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Voltage Regulation for a Photovoltaic System Connected to Grid by Using a Swarm Optimization Techniques

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Abstract— this paper presents voltage regulation of photovoltaic generation (PVG) system connected to three phase grid for any situation of solar radiation using PI controller, PI parameters are tuned using two techniques of swarm algoritm, this techniques are Particle Swarm Optimization (PSO), and Adaptive Weight Particle Swarm Optimization (AWPSO). This paper uses the MATLAB / SIMULINK software, it has been implemented for the comparison of the conventional PI controllers and two techniques used for photovoltaic DC voltage, It has been carried out to compare the settling times and overshoots of each technique.

Index Terms— Photo Voltaic Systems, Particle Swarm Optimization, and Adaptive Weight Particle Swarm Optimization.

1 Introduction

Using photovoltaic (PV) systems as a clean and safe energy source from the sun has been growing rapidly. The PV systems applications in power systems appear throw two main fields as a stand-alone or off-grid applications, or as a grid –connected or on-grid applications.

Off-grid or stand-alone PV systems can be used for supply power to loads that do not have any access to grids, while applications connected to the grid to provide power to local loads and to exchange power with the utility grid are used [1].

In this paper, it was selected the grid-connected PV system because it more commonly used and widespread than off-grid, figure (1) shows the general diagram of on-grid systems.

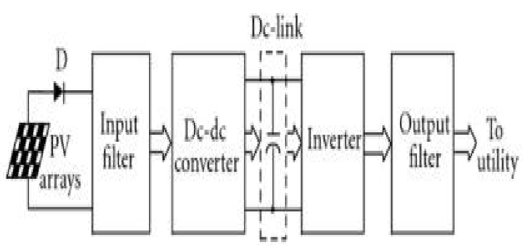

Fig. 1.The general diagram of grid-connected PV systems.

The main components of on-grid system includes:

1) A series/parallel mixture of PV arrays to directly convert sunlight to DC power,
2) A dc-dc converter to adjust the voltage values commensurate with inverter input,
3) An inverter to convert DC power to AC power; also keeps the PVs operating at maximum efficiency, each photovoltaic systems are connecting to the grid through a voltage source inverter [2, 3].

The control methodology in the grid-connected inverter is a classical control problem which contains an inner current control loop and an outer voltage control loop. Figure (2) Shows the block diagram of voltage sourced converter (VSC) control to control in the grid-connected PV systems, voltage loop maintains a constant voltage on the DC link capacitor and provides the reference for the inner current control loop. Also, a Phase Locked Loop (PLL) is used in order to synchronize the grid phase angle with the control system.

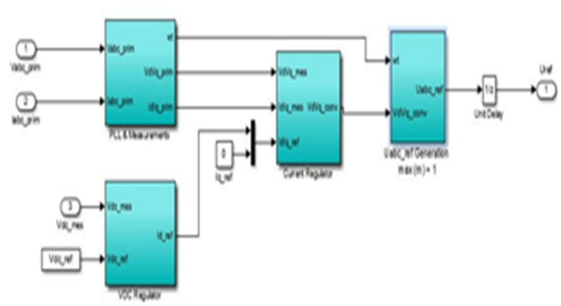

Fig. 2. (VSC) Control for grid-connected PV systems.

This paper is concerned with studying the voltage control by conventional PI controllers, and tuning PI parameters by two types of controller, particle swarm optimization (PSO) and (AWPSO), to minimize the error of DC voltage thus make better use of the PV array, figure (3) Shows conventional PI Controller used to voltage DC regulation.

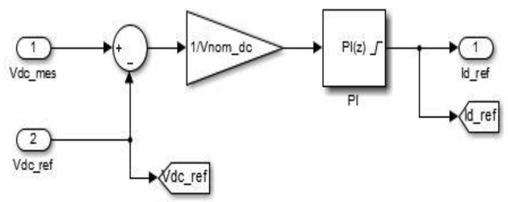

Fig. 3. Voltage DC regulation by using conventional PI controller.

2 Particle Swarm Optimization (PSO)

PSO is a grouping of particles and supports the gathering in his behavior is mainly based on the bird's behavior, as described in [4].This model was developed by Dr.Eberhart and Dr.Kennedy in 1995, this model is inspired by the social behavior of swarms of birds or fish groups as it travels from one place to another, there are many similarities between the PSO and evolutionary computing techniques.The goal of this algorithm is to get a solution and the result is optimal and best through simulate the behavior of birds in the search for the best food and so any system that relies on this algorithm will be formed at the beginning of the random grouping of random solutions, and are searched within this assembly for the perfect solution and through the renovation generations.

Actually, within the PSO algorithm is searched for the best solution across the track and follow the current elements of a best-particles is similar to the behavior of bees and ants, as presented in [5–7]. Each particle has knowledge of the location with best fitness value of the whole swarm which called the global best or (g best). At each point along their path, each particle also compares the fitness value of their (P best) to that of (g best). If any particle has a (P best) with better fitness value than that of current (g best), then the current (g best) is replaced by that particle's (P best). The movement of particles is stopped once all particles reach close to the position with best fitness value of swarm.

Let the particle of the swarm is represented by the N dimensional vector then the equations of the swarm as the following:

Xi =(X1, X2, X3,...XN) (1)

The previous best position of the N^{th} particles is recorded and represented as follows:

P besti = (P best1, P best2,,..., P bestN) (2)

Where:

Pbest is Particle best position (m), N is the total number of iterations.

The best position of the particle among all particles in the swarm is represented by gbest, the velocity of the particle is

The best position of the particle among all particles in the swarm is represented by gbest, the velocity of the particle is represented as follows:

$Vi = (V_1, V_2,...V_N)$ (3)

Where:

Vi is the velocity of each particle i

The modified velocity and position of each particle can be calculated from the current velocity and the distance from particle current position to particle best position

P best and to global best position g best is described in the following equations [6]

$$\boldsymbol{Vi(t) = W.Vi(t-1) + C1.rand(0,1).\big(Pbest - Xi(t-1)\big) + C2.rand(0,1).\big(gbest - Xi(t-1)\big)} \quad (4)$$

$$\boldsymbol{Xi(t) = Xi(t-1) + Vi(t)} \quad (5)$$

i=1, 2, 3…..N (6)

j=1, 2, 3…..D (7)

Where:

Vi(t)	Velocity of the particle i at iteration t (m/s)
X i(t)	The Current position of particle i at iteration t (m)
D	The Dimension (m)
C_1	The cognitive acceleration coefficient and it is a positive number
C_2	Social acceleration coefficient and it is a positive number
rand [0,1]	A random number obtained from a uniform random distribution function in the interval [0,1]
gbest	The Global best position (m)
W	The Inertia weight

3 Adaptive Weighted Particle Swarm Optimization

This technique used as a modification of PSO in multi-objective optimization problems as presented in [8].

AWPSO is consists of inertia weigh (W), and Acceleration factor (A) as described in [7, 12]. The inertia weight formula is as follows which makes W value changes randomly from Wo to 1 as shown in [9, 10, 6].

$$\boldsymbol{W = Wo + rand(0,1).(1 - Wo)} \quad (8)$$

where:

Wo The initial positive constant in the interval chosen from [0, 1].

Particle velocity at ith iteration as follows:

$$\boldsymbol{Vi(t) = W.Vi(t-1) + AC1.rand(0,1).\big(Pbest - Xi(t-1)\big) + AC2.rand(0,1).\big(gbest - Xi(t-1)\big)} \quad (9)$$

Additional term denoted by A called acceleration factor is added in the original velocity equation to improve the swarm search.

The acceleration factor formula is given as follows [11]:

A=Ao+i / n

Where:

Ao	the initial positive constant in the interval [0.5, 1].
n	the number of iteration
C1and C2	the constant representing the weighing of the stochastic ac-celeration terms that pull each particle towards Pbest and gbest posi-tions

4 SIMULATION AND DESCRIPTION

The system which will be investigated in this paper is a 3-phase grid connected PV system as shown in figure (4). A PV array (100-kWatt) is connected to grid (25-kVolt) via a 3-phase 3-level Voltage Source Converter (VSC) and DC-DC boost converter. This system consists of Maximum Power Point Tracking (MPPT), VSC, Phase Locked Loop (PLL), three phase utility grid, and PV array.

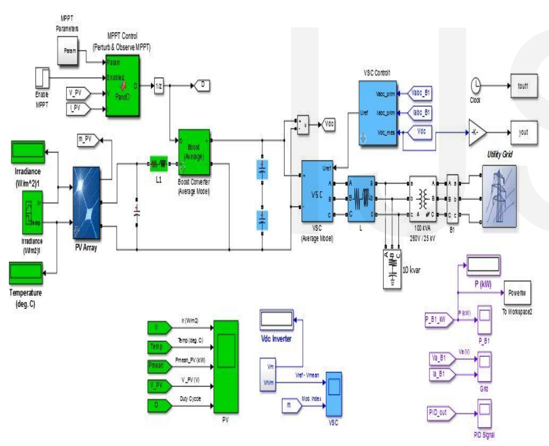

Fig. 4. Three-phase grid connected 100kw PV system.

The PV array consists of 330 Sun power modules (SPR-30E-WHT-D), the maximum power from pv array =100.7 Kw. The manufacturer specifications for one module described in [12] are shown in table (1). The figures (5, 6) shows I-V and P-V characteristics for one module and for the whole array.

Voltage stability analysis of the system will study firstly without controller, and then using conventional PI controllers, and finally using tuning PI parameters by two types of particle swarm optimization (PSO), and (AWPSO), to minimize the error of DC voltage thus make better use of the PV array, figure (7) Show SIMULINK model of voltage regulation by using PI controller based PSO, The parameters of PSO are shown in table (2).

TABLE 1
ONE MODULE PARAMETERS OF PV ARRAY

Number of series connected cell	Open circuit voltage (Voc)	Short circuit current(Isc)	voltage at maximum power (Vmp)	Current at maximum power (Imp)
96	64.2V	5.96 A	54.7 V	5.58 A

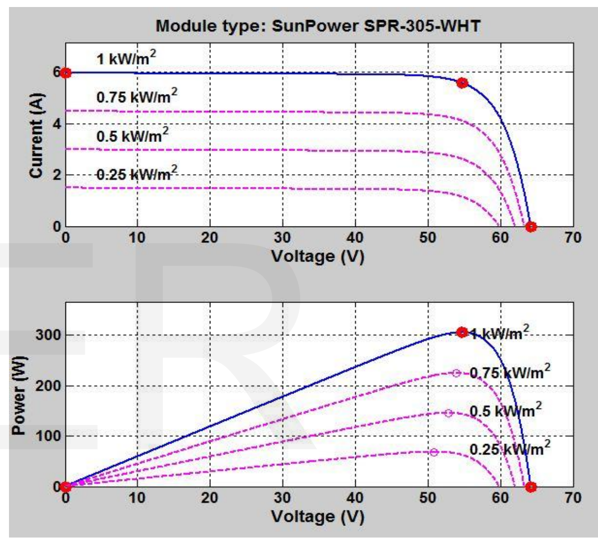

Fig. 5. I-V and P-V characteristics for one module.

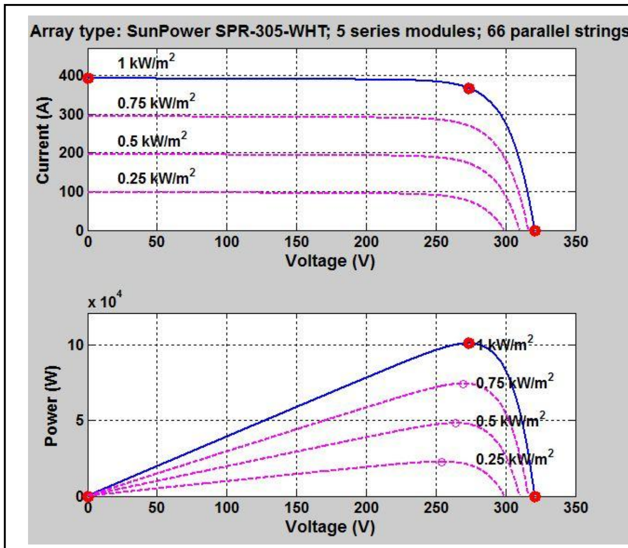

Fig. 6. I-V and P-V characteristics for array.

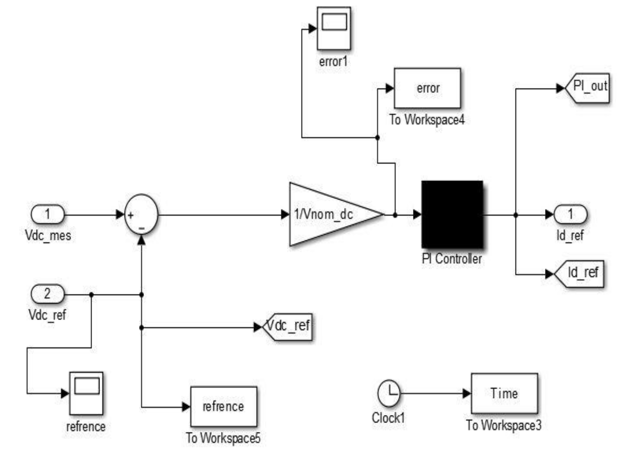

Fig. 7. SIMULINK model of Voltage regulation by using PI controller based PSO.

TABLE2
THE PARAMETERS OF PSO

number of swarm beings(N)	number of iterations	percentage of old velocity(C0)	percentage to of uniform initial of positions (C1,C2)	x0range
25	500	0.65	2	[0 700]

Firstly perform simulation of the system, simulation time =6 sec, the comparison of Error of DC voltage without controller, with conventional PI, and with PI based PSO are shown in figure (8), the settling time and overshoot voltage for PI controller based PSO are the best value comparing with the conventional PI controllers which is evident in table (3).

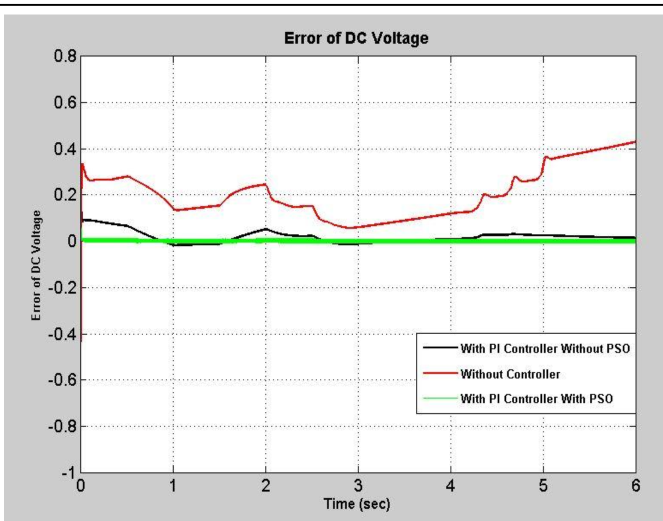

Fig. 8. Error of DC voltage without controller, with conventional PI, and with PI based PSO.

TABLE3
COMPARISON OF RESULTS BETWEEN THE CONVENTIONAL PI AND PI BASED PSO

	KP	KI	Settling Time	Time at max	Overshoot
conventional PI	10.5914	8.5246	3.2001	0.0089	12.7364
PI based PSO	173.463	45.5489	0.0113	0.0072	9.0012

Secondly perform simulation of the system, by using PI controller based PSO, and AWPSPO with difference percentage of old velocity (W0) = 0.35 in eq. (8) in AWPSPO method, writing the best results and compare the results between them. The top 10 results and best result for each method are shown in table (4), the settling time and overshoot voltage of AWPSO are smaller than its values using PSO method. The comparison of Error of DC voltage with PI based PSO, and AWPSO are shown in figure (8).

TABLE 4
COMPARISON OF RESULTS BETWEEN PSO, AND AWPSO

		Kp	Ki	SettlingTime	Time_At_Max	Overshoot
PSO	1	225.801	453.606	0.0116	0.0073	9.9614
	2	172.96	81.5938	0.0113	0.0072	9.04
	3	173.463	45.5489	0.0113	0.0072	9.0012
	4	95.2751	681.634	0.0167	0.0075	12.1361
	5	342.765	550.843	0.0284	0.0073	9.7452
	6	79.7486	675.868	0.0481	0.0075	12.6729
	7	191.54	637.118	0.0155	0.0074	10.5462
	8	58.7747	291.144	0.0484	0.0073	10.3031
	9	72.0033	474.816	0.0167	0.0074	11.4204
	10	189.957	464.843	0.0114	0.0073	10.1293
AWPSO	1	345.826	372.391	0.0271	0.0271	9.5249
	2	166.084	73.737	0.0112	0.0072	8.9815
	3	356.976	379.03	0.0282	0.0073	9.5199
	4	13.8391	580.368	0.0542	0.0085	21.582
	5	23.0025	388.657	0.0797	0.0078	14.2578
	6	149.198	453.205	0.0782	0.0073	10.2577
	7	119.975	442.179	0.0157	0.0074	10.4542
	8	221.292	433.081	0.0115	0.0073	9.9385
	9	155.031	213.829	0.0112	0.0073	9.4261
	10	16.2425	130.891	0.1683	0.008	12.02

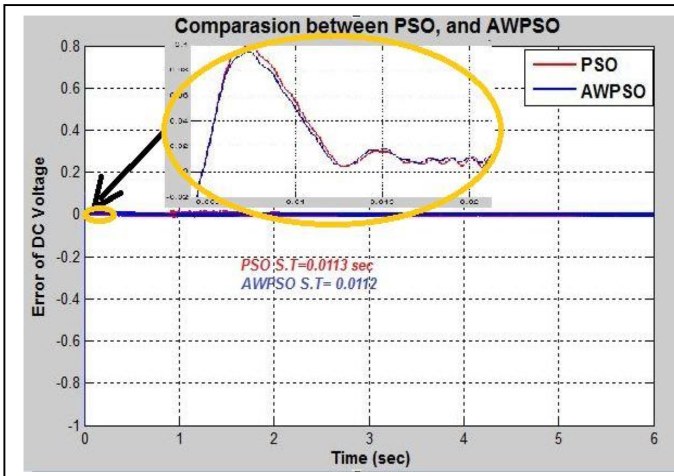

Fig. 9. Comparison between PSO, and AWPSO.

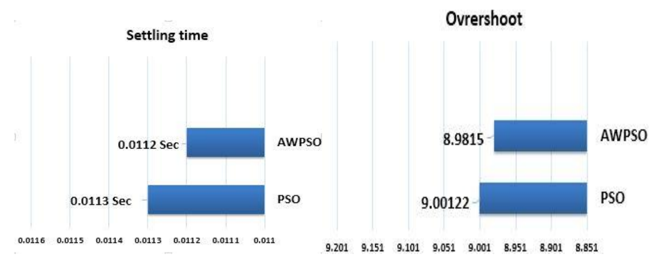

Fig. 10. Comparison between Settling times and overshoots by PSO, and AWPSO

5 CONCLUSION

Artificial intelligence techniques used in this paper are the Partical Swarm (PSO), and Adaptive Weighted Partical Swarm optimization (AWPSO), the settling times and overshoot voltage values with the two types of swarm controllers are compared with the results using the conventional PI controllers, the (AWPSO) technique gives the best results than PSO and conventional PI for this purpose.

REFERENCES

[1] Eltawil, M.A. and Z. Zhao (2010). Grid-connected photovoltaic power systems: Technical and potential problems-A review Renewable and Sustainable Energy Reviews, 14, No.1112-129.

[2] Lakshmanan.S, A. Amit Jain, and B. S. Rajpurohit (2015), 'An Approach to Improve Power Flow Control and Stability Analysis for Grid Connected Solar PV System' International Conference on Circuit, Power and Computing Technologies [ICCPCT].

[3] F. Blaabjerg, Z. Chen and S. Kjaer(2004) 'Power Electronics as Efficient Interface in Dispersed Power Generation Systems', IEEE Trans. on Power Electronics, Vol. 19, N°5, pp. 1184 - 1194.

[4] Soundarrajan A, Sumathi S (2010) Particle swarm optimization based LFC and AVR of autonomous power generating system. IAENG Int J Comput Sci

[5] Azar AT, Vaidyanathan S (2015) Chaos modeling and control systems design. Studies in computational intelligence, vol 581. Springer, Germany. ISBN: 978-3-319-13131-3

[6] Bahgaat NK, El-Sayed MI, Moustafa Hassan MA, Bendary FA (2014) Load frequency control in power system via improving PID controller based on particle swarm optimization and ANFIS techniques. Int J Syst Dyn Appl (IJSDA). IGI-Global, USA 3(3):1–24

[7] Bahgaat NK, El-Sayed MI, Moustafa Hassan MA, Bendary FA (2015) Application of some modern techniques in load frequency control in power systems. In: Chaos Modeling and Control Systems Design, vol 581. Springer, Germany, pp 163–211

[8] Allaoua B (2008) the efficiency of particle swarm optimization applied on fuzzy logic DC motor speed control. Serbian J Electr Eng 5(2):247–262

[9] Azar AT (2010) Fuzzy systems. IN-TECH, Austria, Vienna. ISBN: 978-953-7619-92-3

[10] Azar AT (2012) Overview of type-2 fuzzy logic systems. Int J Fuzzy Syst Appl (IJFSA) 2(4):1–28

[11] Rania HM(2012) Development of advanced controllers using adaptive weighted PSO algorithm with applications,M.Sc. Thesis, Faculty of Engineering, Cairo University, Cairo, Egypt

[12] The 'Module' parameter of the PV Array block allows you to choose among various array types of the NREL System Advisor Model (https://sam.nrel.gov/).