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A Review on Maximum Power Point Tracking (MPPT) Technique for PV Power Generation System

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Abstract— The growing concern on environmental issues caused by fossil fuels and, indeed, on the availability of such energy resources in a long-run basis have settled the ground for the spreading of the so-called green energy sources. Among them, photovoltaic energy stands out due to the possibility of turning practically any household into a micro power plant. One important aspect about this source of energy is that practical photovoltaic generators are equipped with maximum power point tracking (MPPT) systems. Currently, researchers are focused on developing MPPT algorithms for partial shaded panels. In this paper review is presented on the emerging topologies for PV applications that could be used in the generation of new smart inverters.

Keywords— *Photovoltaic Energy Generation, Maximum Power Point Tracking, Partial Shading, Inverters.*

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I. INTRODUCTION

The growing concern on environmental issues caused by fossil fuels and, indeed, on the availability of such energy resources in a long-run basis have settled the ground for the spreading of the so called green energy sources. Among them, photovoltaic (PV) energy stands out due to the possibility of turning practically any household into a micro power plant [1]. In views of that, countries such as Germany, China and Japan have taken the lead, powered either from environmental or commercial aims, of the movement of solar photovoltaic energy spreading [2].

In order to achieve an optimum efficiency of photovoltaic modules, it is necessary to use the MPPT control algorithm of the inverter circuit connected to the panel. The maximum power point tracking (MPPT) is an algorithm that's related to dc-dc power converters and inverters to trace maximum power point during energy conversion method [3]. Thus, the generated energy is maximized in this approach.

From the technical point of view, it is important to highlight that, in addition to PV panels, electronic converters, and others hardware components, PV based power generation systems should be equipped with Maximum Power Point Tracking (MPPT) controllers, otherwise they may not extract the maximum amount of energy from the panel. In fact, the lack of such controllers can even turn the effective power generation impracticable. In short, the amount of power harvested from a panel depends on the voltage in the terminal of the panel itself and this relationship varies with environmental variables such as solar radiance and temperature. Thus, MPPT controllers act searching in real time for the voltage which may lead to the Maximum Power Point (MPP) of the panel. It is worthwhile noticing that methods such as Perturb and Observe (P&O), Hill Climbing, Incremental Conductance, and plenty of others based in artificial intelligence have already been extensively tested, and are considered to be reliable for this purpose.

II. RELATED WORK

Syafaruddin et al [3] proposed a new MPPT system for a partially shaded PV array using an artificial neural network (ANN) and a fuzzy logic with a polar information controller. The triple feedforward NN is trained once for several partially shaded conditions to determine the overall MPP voltage.

Singh et al. [4] modelled the adaptive reference PSO based MPPT algorithm has resulted in considerable improvement in the power output from the PV module. The power output with adaptive reference PSO MPPT algorithm at the load terminal has improved from 3959 Watts to 4969 watts approximately.

Po-Chen Cheng et al. [5] presented a maximum power point tracking algorithm (MPPT) based on Fuzzy Logic Control (MPPT) asymmetric (MPPT) for photovoltaic systems (PV). Two design methods of the membership function (MF) are proposed that can improve the efficiency of the proposed asymmetric MPPT methods based on FLC.

K. L. Lian et al.[6] propose a hybrid method combining P & O and PSO methods. Initially, the P & O method is used to assign the nearest local maximum. From this moment on, the PSO method will be used to search for GMP. The advantage of using the proposed hybrid method is that the research space for the OSP is reduced and the time needed for convergence can be significantly improved. The excellent performance of the proposed hybrid method is verified by comparing the PSO method using an experimental configuration.

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Fernando M. de Oliveira et al. [7] introduced a single-phase photovoltaic (PV) system connected to the grid, based on a global MPPT (Maximum Power Point Tracking) technique, which is performed using the particle swarm optimization (PSO) method). The PSO technique is used to solve problems associated with mismatch phenomena, such as mismatching. Partial shading, where photovoltaic arrays are usually sent.

Karol Basiński et al. [8] proposed a method of tracking the maximum hybrid power point for the photovoltaic system using stochastic evolutionary research and a deterministic ascent climb algorithm. The proposed approach uses the Particle Swarm Optimizer (PSO) to solve a problem of dynamic optimization associated with the control activity in a photovoltaic system.

III. PV ARRAY SYSTEM

A. PV Panel Modeling

A photovoltaic energy conversion system consists of a photovoltaic module, a DC-DC device, an electric converter and ideally an energy storage device (ESS). The photovoltaic module consists of photovoltaic cells connected in series and in parallel to produce the specified nominal power. The cells are produced in a monocrystalline or polycrystalline structure, hence the purity of the semiconductor [3]. The polycrystalline cells, which provide a limited power of 13-14%, are cheaper than the monocrystalline cells, so the efficiency increases up to 20%. This circuit shown in Figure 1 comprises a photocurrent source, a diode and series and shunt resistors in the form of a single-diode or five-parameter model [8]. The calculations of the single diode model depend on the output current:

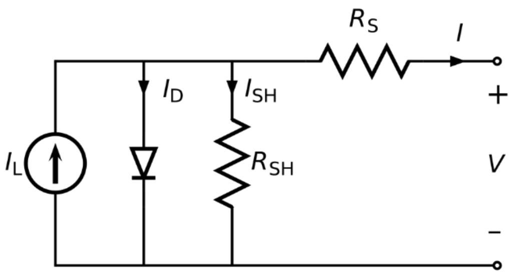


Figure 1: Single-Diode Electrical Equivalent of a PV Cell

$$I_o = I_{PV} - I_D(V) - I_{SH}(V) \tag{1}$$

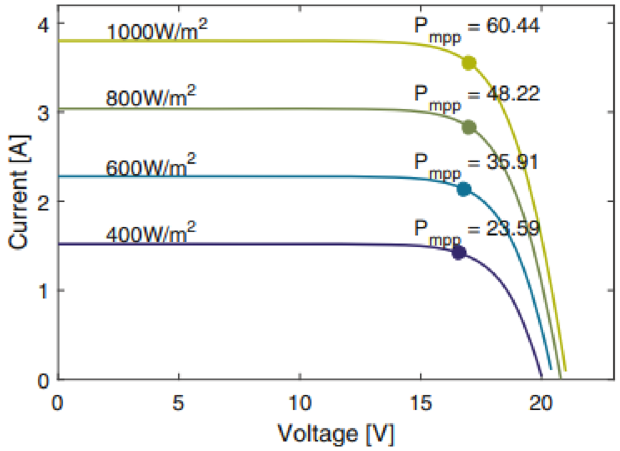
Where (V) shows the dependency of diode current and resistor current to the terminal voltage whereas they're independent from irradiation value.

I_D is current of the diode.

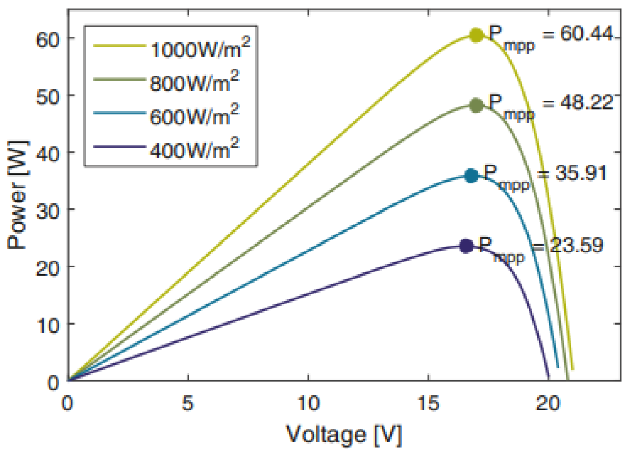
Considering the PV panel, for which the technical parameters are presented in Table 1, one may find out the I-V and P-V characteristic curves displayed in Fig. 2. The dots highlighted on the curves indicates either maximum power or current in which the maximum power is achieved. It is possible to notice from Figs. 2(b) and (d) that changes in the radiance and, more significantly, in the temperature which the panel is submitted shifts the voltage in which the maximum power point is achieved.

Table 1. Parameters of the Panel

Parameter	**Value**
Referential radiance	1000W/m^2
Referential temperature (T_{ref})	298.15 K (25 °C)
Short-circuit current (I_{sh})	3.8 A
Saturation current (I_D)	2.16×10^{-8} A
Number of cells	*36*



(a) I-V curve under constant temperature



(b) P-V curve under constant temperature

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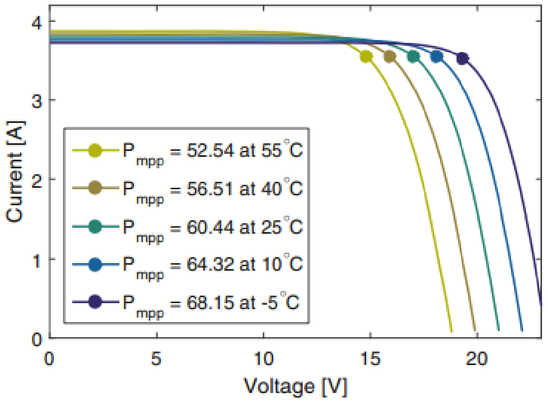
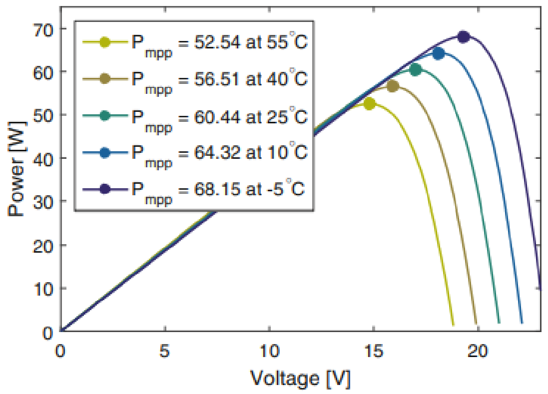


(c) I-V curve under constant radiance



(d) P-V curve under constant radiance

Figure 2: I-V and P-V curves of a PV panel

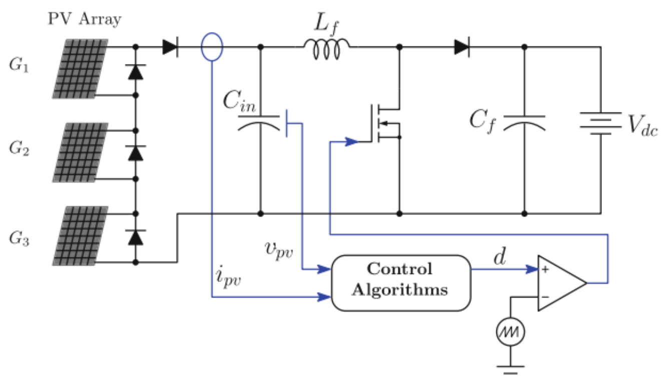


Figure 3: Reference Circuit Used for Simulations

Figure 3 represents the scenario considered for evaluation of the MPPT. Basically, an array of three series-connected PV panels is feeding a battery through a boost converter. It is important to notice that an input capacitor, C_{in}, is paralleled with the PV array just on the input of the converter. This capacitor plays an important role in the circuit because it is the storage element responsible to sustain the voltage across the PV array, v_{pv}. It is also important to notice that it is possible to change v_{pv} by means adjusting the duty cycle, d, of the converter.

B. *Characteristics of the PV Panel Under Partial Shading Condition*

PSC The partial shading occurs when an PV panel or an array of panels is submitted to non-homogeneous distribution of radiance. It means that, due to some external factors such as clouds, leaves or even birds and others animals covering part of the panels, the radiance received by part of the cells of a panel is different from the others. In this situation, either cells or even full panels turn into loads for those associated to them, which requires the use of bypass diodes for enhancing power generation [7]. Nonetheless, the result of having panels bypassed when under PSC is that of changing the characteristic of the P-V curve of the group, making room for multiple maximum points as illustrated in Fig. 3. It must be pointed out that the position of the maximum points and quantity of them depends on factors such as number of cells/panels shaded and unshaded, radiance and temperature. It is also important to realize that the peak value of each maximum not necessarily matches the others and that there is no straightforward rule to determine which maximum point is the greatest. Hence, MPPT algorithms can be trapped into local maxima rather than the global.

IV. MAXIMUM POWER POINT TRACKING METHODS

A. *Constant Voltage MPPT Method*

The constant voltage (CV) methodology is that the plainest MPPT algorithm that's based on regulation the array voltage to trace the MPP voltage V_{MPP}. The PV array voltage is adjusted around VMPP relating to the reference voltage V_{Ref} that's the regulated array voltage. it's supposed to match the V_{Ref} to V_{MPP} within the most correct adjustment. If this can be not the case, then the algorithm tries to accumulate the most adequate adjustment around the V_{MPP}. The CV algorithm assumes that the irradiance and temperature variations on the cells don't cause to significant changes on V_{MPP} and so, the V_{Ref} are often kept constant throughout the operation of algorithm [6-7].

The flow chart of the CV MPPT operation is illustrated in Fig. 4 wherever the PV array voltage is needed to be measured at the start of the algorithm. The algorithm doesn't involve the other input data. The measured array voltage V_{PV} is employed to line up the duty-cycle of dc-dc converter. Then the duty cycle is updated at every turn by comparing the array voltage to reference voltage. Once the array voltage is bigger than reference, the duty cycle is reduced within the next step or vice versa.

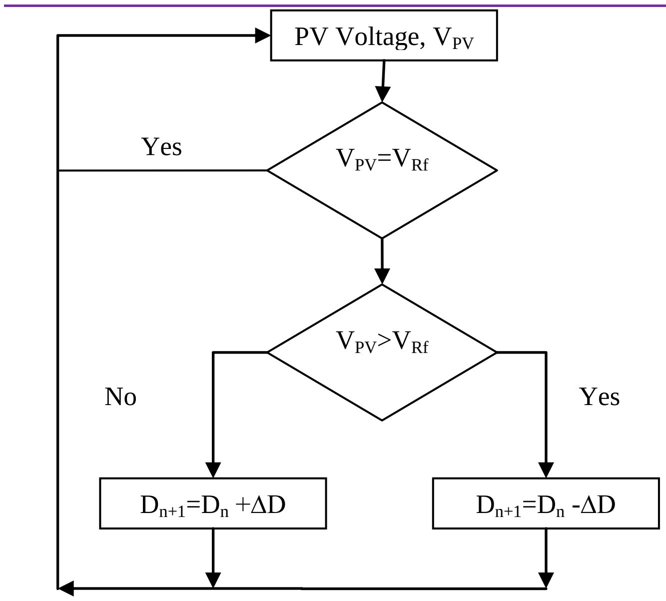


Figure 4: Flowchart of the Constant Voltage MPPT Method

It should be noted that CV method is more efficient comparing to regular P&O technique during the lower irradiance conditions. Therefore, it may be integrated other MPPT methods.

B. Perturb and Observe MPPT Algorithm

The P&O algorithm is one among the foremost widely used and studied technique attributable to its simplicity and sensible implementation. It perturbs the terminal voltage, as its name implies, and compares the particular PV power to previous value [7-8]. The algorithm decides to trace the MPP in one direction or within the other way by comparing the terminal voltage modification and output power increment. Just in case the output power is enhanced against the voltage change, the algorithm keeps on following the MPP in the same direction. Otherwise, it shifts the tracking direction.

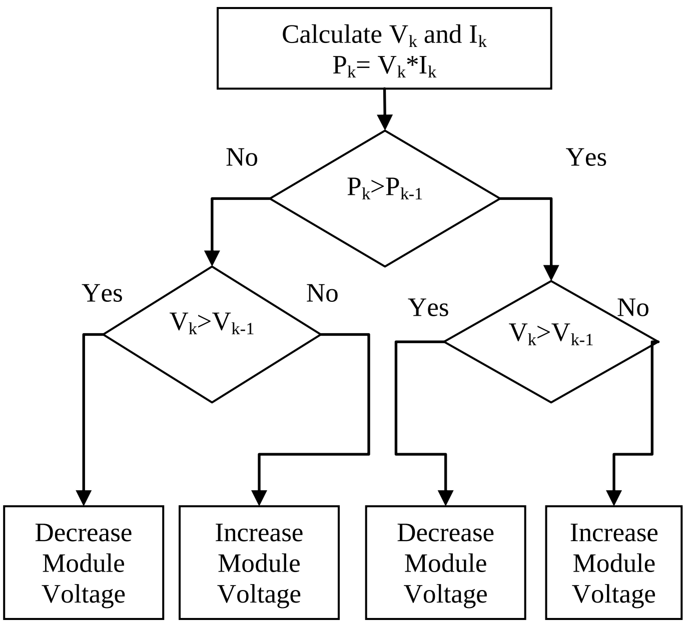


Figure 5: Flowchart of the P & O MPPT Method

C. Fuzzy Logic Control MPPT

The combining AI with regular MPPT algorithms may be a new trend of analysis and application in renewable energy sources. FLC is that the most generally researched artificial technique in MPPT applications since it provides higher performance comparing the traditional ways, and involves easier needs comparing to sophisticate neural or estimation algorithms. These benefits of FLC are integrated to overall system by combining it to existing MPPT controller that gives to acquire most power transfer to the loads.

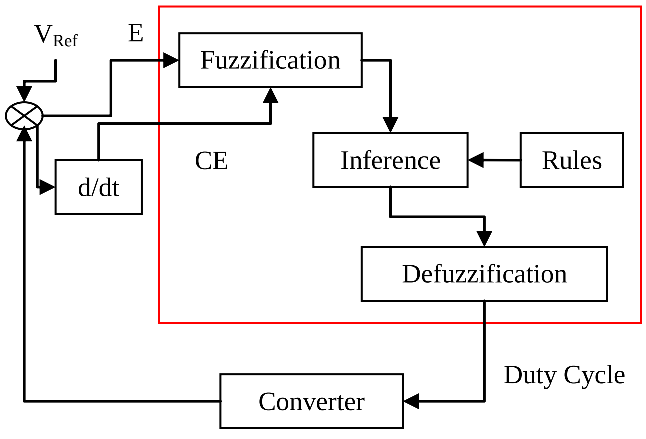


Figure 6: Block diagram of a FLC MPPT controller

The reference input of FLC is employed to see the error signal E and alter rate of the error CE wherever it's shown on the left-hand side of figure 6. The output of FLC is that the duty cycle that's applied to device wherever it's generated by the four sections of FLC. These sections are fuzzification wherever the numerical inputs are regenerate to lexical variables that are outlined by rule base and depended to membership functions.

The levels of membership functions are often increased to present higher resolution within the calculations. The analyzed inputs are weighted in keeping with several strategies, specifically modus ponens, Takagi-Sugeno or Mamdani, within the inference section, and so the lexical outputs of FLC are regenerate to numbers within the defuzzification section so as to come up with the duty cycle. The most widely used defuzzification technique is that the is that the centroid of area (COA) as a result of its eminent averaging properties and more accurate results.

D. Neural Network MPPT

The latest research work on computational MPPT techniques incorporate ANN considers that are significantly effective on wide problematic conditions, for example, incomplete shading. The ANN based MPPT gives fast and reliable estimations against rapidly differing irradiance and temperature parameters. An ANN is made out of a few layers in multilayer perceptron (MLP) structure as appeared in Fig. 7. In a model as appeared in figure, the neural-like association is contained neurons found in the lower portion of figure where the inputs are straightly weighted and summed in a function.

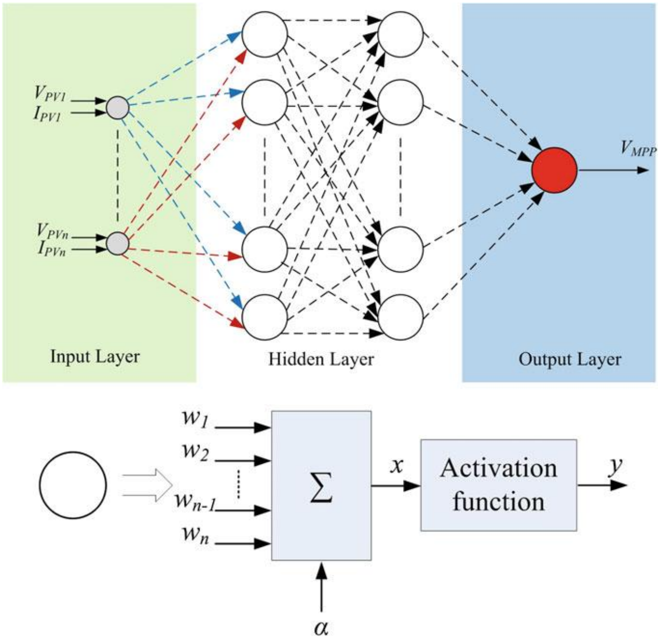


Figure 7: Block diagram of an ANN controlled MPPT algorithm

The sum of weighted input are transferred to a nonlinear function called activation function (AF), and lastly are sent to the following neurons. The definition of input function in AF is depicted as given:

$$x = \sum_{m=1}^{M} W_m X_m + b$$

where $x_1; x_2; \ldots; x_m$ are input signals, and $w_1; w_2; \ldots; w_m$ are the weights of each input signal.

The weights define the significance of each input data and the learning operation of the network is performed regarding to continuously varying weights. The training set of the ANN is composed with several different input and output data where they are voltage and current in inputs and MPP voltage at the output.

E. Particle Swarm Optimization MPPT Algorithm

Particle swarm optimization PSO is a novel swarm optimization algorithm that is firstly proposed by Kennedy as an evolutionary algorithm based on behavior of birds. PSO uses a set of particles that each one suggests a solution to the optimization problem. It is based on the success of all particles that emulates a population where the position of each particle depends to the agent position to detect the best solution P_{best} by using current particles in the population G. The position of any particle xi is adjusted by

$$x_i^{k=1} = x_i^k + v_i$$

where the velocity component vi represents the step size and is calculated by:

$$v_i^k = wv_i^k + c_1 r_1 (P_{best_i} - x_i^k) + c_2 r_2 (G - x_i^k)$$

where x is the inertial weight, c_1 and c_2 are the acceleration coefficients, r_1 and r_2 are random values that belong to the interval of [0, 1], P_{best_i} is the best position of particle i, and G is the best position in the entire population.

A typical MPPT method should be used to integrate PSO algorithm to controller.

Most widely used integration is based on hill-climbing or P&O algorithm to PSO. The flowchart of a PSO MPPT algorithm is depicted in Fig. 8. The operation given in flowchart can be analyzed in five steps that are initialization, fitness evaluation, updating the individual and global best value, updating the velocity and position of each particle, and convergence determination. In the first step, particles are randomly initialized in the distribution space, or are initialized on described grid nodes covering the search space.

Similarly, the initial velocity values are defined randomly. The fitness value of each particle is evaluated in the second step where the fitness evaluation is leaded to provide candidate solution to the objective function. The individual and global best fitness values are determined in the third step

where p_{best_i} and g_{best} are respectively determined. Then the positions are updated and replaced with better fitness values if they are found. The velocity and position of each particle are updated in the fourth step The last step of the flowchart checks the convergence criterion. If the criterion is met, the process is finished. Otherwise, the iteration number is increased and procedure returns to step 2.

The application of PSO MPPT in a PV system is depended to the matching definitions of both systems. The particle positions are used to define the duty cycle of dc converter, and the fitness value evaluation function stands for the output power of PV array. The success of algorithm is performed by increasing the number of particles that provides more accurate MPP tracking operation, even for shading problems. On the other hand, increased number of particles causes higher complexities. The particle range is typically chosen because the number of series connected cells in a PV array so as to get the foremost precise operation time.

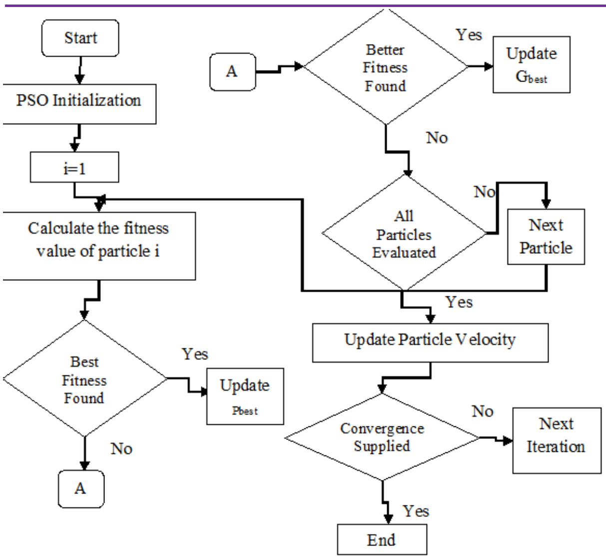


Figure 8: Block diagram of an PSO controlled MPPT algorithm

V. CONCLUSION

A wide type of numerical strategies as well as fuzzy logic, neural networks and different procedure ways are proposed. the foremost recent procedure algorithms as well as GAs, PSO algorithms, and are prominent topics in MPPT algorithms. The trade-off between typical MPPT ways and recent algorithms are associated with quality in algorithm and increased cost in application. However, improved potency and quick response results in extensive researches.

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