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Comparative Study of Maximum Power Point Tracking with a Modified DC-DC Converter

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Abstract:
Maximum power points are used to find the voltages and currents at which a photovoltaic (PV) panel should operate to obtain maximum power. In order to deliver highest power, an efficient DC DC converter and a reliable tracking algorithm are used. There is also the need to continuously find the maximum power under any environmental conditions at all times. This research is intended to study a comparative performance of maximum power point (MPP) which is presented under uniform irradiance condition. The algorithm employed is an improved cuckoo search algorithm and the DC DC Converter(switched mode power supply) has been modified by including a synchronous rectifier connected to a load, the performance of the system is validated using MATLAB/Simulink and practical implementation for this work. A comparison of the MATLAB Simulation with the practical implementation of MPP is presented using maximum power and percentage tracking efficiency as performance metric. From the MATLAB results obtained, maximum extracted power is 26.81W and the hardware implementation gives a maximum power of 28.71W. Tracking efficiency improves by 6.62%.The results shows the practical MPP gives a better maximum power, which consequently improves the Photovoltaic systems efficiency and conversely mitigates the power consumption and the cost of the system than the simulation result obtained in MATLAB.
Keywords: Cuckoo Search Algorithm, DC-DC Converter, MPP, Photovoltaic Cell

1. Introduction

Over the years, mankind has increasingly relied on electricity to address his daily needs. This need can be seen from minuscule gadgets that can be carried to monumental infrastructures that are required for our daily dealings in the 21st century and for the functioning of society as it is today. However, some of the power generation alternatives that produce electricity has increased carbon emission, which has negatively contributed to the increase in global warming. These concerns have led to the need for environmentally friendly power alternatives that are reduce carbon emission and are cheaper, and sustainable. To this end, several energy alternatives such as wind, Solar Photovoltaic (SPV), among others are considered. From this alternative, SPV has seen an exponential rate of adoption as it is comparatively efficient and cheap to other environmentally friendly energy alternatives [3]. According to [14], the PV system meets the energy friendly alternatives by converting sunlight into electricity, without polluting the environment. In addition, the PV alternative does not deplete earth's natural resources and can function with little to no maintenance. As a result of the variations in temperature and solar irradiance, the characteristic performance of the P-V curve shows a non-deterministic, time varying Maximum Power Point (MPP) problem. To increase the efficiency of a PV array, MPPT is used to maximize the energy conversion from photovoltaic module. [6]. A key part of the PV system is its ability to track the MPP of a PV array [14-12]. This key feature is used in conjunction with the power converter to always achieve maximum power from the PV arrays [4]. Moreover, MPP tracking are always embedded in all solar power electronic converters, which can be identified as some variation of controllers.

To determine the appropriate MPP, a tracker is generally installed between the PV systems and the load. The adopted configuration takes into account good performance and fast response with less fluctuation, since the non-deterministic characteristics of the panel's irradiance and temperature impacts the efficiency of the PV. As a result, maximum power cannot be obtained by the load by connecting it directly to the PV, there the need for a Balance of System (BOS). Conventionally, the BOS is essentially a DC-DC converter that adjusts the properties of the load [2-13]. The purpose of the DC-DC converter (step up/step down) is to ensure that maximum power is transmitted between the solar PV and the load [9]. In addition, it functions as an interface between the PV module and the load. To ensure the transfer of maximum power, the duty cycle is changed until the load impedance as observed from the source is varied and matched at the point of peak power with the source [7].

The developed converter is achieved by replacing the diode rectifier with an active rectifier MOSFET to reduce voltage drop at the output. In literature, the conversion efficiency of active or synchronous rectification is increased by mitigating the voltage drop in circuit elements and power losses in switches [12]. The aim of active rectifiers is to mitigate forward voltage drop across the switches. In addition, it aims to achieve zero resistance against current flow to make the switches function like ideal switches. To mitigate the voltage drop as much as possible, integrated circuits fabricated with CMOS technology are been utilized [1].

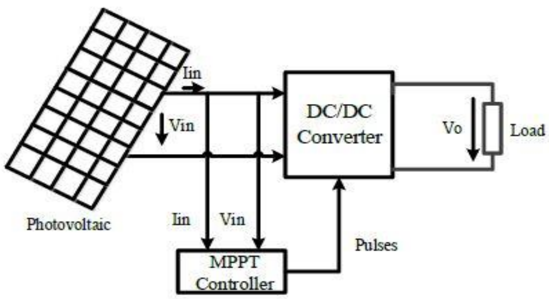

Fig 1 Block Diagram of MPPT System [8]

2. RESEARCH METHODOLOGY

The methodology adopted in this research is described as follows:

2.1 Development of ICSA - Based MPPT

Figure 1 depicts a PV system that embedded with an MPPT. This system consists of PV panels, modified DC-DC converter to ensure that maximum power is transferred from the PV panels to the load [9]. Here, the PV array is interfaced to the load through the boost converter [11].

2.2 Initialization of CSA Parameters

The initial aspects of the algorithm begins by assigning maximum and minimum values of the coefficient parameters, stepmax, stepmin, which are further denoted as d, N, respectively and the maximum number of iterations [5].

2.3 Sense Current and Voltage of the PV Array

The algorithm takes into account the output of the duty cycle to sense the output of the voltage and current respectively of the PV array through the sensors.

2.4 Measure Output Power from Modified DC-DC Boost Converter

The Matlab Simulink implementation of modified boost converter is as shown in figure 5, this modification will reduce voltage drop and increase output power. Evaluation of output power corresponds to the fitness of all agents.

2.5 Update Position of Search Agent

The update of search agents is calculated by performing the Levy flight. In addition, sets of new samples are discovered and updated.

2.6 Add Current Nest Position to Tabu

Update the tabu list by adding all except the best solution to the list. This modification in improved cuckoo search tracking algorithm helps in tracking the maximum power point and reduce time loss.

2.7 In order to implement Practical MPPT techniques the following steps were followed

3. RESULTS AND DISCUSSION

In this section, simulations of the PV modules are presented alongside the modified DC-DC converter. The parameters presented in Table 1 and Table 2 are used to carry out the simulations presented in this work. The operating condition of the PV system under which this MATLAB/Simulink model was developed was considered to be uniform. Figure 2 shows the PV system of single PV module. A single mono-crystalline silicon solar module that was utilized in this experiment consisted of a single solar cell,

Table 1: PV PARAMETERS FOR SINGLE MODULE

Item	Value
Maximum Power (Pmax)	30W
Open Circuit Voltage (Voc)	22 V
Short Circuit Current (Isc)	1.95A
Maximum Power Voltage (Vmp)	18 V
Maximum Power Current (Imp)	1.66A

Table 2: PARAMETERS OF BOOST CONVERTER

Item	Value
Boost Inductor, L(mH)	0.15
Input Capacitor, Cin (μF)	200
Smoothing Capacitor, C(μF)	90
Input Voltage, Vin (V)	(0−12)
Output Voltage, Vout(V)	24
Switching Frequency, fs (KHZ)	50

Fig 2: Shows the Practical Implementation of MPPT

The PV module receives a uniform irradiance of $1000w/m^2$ at varying temperature condition to give a maximum output power of 28.71W.

Table 3: Results of the Practical Implementation of MPPT on 13/09/2022 in Kaduna State, Nigeria

Time	Tracked Power(W)
11:00am	17.74W
12:00pm	20.50W
01:00pm	**28.71W**
02:00pm	27.37W
03:00pm	22.76W

A Typical MPP model in MATLAB Simulink is shown in Figure 3 it includes the PV module which is a constant DC source, the DC DC converter and the MPPT algorithm, the PV module receives a uniform irradiance of 1000w/m^2 at a constant temperature of 25^{0}C to give a Maximum output power of 26.81W.

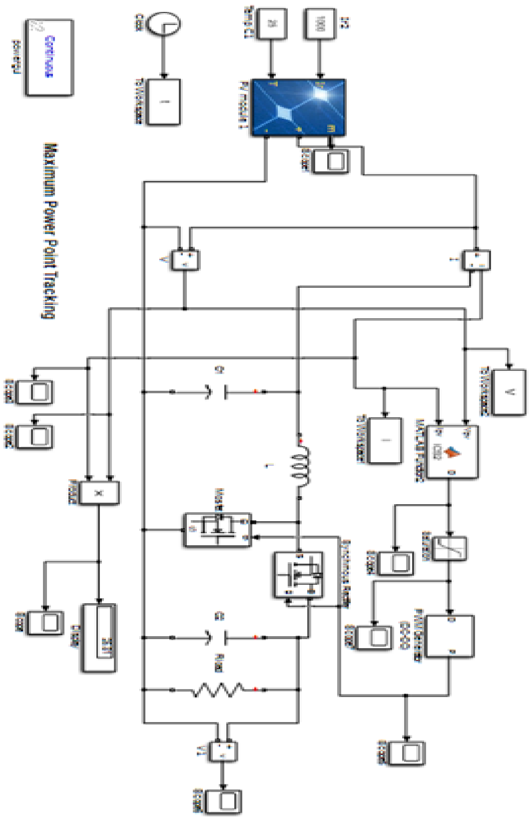

Fig 3: Matlab simulation of MPPT under Uniform Irradiance Condition

The Graph of Power Vs Time as shown in Figure 4. A maximum Power of 26.81Watts was extracted at a tracking time of 0.02seconds was achieved during the simulation process

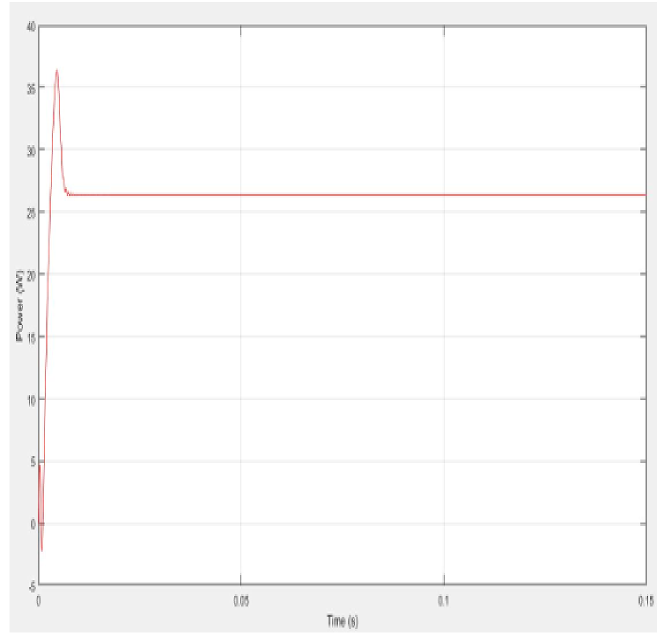

Fig 4: Power curve of Simulated MPPT under uniform irradiance condition

SUMMARY OF MPP PERFORMANCE

A summary of Maximum Power and Tracking efficiencies were presented below.

$$Percentage\,Tracking\ Efficiency = \frac{Maximum\,tracking\ power}{Maximum\ power\ of\ the\ PV\ array} * 100\%$$

Percentage Tracking Efficiency= $\frac{26.81}{30}$ X 100% = 89.75% .

Percentage Tracking Efficiency = $\frac{28.71}{30}$ X 100% = 95.7%.

Table 4: Performance comparison under uniform irradiance condition

Tracking techniques	**DC-DC Converter**	**Method**	**Maximum Power(W)**	**Tracking Efficiency (%)**
ICSA	Modified Boost	Simulation	26.81W	89.75%
ISCA	Modified Boost	Practical Implementation	28.71W	95.7%

The uncertainties were as a result of several factors among which are temperature, irradiance and electrical PV parameters and components tested by the manufacturer under standard test condition (STC).

Table 5: Uncertainty Table

Uncertainty Component	Practical MPP	MATLAB Simulation
Temperature	The test was performed under variable temperature conditions. Temperature has effect on the performance of PV module.	A Constant temperature of 25^0Cwas used during the simulation process as high temperature negatively affects the performance of PV Panels.
Irradiance	Under Uniform irradiance conditions, the PV Panel exhibits only one peak value true value(Maximum power), the higher the irradiance the greater the output current and as a result the greater the power generated..	A uniform irradiance of 1000w/m^2 was tested during the simulation process.
Electrical Components	Electrical Components used such as the input and filtering capacitors, inductor and switching transistor might not exhibits true values calculated, this is because manufactured components can have absolute or relative error during production process. Example a 50µF capacitor can be slightly lower or higher and as such might have effect on the true maximum power.	Electrical Components used such as the capacitor, inductors and switching transistor shows true value calculated. Current and voltage sensors used differ from the Practical implementation.

4. CONCLUSION

Presented in this paper is an MPPT algorithm that is implemented on a modified Boost converter and its simulated and hardware implementation are compared. We modified the boost converter by adding a synchronous rectifier to mitigate the loss of power. Furthermore, the tabu list was embedded into the CSA MPPT algorithm to mitigate tracking time . The Hardware implementation and simulation were developed under uniform irradiance condition, from the MATLAB results obtained, maximum extracted power is 26.81W and the practical hardware implementation gives a maximum power of 28.71W. Conversion efficiency improves by 6.62% .The result shows that the practical MPPT gives a better maximum power, which consequently improves the PV systems efficiency, and reduces both the costs of the system and power than the simulation result in MATLAB.

Recommendations for Further Work

I. The application can be extended to Grid Connected PV system by adding DC-AC Inverter.

II. The Modified converter can be made to operate in Boost-Buck Mode of operation.

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