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USING CLUSTERING METHODS FOR VOLTAGE STEADY-STATE LOAD CHARACTERISTICS IDENTIFICATION

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At present, the electric power industry has shifted to the new information standards IEC 61970 and 61968, collectively called the "Common Information Model" (CIM). These standards define a semantic model that describes the elements of the energy system in the form of objects of specified classes, their properties and connections.

In this regard, the problem of the correct description of one of the most important elements of the power system - the electric load - was most acute for the power engineers. The most reliable way of describing the load is the static load characteristics.

The voltage steady-state load characteristics are the dependences of the active and reactive load power on the applied voltage in the steady state, at a constant (as a rule, nominal) frequency. For the majority of large nodes of the power system, the voltage steady-state load characteristics are approximately described by a polynomial of the second degree:

$$P(U) = P_{BAS} \cdot \left(a_0 + a_1 \cdot \frac{U}{U_{BAS}} + a_2 \cdot \left(\frac{U}{U_{BAS}} \right)^2 \right),$$

$$Q(U) = Q_{BAS} \cdot \left(b_0 + b_1 \cdot \frac{U}{U_{BAS}} + b_2 \cdot \left(\frac{U}{U_{BAS}} \right)^2 \right). \quad (1)$$

Methods of identification the voltage steady-state load characteristics are conducting passive or active experiments [1].

In the passive experiment, the information about the object is collected by passive observation, that is, information obtained in conditions of normal operation of the object. An active experiment is conducted with the use of artificial impact on the object under a special program.

Both methods have their advantages and disadvantages, however, in favor of a passive experiment tells its simplicity and the possibility of implementing for any host load, especially in the presence of telemetry.

Goal: to evaluate the effectiveness of different methods of cluster analysis when solving problems in processing telemetry.

Some of the largest consumers of electrical energy are metallurgical plants. This is due to the technological process and the equipment used, for example, an electric arc furnace (EAF) (fig. 1).

The electric arc furnace is a furnace in which the thermal effect of an electric arc is used for melting metals and other materials.

In this paper we used telemetry data from an electric arc furnace with a capacity of 100 tons (fig. 2).

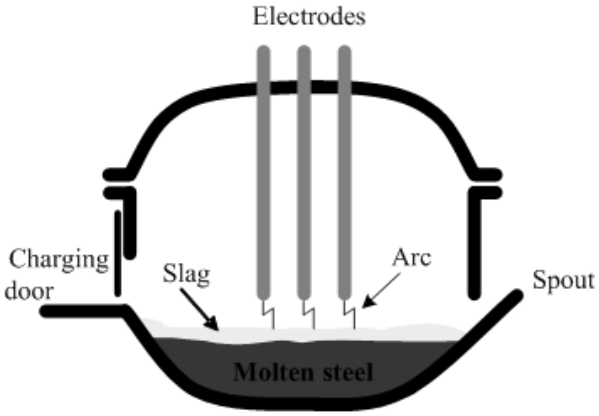

Fig. 1. Scheme of an electric arc furnace

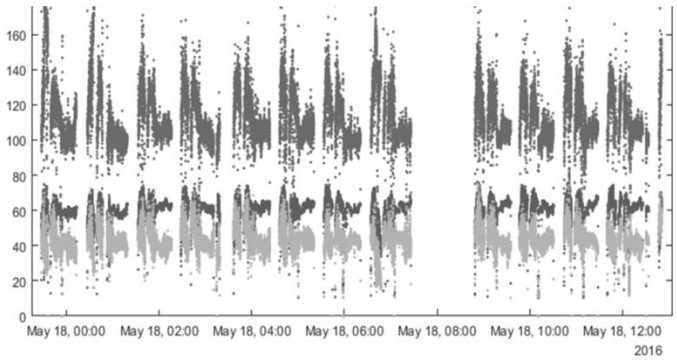

Fig. 2. Telemetry data of active, reactive power and voltage

Clustering (or cluster analysis) is the task of splitting a set of objects into groups, called clusters. Within each group there should be "similar" objects, and the objects of different groups should be as different as possible. The main difference between clustering and classification is that the list of groups is not clearly defined and is determined in the course of the algorithm [3,4].

The application of cluster analysis in its general form reduces to the following stages:

- • Selecting a selection of objects for clustering.
- • Define the set of variables by which objects in the sample will be evaluated. If necessary - the normalization of the values of variables.
- • Calculate the values of the measure of similarity between objects.
- • Apply the cluster analysis method to create groups of similar objects (clusters).
- • Presentation of the analysis results.

Hierarchical clustering

The essence of this method is that at the first stage the similarity or difference between each pair of objects in the data set is determined using different metrics; Further, a hierarchical tree of binary clusters is formed using different algorithms, and then clusters are formed using the results of the second stage.

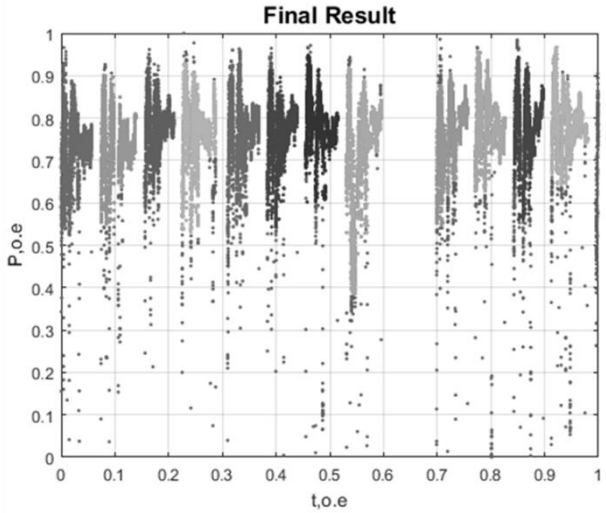

Fig. 3. The final result obtained by hierarchical clustering

Advantages of the method: there is no need to perform additional operations; sufficient quality of clustering; simplicity of implementation.

Disadvantages: the need for several iterations, the sensitivity to the number of clusters.

Other methods will be compared with the results of hierarchical clustering.

Gaussian mixture method

When clustering based on this method, it is assumed that the data is generated by a mixture of probability distributions in which each component represents another cluster. Generative models are usually solved using the EM algorithm, which is the most widely used method for estimating the probability density of a finite mixture. The EM algorithm starts with random or heuristic initialization, and then iteratively uses two steps to solve the roundness in the calculation:

E-Step. Determine the expected probability of assigning data points to clusters using the current model parameters.

M-Step. Determine the optimal parameters for the model of each mixture, using the probability of distribution as a weight.

Advantages: sufficient quality of clustering; there is no need for several iterations.

Disadvantages: the need for an additional unification operation; sensitivity to the number of clusters.

The method of K-means (K-means)

The method of K-means uses an iterative algorithm to minimize the intracluster sum of distances of cluster objects to its centroid across all k clusters, consisting of two stages:

The first phase is designed to search for the approximate value of centroids of clusters and preliminary grouping of objects into clusters.

The second phase is designed to find an exact and final solution.

Advantages: ease of implementation.

Disadvantages: insufficient accuracy; the need for iterations and additional join operations, the sensitivity to the number of clusters.

The method of self-organizing maps of Kohonen

Self-organizing maps Kohonen designed to visualize the multidimensional properties of objects on a two-dimensional map. Kohonen maps produce a mapping of high-dimensional input data to elements of a regular array of small dimension. [5]

Advantages: increased accuracy in determining clusters; there is no need to iterate; visibility, there is no sensitivity to the number of clusters.

Disadvantages: dependence on the number of epochs; need for a join operation.

The result is presented in figure 4:

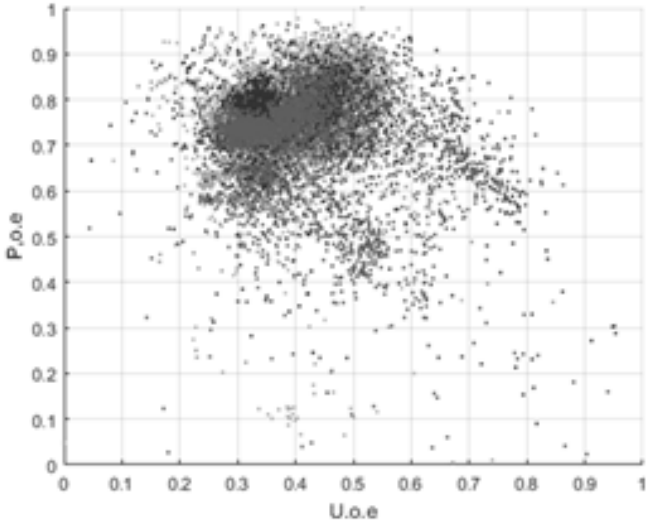

Fig. 4. The Dependence P(U)

Obtained in this study result will be used to identify voltage steady-state load characteristics using regression analysis techniques.

Conclusion

The analysis showed that the most convenient, simple and fast method of cluster analysis from the above is the method of hierarchical clustering. At the same time, the most accurate method is the method of Kohonen maps. The results obtained make

it possible to extract clusters belonging to the same load states from all measurement data for further processing by filtration methods and regression analysis. Thus, the static characteristics of the load can be obtained from the data of a single passive experiment.

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ПРИМЕНЕНИЕ КЛАСТЕРНОГО АНАЛИЗА В ЗАДАЧЕ ИДЕНТИФИКАЦИИ СТАТИЧЕСКИХ ХАРАКТЕРИСТИК НАГРУЗКИ

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Актуализация фактических статических характеристик нагрузки по напряжению (СХН) крупных потребителей энергосистемы России является одной из приоритетных задач совершенствования средств и деятельности по расчету, анализу и планированию текущих и перспективных электроэнергетических режимов согласно Программе инновационного развития АО «Системный оператор Единой энергетической системы». Решается эта задача, как правило, организацией экспериментальных испытаний с изменением напряжения на шинах потребителя. Такие испытания принято называть «активным экспериментом». Другим способом идентификации СХН является накопление и обработка результатов измерений параметров режима без вмешательства в естественный процесс функционирования потребителя, или «пассивный эксперимент».

Как в случае активного, так и в случае пассивного эксперимента одной из задач обработки данных является кластеризация результатов. Это связано с тем, что параметры режима изменяются под воздействием двух причин: как вследствие изменения напряжения, так и вследствие изменения состояния самой