Research on Control Strategy of Electric Heating Load Cluster

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Abstract. At present, due to the rapid development of the economy and the unceasing enthusiasm of the modernization process, human beings are increasingly dependent on electric energy. The development of renewable energy and energy efficiency have become the consensus in the energy field. The randomness of the future solar power generation, wind power and other intermittent and new energy sources in the power grid continue to rise, which is bound to occupy an increasingly important position in the power energy structure. The active regulation capability of the “power supply side” in a high-ratio renewable energy grid is degraded. To ensure safe and efficient operation of the grid, it is imperative to develop the regulation capability on the load side. This paper establishes a cluster aggregation model, clusters the electric heating load through scientific and rational grouping, makes the electric heating load form a load group for unified regulation, formulates an appropriate cluster optimization control strategy, and makes full use of the cluster electric heating control potential to achieve peak clipping. Fill the valley, effectively improve the regulation capacity of the grid.

1. Introduction

Electric heating load has strong randomness and dynamics due to different user habits. Large-scale electric heating load will have certain impact on the safe and stable operation of the system. However, the change of indoor temperature control range by electric heating causes the change of building energy supply. Under the given temperature constraints, the electric heating load has a control range of power and energy in a certain period of time. The electric heating can be time-shifted. Its characteristics make it have greater flexibility in energy demand. As a regulatory resource, it has a considerable response fascination and a large controllability\textsuperscript{[1]}. First of all, gradually promote the large-scale application of household electric heating, according to the energy demand elasticity of electric heating load, adjust the thermal comfort temperature range of winter human body, and will not affect the thermal comfort of electric heating users; secondly, in northern areas, the scale and volume of the load are considerable. The capacity of the electric heating after the cluster which involved in the response is huge, and the control method of participating in the regulation is relatively flexible. It can be considered to rely on the power demand response to participate in the stable operation of the grid. At present, renewable energy power generation such as wind power and photovoltaics are continuously re-into the power grid. Due to the volatility of these intermittent energy sources, the
active regulation capability of the power system is degraded. Therefore, the demand response of the smart grid is utilized to vigorously develop the regulation potential of the load side. It is imperative. The adjustable load such as electric heating can achieve the effect of adjusting the power demand in a short time due to the fast response, and the performance of the device itself and the user's thermal comfort are not affected during this time. Through scientific and rational demand response control strategies, on the one hand, it can cut peaks and fill valleys to a certain extent, and achieve load energy conservation. On the other hand, the electric heating load group can be profitable by means of adjustment, and the power grid can absorb renewable energy more and replace some of the hot spares to obtain energy saving benefits. Compared with the traditional measures to increase the installed capacity, the investment cost is relatively small, and the social and economic benefits are relatively high.

In summary, the electric heating load adjustability assessment and cluster control strategy are studied. The flexibility of the energy demand of the electric heating load is used to improve the power grid regulation capability, and the power grid is safely and stably obtained through the demand response. In the dispatching operation, it has important practical significance.

2. Electric heating load cluster regulation mechanism

The electric heating load can be used as an important demand response resource. The electric heating load is applied to the north in the geographical location and is more dispersed. Therefore, when participating in the demand response regulation, it is necessary to cluster the electric heating load through certain methods. In order to avoid the power supply dispatching center to deal with the demand response regulation, it is faced with a large number of scattered electric heating loads, which can achieve reasonable regulation of electric heating load resources to a certain extent.

![Figure 1](process_of_cluster_electric_heating_scheduling_mechanism.png)

**Figure 1** Process of cluster electric heating scheduling mechanism

Based on the above requirements, as an intermediary between the dispatching center and the electric heating user, the development of the load aggregator can unify the position of the relatively distributed electric heating load, and the cluster participates in the power grid regulation. With the support of increasingly advanced smart grids and advanced communication technologies, load aggregators can fully exploit the load regulation capabilities of electric heating users and achieve peak-cutting and valley-filling effects through certain cluster control. As shown in Figure 1 above, the load aggregator manages multiple clusters of electric heating load, regulates the operating state of the electric heating load group, and performs negative regulation power during peak hours. The regulation
and control instructions positively regulate the heating power of electric heating during the period of low electricity demand, and use the regulation of the cluster electric heating to meet the scheduling requirements of the system dispatching center. It can be seen from Figure 1 that the cluster electric heating dispatching mechanism is as follows: The power system dispatching center relies on load forecasting and normal supply demand, determines the scheduling schedule of the next day, and performs normal distribution through the capacity and quotation provided by the load aggregator; The aggregator relies on the sensors installed in the cluster electric heating load to obtain the initial set temperature and heating power of each cluster electric heating load polymer, and clusters the electric heating load according to the operating parameters of each electric heating load group. Forming n electric heating load aggregates, and then obtaining the load adjustability of each polymer of the cluster electric heating load, and sending corresponding control commands to each cluster electric heating load through each controller; cluster electric heating and each electric heating polymer are after receiving the control command, the relevant operating states of the respective electric heating polymers are adjusted, thereby changing the polymerization power, so that the scheduling plan of the power system dispatching center is realized. The real-time relevant operating state of each cluster electric heating load polymer is obtained through the sensor, and feedback is sent to the load aggregator, so that the power system dispatching center evaluates the effect of the cluster electric heating participation in peak-cutting and valley filling [3].

3. Electric heating load cluster control strategy

The control strategy for electric heating load is generally divided into start-stop control, temperature control and periodic pause control.

3.1 Start-stop Control

The control strategy of directly operating the electric heating load through the switch of the electric heating device, the strategy reduces the large-scale oscillation of the electric heating load power in the recovery process to a certain extent, and the decision variable of the electric heating load start-stop control is the switch State, can control the temperature control of various turn-on and turn-off optimization combinations through various word-of-mouth functions and related constraints By adjusting the initial set indoor temperature of electric heating, the electric heating load is adjusted accordingly to meet the optimal control of the upper and lower limits of household electric heating temperature in the cluster electric heating load. On the one hand, this control strategy can effectively reduce the problem of aggregate load fluctuations. [4] When the temperature regulation and optimization of the electric heating load group is adjusted, the potential of participating in power grid clipping control can be achieved. On the other hand, by adjusting the indoor temperature of the electric heating to adjust the electric heating load accordingly, the operation is convenient, and the temperature requirement of the human thermal comfort can be realized in the reasonable control and control process.

3.2 Temperature Control

According to the thermal comfort of the electric heating user, the temperature control range is divided, so that the upper and lower limits of the temperature are controlled by the periodic suspension control and the electric heating power, that is, the electric heating load group is controlled according to a fixed time period. This chapter considers the following when formulating the cluster electric heating control strategy 4 aspects: 1 to reach the peak clipping index; 2 to meet the human body thermal comfort temperature range; 3 electric heating start and stop control times as few as possible; 4 after the power regulation of the cluster, the impact on the power grid is small, the cluster electric heating load curve meets As smooth as possible. Based on this, based on the clear electric heating load control method and its adjustable capacity, based on the parameter uniformization model established in the previous section, this section proposes an electric heating load cluster control strategy based on the parameter uniformization aggregation model.
Electric heating power

Building indoor temperature

Evaluate the ability of electric heating load to adjust

Determine the scheduling target for a certain period of time

Initial temperature setting

Optimal control strategy for cluster electric heating based on parameter uniformization model

Regulated heating power

Optimize regulation and control to achieve scheduling goals

Update building indoor temperature value

Update cluster electric heating load information

Figure 2 Overall schematic diagram of electric heating load participating in demand response

The adjustable capacity of electric heating load has great potential, but there is a limit to the regulation of the sustainable time control. Therefore, the number of reasonable electric heating groups should not be excessive when the initial grouping according to power is performed. At the same time, when the number of electric heating loads that need to be regulated is increasing, the electric heating load in the polymerization group is also increasing, and the optimization calculation of the electric heating load cluster processing will become very slow[5]. Therefore, for the cluster control of large-scale electric heating load, this section is based on the parameter uniformization polymerization model, and adopts the cluster electric heating load optimization control.

Figure 3 Electric heating load cluster control based on uniform polymerization model

4. Analysis of regulation potential of electric heating load cluster

The following is the simulation analysis of the above-mentioned control potential of the electric heating load cluster based on the homogenization polymerization model, in order to understand the
influence mode and degree of each relevant factor on the cluster electric heating control potential in the overall trend, and verify the homogenization polymerization described in this paper. The feasibility and effectiveness of the model's electric heating load cluster control strategy. The main parameters of the designed simulation study are as follows:

(1) Set the total load in a certain area in winter to 5000 kW, assuming that the electric heating load accounts for about 2800 kW and the rest is a fixed load.

(2) Obtain the equivalent heat capacity C and equivalent thermal resistance Ro of each electric heating user room according to the built uniformization model. The upper and lower bounds of the obtained N heating load polymerization power, where in the equivalent heat capacity C and the equivalent thermal resistance R are randomly selected according to the probability model. The equivalent parameters of the electric heating based on the homogenization model are shown in the table.

| Table 1 Equivalent parameter list of cluster electric heating based on uniformization model |
|---------------------------------------------------------------|
| Electric heating rated power type/kW | Uniform model equivalent parameter | Equivalent parameter mean | Equivalent parameter standard type |
|-------------------------------------|-----------------------------------|---------------------------|-----------------------------------|
| 6                                   | Equivalent thermal resistance R   | 6.47℃/kW                  | 0.72℃/kW                          |
|                                     | Equivalent heat capacity C        | 0.32kWh/℃                 | 0.32kWh/℃                         |
| 7.2                                 | Equivalent thermal resistance R   | 6.86℃/kW                  | 0.75℃/kW                          |
|                                     | Equivalent heat capacity C        | 0.35kWh/℃                 | 0.35kWh/℃                         |
| 8                                   | Equivalent thermal resistance R   | 7.12℃/kW                  | 0.79℃/kW                          |
|                                     | Equivalent heat capacity C        | 0.38kWh/℃                 | 0.38kWh/℃                         |

(3) In the northeastern region, the winter is generally 17:00-18:00 is the peak time of the user's electricity consumption. Due to the heating of the room, the electric heating load is more in this period. According to the standard user model built in Chapter 2, there are three rated configurations. For electric power heating equipment, the maximum heating power is 6 kW, 7.2 kW, 8 kW, the electric heating quantity with rated power of 6 kW is 120, the electric heating quantity with rated power of 7.2 kW is 150, the rated power is The number of electric heating of 8 kW is 1250. The value of the peak cut by the power system dispatching center is Po.

(4) Select the outdoor ambient temperature Tout to be 150 ℃, set the temperature control range to the upper limit of the human thermal comfort range 22 ℃, and the corresponding negative regulation temperature is 20 ℃, 40 ℃, 60 ℃.

Under the above set conditions, the simulation analysis of the regulation potential of electric heating load cluster based on uniform polymerization model is carried out table.

| Table 2 Statistics on the potential of cluster heating heating regulation |
|-------------------------------------------------------------------------|
| Negative temperature regulation/℃ | Adjustable capacity/kW.min | Negative regulation 20% $T_{control}$ / min | Negative regulation 30% $T_{control}$ / min |
|-----------------------------------|----------------------------|-----------------------------------------------|-----------------------------------------------|
| 6                                 | 23533                      | 35.91                                         | 21.20                                         |
| 4                                 | 17126                      | 21.10                                         | 13.10                                         |
| 2                                 | 8820                       | 9.53                                          | 6.17                                          |
As shown in the figure, the demand response control of the cluster electric heating load is carried out in the period of 7 min to 17 min. According to the total load curve when the area is not regulated, it can be seen that during this period, the peak period of power consumption is total. The load power curve reaches the highest value during this time. In order to effectively reduce the peak load to the maximum extent, according to the time shiftability of the electric heating load group, increasing the indoor temperature of the electric heating user in advance before the demand response, so that a certain amount of heat is stored, and a better effect can be achieved when responding to the demand.

5. Conclusion

Based on the regulation mechanism of electric heating load aggregation, the method of polymerization treatment of electric heating load cluster was proposed, and the uniform heating polymerization model of electric heating load parameters was established. An optimal control strategy for electric heating load cluster was proposed. The simulation example showed the feasibility and effectiveness of the uniform heating model and cluster control strategy for electric heating load parameters [6]. The control potential and influencing factors of electric heating load cluster based on uniform polymerization model are analyzed. The results show that when the upper limit of demand response temperature range is 22 °C, the lower the temperature of negative regulation, the smaller the demand response. The sharpening effect is more pronounced. When the minimum temperature of the demand response is determined, the higher the initial temperature upper limit, the larger the peak clipping capacity, and the stronger the adjustable capacity of the cluster electric heating.

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