Energy Optimization Dispatching of Microgrid in The Stand-alone Mode

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Abstract. A microgrid system in the stand-alone mode with photovoltaic, wind turbine, microturbine, fuel cell and energy storage unit is studied. Mathematical models of different distributed power supply and energy storage devices are established. The load demand of the system, the price of purchasing and selling electricity when interacting with the power grid and other constraints are considered. An economic model for optimizing stand-alone operation cost is established. According to the characteristics of the model, an improved genetic algorithm is selected to optimize the nonlinear system. The algorithm has better stability in solving the optimization problem of large state space dimension. The case study show that the proposed economic model is reasonable and the algorithm is effective.

1. Introduction

Microgrid is a small power generation and distribution system composed of distributed generation units, energy storage units and loads. It can be used as the carrier of distributed generation units to access the main network through public connection points, which can effectively solve the grid-connected problem of distributed generation units. Compared with traditional power grid, microgrid is more flexible, less polluting emission, higher energy utilization, lower cost of power generation, and can also improve the reliability and security of power supply. It is an important part of smart grid development in the future [1-4].

As a typical network structure of distributed generation, microgrid has strong flexibility. It can be connected to the power grid or operated separately from the grid. In grid-connected mode, each distributed unit is connected to the power grid with microgrid as its carrier, which can optimize dispatching of distributed units reasonably, improve the traditional power grid’s ability to absorb renewable energy, thereby reducing the consumption of fossil fuels and harmful gas emissions. When power failure occurs in the power grid due to electrical failure, natural disasters or misoperation, the microgrid can be disconnected from the power grid and transferred from grid-connected mode to stand-alone mode, so as to ensure the continuous supply of energy for important loads and improve the
reliability of power supply. In addition, in remote areas where the power grid can not be covered, the construction of microgrid and the operation of the isolated network can improve the local electricity situation [5-11].

In this paper, a microgrid structure with photovoltaic power, wind turbine, microturbine, fuel cell and energy storage devices is adopted. The stand-alone mode in typical summer day is considered. Considering both generation cost and environmental cost, the constraints for safe operation of the model are given. The objective is to minimize the total operation cost in a cycle. A multi-objective optimal dispatching mathematical model for microgrid is established. The improved genetic algorithm is used to optimize the output of each distributed generation at different times, so that the daily comprehensive cost can be minimized and the comprehensive benefit can be effectively increased. The feasibility of the algorithm and the mathematical model of each distributed unit is proved.

2. Energy Optimization Dispatching Model of Microgrid

2.1. Structure of Microgrid in the Stand-Alone Mode

In this paper, microgrid in the stand-alone mode is taken as the research object. Its structure is shown in figure 1, including distributed power supply and load. The distributed power supply includes wind turbine (WT), photovoltaic (PV), microturbine (MT), fuel cell (FC) and energy storage (ES).

![Figure 1. The structure of microgrid in the stand-alone mode.](image)

2.2. Objective Function

The objective of microgrid energy optimization dispatching is to minimize the cost of generating electricity and the emission of polluted gases. Converting the minimum emission of polluted gases into the minimum emission cost of polluted gases can transform the multi-objective into a single objective, that is, the minimum comprehensive cost of microgrid system. According to this, the integrated cost of microgrid system operation consists of the cost of generating electricity and the cost of polluting gas emission. The objective function can be expressed as follows:

\[
\min C = C_G + C_E
\]

where, \( C \) is the total cost of microgrid system (yuan), \( C_G \) is the generation cost (yuan) and \( C_E \) is the cost of pollutant gas emission (yuan). In stand-alone mode, \( C_G \) is mainly composed of fuel supply cost and maintenance cost of distributed units.

\[
C_G = C_F + C_M
\]

where, \( C_F \) is the fuel supply cost (yuan) and \( C_M \) is the maintenance cost (yuan).

\[
\begin{align*}
C_F &= \sum_{i=1}^{N} \left( \sum_{t=1}^{T} C_F \times \frac{P_i(t)}{\eta(t)} \right) \\
C_M &= \sum_{i=1}^{N} \left( \sum_{t=1}^{T} \xi \times |P_i(t)| \right)
\end{align*}
\]

where, \( T \) is total dispatch period (h), \( N \) is the number of micropower supply, \( P_i(t) \) is the output power of distributed unit \( i \) at time \( t \) (kW), \( \eta(t) \) is the generation efficiency of distributed unit \( i \) at time \( t \) (%), \( C_F(t) \) is the fuel of distributed unit \( i \) at time \( t \) (yuan/kW) and \( \xi_m \) is the maintenance cost coefficient of distributed unit \( i \).
where,  \( C_e \) is the penalty fee of type \( j \) polluted gas (yuan/kg),  \( \xi_{ij} \) is the emission coefficient of distributed unit \( i \) and type \( j \) polluted gas (kg/kW).

### 2.3. Constraint Condition

According to the requirement of safe and stable operation of microgrid, several constraints for optimal dispatch of microgrid energy are given.

In any dispatching period, the microgrid must meet the cold and electric power requirements.

\[
P_{c\text{-}load}(t) = Q_{\text{cool}}(t)
\]

\[
P_{\text{load}}(t) = \sum_{i=1}^{N} P_i(t)
\]

where,  \( P_{c\text{-}load} \),  \( P_{h\text{-}load} \) and  \( P_{\text{load}} \) are the cool, heat and electric load demand of microgrid at time  \( t \) (kW), respectively.

In any dispatching period, the output of each distributed generation unit in microgrid is strictly restricted by its capacity, that is, the output of each generation unit has upper and lower limits.

\[
P_i^{\text{min}} \leq P_i(t) \leq P_i^{\text{max}}
\]

where,  \( P_i^{\text{min}} \) and  \( P_i^{\text{max}} \) are the lower and upper limit of the output power of distributed unit  \( i \) (kW).

### 3. Solving Method

Organisms have a strong adaptability to the natural environment, and their ability to survive and reproduce is regular. Influenced by Darwin’s theory of biological evolution and genetics, a professor at the University of Michigan first proposed the basic concept and theory of genetic algorithm. Since then, the exploratory research on biology in nature has continued until 1989. D. E. Goldberg, a student of J. Holland, has summarized and summarized the research on genetic algorithm during this period, and given the calculation process of genetic algorithm.

When genetic algorithm is used to solve the energy optimal dispatching problem of microgrid, the output schemes of each unit in microgrid are mapped into chromosomes by coding. Each output scheme corresponds to an individual. A part of the individual is selected as the initial population, and the fitness values of all individuals in the population are obtained. That is, the smaller the comprehensive cost of operation of microgrid system, the larger the individual fitness values. By comparing the fitness values of individuals, the individuals in the population are selected, crossed and mutated to generate individuals with larger fitness values. Subsequently, through continuous iteration of the population, generations that are more adaptable to the environment will be generated until the termination conditions are satisfied, and the optimal solution of the problem can be obtained.

![Figure 2. The flow chart of genetic algorithm.](image-url)
4. Case Study

4.1. Parameter Settings
For the optimal dispatching problem of microgrid studied in this paper, firstly, local environmental data such as temperature, wind speed and illumination are needed, secondly, the load demand of internal load of microgrid is needed. Finally, according to the parameters of distributed generation, the comprehensive cost of operation of microgrid system is taken into account, and the constraints are considered comprehensively to ensure the security and stability of microgrid. In operation, the optimal dispatching model of microgrid is solved, and the optimal results under typical operation mode of islands in summer are given. Figures 3 show the data curves of local temperature, wind speed and illumination.

![Figure 3](temperature, wind speed and illumination)

Because of the low heat load in summer and the small proportion of the annual heat load, the simulation analysis of the optimal dispatching model of the microgrid in typical summer days is based on the electric load and the cooling load. Figure 4 shows the forecast of the electric load and cooling load in typical summer day.

![Figure 4](electric load and cooling load)

The remaining operating parameters of microgrid system are given in [12].
4.2. Simulation Result
According to the cooling load and electric load demand of typical summer day, the energy optimal dispatching model of microgrid in the stand-alone mode is simulated and solved, and the power generation curves of each unit under typical summer day are obtained as shown in Figure 5.

![Figure 5. The power generation curves of each unit.](image)

MT no longer produces power when it meets the cooling load. At 1:00, 11:00 and 12:00, because the power generated by MT, WT and PV in the microgrid is larger than the load demand and ES is fully charged, it is necessary to limit the output of WT and PV to meet the power balance of the microgrid system; at 20:00, MT, WT, PV, FC and ES are still in the maximum output power that can be achieved, but they can not meet the load demand, so it is necessary to make general use of them. The load is removed (as shown in the figure of off), and the size is 5.94 kW.

5. Conclusion
In this paper, a microgrid structure with photovoltaic, wind turbine, microturbine, fuel cell and energy storage devices is adopted. Considering both generation cost and environmental cost, the constraints for safe operation of the model are given in the stand-alone mode. The objective is to minimize the total operation cost in a cycle. A mathematical model of multi-objective optimal dispatching for microgrid is established. Genetic algorithm is used to minimize the daily integrated cost by optimizing the output of each distributed generation at different times, and the value is 929.83 yuan.

6. Appendices
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