



Development of Maximum Power Point Tracking of Photovoltaic System with a Modified Dc-Dc Boost Converter and an Improved Tracking Algorithm

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ABSTRACT

This research presents a maximum power point tracking of photovoltaic system with a modified dc-dc boost converter using an improved tracking algorithm. Many research works on MPPT were carried out using different techniques but most of these techniques suffer from inefficient selection of DC-DC converters and inefficiencies of the used tracking algorithms. To improve the performance of PV system, a modified DC-DC boost converter and an improved tracking algorithm (cuckoo search algorithm) are presented. In this work a method for tracking the global MPP is presented, which is based on controlling a DC-DC boost converter connected at the PV array output. The tracking algorithm employed (Improved Cuckoo Search Algorithm) was developed in a low cost Microcontroller and its performance was tested under different test conditions. The performance of MPPT controlled DC-DC boost converter are validated by simulation in SIMULINK-MATLAB program. While the performance of the developed modified scheme was evaluated using maximum power, tracking time and percentage tracking efficiency as performance metrics. All simulations were carried out in MATLAB 2018b.

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INTRODUCTION

The growing energy demand coupled with the possibility of reduced supply of conventional fuels, along with growing concerns about environmental preservation has driven research and development of alternative energy sources that are cleaner renewable and produce little environmental impact [10]. Solar energy is one of the primary sources of clean, abundant and inexhaustible energy that not only provides alternative energy resources but also improves environmental pollution. The most immediate and technologically attractive use of solar energy is through photovoltaic conversion. The physics of the PV cell (also called solar cell) is very similar to the classical P-N junction diode. These PV cell converts the sunlight directly into direct current (DC) electricity by the photovoltaic effect [15]. Tracking the maximum power point (MPP) of a photovoltaic (PV) array is usually an essential

part of a System. Maximum Power Point tracking (MPPT) methods have been developed and implemented, that it has become difficult to adequately determine which method newly proposed or existing is most appropriate for a given PV system [5]. Nevertheless, utilizing PV systems as an alternative source of energy requires a substantial amount of investment. In order to reduce the overall cost of PV systems, extraction of the maximum power from a solar cell turns out to be a vital consideration for optimal system design. Efficiency of a PV system is mainly influenced by three factors;

- (i) The efficiency of the PV cell, which depending on the technology, is about 8-15%.
- (ii) The efficiency of the power converters (DC-DC and/or DC-AC) which is normally ranges between 95-98 %.
- (iii) The efficiency of the maximum power point tracking (MPPT) algorithm, which in most of the

cases can go beyond 98%, but in essence the efficiency lies mostly in the maximum power point tracking algorithm.[8]

LITERATURE REVIEW

[1] Presented a photovoltaic power control MPPT using DC DC boost converter. The MPPT strategy based on cuckoo search algorithm was used for the design of control algorithm in power electronics. The results show the effectiveness of the proposed electronic converter but the DC DC converters is less efficient and exhibits power loss due to large voltage drop and inefficiency of the used tracking algorithm making it unable to track MPP.

[10] Presented an MPPT problem where a method of analysing inductance and capacitance of buck,boost and Buck-boost converter connected in PV system was analysed, satisfactory results and tracking of MPP were achieved. But the converters exhibit power loss due to large voltage drop and inefficiency of the used tracking algorithm making it unable to track MPP under partial shading conditions

[14] Presented a DC/DC boost converter implemented to verify the MPPT problems under different environmental conditions. DC-DC boost

converter aided with cuckoo search algorithm helps in tracking global MPP, excellent performance of the proposed model was verified by simulations and experiments, and was able to track maximum power under partial shaded condition. Power loss, less efficiency and losses due to too high output power, excessive input current and large voltage drop across the diode during voltage collapse point, as well as high switching noise that will reduce the quality of the output voltage makes the DC-DC boost converter not suitable for tracking MPP.

MAXIMUM POWER POINT TRACKING

Maximum Power Point Tracking, frequently referred to as MPPT, is an electronic system that operates the Photovoltaic (PV) modules in a manner that allows the modules to produce all the power they are capable of. MPPT is a fully electronic system that varies the electrical operating point of the modules so that the modules are able to deliver maximum available power [15]. To produce maximum power and to get maximum efficiency, the entire photovoltaic panel must operate at this particular point. MPPT is to ensure that the system can always harvest the maximum power generated by the PV arrays [13].

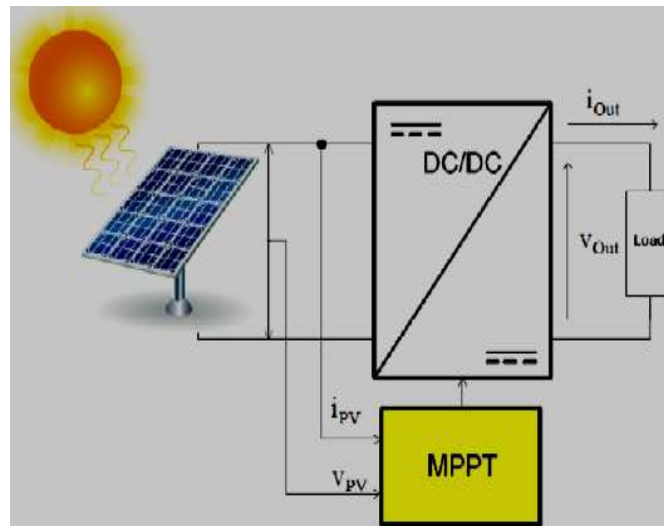


Figure 1: Block Diagram of Typical MPPT System (Attou A *et al.*, 2014).

DC-DC CONVERTER

A DC-DC converter (step up/ step down) serves the purpose of transferring maximum power from the solar PV module to the

load. A DC-DC converter acts as an interface between the PV panel and the load. By changing the duty cycle, the load impedance as seen by the source is varied and matched at the point of the

peak power with the source so as to transfer the maximum power. [11]

Boost Converter

The boost converter is capable of producing a dc output voltage (V_o) greater in magnitude than the dc input voltage (V_s). The circuit topology for a boost converter is as shown in Figure 2.4 [12].

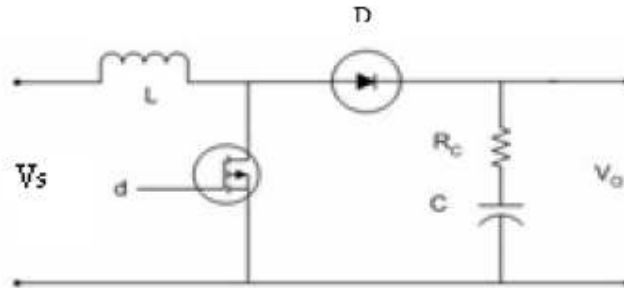


Figure 2 [12]. The conversion ratio is given by the following expression:

$$\frac{V_o}{V_s} = \frac{I_a}{I_o} = \frac{1}{1-d}$$

Knowing the V_a and I_a , we can find the input resistance R_{in} of the converter. This is given by

$$R_{in} = \frac{V_a}{I_a} = R_o(1-d)^2$$

Here, R_{in} varies from R_o to 0 and d varies from 0 to 1. The transfer function of the boost converter is:

$$\frac{V_o}{V_i} = \frac{1}{(1-d)} \left(\frac{1}{1 + \frac{L}{R(1-d)^2}s + \frac{LC}{(1-d)^2}s^2} \right) \quad [12]$$

SYNCHRONOUS RECTIFICATION

A synchronous rectifier is an electronic switch that improves power-conversion efficiency by placing a low-resistance conduction path across the diode rectifier in a switch-mode regulator. MOSFETs usually serve this purpose, but bipolar transistors and other semiconductor switches are also suitable. Active or synchronous rectification can also be found in the literature which increases conversion efficiency by decreasing voltage drop in circuit elements and power losses in switches [6].

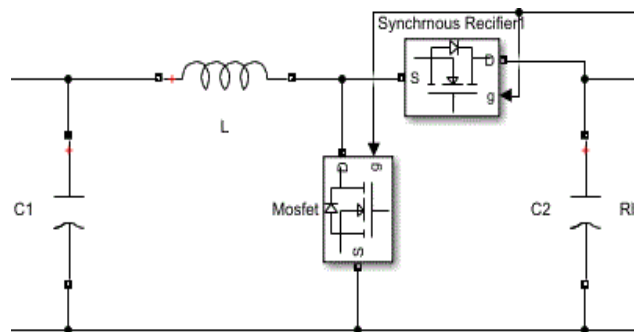


Figure 3: Matlab Model of Modified DC-DC Boost Converter

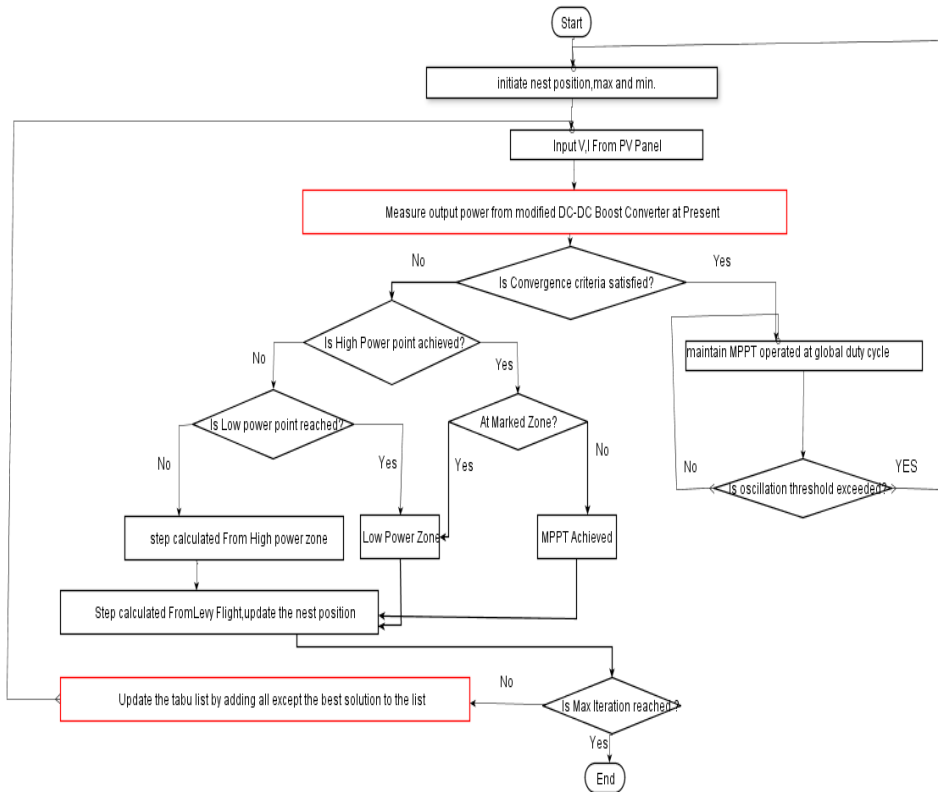


Figure 4: Flowchart of the proposed ICSA MPPT with Modified DC-DC Boost Converter.

RESULTS

In this section, simulations of three different cases with varying degrees of partial shading are presented. The simulation is carried out using the parameters of the PV module and

the boost converter are listed in Table 1 and 2 respectively. The Matlab/Simulink model of the PV system simulations were carried out under uniform operating conditions and partial shading condition.

Table 1: Parameters for Single Pv Module

Item	Value
Maximum Power (P_{max})	60W
Open Circuit Voltage (V_{oc})	21 V
Short Circuit Current (I_{sc})	4.02 A
Maximum Power Voltage (V_{mp})	17 V
Maximum Power Current (I_{mp})	3.5 A

Table 2: Parameters of Boost Converter

Item	Value
Boost Inductor, $L(mH)$	0.15
Input Capacitor, $C_{in}(\mu F)$	200
Smoothing Capacitor, $C(\mu F)$	90
Input Voltage, $V_{in}(V)$	(0–120)
Output Voltage, $V_{out}(V)$	200
Switching Frequency, $f_s(KHz)$	50

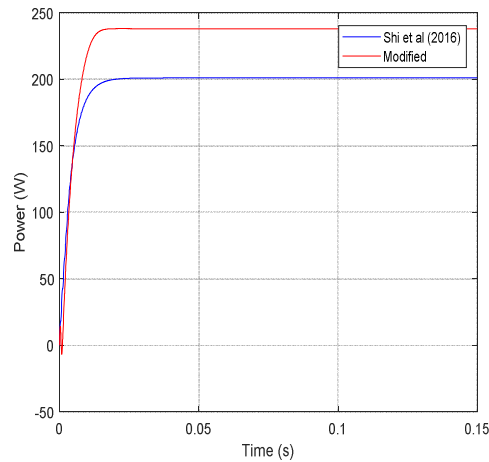


Figure 5: Power curve of MPPT Model under uniform irradiance condition.

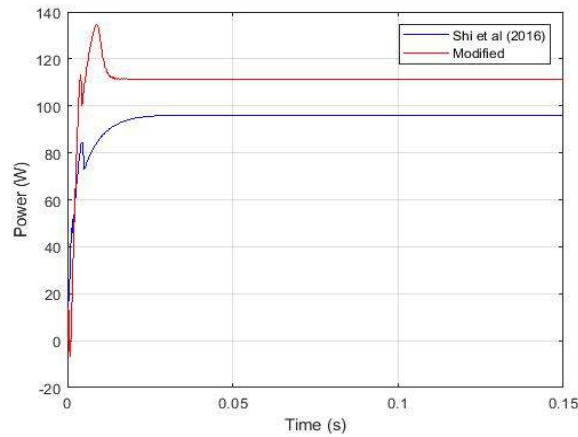


Figure 6: Power curve of MPPT Model under partial shading condition.

Table 3: Performance comparison under uniform irradiance condition

Tracking techniques	DC-DC Converter	Tracking Time (s)	Maximum power (W)	Tracking efficiency (%)
CSA	Boost	0.04	201.1	83.75
ICSA	Modified Boost	0.02	238	99.16

Table 4: Performance comparison under partial shading condition

Tracking techniques	DC-DC Converter	Tracking Time (s)	Maximum power (W)	Tracking efficiency (%)
CSA	Boost	0.04	96.15	80.12
ICSA	Modified Boost	0.01	114.3	95.25

CONCLUSION

This research has developed a maximum power point tracking of photovoltaic system with a modified dc-dc boost converter using an improved cuckoo search algorithm. Modelling of the PV

arrays was developed and implemented based on the work of [14]. The boost converter has been modified by replacing rectifier diode with active rectifier Mosfet in order to reduce power loss. The CSA MPPT algorithm has been modified by



incorporating tabu list in order to reduce tracking time and simulations developed under normal, and partial shading condition. The MPPT technique was implemented on MATLAB R2018b and simulation results were presented. Also the practical implementation of MPP is implemented in this research work. Under uniform irradiance condition the ICESA outperformed the CSA by 50% and the modified DC-DC converter reduce power loss by 36.9W and tracking efficiency improved by 15.41%.

Under partial Shading condition the ICESA outperformed the CSA by 75% and the modified DC-DC converter reduce power loss by 18.15W and tracking efficiency improved by 15.13 %.

REFERENCES

1. Ahmed, J., & Salam, Z. (2014). A Maximum Power Point Tracking (MPPT) for PV system using Cuckoo Search with partial shading capability. *Applied Energy*, 119, 118-130..
2. Attou, A., Massoum, A., & Saidi, M. (2014). Photovoltaic power control using MPPT and boost converter. *Balkan journal of electrical & computer engineering*, 2(1), 23-27.
3. Challa, D. T. R., & Raghavendar, I. (2012). Implementation of incremental conductance MPPT with direct control method using cuk converter. *International Journal of Modern Engineering Research (IJMER)*, 2(6), 4491-4496.
4. De Brito, M. A., Sampaio, L. P., Luigi, G., e Melo, G. A., & Canesin, C. A. (2011, June). Comparative analysis of MPPT techniques for PV applications. In *2011 International Conference on Clean Electrical Power (ICCEP)* (pp. 99-104). IEEE.
5. Esram, T., & Chapman, P. L. (2007). Comparison of photovoltaic array maximum power point tracking techniques. *IEEE Transactions on energy conversion*, 22(2), 439-449.
6. Hashemi, S., Sawan, M., & Savaria, Y. (2009). A novel low-drop CMOS active rectifier for RF-powered devices: Experimental results. *Microelectronics Journal*, 40(11), 1547-1554
7. Ishaque, K., & Salam, Z. (2013). A deterministic particle swarm optimization maximum power point tracker for photovoltaic system under partial shading condition. *IEEE transactions on industrial electronics*, 60(8), 3195-3206.
8. Ishaque, K., & Salam, Z. (2014, January). Dynamic efficiency of direct control based maximum power point trackers. In *2014 5th International Conference on Intelligent Systems, Modelling and Simulation* (pp. 429-434). IEEE.
9. Ishaque, K., Salam, Z., Amjad, M., & Mekhilef, S. (2012). An improved particle swarm optimization (PSO)-based MPPT for PV with reduced steady-state oscillation. *IEEE transactions on Power Electronics*, 27(8), 3627-3638.
10. Kolsi, S., Samet, H., & Amar, M. B. (2014). Design analysis of DC-DC converters connected to a photovoltaic generator and controlled by MPPT for optimal energy transfer throughout a clear day. *Journal of Power and Energy Engineering*, 2(01), 27.
11. Kute, U. T., Pote, R. S., Kumar, M., & Khatri, R. (2014). Implementation of Incremental Conductance (MPPT) technique for PV system. *International Journal of Advanced Research in IT and Engineering*, 3(6), 1-15.
12. Mallika, S., & Saravanakumar, R. (2013). Genetics Algorithm Based MPPT Controller for Photovoltaic System. *International Electrical Engineering Journal (IEEJ) Vol. 4*, 1159-1164.
13. Selvapriyanka, P., & Vijayakumar, G. (2014). Particle swarm optimization based MPPT for PV system under partial shading conditions. In *IJIRSET Inter. Conf. on Eng. Tech. and Science* (Vol. 3, pp. 856-861).
14. Shi, J. Y., Xue, F., Qin, Z. J., Zhang, W., Ling, L. T., & Yang, T. (2016). Improved global maximum power point tracking for photovoltaic system via cuckoo search under partial shaded conditions. *Journal of Power Electronics*, 16(1), 287-296.
15. Sholapur, S., Mohan, K. R., & Narsimhegowda, T. R. (2014). Boost converter topology for pv system with perturb and observe mppt algorithm. *IOSR journal of Electrical and Electronics Engineering (IOSR-JEEE)*, 9(4), 50-56.
16. Wang, J. M., & Lu, C. L. (2013). Design and implementation of a sun tracker with a dual-axis single motor for an optical sensor-based photovoltaic system. *Sensors*, 13(3), 3157-3168.