A Clustering Algorithm for Demand and Response Resource Based on Multi-Scenario

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Abstract. The traditional resource classification method based on information such as industry, commerce and residents cannot fit the target of demand response under different scenarios. This paper proposes a clustering algorithm for demand response resources. This algorithm first uses the Fourier series to select the five - dimensional low - frequency component to compress and extract the load information. Then, the demand response resources are expressed in vector form by combining the output and response characteristics of resources. Finally, the resource clustering algorithm based on fuzzy c-means is used to cluster resources.

1. Introduction

Under the background of power reform, smart grid is faced with a variety of different business scenarios, such as local consumption of new energy, rapid emergency response and differentiated customer service [1]. These business scenarios urge grid companies to classify resources, provide targeted services, and improve the efficiency of demand response when implementing demand response. Therefore, how to cluster demand response resources is an important topic for researchers.

The existing clustering algorithm provides some ideas for solving the above problems. These ideas can be divided into three categories: neural network, clustering algorithm and architecture design.

In terms of neural network, Dai Qian constructed SOM network and established a short-term non-irradiance generation prediction model of photovoltaic system by using BP neural network [2]. These algorithms often have selected specific clustering methods, but some parameters in the methods are uncertain. Through the neural network method, these parameters are determined, and finally the clustering of resources is realized.

Clustering algorithms mainly include two types: c-mean clustering (HCM) and fuzzy c-mean clustering (FCM). These two methods are to set the characteristics of the concerned samples as components, and then construct the vector space. Using the calculation of distance, the samples are clustered. From the perspective of fuzzy clustering, Li Peiqiang et al. proposed two algorithms, fuzzy equivalence relation and fuzzy c-mean value, which achieved load clustering from the level of substation [3]. Zhang Suxiang studied the residential electricity consumption behavior of intelligent communities, and combined the k-means algorithm with cloud computing to complete the classification of residents [4]. Pereira et al. implemented the application of FCM algorithm under the demand response scenario. Using the FCM algorithm, Ivanov performed cluster analysis on wind energy and achieved good results in the Netherlands.

The above algorithms have corresponding application scenarios, and the effect is ideal. But with the development of smart grids, people hope that one system can meet more requirements. This is an objective requirement for the multi-scene demand response algorithm. Therefore, the existing algorithms generally have the following two problems :(1) the clustering algorithm cannot be closely combined with the business, and it is difficult to cluster resources in multiple scenes. (2) the clustering of the algorithm focuses too much on the load characteristics themselves, without considering the scenario and target of demand response.

In order to solve the above problems, this paper first carries out the Fourier transform for the loads based on the load characteristics themselves, then uses the fuzzy c-mean algorithm for clustering, and finally introduces the factors of demand response to correct the clustering. Practice shows that the algorithm can meet the requirements of multi-scene demand response resource clustering.

2. Vector representation of demand response resources

The problem of resource clustering in demand response is to identify the factors that affect resource characteristics [5]. These factors include both objective and subjective aspects. The purpose of clustering is to serve the demand response in different scenarios. Therefore, in the objective aspect, the influencing factors mainly include the responsiveness of resources themselves, response characteristics, and objective requirements of different scenarios. On the subjective side, it depends on the positive degree of user cooperation.

The responsiveness of the resource itself includes the ability to adjust the load and the output characteristics. For air conditioning and other pure load, mainly refers to the ability to reduce load; For energy storage equipment, three factors are included: load reduction, load rise and output. For photovoltaic, wind and other new energy equipment, mainly output characteristics. Since the clustering of demand response resources should be stable for a period of time, the real-time quantity, such as current battery capacity and current load value, is not considered.

$$\left(C_{\mathrm{cut}}, C_{\mathrm{up}}, C_{\mathrm{power}}, S_{\mathrm{response}}, T_{\mathrm{notify}}, F_{a1}, F_{b1}, F_{a2}, F_{b2}\right) \tag{1}$$

3. Load curve and Fourier transform

In the actual project, the load is not collected continuously, but collected every once in a while. Therefore, the load curve is not a "line" but a series of discrete points. Different systems collect data at different frequencies. Common have 48 times/day, 96 times/day, 288 times/day etc. If the load of each point is analyzed directly, the following three problems will occur :(1) the comparison between points and points cannot reflect the variation trend of load curve; (2) the data in the high frequency acquisition system could not be compared between systems with different frequency. (3) multi-point comparison will result in the rise of sample spatial dimension, which will bring great difficulties for calculation. So you need a way of describing the trend of the curve.

Wavelet analysis is one of the means to reduce the dimension of data [6]. Chen Yuanxin used wavelet analysis when predicting load curves [7]. Wavelet analysis can compress the data by constructing different frequency bases. On the one hand, the algorithm can show the overall situation of the data; on the other hand, it can show the details of the data.

However, in the scenario in this article, the details are redundant. Because the daily load curve of the user has a certain similarity and the potential of demand response to the load response is mainly related to the load curve, but not much related to the high-frequency load change. Based on the above considerations, the Fourier transform, which is simpler than wavelet transform, is sufficient to meet the demand.

$$\begin{cases} p(n) = \dfrac{a_0}{2} + \sum_{k=1}^{\infty} a_k \cos\dfrac{2kn\pi}{N} + \sum_{k=1}^{\infty} b_k \sin\dfrac{2kn\pi}{N} \\ a_k = \dfrac{2}{N}\sum_{n=0}^{N-1} p(n)\cos\dfrac{2kn\pi}{N},\ k \geq 0 \\ b_k = \dfrac{2}{N}\sum_{n=0}^{N-1} p(n)\sin\dfrac{2kn\pi}{N},\ k \geq 1 \end{cases} \tag{2}$$

On the basis of defining the resource vector of demand response, cluster analysis can be carried out. Different scenarios have different requirements for demand response resources. If one of the three indexes in the vector is 0, it indicates that the resource has no corresponding ability at all. Therefore, it is necessary to make a preliminary classification based on whether the three indicators are 0. As shown in table 1, the "yes" and "no" in the column of resource component respectively represent whether the resource has relevant capabilities, and "yes" means yes and "no" means no. In the application scenario column, "yes" indicates that relevant resources can be applied in the scenario, and "no" indicates no.

Table 1. Relationship between the vector, classes and application environment of resources

Resources component			The resource type	Application scenarios					
C_{cut}	C_{up}	C_{power}		Orderly peak clippin g	The promotio n of energy efficiency	The optimal economi c	Load fast cuttin g	Environmenta l protection	New energy absorptio n
Yes	No	No	Air conditioning , lighting and other conventiona l loads	Yes	Yes	Yes	Yes	Yes	Yes
Yes	Yes	No	Hot water, electrolytic aluminum	Yes	Yes	No	Yes	Yes	Yes
Yes	No	Yes	Nothing	/	/	/	/	/	/
Yes	Yes	Yes	Energy storage device	Yes	No	Yes	Yes	No	Yes
No	Yes	No	Nothing	/	/	/	/	/	/
No	Yes	Yes	Nothing	/	/	/	/	/	/
No	No	Yes	New energy	No	No	Yes	No	Yes	Yes

4. Clustering algorithm based on FCM

According to different scenarios, it is necessary to classify the resources and set the initial clustering center for each classification. For example, ordered peak clipping can be classified by the time the peak load occurs. For load quick cuts, you can set the response time. For environment-oriented scenarios, new energy classification can be set separately. The number of classifications and the initial clustering center of various categories are set by the user. After user setting, resources can be clustered. Suppose that n terms of resources are classified into c, then, the degree of membership of resources belonging to the classification is. For any j, the following formula is satisfied.

$$c_i = \frac{\sum_{j=1}^{n}\left(x_j \mu_{ij}^2\right)}{\sum_{j=1}^{n}\mu_{ij}^2} \tag{3}$$

Use c_i, update membership μ_{ij} as follows.

$$\mu_{ij} = \frac{1}{\sum_{k=1}^{c}\left(\frac{\left\|x_j - c_i\right\|}{\left\|x_j - c_k\right\|}\right)^2} \tag{4}$$

After obtaining the new membership, set the set of membership as $U^{(k)}$. Where, (k) represents the membership set calculated by the k-th round.

$$U^{(k)} = \begin{pmatrix} \mu_{11}^{(k)} & \mu_{12}^{(k)} & \cdots & \mu_{1n}^{(k)} \\ \mu_{21}^{(k)} & \mu_{22}^{(k)} & \cdots & \mu_{2n}^{(k)} \\ \cdots & \cdots & \cdots & \cdots \\ \mu_{c1}^{(k)} & \mu_{c2}^{(k)} & \cdots & \mu_{cn}^{(k)} \end{pmatrix} \tag{5}$$

The calculation process of equations (3) and (4) is repeated until the following conditions are met and the cycle is terminated.

$$\left\|U^{(k)} - U^{(k-1)}\right\|^2 = \sum_{i=1}^{c}\sum_{j=1}^{n}\left(\mu_{ij}^{(k)} - \mu_{ij}^{(k-1)}\right)^2 \le \varepsilon \tag{6}$$

5. Conclusion

In this paper, a multi-scene demand response resource clustering algorithm is proposed. The algorithm can cluster the response resources according to the target of demand response. The clustering results can provide a basis for the selection of resources and improve the rate of reaching the required response.

At the specific algorithm level, this paper first analyzes the load of resources, and USES the Fourier transform to compress the representation information occupied by the load. This information, along with other parameters, is then used to build the resource space. In the resource space, FCM algorithm is used to realize the initial clustering of resources.

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