Designing and maintaining of circuits of distribution networks with voltage of 10-0.38 kV

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Abstract. The procedure for maintaining circuits in distribution networks with a voltage of 10-0.38 kV is determined in accordance with the Rules of Technical Operation, State Standard. In accordance with these documents, the types of circuits that should be in the subdivisions of electrical networks are determined. All changes in all circuits should be made immediately (after completion of installation work before commissioning), signed by the responsible person. Information on changes in the circuits should be brought to the attention of all employees for whom knowledge of these circuits is required. The need to have the same circuits in production services and subdivisions of electric networks justifies the use of modern information systems such as geographic information systems, which allow working with all types of electric network circuits in multi-user mode. In this case, users will have the most accurate information. The article describes the requirements for supporting circuits designing. The issue of input, preparation and maintenance of data is up to 90% of the cost of a serious project of a geographic information system (according to press). And only 10% is the cost of equipment and software for the geographic information system. A task requiring such costs can be effectively solved only by professional means on professional equipment. The article discusses how to enter electrical network diagrams into geographic information systems and proposes a technique for introducing overhead lines support circuits of 6-10 kV into a geographic information system.

1. Introduction

The main document on the basis of which an order is drawn up for work in distribution electric networks is the support circuits of overhead lines (OHL) of 10-0.38 kV. The support circuit is a conditional graphic presentation on the drawing of the overhead line components. On support circuits of electrical networks should be shown:

- anchor, special supports, as well as supports limiting spans of overhead power lines and communications lines, spans of crossings over roads and railways and other engineering structures with the numbers of these supports;
- the first and the last intermediate supports in spans limited by complex supports;
- the brand, cross-section and length of the wire, as well as the length of the line. These designations are stamped to sections of the line, limited by complex supports. If the line has a wire of the same brand and cross-section, then the wire and the length of such a line are shown on the diagram in one place;
- all crossings with other lines indicating the voltage and location (upper, lower) of the crossed lines,
sections of parallel lines, transitions through engineering structures, rivers, roads and railways, as well as the position of switching devices on ring feeders.

- a record of supports for which lifting is prohibited (supports with an unacceptable degree of decay of wood, unacceptable cracks in reinforced concrete, supports damaged by mechanisms).

The numbering of supports on 6-10 kV overhead lines should be as follows: on the main section of the feeder supports should have numbers from “1” to “N”, on the sealing the supports are numbered with a fraction: in the numerator there is a sealing number, in the denominator there is a number of the support.

Symbols for the elements of the electric network must comply with State Standard “Graphical symbols in circuits”. The symbols for anchor and intermediate supports have a different image and are shown in the Table 1.

**Table 1. Supports of OHL 6-10 kV**

| Symbol for supports | Type of supports                      |
|---------------------|--------------------------------------|
| anchor support      | Wooden support                       |
| wooden support      |                                       |
| intermediate support| Wooden support with reinforced concrete element |
| reinforced concrete support |                                     |
| metal support       |                                       |
| grounding support   |                                       |

**Table 2. Transformer substation**

| Symbol for transformer substation | Type of transformer substation                        |
|----------------------------------|-------------------------------------------------------|
| On the balance sheet of a network company | Substation 35 kV and higher                          |
| On the balance sheet of a consumer    | Closed transformer substation 6-10/0.4 kV             |
|Tower transformer substation 6-10/0.4 kV without external disconnector| |
|Tower transformer substation 6-10/0.4 kV with external disconnector| |
|Package transformer substation 6-10/0.4 kV without external disconnector| |
|Package transformer substation 6-10/0.4 kV with external disconnector| |
|Industrial package transformer substation 6-10/0.4 kV without external disconnector| |
|Industrial package transformer substation 6-10/0.4 kV with external disconnector| |

Symbols for transformer substations with a voltage of 6-10 / 0.4 kV indicate the type of substations and the balance sheet attribution of the property (Table 2). For all substations with a voltage of 6-10/0.4
kV, the dispatch designation, power of the transformer and the name of the consumer (main) should be indicated on the circuits, powered from this TS indicating the category of reliability of power supply (1, 2, except for the third). For the names of consumers on the circuits, abbreviated terms are used (Table 3). Symbols for wires should reflect the purpose of the lines (Table 4). Symbols for supports of OHL 0.38 kV are given in Table 5.

**Table 3. Abbreviations for naming consumers on the circuits**

| Names of the consumer                  | Abbreviation |
|---------------------------------------|--------------|
| Poultry farm, poultry yard           | PF           |
| Incubator                             | INC          |
| Milk production complex, dairy farm   | MPC          |
| Cattle fattening complex              | CFC          |
| Sheep farm                            | SF           |
| Pig farm                              | PF           |
| Workshops                             | WS           |
| Elevator                              | ELEV         |
| Populated locality                    | Dom          |

**Table 4. Symbols for wires on overhead lines**

| Symbol | Line type on 6-10 kV overhead lines | Line type on 0.38 kV overhead lines |
|--------|------------------------------------|------------------------------------|
|        | 0.38 kV lines                       | OHPL 6-500 kV                      |
|        | OHPL 6-500 kV, joint suspension     | OHPL 0.4 kV, joint suspension      |
|        | Street lighting lines               | Radio lines                        |
|        | Communication lines                 | Cable OHPL                         |

**Table 5. Overhead line supports 0.38 kV**

| Support symbol | Type of supports                                      |
|----------------|-------------------------------------------------------|
|                | Wooden support (one-piece support, on wooden elements)|
|                | Wooden support on reinforced concrete elements        |
|                | Metal support                                         |
|                | Support with inclined shore, guy line                 |
|                | Grounding support                                     |
|                | Support with a branch to the input, where “5” is the house number |
|                | Support with a lamp                                   |
|                | Reinforced concrete support                           |

The numbering of supports of OHL 0.38 kV is continuous from “1” to “N”. With a joint suspension of a 0.38 kV overhead line with a 6-10 kV overhead line, numbering is based on the supports of a 6-10 kV overhead line. Symbols for the brand, cross-section, and number of wires and the length of the line are stamped in areas limited by the supports for changing the brand, number of wires, as well as at the
beginning of the branches.

The symbols for the wires on the OHL circuits 0.38 kV are given in Table 4. In the upper right corner of the sheet, a transformer substation switching circuit (sides 6-10/0.4 kV) is performed with the indication of dispatching symbols. On the circuits of OHL of 0.38 kV of populated locality with street names and house numbers, the street name, house numbers with the support from which the house is connected to the line should be indicated. A consumer list should be attached to the 0.38 kV overhead lines circuits of populated locality that do not have house numbers, indicating the support from which the house is connected.

2. Materials and methods

To maintain the current state and provide access to various production services and subdivisions to technological circuits of electric networks, various graphic editors, graphic packages, engineering graphics systems or geographic information systems (GIS) are used [1, 2].

The first approach to cartographic input was the tedious and error-prone use of transparent material with a grid applied, with which data, cell by cell, were manually entered into the computer. In most cases, raster cells were assigned numerical values, which, again manually, were entered into the computer one after another. As a result, the image in raster format was obtained on the computer.

To obtain a vector image in a computer, you can manually put a drawing in front of you and simply draw it in a vector editor. Unfortunately, this method is acceptable only for small circuits. There are two main ways to input (digitize) vector graphics from paper:
- direct input of vector images (lines and points) with a digitizer;
- input of graphic information by the scanner and subsequent vectorization of the received raster images.

A digitizer is a device for manually digitizing cartographic and graphical documentation in the form of a set or sequence of points, the position of which is described by the Cartesian rectangular coordinates of the plane. The digitizer consists of a flat table (tablet) and a reader of information moved along its surface.

Using a digitizer, you can directly enter graphic vector information from diagrams and maps into computer systems and programs (graphic editors, GIS, etc.).

Programs for working with digitizers can allow entering attribute data for a digitized object or it becomes possible to enter data later using GIS tools. As attribute data in electric networks passport data of elements of an electric network act. Some programs for working with digitizers require indicating the positions of nodes, others do not. Some require explicit coding of the topology during digitization, while others use software-based methods for constructing the topology after the database is full.

When performing large projects in modern GIS, the input (digitization) process can be automated using scanner technology. This technology consists of four stages: scanning; cleaning scanned images; vectorization; topological cleaning of graphic data.

The conversion of the raster representation of spatial objects into a vector one is supported by specialized software - vectorizers. By purpose, vectorizers can be divided into universal and highly specialized. The highly specialized vectorizers include the vectorizers of electrical (and, in general, all engineering) networks, which require compliance with the topology specific to this type of network, the creation of original objects and attribute data [3].

Currently, the main sources obtained using modern technical means for creating maps and plans in GIS are:
- geodetic data (field measurement data);
- satellite navigation receiver data;
- aerospace materials;
- laser scan data.

The disadvantage of obtaining geodetic data (field measurement data) is the high complexity, especially when using traditional geodetic instruments. The use of modern geodetic instruments, for instance, an electronic total station is to select the code of the desired object on the display of the total
station and measure its coordinates. Further this information is used in the process of creating maps in GIS [4].

Data from satellite navigation systems are obtained using hand-held GPS receivers to determine the location of energy objects. GPS receivers have an internal memory function that allows saving waypoints and routes with a given name and fixed coordinates. Then the data can be downloaded to a computer for further processing as an ASCII text file with separators of certain structure, or directly in Arc View GIS as a shape file or graphic.

The ground-based “manual” method for determining the coordinates of each line support 0.38-10 kV is practically impossible due to the large number of lines and supports [5, 6]. The fact is that the GPS receiver must visit each support in succession. Most of the time it takes is to get to the desired object. Transportation costs make up a large part of the cost of work, and their productivity is ultimately low. Therefore, methods are needed to automate the process, the “fixing” of supports to the location plan.

3. Results and discussion

One of the ways to automate the process of “fixing” the supports of 0.38-10 kV lines is based on the joint use of a GPS receiver, an electronic recorder of vehicle-tilt angle, laser rangefinders connected to computers and installed on the car. The proposed method allows determining for each support the geographical coordinates, direction and angle of inclination of the support relative to the horizontal based on the processing of information from devices installed on the vehicle. The authors of this technique have obtained a useful model patent [7].

The work on passportization of the land allotment for OHPL (500, 220 and 110 kV) was carried out in the Yamalo-Nenets Autonomous Okrug for JSC Tyumenenergo of the Noyabrsky Electricity Networks. The work consisted in “fixing” only anchor-angle supports. This made it possible to obtain a broken line on the location plan, which with the help of GIS (MapInfo) was transformed into an areal object with a standard width of the land allotment strip. The automation method of obtaining the coordinates of the supports using GPS equipment installed on a helicopter was used. The “fixing” operator monitored the coincidence of the vertical axes of the receiving antenna and the anchor support. The readings for one support were taken twice under different azimuths.

Remote mapping using decoding of aerospace photographs requires the availability of high-quality and up-to-date photographs; in their absence, expensive photographing is necessary.

The creation of a raster-vector basis for the territory of the Podolsk electric networks of JSC Mosenergo was carried out using satellite imagery. The experiment has shown that the use of satellite images has led to a significant reduction in the cost and timing of work compared with geodetic work in the field. However, “fixing” the supports of 6-10 kV lines in this way is linked with significant difficulties. Supports were hardly distinguished in the picture due to the small cross section and barely visible shadows in areas with leafy vegetation, as well as on rough terrain. As a result, field work during the decoding of space photographs was not completely avoided. Field visits were carried out to areas where decoding for one reason or another was impossible, or the results of decoding the images were in doubt.

In [8], in order to automate the processing of satellite images, the authors have proposed software recognition of supports images and automatic generation of a database of their coordinates and types. This method is based on the creation of an image classifier for typical supports with subsequent software search for similar images in photographs. The use of the Kohonen artificial neural network is proposed as a recognition tool, the main advantage of which in this case is high speed due to parallel data processing.

Remote mapping using laser scanning has been carried out by Geokosmos company in combination with digital aerial photography of Intersystem Electric Networks of the South, the Urals, Centre, and Volga with a total length of 9,250 km, to create vector models of OHPL.

When using laser scanning in the electric power industry, the following main tasks are solved:

1. Assessment of the technical condition. Inspection of OHPL in the line side of 100 m from the axis of the line. Problem identification. Passportization of OHPL, determination of actual parameters
regarding span lengths, slacks, dimensions, etc. Identification of deviations from the design documentation. Inspection of substations and other electric grid facilities.

2. Engineering and survey work. Pre-design inspection of OHPL during reconstruction, laying of fiber-optic communication lines, etc.

3. Topographic, geodetic and land survey works. Creation of topographic plans on a scale of 1: 1000 and smaller. Creation of cadastral plans.

   Laser scanning data allows creating a high-quality digital 3D image of supports and objects located along the route with reference to geographical coordinates.

   The most informative result with modern methods for determining the coordinates of energy objects on the location plan has been achieved using laser scanning. However, due to the high cost of laser scanning of the locality and the large length of the networks, this method is of little use for obtaining data on distribution networks.

   Thus, according to the authors, the most acceptable modern methods for entering distribution electric networks are automated methods using satellite navigation systems and programs for decoding aerospace photographs.

   Taking into account the shortage of funds, the authors has proposed the following methodology to introduce 10-0.38 kV overhead lines in GIS:

   1. To compile a table of node objects of the overhead line circuit with their identifiers.
   2. To determine the coordinates of node objects using GPS equipment.
   3. To download field data to a computer.
   4. To perform differential processing of field data to increase coordinate accuracy.
   5. To upload processed data to a specialized vectorizer.
   6. To enter line sections with automatic arrangement of intermediate supports and their numbers using vectorizer.
   7. To enter the resulting circuit in GIS.
   8. To enter attributive information on electrical equipment using GIS.

   It has been proposed to use as nodal objects for a 10-0.38 kV overhead line circuit: power substation; transformer substation 6-10/0.4 kV; anchor-angular, special supports, as well as supports that limit spans of intersections with power lines and communication lines, spans of overpasses through roads and railways and other engineering structures; switching devices.

   A specialized vectorizer must use transformer substations and OHL supports in the form of standard elements in accordance with Tables 1, 2 and 5. And the input of sections of lines is carried out in accordance with the symbols given in Tables 3 and 4.

   GIS data collection is an endless task. The problem of updating information is the most urgent and expensive in all existing GIS. At the same time, GPS mapping equipment accelerates and simplifies the collection of basic GIS data, as well as provides a convenient ability to update information.

4. Conclusion

   The use of GIS can significantly increase the efficiency of all stages of working with spatial data, from the input of source information, performing its analysis and ending with the development of a specific solution.

   There are two main ways of entering vector graphics from paper medium with a digitizer and scanning, followed by vectorization. To enter electrical circuits, it is the most advisable to use highly specialized vectorizers that allow taking into account the topology, create original objects and attribute data.

   The most acceptable modern way to determine the coordinates of distribution electric networks objects is automated methods using satellite navigation systems and decoding aerospace photographs.

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