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SIMULATING THE IMPACT OF MICROGRID GENERATOR SET FAILURES ON MICROGRID PERFORMANCES-BASED ON MONTE CARLO AND HOMER

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ABSTRACT

In order to cope with the increasingly serious world energy shortage and environmental pollution, renewable energy is attracting worldwide attention as a promising solution. Microgrids have been fully developed as a small power system that can operate independently to make up for the growing power gap. However, in the actual operation of the microgrid, there are many factors that affect its overall performance and operational stability. In order to consider more uncertain factors, and thus evaluate the overall performance of the microgrid system more accurately, the HOMER microgrid model is used in this paper, and the sequential Monte Carlo simulation method is used to consider the failure of the generator set and simulate the operation-fault- operation state in the process of power generation. Take the results of HOMER and Monte Carlo simulation as initial evaluation data that takes into account fault conditions. This provides a data source for the subsequent evaluation of the overall performance of the microgrid, using the Multi-criteria decision making (MCDM) method.

KEYWORDS: *Microgrid, Monte Carlo Simulation, Renewable Energy, Uncertainties*

Article History

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INTRODUCTION

In order to cope with the increasingly serious world energy shortage and environmental pollution, renewable energy is attracting worldwide attention as a promising solution[1]. The use of renewable energy and its renewable characteristics make it suitable for sustainable urban development and resource utilization[2][3]. As an important carrier of renewable energy and a medium for external power grids, the microgrid fully integrates the advantages of using multiple energy sources to make full use of renewable resources[4]. Geographical resources in different regions are different, and the type of renewable energy suitable for microgrids needs to be selected according to local resource endowments. There are also multiple complementary effects between different types of renewable energy. Therefore, the assessment and selection of renewable energy in microgrids is very important for decision makers and builders of microgrids. However, in the actual operation of the microgrid, there are many factors that affect its overall performance and operational stability. Among them, the failure of the generator set will directly affect the performance of the microgrid. This paper will consider the problem of generator set failures during microgrid operation and combine Monte Carlo simulation with multi-criteria decision making (MCDM) to more accurately evaluate the performance of microgrid systems.

METHODOLOGY

Monte Carlo Model

The problem of generating unit failure will occur in power generation systems such as microgrids or large power grids, and it is difficult to ensure that the equipment in the power generation system will continue to operate without failure during the entire life cycle. In this paper, the operating status of the generator set in the microgrid is divided into two states: normal operation and fault. In the sequential Monte Carlo method, the time sampling method is used to simulate the normal operation and fault status of the generating set, and the randomly occurring form of the generating set may be simulated at any time in the real world. At the same time, the average failure-free status of the device is considered Mean time to failures (MTTF) tMTTF and mean time to restoration (MTTR) tMTTR. The average trouble-free time and average maintenance time of the equipment are used as parameters to input into the simulation system, and the normal operation-failure status of each generator set is generated by a random number generator. The basic simulation process of sequential Monte Carlo is divided into three parts:

- Assume that at the initial moment, all generating units in the micro-grid are in normal operation;
- Sampling the duration of all generating units in the microgrid system in the current state. It is generally assumed that there is no memory between the previous and the next two failures of the same generator set, and that the duration of the generator set under normal operation and fault conditions obeys an exponential distribution. The duration sampling method is used to sample the duration in the current state of the generator set by generating a random number uniformly distributed between [0,1]. The duration calculation formula is as follows:

  $$t_{MUTi} = -t_{MTTF} \ln R_i$$

  $$t_{MDTi} = -t_{MTTR} \ln R_i$$

- Among them: Ri is a random value in the interval [0,1], is the normal operating time of the equipment, and is the maintenance time of the equipment failure.
- According to the set research cycle of the microgrid system, repeat the content of step (2) repeatedly during the cycle to obtain the normal operation-fault-normal operation state sequence of a certain generator set during the operation cycle, and all the power generation in the system The combined state sequence of equipment can get the overall power generation curve of the microgrid, as shown in Figure 1.

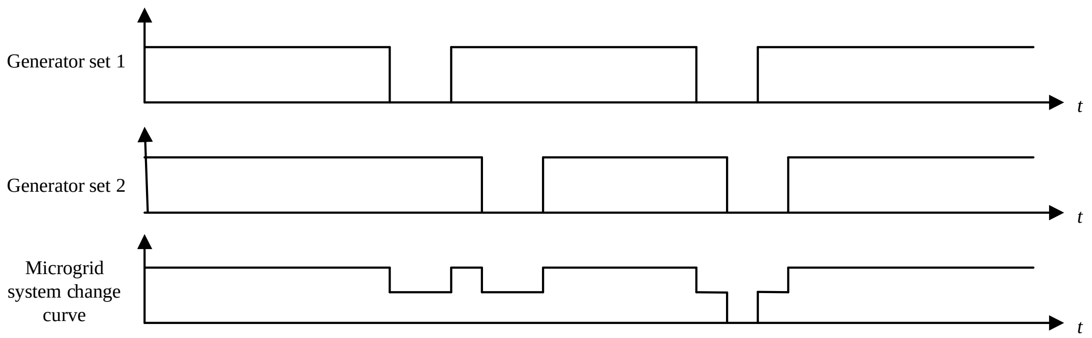

Figure 1: Variation Curve of Power Generation of Generator Sets and Microgrid Systems.

The power generation status of the entire microgrid system is synthesized from the operating status of multiple generating units. Compared to the case of failure to take into account the failure of the generator set, both the amount of electricity generated by the microgrid system and the amount of electricity purchased from the external grid change. These changes may lead to changes in the initial index evaluation values of alternatives, which will cause changes in the optimal renewable energy types and their proportions in microgrids. Therefore, it is necessary to evaluate the alternatives after considering unit failures, compare the results of the two evaluations, and discuss the impact of generator failure on the overall performance of the program.

HOMER Model

HOMER is a simulation software developed by the U.S. Renewable Energy Laboratory for practitioners and academics in the power industry around the world. Users can design a local power grid model based on local geographic resources and power needs, and simulate its full power in Life cycle operations. Because of its user-friendliness, simple operation and powerful features, it has been widely used in microgrid simulation and multi-energy complementary evaluation data acquisition[5][6][7]. HOMER can customize the total installed capacity and installed capacity of each energy generating set by the user. This function can help us to discuss the impact on the overall performance of the microgrid by changing the ratio of each renewable energy installed capacity to the total installed capacity. Therefore, this paper uses HOMER to build the microgrid model and data acquisition.

Microgrids are divided into grid-connected microgrids and island-type microgrids based on their mutual power supply with the main grid. In the existing research, grid-connected microgrids are more suitable for economically developed and densely populated urban areas than island-type microgrids, and being connected to the main grid can ensure stable power supply for the main load. The grid-connected microgrid system consists of direct current (DC) power generation units (photovoltaic panels, wind turbines, etc.), alternating current (AC) loads, external power grids, batteries, and inverters, as shown in the Figure 2.

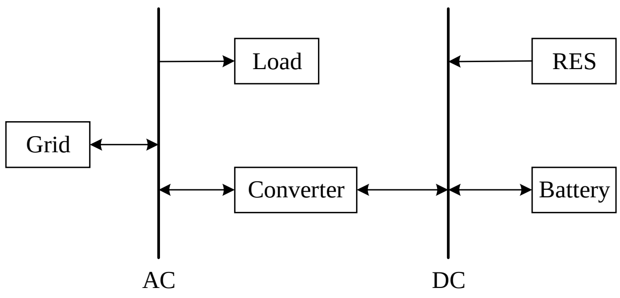

Figure 2: Microgrid Model with different RE Sources.

Among them, photovoltaic and wind power generation units provide power to the system, but they generally generate DC power, which needs to be converted into power that can be used directly by the AC load through an inverter system, and the inverter system can also automatically Stabilize voltage and improve power quality. The storage battery system is composed of multiple storage batteries connected in series and parallel. It can store the excess power of the microgrid when the power supply is sufficient and supply power to the load when the power supply is insufficient. That is to ensure the stability of the power supply. The discharge capacity makes the battery also have the effect of realizing the cascade utilization of renewable energy. As the external power grid, the main grid supplies power to the load when both the generator set and the storage battery are inadequate, and purchases electricity from the microgrid when there is excess power generation, which also plays a role in ensuring the stability of power supply.

Simulation and Synthesis of Homer and Monte Carlo Models

The power generation data of each unit is generated from the natural resource data such as solar energy, wind energy and biomass energy at the location of the microgrid, and the HOMER model, and the annual load curve, wind power generation, photovoltaic power generation and biomass power generation curves are obtained. In this paper, a wind turbine with a rated capacity of 100KW was selected in the HOMER model. Photovoltaic power generation and biomass power generation combine multiple smaller power generation units with higher success rates. In this paper, the unit for setting wind power generators is 100KW/unit, and the photovoltaic generator set and biomass energy generating set are 500KW/set. The capacity of different units can be adjusted according to local conditions. The tMTTF and tMTTR of each renewable energy generating set used in the simulation are shown in Table 1:

Table 1: t_{MTTF} and t_{MTTR} Parameters of Each Generator Set

Renewable Energy Generator	t_{MTTF}	t_{MTTR}
Wind	1920	80
Photovoltaic	1920	80
Biomass	950	50

Taking a photovoltaic generating unit with an installed capacity of 500KW as an example, the annual hourly power generation curve without considering the uncertainty of the generating unit is shown in Figure3:

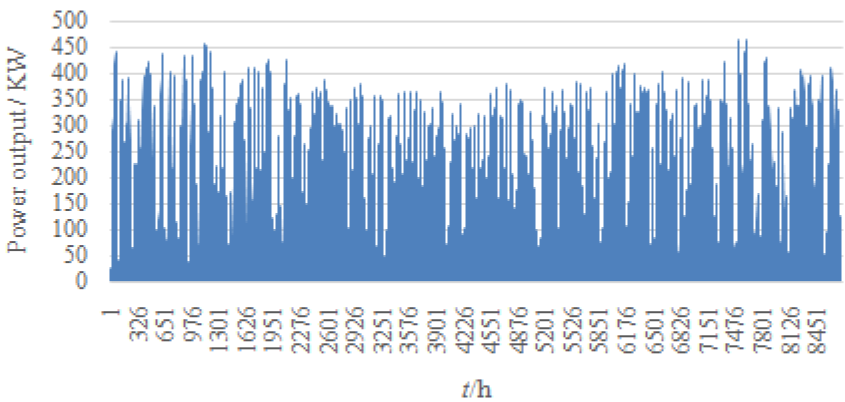

Figure 3: Annual Generation Curve of Photovoltaic Generators without Considering Generator Uncertainties.

Set the operation period T of the generator set, and use the time-sampling method to obtain the normal operation-fault-normal operation status of each generator set in the system within the range of the operating period. sequence. Because the unit can generate electricity in units of hours in HOMER, the Monte Carlo simulation also takes 1 hour as the time step. The initial time t=0,t=t+1. The total duration of the cycle is used as the termination condition. When t>N, the simulation is terminated. In HOMER, 8760 hours a year is used as the simulation cycle. T=8760 hours. The operation status curves of all generating units are combined to obtain the overall operation status curve of the microgrid. Use 0 and 1 to indicate the running status of the generator set, the normal running status is 1, and the fault status is 0, Figure 4 is a state diagram of a photovoltaic generator simulated by Monte Carlo.

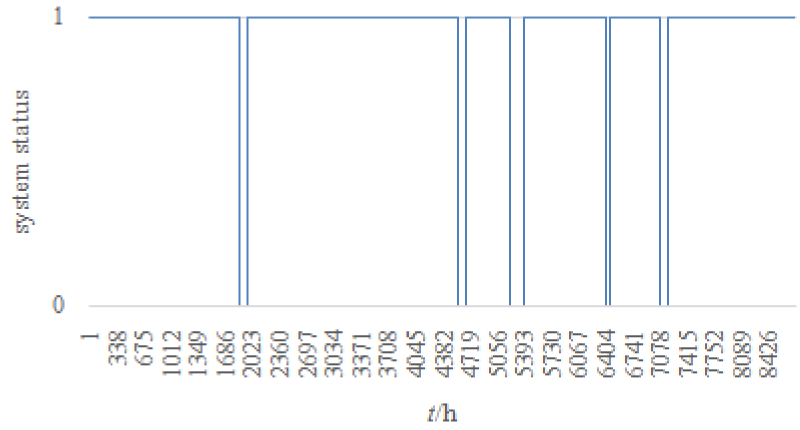

Figure 4: Photovoltaic Generating Unit Operating Status Curve.

The normal operation-fault-normal operation state sequence of each generating unit obtained in Figure4 is combined with the annual power generation curve obtained in Figure3 to obtain the annual microgrid power generation situation considering the generator unit failure.

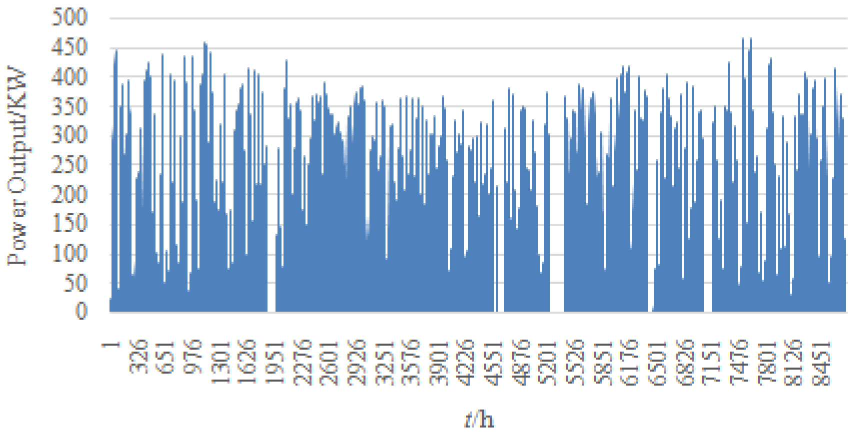

Figure 5: Annual Generation Curve of Photovoltaic Generator Set Considering Generator Uncertainty.

The above completes a simulation to determine whether the termination condition is true. If it is not true, return to Figure 4 and repeat the above process; if it is true, terminate the simulation, and use the last output data as the initial evaluation value of each indicator. The calculation formula of the initial evaluation value of the alternatives under each indicator after N simulations is as follows:

$$B = \frac{\sum_{n=1}^{N} B_n}{N}$$

For sequential Monte Carlo simulations, two conditions are generally used as termination conditions. The first is based on the number of simulations. Before the simulation starts, initialize the number of simulations n=0, advance n=n+1 according to the number of simulations, set the number of simulation terminations to N, and repeat Figure3-Figure4for N times. When the number of simulations exceeds the set total number, the simulation process is terminated. The second is to use convergence as the termination condition. If the coefficient of variation of the initial evaluation value after N simulations is lower than the set value (generally 1% -5%), the function is considered to be convergent and the simulation is terminated. The formula for calculating the coefficient of variation is as follows:

$$\beta = \frac{\sqrt{V\left(\tilde{E}(B)\right)}}{\tilde{E}(B)}$$

Among them, B is the initial evaluation value function of the alternatives under each indicator; is the expected value of the initial evaluation function that changes with the number of simulations; and is the variance of the initial evaluation value function.

In the case of a large number of simulations, these values will gradually converge and the coefficient of variation will be less than the set value. According to the above simulation process, the number of simulation times is selected as the termination condition, and the total number of simulation times N is set to 150 times. At this time, various indicators of the microgrid, such as the cost of energy purchase and operation and maintenance costs will change. Figure6 uses these two indicators as examples to show the changes and convergence trends of the indicator data as the number of sequential Monte Carlo simulations increases.

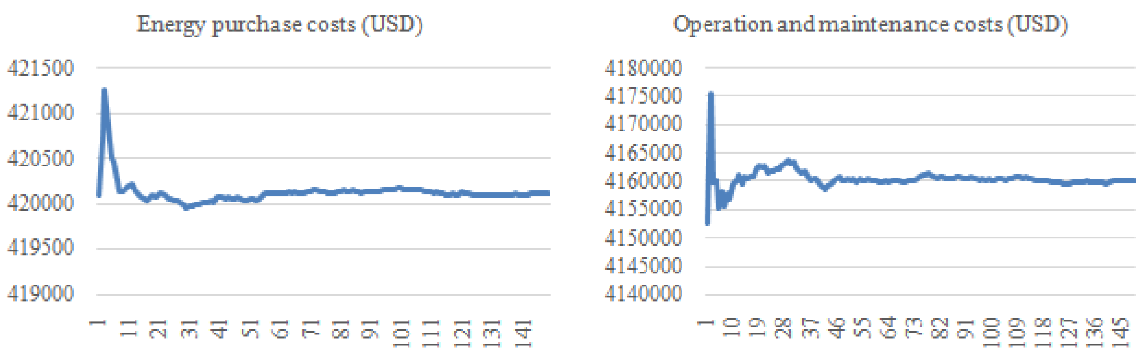

Figure 6: Convergence Trend of Index Evaluation Values Considering Generator Uncertainty.

It can be seen that when the number of simulations is 150, the evaluation value functions have been in a state of convergence. Follow the above steps to calculate the initial evaluation value for each alternative one by one, and then use the multi-criteria evaluation method to evaluate the failure of the generator set. The overall benefit of the microgrid considering the failure of the generator set can be obtained.

CONCLUSIONS

In this paper, the combination of Monte Carlo simulation and HOMER is used to simulate the failure of a generator set during microgrid operation. Firstly, the simulation method of the system operation uncertainty is introduced; then the initial rating data considering the generator set failure is simulated and synthesized based on the HOMER and Monte Carlo models; this provides ideas for the simulation of the uncertainty of the micro-grid generator set.

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