Research on Multi Time Scale Scheduling based on Active Distribution Network

Hongxia Yu\textsuperscript{a}, Tianhang Han

College of information science and engineering, shenyang university of technology, shenyang, liaoning province, 110020, China
\textsuperscript{a}hongxiayu08@sut.edu.cn
\textsuperscript{Corresponding author’s e-mail: 31937683@qq.com, 1018575476@qq.com}

Abstract. The active distribution network is a public distribution network with a flexible structure, which adopts the mode of active management of distributed power supply, energy storage equipment and customer two-way load. In order to reasonably plan the distributed power, coordinate the optimal operation of the distributed power and give full play to the active role of new power sources and loads such as the distributed power, it is necessary for the distribution network to take active management and planning. The multi time scale coordinated control strategy of active distribution network can make up for the prediction error of renewable energy and load in the future, and give full play to the active role of new generation such as distributed generation. Multi time scale scheduling includes the global optimal control of active distribution network on the long time scale, the correction of long time scale prediction error on the short time scale and the regional autonomous control of real-time active distribution network. The study of multi-objective function and multi time scale scheduling can control multiple optimization objectives, integrate economic environment and other factors, which has the significance of compensating the prediction error of renewable energy and load in the future.

1. Introduction

In recent years, the shortage of environment and energy becomes more and more obvious. To improve the composition of energy system, it is urgent to find pollution-free and searchable new energy. However, new energy sources, such as solar energy and wind energy, are characterized by randomness and intermittency, and their large-scale access to the distribution network also brings great challenges to the operation and scheduling of the power grid [1]. The emergence of micro power grid for the comprehensive utilization of renewable energy provides an effective means, through the efficient energy management and coordination control technology, the distributed power supply, load, energy storage device and control device, to form a single control unit, is the solution of distributed renewable energy concentrated grid power supply is an effective way [2-4]. The reasonable and effective dispatching of each output unit can help the micro grid to connect to the distribution network without affecting the quality of the store and reduce the pressure of the distribution network.

Because of the light energy. Uncertain intermittency and randomness, such as solar energy, pose great challenges to grid scheduling. At present, in view of the uncertain intermittency and randomness of solar energy and solar energy, a variety of scheduling strategies have emerged. In this paper, a multi-time-scale scheduling strategy is adopted. In general, the optimal operation scheduling of active distribution network system is based on 24h day-ahead scheduling, with 1h as the time interval.
But wind power and solar power and other renewable energy as an energy generating set by the weather factors such as light intensity, temperature, wind strength effect obvious, if the weather has obvious changes, is an hour of time can appear a variety of changes, the output power of the generator set will appear many obvious fluctuation. If one hour is taken as the time interval, the unit output power may fluctuate several times within one hour, but it does not occur at the time point of optimal scheduling, so it is impossible to accurately predict the change of output and load of the generating unit.

2. Multi-time scale scheduling model

The flowchart of multi-time-scale scheduling strategy is shown in figure 1, which is composed of two prediction models: day-ahead and day-ahead. In the day-ahead scheduling, the power value predicted by the renewable distributed power supply and the power demand value predicted by the load are used to optimize the multi-objective with the optimal economic benefit of the power grid, the minimum active power loss, the minimum voltage deviation, and the minimum wind and light abandoning rate. According to the target of the power grid and the comprehensive requirements of the upper power grid, the scheme of pre-dispatch is finally determined. The scheduling output of day-ahead flexible load can be released. Update the load situation. During daily dispatching, the flexible load is mainly dispatched with the highest economic benefit of the power grid, so as to ensure the stable operation of the power grid and the economy under the circumstance of daily fluctuation of renewable energy.

![Figure 1. Multi time scale scheduling structure.](image)

2.1. Day ahead scheduling model

The goal of day ahead optimal dispatching is to minimize the operation cost of micro grid, that is, according to the day ahead predicted power of renewable energy and load, considering the peak valley difference of electricity price, peak valley difference of load and energy storage life, and combining with the corresponding environmental protection and reliability indexes, through optimizing the output of energy storage and discharge and controllable micro power supply, and determining the power of power purchase and sale of micro grid, the system The total operating cost is the lowest. The objective function can be expressed as:

$$
\min F_1 = \sum_{t=1}^{T} \sum_{i=1}^{N_{d}} \left( C_{OM} \left( P_{Gi}^t \right) + C_{eav} \left( P_{Gi}^t \right) \right) + \sum_{t=1}^{T} \left( C_{PP} \left( P_{grid}^t \right) + I_{sp} \left( P_{grid}^t \right) \right)
$$

Where, $F_1$ represents the operation cost of distribution network, $C_{OM}$ and $C_{eav}$ are the maintenance cost and pollution emission cost of unit operation, $P_{Gi}^t$ is the output of distributed power I in time period T, $P_{Gi}^t$ includes four parts of wind power generation unit $P_{WIND}^t$, photovoltaic power generation unit $P_{PV}^t$, micro gas turbine $P_{MV}^t$ and fuel cell $P_{FC}^t$. $P_{GRID}^t$ refers to the power purchased and sold by the microgrid to the external grid. When it is negative, it means the power sold by the microgrid to the external grid. $C_{PP}(\cdot)$ and $I_{sp}(\cdot)$ are the cost of the power purchased by the microgrid to the external grid and the income from the power sold.
The constraints can be expressed as follows:

1: Power balance constraint

\[ P_{grid}^l + P_{FC}^l + P_{bat}^l + P_{grid}^r + P_{pv}^l + P_{wind}^l = P_{load}^l \]  

(2)

Where: \( P_{load}^l \) is the power load.

2: Upper and lower limits of output of micro gas turbine

\[ P_{MT}^{min} \leq P_{MT}^l \leq P_{MT}^{max} \]  

(3)

Where: \( P_{MT}^{min} \) and \( P_{MT}^{max} \) are the minimum and maximum allowable output power of micro gas turbine respectively.

3: Fuel cell upper and lower limit constraints

\[ P_{FC}^{min} \leq P_{FC}^l \leq P_{FC}^{max} \]  

(4)

Where: \( P_{FC}^{min} \) and \( P_{FC}^{max} \) are the upper and lower limits of fuel cell output respectively.

4: Upper and lower limits of energy storage charge and discharge

\[ P_{bat}^{min} \leq P_{bat}^l \leq P_{bat}^{max} \]  

(5)

Where, \( P_{bat}^{min} \) and \( P_{bat}^{max} \) are the upper and lower limits of energy storage respectively.

2.2. Day scheduling model

When dispatching in the day, the flexible load is mainly dispatched with the highest economic benefit of the power grid, which can make the power grid and the economy run stably under the condition that the renewable energy processing fluctuates in the day. Daily emergency is mainly avoid the occurrence of emergency. It mainly dispatches resources such as flexible load with quick response to ensure reliable operation of power grid. The objective function can be expressed as:

\[ \min F_2 = \sum_{t=1}^{nT24} \left( P_{grid}^l(t) - P_{avggrid}(t) \right)^2 \]  

(6)

Where: \( P_{grid}^l(t) \) is the average power of the tie line in the scheduling period, and \( P_{avggrid}(t) \) is the average power of the tie line in the scheduling period. \( nT24 \) is the whole scheduling cycle.

The constraints can be expressed as follows:

1: Tie line transmission power limit

\[ P_{grid}^{min} \leq P_{grid}^l \leq P_{grid}^{max} \]  

(7)

Where, \( P_{grid}^{min} \) and \( P_{grid}^{max} \) are the minimum and maximum power allowed to be transmitted between the tie line and the distribution network.

3. Case study

In order to verify the effectiveness of the interactive operation strategy in this chapter, a typical European microgrid structure accessing to IEEE 33 node distribution network is simulated, as shown in the figure. After the identification of weak points, there are 10 microgrids connected to the original IEEE 33 node distribution network, 15-24 nodes respectively. For the convenience of representation, 15-18 is a consumptive microgrid, 19-22 is a balanced microgrid, and 23-25 is a supply microgrid. Only the microgrid connected to node 20 is shown in the figure below.
As shown in. In terms of distributed renewable energy, it includes one wind turbine with an installed capacity of 40 kW and one photovoltaic power generation system with an installed capacity of 30 kW; in terms of controllable distributed power, it includes one micro gas turbine with an installed capacity of 80 kW and one fuel cell power generation system with an installed capacity of 40 kW; The total capacity of the energy storage device is 240kw·h, the rated charge and discharge power is 24kw, the initial SOC of the battery is 0.5, the maximum and minimum SOC are 0.9 and 0.2 respectively. The relevant technical parameters of each distributed power supply are shown in Table 1.

Table 1. Related parameters of distributed power supply.

| Distributed power | Upper limit of output | Lower limit of output | Climbing rate |
|-------------------|-----------------------|-----------------------|---------------|
| Micro gas turbine | 80KW                  | 0                     | 16KW          |
| fuel cell         | 40KW                  | 0                     | 8KW           |
| Wind turbine      | 40W                   | 0                     |               |
| photovoltaic      | 30KW                  | 0                     |               |
| Energy storage    | 24KW                  | 24KW                  | 24KW          |

The data of TOU price are as follows: 1.055 yuan / (kW·h) in peak period (10:00-15:00, 18:00-21:00); 0.633 yuan / (kW·h) in normal period (07:00-10:00, 15:00-18:00, 21:00-23:00); 0.291 yuan / (kW·h) in valley period (23:00-07:00).

4. Experimental verification
In order to verify the feasibility of the method, the model is solved based on multi-objective particle swarm optimization. Particle swarm optimization is usually used to solve nonlinear programming problems. It is an intelligent optimization method. Different from the traditional method, it simulates the process of animal behavior optimization in the biological world. It can deal with multiple individuals in the feasible region at the same time, that is, it can evaluate multiple solutions in the search space at the same time, which can effectively ensure that the results of the solution approach the global optimal solution. It is to solve the coordinated optimization problem Excellent algorithm.
Figure 3. Output of each unit.

(1) In the period of load Valley, as shown in Figure 3 (a), period 1 to 6, since it is also in the period of electricity price Valley, the power generated by wind turbine, photovoltaic and power grid shall properly charge the energy storage system while meeting the load demand, so as to reasonably utilize the energy storage for "arbitrage" and improve the operation economy of the system; During the period of 10-15 in the figure, due to the peak period of electricity price, the cost of micro grid power purchase is relatively high. At this time, micro gas turbine and fuel cell become the main power supply unit, and the energy storage system also discharges accordingly. During the period of 18-22, when the load is peak, micro gas turbine, fuel cell and other units are put into operation with the grid to meet the demand of peak load.

Figure 4. Energy storage SOC.

(2) It can be seen from Figure 4 that the energy storage device is mainly charged in the period of low electricity price and low load, and discharged in the period of high electricity price or high load, which not only ensures the balance of SOC in the daily operation of energy storage, but also
effectively plays the role of "peak cutting and valley filling" of energy storage, and improves the economy of system operation.

5. Conclusion
The large-scale access of intermittent distributed generation to the power grid brings challenges to the operation and scheduling of the system. It is an effective technical means to eliminate the intermittent distributed generation based on the optimized operation of the micro grid. In this paper, a multi-objective particle swarm optimization based multi-scale coordinated scheduling strategy of the micro grid is studied. In the pre-dispatch stage, considering the market price, energy storage life and renewable energy prediction information, the optimal economic dispatch model is established with the lowest operating cost. The optimal unit output and optimal energy storage and discharge management under stable constraints are realized. In the intra day scheduling stage, in order to cope with the power fluctuation of tie line caused by the prediction error of renewable energy, the pre day plan is corrected, which effectively realizes the tracking of the planned value of the pre day tie line, and at the same time ensures that the balance constraint of the daily operation energy of the energy storage system is met. The research content of this paper provides a feasible control method for the consumption of renewable energy in microgrid and the participation of microgrid in demand side response, and also provides a theoretical basis and technical means for the multi time scale optimization operation of microgrid.

Acknowledgments
The authors are grateful for the financial support of the National Natural Science Foundation of China (No. 61803273), and the Natural Science Foundation Guidance Project and key research and development program in Liaoning of China (No. 20180550970) and Liaoning Provincial Education Department Key Research Project (No. 2019-ZD-0202).

References
[1] Yang Xia Song, Yong hua Wang, Guang hui Wang, et al. 2010. A comprehensive review on the development of sustainable energy strategy and implementation in China. IEEE Transactions on Sustainable Energy. 5-7.
[2] Sun Huijun, Yan Zhibin, Yu Lei, et al. 2020. Overview of multi-objective optimization operation of microgrid. Shandong electric power technology. 47 (02): 37-42.
[3] Chun-Hao Lo, Nirwan Ansari.2012. The Progressive Smart Grid System from Both Power and Communications Aspects. IEEE Communications Surveys And Tutorials. 6-7.
[4] Dimeas Aris L, Hatziargyriou Nikos D. 2005. Operation of a multiagent system for microgrid control. IEEE Transactions on Power Systems. 5-6.
[5] Chen S X, Gooi H B, Wang M Q. 2012. Sizing of energy storage for microgrids. IEEE Transactions on Smart Grid. 3-6.
[6] Lee Tsung-Ying. 2007. Operating schedule of battery energy storage system in a time-of-use rate industrial user with wind turbine generators: A multipass iteration particle swarm optimization approach. IEEE Transactions on Energy Conversion. 2-4.
[7] Chacra Fouad Abou, Bastard Patrick, Fleury, et al. 2005. Impact of energy storage costs on economical performance in a distribution substation. IEEE Transactions on Power Systems. 25-26.
[8] W Gu Z. Wu X Yuan. 2010. Microgrid Economic Optimal Operation of the Combined Heat and Power System with Renewable Energy. Power and Energy Society General Meeting. 5-6.
[9] Taher Niknam, Abdollah Kavousifard, Sajad Tabatabaei, et al. 2010. Optimal operation management of fuel cell/wind/photovoltaic power sources connected to distribution networks. Journal of Power Sources. 2-3.
[10] Danny, Rodrigo Palma-Behnke. 2020. Energy Management Systems for Microgrids: Main Existing Trends in Centralized Control Architectures. 13(3).