

Maximum power point tracking of photovoltaic under partial shading condition with dual-sepic converter considering dynamic load

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Abstract:

Solar power generation is suited for clean energy and meeting the increasing energy demands owing to its abundance and easy maintenance. However, it has low efficiency as maximum power is not extracted from the photo-voltaic panel due to solar irradiance obstruction causing partial shading condition. This condition creates multiple power peaks of which the maximum power peak is selected for maximum power utilization. To achieve this, a tracker based on spring search algorithm integrated with perturb and observe algorithm (SSA-PO), and operationally tied with DC-DC boost converter was developed for maximum power point tracking of the photovoltaic system at constant solar irradiance and during partial shading conditions. This generated a tracking efficiency of 97.8% at PSC1, 96.3% at PSC2 and 96.9% at PSC3, therefore, yielding an improvement of 0.15% and 2.29% during constant and partial shading conditions, and tracking time was 6.8% and 2.5% improvement when compared with the result of artificial bee colony algorithm with perturb and observe (ABC-PO). Furthermore, considering load variation at the output terminal, a Dual-Sepic converter that operates with the developed algorithm was modelled for efficient tracking of power under constant, partial solar irradiance and dynamic load conditions. The Dual-Sepic converter with developed algorithm has a faster tracking time 0.05 seconds and 1.01 seconds compared to the developed method with boost converter at constant and PSC, which is commendable in PV system operating under dynamic load conditions.

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1. Introduction

The demand for energy world-wide is rapidly increasing, the International Energy Agency (IEA) predicted the world energy consumption will increase by 44% from 2006-2030 [1]. The conventional way of power generation that uses fossil fuel still provides the larger part of energy demand and has the challenges of carbon emission, installation cost and is being depleted [2, 3]. Thus, need for renewable energy. Solar photovoltaic (PV) is widely applied in standalone and on-grid application as a result of its easy maintenance, low cost of installation, absence of noise, and free from pollution [4].

In PV system sunlight is converted into direct current without any green-house gas emission which is widely advocated by governments [5]. The current-voltage (I-V) curve of PV depends on temperature and irradiance. Under constant temperature and increase in irradiance, the PV current increases in direct proportion with negligible effect on PV voltage. Also, at constant irradiance with increase in temperature, the PV voltage decreases with slight increase in PV current [6].

Solar energy needs to be made economical; therefore, the efficiency of the solar panel has to be

improved. To achieve this, several MPPT methods are developed to extract maximum power from the PV system. Therefore, to extract maximum power, the PV panel must be operated at voltage corresponding to MPP (V_{mpp}) [4, 7].

Conventional MPPT methods have been developed, these include, Incremental conductance technique [8][9], Short circuit current techniques [10], Perturb and Observe techniques [11, 12] etc. Perturb and observe method is the simplest method among the various methods, and they all vary in convergence speed, system cost, and the number of sensors to be used in the system [13]. Conventional MPPT methods are effective under uniform irradiance conditions but are ineffective under changing atmospheric conditions and partial shading condition (PSC) [14, 15]. Thus, under PSC, to track the MPP, the conventional methods should be integrated with soft computing algorithms for better efficiency.

Photovoltaic arrays are connected in series or parallel so as to obtain required amount of voltage and current, and there is possibility of partial shading condition as a result of shadow of buildings, trees, moving clouds etc. The panels will receive a varying solar irradiation, which will give rise to partial shading condition [16]. Under

PSC the power vs voltage curve produces multiple peaks with only one peak which represent the true MPP, known as Global MPP (GMPP) and local MPP (LMPP). The conventional methods can only track the LMPP and are unable to track the GMPP due to system non-linearity. This will lead to power loss and low efficiency of the system. To improve the efficiency a soft computing method is fused with the PandO technique or other conventional methods [17].

The aim of this research is to develop an improved PV array MPPT model under partial shading with Dual-SEPIC converter considering dynamic load condition by developing SSA-PO algorithm and apply on PV system configured with boost and dual-sepic converter, and evaluating its performance based on tracking efficiency and time.

1.1 Photovoltaic system

Solar cells act as transducer, which converts the solar irradiance into electric energy. This cells are made of semi-conductor material (silicon) and has the potential to generate voltage of 0.5-1 Volt and current density of 20-40 mA/cm² which depends on the material used and condition of the sunlight. The efficiency of the cells as low as 15% and multiple cells are connected to form a panel or module [18].

1.1.1 Photovoltaic cell model

In solar cell modelling, single diode and double diode model methods are used, also organic cell modelling apart from the silicon cell model is being developed over the years [19] and is the basic energy conversion unit of the PV system [20]. However, the double diode method is complex [16]. To predict the energy generation of photovoltaic cell, the single diode circuit model is common as represented in Figure 1. The output of PV system depends on the solar irradiance and temperature; thus, current values of the system parameter are necessary [21]. The short circuit current (I_{sc}), open circuit voltage (V_{oc}), maximum power voltage (V_{mp}), maximum power current (I_{mp}), fill factor (FF) and cell efficiency are given by the manufacturer data sheet. Other required parameters include: PV current (I_{pv}), PV voltage (V_{pv}), diode saturation current (I_{sat}), series resistance (R_s), parallel resistance (R_p), diode ideality factor (a) and other unknown values are obtained analytically or via optimization technique.

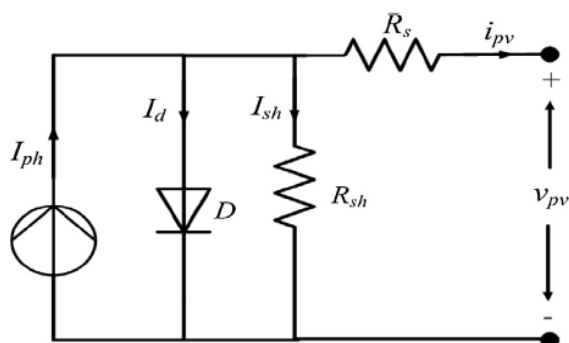


Figure 1: Circuit Diagram of PV Cell Model

The characteristic equation of the one diode model could be obtained from Kirchhoff's current law using in equation 1 [4]:

$$I_{pv} = I_{ph} - I_d - I_{sh} \quad (1)$$

Where, I_{ph} is Photons current, I_d is Diode current, I_{pv} is Photovoltaic current and I_{sh} is shunt resistor current

The characteristic equation in (1) is also expressed using equation 2 [32]:

$$I_{pv} = N_p \left\{ I_{ph} - I_o \left[\exp \left(\frac{q(V_{pv} + I_{pv}R_s)}{N_s A k T} \right) - 1 \right] \right\} - \frac{V_{pv} + I_{pv}R_s}{R_p} \quad (2)$$

Where, I_o is saturation current, N_p is number of parallel cell, N_s is number of series cell, q is electron charge, A is ideality factor, k is Boltzmann constant and T is cell temperature.

The saturation current which is dependent on temperature variation and the photon current are expressed using equations 3 and 4 [28]:

$$I_o = I_{rs} \left(\frac{T}{T_{ref}} \right)^3 \exp \left[\frac{qE_g}{Ak} \left(\frac{1}{T_{ref}} - \frac{1}{T} \right) \right] \quad (3)$$

$$I_{ph} = (I_{sc} + (T - T_{ref}) K_i) \frac{G}{1000} \quad (4)$$

Where, G is irradiance, E_g is band gap energy, I_{rs} is reverse saturation current, K_i is short circuit current temperature coefficient and T_{ref} is the reference temperature.

Cells are connected in series and the group of cells are connected in parallel to form a module or panel. The modules are also connected in series and parallel to meet power demand. A standard panel has 36 or 72 number of cell arrangement [22].

1.1.2 Dual-SEPIC converter

Dual single ended primary inductance converter (Dual-SEPIC) is also known as zeta converter. This dc-dc converter is dual to a SEPIC converter and can act as a step-up or step-down converter depending on value of the ON switch duty cycle [25]. It has no non-operational region and could accommodate the problem of pulsating current making it suitable for distributed generation [26]. Figure 2, shows the circuit diagram of Dual-SEPIC converter. It consists of switch S , two inductors L_1 and L_2 , source capacitor C_1 , and rectifying diode. The switch is turned ON and OFF depending on the duty cycle and the input voltage is deliver to the load (load resistor and the filter capacitor)

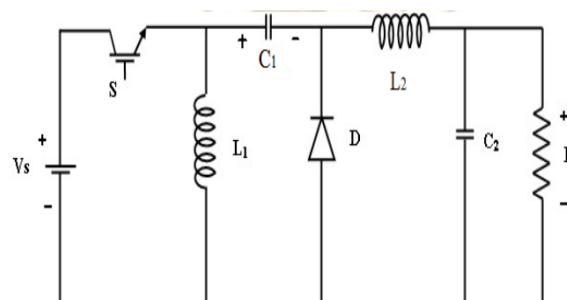


Figure 2: circuit of Dual SEPIC converter [27]

1.1.3 Spring search algorithm (SSA)

The principle behind this optimization technique is based on Hooke's law. Equation (5) is the expression of Hooke's law (spring force) [33].

$$F_s = -KY \quad (5)$$

Where, F_s is spring force, K is a constant and Y is the strain or compression of the spring.

In this algorithm, set of objects search the space randomly. The object with better fitness drags the objects toward itself and higher stiffness coefficient of the spring is attached to it. Force is applied to each object in proportion to their sizes. Therefore, the better position will accumulate more objects over time [33]. Figure 3 shows each object displaced according to spring forces applied to it.

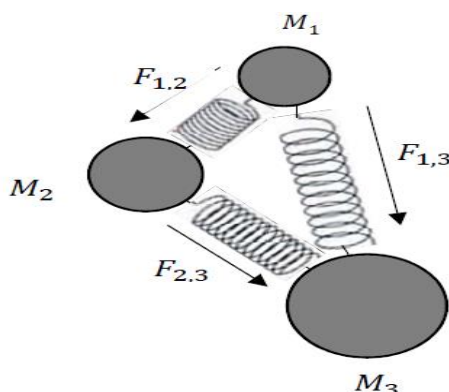


Figure 3: Objects Displaced According to Spring Force [33]

2. Spring search algorithm for MPPT model

The objectives of this research were realized through the implementation of spring search algorithm with boost and dual-sepic converter.

2.1 Objective function and constraints

The problem presented in this research is non-linear, as such, in this research the maximum power point of the PV array is to be optimized. Therefore, the power is the objective function that the algorithm is required to optimize while voltage and current are the decision variables, this is expressed using equation 6 [22]:

$$P_m = \sum_{z=1}^n V_{mz} I_{mz} \quad (6)$$

Where, n is the number of the solar panels, V_{mz} is maximum voltage of solar panel numbered z , I_{mz} is the maximum current of solar panel numbered z .

The duty cycle (D) value of the converter is equal to the reference voltage (V_{ref}), which is equal to the summation of the maximum voltage (V_{mz}) shown using equation 7:

$$V_{ref} = \sum_{z=1}^n V_{mz} \quad (7)$$

The voltage and current of the PV array are constrained due to the characteristics of the component of the solar panel. Therefore, in SSA-PO the following constraints are considered as shown in equation 8 [28].

$$\begin{cases} 0 < V_{mz} < V_{ocm} \\ 0 < I_{mz} < I_{scm} \end{cases} \quad (8)$$

Where, V_{ocz} is the open circuit voltage of solar panel numbered z , I_{scz} is the short circuit current of solar panel numbered z .

The flowchart of the proposed algorithm is shown in Figure 4. Under load variation, the maximum power point changes and the current flows in opposite direction to the voltage is in contrast to when irradiation changes. The constraint required to determine this state is in equation 9 [22]:

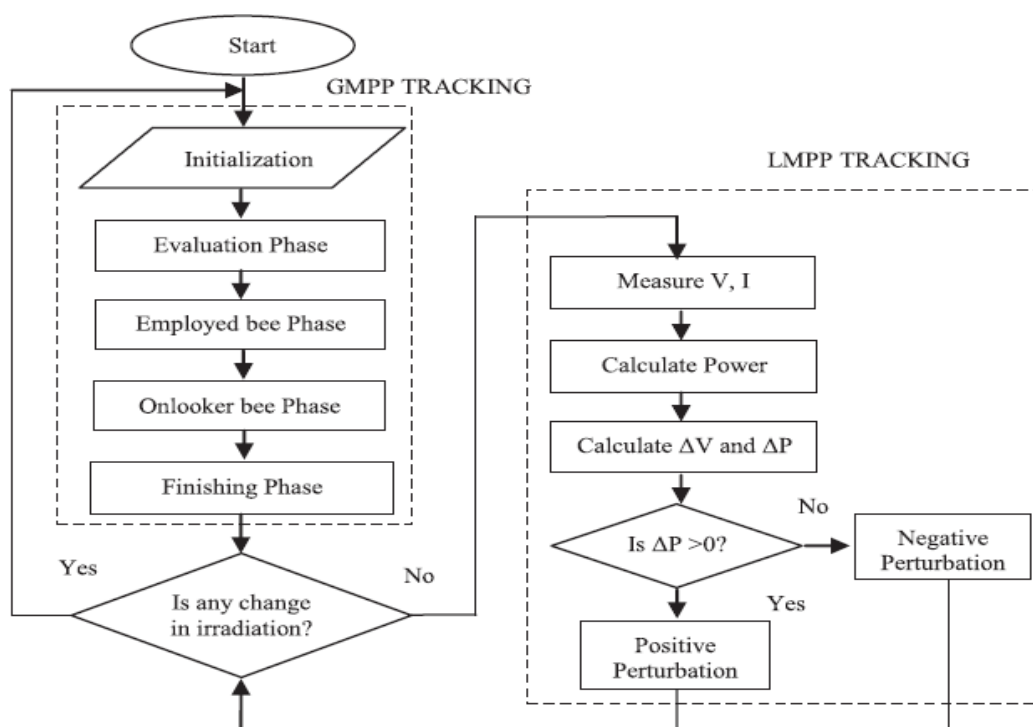


Figure 4: Flow-chart of ABC-PO algorithm [28]

$$\left. \begin{matrix} dV > 0 \\ dI < 0 \end{matrix} \right\} \quad \text{or} \quad \left. \begin{matrix} dV < 0 \\ dI > 0 \end{matrix} \right\} \quad (9)$$

The flowchart of the propose algorithm in Figure 5, showed the start to the termination of the SSA-PO algorithm. First the system environment is formed then initialization and evaluation of object with best fitness position is obtained, which is best power (P_{best}) and duty cycle (D_{best}). The decision block 1, compare the difference between the best power and the other power point. If the difference in power (ΔP) is greater than 0.05 then the process continues, if not the best duty cycle goes to termination phase where it is again evaluated in decision block 2. This decision block monitors the difference between the best power and the other PV powers, this expressed using:

$$\frac{|P_{best} - P_{pv}|}{P_{best}} > 5\% \quad (10)$$

If the value is less than 0.05, then it terminates and the best duty cycle is applied to the converter and the maximum power is tracked and applied to the load. If the difference is greater than 0.05, then another evaluation is done in decision block 3. This decision block determines if the changes in the maximum power point is due to load variation or due to solar irradiance. If the changes are due to load, the direction of the voltage (dV) and the direction of current (dI) will be in opposite direction, and instead of process to re-initialize again the best duty cycle will be obtained and then go to termination phase. If the changes in power is due to solar irradiance, both the direction of the voltage and current will be in the same direction and the process will re-initialize again.

The block 4 of the SSA-PO flowchart determines the duty cycle (D_{best}) when the load is under dynamic condition and the solar intensity is constant. The impedance of the Dual-SEPIC converter is obtained using equation 11.

$$Z_{pv} = \frac{(1-D)^2}{D^2} Z_{load} \quad (11)$$

Where, the output impedance of the converter is equivalent to the connected load. And the input impedance of the converter is equivalent to the impedance of the PV array output. After the GMPP is tracked, the duty cycle D_{best} , voltage V_{best} and current I_{best} , of PV array is stored. When the load varies, these values are substituted into equation 12 to obtain the new load impedance using [22]:

$$Z_{load\ new} = \frac{V_{best}}{I_{best}} \frac{D_{best}^2}{(1-D_{best})^2} \quad (12)$$

When the new load impedance value is obtained, the new duty cycle D_{best} for the PV array to operate at GMPP can be obtained from equation 13 and 14 [22]:

$$D_{best\ new} = \frac{\sqrt{a}}{1+\sqrt{a}} \quad (13)$$

$$a = \frac{I_{best}}{V_{best}} Z_{load\ new} \quad (14)$$

2.2 PV Array Specification

The parameters of a single PV module at standard temperature of 25°C and insolation of 1000W/m² are

shown in Table 1. In this work, the PV array is made up of 2 modules connected in series [28]. To generate the required P-V and I-V curve, three shading conditions are presented, which are:

- When the array are unshaded PSC1 (equal sun irradiance, the two modules having 1000W/m² each).
- When the PV array has a shading pattern of 1000W/m² and 500 W/m² PSC2.
- When the PV array has a shading pattern 300W/m² and 800W/m² PSC3.

Table 1: PV Module Specification of Vikram Eldora-37

Parameter	Value
Maximum power (P_{max})	37W
Voltage at MPP (V_{mpp})	17V
Current at MPP (I_{mpp})	2.25A
Open circuit voltage (V_{oc})	21.8V
Short circuit current (I_{sc})	2.8A
Module efficiency	10.10%
Short circuit current temperature coefficient	0.04%/°C

2.3 PV MPPT model under PSC using ABC-PO algorithm

The procedures for the implementation of PV MPPT model under partial shading condition using ABC-PO are described as follows:

- Initialize by determining the colony size.
- Designate half of the colony to employed bees (N_p) which are the decision variables. And let the other half of the colony represents the on looker bees.
- Distribute all employed bees at random location in the search space, expressed using equation 15:
 $Q_i = d_{min} + rand[0,1](d_{max} - d_{min})$ (15)
 Where: $i = 1, 2, \dots, N_p$, d_{min} and d_{max} are the minimum and maximum duty-cycle of the converter selected between 0.1 and 0.9 values.
- Set maximum cycle number (MCN) after initialization is completed. In each cycle the search process restarts and the evaluation of nectar quantity (PV power) is completed.
- Upgrade each employed bee new position in the vicinity. In order to track the food source position with maximum food nectar (GMPP) in the search environment is expressed using equation 16:
 $Q_{i-new} = Q_i + \phi_i [Q_i - Q_k]$ (16)
 Where: $k = (1, 2, \dots, N_p)$ not similar to i , as it is arbitrary selected. ϕ_i is a variable randomly selected between (-1 and 1).
- Evaluate updated new position with previous position to obtain the maximum quantity position, then the onlooker bees come to the maximum nectar position.
- Determine maximum nectar by comparing with probability factor associated with various positions, expressed using equation 17:

$$P_i = \frac{Fit_i}{\sum_{N=1}^{N_p} Fit_i} \quad (17)$$

Where Fit_i is the fitness factor associated with the nectar source.

- h. The process will reinitiates whenever there is variation in power output or change in solar irradiance and is identified by the inequality condition expressed by:

$$\left| \frac{P_{pv} - P_{pv-old}}{P_{pv-old}} \right| \geq \Delta P_{pv} \% \quad (18)$$

- i. Integrate the PO optimizer with ABC-PO to track the LMPP and terminate based on (viii). The power P_i and increase in voltage ΔV used in PO calculation is obtained using equation 19 and 20:

$$P_i = V_i * I_i \quad (19)$$

$$\Delta V = V_i - V_{i-1} \quad (20)$$

- j. Implement partial shading condition for the solar panels in Matlab/Simulink environment using shading patterns in PSC1, PSC2, PSC3 and connect it to boost converter.
- k. Apply the developed algorithm to the switch of the boost converter and determine the output power and make analysis on results obtained.

The flowchart of the ABC-PO algorithm is shown in Figure 4 while Figure 5 shows the Simulink model for the developed ABC-PO. The algorithm provides the duty cycle required for the tracking of the global maximum power and supply it to the resistive load.

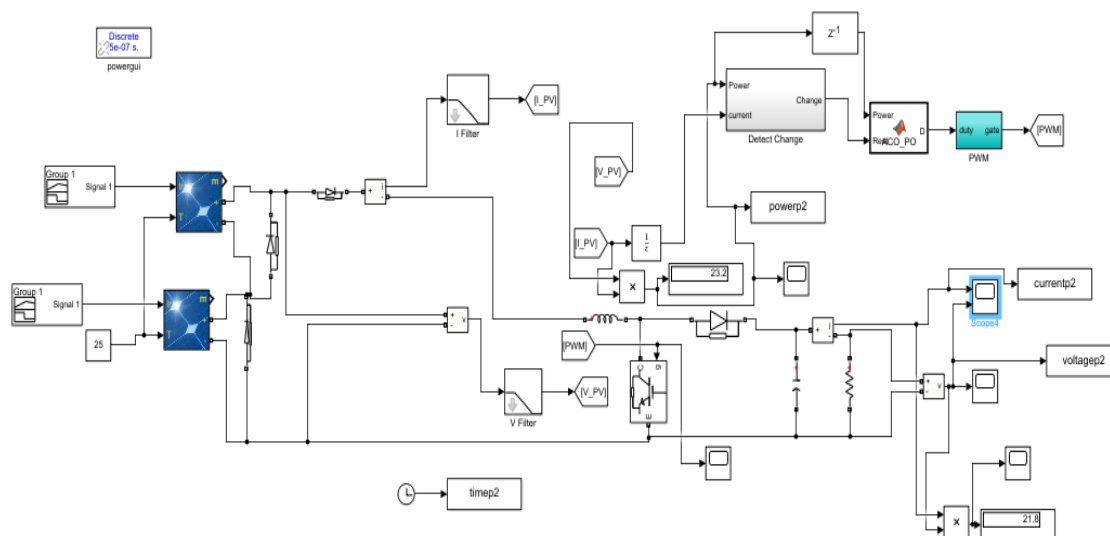


Figure 5: Simulink Model of ABC-PO with Boost Converter

2.4 SSA-PO algorithm with Boost Converter

The development of PV MPPT model under partial shading condition using SSA-PO is described using the following and the flow chart is shown in Figure 6.

- Determine the system space
- Initializing placement of objects (decision variables D_i) randomly in the system space using equation 21:

$$D_i = (D_i^a \dots D_i^d \dots D_i^n) \quad (21)$$

- Evaluate object fitness and obtain P_i using equation (4)
- Determine and select P_{best} and D_{best} from P_i and D_i , which is the power of the solar array and the duty-cycle of the converter.
- Set termination condition if ΔP_i and ΔD_i is $> 5\%$ using equation 10, also shown in block 1 and 2 of the flowchart. Else, the objects will be updated until the condition is met [33].
- Determine the variation in MPP, whether it is due to irradiance or load variation as shown in block 3 of the flowchart in Figure 6.
- Determine $D_{best\ new}$ if load variation occur, else repeat process (i-vi)
- Integrate PO algorithm to determine LMPP and output the result which is used in controlling the duty cycle of the converter.

- Implement partial shading condition for the solar panels in Matlab/Simulink environment using shading patterns PSC1, PSC2, PSC3 and connect it to boost converter.
- Apply the developed algorithm to the switch of the boost converter and determine the output power and make analysis on the results obtained.

Figure 7, shows the developed Simulink model of the proposed SSA-PO algorithm connected to the switching device of the boost converter which has wide acceptance in PV power system as it has good efficiency [29]. The algorithm generates the duty cycle that controls the converter, as such; maximum power tracked by the algorithm is supplied to the resistive load at the output terminal of the converter.

2.5 Dual-Sepic converter with SSA-PO Algorithm

Dual-Sepic converter (zeta converter) is a DC-DC converter which controls the output voltage by stepping up and down of the voltage [30]. Dual-Sepic has advantage of giving a voltage output that is not inverted and free from pulsating current [31]. Figure 8 shows the Simulink diagram of the dual-sepic converter with SSA-PO algorithm.

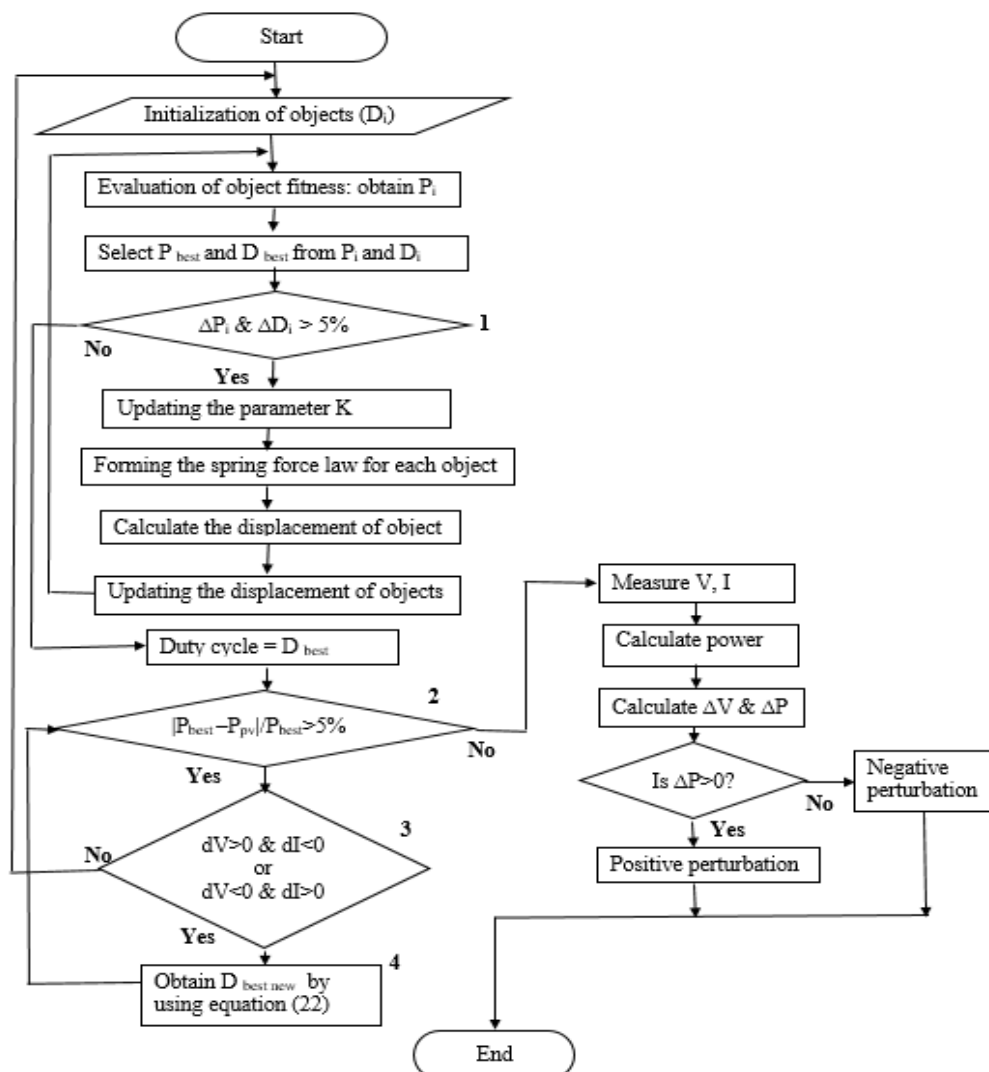


Figure 6: Flow-chart of SSA-PO Algorithm

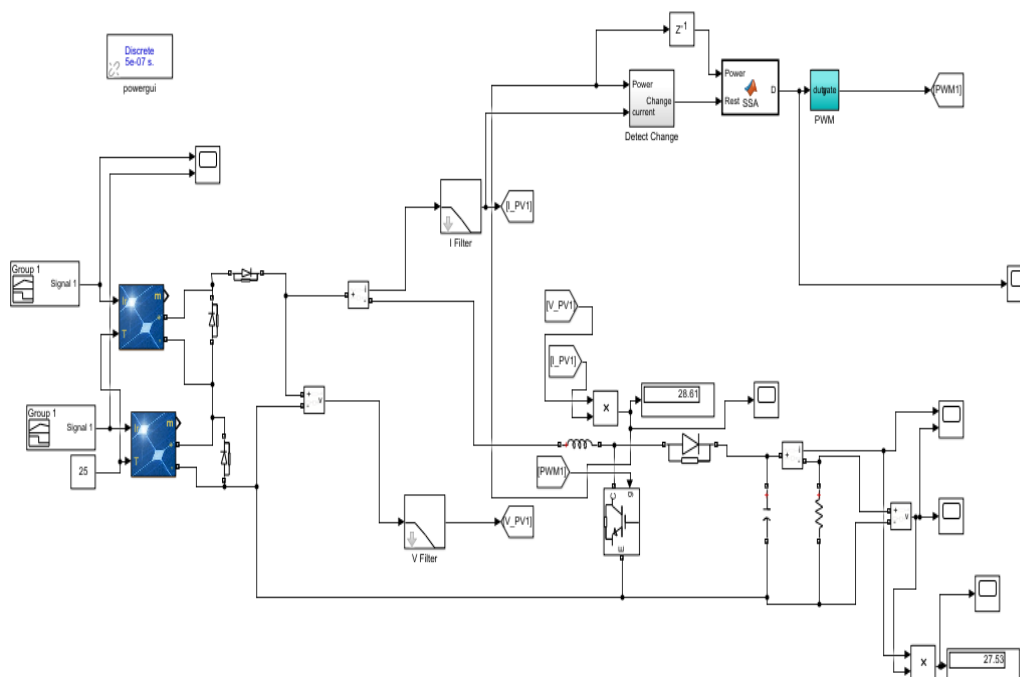


Figure 7: Developed Simulation Model of SSA-PO with Boost converter

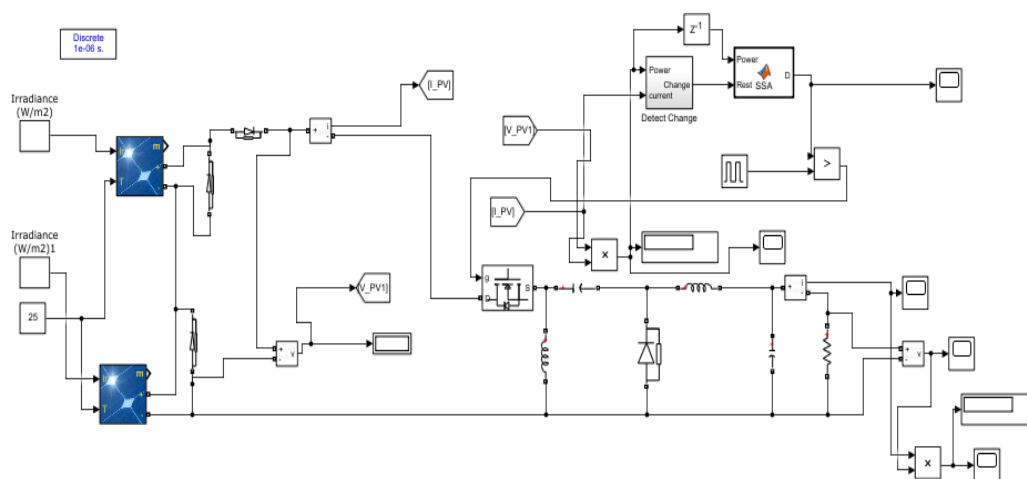


Figure 8: Simulation Diagram of Dual-Sepic Converter with SSA-PO algorithm

3. Result and discussion

In this section, the development of photovoltaic array maximum power point tracking model under partial shading condition with boost converter and dual-sepic converter considering dynamic load is discussed and relevant result are reported. The implementation was carried out in MATLAB/SIMULINK and the result compared with ABC-PO algorithm with boost converter, using efficiency and tracking time as performance metrics.

3.1 Result obtained with ABC-PO method

The Photovoltaic system is simulated in order to obtain the GMPP using the ABC-PO method at constant and when partial shading irradiance occurs as presented in the work of [28].

Figure 9 shows the result obtained with ABC-PO. The power (P) is tracked at 69.06W at time (T) 0.16

seconds as compared to 70.72W of the photovoltaic power of the system at constant irradiance (1000W/m² to 1000W/m²). Therefore, with ABC-PO method, the efficiency is found to be 97.65% with a tracking error of 2.3% at constant solar irradiance. From figure 9, it shows that at time 1 second, the power of the system dropped to 30.63W due to irradiance change from 1000W/m² to 500W/m² PSC2. The ABC-PO tracked the power (P) to be 29.7W at time (T) 1.04 second with tracking efficiency of 96.9% and tracking error of 3.03%.

The voltage-Time plot is shown in Figure 10. The plot showed the voltage at maximum power point (V_{mpp}) which is used to determine the maximum power point of the system. At maximum power point the voltage is found to be 36.24V at constant irradiance. When the partial shading occurred due to irradiance change the voltage dropped to 23.69V.

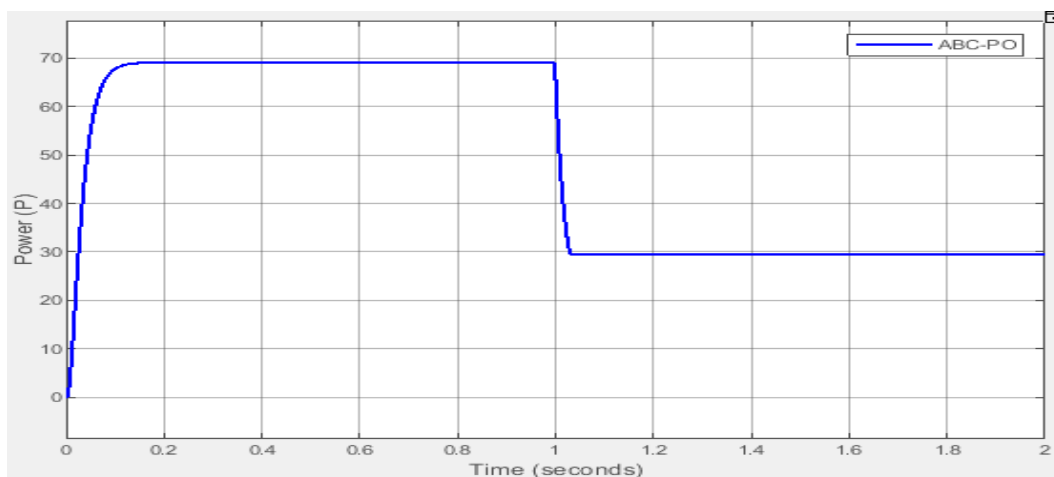


Figure 9: Power-Time Plot PSC1 to PSC2 with ABC-PO

Figure 11 showed the Current-Time plot of current at maximum power point (I_{mpp}), which is used to determine the maximum power point of the system. At maximum power point the current was found to be 1.907A at constant irradiance. While at partial shading when irradiance reduced, 1.2A was obtained at time 1 seconds using ABC-PO method. Figure 12 shows the power-time plot of a

partial shading conditions of PSC2 (1000W/m² and 500W/m²) and PSC3 (800W/m² and 300W/m²). From figure 12, the ABC-PO tracked the power to be 16.13W at time 0.09s. However, at time 1 second the irradiance changed and the power output increases due to increase in solar irradiance on the PV array. The ABC-PO tracked the power to be 21.76W at time 1.056 second.

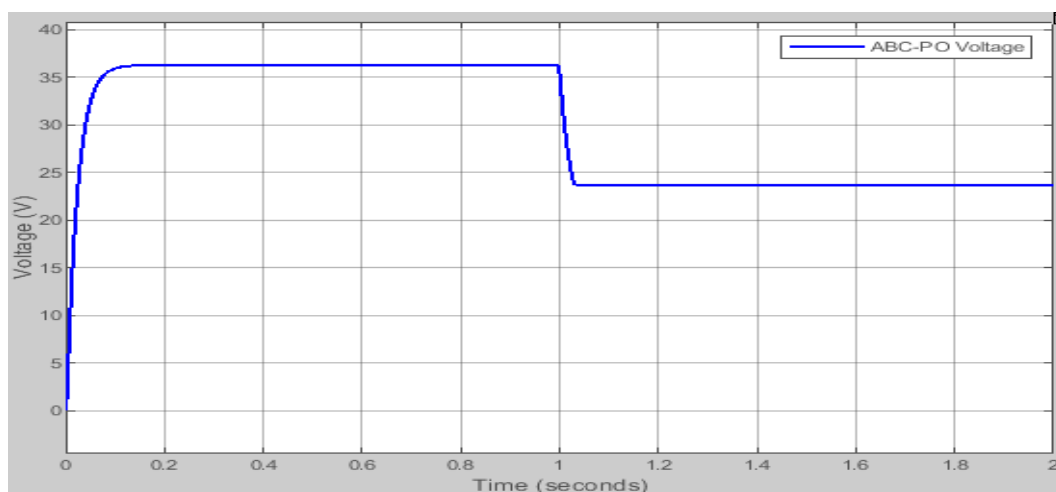


Figure 10: Voltage-Time Plot of ABC-PO

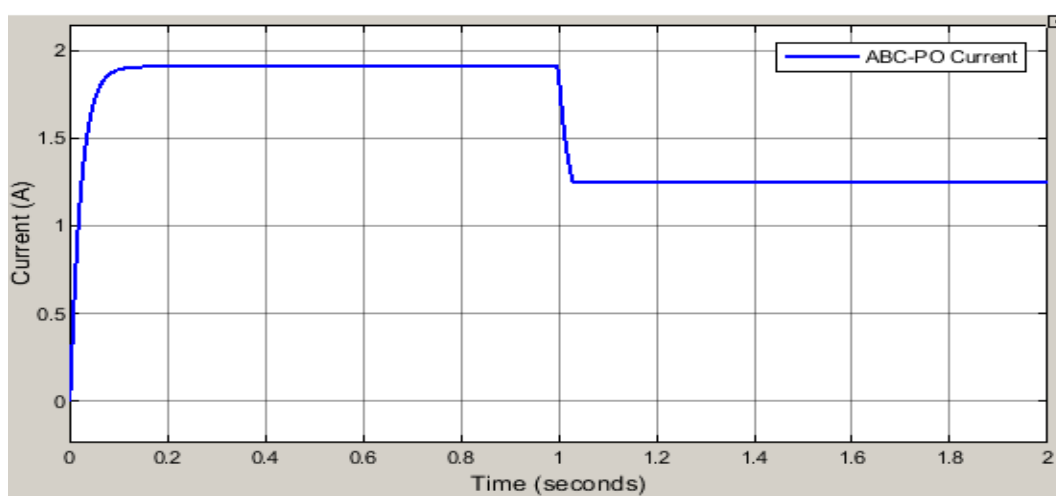


Figure 11: Current-Time Plot of ABC-PO

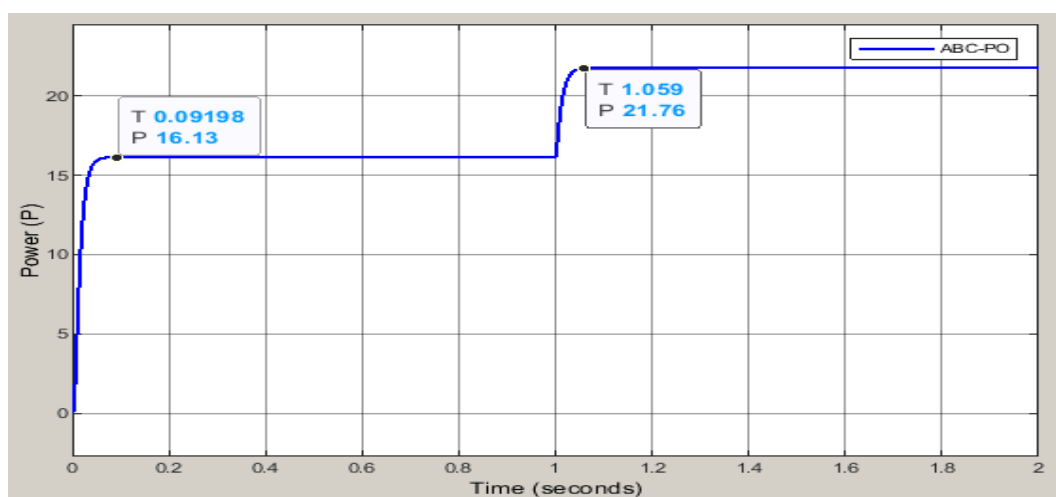


Figure 12: Power-Time Plot of PSC2 to PSC3

3.2 Result obtained with SSA-PO method

In this section the developed technique is used to track the GMPP from the solar array at constant and partial shading condition. From Figure 12, it shows the power tracked when the solar array is under PSC1 and PSC2, when irradiance changes from 1000W/m^2 to 500W/m^2 . The SSA-PO tracked the power to be 73.55W at time 0.149

second as compared to the 75.19W of the photovoltaic system at constant irradiance. The tracking efficiency was found to be 97.8% with tracking error of 2.18% at constant solar irradiance.

From Figure 12, at time 1 second the irradiance changed from 1000W/m^2 to 500W/m^2 and the power dropped. The SSA-PO tracked the GMPP and the power

was found at 27.5W at time 1.075 seconds compared to 28.55W of the photovoltaic system during partial shading condition. This reduction in power output was due to the reduction in solar irradiance received by the solar array. At this condition the tracking efficiency was 96.3% with tracking error of 3.6%.

Figure 13 showed the voltage-Time plot at maximum power point (V_{mpp}) which determines the maximum power point of the system. At maximum power point the voltage

was found to be 37.23V at constant irradiance. When the partial shading occurred due to irradiance change the voltage dropped to 22.83V.

Figure 14 showed the current plot at maximum power point (I_{mpp}), this determines the maximum power point of the system. At maximum power point the current was found to be 1.961A at constant solar irradiance, and 1.204A at partial shading condition with SSA-PO method.

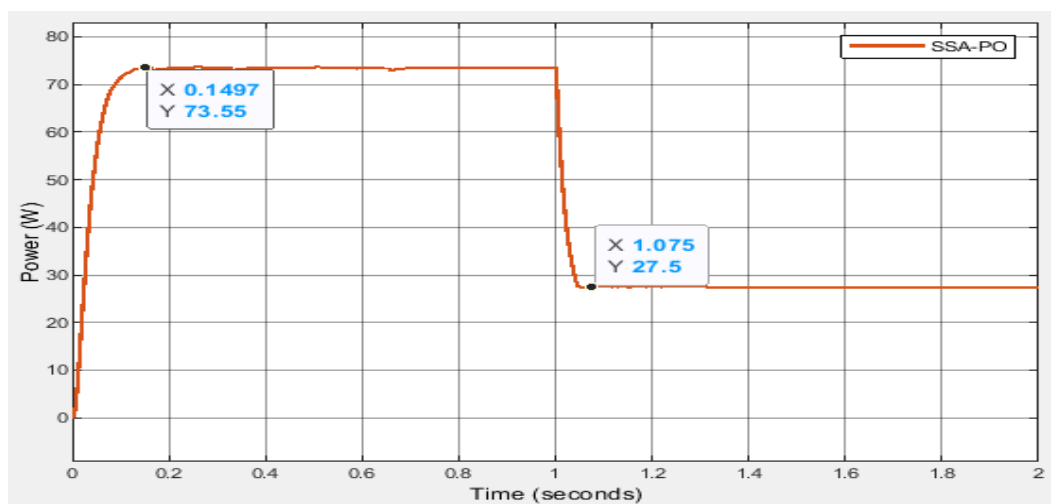


Figure 12: Power-Time plot of PSC1 to PSC2 with SSA-PO Method

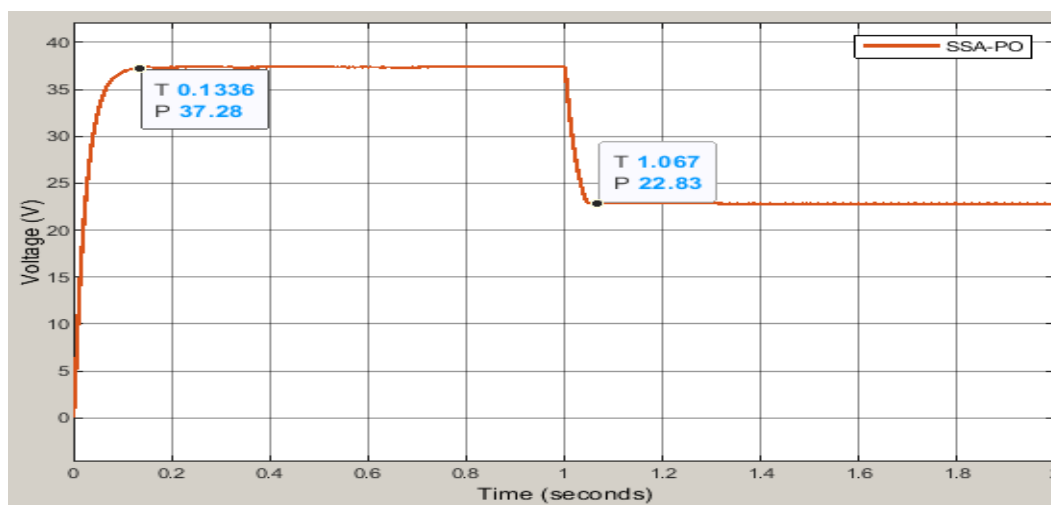


Figure 13: Voltage-Time Plot of SSA-PO

Figure 15 shows the power-time plot of a partial shading conditions PSC2 (1000W/m² and 500W/m²) and PSC3 (800W/m² and 300W/m²). From figure 15 the SSA-PO tracked the power to be 19.95W at time 0.1s. However, at time 1 second the irradiance changed and the power output increases due to increase in solar irradiance on the PV array. The SSA-PO tracked the power to be 27.51W at time 1.029 second, which indicated power increase due to solar irradiance increase.

3.3 Comparison of ABC-PO and developed method

Under constant irradiance and partial shading condition, the result of the developed method and ABC-PO

method were compared. It was established that the SSA-PO performed better during constant solar irradiance than ABC-PO, having tracking efficiency of 97.8% compared with 97.65% obtained from ABC-PO method, thereby adding an improvement of 0.15% on the maximum power.

At partial shading condition the power dropped and ABC-PO performed slightly better than SSA-PO having tracking efficiency of 96.9% compared with 96.3% from the latter. The ABC-PO had a better performance of 0.6% on the maximum power respectively.

Table 2 showed the comprehensive results of the developed method using boost converter and comparing with ABC-PO algorithm operating under constant and partial shading conditions. From the table it was observed

that at PSC1 the developed method has improved tracking time of 6.8% and improved tracking efficiency of 0.15% compared with ABC-PO. At PSC2 ABC-PO has better

performance compare with SSA-PO, and during partial shading PSC3, SSA-PO performed better compared with ABC-PO respectively.

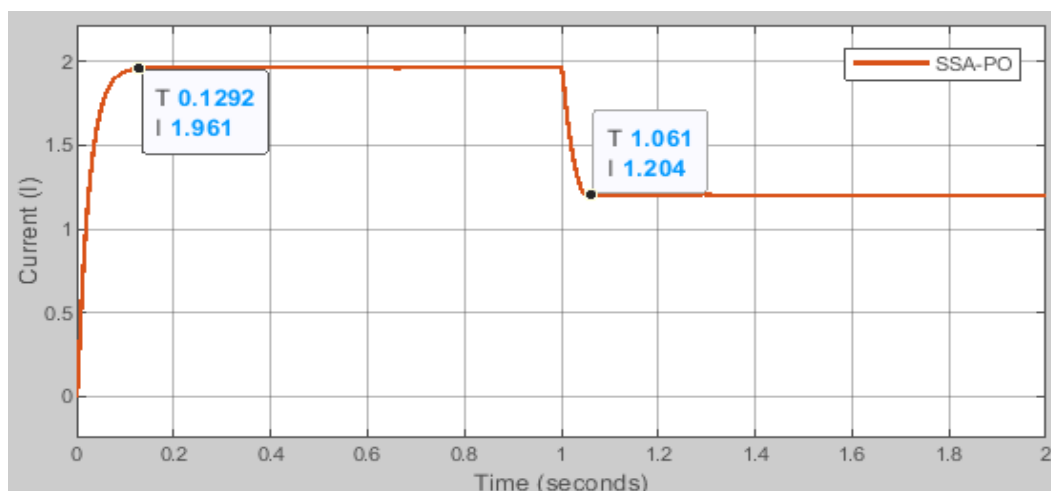


Figure 14: Current-Time Plot of SSA-PO

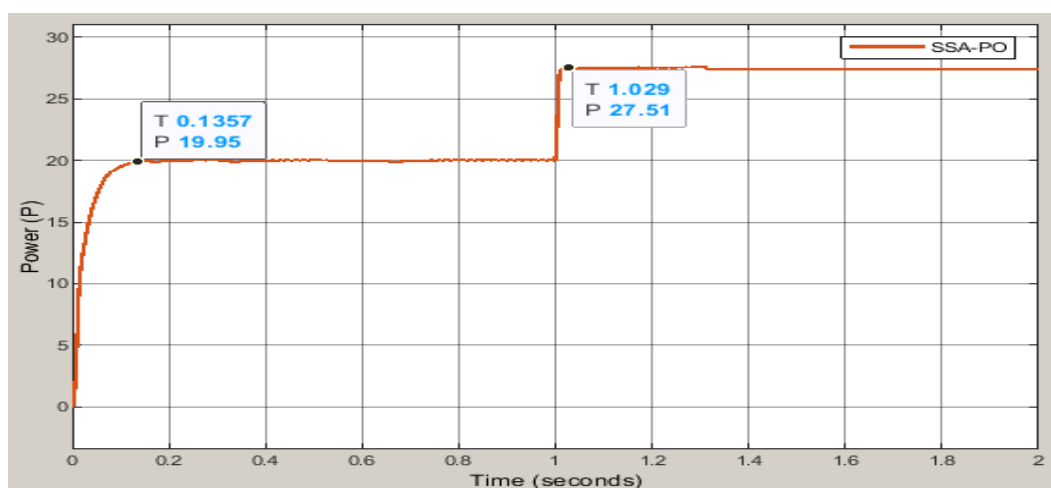


Figure 15: Power-Time Plot of PSC2 to PSC3

Table 2: Results obtained from developed method and ABC-PO at partial shading condition PSC1, PSC2 and PSC3.

Parameter Description	ABC-PO (PSC1, PSC2, PSC3)	Developed method (PSC1, PSC2, PSC3)	% Improvement (PSC1, PSC2, PSC3)
Tracking Time (sec)	0.16, 1.04, 1.056	0.149, 1.075, 1.029	6.8, -3.3, 2.5
Open-circuit Voltage (V)	36.24, 23.69, 20.05	37.23, 22.83, 22.8	0.99, -0.86, 2.75
Short-circuit Current (A)	1.907, 1.2, 1.09	1.96, 1.204, 1.207	2.78, 0.33, 10.7
Maximum Power point (W)	69.06, 29.7, 21.76	73.55, 27.5, 27.51	6.5, -7.4, 26.4
Relative Error (%)	2.3, 3.03, 2.32	2.18, 3.6, 0.01	0.12, -0.57, 2.31
Tracing Efficiency (%)	97.65, 96.9, 94	97.8, 96.3, 96.29	0.15, -0.6, 2.29

3.4 SSA-PO with dual-sepic considering dynamic load

The results of SSA-PO with Dual-Sepic converter are presented in this section. SSA-PO algorithm is used to control the duty cycle of the Dual-Sepic converter to determine the maximum power point of the photovoltaic array while considering the variation of the load at the output of the converter at constant and PSC. When load variation occurs the current and voltage of the system will be in opposite direction and the algorithm will control the switching of Dual-Sepic converter to track the GMPP within

a short period of time. Figure 16, showed the power-Time plot of SSA-PO with dual-sepic converter at constant and partial shading condition. At time 0.05 seconds the algorithm tracked the power at 5w and during partial shading the power was tracked at 4.6w at 1.01 seconds. From the result as shown in table 3, it was observed that the SSA-PO performed better when tracking maximum power point with boost converter compared with dual-sepic converter. However, it was observed that the dual-sepic converter has faster tracking time compared with boost converter which is recommended in dynamic load conditions.

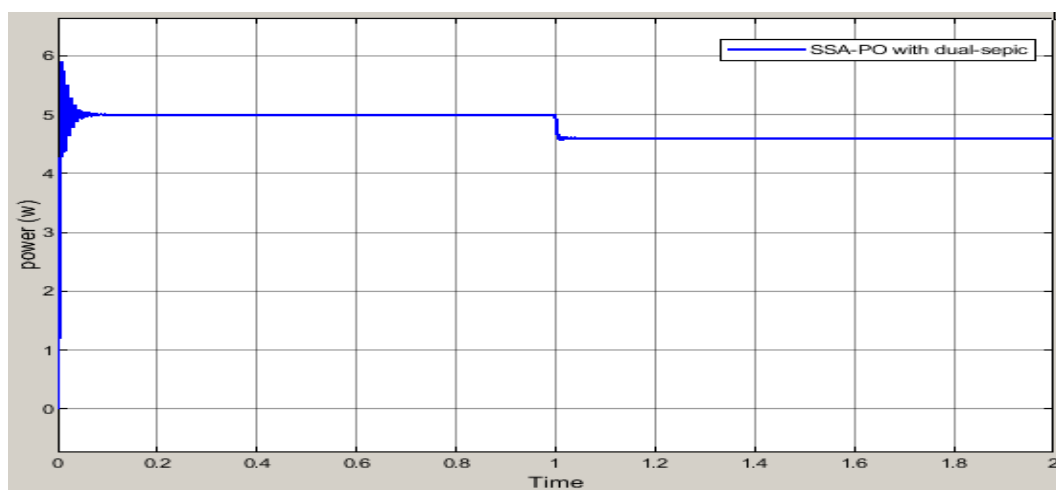


Figure 16: Power-Time Plot for SSA-PO with Dual-Sepic Converter

Figure 17 showed the voltage-time plot for the SSA-PO algorithm with dual-sepic converter employed for tracking of the maximum power under constant and partial shading irradiance conditions. At constant solar irradiance the voltage was tracked at 10V at time 0.05 seconds, and at PSC the voltage was tracked at 9.6V at time 1.01 second.

Figure 18 showed the Current-time plot for the SSA-PO algorithm with dual-sepic converter employed for tracking of the maximum power under constant and partial shading irradiance conditions. At constant solar irradiance the current was tracked at 0.5A at time 0.05 seconds and at PSC the current was tracked at 0.48A at time 1.01 seconds respectively.

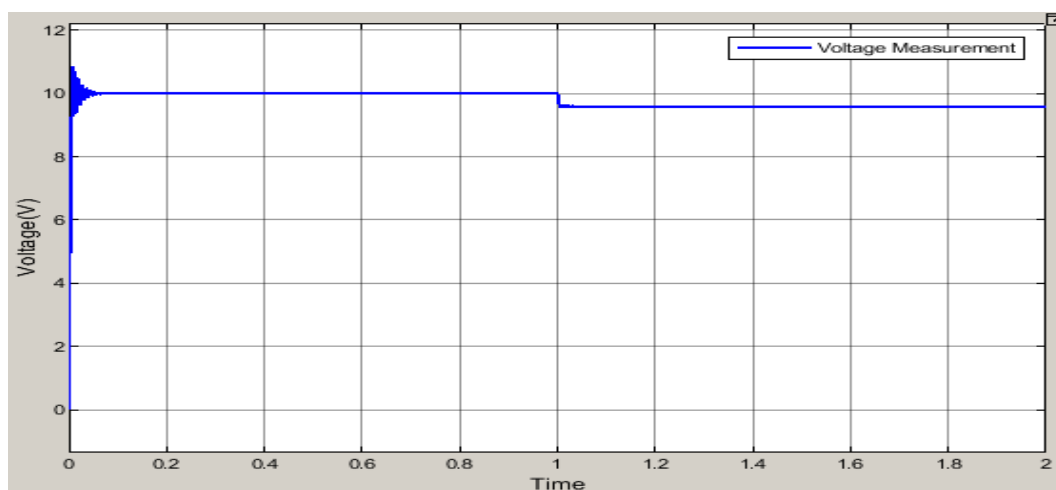


Figure 17: Voltage-Time plot for SSA-PO with Dual-Sepic Converter

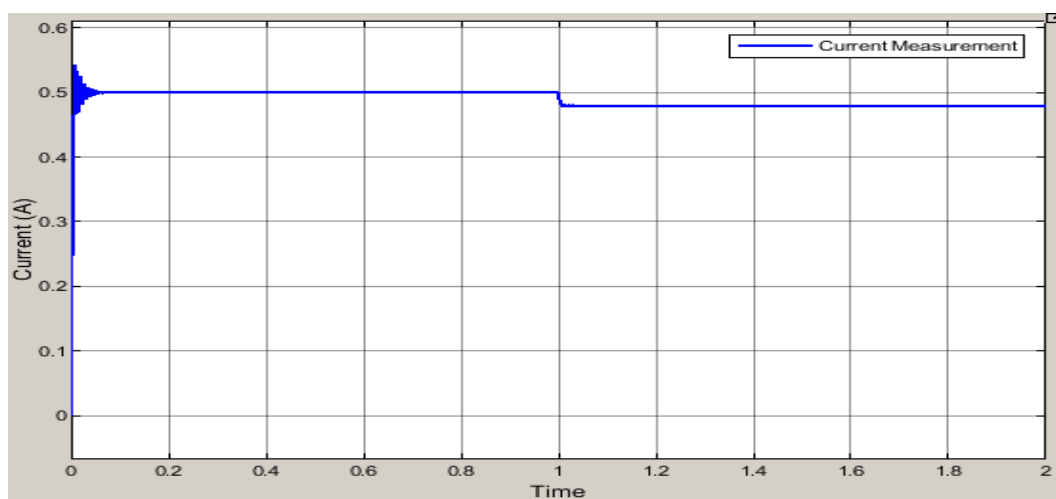


Figure 18: Current-Time plot for SSA-PO with Dual-Sepic Converter

Table 3: Results obtained from SSA-PO algorithm with dual-Sepic converter and SSA-PO with boost converter at constant and PSC

Parameter Description Sepic	SSA-PO dual- (PSC1 PSC2)	SSA-PO boost (PSC1 PSC2)	% Performance (PSC1 PSC2)
Tracking Time (sec)	0.05, 1.01	0.149, 1.075	66.4, 6.0
Open-circuit Voltage (V)	10, 9.69	37.23, 22.83	73.1, 57.5
Short-circuit Current (A)	0.5, 0.4796	1.96, 1.204	74.49, 60.16
Maximum Power point (W)	5, 4.6	73.55, 27.5	93.2, 83.27
Tracing Efficiency (%)	24.75, 23	97.8, 96.3	73.05, 73.3

Table 3, gives the detailed result obtained from SSA-PO with dual-sepic converter and compared with SSA-PO with boost converter. It was observed that, the dual-sepic converter with SSA-PO has a faster tracking time of 0.05 seconds and 1.01 seconds compare to SSA-PO with boost converter at constant and PSC, which is suitable for dynamic load conditions. It was also observed that the SSA-PO with boost converter has better power output efficiency of 73.05% and 73.3% at constant and partial shading condition compare to SSA-PO with Dual-Sepic converter.

4. Conclusion

This research presents the development of maximum power tracking method of a PV system under constant and varying solar irradiance condition with dual-Sepic converter considering dynamic load. In this work, a DC-DC boost converter was modelled and employed between the PV array and the load. A spring search algorithm integrated with Perturb and observes (SSA-PO) MPPT was developed to determine the duty-cycle of the boost converter. Also, a DC-DC Dual-SEPIC converter was modelled and SSA-PO algorithm was employed to control the converter duty-cycle for maximum power tracking under partial shading and load variation. Finally, the developed method result was compared with the performance of ABC-PO using tracking efficiency and time as performance metrics.

The developed work obtained 0.15% and 2.29% improvement in tracking efficiency compared with ABC-PO respectively under constant and partial shading condition. Also, the developed method obtained 8.6% and 2.5% improvement in tracking time under constant and partial shading condition compare with ABC-PO method.

The dual-sepic converter with SSA-PO has a faster tracking time 0.05 seconds and 1.01 seconds compare to SSA-PO with boost converter at constant and PSC, which is suitable for dynamic load conditions. However, SSA-PO with boost converter has better power output efficiency of 73.05% and 73.3% at constant and partial shading condition compare to SSA-PO with Dual-Sepic converter.

Declaration

On behalf of the authors, the corresponding author declares that there is no conflict of interest.

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