

# ORGANIZATION OF DEFORMATION MONITORING IN INDUSTRIAL FACILITIES BASED ON A DIGITAL PLATFORM AND ITS EFFICIENCY

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**Abstract** This article discusses the issues of geodetic monitoring of deformation processes at industrial facilities, the consolidation of measurement results on a digital platform, analysis and early detection of dangerous situations. As an object of research, the concept of the “Deformation Monitoring at Industrial Facilities” platform, which monitors vertical displacement, horizontal displacement and deflection indicators at industrial facilities, is analyzed. The platform combines tacheometric measurements, leveling, GNSS RTK observations, control point coordinates, deformation graphs, 3D model, device status and automatic alerts in a single information environment. Such a system allows you to increase the technical safety of industrial facilities, control the accuracy of geodetic observations and quickly make management decisions.

**Keywords:** deformation monitoring, industrial facilities, geodetic monitoring, GNSS RTK, total station, leveling, vertical reading, horizontal displacement, digital platform, technical security.

**Introduction.** Industrial facilities, especially large industrial buildings, energy facilities, reservoirs, metal structures, mining and oil and gas facilities, are constantly under geodynamic, technogenic and operational influence. Over time, deformation processes occur in structures as a result of foundation settlement, structural deflection, horizontal displacement, vibration, temperature effects or load changes. It is not enough to assess such processes only by visual inspection. Because deformation initially begins at the millimeter level and may not be noticeable. Therefore, it is important to create a high-precision geodetic monitoring system at industrial facilities.

In international practice, geotechnical and geodetic monitoring is considered a systematic observation performed using field instruments. The ISO 18674 series defines the general rules for geotechnical monitoring, the procedure for monitoring deformation, pressure, elongation and other parameters using field instruments. In assessing the accuracy of geodetic instruments, the ISO 17123 series describes methods for checking total stations, levels, GNSS and other measuring instruments in field conditions. From this point of view, the digital deformation monitoring platform is an important scientific and practical tool for continuously assessing the technical condition of an industrial facility, identifying dangerous changes and ensuring the safety of the structure.

**Relevance of the topic.** The organization of deformation monitoring at industrial facilities based on a digital platform is one of the most urgent issues today. Because industrial buildings, production workshops, oil and gas facilities, energy facilities, mining complexes, hydraulic structures and large engineering structures constantly operate under natural and man-made influences. As a result of such influences, objects may experience subsidence, horizontal



displacement, deflection, cracking, uneven deformation of the foundation and a decrease in structural stability.

In traditional monitoring methods, geodetic measurements are kept in separate tables, the results are processed manually, and the analysis process is time-consuming. This limits the ability to detect dangerous deformations in a timely manner. The digital platform allows you to collect all measurement results in a single information database, automatically analyze them, evaluate them in a graphical format, and provide instant warnings about points that exceed the regulatory limits.

Through a digital platform, GNSS RTK, total station measurements, high-precision leveling, data from sensors and sensors are combined into a single system. This increases the reliability of monitoring results, allows for comparison of differences between measurements, and reduces errors due to the human factor.

**Research results and their discussion.** The main tasks of the platform are as follows: The main goal of the "Deformation Monitoring at Industrial Facilities" platform is to consolidate the results of geodetic measurements at control points at industrial facilities into a single digital system, automatically calculate deformation indicators, and provide prompt warnings in the event of dangerous changes.

- display of a 3D model of an industrial facility and the location of control points;
- Store coordinate and height data of deformation marks such as D1–D12;
- taking tacheometric, leveling and GNSS RTK measurements;
- calculation of vertical reading, horizontal displacement and deviation values;
- comparison of measurement results over time;
- formation of deformation graphs and diagrams;
- automatic detection of points exceeding the regulatory limit;
- monitoring the status of devices;
- automatic generation of reports and notifications;
- speed up decision making for engineers, surveyors and management.

In the example provided on the platform, the number of objects is 1, the number of control points is 12, monitoring status 100%, maximum vertical reading -7.0 mm, maximum horizontal displacement 2.58 mm and maximum deviation 1/3800 are shown. These data serve as key indicators for quick assessment of the condition of the facility. The platform consolidates several types of data into a single information base. The platform stores the following data for each industrial facility:

- object name;
- object type;
- location address;
- monitoring status;
- observation date;
- last measurement time;
- number of active control points;
- responsible organization or specialist;
- security status of the facility.



This information is displayed on indicator cards at the top of the platform. For example, indicators such as “Number of Objects”, “Number of Points”, “Monitoring Status”, “Maximum Vertical Reading”, “Maximum Horizontal Shift” and “Deviation” allow the user to quickly understand the overall situation.

**Control point information.** Control points are the main observation units in deformation monitoring. The platform stores the following information for each point:

- point name: D1, D2, D3 ... D12;
- initial coordinates;
- current coordinates;
- height values;
- measurement dates;
- change values;
- risk level;
- Location in the 3D model.

It is important to display control points in the 3D model. This allows you to visually identify where the deformation is occurring. For example, point D11 on the platform is marked in red, indicating that the vertical training standard has been exceeded. Point D5 is marked as a dangerous point for horizontal displacement.

**Geodetic measurement data**The platform combines three main measurement methods:

**Tacheometric method.**This method measures horizontal and vertical angles, distances, and determines the coordinates of control points. For total stations, ISO 17123-5 specifies a procedure for assessing the accuracy and repeatability of coordinate measurements in the field.

**Leveling method.**This method is mainly used to determine vertical deformations, i.e., subsidence or heave values. High-precision geodetic leveling is widely used in vertical deformation monitoring, especially in the monitoring of large engineering structures and dams.

**GNSS RTK method.**GNSS RTK technology allows for the determination of spatial coordinates of control points in real time. ISO 17123-8 defines a procedure for assessing the accuracy and repeatability of GNSS RTK equipment in field conditions.

Combining these three methods on a single platform increases the reliability of deformation monitoring, as each method has its own advantages in detecting different deformation components.

**Types of deformation and their calculation.** On the platform, deformation is analyzed in three main indicators: vertical, horizontal displacement, and deflection.

Vertical is the change in height of a control point relative to its initial position. It is defined by the following expression:

$$S = H_i - H_0$$

Here:

**S**— vertical or sinking value;

**Yes**— current observation altitude;



$H_0$ — initial height.

If the value is negative, it indicates that the point is sinking. In the example of the platform, the vertical reading at point D11 was -7.0 mm. This point is shown in red on the chart and is being marked as a dangerous trend.

Horizontal displacement refers to the deviation of a point from its initial position in terms of X and Y coordinates. It is defined as:

$$\Delta X = X_i - X_0$$

$$\Delta Y = Y_i - Y_0$$

The total horizontal displacement modulus is:

$$\Delta_{xy} = \sqrt{(\Delta X^2 + \Delta Y^2)}$$

The maximum horizontal displacement for point D11 on the platform is shown as 2.58 mm. This value is an important indicator in assessing the horizontal stability of the object's structure.

Deviation is the deviation of a structure from the vertical. On the platform, this indicator is expressed in the ratio of 1/3800. This indicator is usually determined by the ratio of the height of the structure and the horizontal displacement:

$$\theta \approx \Delta / H$$

or in practical form:

$$\text{Deviation} = H / \Delta$$

Here:

$H$ — construction height;

$\Delta$ — horizontal deviation;

$\theta$ — angle of deviation or relative deviation.

The deflection index is important for assessing the structural stability of industrial facilities.

**Information-modular structure of the platform** The platform may consist of several functional modules.

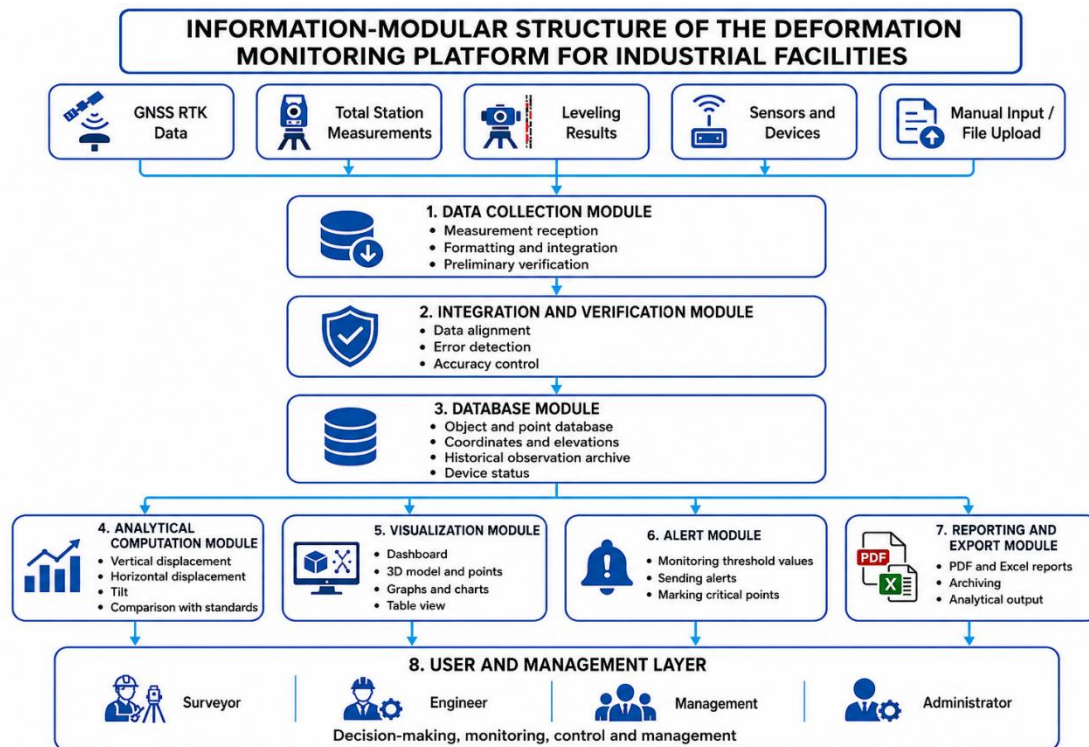


Fig 1. Information-Modular Structure of the Deformation Monitoring Platform for Industrial Facilities

**Data collection module.** This module accepts measurement data from GNSS RTK, total stations, levels, and sensors. Data can be entered manually, uploaded from a file, or transferred to the system through automatic integration.

**Database module** All objects, control points, measurement dates, coordinates, heights, device status and user actions are stored in the database. This module is the basis for historical analysis and reporting.

**Analytical computing module** This module performs the following actions:

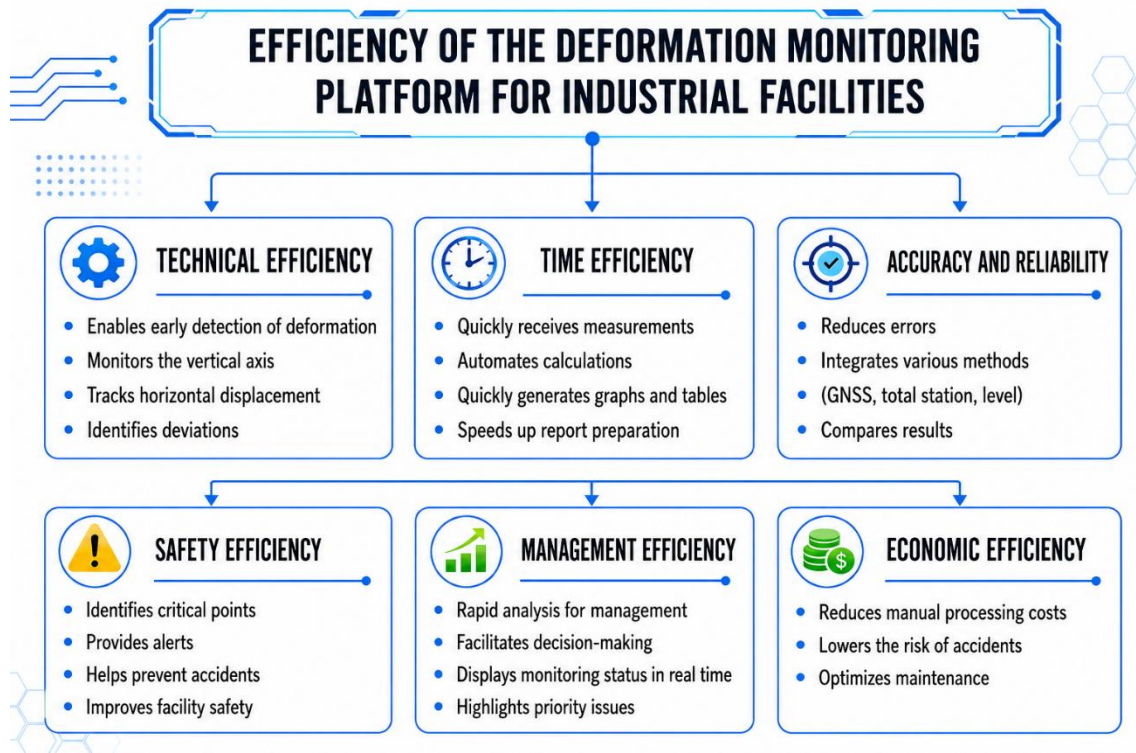
- compares initial and current measurements;
- calculates vertical reading;
- determines the horizontal displacement modulus;
- calculates the deviation value;
- isolates the maximum dangerous points;
- compares with regulatory limits;
- determines the level of risk.

**Visualization module** The platform includes a 3D model, diagrams, color indicators, graphs, tables, and alert windows. The visualization module displays complex geodetic data in a simple and understandable form.

**Notification and alert module** If the deformation exceeds the regulatory limit, the system automatically issues a notification. For example:

- "Vertical reading at point D11 exceeded the standard";
- "The horizontal displacement at point D5 exceeded the norm."

Such warnings are important in preventing accidents. Modern monitoring systems widely use the practice of providing early warnings when specified parameters are exceeded.



**Fig 2.** Efficiency of the Deformation Monitoring Platform for Industrial Facilities

**Expected results.** The following results can be achieved by implementing this platform in industrial facilities:

1. deformation monitoring will be systematized;
2. geodetic measurements are consolidated into a single database;
3. dangerous points are automatically detected;
4. errors due to the human factor are reduced;
5. the report preparation process is accelerated;
6. facility security increases;
7. scheduled maintenance;
8. the possibility of preventing accidents increases;
9. monitoring results are presented in a visual form that is understandable to management;
10. The operational reliability of industrial facilities increases.

**Scientific and practical significance of the platform** The scientific significance of this platform is that it analyzes deformation processes not only as individual measurements, but as a dynamic process that develops over time. That is, previous, current and subsequent measurements are compared for each point.

The platform implements the following approaches to deformation monitoring:

- systematic monitoring;
- repeated geodetic measurements;

- digital database;
- automatic calculation;
- near real-time analysis;
- graphic monitoring;
- risk assessment;
- support decision making.

In practical terms, the platform allows surveyors, engineers, technical supervisors, and facility management to work in a single information space.



Fig 3. Deformation Monitoring of Industrial Facilities

**Conclusion.** The platform for monitoring deformations in industrial facilities is an important scientific and practical solution that allows digitizing geodetic observation processes, consolidating measurement data in a single system, and automatically detecting dangerous changes. Through the platform, a 3D model of the facility, control points, tacheometric, leveling, and GNSS RTK measurements, deformation tables, graphs, device status, and warnings are displayed in a single control window. This serves to increase the technical safety of industrial facilities, speed up monitoring, and improve the quality of decision-making. The analyzed platform is considered an effective digital tool for early detection of deformations in industrial facilities, identification of points exceeding the regulatory limit, monitoring changes over time, and timely implementation of safety measures.

## References



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