Research on the Application Scheme of Air-conditioning Load Regulation for Peak Shifting in Power Grid

Xu Zhou1, *, Siwei Li1, Shiming Tian2, Kaining Luan3, Liang Yue1 and Xiaodan Liu1

1Beijing Guodiantong Network Technology Co. Ltd., Beijing, China
2China Electric Power Research Institute, Beijing, China
3State Grid Jiangsu Electric Power Co., Ltd, Nanjing, China

* Corresponding author e-mail: 1296829358@qq.com

Abstract. With the growth of the national economy and people constantly improve the level of electricity load has maintained a faster, higher growth, the growing impact of the growth of the air conditioning load on the power system economic operation of power supply and demand balance. The grid load clipping the air conditioning load regulation, we design a smart grid shift peak air-conditioning load regulation. The article describes the grid load characteristics of the current economic situation, the load control for the different forms of communication networking chip design and intelligent centralized control of air conditioning load platform design, also described the entire system of communication networking solutions and peaking strategy.

Keywords: Grid load, Automatic climate control, Load control chip.

1. Introduction
In order to meet the increasing energy demand due to industrial and population growth, energy use control has become more economically feasible. With the rapid growth of China's economy, in recent years, the contradiction between supply and demand of electricity in major provinces and municipalities, especially in summer, has been prominent, which has had a certain impact on the local economic development. To fundamentally solve the problem of insufficient power supply, we need not only to increase investment in power, but also to use limited power energy reasonably and effectively. At present, the main manifestations of power supply shortage are: low load rate of power grid, large difference between peak and valley of the system, and serious shortage of peak power. Therefore, the implementation of demand side management, improving the efficiency of power utilization and transferring peak load is a problem that must be paid attention to at present.

Today, with the continuous increase of power demand, the continuous increase of peak load has brought tremendous pressure to the investment of grid infrastructure. In order to achieve peak load in just a few minutes, grid companies have to bear high investment in grid infrastructure. In the ever-increasing demand for electricity load, the load demand of air conditioning occupies a larger proportion. During the peak period of summer, the maximum load of air conditioning in China reached 180 million kilowatts, an increase of 12.5% year on year, accounting for about 1/4 of the total social electricity load.
At present, with the wider and wider application of air-conditioning system in cities of China, the demand for power of air-conditioning system is growing rapidly. The unbalanced characteristic of air-conditioning load has greatly aggravated the peak-valley difference of power grid load. It can be seen from this that the influence of air-conditioning on power grid load is studied, the effect of air-conditioning on peak-shifting and peak-shaving during peak power consumption is studied, the application of air-conditioning in power grid load management is studied, and the air-conditioning load management is coped with the increasing peak load. The meaning of lotus.

2. Design of Peak Shifting Scheme for Power Network of Intelligent Air Conditioning

Through load control of power terminal which accounts for a large proportion of peak load, peak load can be effectively controlled and reduced. Whether in the north or south cities during the peak load period in summer, the air conditioning load (that is, the load brought by the centralized use of air conditioning cooling) accounts for a large proportion of peak load. The effective control of air conditioning load will not only reduce the proportion of air conditioning load to peak load, but also reduce the actual peak load in summer. Thus, the reliable and stable operation of the power grid in summer can be guaranteed, and the peak shifting effect of the power grid can be achieved. Intelligent air-conditioning load monitoring platform obtains load forecasting data and peak warning time from power dispatching automation system, and combines with the actual power consumption of controlled intelligent air-conditioning, analyses and determines the key air-conditioning load control areas, so as to decide when to control the air-conditioning in which areas, through frequency modulation, shutdown and so on. Load control in different ways.

According to the current characteristics of power grid and the development status of intelligent air conditioning, the air conditioning load regulation solution for peak load shifting is designed, which integrates communication network structure, load centralized control monitoring platform, load control chip and overall load control strategy of power grid.

2.1. Communication network

Considering the independence and security of power grid information system, and combining with power dispatching, distribution automation system and other power resource allocation systems, the security, stability and economy of intelligent air-conditioning load control communication network are realized. Combining with the overall network architecture of intelligent air conditioning, the communication network structure consists of terminal information acquisition layer, communication network layer and master station monitoring layer. It realizes the distribution and control of air conditioning load control strategy, so as to achieve the purpose of peak cutting and peak shifting.

The main modes of intelligent air conditioning load control communication are micro-power wireless communication technology, PLC communication technology, 3G/4G mobile communication technology and WLAN communication technology. Next, we illustrate the whole communication network architecture with micro-power wireless + Internet networking scheme.

Data encryption module and micro-power wireless/PLC module are added to the frequency conversion air conditioner to transmit and interact with the control gateway. Air conditioning load control is realized by Internet.

According to the user's environment, this scheme can choose the communication mode to form a network. Two communication ways can achieve the purpose of data acquisition and load control. At the same time, data acquisition enters the load control monitoring platform through the Internet, which reduces the operation cost and can be combined with smart home.
2.2. Strategy of Intelligent Air Conditioning Load Monitoring Platform

In order to satisfy the information accuracy of intelligent air conditioning load monitoring platform, 144-point output curve with 10-minute interval is adopted. At the same time, detailed power demand data are provided for accurate load peak prediction and power dispatch. Reasonable mathematical models and algorithms are used to fully and comprehensively consider the influence of air conditioning load on load characteristics of power grid. Relevant factors. According to the characteristics of air conditioning operation state, there are four major changes in air conditioning load: dynamic operation, static operation, start-up operation and shutdown operation. Among them, the main impact on the power grid caused by air conditioning load is the start-up operation of air conditioning, the shutdown operation of air conditioning and the dynamic operation of air conditioning.

Intelligent air conditioning load monitoring platform obtains load forecasting data and peak warning time from electric power dispatching automation system, combines the actual power consumption situation of controlled intelligent air conditioning, combines the corresponding strategies of energy saving and DR, and carries out air conditioning control according to the key air conditioning load control areas, which can be controlled by frequency modulation and shutdown. Load control is carried out in various ways, and two-way interactive service between load monitoring platform and intelligent air conditioning is constructed.

2.2.1. Air conditioning information upload.

a) Turning on information report

After the air conditioner is turned on, the load control chip of the air conditioner should actively report information to the intelligent air conditioning load monitoring platform, including online notification, air conditioning ID, current working status (start-up information, refrigeration or heating, frequency of frequency converter, air volume, etc.), real-time power, and the accumulative power consumption of the unit.

b) Heartbeat mechanism

When the load control module is on line, the heartbeat packet is sent to the load control monitoring platform every 10 minutes to prove that the air conditioner is on-line. If the load control monitoring platform does not receive the heartbeat packet for more than 15 minutes, the air conditioner is considered off-line.

c) Working status report

After the working state and mode of air conditioning change and reach stability, the changed state, mode and current power are uploaded to the intelligent air conditioning load monitoring platform.
2.2.2. **Load Control Mode.** When the grid load reaches the alarm line, the load control instruction is sent to the intelligent air conditioner by the load control monitoring platform. After the air conditioner receives the instruction, the corresponding processing is done according to its own characteristics.

a) Limit the maximum operating frequency of the compressor, not higher than 90% of its rated operating frequency.

b) Limit the wind speed of the indoor fan: Limit the wind speed of the indoor fan, for the direct current fan, not more than 80% of the maximum wind speed; if the fan is divided, it can not be set to high wind volume.

c) Setting temperature limits: for example, in refrigerated air conditioning, setting temperature is not less than 26 degrees, and the temperature can only be raised, not lowered; in heating air conditioning, setting temperature is not higher than 23 degrees, can only be lowered, can not be raised.

d) With the scheme of target input power, the total input power of air-conditioning should not exceed the limit. Within the limit, the air-conditioning can operate independently, and when it reaches the limit power, it should be carried out in the way of fixed power.

e) Under special circumstances, air conditioning can be shut down.

2.2.3. **Return to normal mode.** In order to avoid new load peaks after peak shaving, it is necessary to restore air conditioning in batches. Load control monitoring platform uses a specific delay algorithm to restore air conditioning in load control mode to normal operation mode in batches. After restoring the normal mode, the air conditioning load control chip should feedback the current working state, restore the working mode of air conditioning in batches, accurately to the desk area, and restore the load under each desk area in batches.

2.2.4. **Load Forecasting.** Load control platform can be regarded as a highly non-linear system about time series in air conditioning load forecasting. Therefore, artificial neural network method is used for load forecasting. Neural network is an information processing system designed to imitate the structure and function of human brain. It has the functions of self-learning, self-organization, associative memory and parallel processing. Yes. And its own non-linearity makes it possible to approach the non-linearity between input and output of the system by using only neural network without knowing the exact mathematical model. Therefore, the forecasting data of regional and load data in the area needing load control can be realized by the model algorithm, which provides theoretical support for load control.

2.2.5. **Factor Analysis of Strategic Development.** In the process of strategy formulation of load regulation, the impact factor of strategy formulation is also the decisive factor that directly leads to the results of load regulation. The influencing factors of the load control strategy include three aspects: the artificial factors of the load control strategy, the factors of power consumption environment and mode, and the urban micro-meteorological factors. Load control strategy human factors mainly refer to price-based and incentive-based control strategies. Power users change their air-conditioning behavior through human factors to achieve the purpose of reducing power load. Power consumption environment and mode factors mainly refer to the prediction of corresponding load according to regional electricity characteristics. According to the load characteristics, the load control strategy is formulated. Because the basic normal load is basically unchanged in a short time, and the proportion of weather-sensitive load in power load is much larger than the sum of special event load and random load, so mastering the changing law of weather-sensitive load can predict the trend of load in a short time, at the same time, it can provide rationality for the load control area and quantity. Basis: Urban micrometeorological factors mainly refer to the impact of climatic phenomena on power users' electricity consumption (air conditioning) behavior, including hot wind, snow, dust and other factors.
2.2.6. **Platform strategy formulation.** Air-conditioning load characteristics are related to many factors, such as geographical location difference, climate environment and air-conditioning application scenario. The characteristics of air-conditioning load will be affected by urban, public buildings and household application scenarios, climate change in winter and summer in the north and south of China, resulting in high correlation and complexity of air-conditioning load control strategy, which brings great difficulty to the study of regional air-conditioning control strategy for urban load management. Based on the analysis of the above factors, the platform air-conditioning control strategy combines the direct load control, interruptible load control and restoring normal mode to form a load control strategy based on mathematical model algorithm and theoretical data.

2.3. **Load Control Chip**

Load control chip is the core of intelligent air conditioning peak shaving. Load control chip is the carrier of the whole control application, and is the core module of intelligent air conditioning condition checking, information judgment and function processing. Based on the real-time, security and reliability of air-conditioning load control, and considering the particularity of the communication network and the diversity of air-conditioning types, different communication modes lead to different principles and architectures of the design of load control chips. Considering comprehensively the scheme of 3G/4G public network and the scheme of multiple communication modes.

2.3.1. **Micropower Wireless Scheme.** The functional block diagram of the micro-power wireless communication air conditioning load control chip is shown in the following figure.

![Fig. 2 Strategy developed by Impact Factor.](image-url)
In the air conditioning load control chip, GDT-MCU is chosen as the main controller to complete the functions of data receiving and receiving, protocol processing, command parsing, power metering, and communicate with the MCU of the air conditioning main control board through UART. Including electric energy measurement, it can collect the corresponding voltage/current sampling, electric energy measurement and other values.

In the aspect of wireless interactive control, the wireless control gateway technology is adopted. The wireless control gateway mainly completes the bridge function between the micro-power wireless local area network and the Internet. The structure and function block diagram is shown in the following figure.

![Fig. 3 Functional block diagram of micropower load control chip](image)

2.3.2. PLC Communication Scheme. The function block diagram of air conditioning load control chip based on PLC communication is shown in the following figure.

![Fig. 5 Function block diagram of PLC load control chip](image)
In the load control chip, GDT-MCU is chosen as the main controller, and PLC signal coupling circuit is used to realize PLC communication in the home.

In the interactive control of PLC communication network, using the technology of PLC control gateway, the PLC control gateway mainly completes the bridge function between the home internal PLC network and the Internet. The functional block diagram is shown in the following figure.

![PLC Bridging Function Block Diagram](image)

In the PLC control gateway, the CPU with network processing ability is chosen as the main controller, and it communicates with the air-conditioning load control chip through the analog front-end and signal coupling circuit of the PLC. When sending and receiving data over the Internet, it is necessary to encrypt/decrypt the data by hardware.

3. Conclusion
Intelligent air conditioning load regulation method for peak load shifting of power grid is the service basis of friendly interaction between power grid and users. It is an important means and key link for power Grid Company to realize load regulation on residential power side. Through the intelligent air conditioning load regulation method, the peak load of power grid can be reduced, the economic input of power grid operation can be effectively reduced, and the infrastructure investment of power grid can be greatly reduced.

Attaching great importance to the impact of intelligent air conditioning load on the safety, stability and economic operation of power grid, and actively utilizing the economic, technical and administrative means of DSM to realize the effective management of air conditioning load, can effectively alleviate the contradiction of power supply shortage, ensure the smooth and safe operation of power grid, and is conducive to optimizing the mode of power consumption. Improving the efficiency of energy use has a far-reaching impact on building a conservation-oriented society and realizing the optimal allocation and sustainable development of power resources.

Acknowledgements
This work was supported by the National Key Research and Development Program of China (2016YFB0901102).

References
[1] ANGEL A. AQUINO L, RAY K. (2011). A control framework for the smart grid for voltage support using agent-based technologies [J]. IEEE Trans on Smart Grid, 2(1): 161-168.
[2] CHENG Yu, ZHANG Li-zi.(2006). The co-integration analysis of power tariff and demand [J]. Proceedings of the CSEE, 26(7): 118-122.
[3] PEDRASA A, SPOONER D, MACGILL I F. (2010). Coordinated scheduling of residential distributed energy resources to optimize smart home energy services[J]. IEEE Trans on Smart Grid, 2(1): 161-168.
[4] TONG shu-lin. WEN fu-shuan. (2010). Measurement and analysis of energy saving environment, Guangdong Province, the largest annual cooling load [J]. North China Electric Power
University (Natural Science), (05).

[5] WEN quan, LI jing-ru, ZHAO jing. (2005). Air conditioning load calculation methods and its application [J], Demand Side Management ,(04).

[6] YIN Shu-gang, ZHANG Yu, BAI Ke-ming. (2009). Based on the real-time intelligent power consumption of electricity price system [J]. Power System Technology, 33(19): 11-16.

[7] ZHANG Zhi-qiang,. et al. Its control measures based on the grid side of the air conditioning load characteristics [J].