Research and Application of a Technology Eliminating Restriction of Electrical Equipment Capacity as Clean Electricity Heating Develops Rapidly

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Abstract—Replacing coal by electricity projects is one of the national public welfare projects. In the field of energy conversion, the larger the number of electric heating users is, the more favorable it is to control air pollution, and the more significant benefits of the society, ecological system and environment are. This paper put forward a technology for solving restriction on rapid development of clean electricity heating due to electrical equipment capacity. It is able to enable a large number of users to access the power distribution network without capacity increase or with little capacity increase, which is beneficial to promoting electric heating extensively and accelerating the process of “replacing bulk coal by clean electric energy” project in China.

1. Introduction
For a long time, northern China is faced with frequent haze and other air pollution during the heating period in winter due to factors like coal-fired heating, which seriously jeopardizes people’s life and health. For this reason, the CPC Central Committee and the State Council organized eight ministries and commissions (including National Development and Reform Commission, National Energy...
Administration and Ministry of Finance) to jointly issue Guidelines on Prompting Electric Energy Replacement in May 2016. It is proposed in this document to implement the spirit of the sixth meeting of CPC Central Leading Group for Financial and Economic Affairs, strategic action plan for energy development and action plan on air pollution prevention and control, improve the proportion of electric energy in end-use energy consumption, adjust measures to local conditions, promote clean replacement of bulk coal gradually, and vigorously promote “replacing coal by electricity”, so as to solve the air pollution in winter in northern China.

In response to the call of the state for improving air quality in winter, local governments at all levels are facing a crucial problem that needs to be resolved immediately while promoting large-scale electric heating, that is, current domestic lighting transformers and distribution lines are unable to withstand the high power of the new electric heating equipment, and upgrading or replacing them all requires users to put lots of money into capacity increase development. (For example, National Energy Administration put over CNY 70 billion on the development of “coal to electricity” supporting grid in Beijing-Tianjin-Hebei Region and the surrounding region in 2017-2019.) Therefore, the focus in this paper is how to reduce the power of electric heating buildings, solve the problem of “clean electricity heating cannot develop rapidly due to restriction by capacity of electrical equipment”, make large, medium and small users give up coal-fired boilers and choose electric heating boldly on the premise of ensuring heating comfort.

2. Method
To solve the problem of “clean electricity heating cannot be developed rapidly due to restriction by capacity of electrical equipment”, we developed an electric heating current limit control intelligent management system. With this system, 50% power of the electric heating building was reduced on the premise of ensuring heating comfort. This system consists of IoT cloud platform, data base station, current limiting controller, relay module and temperature control terminal. Its working principle is shown in the figure 1 below:

![Electric heating intelligent management system working principle structure diagram](image-url)
2.1. Electric Heating Law Mastered by Survey
We performed remote telemetry for over twenty electric heating buildings in one heating cycle at the beginning of project Research & Development, and found out the electric heating law.

Table 1 5-day Average Values in January 2018 (electric heating temperature is set at 20℃)

| Time          | 0:00-6:00 | 6:00-8:00 | 9:00-16:00 | 16:00-18:00 | 18:00-24:00 |
|---------------|-----------|-----------|------------|-------------|-------------|
| Outdoor weather | Night     | Morning sun | Shining sun | Sunset      | Night       |
| Outdoor temperature | −25℃     | −21℃      | −17℃       | −20℃        | −26℃        |
| Electric heating time | About 30min/H | About 20min/H | 0min/H     | About 20min/H | About 30min/H |
| Measured indoor temperature | 20℃      | 20℃       | 23℃        | 20℃         | 20℃         |

Table 2 5-day Average Values in February 2018 (electric heating temperature is set at 20℃)

| Time          | 0:00-6:00 | 6:00-8:00 | 9:00-16:00 | 16:00-18:00 | 18:00-24:00 |
|---------------|-----------|-----------|------------|-------------|-------------|
| Outdoor weather | Night     | Morning sun | Shining sun | Sunset      | Night       |
| Outdoor temperature | −20℃     | −16℃      | −8℃        | −15℃        | −19℃        |
| Electric heating time | About 20min/H | About 15min/H | 0min/H     | About 16min/H | About 20min/H |
| Measured indoor temperature | 20℃      | 20℃       | 25℃        | 20℃         | 20℃         |

We found out that sunlight played a decisive role in heating energy consumption of buildings in the process of measurement. Therefore, the Research and Development conception of “preheating in advance at electric heating valley, and heating buildings with 50% power at morning (evening) peak” is theoretically feasible.

2.2. An Intelligent Algorithm of “Peak Load Shifting and Accurate Preheating in Electric Heating”
We set up a private IoT cloud platform with LoRaWAN server acting as the center, performed secondary development on the complimentary open source software package with genetic algorithm, cluster analysis, decision tree and other technologies, and wrote intelligent software of “peak load shifting and accurate preheating in electric heating” in a creative manner. This software performs intelligent analysis and calculation based on weather forecast, users’ usage pattern, changes in courts electrical load and other historical data, establishes N sets of preheating and time node scheme models for every user room, and determines the best preheating scheme based on changes in outdoor temperature and courts current. In this way, 50% heating power of electric heating buildings was reduced on the premise of ensuring users’ heating comfort. Its working principle is shown in the figure 2 below:
Figure 2  Flow chart of cloud intelligent algorithm for precise preheating of valley shifting and peak filling

2.3. Intelligent Processing Method in case of System Heating Failure

(1) If the system detects overcurrent in the district when implementing heating scheme for the whole, it will adjust the number of the temperature control terminals being heated automatically to reduce the total electric heating power, and figure out the missing heating time of the user room intelligently. Secondary heating will be done upon power recovery of the district.

(2) The system will analyze failure causes intelligently and send alarm message to the administrator and the user in case of heating failure or low temperature failure of the user building.

(3) In case of communication failure of the consumer temperature control terminal, the system will heat the consumer as per the last time node automatically until the failure is eliminated.

2.4. Measures for Preventing Grid Operation Safety from being Affected by System Out-of-control

We managed to prevent electrical equipment overload burnout due to system failure in the “electric heating current limit control intelligent management system” by strengthening technical measures for
safety prevention and inventing an electric heating current limiting controller. The realization process of the technology is as follows:

1. Real-time current information is sent to the intelligent management system.
2. An instruction that allows Line A and Line B electric heating equipment to work simultaneously at power consumption valley from the intelligent management system is received.
3. When the current limiting controller detects overcurrent in case of system off-grid failure, 50% electric heating loads will be disconnected automatically for operation by turn, and red audible and visual alarm will be given out to prevent overload burnout of the electrical equipment.

3. Results
This project reduces the power of the electric heating building by 50%, makes large, medium and small electric heating users get rid of the restriction from electrical equipment capacity and access the power distribution network with capacity increase or little capacity increase method, and solves the problem of “clean electricity heating cannot be developed rapidly due to restriction by capacity of electrical equipment” on the premise of ensuring heating comfort. In addition, it increases the area of the pilot building that was unable to use electric heating by 293,000 m³ within three years, replaces 2,912t/a bulk coal, and reduces 9.57t/a pollutant (PM2.5, SO₂ and amino oxide) emission. Moreover, it drives the overall scientific and technological progress of electric heating industry, fills international & domestic gaps of study on electric heating current limiting control technology, and achieves the leading level of international & domestic similar technologies. Currently, this product has been subject to large-scale application in China.

4. Conclusions
As China will intensify its efforts on “energy conservation & emission reduction and air pollution control” in the future, potential users who cannot use electric heating due to restriction from electrical equipment capacity will be generated every year. Such users are the best target customer of this technical product. We solved the problem that many electric heating users cannot be accessed due to restriction from electrical equipment capacity while gaining profit by promoting the technology. In this way, we have made great contribution to winter air pollution control in China, pollutant emission reduction, improving people’s life quality and health level, and ensuring coordinated and sustainable social and economic development.

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