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Multi-objective optimization operation considering environment benefits and economy based on ant colony optimization for isolated micro-grids

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Abstract

A new multi-objective optimization model considering environment benefits and economy is proposed for isolated micro-grids based on ant colony optimization in this paper. First, through fuzzy processing and satisfaction-maximizing scheme, the multi-objective programming problem is reformulated into a nonlinear mono-objective programming problem. Then, to cope with the uncertainty of photovoltaic and wind power generation, the sequence operation theory is introduced to transform such a chance-constrained programming problem into a corresponding deterministic equivalent problem. Next, an improved ant colony algorithm is used to solve the mono-objective mixed-integer linear programming problem. And finally, the test results demonstrate the effectiveness of the proposed model and algorithm.

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Keywords: micro-grids; distributed generation; multi-objective optimization; fuzzy modeling; chance-constrained programming; improved ant colony algorithm

1. Introduction

In recent years, the distributed generation (DG) is becoming increasingly important. Compared to the traditional centralized power supply, DG has many obvious advantages such as much more economic efficiency, facilitating the environmental protection, and enhancing the safety of power supply. As an

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effective method of using DGs, micro-grids can effectively increase the energy utilization ratio and reduce power generation cost and emissions of pollutants.

There are some previous work has tried to solve the problem. Reference [1] established a micro-grid economic operation model including the cost of the emission, but because of the less constraints model of distributed power supply, it cannot be used in the actual operations. Reference [2] researched micro-grid economic optimizing operation contained, but the lack of the study of battery dynamic operating characteristics. Reference [3] considered the economic costs and system network loss of isolated micro-grid system, but the selection of weight has a great deal of artificial factors, so this method is not accurate.

2. Intermittent DG output model in micro-grids

2.1. Wind power generation

Wind speed approximately obeys the Weibull distribution, the distribution function is:

$$F(v)=1-\exp[-(v/c)^k] \tag{1}$$

the probability density function is:

$$f_v(v)=k/c(v/c)^{k-1}\exp[-(v/c)^k] \tag{2}$$

where v represents wind speed; k is the shape parameter; c is the scale parameter.

The relationship between the output power of wind turbines and the actual wind speed is [4]

$$P_w=\begin{cases}0 & v<v_{in}, v>v_{out}\\ \dfrac{v^3-v_{in}^3}{v_r^3-v_{in}^3}P_r & v_{in}\le v<v_{out}\\ P_r & v_r\le v<v_{out}\end{cases} \tag{3}$$

Where v_r represents the rated wind speed; v_{in} represents the cut-in wind speed; v_{out} represents the cut-out wind speed; p_r represents the rated output power of wind turbines.

2.2. Photovoltaic power generation

It's known that the power output of photovoltaic cell components is [5]:

$$P_{PV}=P_{STC}\frac{G_{ING}}{G_{STC}}[1+k(T_c-T_r)] \tag{4}$$

where P_{PV} is the actual output power of photovoltaic cells; P_{STC} is battery power output under the standard test conditions; G_{ING} is the actual irradiation intensity; G_{STC} is irradiation intensity under the standard test conditions; k is the power temperature coefficient; T_c is the working temperature of cell panels; T_r is the reference temperature.

P_{PV} and G_{STC} obey the beta distribution. The probability density function of P_{PV} is:

$$f(P_{PV})=\frac{\Gamma(\delta+\varphi)}{\Gamma(\delta)\Gamma(\varphi)}\left(\frac{P_{PV}}{P_{PV\max}}\right)^{\delta-1}\left(1-\frac{P_{PV}}{P_{PV\max}}\right)^{\varphi-1} \tag{5}$$

Where δ, φ are both shape parameters of the beta distribution; $P_{PV\max}$ denotes the maximum output power of the PV cells.

3. The micro-grid's multi-objective optimization model

3.1. Chance-constrained programming model