborated in this paper with the reference of various researches undertaken in solar power.

As per classification on the basis of control technique, there are three types. These are direct, indirect and probabilistic methods. In this paper the concern is direct methods which include differentiation, perturb and observe feedback voltage, incremental conductance, fuzzy logic and neural network.

II. Maximum power point tracking

MPPT is a controller to calculate and executed the most possible power from photovoltaic devices[2]. This will improve the overall efficiency of PV systems and decreases power losses. The characteristic of a PV array cell is depicted in Fig-1 below [3].

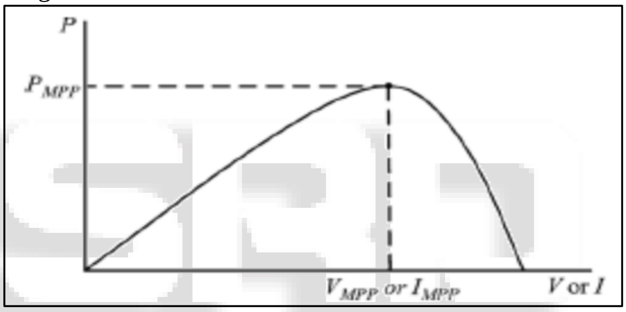

Fig. 1: Characteristic PV array power curve.

III. Perturb & observe

P&O algorithm has a simple control structure and few measured parameters which are required for the power tracking. This technique is independent to the characteristics of PV modules and works by its own characteristics so it can be implemented to all type of PV system[2]. P&O operates by periodically perturbing the control variable and comparing the instantaneous PV output power after perturbation with that before. The direction of every perturbation is determined by the comparisons of output of PV power and PV voltage conditions. The P&O perturbation step-size used in any MPPT technique plays a significant role in determining the accuracy and speed with which the operating point moves towards the MPP. Perturbation step size plays an important role to obtain the accuracy of pursuing MPP. On the other side, the larger are the intrinsic oscillations around the MPP due to large step size in steady-state would reduce the effectiveness of the PV power conversion because of the large error and lost opportunity to generate power. So the smaller the step size smaller the oscillations but only in steady state conditions. So it is recommended to have varying step-size to overcome the drawbacks exhibited by fixed step sizes. A fixed step-size set a constant perturbation step to the reference value in the power converter without the influence of P-V characteristic and weather conditions. A mean of applying the PV power as the control variable which considers the irradiance and the temperature effects, has been selected as the variable step-size[6-12].

The algorithm for the P& O is shown in the fig.2. this shows the flow process how this technique works to achieve accuracy in MPPT and obtaining maximum outcome from PV solar system.

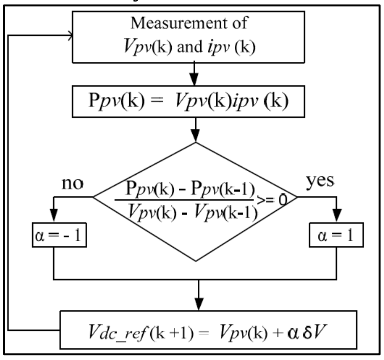

Fig. 2: Algorithm of P & O method for the MPPT

The details of this variable perturbation step-size have been reported in [9].

$$\Delta I = k_r \frac{P_{(k)} - P_{(k-1)}}{P_{PV}}$$

Where P(k) is the present PV power and P(k-1) is the previous measured PV power and kr is one of four constants for the four possible combination of perturbation direction and the Ppv-Vpv slope direction[16].

IV. FUZZY LOGIC CONTROLLER

In the field of research, FLC is the most active area as it is a part of artificial intelligence and works most accurately for power systems. FLC also works independently as P&O works which does not need to know the conditions of PV system and weather conditions and as compare to P& O there is no need to define any specific conditions in step and on which its working depends or by its outcome anything changes. The fuzzy controller functional block for implementation of this algorithm is as shown in Fig.3[3-5]

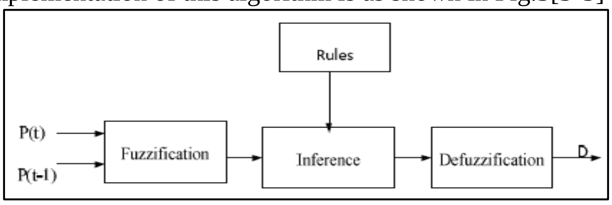

Fig. 3: Block Diagram of Fuzzy logic Controller

The control objective of fuzzy controller is to track the maximum power point as fast as possible under varying weather condition.

Fuzzy logic control generally consists of three stages: A) Fuzzification B) Fuzzy rule matrix & inference engine and C) Defuzzification.

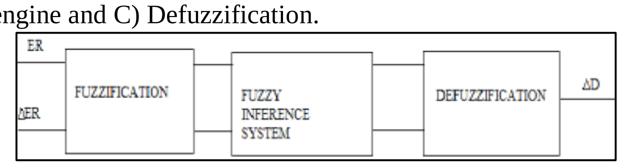

Fig. 4: configuration of fuzzy controller for MPPT

A. *Fuzzification*

The fuzzification comprises the process of transforming crisp values into grades of membership for linguistic terms of fuzzy sets. The membership function is used to associate a grade to each linguistic term. In this thesis FLC MPPT method has two input variables, error ER and change in error and an output variable. The two input variables are described by:

$$ER(m) = \frac{P(m) - P(m-1)}{I(m) - I(m-1)}$$

$$\Delta ER(m) = E(m) - E(m-1)$$

Where, P(m) and I(m) are the power and current of the PV module, respectively. At MPP, ER(m) is zero. These input variables are expressed in terms of seven linguistic variables or labels, such as Negative Large (NL), Negative Medium (NM), Negative Small (NS), Zero (ZE), Positive Small (PS), Positive Medium (PM), Positive Large (PL). For fast convergence and more accuracy output variable which is nothing but the duty ratio (D) of the power converter has nine linguistic variables such as Negative Ultimate (NU), Negative Large (NL), Negative Medium (NM), Negative Small (NS), Zero (ZE), Positive Small (PS), Positive Medium (PM), Positive Large (PL), Positive Ultimate (PU).The input and output membership functions are shown in fig-5 and fig-6 respectively[13-15].

B. *Fuzzy Rule Algorithm*

In this work 49 fuzzy control rules are used as shown in Table 1. Fuzzy rules are designed based on the zero error condition at the steady state of the MPP. The main aim of the rule is to track maximum optimum point by increasing or decreasing the duty ratio of the power converter.

As an example control rule in Table-1:

1) *IF ER is NL AND ER is ZE THEN D is NL*

This implies that if the operating point is distant from MPP towards right hand side and the change of slope in P-I curve is about zero; decrease duty ratio largely (NL). In the same way duty ratio is increases largely (PL) if ER is PL and is ZE. In this paper Mamdani’s method is used with max---min operation to operate the fuzzy combination.

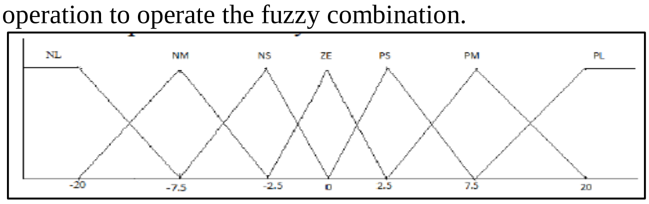

Fig. 5: Input membership function (error ER and change error ΔER) of fuzzy logic controller

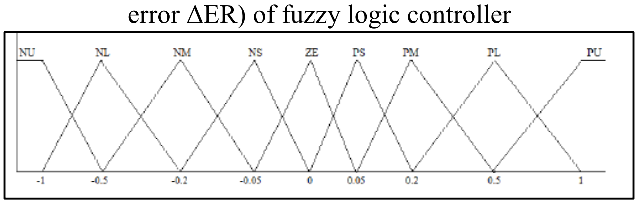

Fig. 6: Output membership function (Δd) of fuzzy logic controller

ER / ΔER	NL	NM	NS	ZE	PS	PM	PL
NL	NU	NU	NL	NM	NS	ZE	ZE
NM	NU	NL	NL	NM	NS	ZE	ZE
NS	NL	NL	NM	NS	ZE	PS	PM
ZE	NL	NM	NS	ZE	PS	PM	PL
PS	NM	NS	ZE	PS	PM	PL	PL
PM	ZE	ZE	PS	PM	PL	PU	PU
PL	ZE	ZE	PS	PM	PL	PU	PU

Table 1: Fuzzy Rule Base Table

C. Defuzzification

This is the third stage of the fuzzy controller, where the fuzzy control subset must be converted to the crisp value. As mentioned earlier the output of the fuzzy controller is the duty ratio of the dc/dc converter, which is a crisp value. So the center of area algorithm (COA) is used to convert the fuzzy subset to duty ratio and the output D can be calculated by:

$$\Delta D = \frac{\sum_{k=1}^{n} \mu(\Delta D_k).\Delta D_k}{\sum_{k=1}^{n} \mu(\Delta D_k)}$$

Where, ΔD is the fuzzy controller output and *Dk* is the center of max–min composition at the output membership function. Fig-4 shows the configuration of fuzzy controller, which consists of input-output variables, Fuzzification, fuzzy Inference rule and Defuzzyfication [17-24].

Ref.	Authors	Publication year	MPPT technique used	Converter control technique	Advantage
7	Chee Wei Tan et al	2008	Perturb and Observe	Boost Converter	variable step-size is necessary to balance the competing aims of speed and accuracy
5	Ahmed K. Abdelsalam et al	2011	Perturb and Observe	Boost Converter	Adaptive tracking; second, no steady-state oscillations around the MPP; and lastly, no need for predefined system-dependent constants, hence provides a generic design core.
1	Radak Blange et al	2015	Perturb & Observe and Fuzzy Logic controller	dc-dc buck boost converter	FLC algorithms significantly improve the efficiency of MPPT and provides faster responses
2	Sankha Pallab Das et al	2015	Fuzzy Logic Based Controller	incremental conductance	fuzzy based IC MPPT controller is superior to conventional IC MPPT controller under rapidly changing weather conditions
3	Rahul Ranjan Jha et al	2016	Fuzzy Logic and ANFIS Controller	DC link voltage control	THD is decreased
4	Narendiran.S et al	2016	Fuzzy Logic Based Controller	Boost Converter	FLC is able to differ the PV operating voltage and seek the MPP
6	Satyajit Mohanty et al	2016	Perturb and Observe	Boost Converter	superior performance such as higher tracking speed and faster convergence towards the GP

Table 1: shows the configuration of fuzzy controller, which consists of input-output variables, Fuzzification, fuzzy Inference rule and Defuzzyfication

V. CONCLUSION

In this paper literature survey is conducted to analysis the use and advantages of various techniques or methods to obtain MPPT of solar PV system. Few of them are listed in table. This survey shows that amount the different techniques of obtaining MPPT fuzzy logic controllers along with boost converter gives an accuracy and fast response comparison with O& P algorithms. Other techniques are responsive but not as fast and accurate as it is. If an author uses FLC along with some modifications in its fuzzy rules with boost converter that will assures to give accurate and fast results to obtain result analysis of solar PV system. Fuzzy logic controller is therefore a human interface tool which works on the fundamental of permutation and combinations of rules which will be implemented on the PV modules to achieve the maximum outcome at the occurrence of maximum gain of solar radiations. This technique is very frequently and easily implemented on MPPT systems with boost converters as DC power is generated from Solar PV module. Maximum tracking of radiation angle and other parameters gives maximum accuracy and efficiency while implementing FLC.

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