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Cuckoo Search optimization algorithm for maximum power-point tracking of photo-voltaic systems

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Abstract - This paper presents a novel approach to determine the maximum power point (MPP) in Photovoltaic (PV) System using the Cuckoo Search (CS) algorithm. Microgrid at islanding mode is operated with renewable energy sources like Solar, Wind and non-renewable energy sources like Diesel generator and Battery which supply load to the system efficiently. With the change in load there is frequency deviation and controllers are required. Cuckoo search (CS) provides several advantages such as the process of tuning parameters is few with high efficiency beside fast convergence. Cuckoo search uses a random walk according to levy flight in searching process. MPPT by using cuckoo search is compared to other two methods, neural network method which needs training for data and the Perturb and Observe method. DC-DC converter is utilized with direct duty cycle control of PWM based controller.

***Key Words*:** PV; cuckoo search; MPPT; levy flight, DC-DC converter; Incremental Conductance.

1.INTRODUCTION

Electrical power has been the greatest demand of all times, irrespective of time. This leads to increase in demand, thus emphasizing to continuously meet the increases demand. Main grids meet the loads catering to optimal economic dispatch. A microgrid is a small-scale power grid that can operate independently or in conjunction with the area's main electrical grid. Any small scale localized station with its own power resources, generation and loads and definable boundaries qualifies as a microgrid. These grids being smaller in size are subjected to larger deviations. To overcome this, controllable sources are used to supply power, to balance out the increase in load demand or the reduction in power generation. However due to the delay in the output characteristics of controllable sources, the frequency oscillations are still present in the microgrid. Hence there is a necessity of designing proper controller parameters to controllable sources for optimal utilization of energy and to maintain minimum frequency deviations. In addition, microgrid if integrated with the mega grid will allow bulk

consumers to save on electricity costs by using their generators during high peak demand periods when power from the mega- grid becomes expensive thereby enhancing the efficiency, reliability and security of large and centralized plants [4]. Due to environmental problems and energy crises, there is an increase in the world's attention in the field of clean and renewable energy generation. Solar energy generation is the most promising renewable energy technologies [1]. In the last few decades, PV systems became common in grid-connected applications and had an important role in power generation in the new century [2]. PV system converts sun light to electricity directly when photons of the sun light hit on the PV array. The performance of solar PV system is powerfully relaying on the operating conditions like sun's geometric location, the ambient temperature and the irradiation levels of sun. PV system must be operated at maximum power to get more efficiency, so that the maximum power point (MPPT) tracking is utilized. In PV cell, P/V and P/I characteristics are non-linear relations, so there are several search methods are popularly used [2-4]. However, there are some problems when using these methods if there are rapid changes in irradiance and temperature. Moreover they cause huge power losses and inability to handle partial shading conditions. These problems can be handled by using artificial intelligence MPPT methods as artificial neural networks [5], Fuzzy logic controller [6], Genetic Algorithm [7], Differential Evaluation [8] and particle swarm optimization [9].

Recently many researches start on a new topology called cuckoo search optimization (CS), [10]. This method has a several advantages over conventional methods and over others methods [10].

In this paper, CS for MPPT of PV system is applied and compared with two methods, namely artificial neural network (ANN) and incremental conductance methods (IC).

2. PROBLEM FORMULATION

The proposed system, Fig. 1, comprises PV module feeding DC-DC converter and its duty ratio is controlled using PID controller to maintain maximum power operation of the PV. CS is used for MPPT with different ecological conditions represented by solar irradiation and cell temperature to ensure the capability of that method to track MPP of the module. The reference voltage calculated from MPPT algorithm tracked by CS is generated at each temperature and irradiation level, Vref. The difference between Vref and the measured output voltage from PV, Vpv, is calculated to produce the error voltage, Verror that is used to stimulate the PID controller. The output of PID controller is compared to saw-tooth waveform to produce the duty cycle for DC-DC converter. PID control parameters are tuned using PSO to obtain better performance [11].

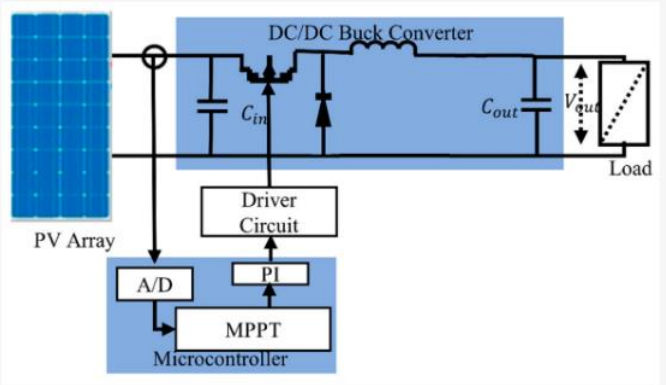


Figure 1: Overall system of PV with MPPT using CS.

The commonly used equivalent circuit of PV solar cell is illustrated in Fig. 2. The model composed of a light dependent current source in parallel with an equivalent diode structure [12]. The output of the current source is directly proportional to the light falling on the cell. The solar cell fails to maintain a fixed current as the load resistance increases. The output current reaches to zero when the load resistance becomes very large. The PV model included temperature dependence of photo current IL, the saturation current of the diode I0 and RS & Rp series and parallel resistances respectively as depicted in Figure.

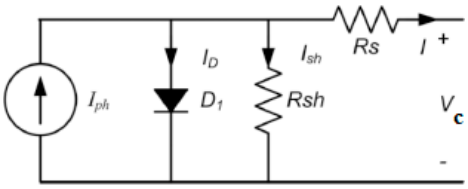
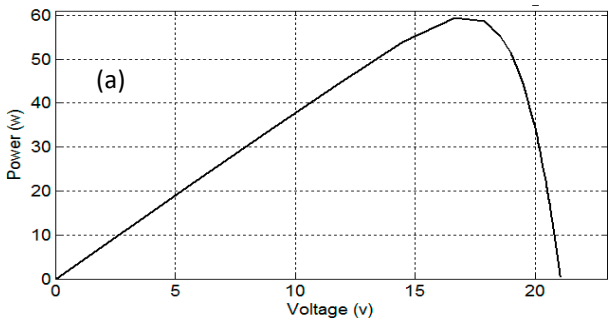


Figure 2: PV Array Mathematical model.

In this paper, the SunPower SPR 305 WHT-D panel will be used [13]. The specifications of the SunPower SPR 305 WHT-D PV panel at steady state conditions (STC) of 250c and 1000 W/m2 irradiation are shown in table1, [14].

Parameters	Values
Number of cell per Module	5
Number of parallel string	66
Voc	64.2 V
Vmpp	54.7 V
Impp	5.96 A



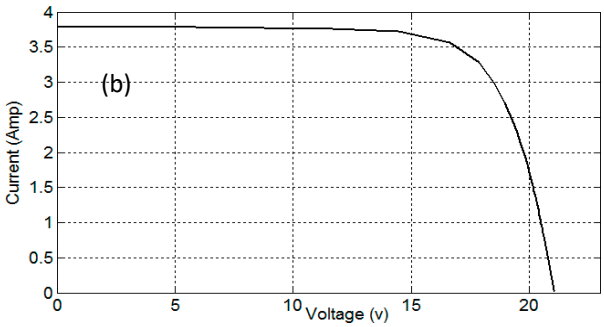


Figure. 3. PV characteristics at STC P-V characteristics & I-V characteristics.

3. DC-DC CONVERTER

A MPPT (Maximum power point tracker) is an electronic DC to DC converter that optimizes the match between the solar array and the utility grid or battery bank. This converter help to convert a higher voltage DC output from solar panels down to the lower voltage needed to charge to batteries. The main application and benefits of maximum power point (MPPT) in solar power system to increase the efficiency and power of solar cells and help to enable them to be competitive solution in an increasingly energy market. The topology of the boost power stage is depicted in Fig.4, [15].

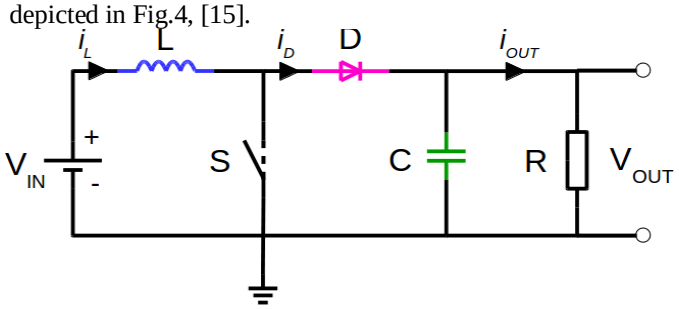


Figure.4 boost converter schematic

By operating a solar panel or array of panels without MPPT controller that can performed maximum power point tracking with lower efficiency or result in wastage of power, and which ultimately require installing more panels for some power requirement. Maximum power point controller is used in PV system to force the PV module operating at its maximum power point (MPP). In this case the PV module produces maximum power output. To overcome the disadvantages of higher initial installation costs and low energy conversion efficiency, MPPT controller used in PV system. The charge controller are connects at the output of solar panels and it compare the panels output to the battery voltage. It then figure out what is the best power that the panel can put out to charge the battery. It takes this and converts it to best voltage to get maximum amps into the battery. Most modern MPPT‟s are around 93-97% efficient in the conversion. The gain can vary widely depending weather, temperature, battery state of charge or load condition and other factors. We typically get a 20-45% power gain in winter and 10-15% power gain in summer. Grid connected system are more popular as the price of solar drops and electric rate go up. There is no battery only inverter available in grid ties system. The efficiency is around 94 to 97% for the MPPT conversion on those.

4. CUCKOO SEARCH

Cuckoo search (CS) algorithm (Yang & Deb, 2009) is a recently introduced meta-heuristic algorithm and is based on the obligate brood parasitic behavior of cuckoo species found in nature. The algorithm starts by dividing the search process into two phases which are a global and a local phase. In the global phase, the formation of new nests takes place while in the local phase, removal of a fraction of worst nests is followed. Here global phase refers to the exploration where as local phase corresponds to the exploitation. The global phase is governed by Lévy flight based random walks rather than simple Brownian or Gaussian walks (Pavlyukevich, 2007). The main reason for the use of Lévy flight is because of their heavy tail, infinite mean and variance, which helps in exploring the search space in a potentially more efficient way. The local phase is governed by selecting two random solutions from the search space with a certain probability, which controls the extent of exploitation. So overall there are three parameters which control the working capability of CS algorithm (Yang & Deb, 2009). The first parameter is the Lévy flight component which controls the exploration search equation, second is the exploitation or local search equation controlled by two random solutions and third is the probability which decides the extent of exploration and exploitation [16]. Brood parasitism is the behaviour of some cuckoo birds, *Tapera* are intelligent birds that imitates the host birds in shape and colour, that may led to increase reproduction probability. It is surprising and magnificence to look at the timing of the process of laying eggs for Tapera. Firstly, cuckoos female select a group of host species with similar nest sites and egg characteristics to their own, then choosing the best from these nests. Host birds could be fooled and accept foreign eggs but if these eggs discovered, they are dumped outside the nest or the nest completely destroyed and go to new area to build a new nest. Usually there are three kinds of brood parasitism namely intraspecific, cooperative and nest takeover [17].

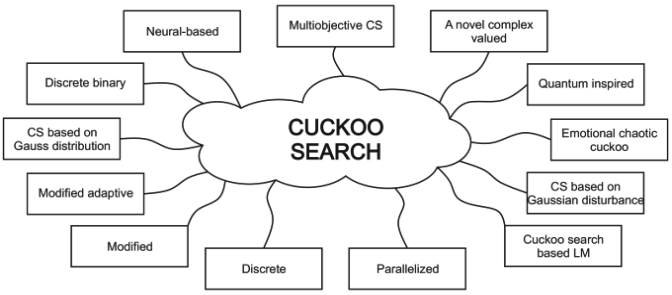


Figure 5: Variants of Cuckoo Search

5. MPPT Algorithm

Maximum power point tracking (MPPT) is an algorithm implemented in photovoltaic (PV) inverters to continuously adjust the impedance seen by the solar array to keep the PV system operating at, or close to, the peak power point of the PV panel under varying conditions, like changing solar irradiance, temperature, and load.

MPPT algorithms are necessary in PV applications because the MPP of a solar panel varies with the irradiation and temperature, so the use of MPPT algorithms is required in order to obtain the maximum power from a solar array. Among all the algorithms P & O and Inc Con algorithms are most common as they have the advantage of an easy implementation. In normal conditions the P-V curve has only one maximum point, so it is not a problem. However, if the PV array is partially shaded, there are multiple maxima in these curves.

Perturb and Observe (P&O) method P&O is an iterative method. It senses the panel operating voltage periodically and compares the PV output power with that of the previous power; the resulting change in power (ΔPPV) is measured. If ΔPPV is positive, the perturbation of the operating voltage should be in the same direction of the increment. However, if it is negative, the system operating point obtained moves away from the MPPT and the operating voltage should be in the opposite direction of the increment [Salas, 2006], perturbation should be reversed to move back towards the MPP. This process continues till dPPV/dVPV=0 regardless of the irradiance and PV module's terminal voltage.

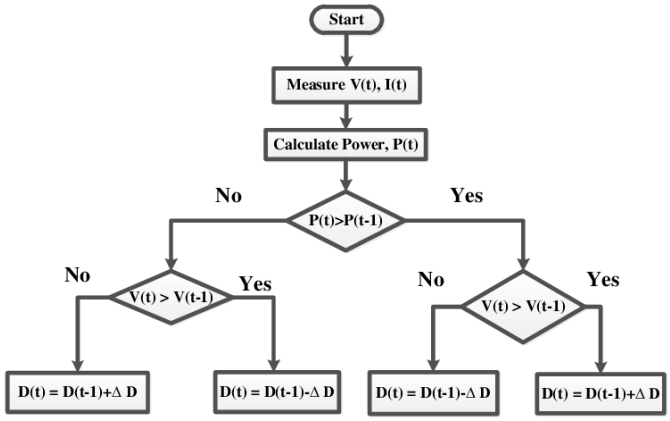


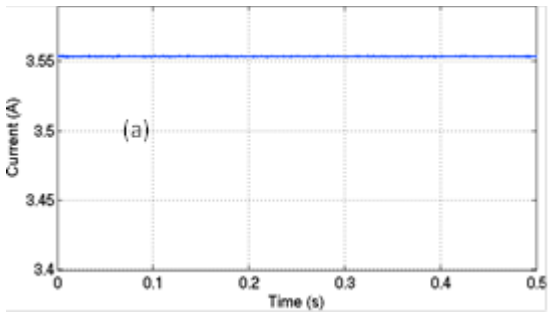
Figure 6: Flow chart of Perturb and Observe method

6. Simulation Results

Cuckoo Search

The simulation of the overall system depicted in Fig.1 is carried out using Matlab/Simulink. The calculated MPP of PV module at STC conditions is 60.4728 W. The Cuckoo search parameters are set as the following: number of iterations is N_{gen}=100, number of nests, which represent different solutions, are n=25 and the probability (discovery rate of alien eggs/solutions), is p_a=0.25.

The current, voltage and power of PV module using CS for MPPT are shown in Fig. 7.



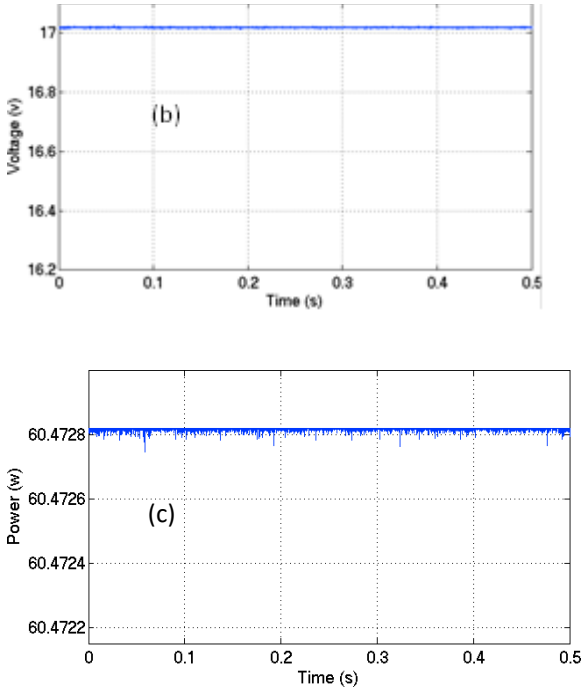


Figure 7:PV characteristics with MPPT using Cuckoo Search at STC current and voltage and power

MPPT Algorithms

To evaluate the performance of the proposed CS MPPT, the conventional incremental conductance method is also used for the same simulated conditions. This method used as a benchmark, we compare the results of cuckoo search not only with this method but also with a neural network MPPT at the same conditions.

The performance of the algorithms (Perturb and Observe and CS) are compared at STC, i.e. T=25 C and G=1000 W/m^2.

From Figure, the CS succeeds in tracking the power more than neural network and incremental conductance

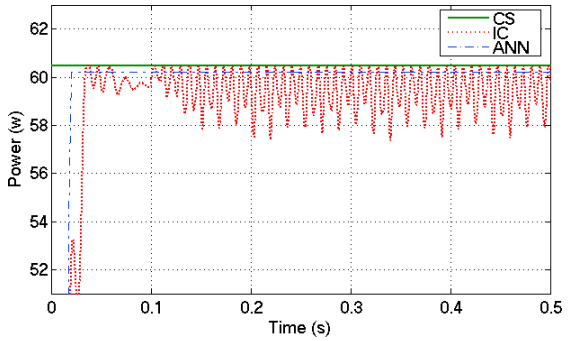


Figure 8: MPPT using Cuckoo Search and P&O,ANN

At steady state the IC reaches the MPP at time 0.1 s. For the time from t=0 to t= 0.1s, the simulation output power from PV has overshoot, after the time t = 0.1 s the waveforms vibrate up and down regularly.

ANN algorithm reaches the MPP at t= 0.021 s. for the time form t=0 to t=0.021s, the output power waveforms has overshoot, after this time the waveform oscillations are very smaller than IC and the tracked power is more accurate. CS reaches the MPP faster than NN and IC. From starting, the system almost stable and operating nearly at the MPP. CS keeps tracking the exact MPP, which is considered an extra feature that leads to higher MPPT efficiency tracked power which equal 60.4728 watt. As incremental conductance keeps on swinging around MPP as in Figure , this causes a losing energy. In case of neural energy, loss is smaller, but in CS, power loss near zero at steady state.

Step changes in irradiance with constant temperature

Irradiance and temperature increases in atypical sunny day, then decreases towards the evening. A set of irradiance steps are imposed on PV module.

Step response of cuckoo search, neural and incremental conductance is illustrated in Fig 10. From this Figure, CS continuously sticks to the MPP. The faster response for CS over the neural and incremental conductance is due to the larger step size according to the simplified le'vy flight used in code. It is shown from these results that CS has the ability to track MPP under step changes. Neural also has this ability with lower efficiency than cuckoo. IC method fall to track system under these changes so cuckoo is the best.

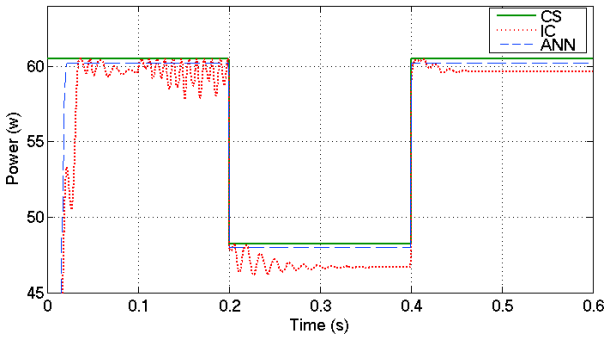


Figure 9. MPPT using CS, IC, ANN with irradiance step change

CONCLUSION

This paper presents MPPT algorithm employing Cuckoo search algorithm, depending on the cuckoo natural behaviour and simplified form of levy flight distribution. Results show that cuckoo is capable of tracking the MPP efficiently. It is confirmed by comparing results with other methods such namely, Perturb and Observe method. Cuckoo search gave maximum power greater than , Perturb and Observe . Moreover in cuckoo search method, no further fluctuations.

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