Importance Evaluation of Power Communication Network Node Based on FCM Clustering

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Abstract—The node importance evaluation of network is of great significance for the improvement of power communication network’s reliability. At present, the indexes used in the node importance evaluation in power communication networks are usually one-sided. Dealing with this, this paper presents a multi-index based node importance evaluation method. In this method, degree centrality, betweenness centrality and eigenvector centrality are employed as indexes, and fuzzy clustering method is adopted to classify network nodes, to finally obtain the set of important nodes. The method can be applied to the evaluation of node importance in power communication network. The experiment reflects the effectiveness of the method.

Keywords-power communication network; node importance; fuzzy clustering

I. INTRODUCTION

Power communication network is the communication network of the power system. It carries all the services of power dispatching, management and production, which is an important part of the power grid. With the construction of smart grid, power communication network carrying the business and the scale continues to expand. The power system is also becoming more and more dependent on the power communication network, so it can be said that the normal operation of power communication network is stable [1]. To a large extent, the important nodes affect the stability and reliability of power communication network. Power communication network is a typical complex network system [2]. Research shows that in scale-free networks, when 5% of the core nodes are attacked, the network will be paralyzed [3]. Therefore, it is of great help to improve the reliability of the network by accurately excavating the important nodes in the network.

Compared with the importance evaluation of the network edges, the importance evaluation of nodes in the network has not been paid much attention, and the existing evaluation methods are relatively limited [4]. At present, the network node importance evaluation mainly uses the degree method [7], betweenness method [5], node deletion method [6], node contraction method [7], and PageRank algorithm [8]. However, each evaluation method has a certain one-sidedness. Using the degree as evaluation index, for example, that the greater the degree of node, the more important the node is, but this method has one-sidedness, some important nodes such as node "bridge" do not necessarily have a larger degree. Node betweenness method does not consider well the influence of nodes on LAN. Node deletion method, analyzes node importance by comparing the change of network connectivity before and after deleting nodes. But if you delete the nodes attached to the end node with a degree of 1, it is difficult to realize an objective importance evaluation of nodes. Although all the above algorithms reflect node importance to some extent, they cannot accurately describe the importance of nodes in the whole network.

In order to evaluate the node importance of electric power communication networks in a more objective way, this article uses degree centrality, betweenness centrality and eigenvector centrality as indexes, to evaluate the importance of network nodes through a variety of comprehensive indexes. It realizes the classification of node importance of electric power communication networks by using FCM clustering method. The result shows that this method can effectively evaluate the importance of single nodes in different types of complex networks.

II. THEORETICAL BASIS

The power communication network is represented by the graph $G=(V, E)$, which is a non-directional loop network, where $V=\{v_1, v_2, ..., v_n\}$ is the set of all nodes of the network, $E = \{e_1, e_2, ... E_m\}$ is the set of the edges between nodes, $|E|= m$.

The importance of the network nodes has a certain relationship not only with the degree of the node itself, but also with the importance of the neighbor nodes, these indexes reflect the influence of nodes. The influence of nodes includes direct influence and indirect influence. Direct influence reflects the node’s own ability to affect other nodes, such as the degree of the node. Indirect influence reflects the node’s ability of to influence other nodes through the network, such as the number of interfaces. In this paper, the degree centrality, betweenness centrality and eigenvector centrality are employed as indexes to evaluate the node importance.

(1) Degree Centrality: connection degree $k$ is defined as the number of edges attached to the node, which reflects the topology characteristics of the network. It shows the node’s direct influence on other nodes in the network. In a network with $n$ nodes, the nodes cannot not exceed $n-1$. Expression of degree centrality:

$$DC_i = \frac{k_i}{n-1} \tag{1}$$

where $k_i$ represents variables associated with node $I$ in the network.

(2) Betweenness Centrality: node betweenness is defined as the ratio of the number of paths that pass through the point to
the total number of the shortest paths in all the shortest paths in
the network. The betweenness of each node is represented by
parameter Bi, which characterizes the ability of node i to control
the transmission of information along the shortest path between
nodes in a network. The betweenness of the node i is defined as
the number of nodes:

\[ BC_i = \sum_{x \in s \neq j} \frac{n_{sx}}{\delta_{st}} \]

Among them, \( g_{st} \) is the number of shortest paths from node
s to node t, and \( n_{sx} \) is the number of the shortest path through
node i in the shortest path of \( g_{st} \) from node s to node t.

3) Eigenvector Centrality: its basic idea is that the
importance of a node depends on the number of its neighbors
and the importance of its neighbors. Remember that Xi is the
measure of importance of nodes, so there are

\[ x_i = c \sum_{j=1}^{n} a_{ij} x_j \]

Where c is a proportional constant and A = (a_{ij}) is the
adjacency matrix of the network. Let \( x = [x_1, x_2, \ldots, x_\text{N}]^T \), then
the above formula can also be written as follows:

\[ \xi = \chi A \xi \]

Equation (4) means that \( x \) is the eigenvector of matrix A
corresponding to the eigenvalue c⁻¹.

III. FCM CLUSTERING

Fuzzy clustering analysis is a method of using fuzzy
mathematics to distinguish objects with similar properties and
to classify them. FCM algorithm is one of the fuzzy clustering
method is more important, the method of clustering results with
each data point membership degree of cluster center, said the
membership degree is used to represent a number.

A. FCM Basic Theory

FCM is an iterative optimization algorithm that divides n
vector xi (i=1, 2, ..., N) into C fuzzy clusters, and the clustering
center of each cluster is obtained to minimize the objective
function, and the objective function of FCM is defined as:

\[ J(U, V) = \sum_{k=1}^{n} \sum_{j=1}^{c} u_{ik}^m d(x_k, v_j) \]

Among them, \( \sum_{i=1}^{c} u_{ik} = 1, u_{ik} \in (0, 1), d(x_k, v_j) = ||x_k - v_j||^2 \), m stands for weighted index, its value range is
1<m<∞. The FCM algorithm is different from the C mean
algorithm, which adds the fuzzy weight index m in the target
function. It is an important parameter in FCM, which affects the
fuzzy degree of fuzzy clustering results. To minimize the target
function, the update method of clustering center and
membership function is as follows:

\[ v_i = \sum_{k=1}^{n} u_{ik}^m x_k / \sum_{k=1}^{c} u_{ik}^m \]

\[ u_{ik} = 1/ \sum_{j=1}^{c} \left( \frac{d_{ik}}{d_{jk}} \right)^{1/(m-1)} \]

B. Algorithm Steps

In the node importance evaluation of power communication
network, this paper divides the nodes into three categories: core
node, important node and common node, that is, the number of
categories \( c=3 \). In order to classify fuzzy degree index \( m = 2 \) [9] [10]; the iteration termination
threshold \( \epsilon = 0.001 \). The FCM algorithm is a simple iterative
process that takes the following steps to determine the clustering
center V and the membership matrix U.

1) From the n data sets X = (x_1, x_2, ..., x_N), the initial clustering
centers \( V^0 = (v_1, v_2, ..., v_C) \) and the threshold \( \epsilon > 0 \) are randomly
selected.

2) Repeat the following operation, the algorithm stops when
\( ||V^{b+1} - V^b|| < \epsilon \), otherwise \( b=b+1 \) will continue to perform the
following steps. \( ||x|| \) is the F-norm of the matrix, \( ||V^{b+1} - V^b|| = \sum_{i=1}^{c} \sum_{j=1}^{c} (p_{ij}^b - p_{ij}^{b+1})^2 \).

a) Using the current \( V^b \), calculate the membership matrix \( U^b \)
using formula (7).

b) Using the current \( U^b \), calculate the clustering center \( V^{b+1} \)
using formula (6).

IV. EXPERIMENTAL RESULTS

In order to effectively illustrate the effectiveness of the
method in this paper, this paper uses the American ARPA
network topology in figure I, which consists of 21 nodes and 26
links. ARPA network topology is the main network topology
that is commonly used when analyzing the importance
of network nodes. The average value of network is 2-3, and the
value of most nodes is 2.

Table I shows the ordering results of node importance based
on literature [11], literature [12] and literature [13]. Three
algorithms of node important degree of sorting is slightly
different, that is because different methods has different focuses
on index selections as well as algorithms, which well testifies
the existence of one-sidedness in each algorithm.

![Diagram](attachment:image.png)

**FIGURE I. ARPA NETWORK TOPOLOGY**

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TABLE I IMPORTANT RANKING RESULTS OF ARPA NETWORK NODES

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Figure II shows the distribution of the various factors in this paper. It can be seen from the figure that the three relationships are not completely positive correlations. Therefore, considering these three factors, we can avoid the shortcomings of single factor evaluation.

V. CONCLUSION

The node importance evaluation of power communication network is an important topic in power communication research. Dealing with the problem that the previous evaluation indexes for electric power communication networks are relatively single, this paper employs betweenness, degree and eigenvector of the node as the evaluation indexes to evaluate node importance. It uses FCM clustering analysis method to establish the node importance evaluation model for electric power communication networks, and to support the electric power communication network’s planning. At the same time, it uses the commonly used network topology model ARPA network to verify the above method. This paper proves that this method can effectively evaluate the node importance of power communication networks.

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REFERENCES


