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INTERNATIONAL JOURNAL OF
ELECTRICAL AND POWER ENGINEERING
Journal Home Page: https://medwelljournals.com/journalhome.php?jid=1990-7958

Maximum Power Point Tracking in SPV System under Linear and Non-Linear Condition

S. Jerril Gilda and K. Niraimathy
Sri Muthukumaran Institute of Technology, Chennai, India

Key words: Maximum Power Point Tracking (MPPT), Perturbation and Observation (P and O), Particle Swarm Optimization (PSO), linear and non-linear, direct irradiance and diffused irradiance, PV system

Corresponding Author:
Jerril Gilda,
Sri Muthukumaran Institute of Technology, Chennai, India

Page No.: 30-35
Volume: 13, Issue 03, 2019
ISSN: 1990-7958
International Journal of Electrical and Power Engineering

Abstract: In this study, maximum power point tracking is done in a solar photovoltaic system for maximum harvesting of power from the sun, so that, the solar power generation can be improved. There are various MPPT techniques used in solar PV system for extracting power from the sun but the most used is perturbation and observation and particle swarm optimization methods. In this study a comparative analysis of perturbation and observation and particle swarm optimization technique is done for maximum power point tracking of solar photovoltaic system under linear and non-linear condition. The efficiency of both the technique is compared and the best technique is applied for maximum power point tracking in a solar PV system under linear and non-linear conditions that prevail in the atmosphere. Linear and non-linear are conditions in the atmosphere that occurs due to direct sunlight irradiance and diffused irradiance on the Earth's atmosphere that affects the solar PV panel insolation level. Under varying atmospheric conditions the solar PV generation is made more efficient by using the best maximum power point tracking technique.

INTRODUCTION

Now a days demand for renewable energy is rapidly increasing due depletion of non-renewable energy resources and increased pollution from the non-renewable system. In renewable energy systems solar energy is obtained very easily and it involves low capitals when compared to other forms of renewable energy systems. Therefore, tapping of solar energy plays an important role towards achieving long lasting, sustainable, environment friendly in fulfilling the energy needs for mankind which are given by Nepal (2012), Pavlovic *et al*. (2012), Eltawil and Zhao (2010). Generally, solar energy are tapped using photovoltaic cells. The whole combined setup of PV system is used for generating solar power. A photovoltaic source has several advantages such as low maintenance cost, no need for fuel, pollution free and contributes to standalone systems as by Gow and Manning (1996). Though, the solar photovoltaic system is very much beneficial it has some of its drawbacks such as low conversion efficiency, nonlinear characteristics of PV arrays and non-reliability on irradiation levels and atmospheric temperature has made some difficulties to extract the maximum power from them as by Alajmi *et al*. (2013). Over the years many papers are concentrated in finding a solution for maximum power harvesting in a solar PV system using many MPPT algorithms. The conventional methods used are incremental conductance, current sweep method, hill climbing methods and the most commonly used are perturbation and particle swarm optimization. Here, in this study a comparative analysis of Perturbation and Observation (P and O) and Particle Swarm Optimization (PSO) is performed to determine which is the best MPPT technique for achieving maximum power harvesting from a solar PV system under varying atmospheric condition similarly by Ishaque *et al*. (2011). The analysis is performed using the simulated results of MATLAB Simulink.

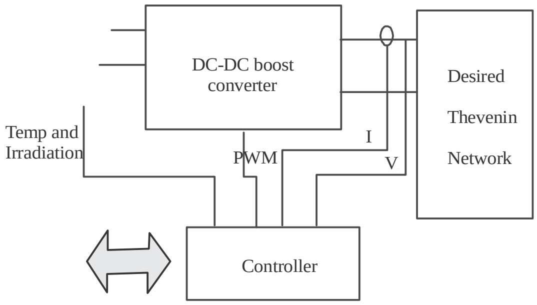

Fig. 1: Solar PV system

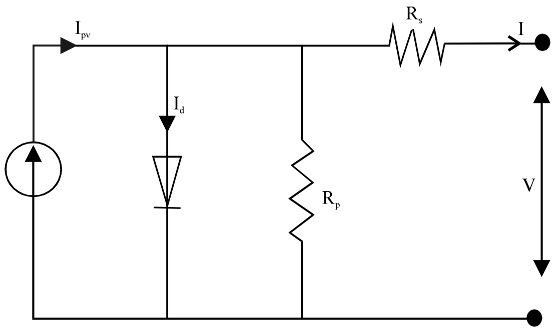

Fig. 2: Solar panel equivalent circuit

MATERIALS AND METHODS

Photovoltaic system: A PV system consists of a solar panel, DC-DC converter, controller, load and battery as shown in Fig. 1.

Solar panel: Solar panel is a P-N junction device in which the sunlight is absorbed by the semiconductor atoms, freeing electrons from the cell's negative layer to flow through an external circuit and back into the positive layer like by Villalva *et al*. (2009). This flow of electrons produces electric current. Figure 2 shows the equivalent circuit of a solar panel. The equations of this circuit are as follows:

$$I = I_{pv} - I_o\left[\exp\left(\frac{V+R_sI}{aV_t}\right)-1\right]-\frac{V+R_SI}{R_p} \quad (1)$$

$$V_t = \frac{N_sKT}{q} \quad (2)$$

$$I_{Pv} = \left(L_{pv,n}+K_I\Delta T\right)\frac{G}{G_n} \quad (3)$$

$$I_o = I_{o,n}\left(\frac{T}{T_n}\right)^3\exp\left[\frac{qE_g}{aK}\left(\frac{1}{T_n}-\frac{1}{T}\right)\right] \quad (4)$$

$$I_{o,n} = \frac{I_{sc,n}}{\exp\frac{V_{oc,n}}{aV_t}} \quad (5)$$

Where:

V_t	:	Thermal Voltage
N_s	:	The Number of series cells
I_{pv}	:	Photovoltaic current
$I_{pv,n}$	:	Photovoltaic current in nominal condition
G	:	Radiation intensity
G_n	:	Nominal radiation intensity = 1000 w/m^2
$\triangle T$	:	($\triangle T = -T_n$) Temperature change
T_n	:	Nominal Temperature = 25°C
E_g	:	The distance of energy bars
Si, $I_{o,n}$	:	Inverse Saturation current in nominal condition
K_I	:	The ratio of short circuit

Current variation to temperature variation in nominal condition, a is a constant value between 1 and 1.5 that is determined by other cell's parameters. By using the Eq. 6 instead of Eq. 4, the accuracy of model increases as a consequence of V_{oc} sensitivity to temperature. In these equations, K_v is the sensitivity of open circuit voltage with respect to temperature:

$$I_o = \frac{I_{sc,n}+K_I\Delta T}{\exp\left[\frac{V_{oc}+K_v\Delta T}{aV_t}\right]-1} \quad (6)$$

$$I_{sc} = \left(I_{sc},n+K_I\Delta T\right)\frac{G}{G_n} \quad (7)$$

$$V_{oc} = V_{oc},n+K_v\Delta T \quad (8)$$

Converter: Converter is an essential part of any PV system regardless of load type. The main role of converter is conditioning the produced power of PV cells in order to meet the load requirements. However, it can be used for matching the panel curve with output load in order to extract maximum power from PV panel.

Controller: A MPPT solar charge controller is the charge controller embedded with MPPT algorithm to maximize the amount of current going into the battery from PV module. The major principle of MPPT is to extract the maximum available power from PV module by making them operate at the most efficient voltage (Alajmi *et al*., 2013). MPPT checks output of PV module, compares it to battery voltage then fixes what is the best power that PV module can produce to charge the battery and converts it to the best voltage to get maximum current into battery. MPPT is most effective under non linear conditions. Cold weather, cloudy or hazy days. MPPT

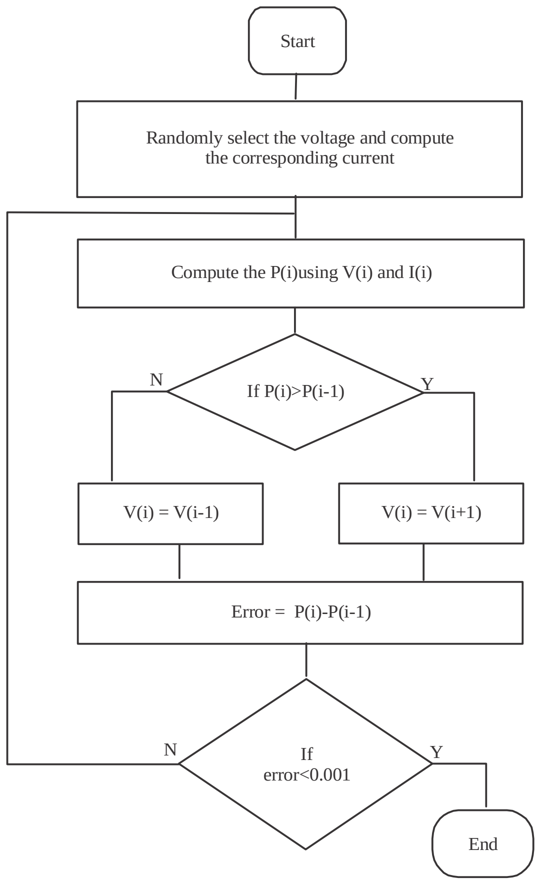

Fig. 3: Flow chart of P&O method

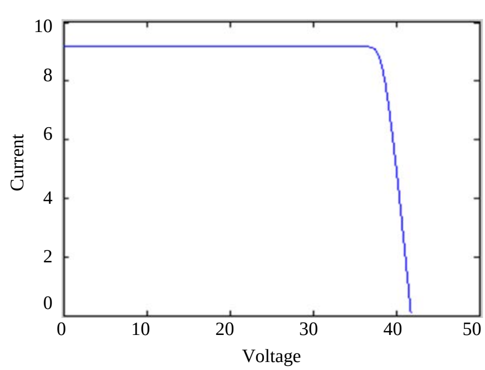

Fig. 4: Characteristic 1-5 curve of P and O (X Y plot)

solar charge controller is used to correct for detecting the variations in the current voltage characteristics of solar cell and shown by Nepal (2012), Pavlovic *et al*. (2012), Eltawil and Zhao (2010), Gow and Manning (1996), Villalva *et al*. (2009) curve (Alajmi *et al*., 2013; Kouchaki *et al*., 2013; Ishaque *et al*., 2011). MPPT solar charge controller is necessary for any solar power systems need to extract maximum power from PV module. It forces PV module to operate at voltage close to maximum power point to draw maximum power.

MPPT using perturbation and observation: Perturbation and Observation (P and O) is based on a comparison of perturbation voltage and changing power. The Perturbation and Observation (P and O) has been used mostly for its simplicity and easy implementation. Applicable to both analog and digital designs. It is also compatible with any kind of PV modules. Oscillations occur during nonlinear conditions. In this method the controller adjusts the voltage by a small amount from the array and measures power. If the power increases, further adjustments in that direction are tried until power no longer increases. This is called the perturbation and observation method and is most common, although, this method can result in oscillations of power output. It is referred to as a hill climbing method because it depends on the rise of the curve of power against voltage below the maximum power point and the fall above that point. The P&O finds the global peak among the local peaks without scanning the entire of P-V curve (Sahnoun *et al*., 2013). The following Fig. 3 shows the flowchart of P&O method.

MPPT using particle swarm optimization: If a PV array is partially shaded by the shadow of building, tree etc., realization of MPPT is a difficult task. The optimal current of each PV module is nearly proportional to the insolation falling on it. Under the partially shaded conditions the conventional MPPT controller may track to a local MPP instead of global MPP. Hence, the generated power may be reduced and PV system efficiency will decrease. Compared to other techniques in this technique a single pair of voltage and current sensors is sufficient to realize the MPPT scheme (Ishaque *et al*., 2012). The PSO uses several cooperative agents and each agent shares the information attained by each individual during the search process. In this method each agent moves in the search space with a velocity, v_i^k and momentum w, according to, its own previous best solution and its groups previous best solution (Fig. 4):

$$V^{k+1} = w*v_i+c1*r1*pbest_i+c2*r2*gbest \quad S_i^{k+1} = s_i^k+V_i^{k+1}$$

Here, $pbest_i = s_i^k$ and $f(s_i^k)>f(pbest_i)$, where, f (also known as objective function) is the generated power P which represents the summation of power generated by each array. Only one current sensor is sufficient for

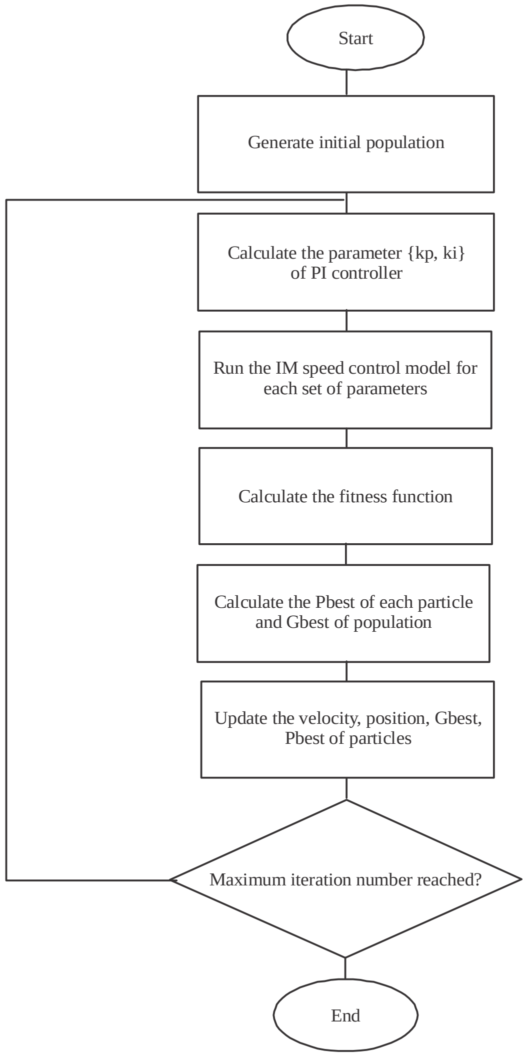

Fig. 5: Flow chart for PSO method

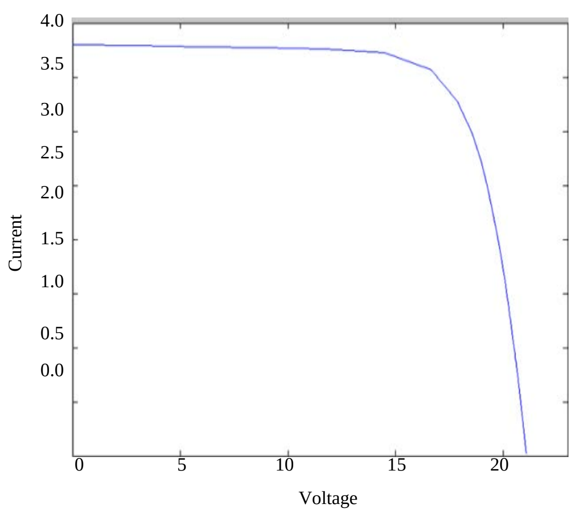

Fig. 6: Characteristic 1-5 curve of PSO (xy plot)

tracking the MPP and can be called as multidimensional MPPT control. Let V represent the terminal voltage and can be represented in the form of N-dimensional row vector:

$$s^k = \left[V_1^k, V_2^k, ..., V_N^k\right]$$

$$v^k = \left[V_1^k - V_1^{k-1}, V_2^k - V_2^{k-1}, ..., V_N^k - V_N^{k-1}\right]$$

When the agents reach to the MPP in steady state, the velocity becomes zero. The agents are reinitialized whenever the following two conditions are satisfied. The researchers add the function of shifting the agents in order to adapt the agents to such situation. The direction of shifting is decided randomly. Hence, this function enables local search around the MPP:

$$|v_i + 1| < \Delta v$$

$$\frac{P(s_i + 1) - P(s_i)}{P(s_i)} < -\Delta P$$

The following Fig. 5 and 6 shows the flow chart for PSO method (Fig. 6).

RESULTS AND DISSCUSSION

The simulated results for P and O and PSO under linear condition and non-linear is given in the following tables.

Comparative analysis of P and O and PSO under linear and non-linear conditions: A comparative maximum power output for P and O and PSO algorithm is executed under linear and non-linear condition (Heydari-doostabad *et al*., 2013). The linear condition is nothing but SPV panel exposed to direct beam of sunlight irradiance where as non-linear condition is that when the SPV panel is exposed to diffused sunlight irradiance, here, the term diffused irradiance occur due to cloudy weather condition or due to reflection of sunlight by huge mountains lying low. The simulated results are obtained to check which algorithm among PSO and P&O is doing better in maximum power point tracking and the comparative output is shown in tables where Table 1 illustrates the maximum power comparative output of PSO and P and O under linear condition and Table 2 illustrates the maximum power comparative output of PSO and P and O under non-linear condition.

Table 1: Simulated results using PSO and P&O technique under linear condition

		Theoretical output of SPV panel			SPV panel output using PSO			SPV panel output using P and O		
GW/m2	T°C	Voltage V (V)	Current I (A)	Power P (W)	Voltage V (V)	Current I (A)	Max power (W)	Voltage V (V)	Current I (A)	Max power (W)
1000	25	38.56	5.44	210.00	39.70	5.29	210.05	40	5.25	210.002
800	25	38.24	4.30	164.65	39.10	4.22	165.37	39	4.23	165.16
600	25	28.24	3.40	097.76	38.22	3.17	121.07	38	3.19	121.04
400	25	19.12	2.27	043.58	37.08	2.10	078.09	37	2.11	78.08
1000	35	35.50	5.36	190.30	36.69	5.40	198.26	37	5.35	198.20
1000	40	33.83	5.35	181.00	35.23	5.48	193.06	35	5.49	192.29
1000	45	32.79	5.29	173.50	33.99	5.48	186.59	34	5.48	186.59
750	29	35.84	4.09	146.88	37.69	3.99	150.43	38	3.95	150.34
800	35	38.23	3.94	150.87	36.15	4.30	155.56	36	4.32	155.55
600	40	28.67	3.50	100.39	33.87	3.24	110.07	34	3.23	110.05
950	45	34.32	4.72	162.00	33.87	5.20	176.40	34	5.18	176.36
500	39	23.89	2.94	070.47	33.53	2.70	090.74	34	2.67	0.90.65

Table 2: Simulated results using PSO and P and chnique under Non-linear condition

		Theoretical output of SPV panel			SPV panel output using PSO			SPV panel output using P&O		
GW/m2	T°C	Voltage V (V)	Current I (A)	Power P (W)	Voltage V (V)	Current I(Amps)	Max power (W)	Voltage V (V)	Current I (A)	Max power (W)
550	25	26.40	3.00	79.20	34.60	2.99	103.454	34	2.80	95.20
800	25	38.24	4.30	164.65	39.10	4.22	165.370	39	4.23	165.16
600	25	28.68	3.40	097.76	38.22	3.17	121.070	38	3.19	121.04
400	25	19.12	2.27	043.58	37.08	2.10	078.090	37	2.11	78.08
1000	35	35.50	5.36	190.30	36.69	5.40	198.260	37	5.35	198.20
1000	40	33.83	5.35	181.00	35.23	5.48	193.060	35	5.49	192.29
1000	45	32.79	5.29	173.50	33.99	5.48	186.590	34	5.48	186.59
1000	25	38.23	5.44	210.05	39.70	5.29	210.050	40	5.25	210.00
750	29	35.84	4.09	146.88	37.69	3.99	150.430	38	3.95	150.34
800	35	38.23	3.94	150.87	36.15	4.30	155.560	36	4.32	155.55
600	40	28.67	3.50	100.39	33.87	3.24	110.070	34	3.23	110.05
950	45	34.32	4.72	162.00	33.87	5.20	176.400	34	5.18	176.36
500	39	23.89	2.94	070.47	33.53	2.70	090.740	34	2.67	090.65

CONCLUSION

Thus the comparitive analysis of maximum power point techniques perturbation and observation and particle swarm optimization is done under linear and non-linear conditions using MATLAB and the maximum power point tracking is carried out and from the results it is seen that particle swarm optimization technique is best suitable under linear and non-linear conditions with reduced steady state oscillations because P&O fails to track maximum power point when the difference between the irradiation level of the shaded modules and non-shaded modules is large. Therefore, PSO is best suited.

REFERENCES

Alajmi, B.N., K.H. Ahmed. S.J. Finney and B.W. Williams, 2013. A maximum power point tracking technique for partially shaded photovoltaic systems in microgrids. IEEE Trans. Ind. Electron., 60: 1596-1606.

Eltawil, M.A. and Z. Zhao, 2010. Grid-connected photovoltaic power systems: Technical and potential problems: A review. Renewable Sustainable Energy Rev., 14: 112-129.

Gow, J.A. and C.D. Manning, 1996. Development of a model for photovoltaic arrays suitable for use in simulation studies of solar energy conversion systems. Proceedings of the 6th International Conference on Power Electronics and Variable Speed Drives, September 23-25, 1996, IET Digital Library, Nottingham, UK., pp: 69-74.

Heydari-doostabad, H., R. Keypour, M.R. Khalghani and M.H. Khooban, 2013. A new approach in MPPT for photovoltaic array based on extremum seeking control under uniform and non-uniform irradiances. Solar Energy, 94: 28-36.

Ishaque, K., Z. Salam, H. Taheri and A. Shamsudin, 2011. Maximum power point tracking for PV system under partial shading condition via. particle swarm optimization. Proceedings of the 2011 IEEE International Conference on Applied Power Electronics Colloquium (IAPEC), April 18-19, 2011, IEEE, Johor Bahru, Malaysia, ISBN:978-1-4577-0007-1, pp: 5-9.

Ishaque, K., Z. Salam, M. Amjad and S. Mekhilef, 2012. An improved Particle Swarm Optimization (PSO)-based MPPT for PV with reduced steady-state oscillation. IEEE. Trans. Power Electron., 27: 3627-3638.

Kouchaki, A., H. Iman-Eini and B. Asaei, 2013. A new maximum power point tracking strategy for PV arrays under uniform and non-uniform insolation conditions. Solar Energy, 91: 221-232.

Nepal, R., 2012. Roles and potentials of renewable energy in less-developed economies: The case of Nepal. Renewable Sustainable Energy Rev., 16: 2200-2206.

Pavlovic, T.M., I.S. Radonjic, D.D. Milosavljevic and L.S. Pantic, 2012. A review of concentrating solar power plants in the world and their potential use in Serbia. Renewable Sustainable Energy Rev., 16: 3891-3902.

Sahnoun, M.A., H.M.R. Ugalde, J.C. Carmona and J. Gomand, 2013. Maximum power point tracking using P&O control optimized by a neural network approach: A good compromise between accuracy and complexity. Energy Procedia, 42: 650-659.

Villalva, M.G., J.R. Gazoli and E. Ruppert Filho, 2009. Modeling and circuit-based simulation of photovoltaic arrays. Proceedings of the International Conference on Power Electronics (COBEP'09), September 27-October 1, 2009, IEEE, Bonito-Mato Grosso do Sul, Brazil, ISBN:978-1-4244-3369-8, pp: 1244-1254.