SSRG International Journal of Electrical and Electronics Engineering
ISSN: 2348-8379/ https://doi.org/10.14445/23488379/IJEEE-V11I8P105

Volume 11 Issue 8, 50-58, August 2024

Original Article

Performance Improvement in SEPIC Converter Using Modified Seagull Optimization Techniques

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Received: 03 June 2024 Revised: 05 July 2024 Accepted: 03 August 2024 Published: 31 August 2024

Abstract *- This research provides a novel technique for enhancing the performance of a Single-Ended Primary Inductor Converter (SEPIC) by utilizing Modified Seagull Optimization Algorithm (MSOA) techniques. The SEPIC converter is widely employed in power electronics for its versatility in voltage regulation. However, challenges related to efficiency and optimization persist. To solve these problems, a modified version of the Seagull Optimization Algorithm is presented in this work. The proposed technique is employed to optimize the control parameters of the SEPIC converter, aiming to achieve improved efficiency and reduced losses. The results of the simulation show how well the Modified Seagull Optimization Algorithm performs the converter under different operating situations. The findings suggest that the proposed method holds promise for practical applications in power electronics, contributing to the advancement of energy-efficient converter designs. Based on a new methodology, the ideal sampling period was identified for the controller to achieve optimal performance. The main research tool is a software suite called MATLAB/Simulink. The main results show that the modified SOA and its intended parameters best meet the requirements of the MPPT controller for PV systems.*

Keywords *- SEPIC converter, Modified Seagull Optimization, Single-ended primary inductor converter, Energy-efficient design, Converter optimization.*

1. Introduction

Solar energy appears promising as it becomes available and widely used as a production method. As a result, some techniques have been employed to increase the efficiency of stand-alone photovoltaic systems. A certain control technique used inside the converter monitors a PV module's power. Because non-linear properties of PV modules, this approach is referred to as the algorithm for tracking maximum power points. It is impossible to generate external energy from a single bare cell.

This is a result of a single solar cell's low output. It must be protected from extreme weather, mechanical shock, dust, and moisture. Connect solar cells to build a PV panel to obtain the required operational voltage and power, either in series or parallel. In this work, the PV panel serves as the system's basic unit, which is modelled with a working voltage of 36 V. In the literature, the effects of temperature and radiation variations have been analysed. PV tests are typically conducted at 1000 W/m2. As the insolation changes, so it performs. In cloudy or rainy weather, the amount of solar power generated will be less. Therefore, in order to alter the PV electrical characteristics and raise the extracted power. This paper's primary contribution is the innovative methodology based on the PSO algorithm for selecting the optimal PV system MPP controller settings. This study also considers the PV panel architecture and configuration when designing and selecting the parameters of the battery-connected Buck converter for DC-DC. The load can be impacted by inconsistent performance when implementing the MPPT algorithm.

To prevent this, closed-loop load control is used to give the system a steady maximum power output throughout the irradiation. Due to the relatively low voltage output characteristics, renewable energy systems and power supplies require significant voltage gain and high-efficiency increases. Common power conversion systems often use to increase the voltage based on the load. A voltage output that differs from the input value in either direction can be produced by a non-inverting DC/DC converter known as a SEPIC [1]. It functions in applications like solar panels MPPT because of these qualities [2].

Efficiency is a critical consideration in MPPT design, so it is important to reduce losses. A small portion of the losses can be avoided using passive components, but most of the losses are caused by moving parts. Once more, these losses may be minimized by choosing the best components. However, switching frequency has a large impact on active component losses. Buck and boost topologies are simple to build, and their tracking range is constrained [3]. In light of these constraints, SEPIC, Cuk, and Buck-boost represent the best choices. SEPIC converter beats any remaining converters and shows remarkable effectiveness by eliminating numerous normal issues. It appears to be useful for a wide range of power electronics applications due to its significant feature of stepping up and down voltage without changing polarity.

The proportional, integral, and derivative terms make up the PID controller. These terms are altered through the use of optimization strategies. The integral component introduces lag into the system, whereas the proportional component manages lag based on the proportion of the system's error. Since the PV maximum power point is dynamic, the ideal option is MPPT control [4]. In order to utilize MPPT, the appropriate DC-DC converter must be chosen. Customers can choose from two types of converters. Cuk converters and SEPIC may produce output voltages that are distinct from input voltages. They likewise have a bigger information current and are more effective than flyback and buck-help converters [5].

Boost converters usually perform better than SEPICs, but they have strict power consumption limits because every time, the output voltage exceeds the input voltage. Despite divergent opinions in the literature about the relative superiority of SEPIC and Cuk, choose to employ the SEPIC converter for this investigation because the Cuk converter's output is reversed [7]. In this paper, MSOA is used to streamline the PID regulator settings when utilized in close loop examination of the SEPIC converter to monitor the greatest power. Different performance measures, such as the percentage of overshoot, rising time, and settling time, are used to analyse the system's stability using fitness functions.

2. Implementation of MSOA in Sepic Converter

Figure 1 depicts the entire control strategy for the SEPIC converter's proposed MPPT-based optimized PID control. The PID parameters can be adjusted to bring them closer to the convergence region, but this does not guarantee that the best option will be determined. PID tuning as in, can ensure that the PID parameters exist around the ideal solution but cannot produce perfect values for the PID parameters.

When optimization is performed for non-converging values, there are two possible outcomes: The first is that finding the optimal solution through optimization is a time-consuming procedure. The process of realizing infinite possibilities is the second.

Figure 1 shows a proposed topology of the entire independent solar system. Get an instantaneous power match between the source's power and the load in order to function as efficiently as possible.

The diode D, the switch S, and the magnetizing inductor in Figure 2, the converter is composed of the resistive load and the capacitor C. The magnetizing inductor continues to function like the inductor used in traditional boost converters [8]. To withstand high voltage, the converter components must be perfect, and the capacitor values must be large. To provide high gain, the linked inductor rotates in a ratio of 1:3 is selected.

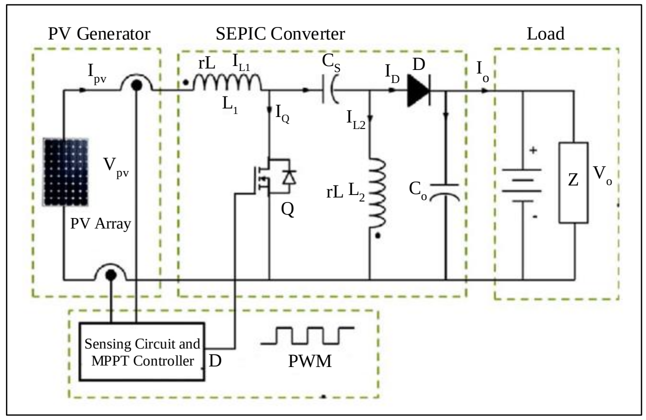


Fig. 1 Proposed topology for MSOA MPPT-based SEPIC converter for PV system

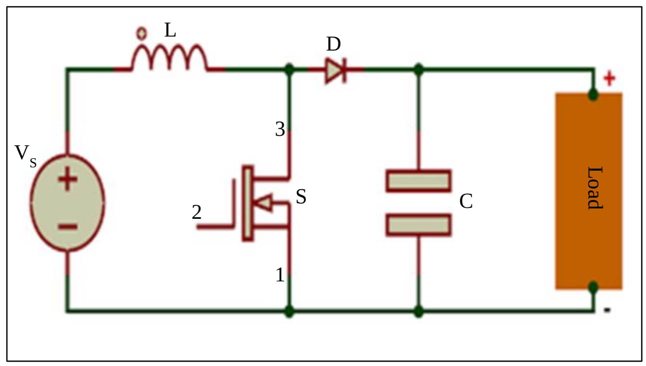
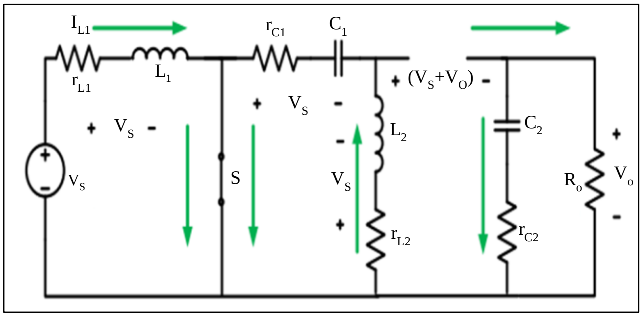


Fig. 2 Circuit diagram of step-up converter

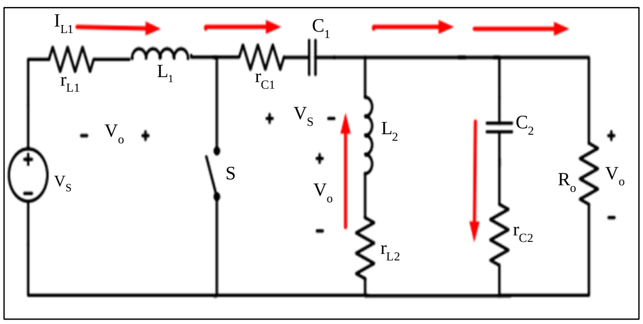
There are two working modes for the DC-DC step-up converter in continuous conduction mode. When the first mode switch is activated, the forward-biased diode D turn on. The source voltage will charge the switching capacitor C through a coupled inductor. The inrush current is cut off when the input source's load current flows through the switched capacitor and turns on the switch. During this procedure, the magnetized inductance is additionally charged via the input source Vin. This mode is hence referred to as the energy storage mode.

Diode D is forward-biased and switches S and D are both open between the power drawn from the source and the load. In order to function as efficiently as possible, it is detected that the source Vin, Lm, C, and N2 are connected in series. This model is, therefore, called the energy recovery mode. In the on and off stages of this converter, the coupled inductor functions as both a transmission device as well as an energy storage device [9]. The secondary coil N2 provides charge to the converter capacitor, while the magnetizing inductor boosts the converter's gain.

SEPIC Converter Design: SEPIC is made up of a resistive load (R0), a duty cycle-controlled switch (S), two inductors, and two capacitors. Figure 3 portrays the practical equivalent of circuits during the switching states.



(a)



(b)

Fig. 3 SEPIC converter switch (a) ON, and (b) OFF

The voltage VC1 exhibits low ripple because the values of the C1 capacitor are set to a sufficient magnitude. After that, since the average currents across capacitors C1 and C2 are zero, we can conclude using KCL that IL2 = ID = I0. The current IL1 increases at a rate when diode D is turned off and switch S is on.

$$\frac{dI_{L_1}}{dt} = \frac{V_S}{L_1}, 0 \leq t \leq dT \tag{1}$$

$$\frac{dI_{L_1}}{dt} = -\frac{V_0}{L_1}, dt \leq t \leq T \tag{2}$$

T represents the complete time period. However, in order to achieve a time domain solution, the internal status and output variables are specified. The process can be broken down into two scenarios.

i) For S ON and D OFF

$$\frac{dI_{L_1}}{dt} = \frac{1}{L_1}(-r_{L_1} I_{L_1} + V_S \;) \tag{3}$$

$$\frac{dI_{L_2}}{dt} = \frac{1}{L_2}(-r_{C_1} + 2) I_{L_2} + V_{C1} \;) \tag{4}$$

$$\frac{dV_{C_1}}{dt} = -\frac{1}{C_1} I_{L2} \tag{5}$$

$$\frac{dV_{C_2}}{dt} = -\frac{1}{C_2}\frac{1}{R_0 + r_{C2}} V_{C2} \tag{6}$$

ii) For S OFF and D ON

$$\frac{dI_{L_1}}{dt} = \frac{1}{L_1}[-(r_{C1} + r_{L1} + r_{C2} r_A) IL_1 - r_{C2} r_A IL_2 - V_{C1} - r_A V_{C2} + V_S] \tag{7}$$

$$\frac{dI_{L_2}}{dt} = \frac{1}{L_2}[-(r_{C2} r_A) IL_1 - (r_{C2} r_A + r_{L2}) IL_2 - r_A V_{C2}] \tag{8}$$

$$\frac{dV_{C_1}}{dt} = -\frac{1}{C_1} I_{L1} \tag{9}$$

$$\frac{dV_{C_2}}{dt} = \frac{1}{C_2} - [(r_A) IL_1 + (r_A) IL_2 - \frac{1}{R_0 + r_{c2}} V_{C2}] \tag{10}$$

Table 1. Details of the prototype's SPV module specifications

Parameters	Value
Solar PV Source	
Rating of Nominal Power	125watts
Voltage of Open Circuit for Each Panel	22.06 V
Current Short Circuit	8.867A
Pmax voltage	18.39 V
Pmax Current	7.43 A
Test Situation	1000w/m^2; 25^{o}C

2.1. Modified Seagull Optimization Algorithm

An entirely new approach for meta-heuristic optimization called Modified Seagull Optimization Algorithm (SOA) [3] has been developed in part due to the natural behaviour of gulls. Seagulls come in many different sizes and lengths. Insects, fish, earthworms, reptiles, and amphibians are all food for albatrosses, which are omnivores. Laridae is the scientific family of gulls. They absorb fish using breadcrumbs and earthworms using the sound of rain their feet make. Most Gulls are colonial birds. They often travel from place to place in search of sufficient food. The seagulls assault their meal as they arrive at an unknown location. The two most salient characteristics of albatrosses are their tendency to hunt and their migration habits. These two natural behaviours are the subject of MSOA, which also offers an appropriate model based on mathematics. A conceptual model of these actions is shown in Figure 4.

The fact that the seagulls were first migrating shows how inquisitive SOA may be. When moving, a flock of seagulls had to keep apart from one another. Add a second variable, A, and use it to obtain the new search agent's position in order to accomplish this [16]

$$\vec{C}_s = A \times \vec{P}_s(x) \quad (11)$$

Where x is the most recent iteration. The search agent's movement behavior is displayed by A, and its current position is represented by Ps, and its position, while it avoids other d' research staff members, is represented by Cs.

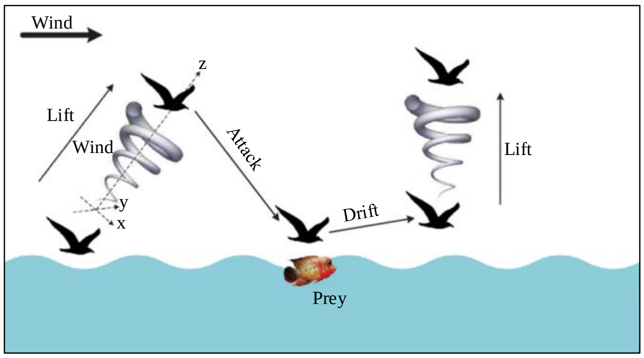


Fig. 4 Seagull migration and attacking patterns

$$A = f_c - \left(x \times (f_c/Max_{iteration})\right) \quad (12)$$

When the value of variable A decreases linearly from its starting value to zero, the variable that controls the frequency of use of variable A is fc. After averting a collision with Dai's neighboring research, the research agent advances to the rank of Best Research Agent [17].

$$\vec{M}_s = B \times \left(\vec{P}_{bs}(x) - \vec{P}_s(x)\right) \quad (13)$$

Where $\vec{M}_s$ r displays the search engine agent's, $\vec{P}_s$ position in relation to the top search engine $\vec{P}_{bs}$. The random value, coefficient B, can be used to weigh the pros and cons of exploration against exploitation. B is calculated in this way:

$$B = 2 \times A^2 \times rd \quad (14)$$

When the search agents swap to the most effective search agent, they may be near each other.

For the following equation, search agents can move relative to the ideal lookup algorithm:

$$\vec{D}_s = \left|\vec{C}_s + \vec{M}_s\right| \quad (15)$$

Where $\vec{D}_s$ displays the discrepancy between the optimal search agent and the one in use right now. Secondly, upon reaching a novel site, gulls strike their prey in a spiral pattern, indicating the potential for MSOA to be leveraged. This behavior is defined as follows in x- z planes:

$$x = r \times \cos(k) \quad (16)$$

$$y = r \times \sin(k) \quad (17)$$

$$z = r \times k \quad (18)$$

$$r = u \times e^{kv} \quad (19)$$

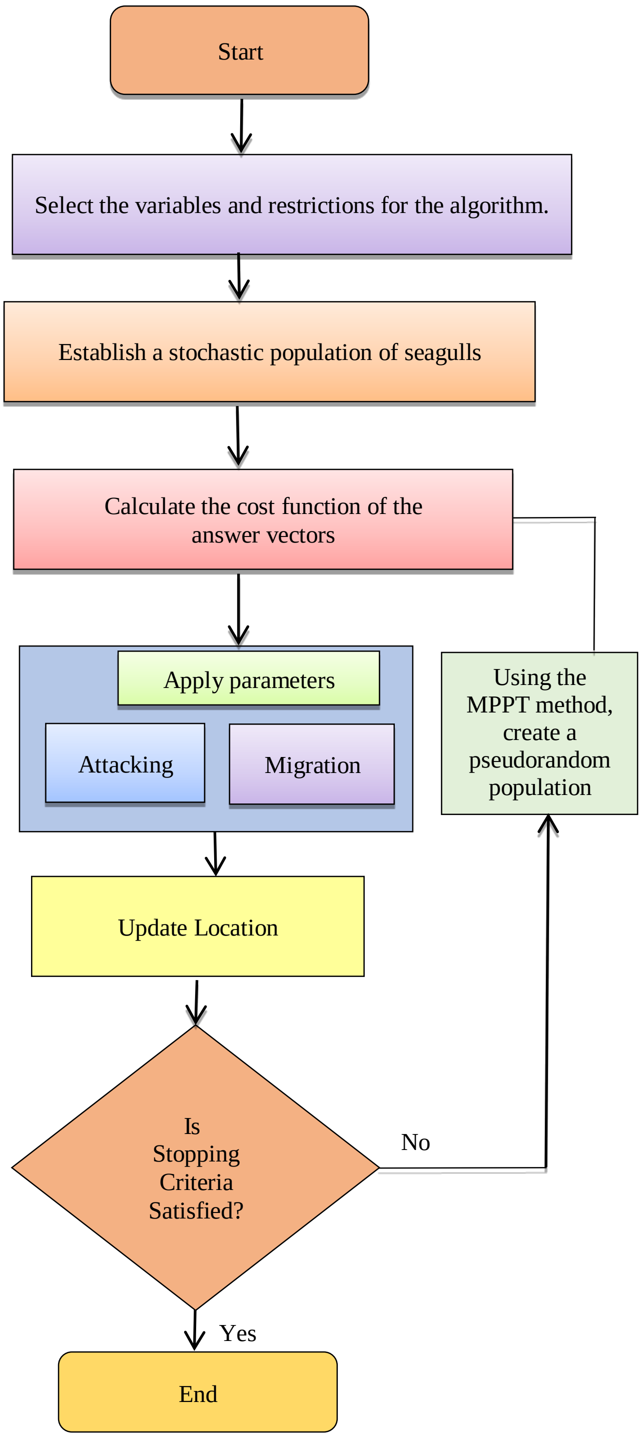


Fig. 5 Flow chart of the MSO

Furthermore, the natural logarithm's base, e, is provided, along with the constants u and v. Using the following formula, the search agent's modified position is found:

$$\vec{P}_s(x) = \left(\vec{D}_s \times x \times y \times z\right) + \vec{P}_{bs}(x) \quad (20)$$

It takes work to assign all duties among the available Virtual Machines (VMs) and find the best option in the cloud environment. Because of this, we require a task scheduling algorithm that works well in order to distribute all user jobs among the available resources while maintaining VM load balance [18].

(i) Input: Population of seagulls (P_s)⃗
Output: Ideal search (P_bs)⃗
procedure MSOA
Initialize parameter A, B and Max_iteration
Assign fc
Assign u
Assign v
while (x< Max_iteration)
(P_bs)⃗ ← CalculateFitness ((P_s)⃗) /* Utilizing ComputeFitness*/, determine each MPPT behavior agent's fitness values.
/*Migration */
rd ← Rand (0,1) /* produce a random no with [0,1] */
/*Attacking behaviour*/
r ← u×e^kv /* In order to produce the MPPT behavior when energy*/.
Calculate the distance (D_s)⃗
(P_s)⃗(x) ← ((D_s)⃗×P) + (P_bs)⃗
return (P_bs)⃗
end process

3. Results and Discussion

However, Table 2 and Figure 6 illustrate the average execution times of the proposed MSOA and alternative algorithms. MSOA is quicker than other approaches, and it does not require evolutionary mechanisms such as crossings and mutations because it is a biologically inspired optimisation methodology. As a result, the proposed technique has significantly greater computing efficiency than its competitors.

When analysing an algorithm's performance, complexity is a crucial factor to consider. Such include PSO, MSGOA, MVO, SCA, GSA, GA, DE, GWO, and SHO, as well as the recommended MSOA, where no is the goal number and np is the population size. O (N × Maxiteration × n_o × n_p × o_f) is the complexity of the MSGOA technique. Since defining the group of spotted hyenas takes O(G) time. O (N × Maxiteration × n_o × n_p × o_f) is the computing complexity of the GWO, PSO, SOA, MVO, and SCA algorithms. The GSA algorithm requires a total time of O (N × f/2 × Maxiteration × n_o × n_p × o_f), with the force component computation taking O(f/2) with the crossover and mutation operators represented by the variables c_s and m_t, respectively. O (N × Maxiteration × n_o × n_p × o_f) is the computational complexity of the proposed MSGOA technique. Since defining the group of spotted hyenas takes O(G) time.

Table 2. The mean duration of proposed and rival methods

Optimizations	Average Time (s)
Algorithm for Seagull Optimization (SOA)	1.2244
Spotted Hyena Optimizer (SHO)	1.3268
Grey Wolf Optimizer (GWO)	1.2535
Modified Sea Gull Optimization Algorithm (MSGOA)	2.2361
Genetic Algorithm (GA)	1.3669

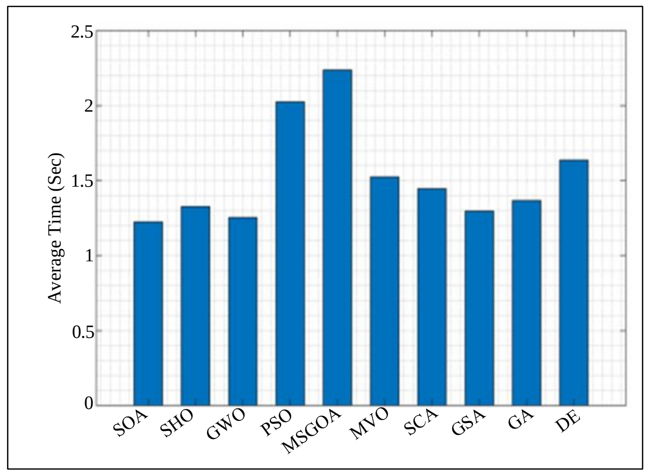


Fig. 6 The average time for metaheuristic algorithms to run

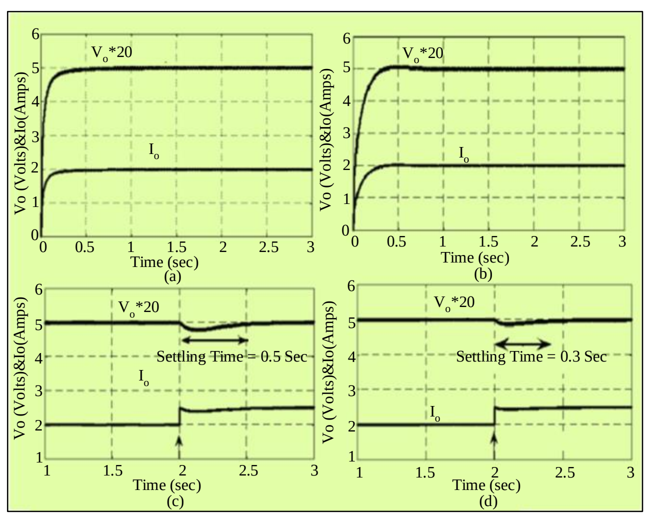


Fig. 7 Output voltage and current of non-optimized and optimized PID controller under various load scenarios

Local data dissemination, computing, storage, and cloud connectivity amongst data-generating devices and applications takes place in a distributed architecture known as cloud computing. One of the biggest challenges facing engineers and scientists today is generating energy from clean, efficient, and environmentally responsible sources. Photovoltaic generation systems are one of the renewable energy sources that receive the most attention because they offer great possibilities for generating electricity.

However, factors such as the sun's temperature and radiation in the atmosphere affect the amount of energy a photovoltaic system can produce. Peak Power Point Tracking (MPPT) technology maximizes solar energy utilization and improves PV power generation efficiency. Numerous approaches for tracking Peak Power Points (MPPT), including modified gull optimization, Incremental Conductance (INC), and based algorithms, have been presented.

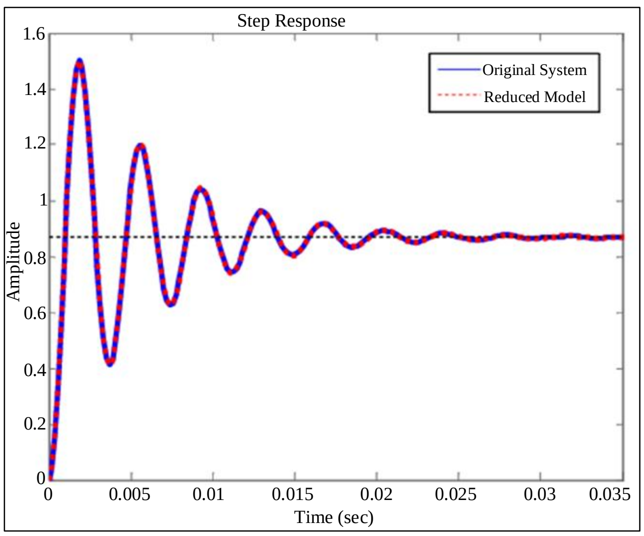


Fig. 8 SEPIC converter step response based on their iterations

PID control is one method for power converter closed loop analysis that is utilized the most. As a result, the approach has been used here to observe the closed loop optimised performance of the SEPIC converter using MSOA.

Table 3. Gain values for MSOA based PID

Gains	MSOA-PID		
	IAE	ITAE	ISE
K_p	29.044	19.114	32.762
K_i	27405.39	25115.704	31994.01
K_d	0.0099	0.0045	0.0123

When the load is varied, the output voltage and current are displayed in Figure 7. Because of the simple implementation and simple control structure, the algorithms are often used in PV systems. The algorithm that performs better than the other methods is the incremental conductivity method because it has high steady-state tracking accuracy and is well suited to rapidly changing atmospheric conditions.

Based on the MPPT reaction time and steady-state accuracy requirements, the incremental conductance algorithm's usual iteration step size is established, and the step-response iterations for the SEPIC converter display the closed-loop system's step response iterations, beginning with the first response and ending with the last response. It is the weighting function implemented directly and the Power/Voltage curves for the proposed method are shown in Figures 8 and 9. The power versus voltage curves for radiation changes, ranging from 250 to 1000 W/m2 at 25 and 50 degrees Celsius, are displayed. The number of PV arrays and the PV-cell values were taken for simulation purposes based on the experimental arrangement.

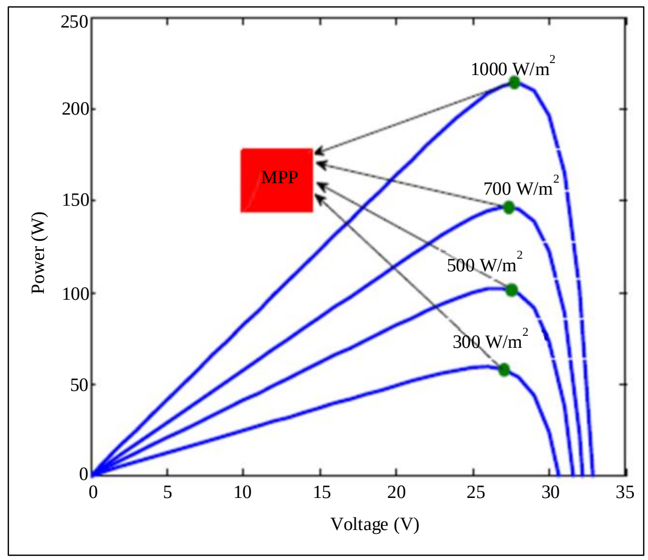


Fig. 9 Power-voltage graphs for photovoltaic array

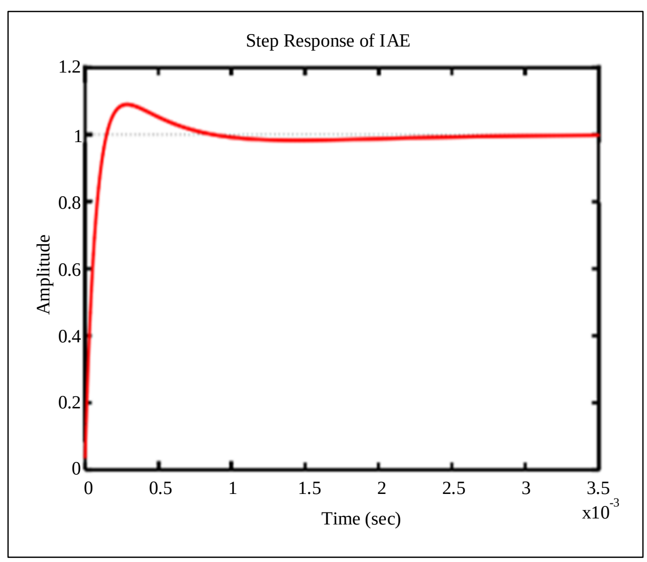


Fig. 10 Step response of IAE

Table. 4 Performance parameters for MSOA based PID controller

Performance Parameters	MSOA-PID		
	IAE	ITAE	ISE
%OS	9.1	17.4	11
Tr	0.00023	0.00052	0.00087
Ts	0.00064	0.00070	0.00080

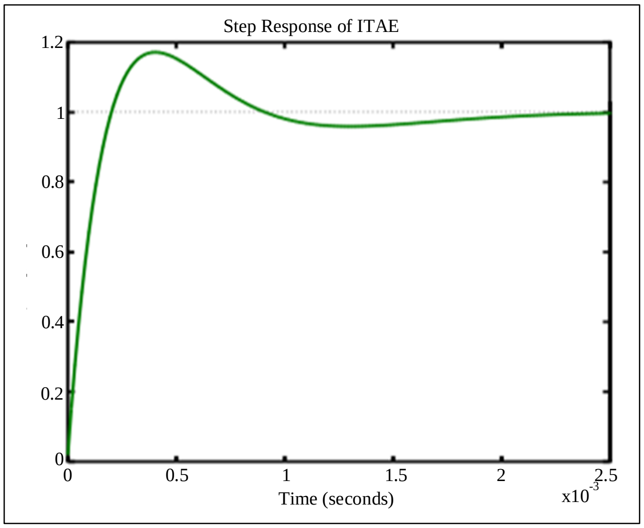


Fig. 11 Step response of ITAE

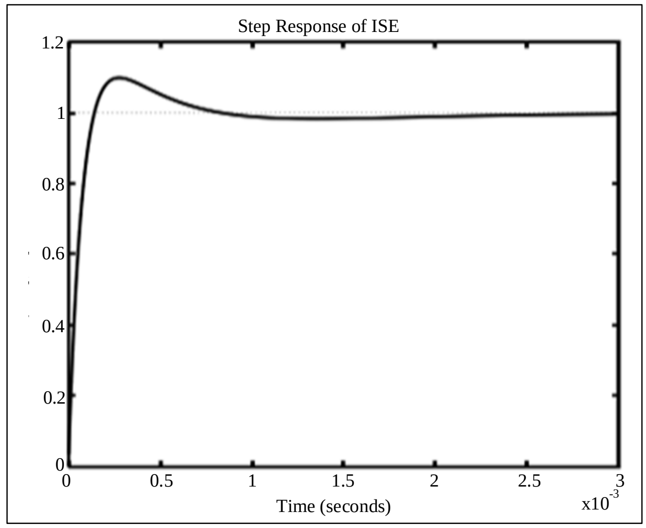


Fig. 12 Step response of ISE

Table 5. Comparing the methods of MSOA MPPT and PSS-based SOA

	SOA	MSOA	Actual Values
PV Power (W)	116.754	117.973	118.8
Duty cycle (%)	48.83	49.89	50.03
Efficiency (%)	98.20	99.36	100
Setting period (ms)	22.5	21.4	-
Maximum Percentage Overtaken (%)	4.92	3.02	-

The MSOA is used in the system to identify the PID controller's optimal settings. The MSOA parameters are set during the error process to obtain the optimised values of kP, kI, and kD. Table 3 displays the values of PID each of the MSOA-based PID controller's performance indices following a comprehensive MATLAB simulation. Figures 10, 11, and 12 show step responses PID controller. Table 4 displays exhibition measurements for an MSOA based PID regulator, like the level of overshoot (%OS), rise time (Tr), and settling time (Ts). Tables 5 compare the scaled-down model in detail and explores SOA and MSOA MPPT techniques in PSS.

4. Conclusion

This work presents a unique SEPIC-based MPPT converter with an optimized PID controller. The control system is implemented in real-time. Traditional MSOA-based trackers offer several advantages, including simplicity and independence from installed systems. The real challenge in the practical use of MSOA is how to ensure that the overall MPP is extracted as efficiently as possible. Through the analysis of academic papers on the MSOA algorithm, it has been determined that, currently, there is no mechanism to choose the best parameter for the maximum power tracker for PV systems based on the algorithm. MSOA. Considering the topology and characteristics of SEPIC (Asymmetric Main Inductance Converter), as well as the arrangement of the solar panels, this work aims to create a practical and reasonable technique to select the most suitable parameters of the MSOA algorithm.

Acknowledgments

The author would like to express his heartfelt gratitude to the supervisor for his guidance and unwavering support during this research for his guidance and support.

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