Grid connected PV system using FB-PSO

Ravi Rajendra Bholane,PG Student, EE Dept, National Institute of Technology, Warangal. mail: ravibholane@gmail.com
Dr. P. Suresh Babu, Assistant Professor, EE Dept, National Institute of Technology, Warangal. mail: drsureshperli@nitw.ac.in

***Abstract*—This Paper presents a MPPT (maximum power point tracking) design for a Grid connected PV (Photo-voltaic) system using FB-PSO (Forward Backward particle swarm optimization) Technique. The FB-PSO is a new improved method which results in maximum efficiency, fast tracking of maximum power point, less steady state oscillations compare to PO (Perturb and Observe) and CPSO (Conventional PSO) methods. The proposed scheme is examine under PSC (partial shading conditions) and its results are compare with other two methods. The FB-PSO algorithm is implemented in MATLAB/SIMULINK and it is observed that proposed method is best compare to PO and CPSO MPPTs.**

***Keywords*— Conventional particle swarm optimization (CPSO), Forward Backward particle swarm optimization (FB-PSO), Maximum point tracking (MPPT), partial shading conditions (PSC), Perturb and Observe (PO), Photo-voltaic (PV).**

I. INTRODUCTION

Renewable energy resources play an important role in electric power generation. There are various renewable resources which is used for electric power generation, such as solar energy, wind energy, hydropower etc. Solar Energy is a best option for electric power generation, since the solar energy is directly converted into electrical energy by solar photovoltaic (PV) modules. These modules are made up of silicon cells (Si). When many PV modules are connected in series and parallel combinations to get a solar PV array, which is suitable for obtaining higher power output. [1]

There are two major approaches for maximizing power extraction in solar systems. They are sun tracking, maximum power point (MPP) tracking or both. In this paper, three MPP tracking techniques are studied and compared [2]. The first technique is based on Perturb and Observe (PO) [3], the second one is based on the Conventional Particle Swarm optimization (CPSO) method and the third method is using Forward-backward Particle Swarm Optimization Technique (FB-PSO). Also a complete grid connected scheme is proposed using all the three optimization techniques and compare their results.

Other MPPT techniques like PO, CPSO, IC (Incremental conductance), HC (Hill climbing) fails to track maximum power under PSC. Stochastic methods like ANN and fuzzy are got maximum power but it requires to train with proper rules. Meta-heuristic optimization algorithm like PSO (particle swarm optimization technique) is best in all for tracking the maximum power in PSC. But, it is having disadvantage of taking large time for tracking power of search space because of random generation of initial population. [4]

This problem is conquered in FB-PSO. In which, initial population is generated in forward and backward direction which results in less settling time than conventional PSO (CPSO). [5]

II. CHARACTERITICS OF PV CELL

A. Basics of PV cell

The equivalent circuit diagram of the PV module is shown in Fig. 1.

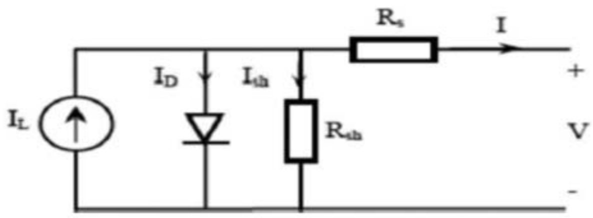

Fig.1. Single diode PV model [6]

The corresponding equation of PV model is shown below,

$$I = Ip - I0\ \left(exp\left[\frac{qo(Vs+IRse)}{AKrTr}\right] - 1\right) - \frac{Vs+IRse}{Rsh} \qquad (1)$$

Where, *I0* is the saturation current, *A* is a diode identity factor, *Kr* is Boltzmann's constant, *qo* is charge of an electron and *Tr* is the temperature in Kelvin. [6]

B. System description

A PV array contains number of PV modules which are connected in series and parallel to get more power [4] as shown in Fig.3. During PSC (Partial shading condition), bypass diode create a hot-spot. So, it behaves as a load instead of source. In this paper, two configurations are considered 20S60P (20series-60parallel) and 30S40P (30series-40parallel) with connected to grid.

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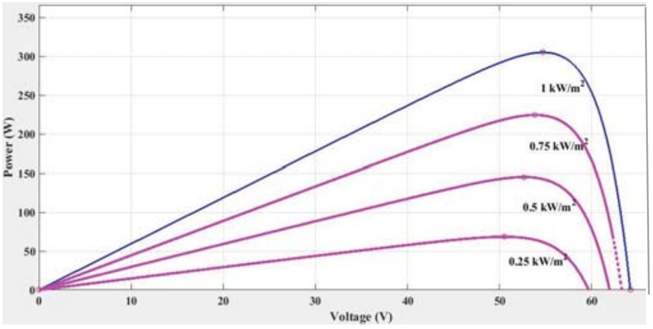

Fig.2. P-V Characteristic of solar module in different irradiation levels at 25^0C temperature.

Both configurations are tested under two different Cases. Case1 has 1000W/m^2 and Case2 has 800W/m^2. Case2 is the replica of PSC (Partial shading condition). [7]

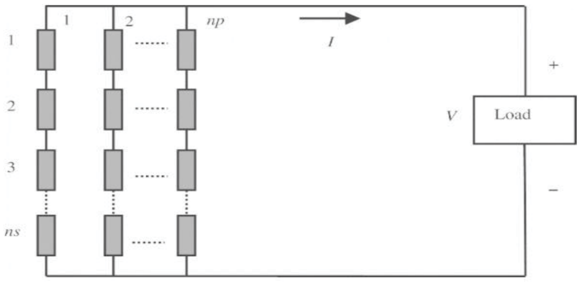

Fig.3. Series-Parallel connected PV modules.

Where *np* is the number of series connected modules and *ns* is the number of parallel connected modules. [1]

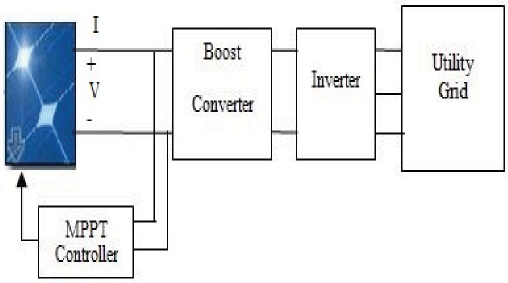

Fig.4.Basic block diagram of grid connected MPPT.

III. FB-PSO ALGORITHM

A. FB-PSO method

In conventional particle optimization technique (CPSO), initial population is randomly generated in search space, which takes large settling time. [8]

In FB-PSO (forward-Backward particle optimization technique) [5], half population is generated in forward direction using (2) and other half population is initialized in backward direction using (3).

$$POPF = X + (Y - X) * rand \quad (2)$$

$$POPB = X + Y - POPF \quad (3)$$

Where, X and Y are the maximum and minimum limit of decision variable, *POPF* and *POPB* are forward and backward population.

The velocity and position update are given in (4) and (5),

$$Vel_i^{\,k+1} = w_r vel_i^{\,k} + c1r1\,\{Pebest_i - pos_i^{\,k}\} + c2r2\,\{Gobest_i - pos_i^{\,k}\} \quad (4)$$

$$pos_i^{k+1} = pos_i^k + vel_i^{k+1} \quad (5)$$

where , i is the particle count, k is the iteration count, w_r is the inertia weight, $c1$ and $c2$ are cognition and social parameters, $r1$ and $r2$ are random numbers, *Pebest* is the personal best of particle and *Gobest* is the global best from all.

In CPSO, the value of w_r is taken randomly in between 0-1. [8] But here, we calculate the value of w_r in between w_{mini} and w_{maxi} by using (6) [5]

$$w_r = w_{maxi} - (w_{maxi} - w_{mini})\frac{k}{Kmax} \quad (6)$$

In MPPT, our objective is to maximize the output PV power and the decision parameter is duty cycle.

As shown in Fig.5, flowchart of FB-PSO, the following points should be considered, 1) Convergence criteria—Convergence criteria met when algorithm goes to maximum iteration. 2) Re-initialization — when system satisfies the (7) and (8), all the parameters are initialized.

$$|vel_{(i+1)}| < \Delta\, vel \quad (7)$$

$$[Po_{(k+1)} - Po_{(k)}) / (Po_{(k)})] > \Delta\, Po \quad (8)$$

Where $Po_{(k+1)}$ is the new power output. For selection of Δvel having two concerns: 1) less value settles at better MPPT but having poor tracking. 2) Greater value causes fast tracking but with more oscillations. [1]

In this paper, the value of $X = 0.9$, $Y = 0.1$, $w_{mini} = 0.1$, $w_{maxi} = 1$, $c1 = 1.7$ and $c2 = 1.3$.

IV. SIMULATION AND RESULTS

The developed system is simulated using MATLAB SIMULINK. System consists of PV array which is connected to boost converter, Inverter and further to the grid as shown in Fig.6. Here, SUN POWER SPR-305WHT model of PV module used. Utility grid has 25 KV distribution feeder and 120 kV equivalent transmission system.

The PV array consists of two configurations [7]. Config.1 consists of 20S60P and Config.2 consists of 30S40P. Both configuration having maximum 366.27KW power output at maximum irradiation level and 800w/m^2 having 293.10KW. In this paper, considered two Cases for both configurations. Case1 has full irradiation i.e.1000w/m^2 and Case2 has 800w/m^2 which shows partial shading.

A. Simulation Result

FB-PSO is a meta-heuristic technique. Its results are compared with PO and CPSO methods. All the above methods were tested under PSC for both 20S60P and 30S40P configurations. For simulation of PV module, the parameters taken for each module as P_{mpp}=305W, V_{oc} =64.2V, I_{sc}=5.96A, V_{mpp}=54.7V, I_{mpp}=5.58A. The design parameters for converter are L=1mH, C_{in}=100µF, C=15000µF, f_s=25 KHz. The parameters of CPSO are $w=0.3$, $C_1=1.7$, $C_2=1.3$.

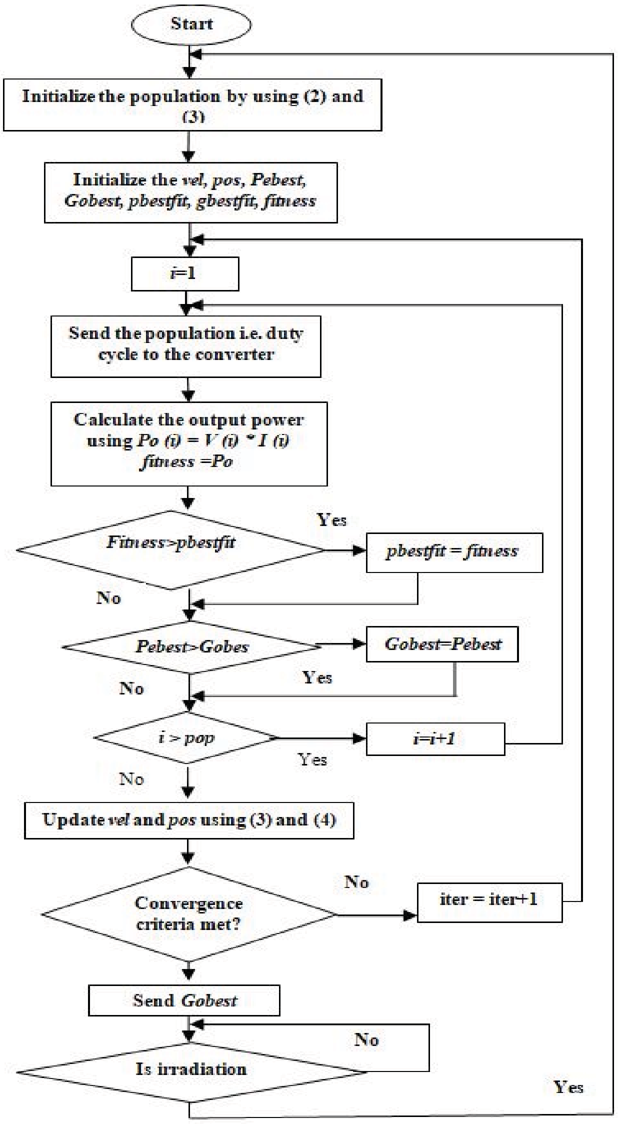

Fig.5. FB-PSO method flowchart [5]

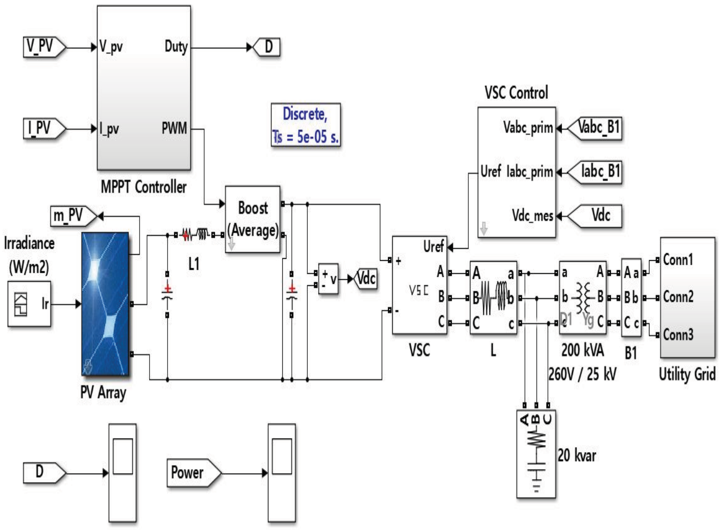

Fig.6. Grid connected PV system with MPPT controller [8]

The output power, voltage and current for the 20S60P configuration with PSC using PO, CPSO and FB-PSO are shown in Fig.7, Fig.8 and Fig.9. The simulation study of Case1 is from 0-1.5sec and Case2 is from 1.5-3sec. In Case1(full isolation), FB-PSO is converges to the GP (global point) at 366.27KW in less time, CPSO tracks the GP at 366.26KW in less time than PO method, and the PO stuck in LP (local point) at 346.3KW as it is not able to compare in between LP and GP. So, it is oscillate around MPP and result in less efficiency. When there is partial shading i.e. Case2 MPPT method gets initiated and FB-PSO locates GP at 287.98KW, CPSO got GP at 287.59KW, PO settle in LP at 284.3KW. Total results are shown in TABLE I [7].

The simulation is repeated for 30S40P configuration with two separate Cases, Case1 (0-1.5sec) and Case2 (1.5-3sec). The FB-PSO method converges to GP at 366.22KW, CPSO settle on GP of 366.21KW, PO reaches at 365.44KW. For Case2 (800w/m^2), FB-PSO gets 278.14KW, CPSO detect 278.13KW and PO gets settle at 275.65KW. The tracking curves are shown in Fig.10, Fig.11 and Fig.12. Total results are shown in TABLE II [7]

The Simulation result showed in fig.15 shows that no oscillation in duty cycle after reaches MPP and very less oscillation in output power in FB-PSO as shown in Fig.16. FB-PSO gets faster convergence than PO in less time, less oscillation with high efficiency.

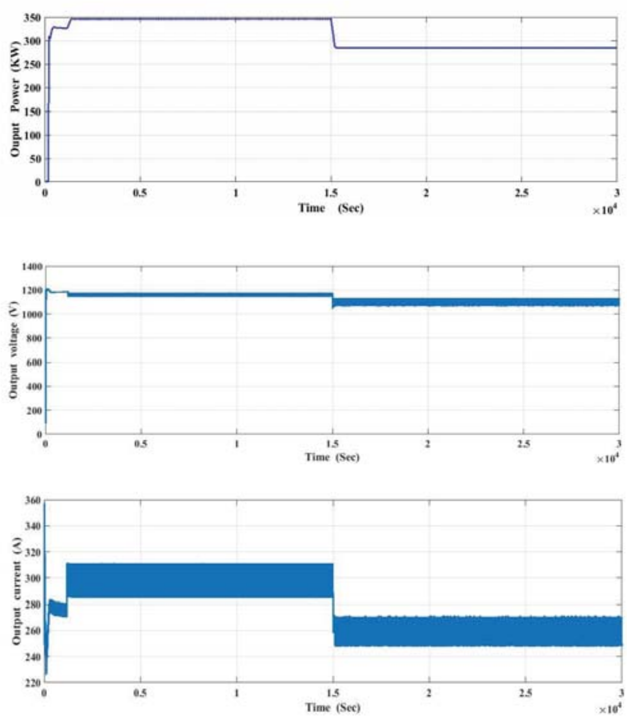

Fig.7 Tracking curves of 20S60P configuration using PO MPPT controller

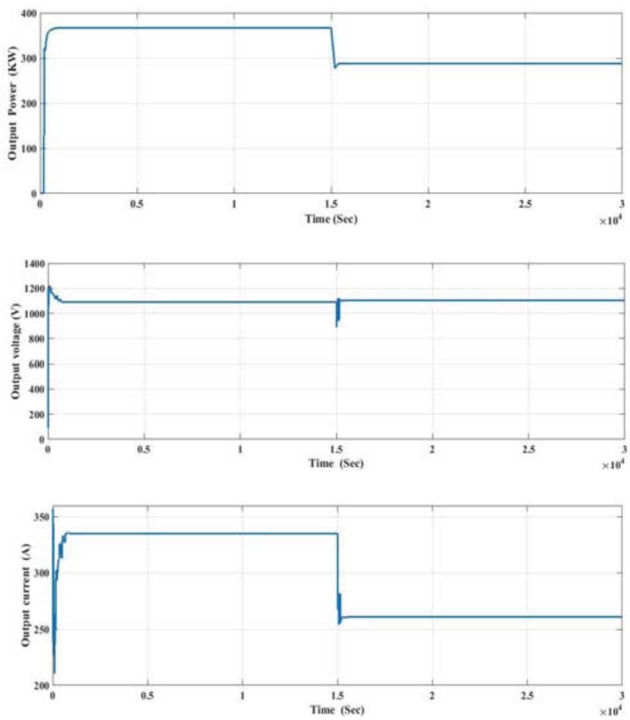

Fig.8 Tracking curves of 20S60P configuration using CPSO MPPT controller.

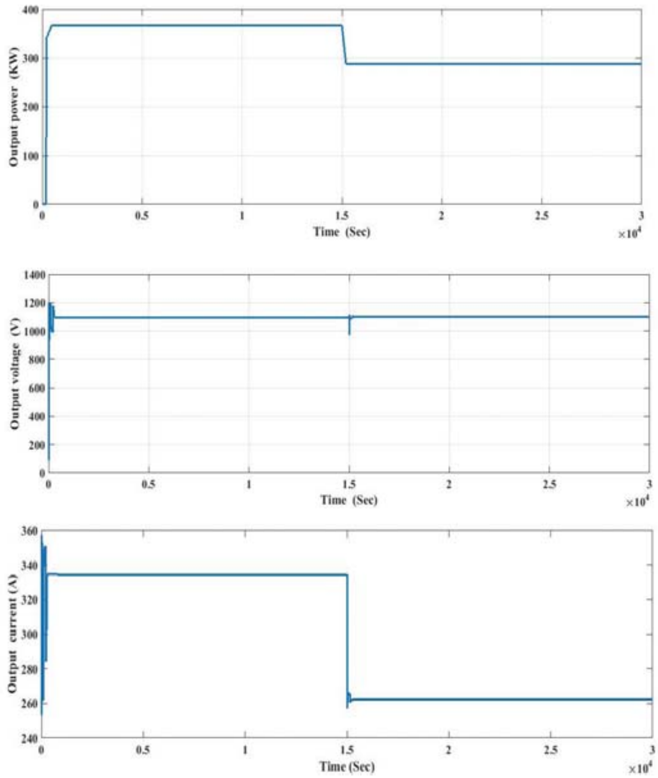

Fig.9 Tracking curves of 20S60P configuration using FB-PSO MPPT controller

TABLE I

CAMPARISION OF ALL MPPT'S IN 20S60P CONFIGUARTION

Case	**P_{max} (KW)**	**Method**	**Output Power (KW)**	**Output Voltage (V)**	**Output Current (A)**	**Efficiency**	**Settling Time (sec)**
Case1 (1000W/m^2)	366.27	PO	346.30	1160	300	0.945	0.1750
	366.27	CPSO	366.25	1092.73	335.18	0.999	0.0973
	366.27	FB-PSO	366.26	1095.67	334.28	0.999	0.0480
Case2 (800W/m^2)	293.01	PO	284.30	1100	260	0.970	0.1200
	293.01	CPSO	287.59	1102.14	26093	0.980	0.1010
	293.01	FB-PSO	287.98	1098.33	262.20	0.982	0.0698

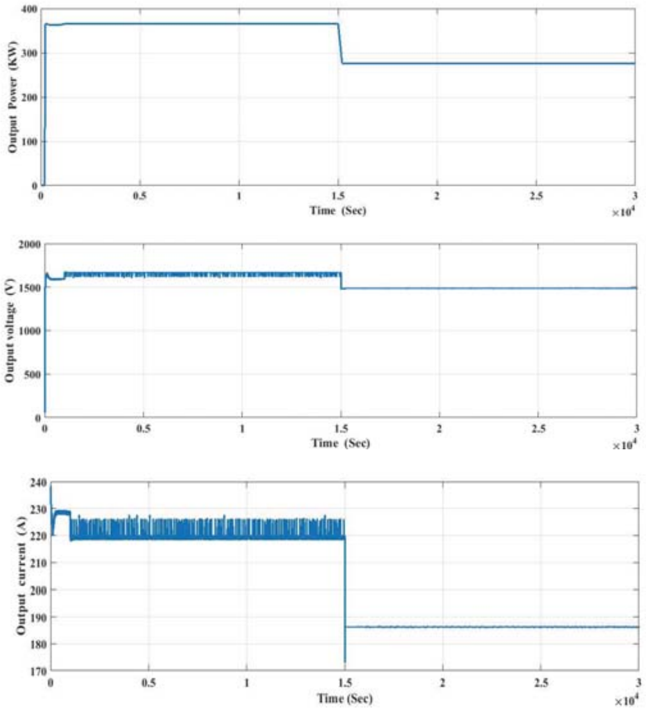

Fig.10 Tracking curves of 30S40P configuration using PO MPPT controller.

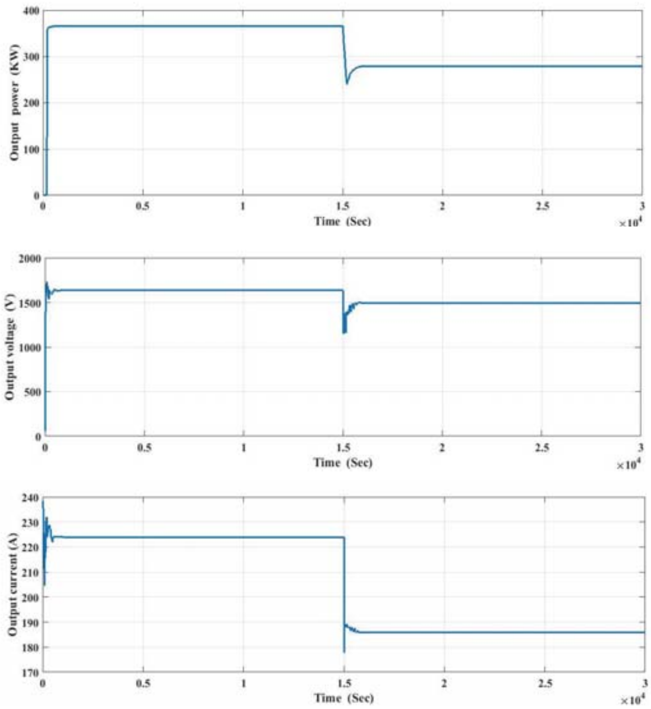

Fig.11 Tracking curves of 30S40P configuration using CPSO MPPT controller.

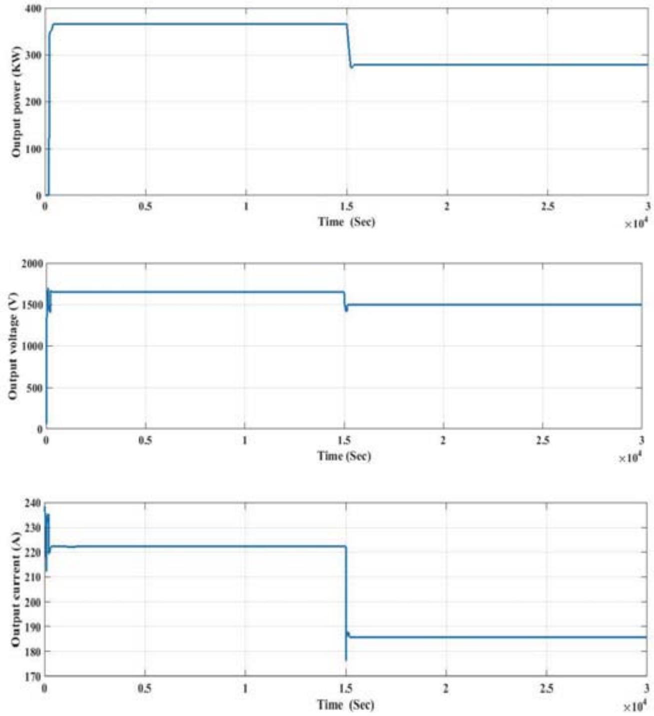

Fig.12 Tracking curves of 30S40P configuration using FB-PSO MPPT controller.

TABLE II

CAMPARISION OF ALL MPPT'S IN 30S40P CONFIGUARTION

Case	P_{max} (KW)	Method	Output Power (KW)	Output Voltage (V)	Output Current (A)	Efficiency	Settling Time (sec)
Case1 (1000W/m^2)	366.27	PO	365.44	1645.1	222.14	0.945	0.1600
	366.27	CPSO	366.21	1635.10	223.97	0.999	0.0670
	366.27	FB-PSO	366.22	1647.82	222.23	0.999	0.0540
Case2 (800W/m^2)	293.01	PO	275.65	1482.20	186.10	0.970	0.129
	293.01	CPSO	278.13	1496.53	185.85	0.980	0.1150
	293.01	FB-PSO	278.15	1497.22	185.82	0.982	0.0610

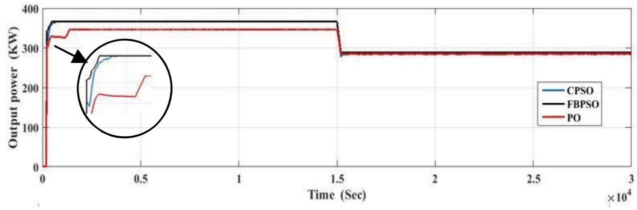

Fig.13 Output power of 20S60P configuration with all MPPT's.

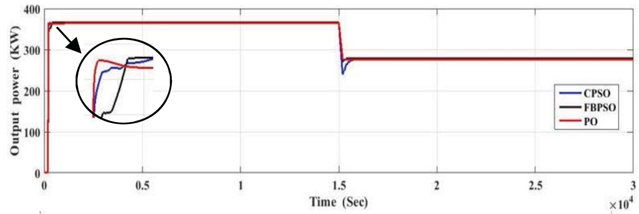

Fig.14 Output power of 30S40P configuration with all MPPT's.

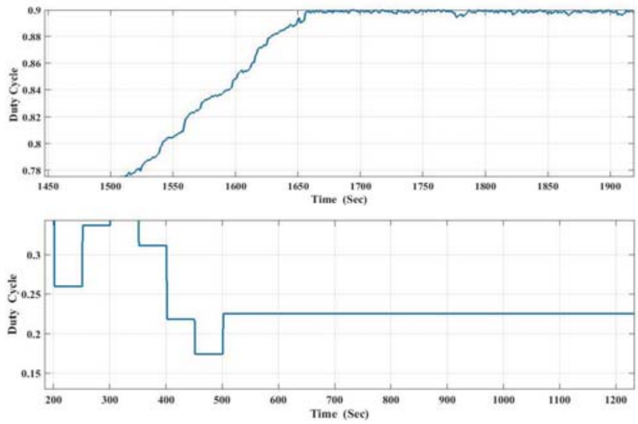

Fig.15. Oscillations in Duty cycle in PO and FB-PSO method.

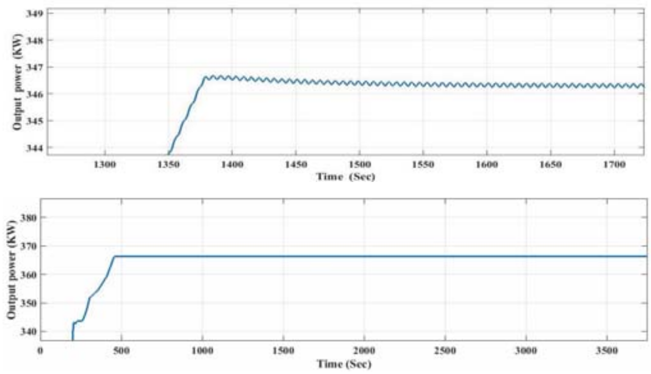

Fig.16. Oscillations in output power in PO and FB-PSO method.

V. CONCLUSION

In this paper, a new method was proposed named FB-PSO in which half of the particles are generated in forward direction and other half particles are generated in backward direction. PO method fails to track MPP. In CPSO, particles are randomly generated. So, system takes more time to settle on maximum power point. But in FB-PSO, the settling time is less. In FB-PSO, particles automatically tracks the best position or move nearer when weather condition change. As a result, reducing in wasting of time to search in wrong area. So, system with FB-PSO has approximately zero steady state oscillations. This improvement tracks MPP very rapidly than conventional methods with high efficiency.

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