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Recent Nature Inspired Techniques for Solar Power Point Tracking Application

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Abstract- Photovoltaic (PV) array generates non-linear I-V and P-V characteristics. As a result, it is difficult to transfer the maximum power from source to load. The Maximum Power Point Tracking (MPPT) is used to track the Maximum Power Point (MPP) and extract the maximum power of solar PV. The disadvantages of conventional MPPT techniques are less MPP tracking speed, high MPP settling time and less accuracy. In order to overcome the disadvantages of conventional techniques, in this article different types of recent nature inspired optimization techniques are reviewed to track the MPP. In addition, the application of optimization technique based Maximum Power Point Tracking (MPPT) technique for standalone and grid connected application is explained in detail. The advantages of optimization techniques are highly reliable, better accuracy, less time to convergence and fast response.

Key-Words: - DC-DC conveter, Optimization methods, MPPT, optimum duty cycle, and PV system.

I. INTRODUCTION

Now a days, the demand of solar power generation keep on working and it is installing different areas such as rooftops, hilly areas, mountains and especially in the areas with low land cost. The major drawback of solar power generation is it high installation cost [1]. From article [2], the types of solar technologies are thin film, crystalline, nanotechnology and compound technology. In these four technologies, the thin film is the most popular technology and promises to reduce the PV cell cost by reducing the utilization of semiconductor material. The efficiency of thin film PV technology is 12 to 13% which is higher than the other three technologies.

In article [3], the P&O MPPT method is used to perturb the duty cycle of the CUK converter and HC is applied to perturb the voltage of solar PV. The advantages of HC and P&O MPPT techniques are a simple structure and takes less time to track the MPP. However, for achieving the good dynamic response of solar PV a large parameters perturbation is required. As a result, excessive power losses occur in the PV system. The IC is the most commonly used power point tracking technique which is applied at a steady state irradiation condition of solar PV. In this technique, the MPP tracking is done by comparing instantaneous and previous conductance of the solar PV [4].

The most efficient and recently developed MPPT technique is IR. In this method, the MPPT tracking speed and accuracy is high when compared to the IC method and it is more suitable for steady-state operating conditions of solar PV because of is an extended operating range. In the current control mode, a variable step size is considered in IR MPPT technique to achieve fast MPP tracking response. At the initial stage, a large step size is considered to operate the operating point of PV closer to the true MPP. After that, a small step size is considered to suppress the oscillations across MPP [5]. The RCC MPPT technique is used in both stand-alone and grid-connected applications to control the duty cycle of three-phase inverter. In the stand-alone PV system, the PV voltage ripples effect on grid voltages. In order to overcome this problem, the PV voltage ripples are utilized to control the operating point of solar PV. The modified RCC control with reduced component count MPPT technique is proposed in the article [6] to reduce the system complexity. Most of the existed MPPT techniques utilizes the signal sign which is generated from the MPPT block. But, in this modified RCC MPPT technique, the error signal sign and magnitude are considered for fast-tracking of MPP.

The tree falling, cloud and building shadows create a shading effect on the PV panel. As a result, the non-uniform irradiation falls on PV system is called as partial shading. The non-uniform irradiations distribution causes two local MPP's and one global MPP exist on nonlinear characteristics of solar PV. Due to the multiple local MPP's and the steady state oscillations across MPP, the conventional MPPT methods are not suitable to track MPP of solar PV at partial shading condition [7]. In order to overcome the drawbacks of conventional MPPT techniques, soft computing and optimization techniques are utilized in article [8] to extract the maximum power of solar PV.

The metaphor-metaheuristic algorithms are applied for solving all complex optimization problems with help of different figures which is called metaphor. The metaheuristic optimization algorithms are used in engineering, finance, and biomedical applications.

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In the past, the algorithms which consist of stochastic elements are called as heuristic algor
ithms which are used to find the solution of nonlinear systems by using trial and error method. Now in recent, from the literature survey [9], the heuristic algorithms are called meta-heuristic algorithms because of accuracy in problem-solving is very high. Due to the feature of global and random search, these techniques solve the high difficulty in optimization problems with less time. In the real world, most of the optimization problems are multidimensional, complex in constraints and nonlinear. Hence, in this article different metaheuristic MPPT techniques are discussed to obtain the MPP of solar PV. Those are Flower Pollination Algorithm (FPA) [10], Bat algorithm (BAT) [11], and Harmony Search (HS) [12].

II. FLOWER POLLINATION ALGORITHM BASED MPPT TECHNIQUE

FPA is inspired by the pollination progression of flower plants. The plant's process of transferring microscopic grains from the male cone (part of the male plant) to female cone (part of the female plant) is called a pollination process. Due to this pollination process, the conception and reproduction of plants increased quickly. The pollinating negotiators are birds, bats, and insects. Sometimes, the pollination exists in a closed flower called self-pollination. When the pollination occurs in a living organism which is having similar properties it produces a fusion progeny in the atmosphere [10].

FPA working behavior depends on four rules. The first one is the global pollination depends on living organs (biotic) and cross-pollination and the second rule is, the self-pollination and abiotic are taken as the district pollination. The third rule is the pollinator constancy is a reproduction process probability which is directly proportional to the similarity behavior of two flowers and the final one is the global and local pollination process continuously controlled by utilizing switch probability. The characteristic equations of local and global pollination are given in Eq's.1 and 2 and its levy distribution function is evaluated by using Eq.3. The main advantage of FPA is high searching accuracy when compared to other algorithms. In addition, the FPA is used to solve both constrained and unconstrained optimization problems such as material design and data clustering.

$$y_i^{k+1} = y_i^k + sl(\gamma)(g_{best} - y_i^k) \quad (1)$$

$$p_i^{k+1} = p_i^k + \varepsilon(p_a^k - p_b^k) \quad (2)$$

$$l(y) = \{\gamma\sqrt{\gamma}\sin(n\Pi/2)\}/\Pi.....0 < s_0 < s \quad (3)$$

Where $l(\gamma)$ is levy function, which is used to transfer the pollen to different flowers (y_i; i=1,2, 3...k). In addition, the strength of pollinator is increased by the use of levy function. The step size (s) of pollinator is controlled by utilizing a scaling factor. FromEq.3, Leavy is applicable for large step size ($0 \lll s_0 \ll s$) of pollinator and $\sqrt{\gamma}$ is the standard gamma function.

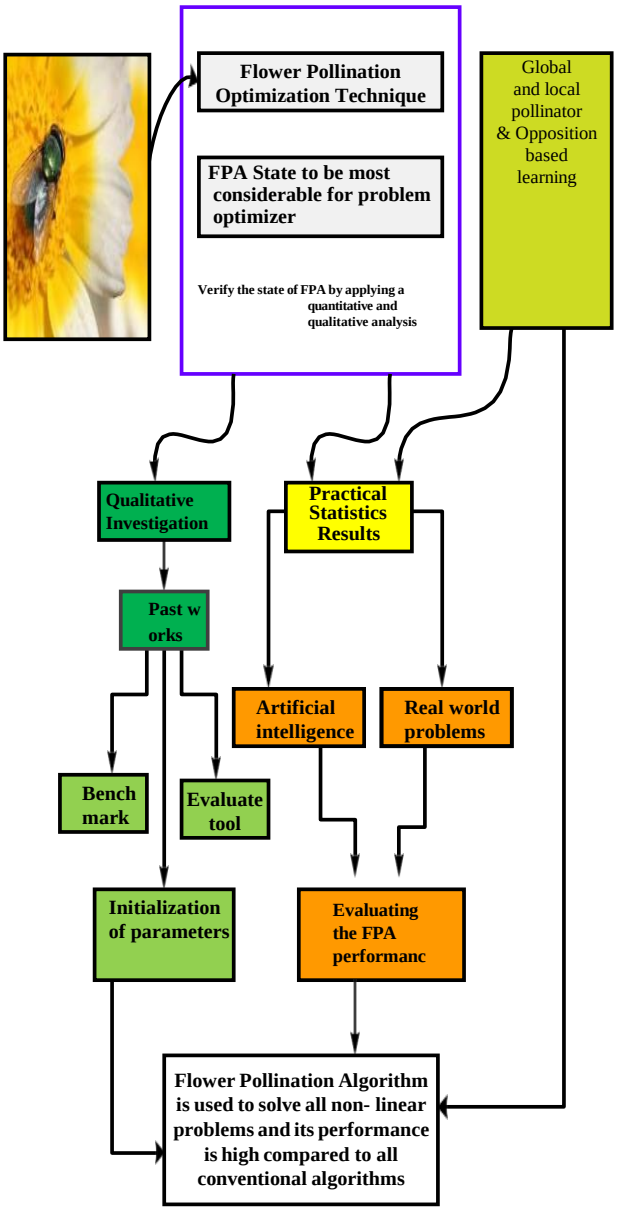


Fig.1. Evaluation of FPA performance by using qualitative and quantitative analysis

Many researchers have proposed FPA for different optimization applications but they haven't given a clear idea of FPA working behavior for different proposed works. In the article [10], the authors analyzed the qualitative and quantitative analysis of FPA for different industrial optimization problem conditions which is given in Fig.1. The qualitative analysis gives how the FPA parameters varying with respect to the optimization problem and in the quantitative analysis, the performance of FPA statically determined by solving a benchmark (CE2013) for real-world optimization problems. In addition, the behavior of FPA is analyzed by considering the global pollinator movement. From the conclusion, the contributor's states that, the FPA performance is high for different nonlinear problems compared to the other heuristic techniques.

In article [11] the researcher considered FPA is an MPPT technique to track MPP under non-uniform irradiation and temperature conditions.

The PV power is chosen as an objective function to extract the maximum power of solar PV. The duty values (x_1, x_2, x_3……x_k) are successfully evolved to track MPP by the use of self or cross-pollination. The initialization of parameters and its MPPT operation based on FPA is given in Fig.2 (a) and (b).

A. *Literature survey of FPA based MPPT Technique*

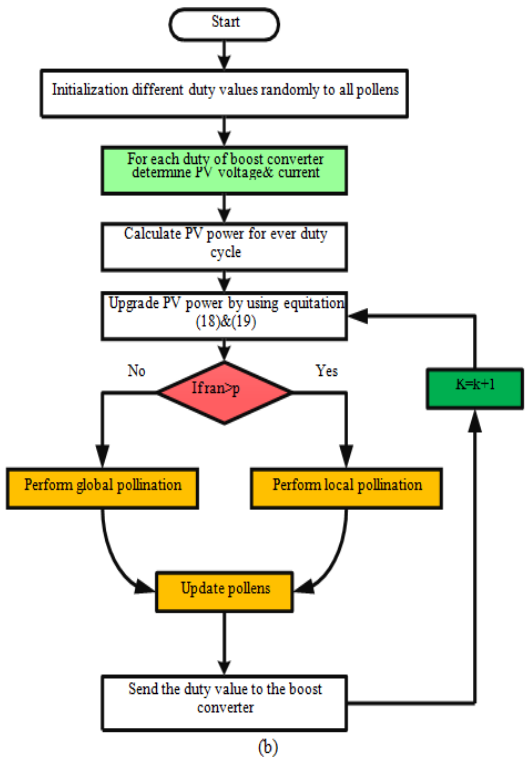
The partial shading effect exists in building integrated photovoltaic systems. To overcome this issue a global flower pollination algorithm is applied on the partially shaded panel to harvest the maximum green energy. In an article [12] the FPA utilized to improve the performance of the PV system at diverse atmospheric conditions and is compared with other MPPT techniques like HC, P&O, and PSO. From the comparison results, the authors claimed that the FPA track the MPP with high speed at different irradiation patterns. In addition, the FPA is used in the article [13] to adjust the duty of the SEPIC converter. In SEPIC converter, the coupled inductor technique is utilized to obtain high voltage gain of PV without varying duty. The FPA is used in PV fed SEPIC converter system to reduce the oscillation across MPP at a greater extent. The analysis of FPA based MPPT technique for different application is illustrated in Table.1.

Table I FPA based MPPT technique for different application.

S. No	Author	Article	MPPT method	Control Variable	Application	Results
1	Ahmed A. Zaki Diab	[12]	FPA	Duty cycle / dc-dc converter	Standalone or Grid-connected systems	The FPA based MPPT technique is compared with swarm intelligence based MPPT techniques in terms of accuracy and tracking time. From the simulation results, the authors concluded that the FPA technique is extracting maximum PV voltage compare to other techniques.
2	Farid Dwi Murdianto	[13]	FPA and P&O	Duty cycle /SEPIC converter	Standalone systems	The SEPIC converter power losses are reduced by using FPA and it is used to step up the PV voltage. The advantages of artificial intelligence FPA for PV with SEPIC converter are wide duty control and less settling time of MPP.
3	Tingting Pei	[14]	Modified FPA	Duty cycle /boost converter	Standalone systems	Sometimes the FPA fails to track MPP at diverse atmospheric conditions. In order to overcome this, a modified FPA is used as MPPT technique to control switch frequency and population fitness value.
4	Neeraj Priyadarshi	[15]	FPA with ANFIS	Voltage or current	Standalone systems	The hybrid ANFIS system tune the FPA to track MPP and PV modeling. The PV fed Luo converter is coupled with brushless dc motor for water pumping application.

- ✓ Initialize the parameters with a maximum number of iterations are 25 with poles=5.
- ✓ Selected duty must be in between ymin and ymax with switching probability is 0.8.
- ✓ Initialize randomly a pole of duty values to extract maximum power (Pbest).
- ✓ In forthcoming iterations, the Pbest is updated to
- ✓ determine gbest.
- ✓ Upgrade the local and global pollinations,
- ✓ Repeat the above process until achieving global PV power
- ✓ Re-initialize the species to obtain new MPP under partial shading condition.
- ✓ *Apply the trial and error method to evaluate the threshold limits of PV voltage and current.*

$$y_i^{k+1} = y_i^k + sl(g_{best} - y_i^k)$$
$$p_i^{k+1} = p_i^k + \varepsilon(p_a^k - p_b^k)$$



(b)

III. BAT ALGORITHM BASED MPPT TECHNIQUE

BAT is one of the recently developed metaheuristic technique and it works based on echolocation of bats. Echolocation is also called as bio-sonar which is used by several kinds of animals to emit the signals in an environment with constant frequency and it receives the other animals' signals which are returned from different objects. In this way, the animals utilize the echoes to identify the object. In the global search space, the long-range jump of echoes is avoided by controlling the pulse emission rate of bats. The advantages of BAT algorithm are high accuracy in universal optimization, good static and dynamic response. The convergence speed of BAT is high when the switching happens in between the stages of exploitation and exploration. In the article [16], the authors say that compared to PSO and GA, the BAT algorithm solves different nonlinear optimization problems with high efficiency. The main features of BAT algorithm are, they can sense the distance between food source and obstacle without visibility and their flying velocity, position and frequency are constant when they go for searching for food. In BAT algorithm there are N microbats and each microbat moves with a velocity (v^t) . The BAT frequency (f) and position (x^t) are derived as,

$$f_k = f_{\min} + \beta \Delta f \; ; \; \Delta f = f_{\max} - f_{\min} \tag{4}$$

$$v_i^{k+1} = v_i^k + f_k^t (x_k^t - x) \tag{5}$$

$$x_k^{t+1} = x_k^t + v_k^{t+1} \tag{6}$$

Where β is vector selected from random distribution and x_k is the best location which is determined after completion of all iterations (t). The selected random value of x_k is greater than the emission pulse rate(r^t) then the exploitation is considered for updating the position (x_{new}) of bats. From Eq.7, the new position of bats is derived as,

$$x_{new} = x_k^t + \varepsilon A^t \tag{7}$$

Where ε is random value which is selected from the gaussian distribution function and A^t is loudness parameter of the bat. The loudness and pulse rate of the ant is derived as,

$$A_k^{t+1} = \alpha A_k^t \tag{8}$$

$$r_k^{t+1} = r_i \; (1 - e^{-\gamma t}) \tag{9}$$

The BAT algorithm is used for MPP tracking by controlling the duty value of the boost converter. Hence, the optimization parameter is duty cycle. The flowchart of the BAT algorithm based MPPT technique is given in Fig.3. Initially, an N number of duty vectors are randomly initiated to all bats in a region [0,1].

The large number 'N' of bats are considered for accurate tracking MPP but the drawback is high convergence speed. So, a small number of bats considered for reducing speed but the disadvantage is less accuracy in MPP tracking. In order to overcome the above drawbacks, a medium number of bats are selected to reduce the convergence speed and improve the accuracy of MPP tracking. In the article [16], there are three different duty vectors considered for MPP tracking which is defined from the method of reflective impedance.

$$D_1 = \frac{\sqrt{\eta z_{\min}}}{\sqrt{R_{pv\_\max}} + \sqrt{\eta z_{\min}}} \tag{10}$$

$$D_2 = \frac{\sqrt{\eta z_{avg}}}{\sqrt{R_{pv\_STC}} + \sqrt{\eta z_{avg}}} \tag{11}$$

$$D_3 = \frac{\sqrt{\eta z_{\max}}}{\sqrt{R_{pv\_\max}} + \sqrt{\eta z_{\max}}} \tag{12}$$

k

Where η is the boost converter efficiency and z_{min}, z_{max} and z_{avg} are the boost converter loads. R_{pv_max} and R_{pv_min} are the maximum and minimum resistances which are reflected from the PV array. R_{pv_STC} is a standard test condition PV resistance. It is illustrated that; the above three duty cycles are the first iteration values. For updating the duty of boost converter and its corresponding bats positions are followed as,

$$v_k^t = w v_k^{t-1} + f_k * (d_{best}^t - d_k^{t-1}) \tag{13}$$

$$d_{new}^t = d_n^{t-1} + v_k^t \tag{14}$$

Where ω is the inertia factor which is used to limit the bat speed.

A. *Literature survey of BAT algorithm based MPPT Technique*

The BAT algorithm-based MPPT technique is used to compensate for the partially shaded PV power at different irradiation and temperature patterns conditions. The working behavior of this technique hinges on the ecological behavior of bats. The BAT algorithm consisting of a property of high accuracy in peak power point tracking.

In addition, the convergence speed of MPP tracking is less by applying automatic switching between exploration and exploitation. The Matlab/Simulink is used to design the BAT algorithm based MPPT. From the simulated results, the energy management at PV systems is done with high accuracy and it compared with P&O and PSO. The analysis of BAT algorithm based MPPT techniques is given in Table.10.

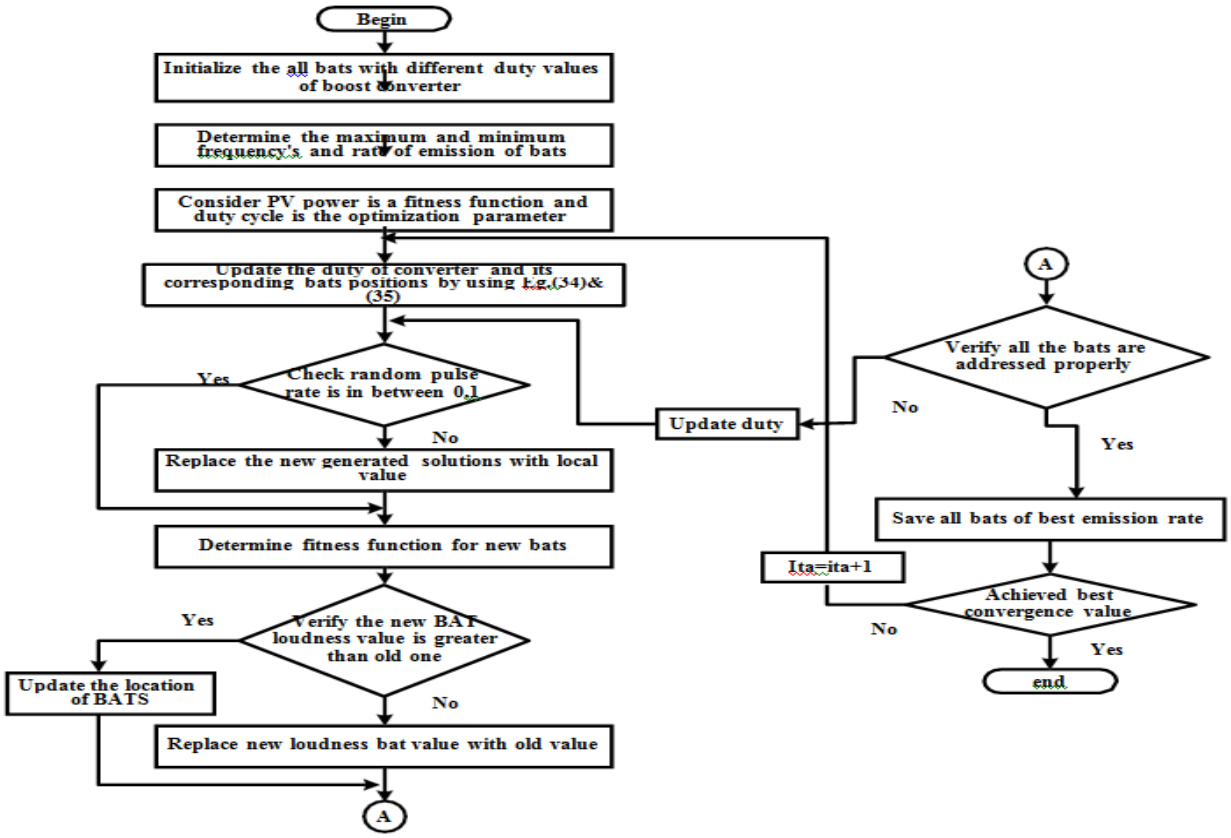


Fig.3. BAT algorithm based MPPT controller

Table.3. Analysis of BAT algorithm based MPPT technique for different applications

S. No	Author	Article	MPPT method	Control Variable	Application	Results
1	Karim Kaced and Cherif Larbes	[16]	BAT	Voltage or current /boost converter	Standalone systems	In authors explained BAT algorithm operation on boost converter duty cycle control application and it is compared with PSO and P&O in terms of the dynamic response of MPP and energy management across PV array.
2	Zhongqiang Wu and Danqi Yu	[17]	Improved BAT	Duty cycle /boost converter	Standalone systems	In this work, an improved BAT algorithm proposed for global MPP tracking. The adaptive weight is used to improve the global searching capability of the previous stage.
3	M. Kadir karagöz	[18]	Modified BAT with P&O	Duty cycle /boost converter	Standalone systems	Here, at first modified BAT MPPT technique used to measure the area of global MPP peak. After P&O applied for MPP tracking in global search space. In this, the hybrid MPP technique performance is good compared to standard classical MPPT techniques.
4	A. S. Oshaba and E. S. Ali	[19]	BAT with PI-controller	Duty cycle /dc-dc converter	Grid-connected systems	The PI controller is designed with MPP in order to monitor the PV system voltage and current parameters.

IV. HARMONY SEARCH MPPT TECHNIQUE

Harmony Search (HS) optimization technique is introduced by Z.W. Geem in the year 2001 and it is inspired by the observation aim of music to search for perfect formal of harmony. The harmony in music evaluates the optimality in the optimization process. The harmony searching process is continuously compared with the jazz musician creativeness process. In addition, the perfect harmony state is determined by utilizing aesthetic standard and a musician is trying to produce music with a perfect harmonic state. In the other hand, the optimal solution is obtained to the optimization problem by considering the given objectives and their constraints [20].

In the year 2001, the author Zong Woo utilized to the above three adoptions to quantitate the optimal search. The three adoptions act as pitch adjusting, randomization and harmony memory. From the article [21], the operation of harmony search method is similar to the GA and it is ensured that the best harmony is selected from the new memory. In order to utilize the harmony memory efficiently, a memory acceptance parameter (r_{eceipt}) is used. In HS, the memory acceptance parameter consists of less value then it takes a few numbers of harmonics from the memory for the optimization process. As a result, the convergence speed of the HS algorithm is reduced. Hence, a large value of memory acceptance is for achieving an optimal solution.

In real-world optimization problems, harmony search is playing a predominant role. The applications of harmony search optimization technique are medical sciences, manufacturing, control systems. In addition, the HS algorithm is used in power systems for fuel cost reduction and optimal dynamic economic dispatch and emission. The visual tracking in image processing has been done by HS algorithm.

From the above optimization applications basis, the author Nishanth Kumar used HS algorithm is used as an MPPT technique to track MPP under the partially shaded condition of solar PV. The basic harmonic search MPPT pseudo code is given in Fig.4. Where the objective function is the duty cycle and the fitness functions are considered as PV power.

Harmony Search pseudo code

Start

select objective pitch function is f(y); y= [y_1, y_2, y_3….,y_n]^T select real numbers for harmony search
initialize the pitch adjusting parameter (r_{pad})
select a particular value of harmony memory for random search
whereas *(k<number of iterations)*
update the harmonics by considering previous harmonics adjust the pitch value to achieve new harmonics
if (ran>raccp); *select the harmony in a random manner*
else if (ran>rpa); *vary the pitch within the limits*
or else
Select random pitch value for producing new harmony
else if
Select the best new location
end while
evaluate the present best harmony
end

Fig. 4. Pseudo code for harmony search

A. *Literature survey of HS based MPPT Technique*

The drawback of PV is partial shading which is eliminated by applying different MPPT methods. Those are classical and heuristic MPPT techniques. In this article, the heuristic HS algorithm applied to track MPP under nonuniform temperature conditions. In an article [22], the HS and GSA are proposed to tune the gain of PI controller which is given in Table.4. The PI controller controls the dc-link voltages of boost converter. The PV voltage and current parameters are sensed by using a sensor and which are given to the MPPT controller to generate the switching pulses. The hybrid HS and GSA based MPPT controller reduces the steady state oscillations across MPP and improves the dynamic response of the system.

Table.4. Analysis of HS algorithm based MPPT technique for different applications

S. No	Author	Article	MPPT method	Control Variable	Application	Results
1	Nishant Kumar,	[20]	NHS	Duty cycle /boost converter	Grid-connected systems	The normalized harmonic search is improved version of harmonic search. In the NHS, the searching capability is increased by utilizing a normal distribution factor.
2	Ikhlaq Hussain	[21]	Improved NHS	Duty cycle /boost converter	Standalone systems	The article explains the improved NHS algorithm for fast finding MPP under uniform and non-uniform conditions. Here, a single sensor used to sense the PV voltage and current. As a result, the cost of MPPT development is reduced. In addition, the computational complexity is also very less.
3	Attia and Mahmoud A	[22]	NHS and GSA with PI controller	Duty cycle /boost converter and inverter	Grid-connected systems	The dc-dc converter and inverter are interfaced with PV and its dynamic response is improved by utilizing a PI-controller. The harmony

V. CONCLUSION

The nature inspired optimization MPPT techniques performance is compared with hybrid MPPT techniques. From the above observation, it is concluded that, the harmony search algorithm is mainly depending on the quality of music. The stages involved in harmony search are one is a highly skilled musician required to idealizes the improvisation development. There are three possible adoptions are required to play peaceful and famous music (a series of pitches) based on its memory are play some known music and compose new music. Moreover, this algorithms gives high convergence speed, less MPP tracking and high efficiency.

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