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Smart Energy Empowerment in Smart and Resilient Cities

Renewable Energy for Smart and
Sustainable Cities

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Editor

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and Sustainable Cities

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Particle Swarm Optimization and Artificial Neural Network



Frequency Control in Microgrid Power System with Renewable Power Generation Using PID Controller Based on Particle Swarm Optimization

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Abstract. This paper addresses an application of proportional-integral-derivation (PID) controller based Particle Swarm Optimisation for frequency control of a microgrid power system with the integration of wind power generation and PV generator. Fuel cell and diesel engine generator are used as secondary sources. The Energy Storage System is often applied in the microgrid system for supply energy to the connected load. Particle Swarm Optimization is used to tune the gains of the PID controller through revolving of an objective function. The PSO is robust and more efficient optimization method. The main objective of this work is to reduce the fluctuations of the system frequency and power system. The results shows that the PID controller based PSO given better performances of system for frequency and power regulation in comparison with PID controller based Genetic Algorithm.

Keywords: Renewable energy · Hybrid power system · PID controller · Frequency control · Particle Swarm Optimization

1 Introduction

In the last decades, the increase of the depletion and environment impacts of the fossil fuel cell to using new renewable green energy in order to limit the power demand and avoid the greenhouse caused by the emission of gas from fossil fuel sources [1]. However, the energy from renewable energy sources such as wind and photovoltaic is not constant and varies according to the weather conditions. The stochastic and intermittent nature results in some fluctuations in power and frequency system that must be controlled using an adequate control strategy [2, 3]. One of the most existing

solutions is to combine more than one of these sources with a storage system and conventional sources called hybrid energy system which is largely used to overcome the need for energy and decrease the effect of the greenhouse. The reason for using the energy storage system is to absorb the fluctuations from wind and photovoltaic systems and supply this stored power to the load later. This hybrid energy system can operate in connected mode or in island mode in rural areas [1]. The main challenges that face the use of hybrid energy system are to promise the electricity supply to customers and providing for the long term energy security [4]. Control system based PID controller is commonly used in industry due to its simplicity and clear functionality amongst all other control schemes [8]. Several works are done using the PID controller for control of a hybrid energy system such as reported in [5–7].

Frequency and power fluctuation present a big challenge in the operation of such a hybrid energy system. Many researchers investigate the optimal design of PID controller parameters using various optimization techniques such as Genetic Algorithm, Particle Swarm Optimization, and Mine Blast Algorithm for frequency and power control in a hybrid energy system. In [9] the authors discuss the frequency control of stand-alone microgrid with a battery energy storage system using particle swarm optimization (PSO). In [10, 11] the authors studied the frequency control of the hybrid energy system using PID/PI based GA. Another optimization method called MBA is reported in [12] in order to optimize the PID controller parameters for hybrid microgrid system.

For tuning the optimal values for the PID controller parameters, we propose to use the PSO technique proposed to be applied. This technique developed by Kennedy and Eberhart in 1995 [13], is a stochastic search, robust and flexible in solving of optimization problem due to its high-quality of solution within shorter calculation time and stable convergence characteristic than other stochastic methods [14].

The rest of the paper is summarized as follows: the configuration of the proposed system is presented in Sect. 2. In Sect. 3 the controller strategy and optimization method are addressed. The simulation results and discussions are reported in Sect. 4. This paper is ended by a conclusion in the last section followed by a reference.

2 Configurations of Microgrid Power System

The various microgrid energy system components are presented by first-order transfer function as shown in Fig. 1. In this study, power is generated by a WTG, a PV, a FC, and a DEG generator. The integration of different energy storage system devices can facilitate the reliable power supply to the connected load. The storage systems along with PV and FC are to be connected through suitable converters but have not been considered here in order to avoid the complexities in the modeling. The energy storage systems BESS and FESS store energy during the surplus generation and release efficiently during the peak-load demand. The DEG is to be taken as the standby generator which starts automatically to make up the deficit power demand. The parameters of different components of the proposed system are given in the Table 1 [11, 15–17].

Microgrid system consists of various distributed generation connected together for forming independent units which can operate in two modes; isolated mode in remote

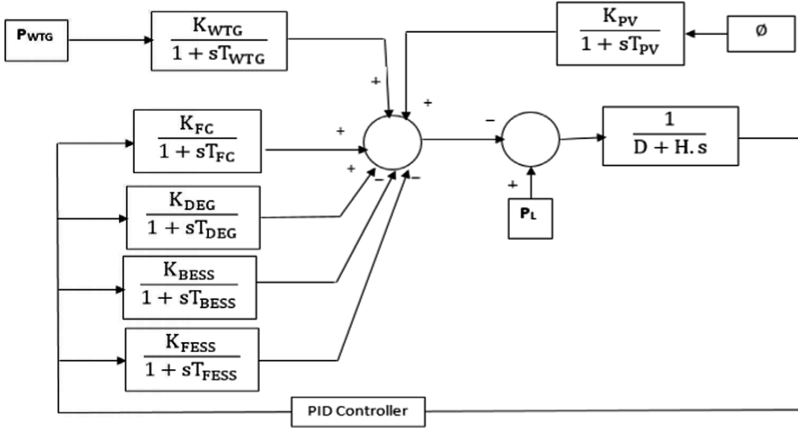


Fig. 1. Hybrid energy generations with the storage energy system

Table 1. Microgrid parameters

Component	Gain (K)	Time constant (T)
Wind turbine generator	$K_{WTG} = 1$	$T_{WTG} = 1.5$
Photovoltaic generator	$K_{PV} = 1$	$T_{IN} = 0.04$ $T_{IC} = 0.004$
Fuel Cell (FC)	$K_{FC} = 0.01$	$T_{FC} = 4$
Diesel engine generator	$K_{DEG} = 0.003$	$T_{DEG} = 2$
Battery energy storage system	$K_{BESS} = 1$	$T_{BESS} = 0.1$
Flywheel energy storage system	$K_{FESS} = 1$	$T_{FESS} = 0.1$

areas or in conneted mode to support and enhance the microgrid security and reability. The microgrid can increase the reliability and efficiency of the power system.

3 Controller Design and Optimization Technique

In this, the proposed controller and optimization method are discussed.

3.1 PID Controller

The conventional Proportional Integral Derivative Controller (PID) is considered the most popular controller used in almost all the industries processes. It can provide excellent control performances due to its quite structure and robustness. PID is the most simple and easy understood controller despite the varied dynamic characteristics of process plant [6].

A proportional controller has the effect of reducing the rise time, but cannot eliminate the steady-state error. An integral mode has the ability to eliminate the steady-state error [7].

PID controller is a control scheme generally used in an industrial process system. A standard PID controller structure is also known as the “three terms” controller, whose can be presented by a transfer function in the ideal form in (1) or in the parallel form in (2) [8].

$$G(s) = K_P \left(1 + \frac{1}{T_I s} + T_D s \right) \tag{1}$$

$$G(s) = K_P + \frac{K_I}{s} + K_D s \tag{2}$$

Where K_P , K_I and K_D are the proportional, integral and derivative gain respectively, T_I and T_D are integral, and the derivative time constant respectively (Fig. 2).

PID controller composed of three types of control actions, Proportional, Integral, and Derivative control action.

The “three-term” functionalities are highlighted below [5, 6].

- The proportional term – gives a control action proportional to the error signal through the all-pass gain factor.
- The integral term – mismatches’ steady state errors through low-frequency compensation by an integrator.
- The derivative term – enhancing the transient response through high-frequency compensation by a differentiator.

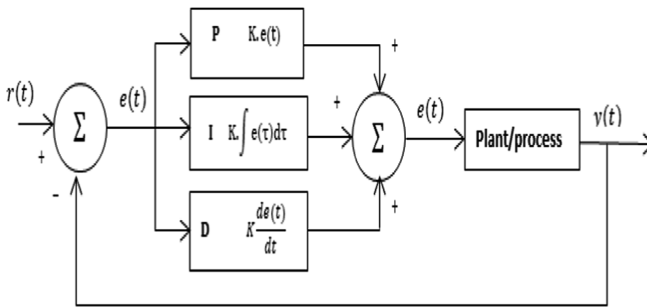


Fig. 2. Block of PID controller model

The objective function (J) used for optimizing the controller parameter’s has been considered an integral performance index over the simulation period using the weighted sum of squared frequency deviation (Δf) and the deviation of the control signal (Δu) as given by (3).

$$= J_{opt} = \int_{T_{min}}^{T_{max}} [w(\Delta f)^2 + \left(\frac{1-w}{K_n} \right) (\Delta u)^2] dt \tag{3}$$

Where w dictates the relative importance of the two objectives (i.e., Integral of Squared Error—ISE and Integral of squared Deviation of Control Output—ISDCO), and its value is taken as 0.7. $Kn = 10^4$ is the normalizing constant to scale ISE and ISDCO in uniform scale. The model of the objective function is presented using Matlab/Simulink.

3.2 Interview on PSO algorithm

Many problems have not an exact solution that gives the results in a reasonable time. For overcoming these problems some metaheuristics methods which offer an approached solution after many iterations are recently proposed. Among these methods Particle Swarm Optimization algorithm that has generic principle to be applied in many fields of optimization problems. PSO is a stochastic optimization algorithm developed by Eberhart and Kennedy, inspired by the social behavior and fish schooling of bird flocking. Each particle in the swarm is a different possible set of the unknown parameters of the objective function to be optimized. The swarm consists of N particles moving around in a D -dimensional search space. Each particle is initialized with a random position and a random velocity [9]. The new velocity can be calculated by the fellow formula.

$$V_{i+1} = w.V_i + C_1.r_1(P_{best} - X_{i_k}) + C_2.r_2.(G_{best} - X_i) \quad (4)$$

$$X_{i+1} = X_i + V_{i+1} \quad (5)$$

Where V_i is the component in the dimension of the particle velocity in iteration, X_i is the component in the dimension of the particle position in iteration, C_1 and C_2 are constant weight factors, P_{best} is the best position achieved so far by particle, G_{best} is the best position found by the neighbors of particle, and are random factors in between 0 and 1 interval, and w is inertia weight which is started from a positive initial value (w_0) and decreases during the iterations by $W_{k+1} = \beta.W_k$.

The algorithms of PSO can be described as follows:

Step1: Initialize a population of particles with random positions and velocities on D -dimensions in the problem space.

Step2. Evaluation of desired optimization fitness function in D variables for each particle,

Step3. Comparison of particle's fitness evaluated with its best previous position. If the current value is better, then set the best previous position equal to the current value, and p_i equals to the current location x_i in D dimensional space.

Step4. Identifying the particle in the neighborhood with the best fitness so far, and assign its index to the variable g ,

Step5. Change velocity and position of the particle according to Eqs. (4) and (5).

Step6. Return to step 2 until a criterion is met or end of iterations.

The flowchart of this algorithm is presented by Fig. 3 as follow:

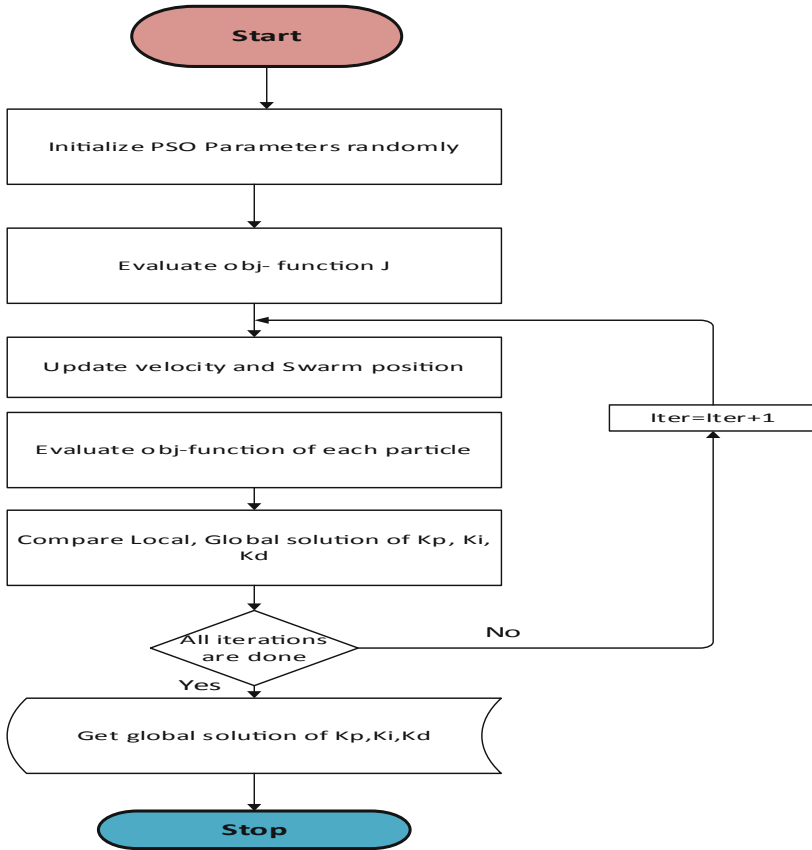


Fig. 3. Flowchart of PSO algorithm

4 Results and Discussion

The proposed configuration of the microgrid is simulated under nominal condition during 120 s using Matlab/Simulink interface. A PID controller is introduced in order to eliminate the frequency and power fluctuations provoked by the integration of renewable power generation such as PV and wind which have intermittent nature and stochastic changing during the simulation time. The simulation results are showed in followed figures (Figs. 4, 5, 6 and 7).

The change in power demand and generation causes fluctuations in frequency and power deviations which are settled down after few second due to the coordination with generation sources and storage devices through the controller. With a thorough analysis of results, it can be observed that small deviation of frequency and power is achieved by using of PID controller based PSO compared to the results given using GA based PID controller. The proposed controller based PSO appeared better than the controller based GA in performances and stability of the system.

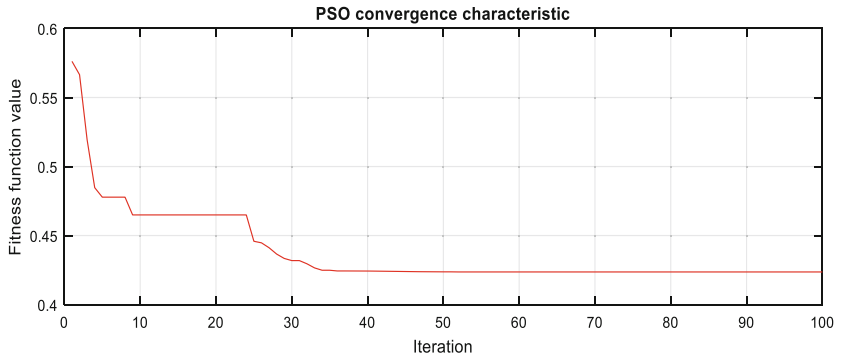


Fig. 4. PSO convergence characteristic

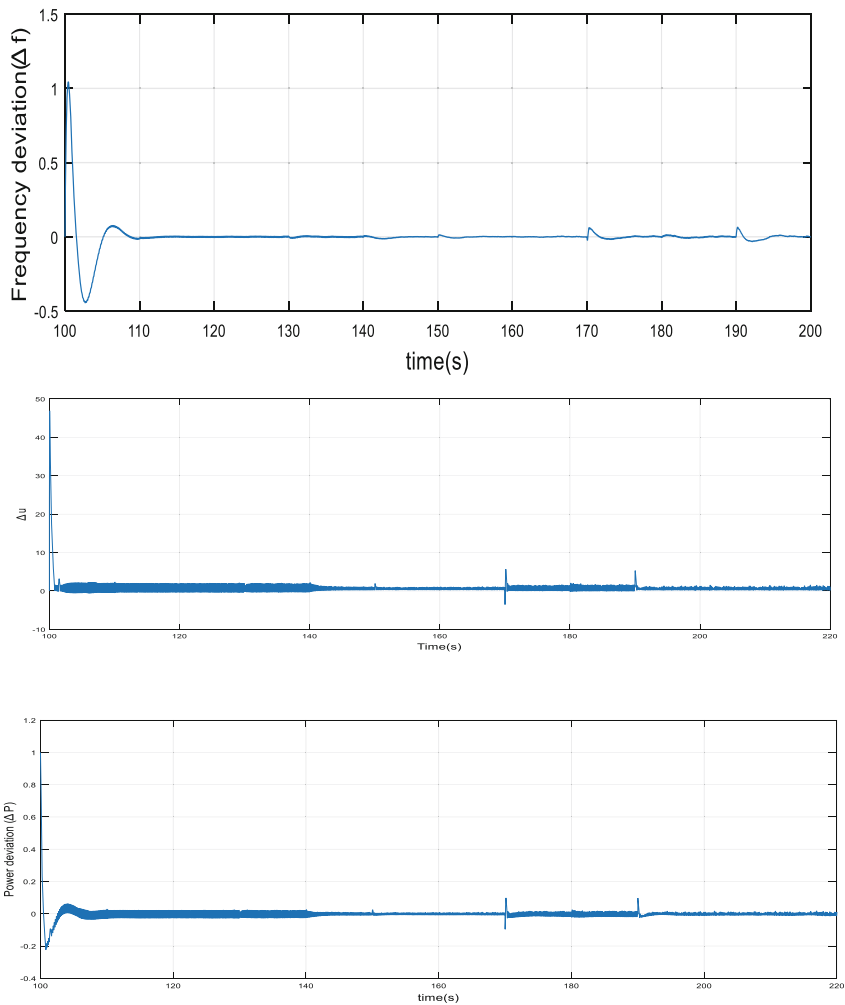


Fig. 5. Frequency and power deviation with signal control

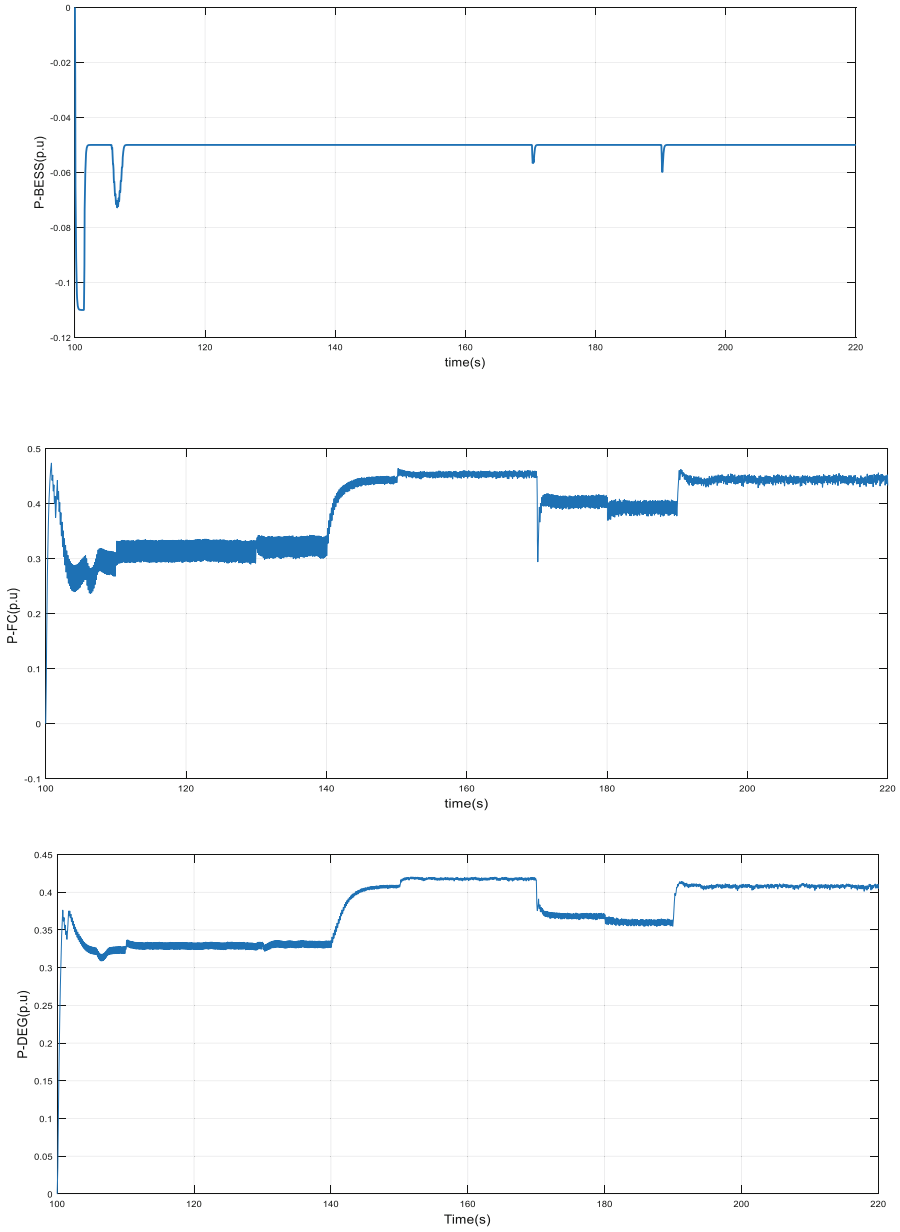


Fig. 6. Generated power by each component of a microgrid

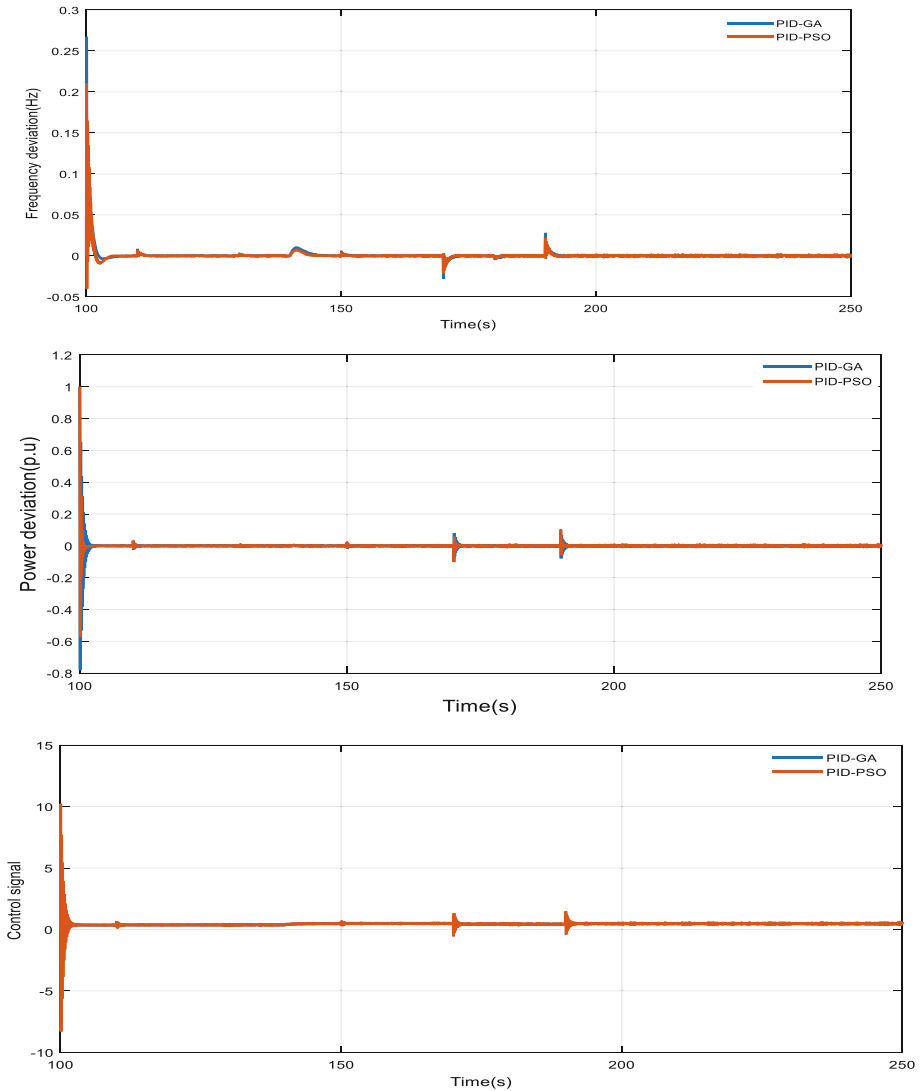


Fig. 7. Power and frequency deviations with control signal using the best PID based GA and PSO.

5 Conclusion

The proposed hybrid system consisting of PV, WTG, FC, DEG, BESS, and FESS is presented, controlled using PID and simulated autonomously. The system components are modeled using the first order transfer function considering reasonable approximation. Different types of energy storage such as BESS and FESS have been used to absorb the fluctuation in output power of photovoltaic and wind systems. However, a

control scheme based on the PID controller is used to provide power and, frequency deviations. The PID parameters are optimized using the Particle Swarm Optimization algorithm. The obtained results are compared with the Genetic Algorithm based PID controller. This proposed method is a good choice for application in control of the hybrid energy system based on the renewable energy system in comparison with Genetic Algorithm.

References

1. Bouzid, A.M., Guerrero, J.M., Cheriti, A., Bouhamida, M., Sicard, P., Benghanem, M.: A survey on control of electric power distributed generation systems for microgrid applications. *Renew. Sustain. Energy Rev.* **44**, 751–766 (2015)
2. Anwar, M.N., Pan, S.: A frequency response model matching method for PID controller design for processes with dead-time. *ISA Trans.* **55**, 175–187 (2015)
3. Senjyu, T., Nakaji, T., Uezato, K., Funabashi, T.: A hybrid power system using alternative energy facilities in isolated Island. *IEEE Trans. Energy Convers.* **20**(2), 406–414 (2005)
4. Mahmoud, M.S., Hussain, S.A., Abido, M.A.: Modeling and control of microgrid: an overview. *J. Franklin Inst.* **351**(5), 2822–2859 (2014)
5. Das, D.C., Roy, A.K., Sinha, N.: GA based frequency controller for solar thermal–diesel–wind hybrid energy generation/energy storage system. *Int. J. Electr. Power Energy Syst.* **43** (1), 262–279 (2012)
6. Das, D.C., Roy, A.K., Sinha, N.: Genetic algorithm based PI controller for frequency control of an autonomous hybrid generation system. In: *World Congress on Engineering 2012*, London, UK., 4–6 July 2012, vol. 2189, pp. 953–958. International Association of Engineers, March (2010)
7. Shayanfar, H.A., Shayeghi, H., Younesi, A.: Optimal PID controller design using Krill Herd algorithm for frequency stabilizing in an isolated wind-diesel system. In: *Proceedings on the International Conference on Artificial Intelligence (ICAI)*, p. 516. The Steering Committee of The World Congress in Computer Science, Computer Engineering and Applied Computing (WorldComp) (2015)
8. Shayanfar, H.A., Shayeghi, H., Younesi, S.A.A.: Design of optimal PID controller using Jaya algorithm for frequency stabilizing. In: *An Isolated Wind-Diesel System* (2016)
9. Iruthayarajan, M.W., Baskar, S.: Evolutionary algorithms based design of multivariable PID controller. *Expert Syst. Appl.* **36**(5), 9159–9167 (2009)
10. Kerdphol, T., Fuji, K., Mitani, Y., Watanabe, M., Qudaih, Y.: Optimization of a battery energy storage system using particle swarm optimization for stand-alone microgrids. *Int. J. Electr. Power Energy Syst.* **81**, 32–39 (2016)
11. Rajesh, K.S., Dash, S.S.: Load frequency control of autonomous power system using adaptive fuzzy based PID controller optimized on improved sine cosine algorithm. *J. Ambient Intell. Humaniz. Comput.* **10**(6), 2361–2373 (2019)
12. Ranjan, S., Das, D.C., Latif, A., Sinha, N.: LFC for autonomous hybrid micro grid system of 3 unequal renewable areas using mine blast algorithm. *Int. J. Renew. Energy Res. (IJRER)* **8** (3), 1297–1308 (2018)
13. Debbarma, S., Bhattacharya, M., Meena, B. K., Datta, A.: Frequency control of autonomous hybrid power system using smart controllable load. In: *2015 International Conference on Robotics, Automation, Control and Embedded Systems (RACE)*, pp. 1–7. IEEE, February 2015

14. Maiti, D., Biswas, S., Konar, A.: Design of a fractional order PID controller using particle swarm optimization technique. arXiv preprint [arXiv:0810.3776](https://arxiv.org/abs/0810.3776) (2008)
15. Lee, D.J., Wang, L.: Small-signal stability analysis of an autonomous hybrid renewable energy power generation/energy storage system part I: time-domain simulations. *IEEE Trans. Energy Convers.* **23**(1), 311–320 (2008)
16. Pan, I., Das, S.: Kriging based surrogate modeling for fractional order control of microgrids. *IEEE Trans. Smart Grid* **6**(1), 36–44 (2014)
17. Ray, P., Mohanty, S., Kishor, N.: Small-signal analysis of autonomous hybrid distributed generation systems in presence of ultracapacitor and tie-line operation. *J. Electr. Eng.* **61**(4), 205–214 (2010)



Five PV Model Parameters Determination Through PSO and Genetic Algorithm, a Comparative Study

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Abstract. The main goal of this paper is the application of PSO (Particle Swarm Optimization) and Genetic Algorithm (GA) in Renewable energy in general and particularly photovoltaics (PV) in order to extract the five parameters that governs the PV module (the photocurrent, the serial resistance, the saturation current, the parallel resistance and the ideality factor). Indeed, PSO and GA are intelligent post-analytic global optimization algorithms that give a minimal error. The application of these algorithms aimed at comparing the experimental results of a fairly well known photovoltaic module with is the MSX 60 has given good results. This is confirmed by the calculation of statistical performance measurement factors such as RMSE (root-mean-square error) and MAPE (mean absolute percentage error).

Keywords: Optimization · Five PV parameters · PSO · GA

1 Introduction

The Photovoltaic solar energy which is a clean energy comes from the conversion of sunlight into electricity through semiconductor materials such as silicon or composite materials. These photosensitive materials have the property of releasing their electrons under the influence of an external energy (light and temperature). This junction constituting the solar cell is based on solar modules constructed by manufacturers. Modeling and simulation of PV module helps in better understanding in terms of the behavior and characteristics [1]. Many models have been developed to reflect the true behavior of the solar module such as Ideal Photovoltaic model (model of three parameters), 1D-2R model (five parameters model) and the two-diode model (the seven parameters model) [2]. The most used common model is the five parameters model for its offering a closer representation of the solar cell [3]. These five parameters are the: photocurrent (I_{ph}), serial resistance (R_S), saturation current, (I_0), parallel resistance (R_{sh}) and the ideality factor (n).

There were different optimizing algorithms For evaluating and optimizing the PV model [4–8]. In general, we can classify these algorithms in three groups: (a) analytical methods such as Newton-raphson method [9], (b) iterative methods like search fitting curves [10, 11], (c) intelligent algorithms (heuristic and metaheuristic). Among the heuristic methods it can be found the PSO algorithm and the genetic algorithms [12–14].

The remainder of the paper is organized as follows. In Sect. 2, the problem of solar cell modeling is presented.

Section 3 describes the GA algorithm as well as PSO algorithm. The different results and discussion with validation are exposed in Sect. 4. Finally, Sect. 5 gives a summary and conclusions.

2 The Five Parameters PV Cell/Module Modeling

Due to its simplicity and acceptable accuracy, the single-diode (five parameters) model has been selected (see Fig. 1).

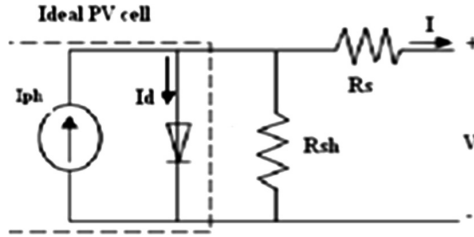


Fig. 1. Equivalent model of five parameters solar cell

From Fig. 1, it can be shown that the output current of the solar cell can be given as follows:

$$I = I_{ph} - I_{rs} \left[e^{\left(\frac{q(v + R_s I)}{A \cdot k \cdot T} \right)} - 1 \right] - \left(\frac{q(v + R_s I)}{R_{sh}} \right) \quad (1)$$

PV cells are connected together in series and parallel solar cell combinations to form a module the terminal equation of the PV module can be written as follows [15]:

$$I = N_p I_{ph} - N_p I_{rs} \left[e^{\left(\frac{q(v + R_s I)}{A \cdot k \cdot T \cdot N_s} \right)} - 1 \right] - N_p \left(\frac{q(v + R_s I)}{N_s \cdot R_{sh}} \right) \quad (2)$$

Where:

V is the cell output voltage; q is the electron charge ($1.60217646 \times 10^{-19}$ C); k is the Boltzmann's constant ($1.3806503 \times 10^{-23}$ J/K); T is the temperature in Kelvin; I_{rs} is the cell reverse saturation current; A is the diode ideality constant; N_p is the number of PV cells connected parallel; N_s is the number of PV cells connected in series.

The generated photocurrent I_{ph} depends on solar irradiation and it's by the following equation:

$$I_{ph} = [I_{sc} + k_i(T - T_r)] \frac{G}{1000} \quad (3)$$

Where:

k_i is the short-circuit current temperature coefficient; G is the solar irradiation in W/m^2 ; I_{sc} is the cells short-circuit current at reference temperature; T_r is the cell reference temperature.

The cell's saturation current i_s varies with temperature according to the following equation

$$I_{rs} = I_{rr} \left[\frac{T}{T_r} \right]^3 \exp \left(\frac{q \cdot E_G}{k \cdot A} \left[\frac{1}{T_r} - \frac{1}{T} \right] \right) \quad (4)$$

Where:

E_G is the band-gap energy of the semiconductor used in the cell. I_{rr} is the reverse saturation at T_r .

3 PV Module Parameters Extraction Based on GA & PSO Algorithms

Using the objective function well defined by the Eq. (1), it can be easily implemented on the heuristic algorithms such as genetic algorithm (GA) and particle swarm optimization (PSO) for determining the five parameters of our chosen model 1D–2R.

3.1 Genetic Algorithm (GA)

The genetic algorithm is a search heuristic inspired by the process of natural selection (well reputed as Darwin's theory). Its principal application is to generate useful solutions to optimization and search problems. The Genetic Algorithm was originally proposed by Holland (Holland 1975). After that, many authors (Goldberg 2000; Michalewicz 1994) have modified the existing one and improved genetic algorithms are proposed) [16]. Procedure of the GA starts from a seed and generates a set of individuals. Each of these individuals can extract a group of parameters, the best-fitted parameters are selected to form the new population when the process has been repeated 50 000 times until this iterations procedure been accomplished [17].

The basic components common to almost all genetic algorithms are [18]:

- a fitness function for optimization
- a population of chromosomes
- selection of which chromosomes will reproduce
- crossover to produce next generation of chromosomes
- random mutation of chromosomes in new generation.

For the implementation of GA to perform PV module parameters extraction the fitness function has the role of optimizing the objective function defined above (I – V curve) and the population of chromosomes express the five electrical PV cell parameters (I_{ph} , I_0 , A , R_s and R_{sh}). The task of selection and crossover is to promote chromosome with high fitness. On the other hand, the random mutation ensures diversification of solutions by creating another generation.

3.2 Particle Swarm Optimization (PSO)

Particle Swarm Optimization (PSO) is an heuristic optimization (sometimes called metaheuristic), invented by Russel Eberhart and James Kennedy in 1995, inspired by the behaviour of social organisms in groups, such as bird and fish schooling or ant colonies [19]. This optimization method is based on the collaboration of individuals with each other. Elsewhere this method has many similarities with the genetic algorithm except for the use of a group (swarm of particles) instead of an individual (chromosome) in the search.

Just the algorithm starts each particle is positioned randomly in the search space of the problem. Each iteration moves the particles according to 3 components: (1) Its current velocity $v_i = (v_{i1}, v_{i2}, \dots, v_{id})$ with i is the rank of the particle. (2) Its best positions (or solution) namely p_i . (3) The best solution obtained before (previous best position) which is p_g . This gives the following equations [4]:

$$v_i^{n+1} = w * v_i^n + C_1 * r_1 * (Pbest_i - x_i^n) + C_2 * r_2 * (Gbest - x_i^n) \quad (4)$$

$$x_i(j+1) = v_i(j+1) + x_i(j) \quad (5)$$

Where: x_i is the position of the particle, C_1 and C_2 are acceleration factors r_1 and r_2 are two uniform random numbers between 0 and 1. w is an inertia weight (had a high value for searching global solution). v_i is the initial velocity. j is the iteration index. $Pbest$ and $Gbest$ are respectively: personal and global best fitness of each particle. The global solution is indeed represents the desired solution of the solar cell equation.

4 Results and Discussions

The GA and PSO algorithms were implemented on the MSX 60 PV module (polycrystalline) by using the Matlab software (see Table 1).

Table 1. Manufacturing datasheet of MSX 60

Characteristics	Value
Open-Circuit Voltage (V_{oc})	21.1 V
Optimum Operating Voltage (V_{mp})	17.1 V
Short-Circuit Current (I_{sc})	3.8 A
Optimum Operating Current (I_{mp})	3.5 A
Maximum Power at STC* (P_{max})	60 W
Number of cells	36
Temp. coefficient of V_{oc}	-80 m V/°C
Temp. coefficient of I_{sc}	0.0024 A/°C

For measuring the efficiency of the proposed algorithms, we opted for statistical tools by calculating the errors: *RMSE* (root-mean-square error) and *MAPE* (mean absolute percentage error).

RMSE is defined by [20]:

$$RMSE = \sqrt{\frac{1}{N} \sum_{i=1}^N f_i(V_m, I_m, x)^2} \quad (6)$$

Where, *N* is the number of the experimental data.

The formula of the mean absolute percentage error (*MAPE*) is as follows:

$$MAPE = \frac{1}{N} \sum_{i=1}^N \left| \frac{A_i - F_i}{A_i} \right| \cdot 100 \quad (7)$$

Where A_i is the actual value and F_i is the forecast value, *N* is the number of the experimental data.

In this section, the proposal methods (PSO & GA) are applied to extract the five parameters governing the MSX60 solar module under standard test conditions (STC: 1000 W/m², 25 C°). Referring to the experimental I–V curve and the manufacturer’s given datasheet, a statistical study performed by calculating the *RMSE*, the *MAPE* and the execution time was done. The different results can be shown in Table 2.

Table 2. Extracted parameters for the MSX 60 PV module under STC

Parameters	GA algorithm	PSO algorithm
R_s [Ω]	0.4843	0.4821
R_{sh} [Ω]	2.0001×10^4	2×10^4
A (ideality factor)	1.0001	1
I_{ph} [A]	3.7999	3.7999
I_0 [A]	4.6314×10^{-10}	4.6121×10^{-10}
<i>RMSE</i>	0.0723	0.0707
<i>MAPE</i>	1.8035	1.7734
Time execution [s/run]	4529.5486	1468.2126

The results in Table 2 show that statistically the results of the PSO are much better than those of the GA (see values of *RMSE* and *MAPE*). Another advantage of the PSO is its relatively low execution time compared to the algorithm GA.

The Figs. 2 and 3 shows experimental model (curve I–V) and the estimated characteristics (computed model with PSO and GA) applied on the MSX 60 PV module.

It can be seen from Figs. 2 and 3 the acceptable matching curves between experimental and proposal models. It’s due also for the integration of Nelder-Mead algorithm in the main PSO-GA programmes in order to resolve the non linear objective function. That’s the reason of the enhancement of results.

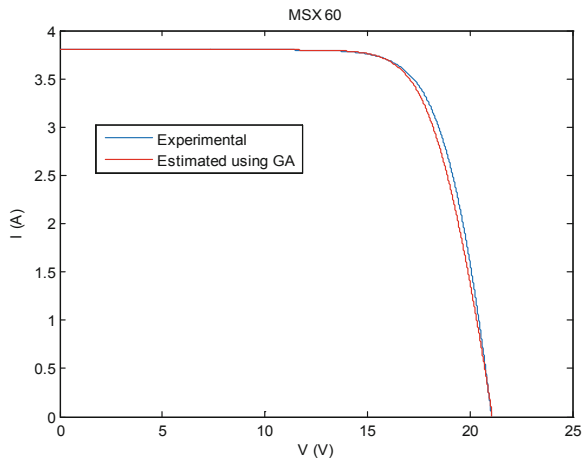


Fig. 2. GA model of the five parameters PV MSX60 module

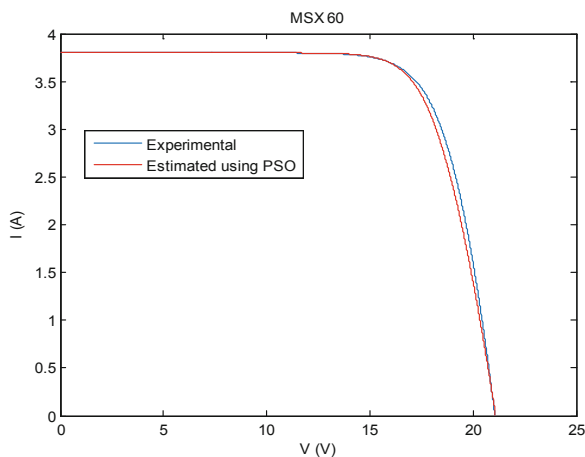


Fig. 3. PSO model of the five parameters PV MSX60 module

Figure 4 depicts the comparison between the convergence characteristics of GA and PSO algorithms depending on number of iterations. As an initial solution GA algorithm is the best but in terms of accuracy and speed of convergence it's very clear that the PSO algorithm is better than GA. In general both PSO and GA methods converge towards the global solution, which is an advantage.