

Design and development of cuckoo search algorithm based maximum power point tracking system under complex operational conditions

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Abstract

The Electric power in modern time becomes one of the most important requirements in the world. There are several sources of electricity such as oil, nuclear power, waterfalls and some natural resources such as wind and solar energy. In the past decade, due to many restrictions on natural sources of energy input in pollution and environmental damage, scarcity of resources, there is a need to use renewable energy sources. In India, petroleum is the main and natural supplier of electric power. But the traditional energy crisis has forced the world to prepare for the solar system. The MPPT algorithm for PV systems based on the cuckoo search is discussed in detail in this research. Additionally, Cuckoo search (CS) has a number of advantages, including a simple tuning method with great efficiency as well as fast convergence. Random walks based on le'vy flying are used in Cuckoo search. The results reveal that CS can track MPP in a variety of operating circumstances with smaller power losses than the other two methods tested. CSA solar photovoltaic (PV) system is designed using three different methods for tracking the system's greatest power point (MPPT). MATLAB Simulink software is used to model and simulate the proposed system's performance. There are encouraging results under difficult operating conditions for a maximum-point tracking system based on cuckoo search algorithm. The model is viewed in two different shading patterns. Using the PV Array Block, we were able to create partial shade conditions by varying the input radiation values for each of the four serial-connection modules. The output of the optimization block is fed to the boost converter via its duty cycle output, which in turn feeds the panel. When partial shading is possible, the optimization of the cuckoo search method outperforms the conventional and soft computing-based algorithms.

Keywords: Solar Photovoltaic System, Maximum Power Point Tracking, Cuckoo Search Method, Boost Converter.

Introduction

There are two types of energy sources in the world: renewable sources of energy and non renewable energy sources. Renewable energy is the type of abundant energy from the earth. Wind energy, solar energy, geothermal energy and biomass are different types of renewable energy sources. These resources are inexhaustible. The known benefits of renewable energy sources are their own nature, rich in quantity and above all ecological, as opposed to non-renewable energy sources. Today, more research is being done to improve the technology for the efficient conversion of renewable energy sources into useful sources of electricity. Although the literal conversion efficiency of renewable energy sources is

lower than that of a conventional energy source, technology is being developed and improvised daily to improve its efficiency by over 90%. Now, for future energy consumption, renewable energy is essential. These sources are also widely used because of their ecological compatibility and unrestricted availability. Wind and solar energy are considered to superior to most of the renewable resources.

A. Scope of the Research

Global energy demand is constantly growing, and fossil fuel exploration is a priority. These oils are not durable but pollute the environment. The use of RE is affected by the scarcity of fossil fuels and the unfavorable climate because renewable energy is a large part of the energy obtained from solar. Energy from the sun is a natural source that its use will not damage and is becoming increasingly popular in order to reduce the demand for electricity in the traditional sector of power generation, the optimal use of these natural resources is essential for power generation. There are various methods of using a solar system with MPPT to generate electricity in practice. For maximum power transmission the constant flow technique is used. This technique should have some significant functions to improve stability and efficiency.

Introduced the model and simulation of an independent hybrid energy system that combines two renewable energy sources (solar energy) and two different MPPT techniques to generate the highest amount of energy produced of photovoltaic energy systems. In addition, perturb, observation, and incremental conductance MPPT methods were developed and validated to compare with existing photovoltaic systems. The simulation results show technology has advantages in high speed, the high energy efficiency of photovoltaic power generation system, and low oscillation. Compared to other methods, it has better efficiency and effectiveness.

B. Objectives

The objectives of this research paper are,

- Simulation of solar power system.
- Design and analysis of Cuckoo Search MPPT controller with Boost converter for PV system.
- Tracking of MPP of module using MPPT algorithm.
- Comparative study of MPP tracking using MPPT algorithm without MPPT technique.

Related Previous Research

Hamzeh et al. (2015) DC Micro-grid with photovoltaic. Controlled energy storage systems include batteries, super-capacitors, DC loads, electric motors, and energy management systems (EMS). The main goal is to manage the demand for goods effectively. Simple adaptive energy management control is achieved. In MATLAB / Simulink, the system is configured with different input conditions and loads, and the results are obtained. It is found from the obtained results that the DC Micro grid using the energy control system meets the requirements of all the conditions [10].

Lee et al. (2013) proposed MPPT monitoring technology for solar photovoltaic systems. This technique considers the thermal stress exerted by the semiconductor switch on the converter. As a result, losses are reduced, and overall efficiency is improved. The algorithm works better with climate change changing the environment [11].

Wei et al. (2016) MPPT algorithm developed for energy conversion systems. Combine the artificial neural network and the Q learning algorithm to obtain the maximum energy point. Follow the maximum power of the corresponding rotor speed. The results and experiments are provided to validate the ANN-based MPPT control algorithm designed for a 5MW wind-to-wind energy conversion system (WECS). The small chemical WECS Artificial neural networks require more training time [12].

Elbehairy et al. (2019) proposed an optimization study to apply a flower pollen optimization algorithm to obtain high yield power in an independent PV system under different shade conditions. The characteristic properties of photovoltaic systems can have multiple power peaks in shady conditions. This may result in the traditional method (MPPT) failure (MPPT) on the local surface without seeing the ground's surface. You can use artificial intelligence (AI) tools to get the highest energy points. The global MPPT method through the shadow measure is introduced. This method is based on simulating random changes through an AI flower pollination algorithm. A simulation was performed on a 100 kW photovoltaic power plant, and the results proved the superiority of this method [13].

Chitra et al. (2021) presents the demonstrating and recreation of sunlight based controlled DC engine speed controls utilizing MPPT and DSMC. DC engines have non-straight qualities like rubbing, kickback and the voltage produced by the photovoltaic generator are incredibly fluctuating because of the variety in luminance. These nonlinear attributes influence framework execution in low speed applications like compound preparing. Thusly, an effective nonlinear regulator is required when there are vulnerabilities on the heap side and voltage changes on the source side; DSMC can beat these issues. Fueled by a sunlight based board, the Boost converter is set to the P&O MPPT calculation for greatest force. The expanded voltage is provided to the DC engine through the exchanging circuit and the speed of the DC engine is constrained by DSMC strategy utilizing an upgraded voltage control technique. The chopper door beat is constrained by the discrete regulator against the real speed. The issue of non-linearity of the framework is settled with DSMC and its power is exhibited by presenting varieties in light. The proposed controlled framework utilizes sun based energy in a vigorous, proficient, straightforward and practical way [15].

Proposed Methodology

MPPT Algorithm

As mentioned earlier, because the MPP of a solar panel varies with radiation and temperature, the MPPT algorithm is helpful for PV applications, so it is required to use the MPPT algorithm to obtain the most significant power of needs of solar cells. Over the past decade, many ways to find MPP have been discovered and published. These technologies vary in many aspects, such as sensor requirements, complexity, cost, detection efficiency, speed, accurate tracking of light and temperature changes, the materials needed for the application or person information, etc. This technologies have the advantages of being easy to apply and some disadvantages, as shown later. Other technologies based on different concepts include fuzzy logic controls, ear networks, open or short-circle volumes, current probes, etc. Most of these methods produce at least locally, and some methods, such as open circular or short-circular circuits, give an average MPP

rather than an actual MPP. Under normal circumstances, the V-P curve has only one significant value, so this is not a problem. Though, if the PV curve is partially blurred, there will be multiple maxima in these curves.

P & O Algorithm

The P&O algorithm is also called "climbing," but both names refer to the same algorithm depending on its application. The correction includes disruption of the power cycle of the power converter and P&O and disruption of the working power of the DC link between the photovoltaic array and the power converter. On the upside, interrupting the power converter's circuit breaker means changing the DC link between the PV array and the power converter so that one technology refers to the same technology.

Algorithmic steps:

- Measure the two consecutive values of voltages and currents of solace PV.
- Calculate the powers $P(n)$ and $P(n-1)$.
- If the powers are increasing, then decrease the duty cycle.
- If the powers are decreasing, then increase the duty cycle.
- Go to step 1.

Boost Converter

The boost converter is a switch-mode DC-to-DC converter whose output voltage is greater than the input voltage. The Boost converter gets its name because the input voltage, like the boost transformer, is boosted to a level greater than the input voltage. According to the law on energy saving, input power must be equal to the output power (provided that there is no loss in the circuit)

Input power (P_{in}) = output power (P_{out})

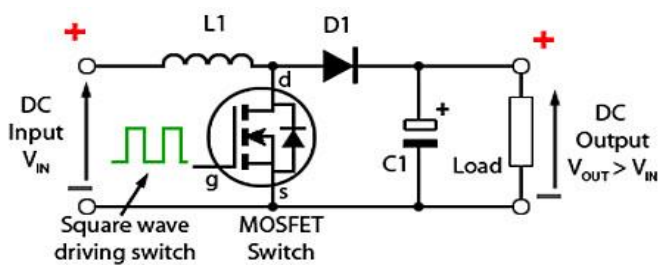


Fig. 1. Boost Converter Topology

The boost converter can operate in two modes:

Continuous conduction state where current flowing throughout the inductor is never zero, i.e., that the inductor is partly discharged before the start of the button cycle.

Discontinuous wire condition where the current flowing through the inductor is zero, i.e., the inductor is completely discharged at the end of the switching cycle.

Results

The results of the proposed model are measured after SPV system, at battery and load. All results are categorized in two cases;

- Results without MPPT System
- Results with MPPT System and Zero Irradiance after 0.52 Second

Results without MPPT System

PV System Results without MPPT System

The figure 3 showing the waveforms of voltage, current and power generated by SPV system. The value of generated voltage, current and power are 30.9 volt, 400 Amp. And 12.5 Kw respectively.

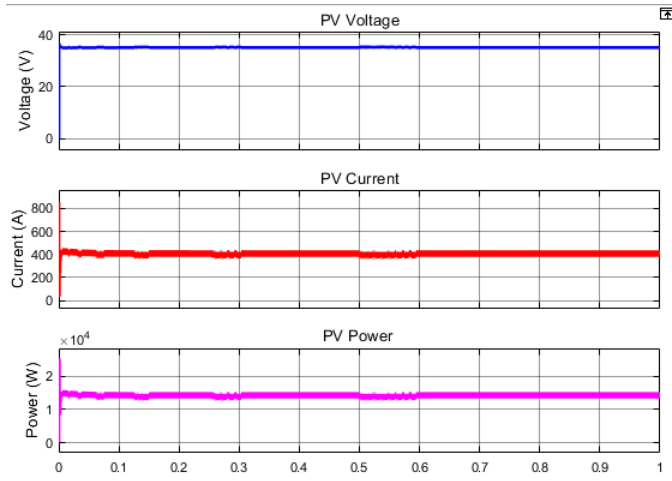


Fig. 2. Voltage, Current and Power of SPV System without MPPT System

Battery Results without MPPT System

The figure 4 showing the waveforms of voltage, current and state of charging (SOC) at battery system. The value of battery voltage and charging current are 53 volt, 190 Amp. respectively.

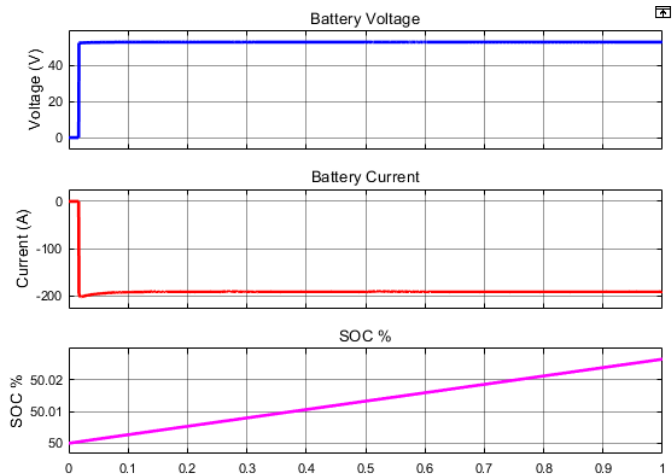


Fig. 3. Voltage, Current and SOC of Battery without MPPT System

Load Results without MPPT System

The figure 5 showing the waveforms of voltage and current measured at load side. The value of load voltage and current are 53 volt, 45 Amp. respectively.

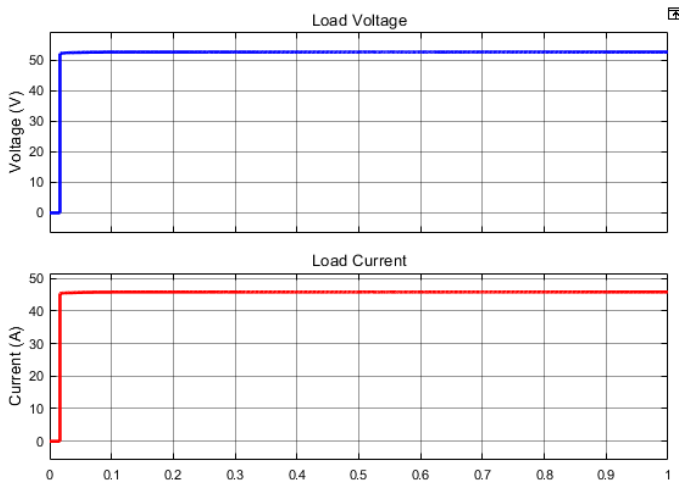


Fig. 4. Voltage and Current at Load without MPPT System

Results with P & O MPPT System

PV System Results with MPPT System and Zero Irradiance after 0.52 Second

The figure 6 showing the waveforms of voltage, current and power generated by SPV system with MPPT system and zero irradiance after 0.52 second. The value of generated voltage, current and power are 0 volt, 0 Amp. and 0 Kw respectively.

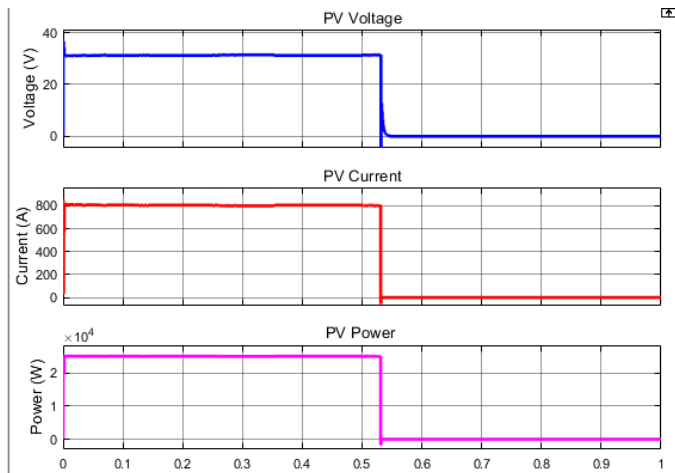


Fig. 5. Voltage, Current and Power of SPV System with MPPT System and Zero Irradiance after 0.52 Second

Battery Results with MPPT System and Zero Irradiance after 0.52 Second

The figure 7 showing the waveforms of voltage, current and state of charging (SOC) at battery system with MPPT system and zero irradiance after 0.52 second. The value of battery voltage and charging current are 51 volt, 43 Amp. respectively.

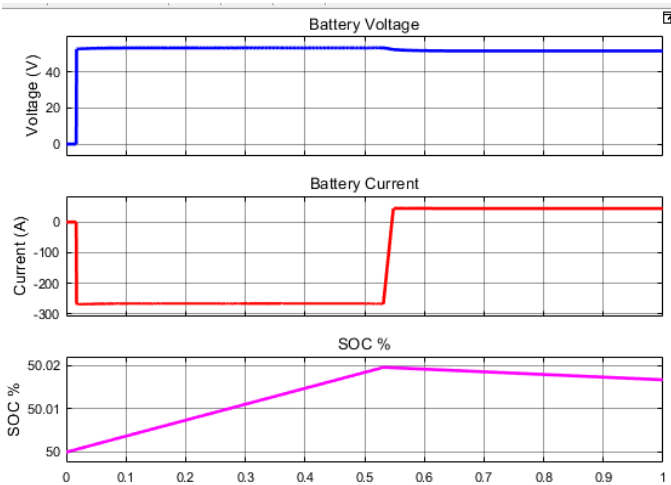


Fig. 6. Voltage, Current and SOC of Battery with MPPT System and Zero Irradiance after 0.52 Second

Load Results with MPPT Zero Irradiance after 0.52 Second

The figure 8 showing the waveforms of voltage and current measured at load side with MPPT system and continuous irradiance. The value of load voltage and current are 51 volt, 43 Amp. respectively.

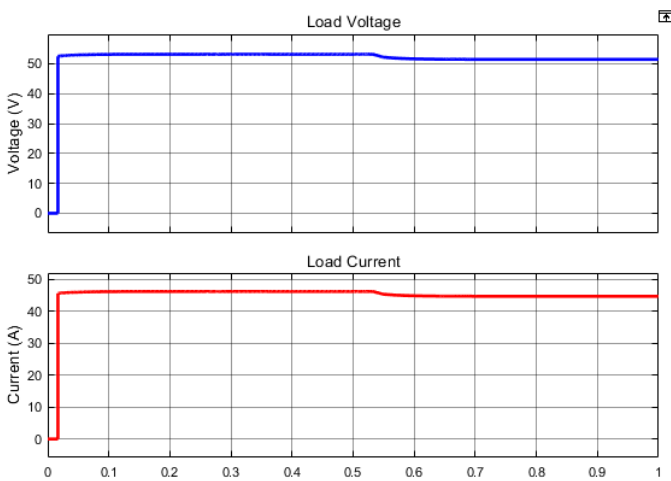


Fig. 7. Voltage and Current at Load with MPPT System and Zero Irradiance after 0.52 Second

Conclusion

The proposed simulation is responsible to obtain the maximum power from the solar photo voltaic system as well as control the charging of battery under over charging conditions.

In the simulation results obtained for the maximum power, perturb and observe MPPT algorithm. The overall performance analysis of a SPV system with MPPT improves the output of solar system under MATLAB/ SIMULINK software.

Table 1 showing the performance of proposed system with and without MPPT system. From the below table it is clear that the SPV output are higher with MPPT system as compare to without MPPT system.

Table 1: Comparison of Results Obtained

Sn.	Parameters	Results with MPPT	Results without MPPT
1	Voltage	30.9 V	30.9 V
2	Current	800 A	400 A
3	Power	25.1 KW	12.5 KW
4	Battery Voltage	53 V	53 V
5	Battery Charging Current	275.2 A	190 A

The maximum power can be tracked using P & O MPPT technique. Hence, the output will get the optimum power supply for the load and the solar design consists of photovoltaic (PV) panels, batteries as energy storage systems, dc-dc boost converter with resistive load. MPPT uses augmented conductivity technology applied to photovoltaic energy systems.

Single source renewable power generation can therefore meet load demands.

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