Research on optimal Dispatching Strategy of micro-grid based on Particle Swarm optimization algorithm

Ning Wang1*, Hongtao Li2, Qianmao Zhang1, Litao Shi3, and Xin Geng3
1State Grid Hebei Economic Research Institute, Shijiazhuang, Hebei, 050000, China
2State Grid Hebei Electric Power Company, Shijiazhuang, Hebei, 050000, China
3 Power China Hebei Electric Power Design & Research Institute Co., Ltd, Shijiazhuang, Hebei, 050000, China
*Corresponding author’s e-mail: 1182206007@ncepu.edu.cn

Abstract. Optimizing micro-grid dispatch is one of the important ways to improve the efficiency of renewable energy utilization. In this paper, a micro-grid system, including photoelectric, wind power, diesel engine, and the battery is optimized based on the Particle Swarm Optimization algorithm. Constrained by operation condition, a multi-objective optimization scheduling model including fuel cost, operation cost, and pollution gas emission cost is established, and multi-objective Particle Swarm Optimization (MOPSO) is used to solve the optimization scheduling problem of micro-grid. The simulation results show that the model can promote the optimization of micro-grid dispatch.

1. Introduction
Large-scale renewable energy generation brings great challenges to the safe and reliable operation of the power grid. Micro-grid is established to solve these problems. Micro-grid is a small network relative to a large grid. Compared with a large grid, a micro-grid can be regarded as a controllable source, which can exchange energy with a large external grid according to the actual demand and operation target. On the one hand, micro-grid is a carrier of Distributed Generation (DG), load, and energy storage equipment, which can ensure the cost-efficiency and flexibility of distributed power. On the other hand, the operation mode of the micro-grid is flexible, the grid-connected mode stand-alone mode can ensure the supply of important loads [1,2,3].

With the development of micro-grid technology, the non-cost benefit of micro-grid has restricted its development. Therefore, the economic dispatching of micro-grid is studied. Literature [4] proposed a capacity optimization model for micro-grid battery energy storage based on the influence of battery energy storage operation characteristics. Literature [5] proposed a day-ahead market optimal bidding strategy for a micro-grid consisting of intermittent distributed generation, storage, dispatchable distributed generation, and price response load. Literature [6] proposed a two-stage hierarchical optimization method for micro-grid energy management system in smart grid environment, aiming at the advantages and application prospects of micro-grid.

At present, the research on the optimal economic dispatching model of micro-grid mainly has considered the equipment investment cost, operation cost, fuel cost, and power purchase or sale cost of the main power grid [4-6]. Many researchers have used a genetic algorithm to solve problems [7-8], and Particle Swarm Optimization algorithm has seldom used to study the optimal scheduling of microgrid.
Based on the analysis of the power characteristics of the micropower supply, the dynamic economic load distribution in the micro-grid in stand-alone mode is studied.

The cost-efficiency, environmental protection property, and reliability of the micro-grid are considered, and a multi-objective optimization scheduling model is established to the minimum operating cost and pollutant treatment cost. Meanwhile, a multi-objective Particle Swarm Optimization algorithm with fast searching speed and strong searching ability is adopted to solve the problem. The correctness and effectiveness of the mathematical model and optimization method can be ensured.

2. Micro-grid dispatching model

2.1. Objective functions

There are two objective functions of micro-grid operation optimization, one objective function is in the grid-connected mode, and another objective function is in the stand-alone mode.

There are four types of cost in the grid-connected mode: fuel cost, operation cost, penalty cost, and purchase and sale cost generated by the electricity exchange between the micro-grid and the power grid. The objective functions are shown as follow:

\[
C_1(P) = F_1(P(t)) + F_2(P(t)) + F_3(P(t)) + C_{buy}(t) \times P_{buy}(t) - C_{sell}(t) \times P_{sell}(t)
\]

\[
C_2(P) = \min \sum_{t=1}^{T} \left( F_1(P(t)) + F_2(P(t)) + F_3(P(t)) \right)
\]

There is no cost generated by exchange power in the stand-alone mode. There are three types of cost in the grid-connected mode: fuel cost, operation cost, and penalty cost.

\[
C_2(P) = \sum_{t=1}^{T} \left( P_{loss}(t) + P_{loss}(t) \right)
\]

2.2. Operation constraint

The constraints of the objective function in the operation of the micro-grid mainly include the node power flow constraints and the power balance constraints of the micro-grid.

(1) Node power flow constraint conditions of micro-grid

\[
P_{Gi} - P_{Li} = U_i \sum_{j=1}^{N} U_j \left( G_{ij} \cos \delta_{ij} + B_{ij} \sin \delta_{ij} \right)
\]

\[
Q_{Gi} - Q_{Li} = U_i \sum_{j=1}^{N} U_j \left( G_{ij} \sin \delta_{ij} - B_{ij} \cos \delta_{ij} \right)
\]

Where, \( N \) represents the total number of nodes in the micro-grid system, \( PGi \) and \( QGi \) represent the active power and reactive power injected by the micro-power supply on node \( i \) in the micro-grid, and \( U_i \) and \( U_j \) represent the voltage amplitude of node \( i \) and \( j \) in the microgrid, and \( G_{ij} \) and \( B_{ij} \) represent the conductivity between node \( i \) and node \( j \). \( \delta \) represents the voltage phase angle difference between nodes \( i \) and \( j \), \( \delta \) represents the voltage phase angle difference between nodes \( i \) and \( j \).

(2) Constraints on the power balance of micro-grid

Power balance conditions of micro-grid:

\[
P_{WT}(t) + P_{MT}(t) + P_{PV}(t) + P_{FC}(t) + P_{BATT}(t) + P_{sell}(t) = P_{load}(t) + P_{loss}(t)
\]

Power balance conditions in the operation of isolated micro-grid:

\[
P_{WT}(t) + P_{MT}(t) + P_{PV}(t) + P_{FC}(t) + P_{BATT}(t) = P_{load}(t) + P_{loss}(t)
\]
negative in the discharge state, \( P_{buy}(t) \) is the electric energy purchased by the micro-grid system at time \( t \), \( P_{sell}(t) \) is the electric energy sold by the micro-grid system at time \( t \), \( P_{load}(t) \) represents the power demand of the micro-grid system load at time \( t \), and \( P_{loss}(t) \) is the lost power of the micro-grid system line at time \( t \).

3. Particle Swarm Optimization algorithm

Standard particle swarm algorithm the basic idea is: random initialization of a group of no quality and volume of the particles, each particle as to seek a solution of the problem, the fitness function is used to measure the pros and cons of the particle, all particles in the feasible solution space according to a certain speed, and continue to follow the current optimum particles after several generations of search for the optimal solution of the problem. The specific algorithm flow of Particle Swarm Optimization is as follows:

- Initialize the particle swarm: iteration particle with random position and velocity
- Calculate the fitness value of each particle according to the fitness function.
- For each particle, compare the adaptation value of its current position with the adaptation value of its previous best position; if the adaptation value of the current position is bigger, the global best position is replaced by the current position.
- For each particle, compare the adaptation value of its current position with the adaptation value of its global best position, if the adaptation value of the current position is bigger, the global best position is replaced by the current position.
- Update the velocity and position of each particle according to the formula.
- If the end condition cannot be met, go back to step (2), and if not, the global best position is the global optimal solution.

The influence parameters that need to be considered in the Particle Swarm Optimization algorithm include population size \( M \), inertia weight factor \( \omega \), contraction factor \( \chi \), learning factor \( c_1 \) and \( c_2 \), maximum velocity \( v_{max} \), maximum iterations number \( T_{max} \), etc.

\[
\omega = \omega_{max} - \frac{(\omega_{max} - \omega_{min}) \times t}{T_{min}} \tag{6}
\]

the population size \( M \) of particle swarm is generally determined. For Particle Swarm Optimization with general complexity, 30-50 population sizes of particles can accomplish optimization calculation. The expression of the inertia weight factor is shown in equation 6.

\( \omega_{max} \) is the upper limit of the inertia weight factor, \( \omega_{min} \) is the lower limit of the inertia weight factor, and \( T_{max} \) is the maximum evolutionary algebra of particle swarm. The general values of inertia weight factors are between 0.9 and 1.2.

4. Simulation and Analysis

4.1. Simulation parameter setting

Dc micro-grid model is adopted in this paper, under the condition of grid-connected operation and two-way flow of energy, the power exchange range between the power grid and the micro-grid is from -1kW to 1kW. Power parameters, on-grid price, and algorithm parameters are shown in table 1, table 2, and table 3. Data are from the National Energy Administration. The electricity demand fluctuates with time, and the grid load curve in the operating cycle is shown in Figure 1.

| Table 1 Power supply parameters |
|--------------------------------------------------|
| Lower limit(kW) | Photovoltaic generation | Wind power generation | Battery generation | Diesel generation |
| Upper limit(kW) | 0 | 0 | -200 | 200 |
|                  | 180 | 250 | 250 | 600 |
Table 2 Feed-in-traffic

|                      | Price(kWh) |
|----------------------|------------|
| Photovoltaic generation | 0.860      |
| Wind power generation | 0.529      |
| Diesel generation    | 0.371      |

Table 3 Parameters of Particle Swarm Optimization algorithm

|                              |             |
|------------------------------|-------------|
| Learning factor n1           | 0.4         |
| Learning factor n2           | 0.4         |
| Population size              | 3000        |
| Maximum number of evolution  | 2000        |

Fig. 1 Load curve of the power network within the operating cycle.

4.2. Simulation results and analysis
In this paper, the Micro power-grid system is optimized in 24 hours of a certain day. In the operation cycle of a certain day in the micro-grid system, the total photovoltaic power curve and its absorption power curve are shown in Fig.2.
As shown in Fig. 3, because the power consumption is less and light intensity is bigger at 14:00, PV power consumption capacity is insufficient, but most photovoltaic power generation can be absorbed in the rest of a day.

As shown in Fig. 3, because the power consumption is more in the morning and at night, photovoltaic power generation and wind power generation cannot meet the demand for power during 8:00-10:00 and 21:00-23:00. As a result, batteries discharge power to ensure the reliability of the power supply. Because power consumption is less during 2:00-7:00, and the output power of micropower sources such as photovoltaic power generation and wind power generation are more during 13:00-14:00 and 15:00-19:00, the electricity produced by micropower sources is more than the demand of grid load. As a result, batteries are charged to make full use of the surplus power.

To sum up, in the process of load optimal allocation, most of the power produced by wind and photovoltaic generation is consumed by production and life, and the excess or insufficient power is...
regulated by diesel engines and batteries. The optimal dispatching method of micro-grid proposed can reduce the comprehensive cost of operation. This method is cost-effective and practical and is of great significance to production and life.

5. Conclusions
In this paper, power balance, power flow constraint, output limit, and other constraints are considered in the constraints of the objective function, penalty, fuel cost, and operation cost are considered in the objective function, and the Particle Swarm Optimization algorithm is adopted to realize the overall optimal operation in grid-connected mode and stand-alone mode. The simulation results show that the algorithm can improve the consumption capacity of the power grid and reduce the operating cost of microgrid while ensuring the reliability of the power supply.

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