Design and Analysis of PSOA and CSA Based MPPT Algorithms for Partial Shading Conditions

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Abstract-Due to the increased energy demand on the electricity grids, non-conventional energy sources (NCES) like PV, wind power plants are encouraged to establish and operate with the grid. Out of the available NCES, Photovoltaic generating systems (PVGS) are widely penetrated to the grids. As the output power extracted from the PVGS is non-linear in nature, it becomes fluctuating depending on the available Irradiance (G), Temperature (T) and partial shading conditions (PSC). So, there is a need for the development of maximum power point tracking (MPPT) algorithms in the PVGS for maximizing the output power and minimizing the fluctuations. In this article, design and analysis of two advanced MPPT algorithms namely particle swarm optimization Algorithm (PSOA) and cuckoo search Algorithm (CSA) is presented. These two algorithms are used to control the duty cycle of boost converter in order to maximize the PVGS output power. The proposed design is modelled using Matlab/Simulink software and the results were obtained and analyzed.

Keywords – MPPT algorithm, PV generating system, Particle Swarm Optimization algorithm, Cuckoo search algorithm, Partial shading conditions.

I. Introduction

Now-a-days, the electricity grids are overloaded due to the increased power consumption by the industrial as well as the domestic consumers. For this reason, the generating capacities of the existing power plants should be increased, or else new power plants are to be installed. Due to the limitations of transmission line capacities, new power plants are encouraged to install. While conventional energy sources are decreased day to day, NCES are encouraged to establish and operate with the existing grids. Among all the available NCES, PVGS are the widely used sources due to its availability and ecofriendly nature. The total NCES installed in the world up to the year 2019 as per the article of Renewable capacity statistics 2020 by International renewable energy agency is 2536853 MW and the solar energy capacity is 586434 MW [1]. The PVGS systems comprises of number of PV arrays which are connected in parallel and series structures depending on the requirement of output voltage and current. The basic design modelling of PV array is discussed in [2]. The major drawback of PVGS is having the fluctuating output power due to G and T variations throughout the day, due to this reason a charge controller comes into existence which contains the MPPT algorithm to maximize the PVGS power. The most widely used MPPT algorithms are discussed in [3], which only works for the single peak operating point in the P-V curve. For the PSC case where there will be a multiple peak occurs in the system [4, 5]. Identifying the global peak from the multiple peak is not possible with the basic MPPT algorithms, to identify the global peak under PSC advanced MPPT algorithms like PSOA and CSA is used [6]. To know the global peak the complete characteristics of the PV array and its connection structures should be analyzed, the different connection structures of PV arrays is discussed in [7, 8]. This paper uses a 250 W Taiwan semiconductor Manufacturing TS-250P4-AD panels to design an array, the maximum capacity of the PVGS is 1000 W. This paper models the PVGS along the PSOA and CSA MPPT to maximize the output power of the PVGS. This paper proposes the PSOA and CSA MPPT algorithms to identify the global peaks in the PVGS under PSC conditions to reduce the power losses in the system and the results were compared and analyzed.

The rest of the paper is organized as follows. Section II presents the Modelling of PVGS under PSC. Section III introduces the description of PSOA. Section. IV introduces the description of CSA. section V presents the simulation results of the proposed system and section VI concludes the article.

II. MODELLING OF PVGS UNDER PSC

The basic connection styles for Modelling the PVGS under PSC are mainly classified in to three types. The first one is the parallel tied modules, the second one is the series tied modules and the last one is the cross tied modules. Out of three connection styles series tied modules are highly effected under PSC's as discussed in [7, 9-10]. For this reason, in this article series tied modules are considered for extracting the electrical characteristics of the PVGS.

2.1 Effects PSC on PVGS –

The PVGS is formed by connecting four modules in series as shown in Fig. 1. The output electrical characteristics of this connection is shown in Fig. 2, which shows the multiple peak occurs under PSC conditions.

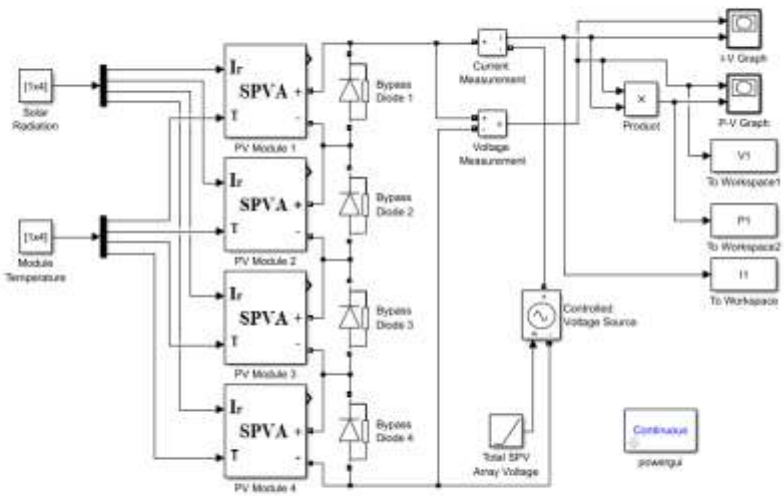
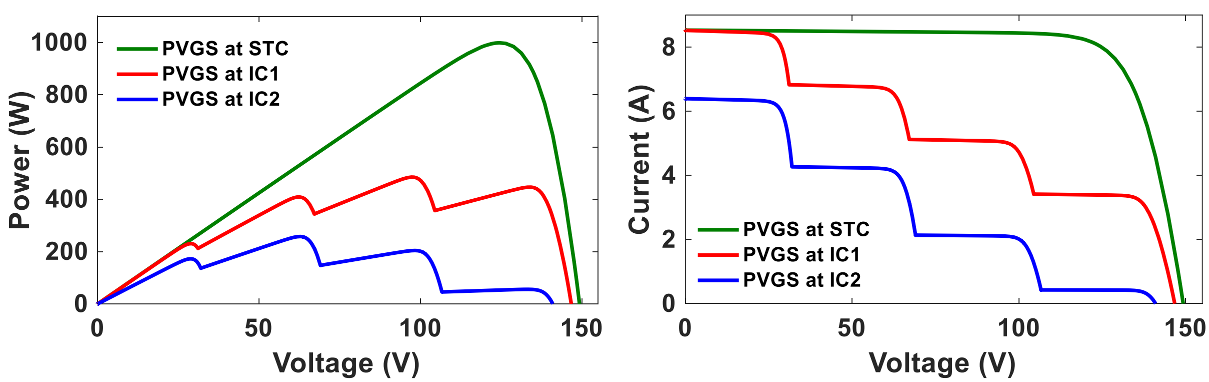


Figure 1. PVGS with Series Tied Modules

For the analyzing the effects of PSC and for extracting the electrical characteristics of PVGS three case studies have been taken by varying the G. For case study 1 the value of G and T are taken at standard test conditions (STC) i.e., G is taken as 1000 W/m^2 for all the PV modules and T is kept constant at 25 ℃. For case study 2 the values of G are taken as 1000 W/m^2, 800 W/m^2, 600 W/m^2, 400 W/m^2 for 4 PV modules respectively, these values are considered using irregular conditions 1 (IC1) which represents PSC on the PV panels and the T is taken as 25 ℃, and similarly for the case study 3 also irregular conditions 2 (IC2) are considered and the G values are 750 W/m^2, 500 W/m^2, 250 W/m^2, 50 W/m^2 and the T is taken as 25 ℃.



(a) (b)

Figure 2. PVGS with Series Tied Modules

From the characteristics of PVGS multiple peaks occurs in the P-V curves, and for identifying the global peak from the multiple peaks advanced MPPT algorithms like PSOA and CSA is used in this paper.

III. PARTICLE SWARM OPTIMIZATION ALGORITHM

PSOA was developed based on the mammalian swarm actions, in which each mammalian was taken as an particle in order to get the objective function globally [11]. In this algorithm by using (1) and (2) the swarm velocity is identified and used to adjust the current position (CP) [6].

$$v_i^{1+K} = \omega_o v_i^k + r_1 c_1 (G_{best} - CP_i^k) + r_2 c_2 (P_{best} - CP_i^k) \quad (1)$$

$$CP_i^{1+K} = CP_i^k + v_i^{k+1} \quad (2)$$

where,

c_1, c_2, and r_1, r_2 = random values taken from 0 to 1
ω_o = weight of Inertia
P_{best} = Personal best
G_{best} = Global best

Mainly, PSOA works to identify the P_{best} duty cycle (D) and it will be stored in the PWM box. This algorithm initializes the value of D randomly and stores it in a matrix form. The algorithm runs if the system requires power to the load. The flowchart for the PSOA is shown in Fig. 3.

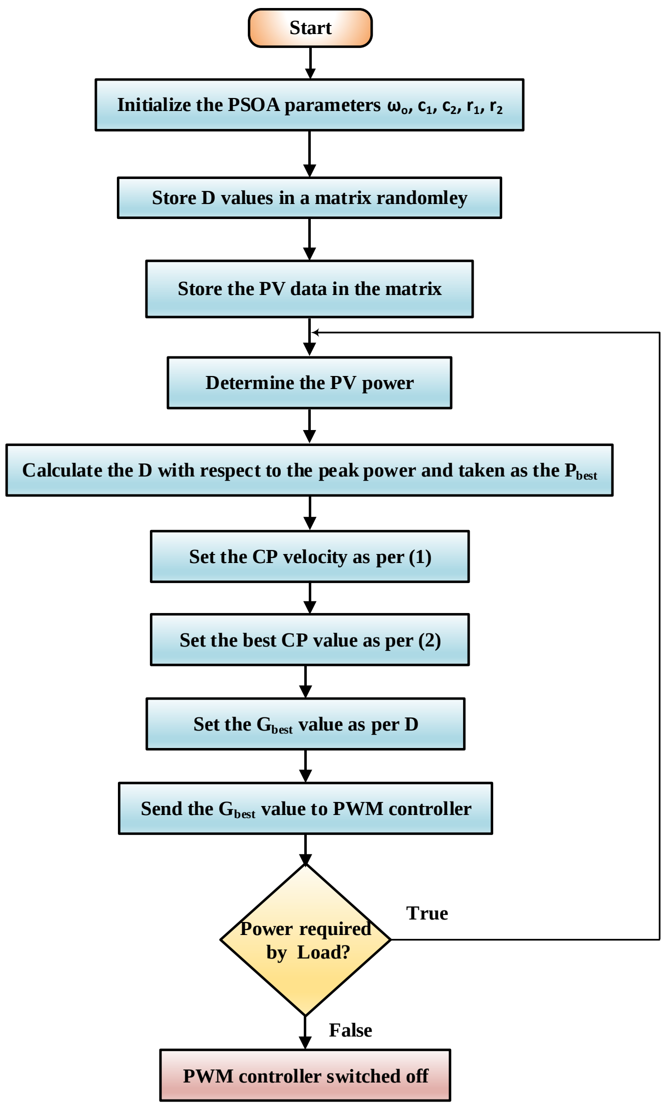


Figure 3. Working flowchart of PSOA

IV. CUCKOO SEARCH ALGORITHM

CSA was developed based on the reproduction parasitism of cuckoo, the optimization function was discussed in [12]. In this algorithm by using (3) and (4) the Levy flights are used to update the D in terms of Gamma function (γ) [6].

$$\delta = \left[\frac{\gamma(\beta+1) \times \sin\pi \times \left(\frac{\beta}{2}\right)}{\gamma\left(\frac{\beta+1}{2}\right) \times \beta \times 2^{\frac{\beta-1}{2}}} \right]^{\frac{1}{\beta}} \quad (1)$$

$$CP_i^{1+K} = CP_i^k + \alpha \times G_{best} \times \frac{|u|}{|v|^{\frac{1}{\beta}}} \quad (2)$$

where,

u = uniformly distributed matrices of value 1

v = uniformly distributed matrices of value δ

Mainly, CSA works to identify the G_{best} value of D and it will be stored in the PWM box. This algorithm initializes the value of D randomly and stores it in a matrix form. The algorithm runs if the system requires power to the load and ignores the worst solutions and replace them by new nests. The flowchart for the CSA is shown in Fig. 3.

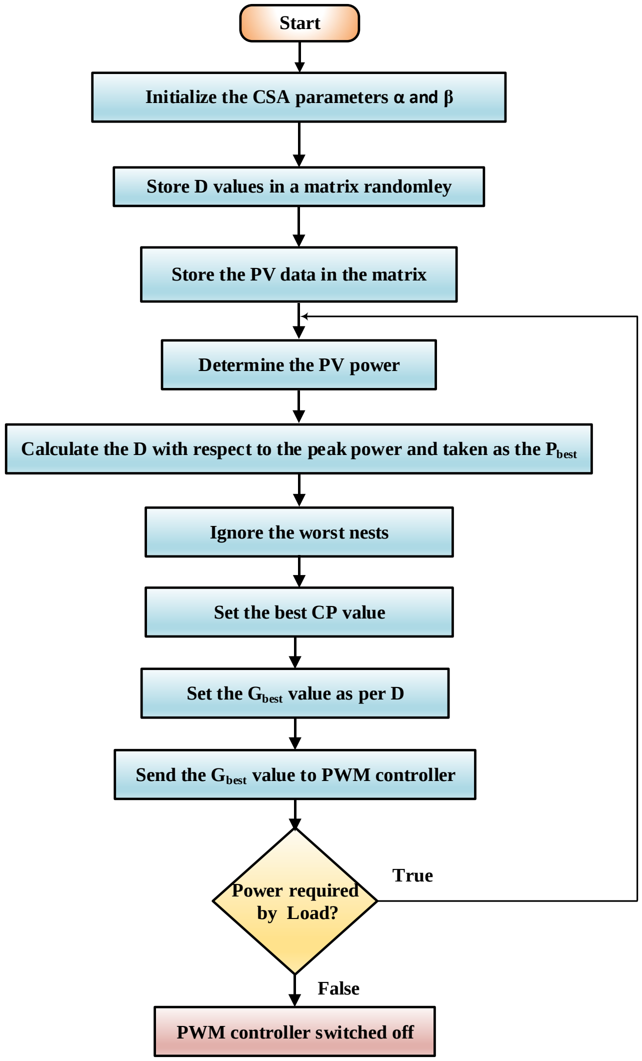


Figure 4. Working flowchart of CSA

V. Simulation outcomes

The simulation circuit of the designed PVGS system with PSOA and CSA MPPT algorithms are shown in Fig. 5 and Fig. 6 respectively. The simulation parameters for the system is presented in Table. I.

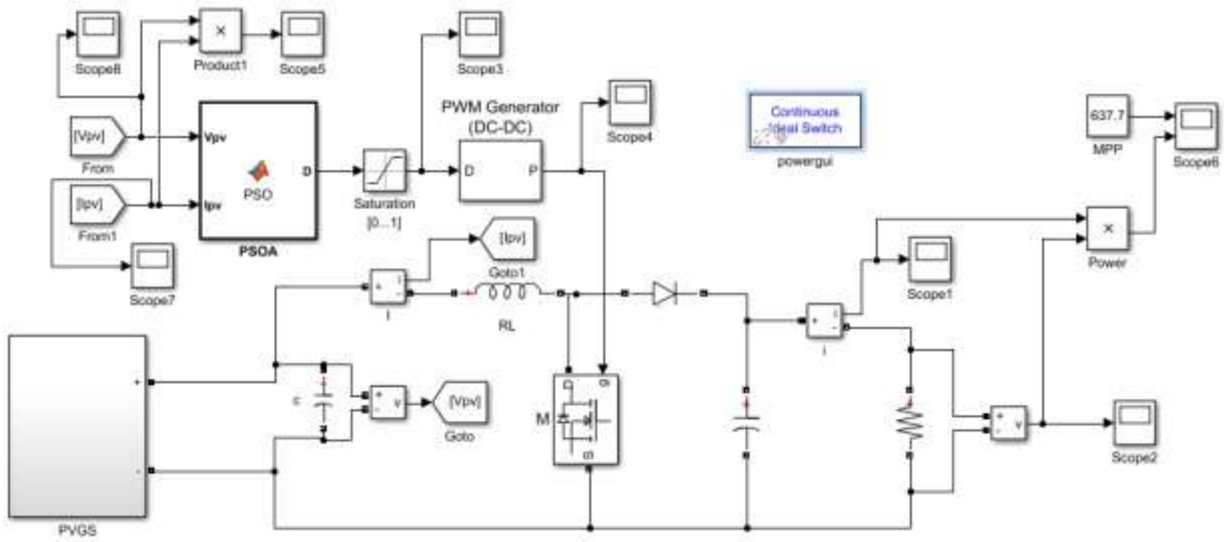


Figure 5. Simulation Circuit of PSOA

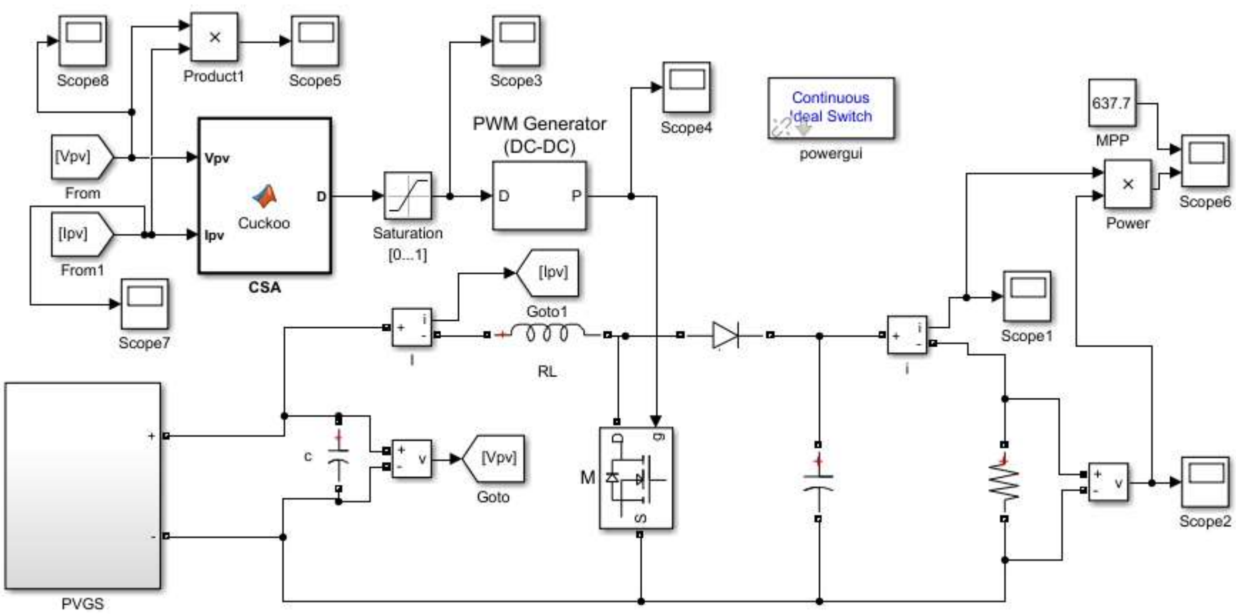
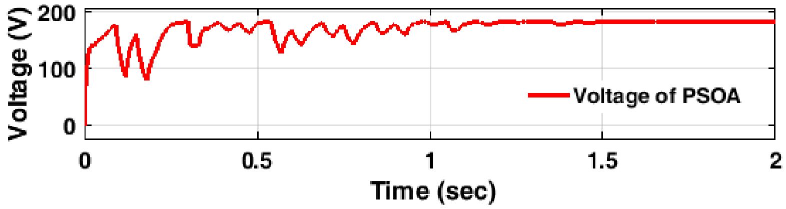


Figure 6. Simulation Circuit of CSA

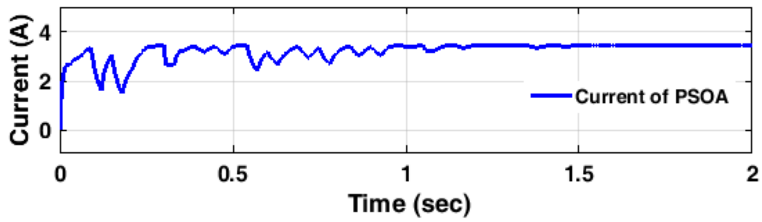
Table -1 Specifications of single PV module

Parameters	Ratings
Module Power	**250 W**
Open circuit voltage, V_{oc}	**37.32 V**
Short circuit current, I_{sc}	**8.5 A**
Cells per module	**60**
Voltage at MPP, V_{mp}	**31.14 V**
Current at MPP, I_{mp}	**8.03 A**

For result verifications PSC conditions are considered and the G values are taken as 500 W/m^2, 1000 W/m^2, 800 W/m^2, 1000 W/m^2 on the 4 modules respectively. The simulation results of PSOA shows that the voltage and current waveforms has some oscillations, and it takes 1 to 1.5 sec to track the mpp point. Fig. 7 shows the simulation results of PVGS with PSOA.



(a)



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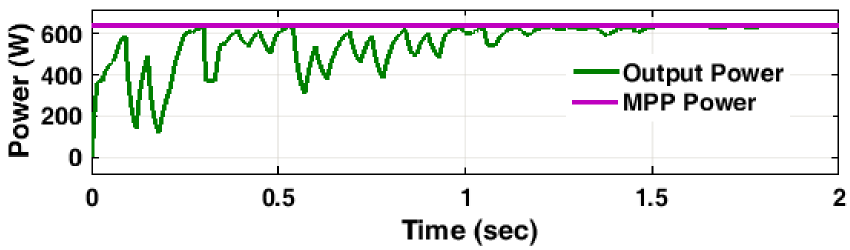
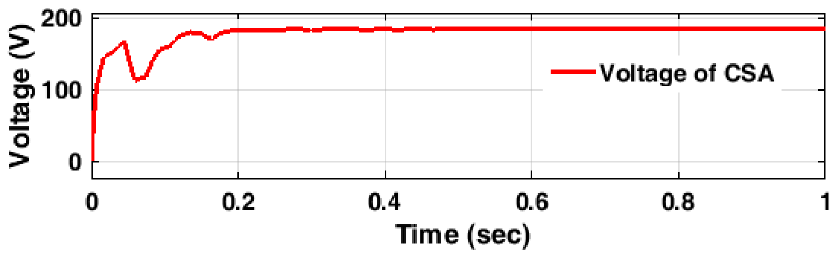


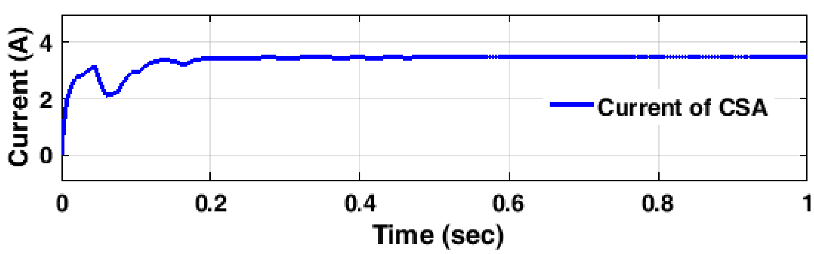
(c)

Figure 7. Simulation results for PSOA. (a) Voltage (b) Current (c) Output power vs MPP power

Similarly, the simulation results of CSA shows that the voltage and current waveforms has less oscillations as compared with the PSOA, and it takes around 0.2 sec to track the mpp point. Fig. 8 shows the simulation results of PVGS with PSOA.



(a)



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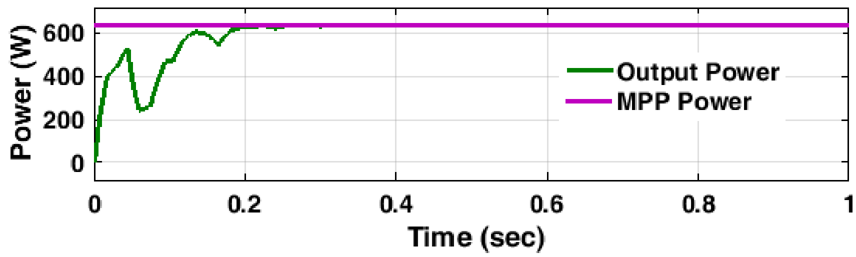

(c)

Figure 8. Simulation results for CSA. (a) Voltage (b) Current (c) Output power vs MPP power

As compared with the results of PSOA with the CSA, CSA has the better tracking speed, better performance and less oscillations in the power.

IV.CONCLUSION

This article presents the design modelling of PVGS system with advanced MPPT algorithms for PSC. The electrical characteristics of the PVGS system is extracted under different operating conditions using three case studies, which shows the multiple peaks occurs in the P-V curve when the system exposed to the PSC. For effective tracking under PSC conditions in this paper PSOA and CSA algorithms were analyzed using different values of G and T. From the results is clear that CSA has better performance, fast tracking, less oscillations in the output power and leads to high efficiency output when compared with the PSOA under PSC.

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