The Method of Selection of the Key Geodynamic Objects

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Abstract. In this paper as an indicator manifestations of geodynamic processes in a large area are invited to select the most sensitive and informative geological structures to the appearance of endogenous and exogenous factors that contribute to the development of geodynamic processes and negative changes in the geological section. Such places are key geodynamic objects that can provide early warning of the beginning of the development of destructive geological processes that have no external signs of existence. Watching the local geodynamic key objects and with the involvement of the hydrology data, geology, meteorology and geo-information technologies, it is possible to form a forward-looking assessment of destructive geological processes over a large area. The paper proposes a method for detecting the key geodynamic objects, including the distributed processing algorithms informative sections of heterogeneous data, the temperature and the hydrological correction of the measurement results. The proposed approach is based not only on statistical methods and morphological analysis of the territory, but also on the use of mathematical models of the interaction of hydrological, geological and man-made environments.

Keywords: geoelectrical monitoring of geodynamic object, forecasting, localization of objects, key objects.

1 Introduction

It is known that the development of suffusion processes intensity of geodynamic changes of local sites of geological environment characterized by much greater performance than that of the total of its variations. Consequently, information about the occurrence of destructive processes through the use of selective geodynamic control can be obtained much earlier than in the monitoring geodynamic environment in general. Therefore, the practical use of geomonitoring systems built on the basis of geoelectric sounding methods is appropriate for monitoring the bearing capacity of overlying and underlying soil during the operation of industrial facilities, as well as to ensure the protection of natural and man-made objects from the possible consequences of accidents at suffusion danger [1, 2]. Such systems through the application of information processing algorithms for heterogeneous monitoring data allow to register changes in the geodynamic control objects and obtain forecasts of the possibility of man-made disasters [3].

In this article, the example of suffusion processes the technique of constructing a regression geoelectric monitoring data processing algorithms with key geological objects in order to create predictive assessments of geodynamic.

2 The geological features of the site and the selection of the geodynamic control zones

Geodynamic monitoring carried out at the site of the alleged construction of Nizhny Novgorod NPP, which is located in the basin of the lower reaches of the river Oka (Figure 1a). The presence of low-mineralized water in the alluvial layer, lying in the valley r. Oka close to the surface, as well as the dominant stratum of carbonate and sulfate rocks, is the cause of the dynamics of the karst valley. Herewith, man-made increase in groundwater levels is the cause of the rapid process of karst formation and increase the risk of catastrophic situations at nuclear power plants.

The organization of the geodynamic control should take into account that there are two main types of geodynamic movements karst environment. This cyclic variation with varying intensity and duration of the period, characterized by cyclical changes in the structure of the medium, as well as the trend of variation which are of a pronounced character and having a constant direction for a long time, with the result that they are the main source of mechanisms of technological disasters [4]. Therefore, based on geological data it was determined optimum geoelectric zone control which will be geodynamic more pronounced than in other areas, for the same man-caused load. Monitoring of the local area will provide more accurate forecasts of geodynamic activity surrounding area (Figure 1b).

In addition geoelectric monitoring data by supplemented of stationary observations, including the monitoring of hydrogeological regime fracture-karst aquifer and overlying and geodetic monitoring of surface subsidence, changes in morphometric characteristics of the relief, the failures and deformations.

3 Key geological objects

For geodynamic control used multipolar equipotential electrical installation, developed together with IPE RAS. It is designed to monitor of the geodynamics of surface irregularities in the cases of the need provided increased sensitivity to the specific changes in the object of investigation. High efficiency is achieved by increasing the sensitivity of the measuring system,and the initial installation and operational positioning of the installation by controlling the sources of probing signals [5]. Operation is based on the fact that the source of the probing signals in the test environment is created in accordance with the principle of

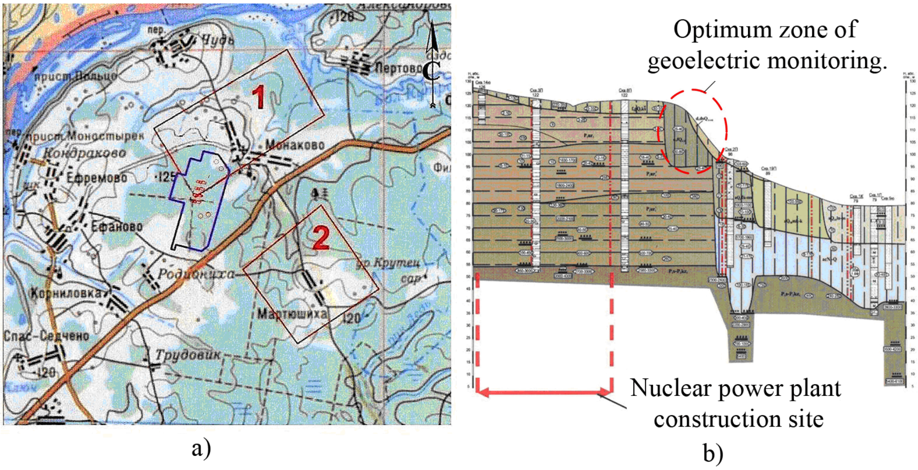

Fig. 1. Geological features of the site and the selection of zones and geodynamic control a) area of alleged placement of Nizhny Novgorod NPP; b) the geoelectric monitoring zone

superposition of a spatially-distributed signal forming a total zero signals in the measurement sensors of geoelectric field.

In this case the control signals of initial setting and positioning of geoelectric measuring systems, be formed in accordance:

$$\bar{U}_i(t_0) = F_U(M_{Si}, \bar{U}^*(t_0)), \tag{1}$$

where F_U the option forming of primary positioning on the control vector, by system $\bar{U}^*(t)$ of space-time processing data control at start time $t = t_0$,M_{Si} a vector of model parameters.

Later the geoelectric measuring system is functions, directly, in the semi-automatic mode using the following algorithm:

$$\bar{U}_i(t) = \bar{U}_i(t_0) + \Delta U(M_{Si}, \Delta\bar{a}_i) + F_U(\Delta M_{Si}, \bar{U}^*(t)), \tag{2}$$

where $\Delta U(M_{Si}, \Delta\bar{a}_i)$ the ongoing management of the positioning of the electrical installation of the vector of geodynamic variations$\Delta\bar{a}_i$; ΔM_{Si} the correction model.

Increase of sensitivity leads to an increase in noise level caused by thermal and tidal deformation effects. In addition, operational management of electrolocation signals is the presence of the trend component in the recorded signals, which is determined by the structural changes of the object [6].

Geoelectrical control method is based on the principle of linear and stationary of the geoelectric section, the transfer function $\Delta H_{ij}(p, \alpha_1, ..., \alpha_l)$ is determined by a system of spatial functions of control object $\psi_{ij}(p)$ with nominal geodynamic parametersα_0^i:

$$\varDelta U_i = \sum_{j=1}^{n} \varDelta H_{ij}(p) I_j(p), \tag{3}$$

$$\varDelta H_{ij}(p, \alpha_1, ..., \alpha_l) = \frac{K(p)}{S_i(p)} \sum_{k=1}^{l} \left[\frac{\partial \psi_{ij}(p, \alpha_1^0, ..., \alpha_l^0)}{\partial \alpha_k} \varDelta \alpha_k \right], \tag{4}$$

where I_i probe signal of i-th source; $\varDelta U_i$ the response of i-th source; $K(p)$ Contrast Ratio of environs; $S_i(p)$ the dependence of the measurement channel gain.

These relations (1-4) makes it possible to solve the inverse problem - selection of properties of the local geodynamic object by adjusting the parameters of sensing sources, which is a key aspect of the organization of geodynamic control [7].

Monitoring of the key geological objects - places with an active geodynamics and the most sensitive to endogenous and exogenous factors, and further predicting of geodynamics on the entire territory requires a change in the structure of the geodynamic system of forecasting described in [7]. The main changes relate to the prediction block, its structure shown in Figure 2.

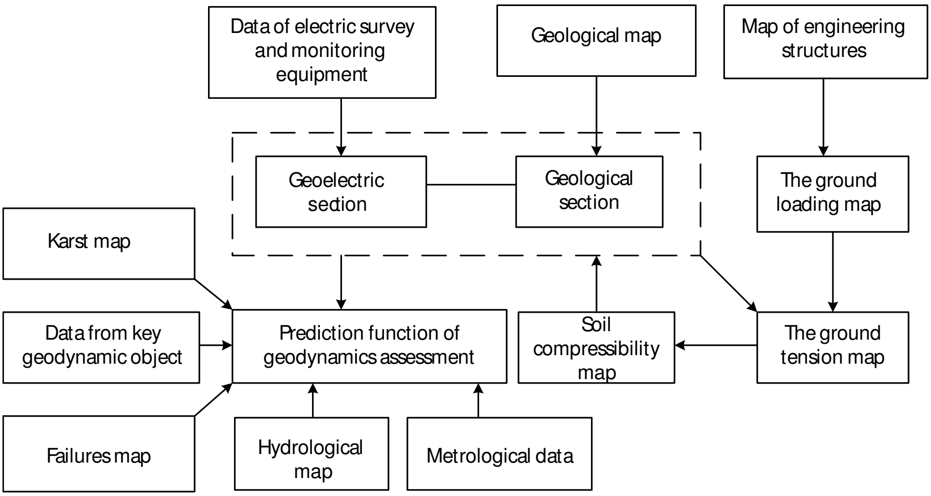

Fig. 2. Structural blocks of the prediction unit

Obviously, the key geodynamic objects for example, the suffusion processes , be chosen from the condition of the probability of the process itself: the presence of soluble species, and the solvent approach, removal of soluble species. Identify key geodynamic objects possible in rose histogram (Figure 2), which characterize the direction of the formation and propagation of failures, faults, the dominant structure of the network of cracks, etc. The diagram shows not only the direction of education failures, but also their concentration on the area.

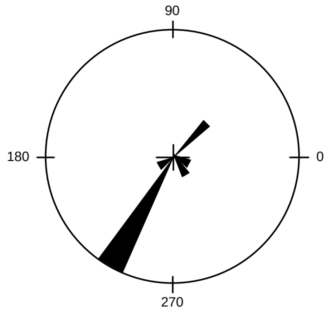

Fig. 3. Rose histogram

Expression (4) defines the principle of superposition of the probing signals by which to judge the possibility of providing separate characteristics of the environment (the object) by controlling the parameters of the source. This is one of the most important aspects of the organization of monitoring of geodynamic objects [10].

Based on the provisions described in this article, it is proposed to carry out the processing of heterogeneous data through specialized algorithms. Block diagram of the Information Technology Services of Geodynamic control system reflects the principle of joint processing of hydro-geological data (Figure 4).

The physical layer describes the physical methods of obtaining information that may be required to detect errors ε_i and measurement errors in data analysis. On the same level a scheme of placing primary transducers (sensors, measuring tools and devices) are described. The main objective of this level is acquisition (measurement) of raw data D_i. This level is the hardware and hardware-software (in the case of digital sensors). Such devices as sensing devices, sensors, blocks of a positioning in space that define the coordinates X_i, Y_i, Z_i measuring devices function in this level.

The link layer is represented by all kinds of measuring complexes, systems and instrumentation, and is a hardware-software. A modules and services related to prior and primary data processing, presentation and storage of primary D_i and processed D_i' data, supporting information: methods of measurement and processing, a model of locative level, required X_i', Y_i', Z_i' and fixed X_i, Y_i, Z_i positions of the primary converters in space are working in this level.

The link layer describes the working of the geographic information-analytical systems regulation and control (GIASC) of natural-technical systems (NTS) at the locative level, so there are also function modules and forecasting services, and the development of administrative decisions at the locative level. A control solutions are formed on the basis of received predictive estimates of f and functioning models of natural, technical, natural-technical and social systems.

A errors e forecasting and regulation at the NTS of the locative level are transferred network layer and serve as the basis for the correction components of operating at the link layer.

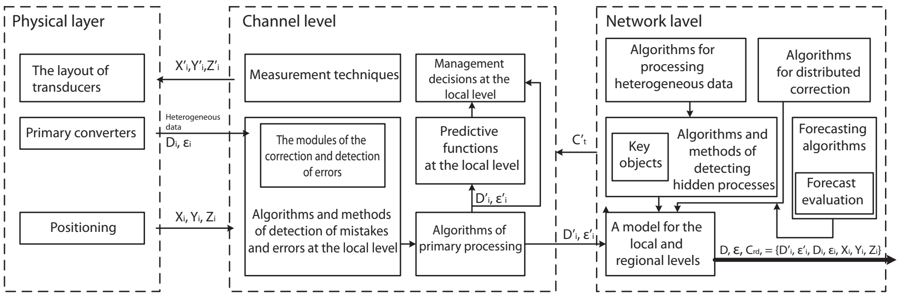

Fig. 4. Block diagram of information and technical support geodynamic monitoring system. ε_i the errors; ε_i' the compensation factor; D_i' the raw data; D_i the processed data; X_i, Y_i, Z_i the recorded position in space of the primary converters; X_i', Y_i', Z_i' the desired position in space of the primary converters; C_t' the synchronization signals and control.

One of the key factors determining the performance indicators of hemodynamic assessment at the geoelectric monitoring are used the earth models and models of geodynamic objects themselves. For a qualitative prediction of suffusion processes necessary to carry out an assessment of the expected location of displays and take into account their size, it is also necessary to take account of spatial-temporal geodynamic parameters. Therefore, the forecast is built on the basis of geomechanical models of different orders that can take into account the mechanism of interaction with the technosphere suffusion processes and geological conditions of its development.

For reasons of forecasting by the geoelectric monitoring necessary step is to establish the conformity of spatial functions in equation (4) for the transfer function of the geoelectric section geomechanical conditions of formation of local failures as described in [11,12].

This ratio can be set by considering the problem of the distribution of the geoelectric field of a point source field in the presence of a spherical in homogeneity, in which you can take as suffusion processes. The solution described in [13, 14, 15] to determine the characteristics of the occurrence of the ball on the observed distortions introduced them to the spatial distribution of potential geoelectric field.

The transfer function of the geoelectric section, which defines the displacement of equipotent lines i-source in space, taking into account the double anomalous component of the field is of the form:

$$\mathit{\Delta} H_{ij}(p,a,h) = K(p)\psi_{ij}(a,h) = 2K(p)\frac{a^3 r_{ij}}{(r_{ij}^2 + h^2)^{3/2}}, \tag{5}$$

where $h = z + a$ the depth of the sphere below the surface, a the radius of the sphere, r_{ij} the distance between the electrodes i and j.

Depth assessment of the changes occurrence spherical near-surface heterogeneity and its size can be made on the basis of (5), using it to forecast future geodynamic suffusion processes as an assessment:

$$R_z = \sqrt[3]{\frac{3\sqrt{3}\Delta\hat{H}h^2}{2K(p)}}, \tag{6}$$

where $\Delta\hat{H}$ the maximum estimated offset value of the equipotent line. The results of the regression of processing time series are geodynamic background information for predictive modeling underlying the decision of geodynamic processes forecasting problem [16, 17].

Geoelectric model of geodynamics suffusion processes can be represented by a discrete linear system [11] defined by the difference equation:

$$Y_k[i] + \sum_{i=1}^{n}\sum_{j=1}^{m} a_{ij} Y_k[i-j] = S_k[i], \tag{7}$$

where $Y_k[i]$ the counts recorded geodynamic process on k-th registration point; a_{ij} the model coefficients; $S_k[i]$ samples generated by a random process with geodynamic parameters $M\{S_k[i]\} = 0$, $M\{S_k[i]S_k[j]\} = \sigma_k^2\delta_{ij}$ (δ_{ij} the weights of the model).

System regression of the original equations is formed on the basis of the expression (7):

$$Y^T[i] = F_a[i] + a^T[i] + s^T[i], \tag{8}$$

where $Y^T[i] = [Y[m+1], ..., Y[l]^T$;

$$F_a[i] = \begin{bmatrix} -Y[m] & -Y[m-1] \cdots & -Y[1] \\ -Y[m+1] & -Y[m] & \cdots & -Y[2] \\ \vdots & \vdots & \ddots & \vdots \\ -Y[l-1] & -Y[l-2] & \cdots -Y[l-m] \end{bmatrix};$$

$a^T[i] = [a[1], ..., a[m]]^T$; $s^T[i] = [s[m+1], ..., s[m+l]]^T$; l the depth of predictive estimates.

Application in the analysis of suffusion processes predictive estimate of a regression model (8) allows you to make predictions that take into account not only the impact of cyclical planetary factors, but also man-made impacts. Figure 5 shows the preliminary interpretation of geological and geoelectric section in the area of geodynamic control.

On the basis of regime observations were interpreted registered signals geodynamic variations. Figure 6 shows the variations registered geodynamic gain bipolar equipotential geoelectric installation during the annual observations from May 2013 to April 2014.

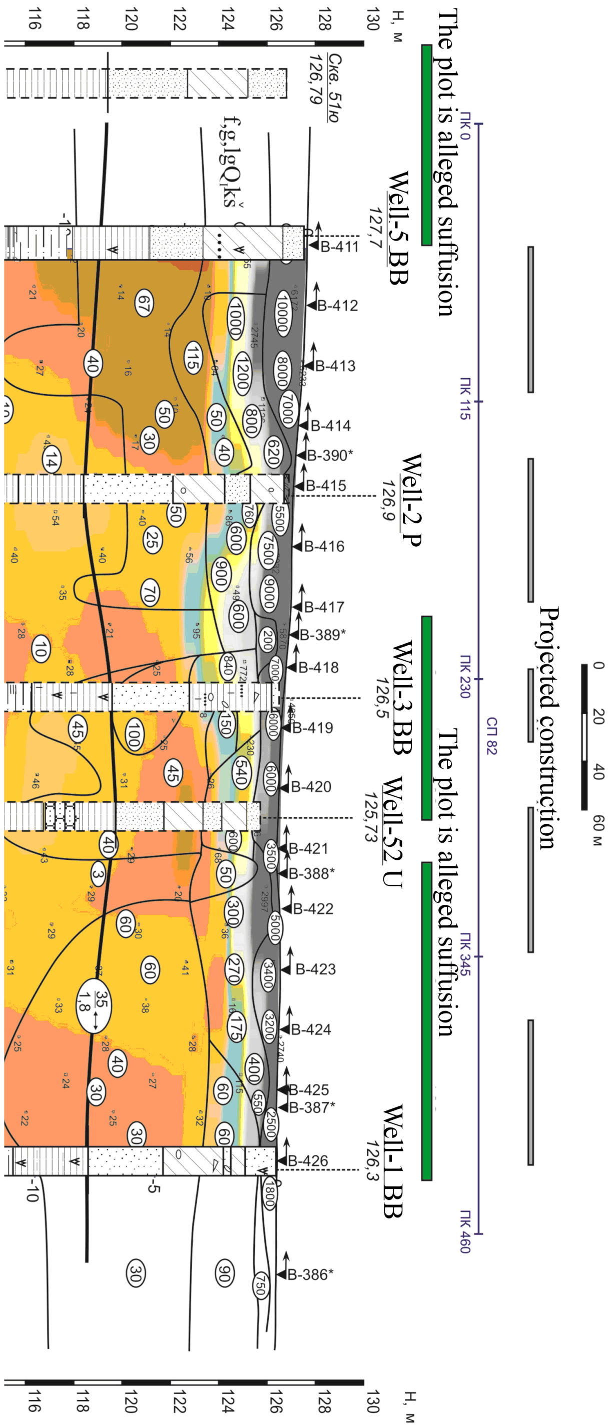

Fig. 5. The preliminary interpretation of geological and geoelectric section in the area of geodynamic control

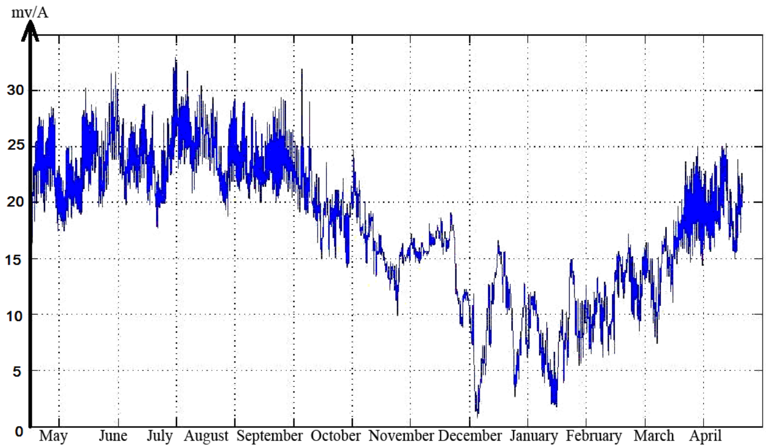

Fig. 6. Time series of geodynamic variations of the transmission coefficient of a two-pole equipotential geoelectric installation

4 Conclusions

The data are in good agreement with the hydrological observations of the water level in the river Oka and calculated as the ratio of mineralized areas at the top and bottom of the river.

Based on these algorithms in this article was obtained prognosis estimation of dip by models karst suffusion processes. As a result, it was found that the use of these algorithms, the formation of forward-looking assessments in geoelectric monitoring promotes the release of a high degree of reliability and the conditions of dip karsting the development of suffusion processes. Increasing the depth of predictive assessments and improving the efficiency of the proposed method is achieved by increasing the number of sensing points of the geoelectric field and the number of sounding sources.

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