The principles of spatial data organization of distribution power networks in geographic information systems

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Abstract. Spatial data in geographic information systems is organized in various ways. The first method is the principle of layer-by-layer organization of information (it is often called classical), the second is based on the object approach. The choice of models and methods of organizing data in geographic information systems is much more important than the choice of software package since it directly determines many of the functionality of geographic information systems. Some functions are either not implemented for certain ways of organizing data or they are provided by complex manipulations. The article discusses how to organize spatial data for presentation in geographic information systems. The analysis, comparison and justification of the use of an object-oriented method of representing spatial data for the display of rural distribution electric networks in geographic information systems are carried out. The structure of the “object tree” of the supporting scheme of the overhead line of 6-10 kV is proposed.

1. Introduction
Geographic Information Systems (GIS) are computer systems that allow you to effectively work with spatially distributed information. The basis in the geographic information systems is technological maps and diagrams of power networks and databases of electrical equipment. With the help of geographic information systems it became possible to accumulate and analyze such information, quickly find the necessary information and display it in a convenient form for use, solve technological problems of operating power networks.

The idea of the existing models and methods of organizing data in the GIS should have both an end user and a leader involved in solving strategic issues of the implementation and development of geoinformation technologies for managing power networks. The choice of the method of organizing data determines many of the functionality of the created GIS, system performance, the ability to perform the required functions and expand their list in future [1].

2. Materials and methods
Spatial data organization in in the GIS is possible in two ways. The first method is the principle of layer-by-layer organization of information which is the most common way of organizing data in the GIS, Figure 1. The essence of the method is that objects are divided into thematic layers and objects that belong to one layer.
A layer (spatial data) is a subset of spatial objects of data domain that have a thematic commonality and a coordinate system that is uniform for all layers [2]. A lot of various data has different characteristics and in the process of visual processing this set can be informationally overloaded. To reduce the information load on the operator the graphic data is typed and combined into layers. The objects of the separate layer are saved in a separate file, have their own identifier system which can be accessed as a set. Layering simplifies the processing process and increases the speed of displaying a map (diagram) on the monitor screen.

![Figure 1. An example of layer-based data organization (topographic base, forests, river roads, buildings, power networks).](image)

In a layered picture of the world each of the layers is the registration of changes in one variable on the earth’s surface. Each layer corresponds to the specific set of semantic data which is stored in tabular form. Layers in the GIS can be both vector and raster [3]. For effective management of power networks, the GIS should be based on a vector model of spatial data. Let us assume the option of using the raster substrate of the location map [4, 5].

Within the framework of the layer-by-layer organization of information, there are two specific implementations: vector-topological and vector-nontopological models.

The first implementation is vector-topological. There are limitations in this model: objects of not all geometric types can be placed in one thematic layer at the same time. For example, in the ARC/INFO system in one coverage you can place either only point or only linear or polygonal objects, or their combinations, except for the case of “point polygonal” and three types of objects at once.

The second implementation – vector-nontopological model of data organization is more flexible model, but often only objects of the same geometric type are placed in a single layer.

The number of layers for layer-by-layer data organization can be very large and depends on the particular implementation. When organizing data in layers it is convenient to manipulate large groups of objects represented by layers as a whole. For example, you can turn layers on and off for visualization and define operations based on the interaction of layers.
The classic concept of layer-by-layer presentation of graphical information is not effective for managing the operation of power networks.

Using the vector topological model we can create a layer of power networks where the issue of topological connectivity of the power network will be solved, but all objects of the power network will lose their autonomy. It will be difficult for each type of electrical object (poles, transformer substations, sections of overhead lines, etc.) to attach semantic information (for example, passport data, design data, a special feature, etc.) and it will be impossible to effectively manage individual types of power network objects.

Using the vector-nontopological model we can create layers for each type of power network objects with their own set of semantic information for each layer. In this case the elements of the power network will be on different layers and there will be difficulties in determining the topological connectivity of the objects of the power network. To eliminate this drawback developers began to create additional software modules in order to obtain data from different layers (files) of their processing of topology construction and saving it in temporary data stores.

The second method is based on the object approach. In the object method there is no breakdown of information into thematic layers. Grouping of objects takes place in a more complex way in accordance with the logical relationships between them, with the construction of hierarchies that correspond to their general and private properties. This approach is closer to the structure of human thinking. It is effective when you want to emphasize the individual logical relationships of objects. But it is less effective if it is necessary to introduce into consideration features that are continuously distributed in space.

![Figure 2. The structure of an object-oriented database.](image)

The object model for the presentation of graphical information is based on the construction of the “object tree” broken down into classes and subclasses of objects with a specific set of semantic data stored in tabular form. A group subordinate in the hierarchy, a subclass or a class of objects in this case acts as an analog of the layer, but with great functionality.

Object-oriented GIS is a further development of the object representation of graphical information. Object orientation is not always understood here in the sense that the GIS is written with object-oriented tools, but in the fact that the same mechanisms should be provided to the user of the system.
for organizing data. Object-oriented data models allow you to simultaneously simulate the state and "behavior" of objects in the GIS. The structure of an object-oriented database is graphically representable in the form of a tree whose nodes are objects (Figure 2).

When using object-oriented models it becomes easier to use GIS data, the software will work with natural concepts for the user such as a support, a switch, a power line, etc. and not with system-oriented concepts such as points, lines and polygons. The true potential of object technology lies in the fulfillment of the task of modeling and sequential analysis which is simpler, more consistent with the way people think normally [6].

In general, an object-oriented approach in its pure form is less common than a layered one, partly due to great difficulties in the practical organization of the entire system of object interconnections. Labor costs for the preparatory stage of the formation of a specific database structure can be very large [7]. Certain difficulties are also possible with changing the once formed database structure and adapting it to new tasks.

3. Results and discussion
The supporting circuits of overhead lines (OHL) 6-10 kV are the primary source of information for many calculation tasks and the basis for a work order in rural distribution power networks. Figure 3 shows a fragment of the supporting circuit of a 10 kV overhead line.

![Substation 35/10 kV](image.png)

**Figure 3.** The fragment of the supporting circuit 10 kV of rural distribution electric networks.

The support scheme in the GIS can be represented by the following objects [8]:
- sections of lines characterized by the length, brand of wire, cross-section, a graphic image in the form of a broken line going out from one node and coming to another node;
- a power substation characterized by a name and displayed as an pictogram with a specific name;
- step-down transformer substations characterized by the number (name), quantity and rated power of transformers, the type of consumer supplied, the graphic image in the form of pictograms with specific names;
- supports characterized by a number (tap number / support number), type and displayed in the form of pictograms with specific names;
- other objects.
Figure 4. The structure of the "object tree" of the supporting circuit overhead lines of 6-10 kV of rural distribution networks.
Based on the foregoing it is proposed to use the following structure of the “object tree” shown in Figure 4 when forming the supporting circuit 6-10 kV overhead line of rural distribution networks in the GIS.

For each object in the GIS the name of the object, the color scheme (background (fill) and outline color of the object), the sign of visibility (activity), the upper and lower boundaries of visibility, the thickness of the outline line and its type, access rights to the object depending on the user authority must be specified. The following parameters are additionally set for objects of type “text”: font, font size, alignment of text line, rotation, DB text field, text output effect. For objects of the "pictogram" type, a plan (the pictogram may consist of several independent images, displaying). In addition, the following object properties must be filled in: ID - the graphic address of the object, user functions, screen form (passport data of the object), transition to the internal circuit of the object, multimedia files.

4. Conclusion
The GIS for use in rural electrical distribution networks should be based on a vector model of spatial data. Let us suppose the option of using a terrain map as a raster substrate.

The concept of layering graphical information is not effective for managing the operation of power networks.

More promising is the object-oriented way of representing the graphic information of power networks. Object orientation is not always understood here in the sense that the GIS is written with object-oriented tools, but in the fact that the same mechanisms (inheritance of class properties, encapsulation, polymorphism) must be provided to the system user for organizing data.

The “object tree” structure is proposed for supporting circuits 6-10 kV overhead lines of rural distribution networks.

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