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MAXIMUM POWER OPTIMIZATION USING FLOWER POLLINATION ALGORITHM UNDER PARTIAL SHADING CONDITION FOR SOLAR PANEL

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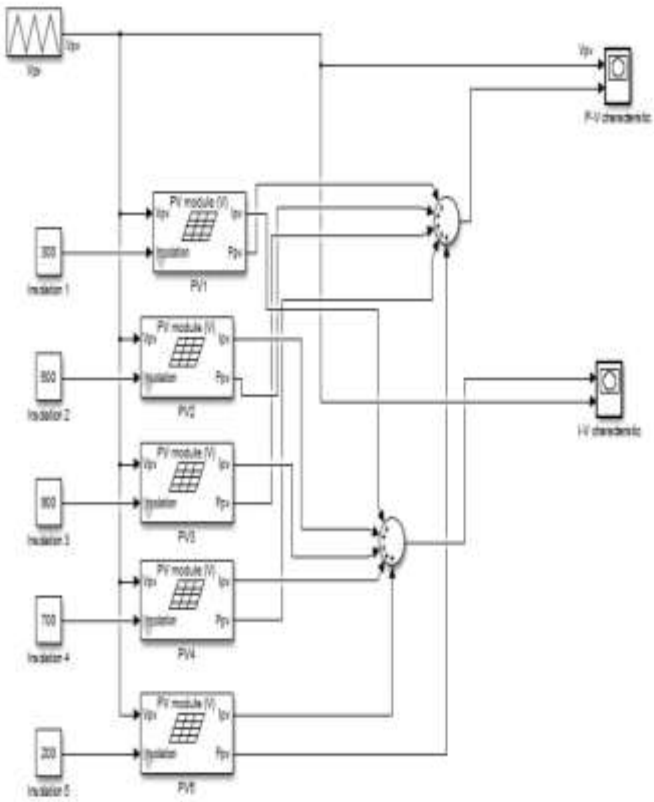
Abstract— **Photovoltaic (PV) output power depends on insolation, temperature, panel configuration and shading. Most of the time PV panels get affected by clouds, shadows of trees, towers and buildings etc. partially or completely. Under partial shading condition, PV panels exhibits a multiple power peaks. So far it is very complicated to find the global maximum power among multiple power peaks under partial shading condition. This paper proposes a new metaheuristic technique called Flower Pollination Algorithm (FPA) to find the global best duty in order to extract a maximum output power from PV system under partial shading conditions. The proposed FPA technique is simulated using MATLAB/SIMULINK and it is observed that the simulation results of FPA algorithm gives a better result compared to PSO and RDPSO algorithms.**

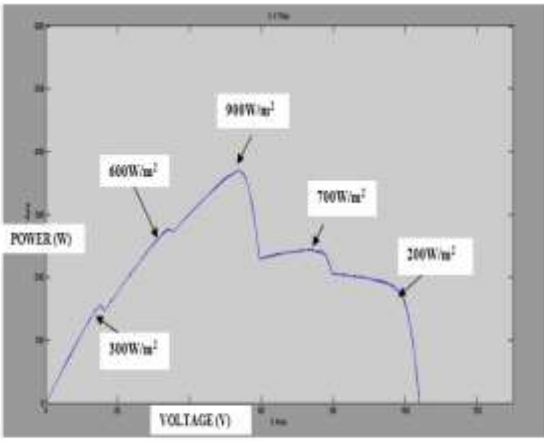
Index Terms— **Renewable energy sources, Photovoltaic cells, Particle swarm optimization, MATLAB, Power converters**.

I. INTRODUCTION

Among various nonconventional energy sources PV is most commonly used because of no pollution, absence of noise, no gas emission and less maintenance [1], [4], [10]. Under uniform insolation, PV system gives single peak but non uniform insolation PV exhibits multiple peaks as shown in Fig.1 (b) using the simulation model presented in Fig.1 (a) and it is complicated to identify the global maximum power from several maximum [13]. Many optimization algorithms are implemented to identify the global best duty to extract maximum power from PV system under partial shading condition. The traditional methods like P &O (perturb and observe), Hill climbing method are used to extract maximum power (MP) from PV. These methods produce an oscillation at MPP which results in power loss [2], [3]. To increase the PV system efficiency and to minimize the oscillations, Incremental Conductance (INC) method is used but INC does not reduce the oscillations completely [3]. The conventional methods are not suitable for nonuniform insolation condition. In order to find the global maximum under PSC various artificial intelligence approaches are proposed and implemented by several researchers. The drawback of artificial intelligence are large data are required to give a training and also requires a fuzzification, defuzzification and rule base stages [4]. To overcome these issues evolutionary algorithms (EAs) are proposed and implemented by various researchers. EAs have the capability to handle non linear characteristics of PV panels. Particle Swarm Optimization (PSO) is the one of the metaheuristic method and it is mainly used in many applications because of more flexible, less number of controlling parameters and also saves the information regarding the search space upto the completion of iteration. The main disadvantages of original PSO is local search ability is poor and the convergence is slow [7], [8]. To rectify this QPSO (Quantum behaved PSO) was proposed to improve the search ability [9]. Ishaque proposed a DPSO method to find the GMPP (global maximum power point) by removing the random numbers in velocity equation but this algorithm loses the advantages of evolutionary algorithm [5]. This paper proposes a flower pollination process of flowering plants [9] to find the global best duty from PV system under PSC to extract maximum power.



(a)



(b)

Figure 1. (a) Simulink model of PV panels with different isolation (b).P-V Characteristics of solar panels with different insolation

II. MATHEMATICAL MODELING OF PV PANEL

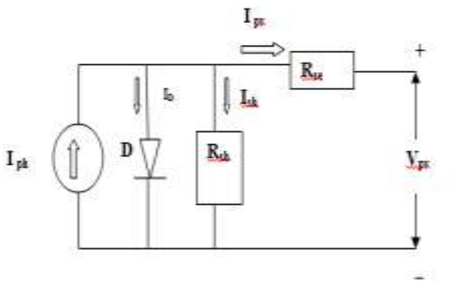


Figure.2 .Single Diode model of PV cell

The PV panel consists of number of solar cells. Power generation can be increased by connecting the PV panel in series or parallel. Fig.2 presents the single diode model of PV cell. The equations given below are used to describe the modeling of single PV module (11). The module photo current (Iph) is given by

$$I_{ph} = \left[I_{scr} + K_i(T - 298)\right] * \lambda / 1000 \tag{1}$$

where Iscr is the PV module short circuit current, Ki is the coefficient of temperature (0.00157%/^{0}C), T is the working temperature in Kelvin, and λ is the irradiance of PV module (1000W/m^2). The Photovoltaic current from the module (Ipv) is given by

$$I_{pv} = N_p * I_{ph} - N_p * I_0\left[\exp\{q * (V_{pv} + I_{pv}R_s) / N_s AKT\} - 1\right] \tag{2}$$

where Vph=Voc, N_P is the number of cells in parallel, Ns is the total number of cells in series. Rs is the resistance of a PV module in series, q is the charge of an electron (1.6x10-19), K is Boltzmann's constant. A is the diode ideality factor and its value is 1.6.

III. INTRODUCTION TO FLOWER POLLINATION ALGORITHM

In 2012, Xin She Yang developed FPA algorithm [9]. It is the one of the nature inspired metaheuristic algorithm to find the global optimum solution. Pollination has two divisions such as abiotic and biotic. 90% of pollination is biotic. In biotic pollination, pollen is transferred by insects, birds and animals. Remaining 10% of flowering plants are abiotic and it is mainly due to wind and rain and it does not require any pollinators.

Pollination takes place either by a self pollination or cross pollination. Pollination occurs between different plant are called cross pollination and self pollination is among same flower or different flowers of the same plant. Biotic and cross pollination are considered as global pollination because pollinators can travel over a long distance. Abiotic and self pollination are considered as local pollination. Flower constancy can be assumed as the reproduction probability and its value is proportional to the similarity or difference of two flowers. There are four steps of flower pollination algorithm [12], [14] are

(i) Global pollination is mainly due to biotic and cross pollination
(ii) local pollination is mainly due to abiotic and self pollination

(iii) Flower constancy is as considered as reproduction probability
(iv) local and global Pollinations are controlled by switch probability p ϵ [0,1]

In global pollination, pollinators can travel over a long distance. This ensures a pollination and reproduction of the fittest and it is represented as g*. Global pollination is given by

$$X_i^{t+1} = X_i^t + L(X_i^t - g*) \tag{3}$$

where x_i^t=pollen i at iteration t, g* =current best solution, L = strength of the pollination and it is given by

$$L \approx \lambda\Gamma(\lambda)\sin\left(\frac{\pi\lambda}{2}\right) / \pi * \left(\frac{1}{S^{1+\lambda}}\right), \text{(s>>s}_0\text{>0)} \tag{4}$$

where $\Gamma(\lambda)$ =standard gamma function and λ is called scaling factor to control the step size and it is assumed as 1.5. The equation (5) shows the local pollination and flower constancy expression

$$x_i^{t+1} = x_i^t + \varepsilon(x_j^t - x_k^t) \tag{5}$$

Here x_j^t and x_k^t are pollens from the different flowers of the same plant and ϵ is uniform distribution with values (0, 1). In this simulation P is assumed as 0.7. Fig.3 illustrates the flowchart of proposed algorithm.

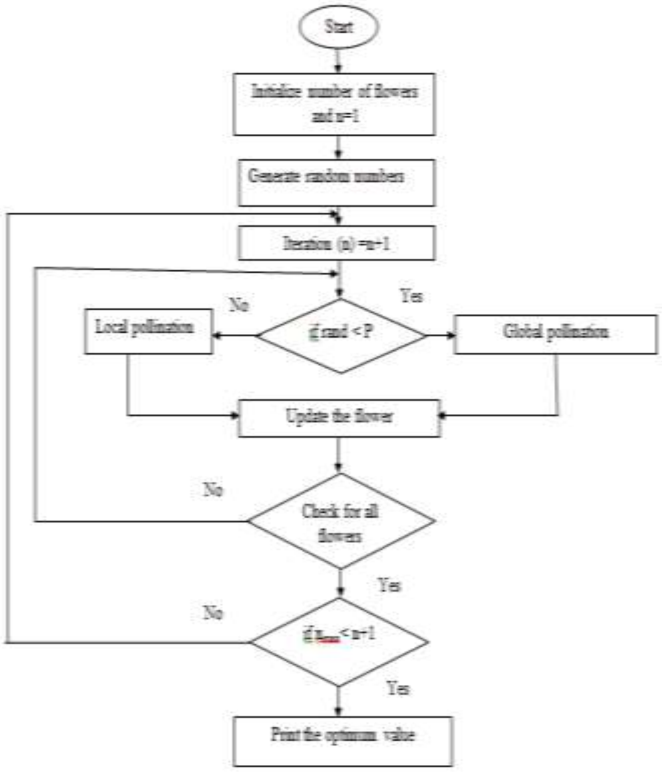


Figure 3. Flowchart of proposed algorithm

IV. INTRODUCTION TO RDPSO TECHNIQUE

Inertia weight in the velocity equation of the canonical PSO is replaced by the random velocity component in RDPSO algorithm [8]. Therefore, the particle velocity in the RDPSO algorithm has two components namely thermal or random component and the drift component. The velocity can be expressed as V_R+V_D. Random motion present even there is no external electric field and this motion is used to find the global search of the particle. The drift motion is caused by electric field and its directional motion is opposite of external electric field and it is used for local search. The velocity of particle [6] i in the j^{th} dimension can be expressed mathematically by

$$V_{i,n+1}^{j} = VR_{i,n+1}^{j} + VD_{i,n+1}^{j} (1 \le i \le M, 1 \le j \le N) \quad (6)$$

where $VR_{i,n+1}^{j}$ is the random velocity component and $VD_{i,n+1}^{j}$ is the drift velocity component. We can represent the random velocity component as

$$VR_{i,n+1}^{j} = \sigma_{i,n+1}^{j} \varphi_{i,n+1}^{j} \quad (7)$$

where $\varnothing_{i,n+1}^{j}$ is a random number with a standard normal distribution (i.e) $\varnothing_{i,n+1}^{j}$ ~N (0, 1), $\sigma_{i,n+1}^{j}$ is the standard deviation of the distribution.

$$\sigma_{i,n+1}^{j} = \alpha \left| C_n^j - X_{i,n}^{j} \right| \quad (8)$$

where $C_n = (C_n^1, C_n^2, ...C_n^N)$ mean best (m_{best}) is position of all the particles and α is the thermal coefficient.

$$C_n^j = \left(\frac{1}{M}\right) \sum_{i=1}^{M} P_{i,n}^{j}, (1 \le j \le N) \quad (9)$$

Therefore $VR_{i,n+1}^{j}$ becomes

$$VR_{i,n+1}^{j} = \alpha \left| C_n^j - X_{i,n}^{j} \right| \varphi_{i,n+1}^{j} \quad (10)$$

and the drift velocity component can be expressed as

$$VD_{i,n+1}^{j} = \beta \left(P_{i,n}^{j} - X_{i,n}^{j} \right) \quad (11)$$

The value of β must be set to $1 \le \beta \le 2$ to obtain the local search ability of the particle good. The new velocity and position equations are given below

$$V_{i,n+1}^{j} = \alpha \left| C_n^j - X_{i,n}^{j} \right| \varphi_{i,n+1}^{j} + \beta \left(p_{i,n}^{j} - X_{i,n}^{j} \right) \quad (12)$$

$$X_{i,n+1}^{j} = X_{i,n}^{j} + V_{i,n+1}^{j} \quad (13)$$

In this paper, RDPSO algorithm is compared with the FPA algorithm and the simulation results are discussed below.

V. SIMULATION RESULTS OF PV SYSTEM UNDER PARTIAL SHADING CONDITION

In this paper, FPA is proposed to find the best duty value to extract a maximum power from PV panels under PSC and this algorithm is compared with the PSO and RDPSO technique. The simulink model is shown in Fig.5. Using the simulink model, the duty value given to the MOSFET of the boost converter is optimized separately by using FPA, PSO and RDPSO algorithm with a constant load resistance of 100Ω. The subsystem of PSO and RDPSO is shown in Fig.4. The simulink model of PSO and RDPSO algorithm was implemented using simulink/MATLAB as shown in Fig 5. This model consists of two panels namely panel 1 and panel 2 with insolation of 1000W/m^2 and 500W/m^2 respectively. The power rating of each panel is 200W. Panel 1 has no shading and panel 2 has partial shading with value of 500W/m^2. The panel specification is tabulated in Table.1

Table.1 Specification of PV panel

Details of PV panel	**Ratings**
Rated Power	200W
Open circuit voltage (Voc)	21.6V
Short Circuit current (Iscr)	12.874A
Voltage at maximum power	17.4V
Current at maximum power	11.494A
Total number of cells in series	36

Total number of cells in parallel	1
Irradiance	1000W/m^2
Temperature	470C ±20C
Temperature coefficient of power	0.00157%/^{0}C

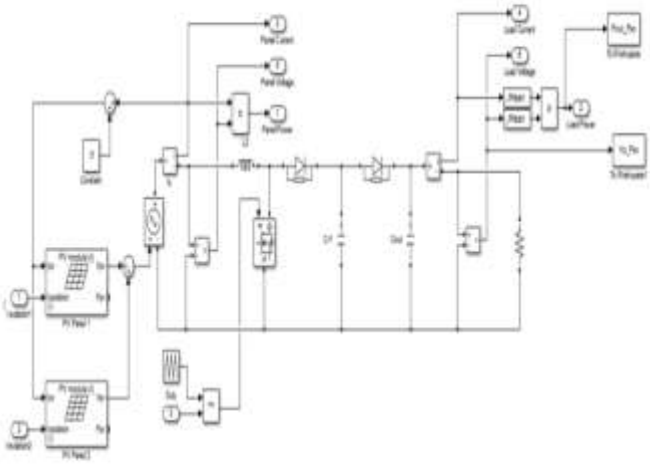


Figure 4. Simulink model of proposed system

From the simulation result shown in Fig.6, it is observed that the power extracted from the PV panel under PSC using RDPSO is more compared to PSO.

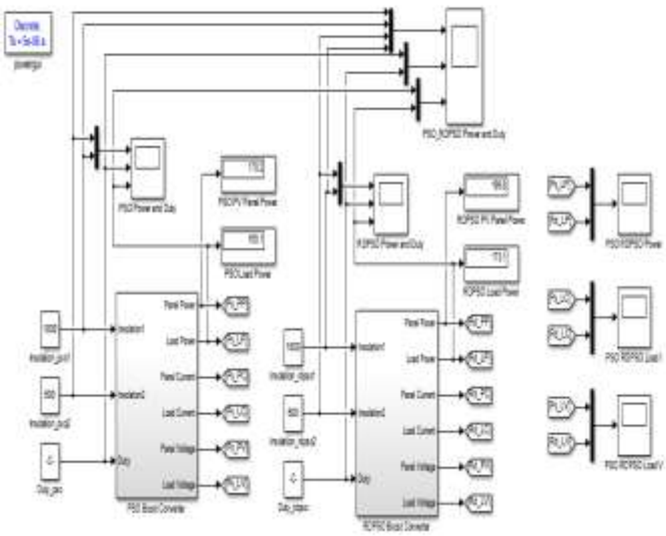


Figure 5. Simulink model of PSO and RDPSO algorithm

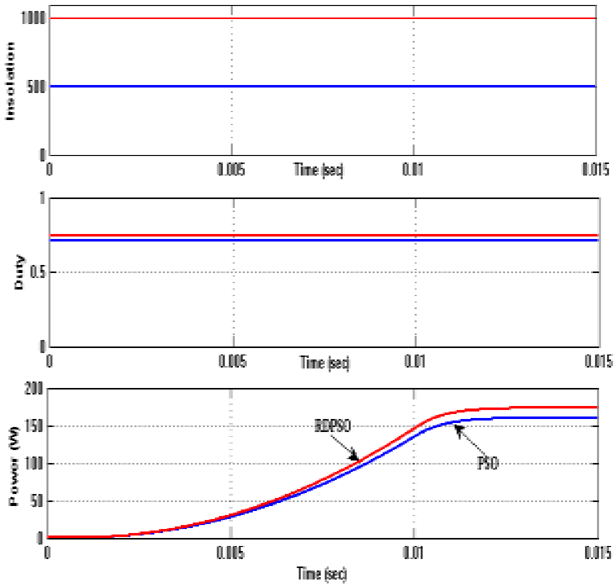


Figure 6. Simulation results of Insolation, Duty and Power with respect to time using PSO and RDPSO algorithm with constant load resistance

Duty value for boost converter was optimized separately using FPA algorithm and PSO algorithm and its value was used in simulink model shown in Fig.5. The simulation result obtained using PSO and FPA algorithm is compared as shown in Fig.7.

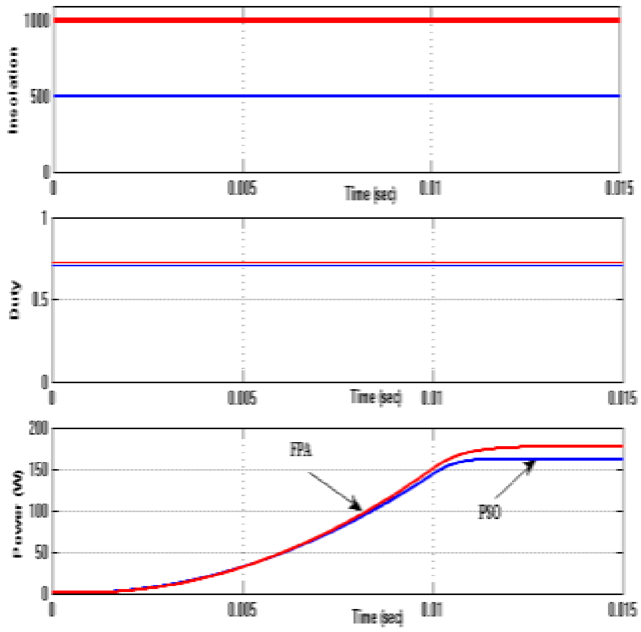


Figure 7. Simulation results of Insolation, Duty and Power with respect to time using PSO and FPA algorithm with constant load resistance

Similarly optimized duty values using PSO, RDPSO and FPA algorithm were obtained and used in the simulink model as shown in Fig.8. The parameter settings are listed in Table.2 for PSO, RDPSO and FPA optimization techniques.

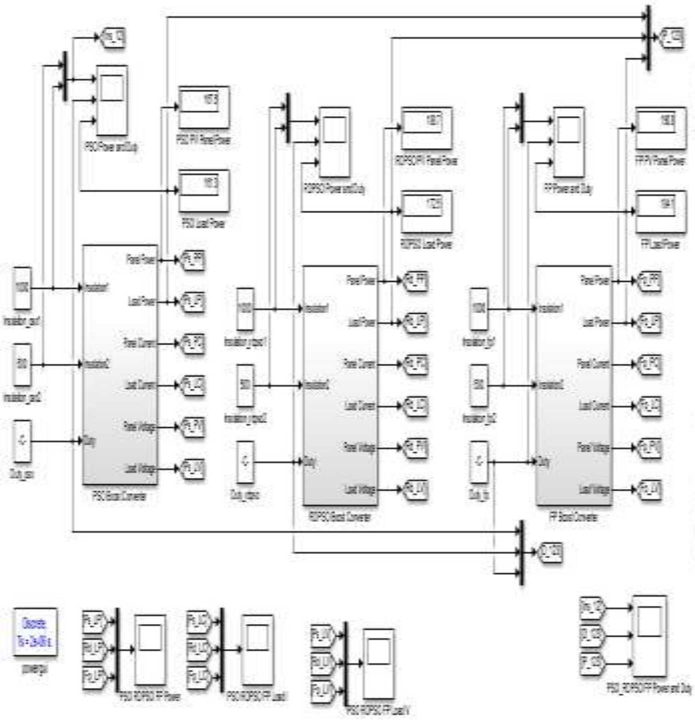


Figure 8. Simulink model of PSO, RDPSO and FPA algorithm

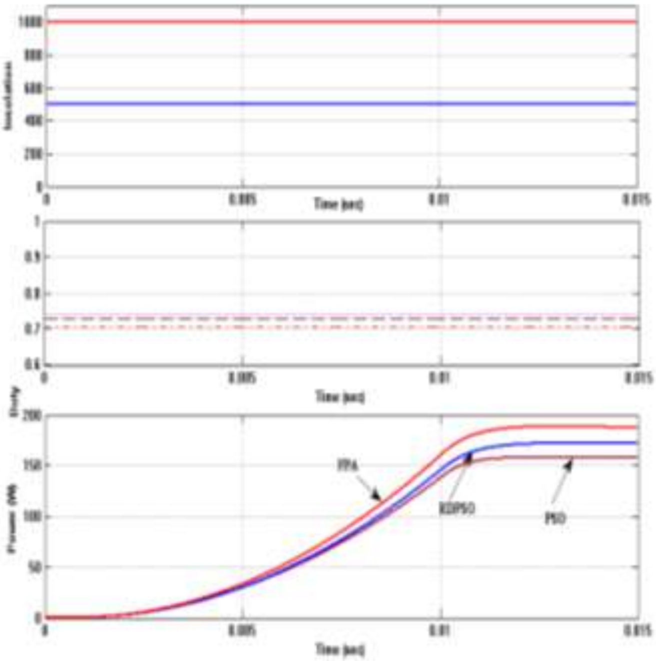


Figure 9. Simulation results of Insolation, Duty and Power with respect to time using PSO, RDPSO and FPA algorithm with constant load resistance

Table .2 Parameter settings of PSO, RDPSO and FPA algorithm

PSO	RDPSO	FPA
Number of particle=30	Number of particle=30	Number of flower=30
Number of iteration=10	Number of iteration=10	Number of iteration=10
Dmin=0.6	Dmin=0.6	Switch probability = 0.7
Dmax=0.9	Dmax=0.9	Gamma function=1.5
	α_{min}=0.3	Scaling factor=0.3
	α_{max}=0.9	Step size=0.01
	β=1.5	F_{min}=0.6
		F_{max}=0.9

Fig 9 shows the insolation, duty and power with respect to time and it is noticed that the power extracted from FPA is more compared to PSO and RDPSO. Table.3 shows the duty and power for various techniques for various insolation.

Table.3 Duty and power for various techniques with various insolation.

R_L (Ω)	Insolation (W/m^2)		Optimized Duty Value			Output Power		
	Panel I	Panel 2	PSO	RDPSO	FPA	PSO	RDPSO	FPA
100 Ω	600	300	0.681	0.639	0.613	71.3	73.1	96.2
	700	350	0.607	0.663	0.625	93.7	95.1	102.4
	800	400	0.698	0.684	0.702	130.3	133.4	141.6
	900	450	0.700	0.721	0.694	151.7	156	157.4
	1000	500	0.707	0.739	0.727	157.6	172.5	187.4

Fig.10. Shows the simulation result of power V_s voltage for various value of load resistance. It is observed that the proposed algorithm performs better compared to PSO and RDPSO technique.

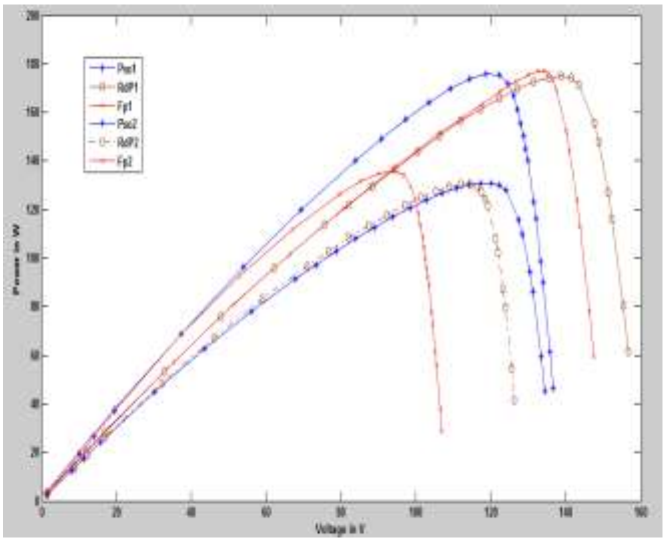


Figure 10. Simulation results of power with respect to voltage using PSO, RDPSO and FPA algorithm with variable load resistance

From the results of Fig.9 and Fig.10, it is clear that the power extracted is higher using FPA when compared to PSO and RDPSO algorithm.

VI. CONCLUSION

In this paper, the maximum output power from the PV panels connected in series as shown in Fig.4 using FPA algorithm is 187.4W with respect to theoretical expected wattage of 200W. It is comparatively higher when compared to PSO and RDPSO optimization technique with respect to Table.3 for constant load resistance. For variable load conditions the power extracted from PV panels under PSC using FPA optimization technique is more as shown in Fig.10. Hence FPA algorithm provides better solution for maximum power extraction under PSC.

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