Experience from using the HYNI automated hydrostatic measuring system for monitoring movement at the 1000 MW Temelín nuclear power station in the Czech Republic.

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Introduction

The issue of monitoring shifts (vertical deformation) of buildings is addressed by Czech technical standards CSN 73 0405 on "Measuring Shifts of Construction Objects" and "CSN 73 1001 Building Foundations, Foundation Soil under Areal Foundations". These standards describe measurements of location and shape (shift and deformation) of buildings and their parts relative to the position and shape in the initial stage of measurement caused by changes in the foundation soil material under the object, or in its vicinity due to construction or other activity, the effect of static, dynamic or seismic strain or other factors. The CSN 73 0405 standard deals with all building types, for which specific legislation does not apply. It does not apply to measurements done:

1. during load tests of building constructions,
2. for land subsidence and landslides,
3. for deviations of geometric parameters of actual completion of buildings during construction which are determined during the inspection accuracy by other CSN standards.

1. Purpose of Shift Measurements

The purpose of measuring the shifts is to:

1. Obtain documentation for the assessment of behavior of the foundation soil and he effect of construction of nearby objects,
2. comparison of actual shift magnitudes to predicted values, calculated in as part of the construction project,
3. monitoring of the state, functions and security of new constructions and existing buildings affected by construction activity in their vicinity.

Building shifts are measured during their construction and after its completion if:

1. shifts can be significant for safety and the use of the built object or facility
2. unusual or new structures, for example are used; e.g., foundations of the turbine plate for turbines of 100 MW output and above (CSN 73 1020),
3. high-rise objects are built with a height greater than 50 m (e.g., a dam wall),
4. built object are sensitive to the effects of shifts or are founded in adverse geological conditions,
5. objects are constructed on a previously undermined area (CSN 73 0039) and this measurement corresponds to the significance of the object.

It is necessary to establish a measurement project for each structure, whose shifts are to be measured, specifying the purpose and means of measurement, expected magnitudes of shifts, measurement accuracy with prior analysis, method of point stabilization and measurement time frame.

Construction of the Temelín nuclear power plant represents a unique technical undertaking with the use of new technological procedures, advanced construction methods and construction technologies. The main production block of the power plant consists of the reactor building (ground plan 68 x 68 m, height 66 m), engine house (128 x 49 x 49 m) distribution facility (98 x 22 x 23 m) and the exchange station (48 x 17 x 26 m). The engine house is a single-nave steel hall where the turbo engine aggregate and related service equipment of this non-nuclear part of the power plant. The building structure is divided into these parts:

1. base plate, - a reinforced concrete structure measuring 61,1 x 16,4 x 2,7 m,
2. reinforced concrete structure formed by the 2 x 8 pillars fixed in the base plate at -5.1 m connected in the upper parts by stringers and crosspieces. Stringers have 86 vibration isolators installed at the pillar locations at the +10.95m level and GERB 26 viscose absorbers (flexible mounting system enabling horizontal adjustment of the turbo engine aggregate).
3. Turbogenerator upper foundation plate at the +15m level. This reinforced concrete plate has built-in anchor elements and outer dimensions of 60 x 16 x 3.5m.

2. Measurement Accuracy

The accuracy of building shift measurements of shifts is defined by the deviation threshold value for determination of the length of the resulting shift vector, or its elements. The deviation threshold value, unless stated otherwise, is determined as:

$$\delta_1 \leq 2/15\ p. \qquad (1)$$

where p is the expected total shift or its component in mm.

The deviation threshold value for a device with increased requirement for stability, reliability, safety and operation economy, the δ_1 is reduced by 1/3, unless determined differently by the designer. The threshold deviation value of shift measurements of used building facilities, affected by construction activities in the vicinity, should not exceed the value of:

$$\delta_2 \leq 2/15\ p_k. \qquad (2)$$

where p_k is the critical shift value in mm. If reached, safety of the monitored object is threatened.

3. Stationary automated hydrostatic measuring system

Requirements on the stability of accuracy measurements (in height terms) of the technological facility and buildings hosting the engine aggregates, and turbogenerator of 500 MW and 1000 MW outputs and the foundation plate of the reactor room, were incorporated in the development of the HYNI and INVA sensors by the Research Institute of Geodesy, Topography and Cartography, in cooperation with other institutions. The measurement accuracy of these sensors is stated as standard deviation of elevation measurements a part of the system aggregate accuracy of the entire measuring system (up to the distance of 100 m) $\delta \leq \pm 0.05$ mm.

Fig. 1 – Compled HYNI sensors

The stationary hydrostatic measuring system consists of hydrostatic sensors HYNI which are connected by hoses filled with liquid and data transmission cables power supply. The number of sensors in a measuring system is determined by the requirements of the case with up-to the maximum of 126 sensors used the measuring system. Due to possible measurement of vertical shifts at different height levels, it is possible to include the INVA sensors which enable connecting different levels and it is possible to continuously monitor distance changes of these interconnected levels. Evaluation of individual shifts is automated using the established reference points and on the basis analysis of the measured data, even height stability of reference points is assessed.

An important characteristic of the measuring system is its ability of acquiring continuous measurements without operator intervention. Data collection takes place in previously specified time intervals and measured values can be viewed at any time while the automated measurement programme is running.

Technical parameters of the sensor:
Sensor dimensions: width 205 mm,
height 275 mm, depth 275 mm
Screws for the input of fluid and air: 1/2

Weight:	13kg
Power supply:	18–30 Vss, 0,5 A
Measuring range:	10-90 mm
Communication:	RS 485
	double-wire circuitry

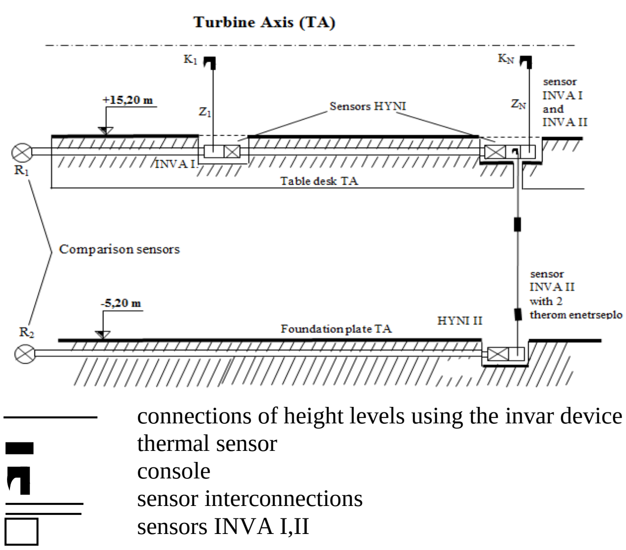

Fig. 2 – Connection scheme of sensor HYNI and INVA in height terms at TA

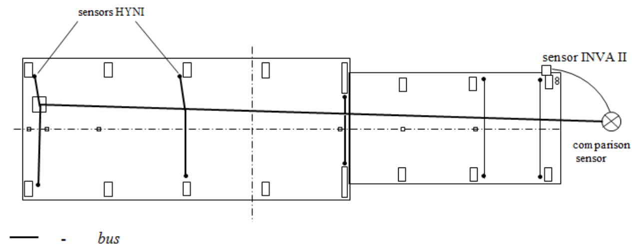

Fig. 3 – The HYNI system at the – 5,20 m level at the engine house (plan view)

Fig. 4 – Side view on the TA from the side of the exciter. Connection between sensors INVA to HYNI

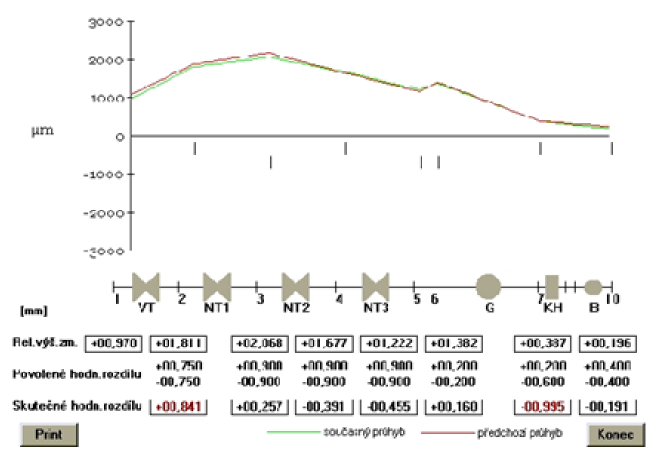

Fig. 5 – The sag curve of the TA

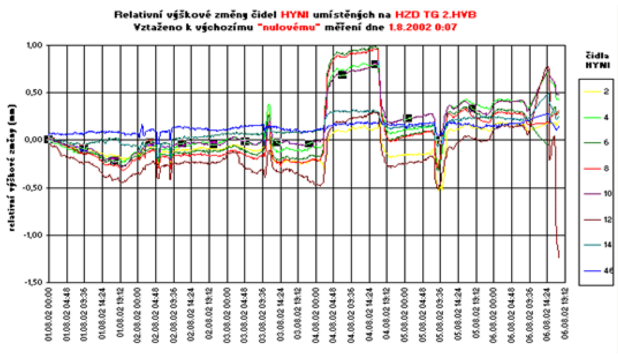

Fig. 6 – Recorded height deformations during discharge and recharge of condensers

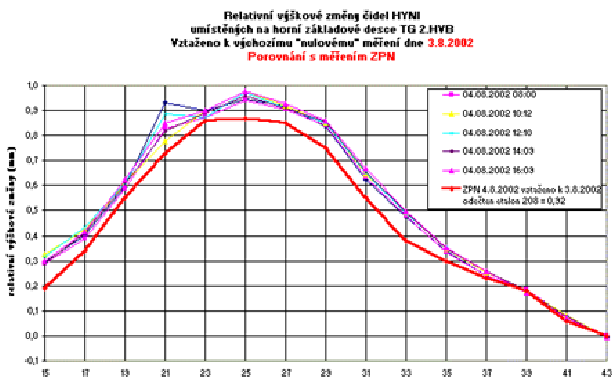

Fig. 7 – Comparing the results of measurement system HYNI and very accurate leveling

4. Conclusion

Results of measurements are used for a planned and efficient maintenance while providing evidence to enhance the security and reliability of the turbo engine and extension of its service life. Measured results of the development of the deformation of the bottom foundation plate shows that the magnitude of deformation does not exceed 20% of the criteria of the CSN 73 1020. Deformations of the upper foundation plate reach, in comparison with the relevant criteria, a maximum of 70% of their value, and a substantial part of the established magnitude of deformation of the upper foundation plate is mainly caused by the change of the temperature field base – TG.

Literature Cited

[1] ČSN 73 0405 Measurement of shift of building objects.

[2] ČSN 73 1001 Foundation of buildings. Base soil under areal foundations.

[3] ČSN 73 1020 Basics of design of torque machines.

[4] ČSN 73 0039 Designing of objects in an undermined area – Basic rules.