Research on optimal allocation for island microgrid based on state of charge

Guanglei Li¹*, Dehua Wang¹, Zheng Xu², Yuejiao Wang¹ and Fei Jin³

¹State Grid Shandong Electric Power Research Institute, Jinan, Shandong Province, 25002, China
²State Grid Shandong Power Supply Company, Jinan, Shandong Province, 25001, China
³State Grid Weifang Power Supply Company, Weifang, Shandong Province, 261002, China

*Corresponding author’s e-mail: lovexjtuylgl@126.com

Abstract. Making use of the characteristics of complementation of renewable energy, a new optimal control strategy for microgrid is proposed to choose the appropriate opening capacity of distributed energy such as wind power, photostatic, gas turbine and energy storage system. According to this strategy, this paper realizes analysis and evaluation of capacity optimization through establishing mathematical model. Then the optimal operation plan is solved by means of multi-objective optimization algorithm. Finally, a numerical example shows the applicability of the strategy. The optimal ratio of power supply is realized to guide engineering construction.

1. Introduction

With the rapid development of China's marine career, the development and utilization of marine resources has been listed as a great strategic measure of economic construction. Protection, development and management of islands have become the hotspot of marine industry in the new century. Microgrid can effectively combine multiple types of distributed power supply to improve energy efficiency. Utilization of microgrid is the effective method to solve power supply in islands and remote communities [1-4].

Different from the traditional power system, intermittent renewable island grid will combine the distributed power and load and energy storage device, and then electrical energy collection, power transmission, electrical energy storage and electrical energy will become the new power switching system of allocation in the future. This situation becomes the new type of electric power exchange system, which integrates energy collection, electric energy transmission, electric energy storage and electric energy [5-6].

Aiming at the island microgrid operation requirements of intermittent renewable energy, this paper propose the optimization matching method of the unit considering the SOC of energy storage system and analyze online unit optimal operation strategy, which is combined with energy storage system constraints.
2. Project overview

According to recent developments, the independent microgrid system was mainly composed of micro gas turbine generation system, photovoltaic generation system, wind turbine generation system, energy storage system, diesel generator set and control center. Intermittent renewable energy island power grid structure is shown in Figure 1.

The functions of each part of the system are shown as follows.

1) Photovoltaic generation system is composed of solar panels connected in series and parallel, photovoltaic cells absorb solar energy and issue direct current, which is connected to microgrid system by DC/AC converter.

2) Wind turbine generation system is driven by the wind, which is located after rectification and inverter process connected to microgrid system. This is the main power source of the system.

3) The energy storage system is composed of a lithiumion battery or a lead-acid battery and a suitable bidirectional AC/DC converter. According to the system renewable energy electric power generation and load situation, energy storage system can be in charge or discharge state.

4) Micro gas turbine generation system is driven by steam turbine driven by methane. Other combustible gas has the characteristics of low generating cost and friendly environment, so it is one of the main power supply of systems, which can be used as renewable energy generation supplement.

5) Because of high cost of generate electricity, poor environmental benefit and slow power regulation, diesel generator is used as reserve power supply in the system studied in this paper.

6) The main function of the system is to complete the following tasks, such as controlling the energy flow of each part, making the system run normally and orderly.

3. Optimized operation strategy

Because photovoltaic and wind power generation is the sustainable energy source, so this does not produce any pollution. Therefore, when the light and wind resources are abundant, the system will give priority to use the photovoltaic and wind power generation [7-8]. When the total power of photovoltaic and wind power generation is not less than the power demand of the load, power deficit can be calculated by the following formula.

\[ P_{\text{PV}}(t) + P_{\text{WT}}(t) \geq P_{L}(t) \]  \hspace{1cm} (1)

\[ P_{\text{ESS}}(t) = P_{\text{PV}}(t) + P_{\text{WT}}(t) - P_{L}(t) \]  \hspace{1cm} (2)
In the above formula, $P_{PV}(t)$ is the generation power of PV system, $P_{WT}(t)$ is the generating power of wind turbine unit, $P(t)$ is the power demand of the load, $P_{ESS}(t)$ is defined as charging power of an energy storage system. When $P_{ESS}(t)$ is positive, the energy storage system is in charge state. While $P_{ESS}(t)$ is negative, the energy storage system is in discharge state.

If the super capacitor state of charge in the energy storage system is higher, when the electric energy of the energy storage system reaches the rated capacity, so it is necessary to abandon a part of power. $S_{ESS}(t)$ is defined as the electricity of energy storage system, the rated capacity of the energy storage system is $S_{ESS,N}$. So it can be calculated by the following formula.

$$S_{ESS}(t + \Delta t) = \min[S_{ESS}(t) + P_{ESS}(t) \cdot \Delta t, S_{ESS,N}]$$  \hspace{1cm} (3)

Thus, abandoned power value is calculated as follows.

$$P_{ab}(t) = P_{ESS}(t) - \frac{[S_{ESS}(t + \Delta t) - S_{ESS}(t)]}{\Delta t}$$  \hspace{1cm} (4)

According to the battery discharge depth to develop different charge and discharge strategies, it is necessary to consider the influence of the discharge depth on the battery life. When the state of charge SOC of the energy storage system is higher than a certain set value $SOC_{set}$, the power of energy storage system $S_{ESS}(t)$ is larger than a certain value $S_{ESS, set}$ between the maximum and minimum power of the energy storage system.

4. Example analysis
The above method can be applied to different load demand and other basic data. The algorithm is used to solve the calculation example, the relationship between the two best solutions is obtained, which is shown in Figure 2. With the increase of utilization rate of photovoltaic and wind power generation, the cost of the system increases accordingly. Photovoltaic and wind power generation utilization ratio is less than 80%. While with the increase of the utilization ratio, the annual value of cost and annual operating cost increase very slow. If the utilization rate is greater than 80%, the annual value of cost and operating cost increase rapidly, especially after the utilization ratio is higher than 90%.

![Figure 2. load power requirements](image)

The relationship between capacity and utilization ratio of each component is shown in Figure 3. With the increase of utilization ratio of photovoltaic and wind power generation, the configuration capacity of PV and wind driven generator increases obviously. When the utilization ratio is greater than 80%, the energy storage capacity is gradually increased and the rated power of micro-turbines is gradually reduced. When the utilization rate is close to 100%, the configuration capacity of
photovoltaic and energy storage battery increases sharply, but configuration capacity of Wind driven generator decreases sharply. At this point, the rated power of the micro gas turbine unit is reduced to 0. The decrease of fan capacity is mainly due to the increase of energy storage capacity, which can store more surplus electricity when the PV and wind power are abundant.

![Figure 3. The relationship between component capacity and UPPW](image)

5. Conclusion

According to the operation strategy of the combination optimization of the online unit of the microgrid, the optimization variables and constraints of the objective function are determined. Based on these factors, this paper establishes the mathematical model for the capacity optimization of island independent microgrid. Then the algorithm based on multi-objective optimization is optimized to solve. Finally, these results prove the effectiveness of the proposed method, which can be produced to guide the planning and design of distributed power supply, operation control, etc.

Acknowledgments

This work was supported by science and technology project of state grid shandong electric power company.

References

[1] Wang, Chengshan., Wu, Zhen., et al. (2014) Research on key technologies of microgrid. Transactions of China Electrotechnical Society, 29:1-9.

[2] Yu, Peng., Liu, Xinghua., et al. (2018) Study on operation control of island microgrid with high renewable energy penetration. Power System Technology, 42: 779-788.

[3] Zhou, Zhichao., Guo, Li., et al. (2014) Optimal planning and design of the wind diesel storage biomass micro grid system. Automation of Electric Power Systems, 38:16-21.

[4] Shen, Chen., Wu, Xiangyu., et al. (2014) Practice and rethinking of microgrids. Power System Protection and Control,42:1-11.

[5] Liu, Qiu., Huang, Minxiang. (2014) Optimal energy allocation of microgrid based on reliability and economy by considering characteristics of micro source. Power System Technology,38:1352-1357.

[6] Zhao, Bo., Wang, Chengshan., et al. (2013) A survey of suitable energy storage for island stand-alone microgrid and commercial operation mode. Automation of Electric Power Systems,37:21-28.

[7] Guo, Yajuan., Chen, Jinming., et al. (2017) A review on AC/DC hybrid microgrid key technology containing distributed new energy. Electric Power Construction, 38:9-18.

[8] Luo, Xing., Wang, Jihong., et al. (2015) Overview of current development in electrical energy storage technologies and the application potential in power system operation. Applied Energy, 137: 511-536.