Research of Local Deformation Processes of the Dniester PSPP Territory at 2010–2015

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Abstract – The parameters of horizontal earth crust deformation on the Dniester PSPP territory for the period (2010–2015) were calculated. Using obtained data, maps of dilation velocity distribution were constructed. It was found that the epicenters of extreme values of dilation velocity distribution coincide with the construction site of the main elements of the objects. Calculated parameters of horizontal crustal deformation and built by these parameters maps prove significant deformation processes in studied region which connected with construction work and starting of first and second hydropower units. Established that automated deformation monitoring system must be deployed at the Dniester PSPP territory.

Key words – geodynamic researches, local deformation, deformation parameters, dilatation, GNSS, Dniester PSPP.

I. Introduction

The recent earth surface deformations research is mainly focused to use such methods as Satellite laser ranging (SLR), radiointerferometry (VLBI), Doppler Orbitography and Radiopositioning Integrated by Satellite (DORIS) and satellite methods (GNSS). GNSS method is the most common and widespread, due to the fact that the networks of the permanent geodetic stations have thickened in recent years. Such networks evenly cover the territory of almost all continents, islands and peninsulas. Therefore, a large number of publications appeared which is related to the study of the earth surface deformations in Europe [12][12], Antarctica [10], Central Asia [2], the British Isles [5], the Apennine [14], the Iberian [7], the Scandinavian peninsulas [15] etc.

In addition to the research of the earth surface deformations of large areas, there is often a need to define such deformations in local areas in order to forecast and analyze different tectonic and geological processes, to determine a safe place for construction and various industrial facility operations etc.

The [9] reveal an improved method to process the results of GNSS observations and to determine local deformations. For the research were used a 19 GNSS points which are placed in the polish part of Karkonosze Mts and in the Karkonosze Foreland in Western Sudetes. The analyses of vector lengths' differences between GNSS points have shown significant changes (more than 5 mm) near water reservoirs and mining areas. However, according to the authors of [4], a relatively short research period between 2001–2003 can not reflect the basic data for qualitative deformation analysis, so the results [4, 9] have mainly cognitive and practical value.

The publication [6] present the deformation process research of the eastern part of the Betica province (Spain) based on observation networks CuaTeNeo, which consists of 15 GNSS points. Processed results in the period 2007–2011 showed a velocity field lower than 2 mm/yr with a dominant trend oriented parallel to the Eurasia and Nubia relative plate convergence. Stations located farther inland exhibit lower velocity vectors.

In a paper [3] a similar research was conducted in the northern part of Egypt. During 2007–2012 according to the 13 GNSS points was calculated a speed of deformation which vary between 2–4 mm/yr. It was identified that the main movements occurs in the north-east.

The majority of technical engineering facilities in Ukraine are equipped with pylons for periodic GNSS measurements and further determinations of local deformations. Europe's largest Dniester pumped storage power plant (PSPP), which is located in the foothills of the Carpathians in the Chernivtsi region on the right Dniester river bank, is not an exception. According to [8] since 2004 periodic measurement of GNSS points is conducted, evenly located in the Dniester PSPP. According to periodic measurements conducted during the years 2005–2014 the rate of horizontal movements of Dniester PSPP GNSS points is 0,5–1,2 mm/yr, and they basicaly move to the west [8].

The construction of Dniester PSPP was launched in 1983 but till now only 3 of 7 hydropower units are commissioned, which is the first stage of construction. To build the upper reservoirs and stations, a large amounts of soil was moved which has resulted in the changes in tension at the top of the crust. Furthermore, the load of the station itself cause various geophysical processes in the ground that can even trigger earthquakes. In addition, the area where the Station is located is seismically active and this activity constantly increases. Its growth is associated with the commissioning of the upper reservoir in 2012–2013. Therefore, the construction and operation of such a facility must necessarily be accompanied by monitoring the horizontal and vertical movements of the crust, as well as accompanied by the detailed analysis of deformations. Constant monitoring and control of these processes can prevent disasters and their consequences.

II. Methodology

In 2003, geodetic control network Dniester PSPP was established to support the construction and observation of deformations of the slopes in the area of the main hydropower structures. Laid network is consisted of 15 items, conventionally divided into a framework and a working network, which respectively numbered 7 and 8 points [8]. This network can be considered as a local geodynamic ground. In January 2004, first series of measurements were held. Since that time, measuring network has expanded each year and became more supplemented. Currently, on the study area located

38 observation points. At these points, periodically GNSS measurements are held. As a result, the processing of measurement data obtained absolute velocity vectors of horizontal movements and their components.

Deformation parameters of the crust can be calculated for the centers of elementary triangles, which divided the study area. Therefore, using a Delaunay triangulation, the study of deformation processes on the territory of the Dniester PSPP was divided into the network triangles with vertices GNSS points. With linear interpolation within each triangle by three of its vertices calculated deformation parameters, so that for each set of points in each triangle had their calculated parameters of horizontal deformation. Deformation of the crust can be described by the following parameters:

- relative rotation ω − characterizes the reversal triangular element as a whole in relation to the coordinate system of the first epoch;
- relative shift γ_1, γ_2 in axes *X* and *Y*;
- general shift γ, that characterizes horizontal heterogeneity of deformed area;
- dilatation Δ − a relative expansion or compression of a surface area;
- maximum compressive or tensile E_1, E_2;
- Θ – maximum compressive or tensile E_{max}.

For the calculation of given parameters, common expressions are used [1, 13].

The results were used for mapping circuits for annual distribution of velocity dilatation on the territory of the Dniester PSPP in the period from 2010 to 2015.

III. Results

Every year the number of reference points of geodetic network Dniester PSPP has increased, the number of triangles, for which it was necessary to calculate horizontal deformation parameters, has increased also (Fig. 1).

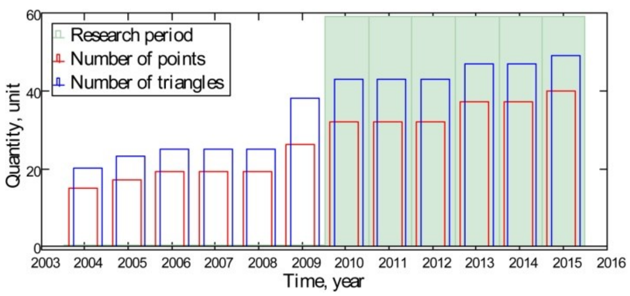

Fig. 1. The annual amount of geodetic control points and triangles for which it was necessary to perform calculations parameters of horizontal deformation of Dniester PSPP area

During the study period in the territory of the Dniester PSPP were held 5 cycles of monitoring (basically, measurements were made in mid-October). Since the installation is under construction, the study period is divided into three main stages of the first phase:

- installation and commissioning of the first hydropower unit (20 December 2010);
- top commissioning reservoirs throughout the area to mark 220.5 m volume of 19.3 million.m^3 (26 October 2012);
- installation and commissioning of the second hydropower unit (22 December 2013).

The dynamics of given events is shown on (Fig. 2).

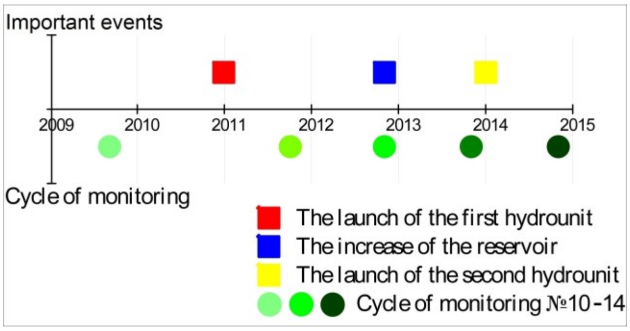

Fig. 2. Dynamic of monitoring cycles and the main stages of construction at the Dniester PSPP

Using the common expression [1, 13], the parameters of horizontal deformation of Dniester PSPP area were calculated. The obtained results were used for mapping the distribution of velocities dilatation for each year of the study (Fig. 3-6).

Analyzing the given maps (Fig. 3-6) we see that annually are set extreme positive (tensile) and negative (compression) indexes of velocity crustal dilatation of the Dniester PSPP. It was found that the epicenters of extreme values coincide with the construction site of the main elements of the object.

In our opinion, the extreme positive indexes of dilatation speed in 2011 (Fig. 3) is the result of commissioning of the first hydropower unit of the Dniester PSPP. In contrast to this, obtained extreme negative indexes in 2014 (Fig. 6) is the result of commissioning riding reservoir. The absence of significant changes in dilatation speed on the territory of the Dniester PSPP in 2012-2013 is caused by low dynamics of building developments (Fig. 2).

The analysis confirms that the territory of the Dniester PSPP is subjected to local deformation processes resulting from the operation and construction of the station. Also according to [16], this area is located in a place, where a change in the sign of current tectonic movements occurred, therefore it is a direct indicator of the possible creation of new zones of local seismic activity.

The results, obtained from the single annual measurements, make it impossible to identify short-term deformation processes. Therefore, in order to identify and track such processes as well as their interpretation, it is appropriate to increase the frequency of measurement cycles. For continuous monitoring and evaluation of seismic hazard, it is necessary to deploy automated system for monitoring deformations in the area of hydropower. It will enable regular observations of the construction and operation of the Dniester PSPP in order to ensure its safe operation conditions for the preservation of life and health, the environment and economic infrastructure.

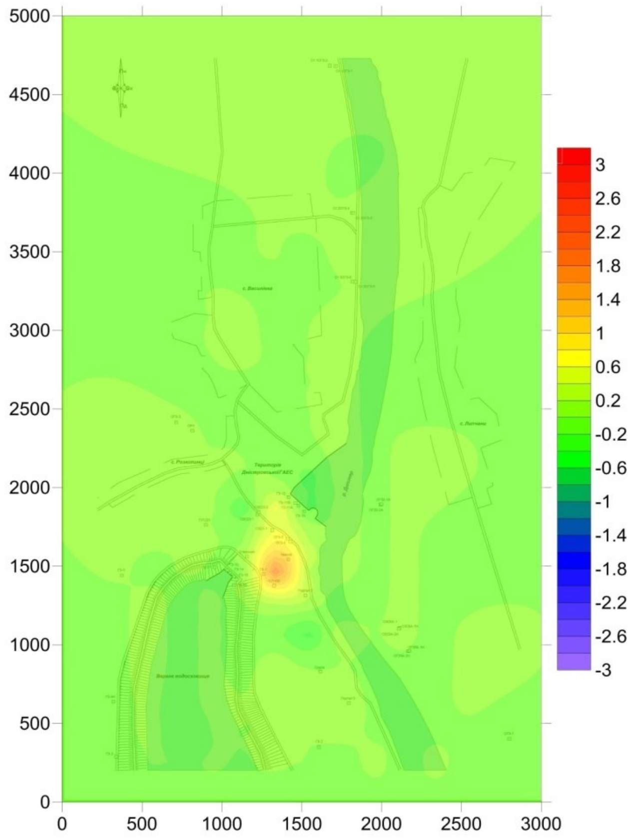

Fig. 3. Map of dilation velocity distribution in the territory of the Dniester PSPP in 2011

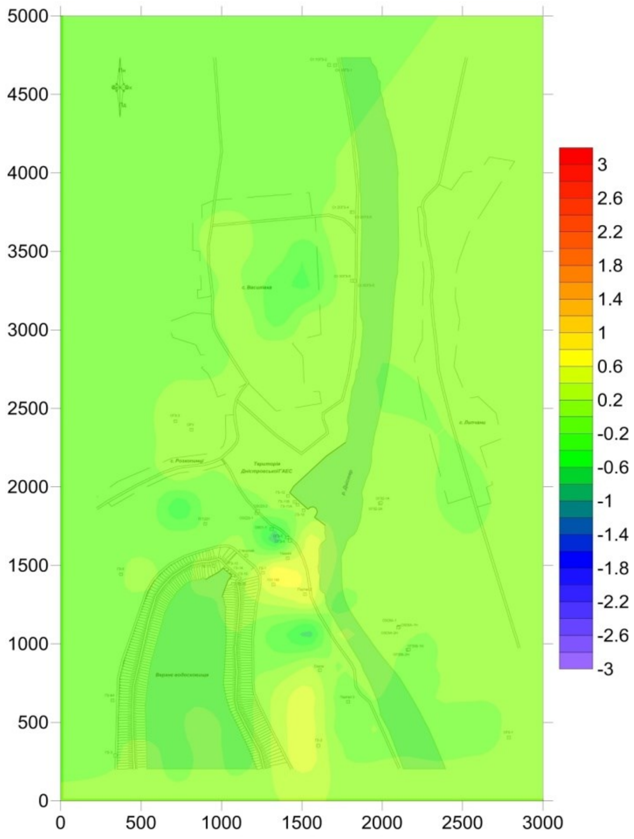

Fig. 4. Map of dilation velocity distribution in the territory of the Dniester PSPP in 2012

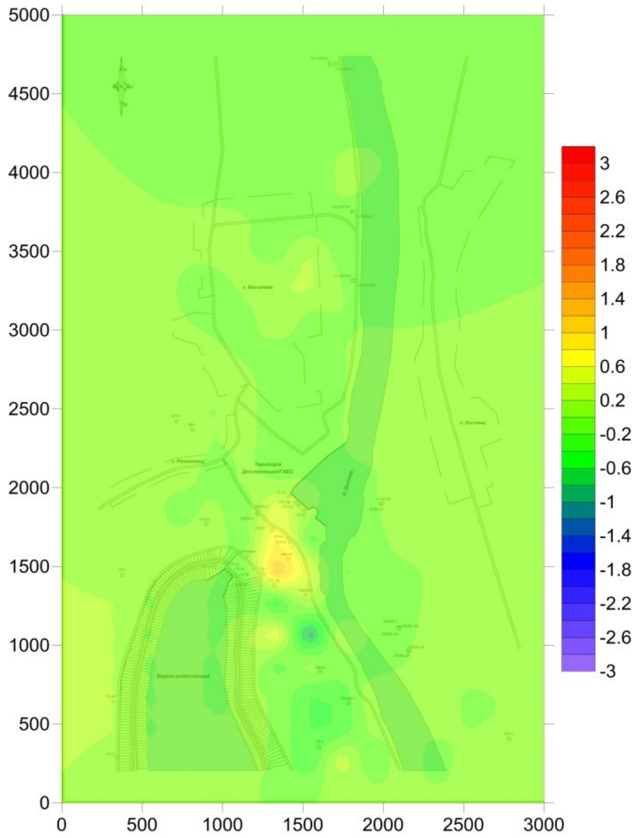

Fig. 5. Map of dilation velocity distribution in the territory of the Dniester PSPP in 2013

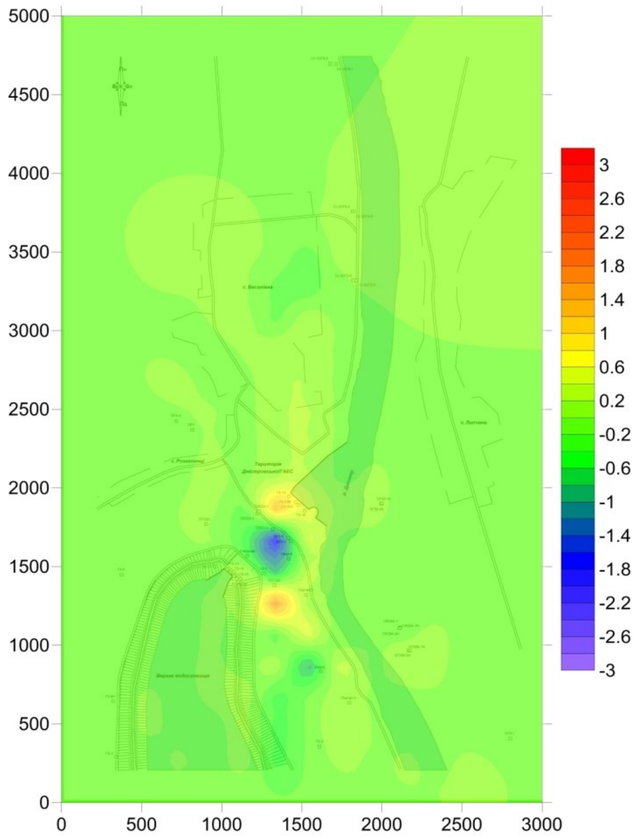

Fig. 6. Map of dilation velocity distribution in the territory of the Dniester PSPP in 2014

Conclusion

The horizontal deformation parameters were calculated: dilatation, relative displacements of the earth's crust, the overall shift azimuth, the axis of maximum and minimum deformation and deformation axis azimuth main territory of the Dniester PSPP for each year of study.

The obtained results of horizontal deformation parameters were used for mapping the distribution of velocities dilatation area Dniester PSPP for each year of the study

Annually, on the Dniester PSPP territory are set manifestations of extreme positive (tensile) and negative (compression) of velocity crustal dilatation. It was found that the epicenters of extreme values coincide with the construction site of the main elements of the object.

The analysis confirms that the territory of the Dniester PSPP is exposed to short-term local deformation processes resulting from the operation and construction of the station in the seismic activity zone. Therefore, automated deformation monitoring system must be deployed in the area of hydropower plant.

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