Optimization of Microgrid Battery Capacity using PSO with Considering Islanding Operation

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Article Information

Received:
6 March 2020

Received in revised form:
2 May 2020

Accepted:
5 May 2020

Volume 2, Issue 1, June 2020
pp. 1 – 4

https://doi.org/10.23960/jesr.v2i1.34

Abstract

Electrical is used for various activities in all sectors. Rapid increase of electricity demand recently, makes it necessary to have an even more efficient method for generating electricity. Renewable energy and the microgrid provides an integrated and alternative solution for electricity generation. In microgrid systems, energy storage devices are one of important aspects. Batteries are one kind of the energy storage technologies widely used in power system and hence, their suitable capacity must be determined in order to develop an effective system installation. In this research, sizing optimization of battery capacity is modeled as a minimization of microgrid battery capacity using the Particle Swarm Optimization/PSO algorithm with considering islanding operation of the system for effective battery installation. Results show that optimal battery capacity can be obtained and the developed computational model gives satisfactory results for the system under study.

Keywords: *Battery, microgrid, energy storage system, PSO algorithm*

I. INTRODUCTION

Electrical is used for various activities in all sectors. The existing electrical energy is mostly generated from conventional power generation that uses fossil energy sources. Rapid increase of electricity demand recently and considering environmental impacts, makes it necessary to have an even more efficient method of generating electricity. Renewable energy and the microgrid provides an integrated and alternative solution for electricity generation.

Microgrid is a system consist of power distributed generation units, energy storage systems, and loads, which can operate in grid-connected or stand-alone [1]. In Microgrid sytems, energy storage devices are one of important aspects. Energy storage is a solution to resolve load mismatches and connecting renewable energy generations in microgrid systems. Batteries are one kind of the energy storage technologies widely used in power system and hence, their suitable capacity must be determined in order to develop an effective system installation.

There are several research done for optimization battery capacity in previous studies. Some previous studies that have been done include; Reliability constrained optimal sizing of energy storage system in a microgrid [2], Sizing of Energy Storage for Micro-Grids [3], Optimum battery energy storage system using PSO considering dynamic demand response for microgrids [4], MPI based PSO algorithm for the optimization problem in micro-grid energy management system [5], and Optimal sizing of battery energy storage systems for microgrids [6]. Based on these previous studies, this study focuses on optimization microgrid battery capacity with considering islanding operation mode. The method used for optimization battery capacity in this study is Particle Swarm Optimization (PSO). The purpose of this study is focusing on to determine optimal capacity battery of microgrid by using the PSO method for prevent instability of microgrid system and develop an effective microgrid system installation.

II. METHODS

Particle Swarm Optimization/PSO [7] is an optimization technique that provides population-based search procedures. Each individual, called a particle, will be distributed in the solution space randomly and will try to move positions to find other positions.

These particles are moved around in the search-space and the movements of the particles are guided by their own best known personal position in the search-space as well as the entire global best known position. Each particles have fitness values which are evaluated by the fitness function to be optimized, and have velocities which direct the positions of the particles. The particles swarm through the search space by following the current optimum particles. Fig. 1. shown a visualization of changes in the position of particles to find the best position.

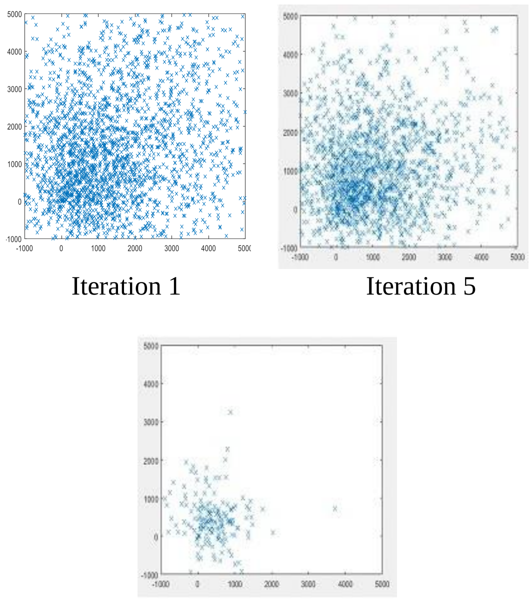

Fig. 1. A Visualization of Position of Particles to Find the Best Position.

Particles in each space have positions which are then encoded as coordinate vectors. The position vector is considered as a state occupied by a particle in the search space. Each position in the search space is an alternative solution that will be evaluated using the objective function to be optimized. In the PSO algorithm, the movements of the particles are guided by their personal best position in the search-space as well as the entire global best position. Each particle movement influenced by their personal best and global best [8, 9]. All of particles have fitness values and have velocities which direct the swarm of the particles. The particle maintains position in the search space, personal best position and velocity. The velocity update equation of PSO is expressed as follow.

$$v_{t+1} = c_0 v_t + c_1 r_1(t) \times (p_t - x_t) + c_2 r_2(t) \times (\hat{p}_t - x_t) \qquad (1)$$

The equation for position update of PSO is expressed as follow.

$$x_{t+1} = x_t + v_{t+1} \qquad (2)$$

where c_0 is inertial coefficient, c_1, c_2 are acceleration coefficients, v_t is is the particle's velocity at time t, x_t is particle's position at time t, v_{t+1} is velocity update, x_{t+1} is particle's position update, r_1, r_2 are are random values which are regenerated every velocity update, p_t is pbest, and $\hat{p}_t$ is gbest/global best solution.

This study was conducted with a grid connected microgrid system by considering islanding operations. In this study, IEEE 9 buses system (shown in Fig. 2) is used as one of study cases of microgrid model system to determine battery capacity based PSO algorithm.

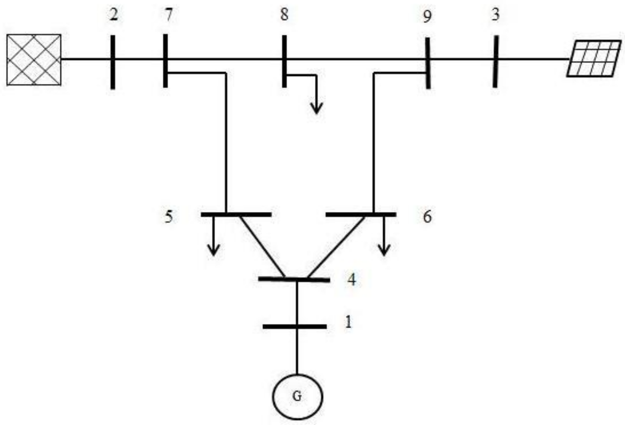

Fig. 2. Single Line Diagram Case System

The optimization of microgrid battery capacity considering islanding operation in this study is accomplished using DigSilent PowerFactory DPL Script. The process of the optimization based PSO is described as follow.

1. Initialize the parameters, number of particles, lower bound, upper bound variable constraint, itermax, and define the constraint of objective function.
2. Determine the position and velocity of each particle randomly.
3. Initialize iteration i = 1
4. Initialize particle j = 1
5. Execute the objective functions.
6. Find particles personal best position (Pbest) and global best position (Gbest).
7. Increase iteration i = i + 1
8. If iteration i+1 ≤ Itermax, go back to step 5 and update the new position and velocity for the next iteration.
9. If iteration i+1 ≥ Itermax, the algorithm process stop and the optimal solution Gbest obtained.

The purpose of objective function in this study is to determine optimal power battery of microgrid with considering islanding operation to prevent instability of microgrid system and to develop an effective microgrid system installation. The objective function can be expressed as follow:

$$MinF(X) = (\min)P_{BESS} \tag{3}$$

the objective function is optimized under the equality power constraint as follow :

$$\sum P_{gen} - P_{dmd} = \Delta P \tag{4}$$

the mentioned objective function is optimized with meeting the inequality constraint as follow :

$$P_{\min BESS} \le P_{BESS} \le P_{\max BESS} \tag{5}$$

$$C_{\min BESS} \le C_{BESS} \le C_{\max BESS} \tag{6}$$

where P_{BESS} is rated power capacity of microgrid battery (MW), $\sum P_{gen}$ is total power microgrid generations, P_{dmd} is load total, $P_{\min BESS}$ is the minimum rated power capacity of battery, $P_{\max BESS}$ is maximum rated power capacity of battery, $C_{\min BESS}$ is the minimum rated energy capacity of battery, $C_{\max BESS}$ is maximum rated energy capacity of battery.

III. Results and Discussions

In this study the utility grid disconnected from the microgrid system and microgrid operated in islanding operation, so the microgrid operates autonomously and serving their own local demand. The PCC/point of common coupling is connecting the microgrid system to the grid utility and is able to switch the microgrid system mode to islanding if a fault occurs to the system or for maintenance. In this study to get the optimal microgrid battery capacity from the simulation results, the number of particle used is 30 and iteration used is 50 iterations. The number of iterations and particles used are efficient considering the running simulation time needed. Fig. 3 shows the PSO algorithm flow chart for the optimization battery capacity in this study.

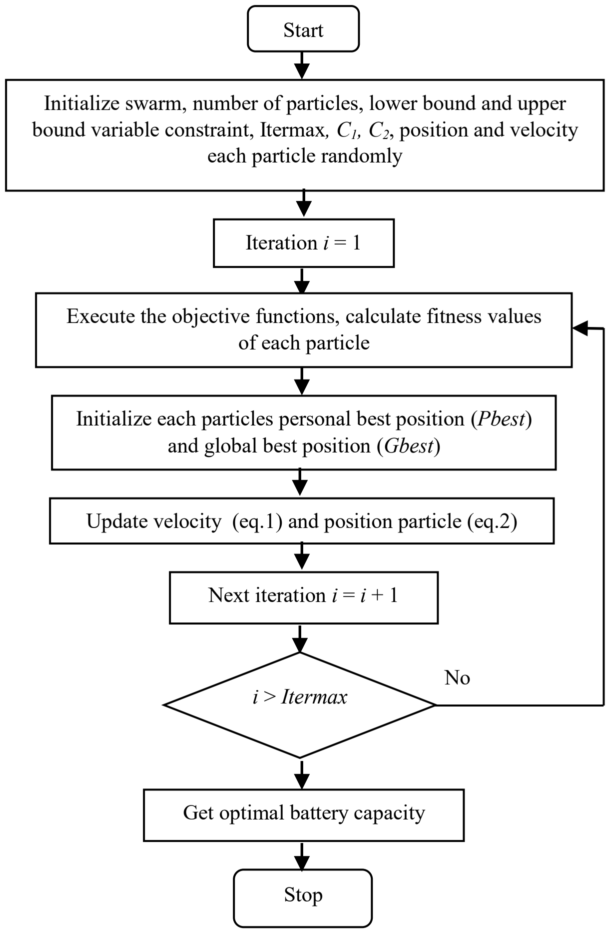

Fig. 3. Flow Chart of the PSO Algorithm

In this study, the microgrid consists of two power generations. Microhydro with the output power of 1.4 MW and photovoltaic with the output power of 1 MW. The peak load of the microgrid system is 3 MW. The battery power and energy capacity obtained by the simulation results in this study are shown as in table 1.

Table 1. Simulation Result of Battery Capacity

	Battery based PSO	**Battery based Power Balance Method**
Energy capacity	6.3218 MWh	6.4 MWh
Power capacity	1.5804 MW	1.6 MW

The power stored in the battery is used to supply the load and for stabilizing the microgrid system if there is a lack of power generation also when the microgrid system operate in islanding. The simulation results obtained based PSO algorithm in this study is verified with analytic power balance system method. Fig.4. shows the graphic of the result after optimization battery.

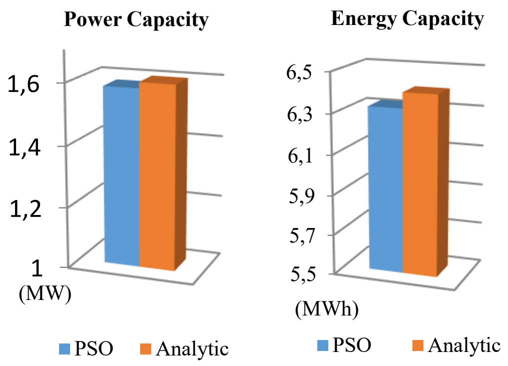

Fig. 4. The Result of Optimization Battery

It is seen that the optimal capacity battery obtained based the PSO method is not much different from the results obtained by the analysis method based on the power balance method. The result obtained from the simulation using PSO method shown that the optimal sizing of battery can achieve the best optimal sizing of battery compared with analysis method based on the power balance method and can save a optimal amount of battery capacity needed for the effective system.

The optimization result of battery capacity based PSO method can satisfies the load demand when microgrid operated in islanding operation under this study. The proposed battery capacity using PSO-based algorithm can help the system operator to guarantee the optimum battery capacity of the microgrid system, so that the microgrid system can operate in optimal conditions with effective battery capacity.

IV. Conclusions

This study presents an optimization of microgrid battery capacity using PSO with considering islanding operation. The simulation results of battery based PSO algorithm in this study was compared with the battery capacity obtained from battery based power balance method. Based on the results and discussion can be concluded that the result of optimization micogrid battery based PSO in this study satisfies the deficit load in microgrid system when operating in islanding mode.

Further works can be performed using another optimization method so that it can clearly evaluate the optimal battery capacity which can measure every application by the battery and maximize the benefits of a battery in microgrid system.

References

[1] F. Katiraei, R. Iravani, N. Hatziargyriou and A. Dimeas, "Microgrids Management," *IEEE Power Energy Mag.*, vol. 6, no. 3, pp. 54-65, 2008.

[2] S. Bahramirad, W. Reder and A. Khodaei, "Reliability constrained optimal sizing of energy storage system in a microgrid," *IEEE Trans. Smart Grid*, vol. 3, no. 4, pp. 2056-2062, 2012.

[3] B. Zhao, C. X. Guo and Y. J. Cao, "An improved particle swarm optimization algorithm for optimal reactive power dispatch," in *EEE Power Engineering Society General Meeting*, San Francisco, 2005.

[4] T. Kerdphol and Y. M. Y Qudaih, "Optimum battery energy storage system using PSO considering dynamic demand response for microgrids," *International Journal of Electrical Power and Energy Systems*, vol. 83, no. 1, p. 58–66, 2016.

[5] S. Wang, L. Su and J. Zhang, "MPI based PSO algorithm for the optimization problem in micro-grid energy management system," in *Proceedings of the 2017 Chinese Automation Congress (CAC)*, Jinan, 2017.

[6] H. Alharbi and K. Bhattacharya, "Optimal sizing of battery energy storage systems for microgrids," in *IEEE Electrical Power and Energy Conference*, 2014.

[7] J. Kennedy and R. Eberhart, "article swarm optimization," in *Proceeding of IEEE Int Conf Neural Networks*, 1995.

[8] H. Bevrani, F. Habibi, P. Babahajyan, M. Watanabe and Y. Mitani, "Intelligent frequency control in an AC microgrid: on-line PSO-based fuzzy tuning approach," *IEEE Trans. Smart Grids*, vol. 4, pp. 1942-1948, 2012.

[9] A. Esmin, G. Lambert-Torres and A. C. Z. d. Souza, "A hybrid particle swarm optimization applied to loss power minimization," *IEEE Trans. Power System*, 2005.