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Use Of Geo-Information Systems For Solving Analytical Problems In The Power Industry.

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ABSTRACT

This article discusses the use of information of geographic information systems for calculating the modes of the electrical network in the mode-technological software systems.
Keywords: geographic information system, scheme, integration, source data, electrical network object.

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INTRODUCTION

Effective management of the operation of electrical networks is impossible without the use of modern information technology (IT). Geoinformatics is a rapidly developing area of modern IT, which has found wide application in the electric power industry. The basis of geographic information systems (GIS) is graphic and semantic information associated with it. As a semantic information in the power industry used a database (DB) for electrical equipment, and as a graphics card, plans, schemes.

Electrical network diagrams should be submitted to GIS using vector graphics. It is acceptable to use a terrain map as a raster substrate with a vector layer on it containing an electrical network.

The problems solved with the help of or in cooperation with GIS can be divided into three groups: informational reference; calculated and analytical; operational and managerial.

The use of GIS technologies most often boils down to visualizing a network map on a map or a terrain plan and solving information and reference tasks. The next step in the application of GIS is the solution of settlement and analytical problems, through the integration of GIS with regime-technological software systems (RTST).

MATERIALS AND METHODS

Mode calculations are basic in the tasks of design, operation and development of electrical networks.

Geometrically, the electrical network is associated with a linear graph. The linear graph G is a diagram obtained from the network equivalent circuit by replacing each circuit element with a line segment of arbitrary length. For electrical networks, a linear graph is usually connected and oriented. A network graph is said to be connected if there is at least one path between any of its two nodes, and oriented if a definite orientation is assigned to all its branches, which coincides, as a rule, with the accepted positive direction of current in the network elements.

A part of the original graph G forms a subgraph G_a. Two subgraphs G_1 and G_2 are called complementary if their branches are different and one subgraph complements the other to the original network graph. An example of complementary subgraphs in electrical networks are trees and chords (connections) of the network graph. A tree is a subgraph that includes all nodes in the original network graph and does not contain contours. Chords (connections) is a subgraph that complements the tree to the original graph.

Generalization of the calculation of electrical circuits of alternating current as a problem of graph theory, i.e. in the form of the Dirichlet problem with complex resistances, used in [1-3] to prove the existence and uniqueness of solving linear equations of the steady state for an alternating current network with only r, L or only with r, C, where L, C is inductance and capacitance. Note that the proof of the existence and uniqueness of the solution for a DC network is given in the literature indicated in [4].

RESULTS AND DISCUSSION

The Dirichlet problem involves setting a connected graph $G=(x,\ u)$. For this you need to specify all the vertices of the graph $x \in X$ and all the connections of their arcs $u \in U$.

The formulation of the Dirichlet problem with complex resistances is as follows [1]:

A related graph is given $G=(x,\ u)$. Let's set for each vertex $x \in X$ complex number $\underline{q}(x)$ - excess at the top x so that

$$\sum_{x \in X} \underline{q}(x) = 0 \quad (1)$$

We introduce for each arc $u \in U$ following functions:

1) complex function $\underline{\varphi}(u)$ - excess compatible stream $\underline{q}(x)$ so that

$$\sum_{u \in U_x^+} \underline{\varphi}(u) - \sum_{u \in U_x^-} \underline{\varphi}(u) = \underline{q}(x) \quad (2)$$

where U_x^+ and U_x^- – many arcs respectively outgoing and entering in x;

2) complex function $\underline{\pi}(u)$ – potential difference so that for any cycle μ

$$\sum_{u \in V'(\mu)} \underline{\pi}(u) - \sum_{u \in V''(\mu)} \underline{\pi}(u) = 0 \quad (3)$$

where $V'(\mu)$ and $V''(\mu)$ – sets of arcs directed respectively to the side of a loop and to the opposite;

3) complex function $\underline{Z}(u)$ – arc resistance and complex function $\underline{Y}(u) = \frac{1}{\underline{Z}(u)}$ – arc conductivity.

All real and imaginary components of resistance, i.e. *Re* $\underline{Z}(u)$ and $Jm\underline{Z}(u)$ have one sign.

Define a complex function $\underline{p}(x)$ – potential graph function if for each $u = (x_1,\ x_2)$

$$\underline{\pi}(u) = \underline{\pi}(x_1,\ x_2) = \underline{p}(x_1) - \underline{p}(x_2) \quad (4)$$

Dirichlet problem. In this column, determine the flow $\underline{\varphi}$, compatible with given excess $\underline{q}$ and such that

$$\underline{\pi}(u) = \underline{Z}(u) \cdot \underline{\varphi}(u) \quad (5)$$

Numbering of the elements of the graph of the electrical network. Each vertex or node of the graph $x \in X$ usually one number is assigned, for example, i, $i = 1, \ldots, N+1$, where N – number of primary nodes in the network.

Arcs (edges) or connection graph $u \in U$ may be numbered differently. Connection connecting nodes i and j may be indicated by two numbers i and j, those by numbers $i\ j$ [1]. In other cases, the connection is denoted by one number, for example $l = 1, \ldots, M$, where M – number of network branches.

Once again, we emphasize that in order to specify a connected graph of a network G diagram one must know which nodes are connected by connections. For this you need to know the numbering of all network nodes and branches connecting these nodes. Branch numbering, $l = 1, \ldots, M$ without specifying which nodes are connected by these branches is not sufficient to specify the associated graph of the network

[1] It must be borne in mind that the number $i\ j$ – this is not one number, but two different numbers i and j.

diagram G. Information about connections should be compiled according to the rule: node-node, connection between them [5].

The database (DB) of the electrical network contains information about the network objects and mode parameters. In [5] it is said that the network database includes “network elements and mode”. Below we will call the database object of the electrical network - the network object or mode parameter.

The electrical network DB described in [5] contained the following arrays: 1) connections; 2) transformer substations; 3) measurements; 4) nutrition centers. These arrays include the following objects: 1) an array of connections — lines and cables, switching devices, reactors; 2) an array of transformer substations - distribution transformers, switching equipment, relay automation, capacitor batteries; 3) an array of measurements - measuring systems and devices; 4) an array of power centers - transformers, reactors, switching equipment, instrument transformers. In our opinion, a separate data array on measuring complexes is now needed to measure electricity.

The numbering of the objects of the electrical network database cannot use only one or two digits, as the numbering of the vertices and edges of the graph. For these purposes, it is necessary to use the description language (DL) of the input information [5].

In the database of objects of the electrical network, when choosing DL, it is necessary to maintain the maximum amount of communication with the industry language adopted in the power system [5]. Our experience confirmed the indication [5] that the principles of operational numbering, designations of network objects and mode parameters vary significantly in different enterprises of the electrical network even of one power grid. At the same time, different designations of the electric network contain the same designations of objects.

For example, the support number is indicated by x/y, where x – desoldering number, y – support number on tap x. At the same time, different types of supports, for example, anchor, corner, etc., can have their own way of designation in DL.

In DL, it is desirable to apply industry numbering or personnel terms for all network facilities: transformers, cables and their couplings, elements of measuring complexes, etc.

Integration of electrical network databases means the ability to automatically use information about the network object in different databases. For example, if two databases are integrated, then at the request of the user, you can automatically switch from information about an object in one database to information about it in another database and vice versa. Below we will consider the following types of databases:

1) semantic (for example, a database of objects of the electrical network);

2) graphic (for example, geographic information system - GIS).

We denote the graph of the electrical network connection diagrams. $G(x, u)$ and graph of the connection scheme of electrical network objects $G_{obj}(x_{obj}, u_{obj})$.

The equation describing the integration (or interrelation) of the base of objects and their graphic representation in GIS:

$$ob_{j\,DB} \rightarrow V_{ob\ j\,GIS}, \tag{6}$$

where $ob_{j\,DB}$ – an object j in the database of electrical network objects; $V_{ob\ j\,GIS}$ – object image j in GIS; $\rightarrow$ – one-to-one correspondence, i.e. the transition from the object in the database network to its graphic image in the GIS.

With integration (6) for any object j in the database you can define its image in the GIS.

The equation of integration or transition from the image of an object in a GIS to an object in the database can be written similarly to (6):

$$ob_{j\,DB} \leftarrow V_{ob\ j\,GIS}\ . \quad (7)$$

integration of electrical network database with network diagram graph $G(x,u)$ can be described by the following equation:

$$\left.\begin{array}{l} ob_{j\,DB} \leftrightarrow x \in X \\ or \\ ob_{j\,DB} \leftrightarrow u \in U \end{array}\right\}. \quad (8)$$

where $x,\ u$ – sets of vertices and arcs (edges) of a connected graph $G = (x,\ u)$.

Equation of integration of the image of objects in GIS and nodes or links in the graph of the electrical network $G(x,\ u)$, can be written similarly (8):

$$\left.\begin{array}{l} V_{ob\ j\,GIS} \leftrightarrow x \in X \\ or \\ V_{ob\ j\,GIS} \leftrightarrow u \in U \end{array}\right\}, \quad (9)$$

where $x,\ u$ – the same sets as in (8).

It is useful to use a connected graph of the connection scheme of electrical objects. $G_{ob\ j}\left(x_{ob\ j}, u_{ob\ j}\right)$. The vertices (nodes) of this graph will be denoted $x_{ob} \in X_{ob}$. Arcs or edges (links) of this graph will be denoted by $u_{ob} \in U_{ob}$. The numbering of the elements of the graph of the connection scheme of electrical network objects can be carried out, as well as for the graph of the network diagram.

Integration G_{ob} with the base of objects and with GIS is determined similarly (8) и (9):

$$\left.\begin{array}{l} ob_{j\,DB} \leftrightarrow x_{ob} \in X_{ob} \\ or \\ b_{j\,DB} \leftrightarrow u_{ob} \in U_{ob} \end{array}\right\}, \quad (10)$$

$$\left.\begin{array}{l} V_{ob\ j\,GIS} \leftrightarrow x_{ob} \in X_{ob} \\ or \\ V_{ob\ j\,GIS} \leftrightarrow u_{ob} \in U_{ob} \end{array}\right\}, \quad (11)$$

where x_{ob} and u_{ob} – vertices (nodes) and edges (links) in the graph of the connection scheme of electrical network objects G_{ob}.

Integration of GIS and mode-technological software systems. We will use the following notation:

$ob_{j\,G}$ - j object graph $G[\text{node (vertex) or branch (edge)}]$;

$TI_{ob\ j}$ - topological information about the object j of the electrical network;

$PD_{ob\ j}$ - passport details of the electrical network object j;

$ob_{j\,GIS}$ - object j GIS electrical network contains graphic and semantic information about the object j of the electrical network;

D_{RTST} - data for the calculation of the mode of distribution of the electrical network in the mode-technological software complex (RTST).

Initial data for the calculation of the distribution network mode D_{RTST} include passport data of electric grid facilities and topological information about them, i.e. about the electrical network connection scheme, adjustable parameters of the mode [2] and loads in the nodes.

$$D_{\text{RTST}} = \left[PD, TI_G, Y, S_{\text{heat}}\right], \tag{12}$$

where PD and TI_G – passport data of network objects and topological information of the network connection scheme, S_{heat} – load vector in nodes, Y – vector of adjustable mode parameters.

Getting topological information about the object j graph G of the electrical network connection scheme according to the image of the object j GIS can be written as follows:

$$V_{ob\ j\,GIS} \rightarrow TI_{ob\,G}\,. \tag{13}$$

For the entire network (13), you can write this:

$$V_{GIS} \rightarrow TI_G\,. \tag{14}$$

where V_{GIS} – image of electrical network in GIS.

Note that (14) is a more general entry (11).

Expression (13) for the entire electrical network can be written as:

$$\left[PD, V_{GIS}, Y, S_{heat}\right] \rightarrow \left[PD, TI_G, Y, S_{heat}\right]. \tag{15}$$

These expressions (14) or (15) in particular describe the integration of GIS “Energo-Graf” and RTST “RERSPC” [6], by using the information exchange between GIS and RTST.

CONCLUSION

Solving the problem of integrating GIS with RTST is possible in two ways:

- the use of information exchange between the database GIS and DB RTST electrical networks;
- embedding the design modules of RTST electrical networks into GIS software.

Each of the options for integrating GIS and RTST has its advantages and disadvantages. The choice of integration option depends on the specific software and the possibility of its modification. The advantage of information exchange lies in the relative simplicity of the programmer's solution, the lack of duplication of information in the GIS database and the RTST database. The advantage of embedding the calculated software modules in the GIS software is the use of a single database and a software product with a single interface, the disadvantage is the complexity of software modification.

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