A method for distributed power consumption based on the combined heat and power system

Li Si-wei, Han Shen-zhao, Yu Bo, Lu Xin, Qi Wen
Beijing Zhongdianfeihua Technology Co.Ltd(Tianjin), China
105648026@qq.com

Abstract. With the development of the society and human progress, now resource problems has become one of the major problems faced by people all over the world, the development of new energy and clean energy is the priority now, is now the main power system. Winter heating is one of the main sources of pollution now, so it is very important to study the electric heating system.

1. Introduction
With escalation of the conflict between power supply and demand, and upgrade of the power use structure in recent years, the winter heating model has been transformed from the traditional coal-fired combined heat and power generation to the gas heating and the electric heating. Statistics show that, due to impact of low temperature and high moisture in winter, the electric boiler load is taking up an increasing percentage in the whole grid load. This poses a tremendous challenge against the grid planning and construction as well as normal operation of the grid. Meanwhile, the user-side distributed power switching-in is accelerating, the flexible load control methods become increasingly invasive, and the demand-side regulation methods are uncertain and diverse. All this necessitates seeking a determinable method for grid virtual peak regulation. Regulation of the credible capacity and the target combination is a core technology in this research field. Besides, the technology is applicable to the grid virtual peak regulation and the regional distributed photovoltaic power consumption of the user-side energy (including regional energy and micro-grid).

2. User type
Along with urban economic development and constant changes of urban construction models, four types of users in general have been found in the grid virtual peak regulation. They are the household decentralized residential users, large-scale centralized industrial and commercial users, large-scale single system industrial and commercial users, and interconnected reciprocal distributed energy aggregator users, respectively.

3. Resource management
Peak regulation resources are mainly for the purpose of balancing the grid peak value load output or virtualizing the load output equipment. In this paper, the distributed photovoltaic, virtual energy storage and actual energy storage have been combined to achieve mutual complementation and overall integration, and effectively smoothen the energy demand of the regional grid. That the output increases along with the increase of load and stays at a stable value after reaching its peak is a major distributed photovoltaic characteristic in summer. Virtual energy storage can be generally divided into
two kinds. One is flexible load management, which mainly adopts the electric boiler with thermal storage for load reduction. There are four methods of load reduction, and the specific amount is identified according to the unit load in operation. Virtual energy storage of the kind is characterized by gradient load reduction, meaning that load cannot be reduced to the preferable level at once. The other is rigid load management, which mainly serves to realize direct control of nonproductive load, such as lighting. In contrast the above virtual energy storage, this virtual energy storage has more effective control, but its load capacity is small. The energy storage method, though responding to the grid peak frequency regulation instructions and strategies, has not yet found wide applications.

![Centralized AC system control schematic diagram](image)

**Fig. 1 Centralized AC system control schematic diagram**

4. Regulation models
In terms of participation models, energy use of users is diagnosed to identify the adjustable load resources and types. They are further divided into adjustable control and interruptible control. Then, the regulation measurement terminal is installed for the purpose of statistically analyzing the load data. Finally, the big data intelligent analysis method is employed to analyze the demand-side electricity use based on a multi-time scale.

| User name         | Equipment           | State    | Threshold value | Type       | Operation hours |
|-------------------|---------------------|----------|-----------------|------------|-----------------|
| Joy City 1        | Lighting 1          | Operating| 20kW            | Interruptible | 10:00–21:00    |
| Joy City 2        | Boiler main machine 1 | Standby  | 300kW           | Adjustable | 09:30–20:40    |
| Northern Financial Building 1 | Lighting | Standby  | 40kW            | Interruptible | 07:00–18:00    |

In terms of regulation models, the participation models of users are statistically analyzed. Then, data of participation models are divided according to the industry-based or equipment-based control types. Finally, three regulation modules are found, namely global optimization response, fewest users
response, and emergency demand response.

Fig. 2 Building large-scale air-conditioning load virtual peak regulation logic chart

5. Global optimization response

During global optimization of variables, the user “optimization algorithm” is built based on classification of regulation models. The optimization algorithm is used to screen user participation. Besides, the credible capacity boundary is built for the grid by setting up the global constrained optimization and controlling the mathematical model. Finally, the control objectives are identified via equipment calibration.

\[
\sum_{i=1}^{a} P_{i, \text{max}} < P
\]

User: \[1 \quad 2 \quad 3 \quad 4 \quad \cdots \quad a \quad a+1 \quad \cdots \quad n\]

\[
\sum_{i=1}^{a+1} P_{i, \text{max}} \geq P
\]

Fig. 3 Global optimization response schematic diagram

The constraint can be written as below:

\[
P_{t,j} = \begin{cases} 
\sum_{i=1}^{a} P_{i, \text{max}} < P \\
\sum_{i=1}^{a} P_{i, \text{max}} \geq P
\end{cases}
\]  

Where, \(P_{t,j}\) stands for the response capacity, and \(P\) for the actual response boundary. Based on Eq. (1), it can be concluded that major boundary of the global optimization response is actually the
minimum response boundary of the global variables.

Below is the mathematical expression:

\[
\sum_{i}^{n} P_{i,j} = \alpha \sum_{i}^{a} P_{il} + \beta \sum_{i}^{a} P_{DIL} \cdot L_s
\] (2)

Where \( \alpha \) denotes the participation factor of the interruptible load users; \( \beta \) denotes the participation factor of the uninterruptible load users; \( P_{il} \) denotes the interruptible load; \( P_{DIL} \) denotes the uninterruptible load; \( L_s \) denotes the adjustable coefficient.

Then, the optimization objective function can be written as below:

\[
\min Price = \min \left( \text{Price}_{\text{Grid}}, P_{i} - \sum_{i=1}^{n} \text{Price}_{il} - \sum_{i=1}^{n} \text{Price}_{DIL} \right)
\] (3)

\[
\eta(k) = 1 - \eta(x) = 1 - \frac{C_M^x C_{N-x}^n}{C_N^n}, [x = 0,1,2,.....n]
\]

6. Conclusions

The boiler and air-conditioner regulation method aiming at realizing the grid peak transfer can contribute to friendly interaction between the grid and the users. It is an important method and critical link for the grid company to realize load regulation on the power use side of residents. Results suggest that the boiler load smart regulation method proposed in this paper can help reduce the grid peak load and cut the grid operation and construction input.

Therefore, influence of the boiler load on safety, stability and economical operation of the grid should not be ignored. The technological, economic and administrative methods of the power demand side should be combined to realize efficient management of the air-conditioning load, effectively alleviate the conflicts between power supply and demand, and ensure steady and safe operation of the
grid. Meanwhile, these countermeasures adopted are conducive to optimization of the power use style and improvement of the energy use efficiency. Most importantly, these countermeasures have a far-reaching influence on optimal configuration of electricity resources and sustainable development.

References;
[1] Q/GDW-518. Technical guide for smart power utilization service system[S]. 2010
[2] TONG Shu-lin, WEN Fu-shuang & Chen-liang. A two-dimension wavelet threshold de-noising method for electric load data pre-processing [J]. Automation of Electric Power Systems, 2012. 02.
[3] YIN Shu-gang, ZHANG Yu, BAI Ke-ming. A smart power utilization based on real-time electricity prices[J]. Power System Technology, 2009, 33(19): 11-16.
[4] ZHANG Zhi-qiang, et al. Analysis of air-conditioning load characteristics and countermeasures [J].
[5] TONG shu-lin,WEN fu-shuan. Calculation and analysis of the annual maximum high-temperature related load in the energy saving and emission reduction environment in Guangdong Province [J]. North China Electric Power University (Natural Science), 2010. 05.
[6] WEN quan, LI jing-ru, ZHAO jing. Air conditioning load calculation methods and its application [J]. Demand Side Management, 2005. 04.
[7] CHENG Yu, ZHANG Li-zi. The co-integration analysis of power tariff and demand[J]. Proceedings of the CSEE, 2006, 26(7): 118-122.
[8] ANGEL A. AQUINO L, RAY K. A control framework for the smart grid for voltage support using agent-based technologies[J]. IEEE Trans on Smart Grid, 2011, 2(1): 161-168.
[9] PEDRASA A , SPOONER D , MACGILL I F. Coordinated scheduling of residential distributed energy resources to optimize smart home energy services[J]. IEEE Trans on Smart Grid, 2010, 2(1): 161-168.
[10] NEGENBORN R, HOUWING M, SCHUTTERr D B, et al. Adaptive prediction model accuracy in the control of residential energy resources[C].Proceedings of 2008 IEEE International Conference on Control Application. Pisa, Italy: IEEE, 2008: 311-316.
[11] HAAS R, NAKICENOVIC N, AJANOVIĆ A, et al. Towards sustainability of energy systems: a primer on how to apply the concept of energy services to identify necessary trends and policies[J]. Energy Policy, 2008, 36(11): 4012-4021.