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Research on the Features and Calculation Method for Credible Reserve Capacity of Aggregated Air Conditioners

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Abstract

With their proportion increasing gradually, air conditioners can be a feasible option to provide certain amount of reserve for power systems using the cycle work property. In order to calculate the reserve capacity provided by aggregated loads, the responsive time and reserve characteristic are analyzed based on the physical model for a single air conditioner. According to the simulation data, the nonlinear regression model is established between the responsive time *t*, reserve capacity *R* and the key parameter distribution. Statistical tests and error analysis proved the model precision and the credibility of load reserve.

Keywords: air conditioners; reserve capacity; dynamic characteristic; nonlinear regression

1. Introduction

Traditionally, reserve capacity of the power system is provided by the generators and the tie-line power in the region to ensure the power grid safe and stable[1]. As large-capacity of intermittent energy is paralleling in power grid and load demand is increasing quickly, It will lay out more and more for generation side to provide reserve capacity. Research shows that load-side can also provide reserve capacity and realize reserve responsible quickly[2-4].

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Thermostatic controllable loads (such as air conditioners with cycle working period) can adjust their power demand and provide reserve by changing target temperature so as to controlling load working status. This method does little influence to users and costs lower [5-10]. Controllable load simulation model and various controllable aggregation models are established in literature [6-8], and research has showed that thermostatic controllable loads (such as air conditioners, refrigerators, water heaters, *etc*) all can provide quick reserve capacity by changing their target temperatures to response the frequency change. Experiment has showed that controllable loads carry out DDC strategy could showdown the decreasing speed of power system frequency and reduce system failures, at the same time decrease the dependence to quickly starting generators, which could provide certain reserve[9]. Research in literature [11] provided that during the load peak period or when reserve provided by generator-side was inadequate, peak load could be reduced by changing the thermostatic controllable loads' setting temperatures, which reduced the generating pressure and ensured the operating security and reliability of power grid. Experiment research in literature [12] showed that aggregated air conditioners had the advantages of responsible time and predictable when providing reserve. In all, air conditioners participated in power system scheduling would increase the operating stability of power system.

In order to realize controllable loads participating in power system scheduling and provide credible reserve, firstly we should determine the dynamic responsible time for controllable loads and reserve capacity which controllable loads can provide. Based on the aggregated air conditioners model in literature [13], this paper analyzed the dynamic characteristics for air conditioners providing credible reserve. By a lot of simulation experiments, nonlinear regression analysis method is used to analyze the experiment data, then fit the analytical relationship of dynamic responsible time *t* and reserve capacity *R* with the distribution characteristic of external parameters, which can support the controllable loads providing credible reserve.

2. The Responsible Time and Capacity Property Analysis of Loads Reserve

Aggregated loads can provide reserve by adjusting the setting temperatures. According to the working principle of air conditioners, this paper analyzed the aggregated loads responsible time and reserve capacity property, then research on the analytical calculation method for responsible time and reserve capacity.

2.1The Responsible Time Property Analysis for Load Reserve

Euler method was used to formula (1) which would be discreted to form the indoor temperature difference formula showed as formula (2). Analyzing the related coefficients of formula (2), C_{in} is the most significant factor in all the external parameters. C_{in} is smaller or the rated power of an air conditioner is bigger, the indoor temperature will change quickly and the working period of air conditioners will be shorter. By changing the setting temperature of the air conditioner, the working state of the air conditioner will change from initial state into another cycle period. The dynamic changing time is effected by the indoor temperature changing speed. When the indoor temperature changes more quickly and the cycle period is smaller, the dynamic changing time will be less. In all, Ci_n and the rated power P of the air conditioner are the most significant factors effecting the dynamic working state change.

$$\frac{\mathrm{d}}{dt}\begin{pmatrix} x_{ew} \\ x_{in} \\ x_{iw} \end{pmatrix} = [A]\begin{pmatrix} x_{ew} \\ x_{in} \\ x_{iw} \end{pmatrix} + [B]\begin{pmatrix} X_{ext} \\ I_{ew} \\ I_{eq} \\ I_{dev}\cdot m(t) \\ X_{adj-r} \end{pmatrix} \tag{1}$$

$$x_{in}(t_{n+1}) = x_{in}(t_n) + \Delta t * (a_{21}x_{ew}(t_n) + a_{22}x_{in}(t_n) + a_{23}x_{iw}(t_n) + b_{21}X_{ext} + b_{24}\cdot m(t_n)\cdot I_{dev} + b_{25}X_{adj-r}) \tag{2}$$

式中：$a_{21} = \frac{1}{C_{in}R_{\mathrm{ew}}}$, $a_{22} = \frac{-1}{C_{in}}(\frac{1}{R_{ew}} + \frac{1}{R_{iw}} + \frac{1}{R_{gs}})$,

$a_{23} = \frac{1}{C_{in}R_{iw}}$