Tsunami earthquake detected in the nuclear power plant

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Abstract. *This paper informs about rare case of the remote earthquake detection in nuclear power plant Jaslovské Bohunice with nuclear reactor shaft tilt measuring system. It brings a graphical presentation of reactor shaft movements detected on 26.12.2004 together with comment and recommendation to future activity.*

Keywords: Tsunami earthquake, hydrostatic sensor, pendametric sensor, nuclear power plant

1. Introduction

During the Christmas holidays in 2004, the hydrostatic and pendametric sensors used in the systems used for the nuclear reactors tilt measurement recorded a weak movements of the reactors objects in nuclear power plant Jaslovské Bohunice.
Improvement of the nuclear power plant running safety was the reason for research and development of the nuclear reactors tilt measuring devices. Since 1985 a whole family of measuring devices and methods has arisen; subsequently, they were checked in the framework of several research projects.

2. Measuring methods and systems

Tilt measuring systems running in the mentioned power plant use methods of hydrolevelling and pendametry with unified optoelectronic measuring of hydrostatic liquid level and damped pendulum wire respectively. In contrast with classical levelling method, which allows to measure this parameter only during the reactor shut- down state, the measuring principles and methods applied allow for a practically continuous measuring of the reactor tilt vector.

A schematic diagram of the reactor tilt measuring system is shown in Fig. 1.
Hydrolevelling is a well known levelling method, and in connection with the application of optoelectronics and microprocessors has some advantages to purely optical methods. A minimum of three hydrolevelling sensors are necessary in order to measure reactor shaft tilt vector.

Three hydrolevelling sensors, developed and made at the Institute of Measurement Science, Slovak Academy of Sciences [1,2,3], were used for reactor tilt vector measurement. The optoelectronic sensor (Fig.2.) in system of connected vessels consists of a flat window cell made of a metal frame with optical glass and an optoelectronic system for hydrostatic liquid level measurement. This optoelectronic part is based on a CCD line image sensor. The sensors are interconnected by hydraulic and pneumatic pipes. This system of connected vessels is also interconnected with power supply and via communication cables with the central industrial computer. Liquid temperature in sensors is measured by means of thermometers built in the sensors. This temperature is used for measured data correction influenced by liquid

temperature dilatation. The liquid levels in individual vessels lie in one horizontal plane when certain physical conditions are fulfilled. This plane can then serve as the reference plane for the height differences (elevations) between the individual points' measurement. The range of height difference measurement is ±10 mm, measuring precision is 0,01 mm.
The pendametric method uses the properties of a vertically damped pendulum. Its hinging point is connected to the measured object. The position of the pendulum wire is measured biaxially in a reference plane which is usually horizontal. The wire's position in the reference plane and its length determines the reactor shaft tilt. The optoelectronic method is used for this position measurement such as in the hydrolevelling method. Such measurement unification simplifies the whole measuring system.

Although one biaxial pendametric sensor (Fig.3.) is sufficient for tilt vector measurement, into measuring system incorporates two pendametric sensors as a purpose-built redundancy.
Interconnection by power supply and standard RS 422 communication cables are also common for hydro-levelling sensors. The measuring range of the pendameter wire position is ±2 mm in both coordinate axes; the resolution is 0,001 mm.
Fig.4. shows the both hydrolevelling and pendametric sensors installed on the reactor shaft.

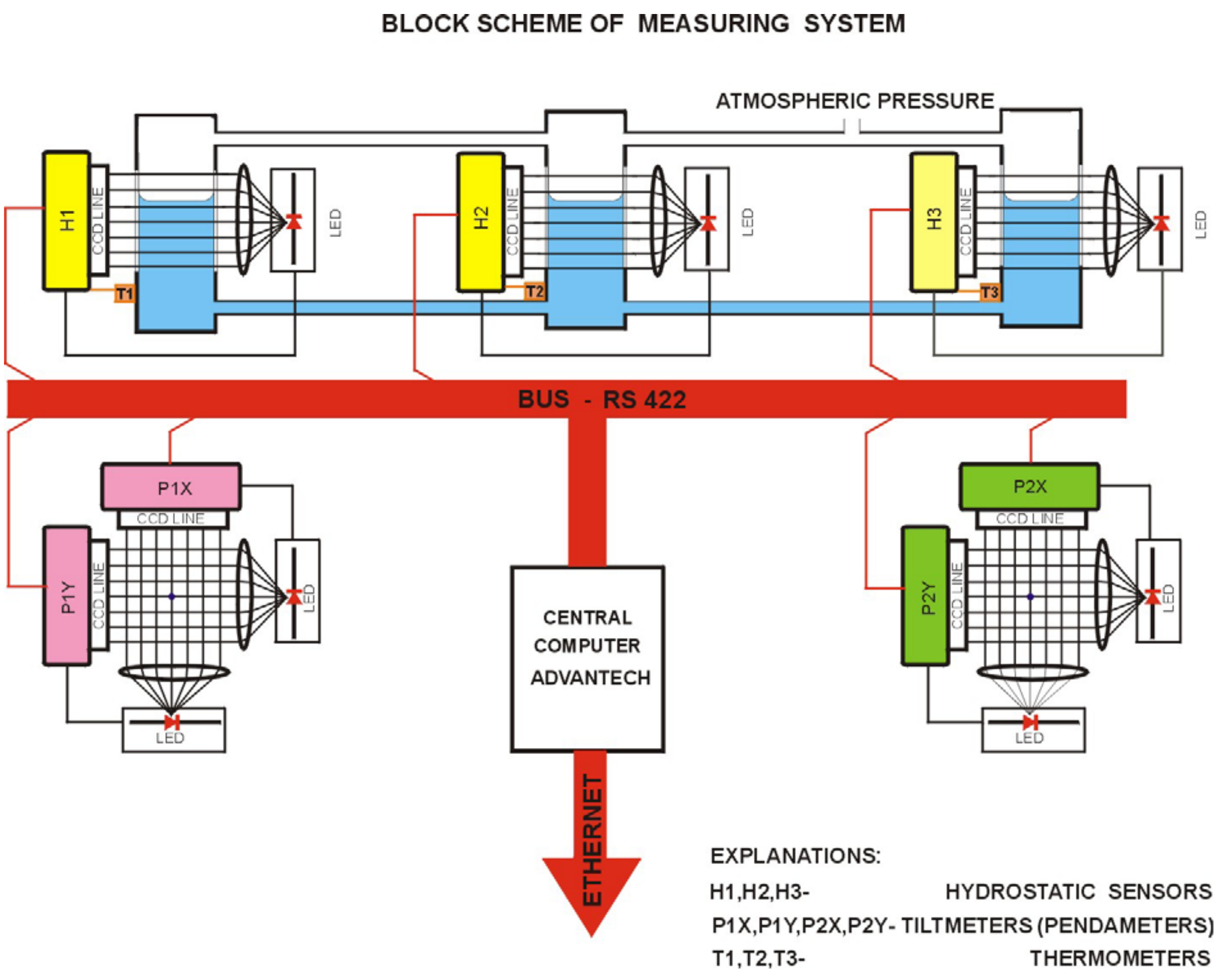

Fig.1. Block scheme of the measuring system

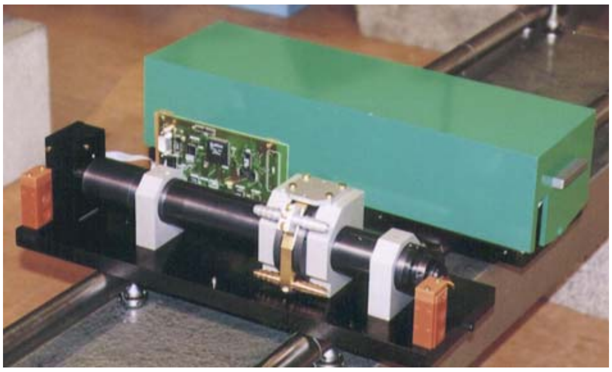

Fig. 2. Hydrolevelling sensor

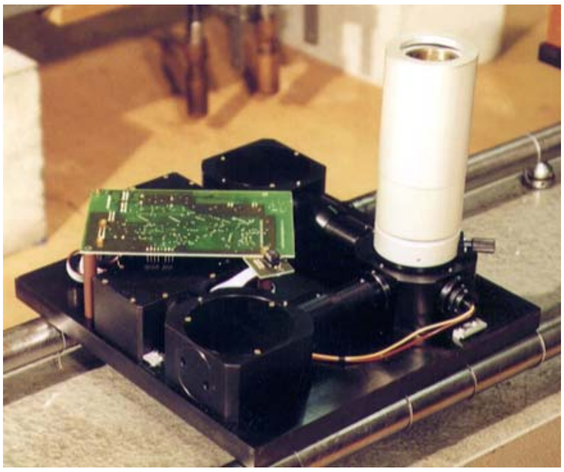

Fig. 3. Pendametric sensor

Fig . 4. The installation of hydrolevelling and pendametric sensors on the reactor shaft.

The topology of the three hydro-levelling sensors located on the reactor shaft perimeter allows to measure its tilt vector in the power plant coordinate system. All sensors are fixed in the ferro-concrete reactor shaft body with special rods without damaging the reactor's hermetic zone.

Central IPC allows for a user-friendly presentation and archivation (storage) of measured data. The measurement regime, including the measuring (sampling) interval, may be programmed according to user's requirements.

3. Results

The signals recorded by the measuring systems [3] are depicted on the Figure 5. The Figure shows two perturbations: the first, on 23rd December starting at 15.40 GMT and the second on

26th December at 01.20 GMT. Figure 6 shows a more detailed part of measurements dated 26th December, 2004. Two upper records were detected with pendametric sensors, the lower one with the smaller amplitude by the hydrolevelling sensors. The time and shape of mentioned readings are influenced by the sampling period, which was about 5 min., as the measuring system is designed for quasistatic tilt measurement.

An analysis of these unusual measurements raised the question of whether or not they were connected with the earthquake off the Indonesian coast that gave rise to the devastating tsunami.

4. Discussion

Our colleague from the Geophysical Institute, Slovak Academy of Sciences were contacted and they confirmed that the earthquake off the coast of Sumatra, with measured magnitude 9,0 was indeed responsible for the noticeable peaks recorded in the power plant. This earthquake was detected also in Czech and Polish seismic stations.

In spite of that the tilt measuring apparatus is not designated for measurement of the fast changes in the reactor's position, the nature of seismic waves in this case allowed detection of these earthquakes. The accelerometers serve to this purpose but seismic waves frequency was out of accelerometers' frequency range.

5. Conclusions

In terms of safe operation of the power plant, the fact that the reactors' position after the earthquake was the same as before is important. Although reactor's movements were real-valued, with amplitude of 0,1 mm p-p on the reactor pressure vessel flange, no other apparatus registered these movements.

For more precise and credible dynamic measurements it would be necessary to increase the measurements' frequency and synchronise local power plant time with GMT.

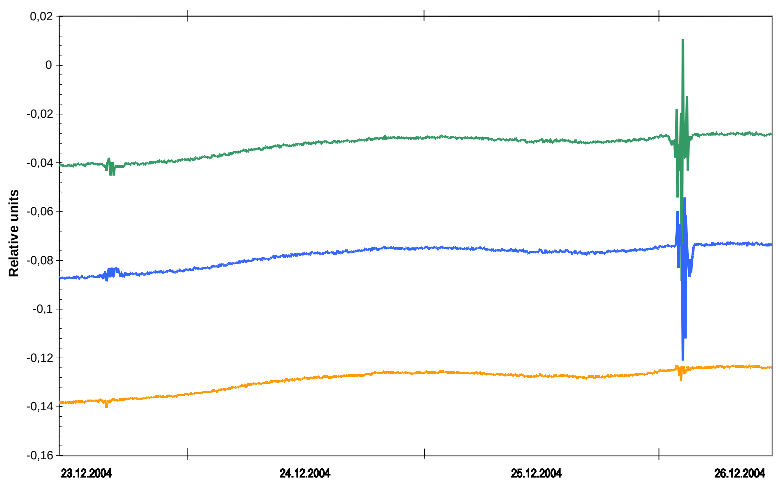

Fig.5. Records of hydrolevelling (orange line) and two pendametric subsystems (green and blue lines) from 23rd – 26th December, 2004. The large perturbation corresponds to the Sumatra earthquake, the smaller perturbation corresponds to earthquake between Australia and Antarctica.

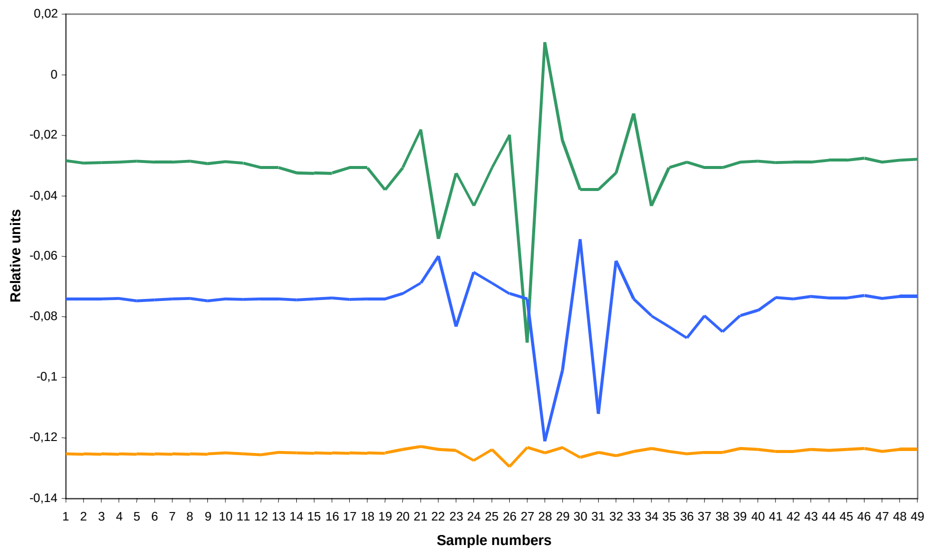

Fig.6. Spread records from 26 th December, 2004 for all three subsystems marked as in Fig.5.

Acknowledgement

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