www.rericjournal.ait.ac.th

Comparison Method of PSO and DE Optimization for MPPT in PV Systems under Partial Shading Conditions

Neethu M.*[,1] and R. Senthilkumar*

Abstract – *Solar power is the conversion of energy from sunlight into electricity by using photovoltaic cell. The output power of the PV array decreases due to partial shading conditions such as clouds, trees, buildings, etc. There are a variety of traditional methods are available for tracking maximum power point. But these all techniques perform well only in uniform irradiation conditions, however during partial shaded conditions; these are not capable to search the global maximum power point. Therefore, there is a proper optimization technique is essential for maximum power point tracking in PV system under partial shading condition. In this paper we will evaluate the performance of PSO and DE algorithms for maximum power point tracking in partially shaded condition with a PV panel connected to load via CUK converter is verified on MATLAB/Simulink environment. The simulation results shows that the two techniques defeat the partial shading problems extremely well with a maximum output power and the DE method has advantages compare to PSO method. From this comparison it is observed that faster convergence is achieved in DE algorithm when compared to PSO algorithm.*

Keywords – *differential evolution algorithm, maximum power point tracking, partial shading condition, particle swarm optimization, photovoltaic.*

1. INTRODUCTION

The need for non-conventional and clean sources of energy is increasing throughout the world. With increasing popularity of solar systems, there is always an eminent need in making an efficient the PV system. The efficiency of the energy conversion in the solar energy system will be high only at certain voltage and current conditions at which the power will be maximum. Hence the operating point is called maximum power point. It is found non-linear for power-voltage curve of a PV panel and thereby it also depends sunlight irradiance and temperature of the atmosphere. The variation in voltage and power due to temperature is less significant when compared to sunlight irradiance [1]. Since the sunlight irradiance is not constant throughout the day, the power output of a PV panel will also not constant. Besides, the MPP will also shift with change in sunlight irradiance and atmospheric temperature [2]. MPPT technique is to be used for achieve maximum power under different temperature and irradiance [3].

Another major problem associated with solar power generation is handling partial shading condition (PSC) due to passing clouds. During partial shading conditions the sunlight irradiance will not be uniform over the entire panel [4]. In a photovoltaic system, for obtaining a required power rating the PV panels are arranged in series and parallel connections. Under partial shading condition, the PV panels are subjected to non-uniform irradiance and in this situation the power-voltage characteristics exhibits multiple power peaks. The maximum of this power peak is called global power peak (GPP). The power output of a PV system under partial shading condition will be a maximum only when it is operated at GPP has been presented in [5]. Therefore, under partial shading condition the operating point should be maintained at GPP in order to take out maximum amount of power from partially shaded PV system [6]. In order to solve the stated problems is not practical; since they create the case of LMPP, hence partial shading algorithm is stated. Hence we use artificial intelligence method instead of traditional methods like perturb and observe, incremental conductance method *etc*. Thus from this work, we have simulated of PSO and DE (differential evolution) to determine the DC-DC converter switching process specially CUK converter [7].

2. PROPOSED SYSTEM

The block diagram of the partially shaded PV system selected for analysis of particle swarm optimization (PSO) technique is shown in Figure 1. The proposed PV system consists of four PV panels in series under shading condition, CUK boost converter, MPPT controller and load. In this project PSO and DE technique is used to determine the best PWM duty for the CUK converter to track MPP under PSC [8]. The PSO and DE algorithms are simulated using MATLAB / SIMULINK and the obtained results are presented in next section partially shaded condition (PSC) PV panel connected to load via CUK converter. PSO and DE algorithm is utilized to decide the optimum PWM duty for CUK boost converter to accomplish most extreme power from the PV panel under PSC. Searching the best

* Department of Electrical and Electronics Engineering, Vimal Jyothi Engineering College, Kannur, Kerala, India.

[1]Corresponding author:
Tel: +91 9995595232.
Email: neethum201@gmail.com.

PWM duty is the objective and power produced by the PV panel is fitness value to decide the best objective. The power produced by the PV panel depends on the level of irradiation [9] and maximum power at any irradiance condition can be achieved by changing PWM duty of CUK.

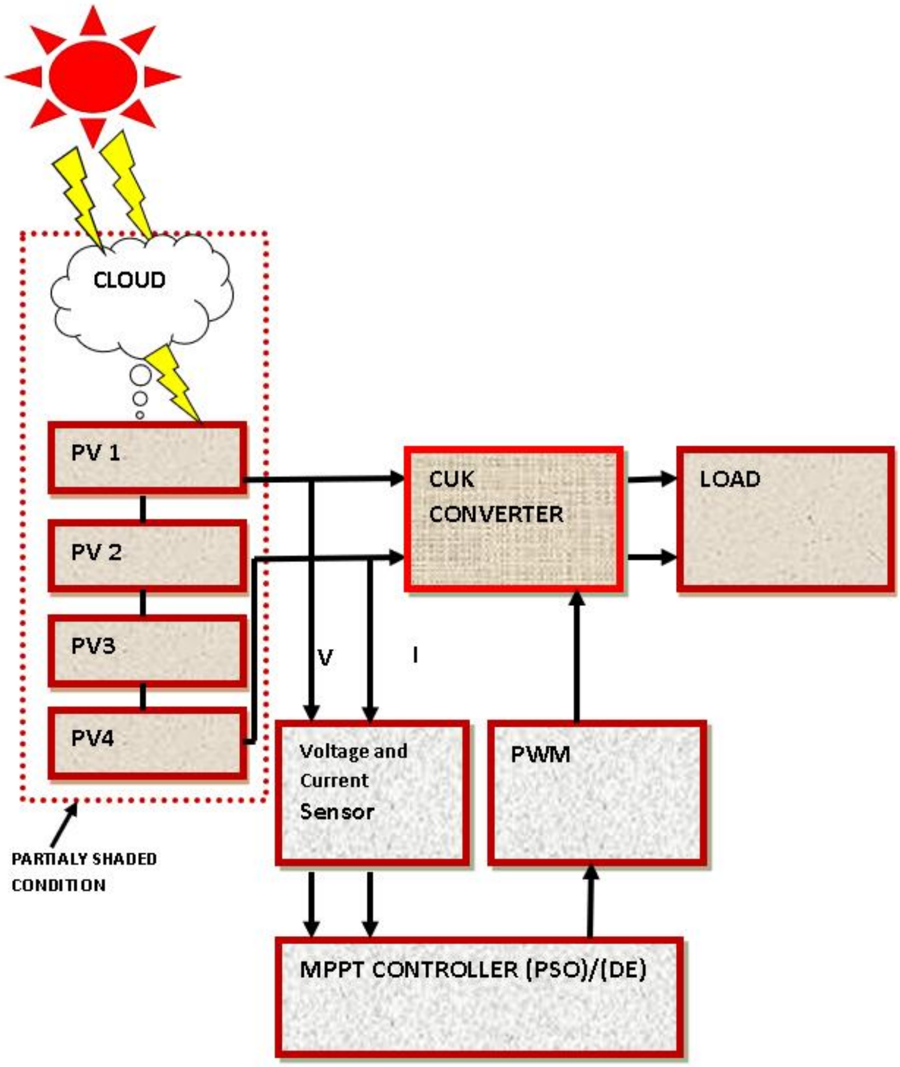

Fig. 1. Partially shaded PV system with PSO/ DE MPPT controller.

For a particular irradiance level, from the PV panel the maximum power will be extracted at a particular PWM duty. Hence when there is a change in irradiance level the PWM duty has to be changed to extract maximum power [10].

3. MODELLING OF PV PANEL UNDER PARIAL SHADING CONDITIONS

The basic operating principle of solar cell is the photo-voltaic effect by which light energy is directly converted to electrical energy. Single diode or two diode *etc*., are classified as the equivalent circuit of the solar cell. Single diode model is very simple and more accurate [11].

Figure 2 show the circuit of single diode solar cell model. It consists of shunt resistance R_{sh}, series resistance Rs, diode current I_d, module photo current I_{ph}, current from PV panel is $I_{pv,}$ voltage from PV panel is V_{pv} and I_{sh} is the shunt current.

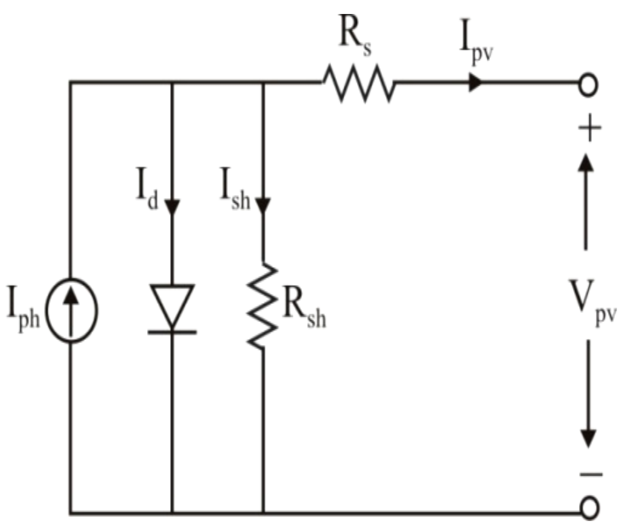

Fig. 2. Equivalent circuit of single solar cell.

Table 1. PV panel specifications.

Parameters	Values
Pmax (Maximum power)	215W
Voc (Open circuit voltage)	20 V
Vmp (Voltage at maximum power point)	15V
Isc (Short circuit current)	20A
Imp (Current at maximum power point)	16A
Panel efficiency	13.7%
Dimension	1626x964x4m
Test condition	AM 1to5, 1000 W/m2, 25^{0}C

The mathematical model of PV panel is obtained from the expression for the output current from the PV module (I_{PV}) is represented as,

$$I_{pv} = N_p * I_{ph} - N_p * I_0 \left[exp\left\{ \frac{q * (V_{pv} + I_{pv} R_s)}{N_s AKT} \right\} - 1 \right] \quad (1)$$

Vpv=Voc =open circuit voltage (V) and the expression is given by [12] ,

$$V_{oc} = V_{oc,ref}\left[1 + a\ln\left(\frac{S}{S_{ref}}\right) + \beta(T - T_{ref})\right] \quad (2)$$

4. MODELLING OF CUK CONVERTER

In the CUK converter input voltage source (V_i) and the output voltage source (C_o) are converted current sources by using two inductors L_1 and L_2. Inductor maintains a constant current as a current source at a short time scale [13]. Due to resulting in high energy loss this conversion is essential because, by connecting capacitor to the voltage source energy loss is produced also the current also get reduced by the load resistance. Using a current source (the inductor) charging of a capacitor results in limiting the load current and also reduces the energy loss. Thus CUK can operate under both continuous and discontinuous mode similar to that of buck, boost, and buck-boost. Compared to other converters CUK also works in discontinuous voltage mode [14].

The parameters CUK DC-DC converter is calculated using the Equations 3, 4, 5 and 6.

$$V_o = \frac{V_{in} D}{1 - D} \quad (3)$$

$$L_{1min} = \frac{(1 - D)R}{2Df} \quad (4)$$

$$C_{min} = \frac{(1 - D)V_{out}}{V_{ref} 8 L_{2min} f^2} \quad (5)$$

$$L_{2min} = \frac{(1 - D)R}{2f} \quad (6)$$

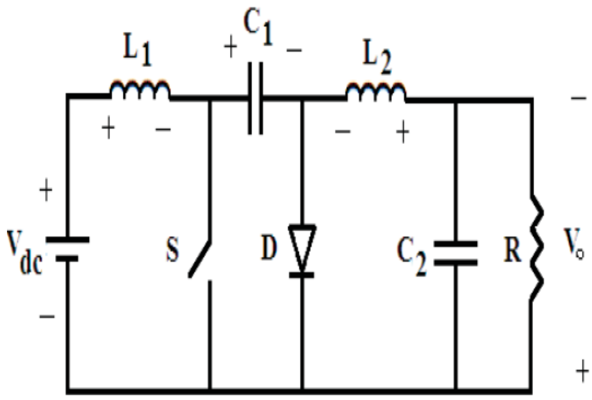

Fig. 3. CUK converter.

The specifications of CUK converter shown in Table 2. PV panel is connected as the input to the CUK converter, the output of the CUK is taken from the resistive load [15].

Table 2. Parameters of CUK converter.

Parameter		Value
Switched frequency (fs)		25 KHz
Filter capacitor	Input side	1000x10-6μF
	Output side	500x10-6 μF
Inductor (L)		0.5x10MH
Capacitor (C)		5x10-6 μF

5. MPPT PARTIAL SHADING ALGORITHMS

5.1 *Implementation of PSO Algorithm*

The various steps in implementing PSO algorithm are:

Step 1: Choose a swarm of particle (N) and number of iterations (iter_max).

Step 2: Select upper limit and lower limit for PWM duty.

Step 3: Generate PWM duty for each particle.

Step 4: Determine initial fitness of each particle by running simulation with initial PWM duty.

Step 5: Let the maximum value of fitness be initial $P_{bestfit}$ and corresponding PWM duty be initial Pbest, duty. Let the initial Gbest, fit = Pbest, fit and Gbest, duty=Pbest, duty.

Step 6: Start an iteration. Let iteration count be “iter”.

Step 7: Run simulation with PWM duty of j^{th} particle and determine the maximum power, P_j_iter.

Step 8: Check whether P_j_iter is greater than $P_{best, fit}$, if true then make P_j_iter as $P_{best, fit}$, and corresponding duty as $P_{best, duty}$, if false go to next step.

Step 9: Increment particle count, j, and if particle count is greater than N then go to next step otherwise repeat steps 7 and 8.

Step 10: Check whether $P_{bestFit}$ is greater than $G_{bestFit}$, if true then make $P_{bestFit}$ as $G_{best, fit}$, and corresponding duty as $G_{best, duty}$, if false go to next step.

Step 11: Update duty of each particle using velocity equation of PSO algorithm.

Step 12: Increment iteration count, iter, and if iteration count is greater than iter_max then go to next step otherwise repeat steps 6 to 11.

Step 13: Print, $G_{best, duty}$ as PWM duty to achieve MPPT and $G_{best, fit}$ as maximum power that is being tracked.

5.2 Implementation of DE Algorithm

The various steps in implementing DE algorithm are:

Step 1: Initialize the population as NP, total generation as k, Scaling factor = 0.7 and Cross-over constant = 0.2. The decision variable for each member of the population is duty.

Step 2: Choose minimum and maximum limit for decision variable as 0.1 to 0.9.

Step 3: Generate initial decision variables (trial vectors) for each member of the population.

Step 4: Run the SIMULINK file and generate the initial fitness value (Pmax) for each member of the population.

Step 5: Let maximum of initial fitness values be best fit, B_{fit} and corresponding trial vector is best duty, B_{duty}.

Step 6: Start the generations (initial values are first generation).

Step 7: For each member of the population, select any three vector variables randomly.

Step 8: Now, calculate the mutated vector using the scaling factor, a, b and c vectors.

Step 9: For cross-over, verify if mutated vector for a variable is between 0 and crossover constant if so replace mutated vector as trial vector, otherwise go to next step.

Step 10: If trial vector violates the minimum or maximum limit then keep the limit violated as trial vector values.

Step 11: Run SIMULINK file and calculate the new fitness value.

Step 12: Continue for all the members of the population (Step 7 to 11).

Step 13: Determine the best fit in the next generation.

Step 14: Compare the best fit of previous generation with best fit of next generation and greater among the two is considered as best fit among the generations, and so Bfit is replaced by the highest fitness value and corresponding duty as Bduty.

Step 15: Continue the process for all the generations (Step 7 to 14).

Step 16: Print B_{duty} and B_{fit}.

6. SIMULATION RESULTS AND DISCUSSIONS

The simulink model of PV array consists of four panels in series and the specifications are tabulated in Table 1. The temperature value is 25^{0}C. Power-voltage characteristics under partial shaded condition is analyzed. Partial shaded condition is achieved by varying irradiance level of PV panels.

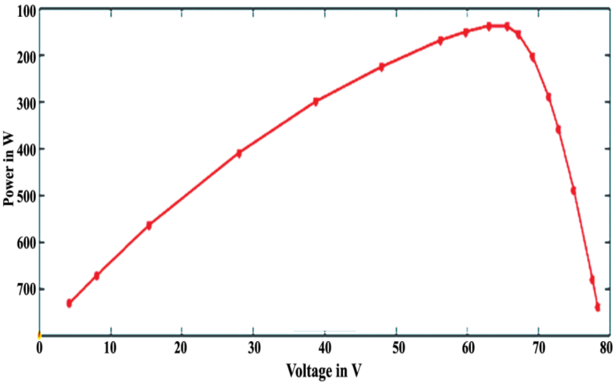

Fig. 4. Power voltage characteristic for partial shaded condition.

Irradiance levels for four panels are set at 900, 800, 700and 600W/m^2. From simulink model for PV system with four PV panels, the PV characteristics under varying load resistance in PSC is shown in Figure 4. To observe the two optimization methods to find Global maximum power point in partial shading condition by varying the irradiation of each PV modules in array connections. From the P-V characteristics it is the increase in irradiance level increases the current and power value and the decrease in irradiance level reduces the current and power values.

Under partial shading condition (PSC), the PV array exhibits local and global power peak (GPP). Therefore, under PSC the GPP point has to be tracked to achieve MPP. Tracking GPP is the main challenge under partial shading condition. To overcome these issues, optimization techniques are used to track the GPP. The objective function of MPPT controller is maximum power point tracking under PSC. This is achieved with two different optimization techniques PSO (particle swarm) and DE (differential evolution), which determine the best duty value for CUK converter to extract maximum power and results are compared. Figure 5 shows the simulation circuit of PSC panel PV system with CUK converter. Figures 6 and 7 shows global maximum power point tracking process of four panels of PSO optimization and DE optimization for maximum power point tracking in partial shading conditions. The PSO optimization is performed by selecting 3 generations and with 10 populations in each generation and the time taken for tuning is 705 seconds to get optimized duty and in the case of DE is 1 generation,10 population and the tuning time is 366 seconds.

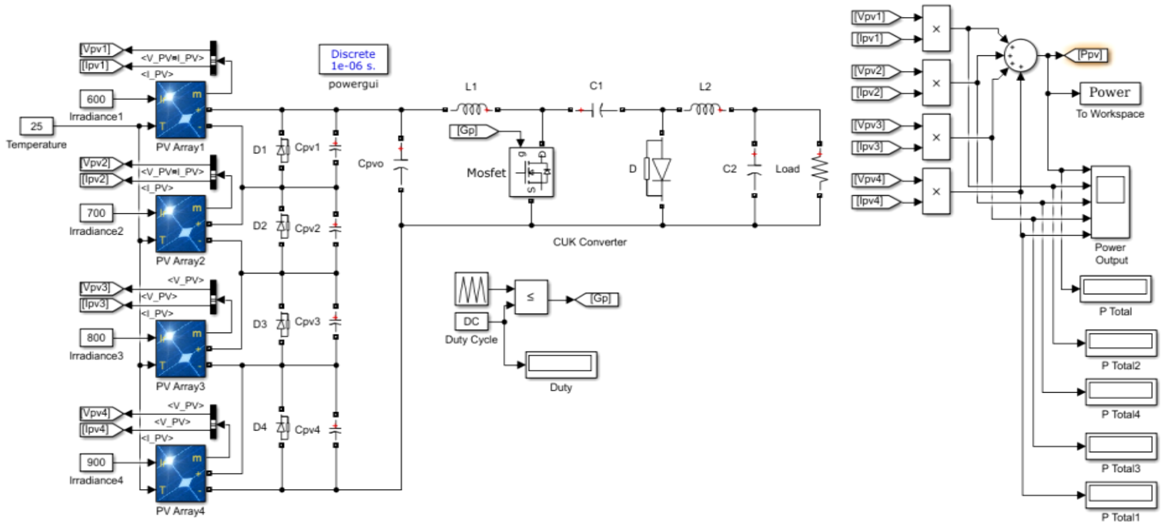

Fig. 5. Simulation circuit of PSC PV system with CUK converter.

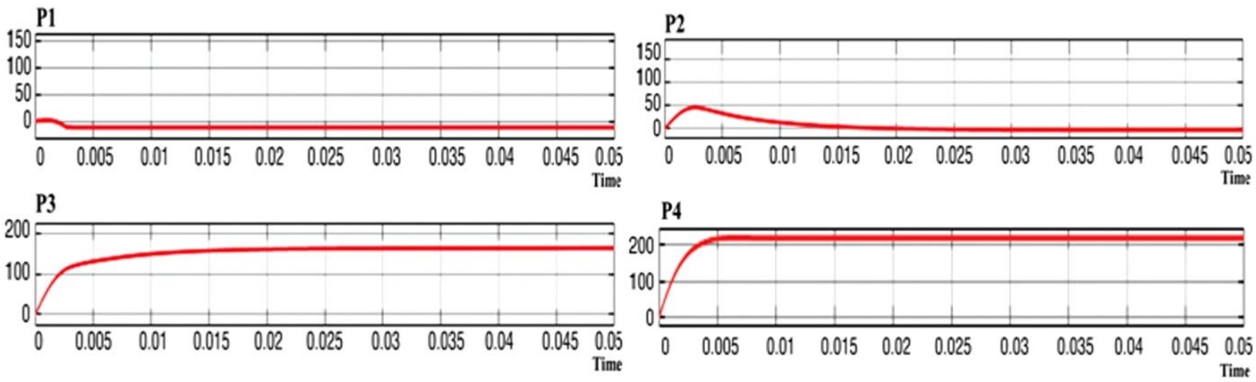

Fig. 6. Tracking process of GMPP from the four panels P1, P2, P3, P4 for PSO optimization.

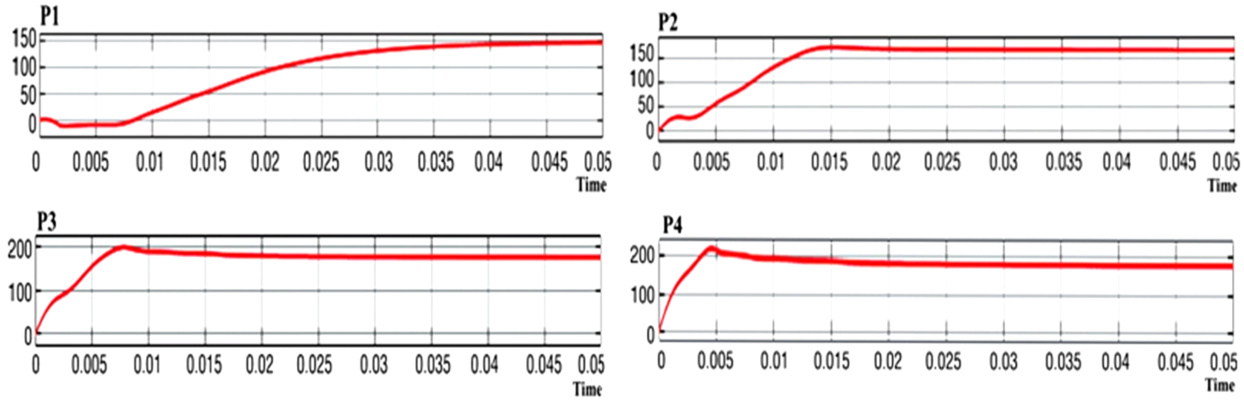

Fig. 7. Tracking process of GMPP from the four panels P1, P2, P3, P4 for DE optimization.

The total maximum power tracking process by using PSO and DE optimization is shown in Figure 8. The results and analysis by comparing PSO and DE shown in Table 3.

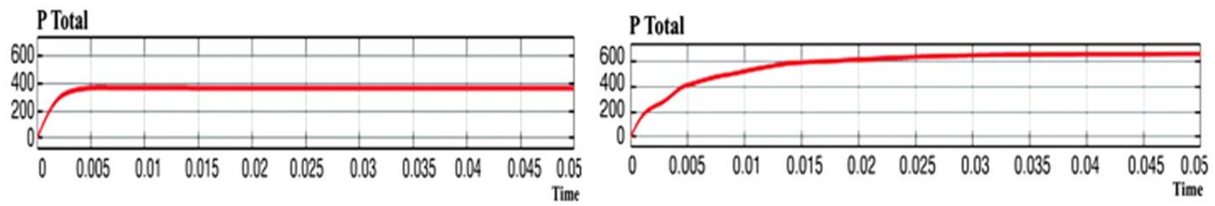

Fig. 8. Total output power of PSO and DE optimization.

Table 3. Comparison of PSO and DE optimization.

Algorithm	Generation	Population	Optimized Duty	Total Power of Four Panels(W)				Maximum Power (W)	Tuning Time (S)
				P1	P2	P3	P4		
PSO	3	10	0.3915	12.14	48	162.5	218.2	365.9	705
DE	1	10	0.5855	144.9	167.7	173.8	177.4	663.8	366

7. CONCLUSION

The simulation of maximum power point tracking in PSC photovoltaic array connected to standalone R load via CUK converter is performed with two different optimization techniques PSO (particle swarm optimization) and DE (differential evolution), which determine the best duty value for CUK converter to extract maximum power and results are compared. The results are presented in Table 3. PSO algorithm reaches the GMPP by optimizing ten populations with three iteration. In PSO, best optimized duty cycle obtained is 0.3915 and the highest power obtained is 365.9W.In the case of DE, it reaches GMPP by optimizing ten populations with 1 iteration it is found that the best optimized duty ratio is 0.5885 and the highest power obtained is 663.8. The tuning time of DE is only 366s, where PSO have taken 705s to reach the GMPP. From this comparison it is observed that faster convergence is achieved in DE algorithm when compared to PSO algorithm.

NOMENCLATURE

I_{ph}	Module photo current
I_0	Module saturation current
I_{pv}	Current from the PV module
N_p	Total number of cells in parallel
Ns	Total number of cells in series
Rs	Series resistance of a PV module
V_{oc}	Open circuit voltage
D	Duty cycle
P_{best}	Particle best position o
G_{best}	Global best position

REFERENCES

[1] Madhusmita M. and S. Selvakmar. 2019. Global maximum operating point tracking for PV system using fast convergence firefly algorithm. *Turkish Journal of Electrical Engineering and Computer Sciences* 27: 4640–4658.

[2] Raj, C.M. and T.V. Kumar. 2015. An efficient MPPT control algorithm for solar power plant battery charging system with the improved steady state response. *International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering*, 4(4).

[3] Hong Y., Beltran A.A., and Paglinawan A.C., 2017. Real-time simulation of maximum power point tracking control using fuzzy logic for standalone PV system. In Proceedings of the *IEEE 3rd International Future Energy Electronics Conference and ECCE Asia (IFEEC - ECCE Asia),* Kaohsiung, China; pp. 710–715.

[4] Ramli M.Z., and Z. Salam. 2014. A simple energy recovery scheme to harvest the energy from shaded photovoltaic modules during partial shading. *IEEE Transactions on Power Electronics* 29(12): 6458–6471.

[5] Bai J., Cao Y., Hao Y., Zhang Z., Liu S., and Cao F., 2015.Characteristic output of PV systems under partial shading or mismatch conditions. *Solar Energy* 112: 41–54.

[6] Raj J.S.C.M. and A.E. Jeyakumar. 2014. A novel maximum power point tracking technique for photovoltaic module based on power plane analysis of I-V characteristics. *IEEE Transactions on Industrial Electronics* 61(9): 4734–4745.

[7] Murdianto F.D., Efendi M.Z., Setiawan R.E., Hermawan A.S.L., 2017. Comparison method of MPSO, FPA, and GWO algorithm in MPPT SEPIC converter under dynamic partial shading condition. In Proceedings of the *International Conference on Advanced Mechatronics, Intelligent Manufacture, and Industrial Automation (ICAMIMIA)*, Surabaya, pp. 315–320.

[8] Dileep G. and S.N. Singh. 2017. Application of soft computing techniques for maximum power point tracking of SPV system. *Solar Energy* 141: 182–202.

[9] Phimmasone V., Kondo Y., Kamejima T., and Miyatake, M., 2011. Verification of efficiency of the improved PSO-based MPPT controlling multiple photovoltaic arrays. In Proceedings of the *IEEE Ninth International Conference on Power Electronics and Drive Systems,* Singapore, pp. 1015–1019.

[10] COMPEL. 2006. *The International Journal for Computation and Mathematics in Electrical and Electronic Engineering* 24(4).

[11] Sridhar R., Jeevananthan S., Dash S.S., and Vishnuram, P., 2016. A new maximum power tracking in PV system during partially shaded conditions based on shuffled frog leap algorithm. *Journal of Experimental & Theoretical Artificial Intelligence* 29(3): 481–493.

[12] Lee D., Noh H., Hyun D., and Choy I., 2003. An improved MPPT converter using current compensation method for small scaled PV applications. In Proceedings of the *Eighteenth Annual IEEE Applied Power Electronics Conference and Exposition*, USA, pp. 540–545.

[13] Srivastava R. 2016. Solar power current status, challenges and policies in India. *Research & Reviews: Journal of Engineering and Technology* 2319–9873.

[14] Hemalatha C. and A. Archana. 2014. Advancement in solar panels and improvement in power production with indoor application. *International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering* 3(4).

[15] Tan C.Y., Rahim N.A., and Selvaraj J., 2014. Improvement of hill climbing method by introducing simple irradiance detection method. In Proceedings of the *3rd IET International Conference on Clean Energy and Technology*, Malaysia, p. 46.