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Review of MPPT Techniques under Partial Shading Condition

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Abstract This paper briefs about partial shading condition and different methods in literature which can be used under partial shading condition. This will be helpful for all who want the idea of partial shading condition and also get a fair idea about different techniques available and also update themselves with current happenings about MPPT.

Keywords: *Photo Voltaic(PV), Global Maximum Power Point(GMPP), Perturb and Observe(P&O), incremental Conductance(IC), Maximum Power Point Tracking(MPPT)*

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1. Introduction

Despite the concerns of solar power generation being costing more than other conventional methods of power generation. Commercialization of PV power systems in happening at a rapid pace throughout the world. MPP tracker decides the efficiency of any PV system. Research communities are attracted towards MPPT because of its simplicity yet complex under partial shading condition. Many algorithms have been developed in the past like P&O, IC but they cannot locate real MPP and get stuck with local MPP.. Many alterations to conventional and also new algorithms have been proposed to track the GMPP.

The content on MPPT has increased so much recently that it is difficult for any researcher to update himself with the literature unless precise summaries are not provided. In this paper only significant work has been cited and papers with minor modifications may not be included in reference list. Apologies are offered to authors.

1.1. Partial Shading

When one(or many) of the module in a solar panel comes under the effect of shading(which can be due to trees, neighboring buildings, clouds and many more circumstances can be there), its voltage drops, so, it works as a load instead of working as a generator [1]. A bypass diode is connected to ensure that particular shaded module doesn't get damaged. Voltage mismatch can occur in parallel connected modules. So, a blocking diode is connected for providing protection under such conditions.

Under Partial shading (when some part of module is under shading), bypass diode starts conducting. So, in P-V curve we do not get a unique maximum power point (MPP) but receive several local peaks and one MPP. Bypass diode can be uninstalled from the system to simplify the complications of so many peaks, but as a result power is reduced which significantly increase the cost of solar power generation. So, a bypass diode is not removed.

2. Conventional MPPT Techniques

2.1. Perturb & Observe(P&O)

Working Principle is provided in figure. Firstly, voltage and Current are sensed from which power is calculated, if the new power calculated is greater than previous power calculated then perturbation (Φ) is, provided which effects the power and the new power is retained. In next cycle this process is repeated and power never sticks to a point even if it is MPP. Perturbation can be fixed step and adaptive.

Authors in [2] has proposed a two-stage grid connected inverter; authors in [3] has proposed a novel MPPT control algorithm for a half bridge inverter; Authors in [4] designed the one-cycle controller for single-stage inverter. In [5], MPPT for soft- switching boost converter is proposed; authors in [6] propose a three-point weight comparison P&O method. An adaptive P&O scheme by authors of [7] has been proposed.

P&O has advantages of its simplicity. But because of limitations in conventional P&O, modifications are required. In [8] a two-mode modified P&O is proposed by authors, but tracking speed is reduced under few shading conditions; In [9] authors have proposed a new GMPP algorithm, in this P&O algorithm is embedded in Genetic Algorithm(GA) which creates a single algorithm, due to this number of sampling cycles is reduced. In [10], an alternative P&O using the comparison of two instantaneous power values is proposed, but it is a

complex method; Authors in [11] propose a voltage sweep method.

2.2. Incremental Conductance

We know that at MPP, the derivative of power with respect to voltage (dP/dV), is zero, i.e.,

$$dP/dV = d(VI)/dV = I + V*(dI/dV) = 0 \quad (1)$$

Equation (1), can be rearranged in the following form :

$$-1/V = dI/dV = \Delta I/\Delta V \quad (2)$$

where ΔI and ΔV are the increments of PV current and voltage, respectively. The rules for IC can be described as :

$$dI/dV = -1/V, \text{ at MPP} \quad (3.1)$$

$$dI/dV > -1/V, \text{ left of MPP} \quad (3.2)$$

$$dI/dV < -1/V, \text{ right of MPP} \quad (3.3)$$

Because the equation (3) is derived from P-V curve, the current cannot be used as the final output. Instead P-I curve is utilized. From the above set of equation (3) we can infer that perturbation occur in such a way that it moves towards MPP. When it reaches the MPP it stops there and again move only when a change in current is observed [12]. Authors in [13] proposes IC without battery. In works by authors [14,15], IC method is proposed by applying a two-mode scheme. In [16] authors proposes, a hybrid approach. In [17] an error is introduced with the help of instantaneous conductance and the incremental conductance.

Authors in [18] propose an improved IR method. In [19] authors, change the value of perturbation in original IC with respect to dP/dV. Authors in [20] propose a modified IC method. Authors of [21] suggest another adaptive IC. Authors of [22] proposed an alternate adaptive IC. But at both local peaks and global peak has dP / dV = 0 so IC can't differentiate among them, so modifications are required. Authors of [23] propose a neural network based modified IC algorithm. Authors of [24] implement a two-stage IC method; authors of [25] propsed a linear function to reach real MPP.

2.3. Hill Climbing (HC)

In the HC the operating point of the solar panels is updated by perturbing the duty cycle. Following equations summarize the HC operation:

$$d(k) = d(k) + \Phi, \text{ if } P(k) > P(k-1)$$
$$d(k) - \Phi, \text{ if } P(k) < P(k-1)$$

where d(k) is duty cycle and (Φ) is step-size(fixed or adaptive).

The HC method is also known as direct duty cycle technique. Authors of [26] utilize HC in buck converter battery charging PV system, in [27], the authors apply HC for fly back inverter; authors of [28] utilize HC on a high gain inverter. In [29], HC is applied in parallel connected MPPT system. Authors in [30] suggested three-level boosting MPPT control; authors of [31] proposed fully adaptive HC. The algorithm gets stuck at the local peaks, so, modifications are required. In [32], duty cycle sweep methodology has been proposed. Work by authors of [33] applies multiple input boost converter for micro-inverters based on modified HC.

3. Soft Computing Techniques

3.1. Fuzzy Logic Controller (FLC)

The work of the FLC is to reach MPP faster. There are four segments required for designing a fuzzy logic controller are: fuzzification, rule base, inference engine and defuzzification. Fuzzification is the process of changing the PV panel parameters into fuzzy sets utilizing a pre-determined fuzzy membership function. The rule base is a collection of rules which set the output for given values of input. The inference engine generates a logical decision based on the given inputs and fuzzy rule base. The defuzzifier then convert the fuzzy output back to actual value [34]. In [35], an FLC uses seven linguistic variables, in [36] and [37], significance is given to specific linguistic variables. Authors of [38] had provided array power variation and duty cycle as inputs to FLC. Work by authors of [39] suggests 3-input FLC. In [40], authors utilize the Fuzzy Cognitive Networks (FCN). In [41], FLC in conjunction with HC method is employed. In [42], an adaptive FLC is suggested; Authors of [43] suggests a single input fuzzy logic controller (SI-FLC).

During partial shading, all peaks (local and true MPP) shows same dP/dV characteristic. As a result, FLC too cannot track the true MPP. In [44] authors have proposed a modified FLC having three stages of operation; authors of [45], have proposed Fuzzy wavelet network.

3.2. Artificial Neural Network (ANN)

In ANN inputs are PV array parameters such as V_{oc} and I_{sc}. The output is a reference signal, which can be voltage, current or duty cycle. The neurons have to be trained. Once it is trained, ANN can be utilized as MPP estimator which will provide the reference value to the MPPT controller for controlling purposes. In [46], the ANN identifies the MPP using a gradient descent algorithm; in [47] authors have developed an ANN based P&O controller. Authors in [48] suggests a novel ANN technique; In [49] authors propose a three layer feed-forward ANN, in conjunction with FLC.

3.3. Particle Swarm Optimization (PSO)

PSO is a population-based search method, developed on the nature of bird flocks [50]. The algorithm has a number of particles where each particle can be a candidate solution Particles copy the success of nearby particles, and get to their own successes. The position of a particle is dependent on the best particle nearby, also best solution searched by the particle. Particle position, x_i, are found using:

$$x_i^{k+1} = x_i^k + v_i^{k+1} \quad (4)$$

Note that in (4), where the velocity component, v_i, represents the step size. The velocity is calculated by:

$$v_i^{k+1} = wv_i^k + c_1 r_1 \left\{P_{best\,i} - x_i^k\right\} + c_2 r_2 \left\{G_{best} - x_i^k\right\} \quad (5)$$

where, w is the inertia weight, c_1 and c_2 are the acceleration coefficients, r_1, r_2 belongs to U(0,1), $P_{best\ i}$ is the personal best position of particle i, and G_{best} is the nearby best position of particle i.

Authors in [51] utilizes the PSO algorithm to predict the MPP of PV system; Authors of [52,53] employs PSO to track the true MPP; Authors of [54] formulated an analytical expression and then the PSO is employed to track the MPP. In [55], current based PSO is suggested; by the authors of [56] an Adaptive Perceptive PSO (APPSO) have been proposed; in [57], the authors combine PSO with IC methods; by authors of [58] PSO algorithm have been employed in the direct control structure; improvement of [58] (suggested by the same authors) is available in [59].

4. Conclusion

Going by the amount of research work, it can be concluded that the MPPT is continuously being researched. This implies that improvements and new techniques are destined to happen in near future. In uniform isolations conditions there is no as such problems and only efficiency is being increased by improving or combining existing technique. But the real concern is for partial shading condition where still new techniques are being developed. In new techniques PSO shows the greatest viability. But research will continue to get the maximum power from PV system.

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