Geodetic Precise Measurements of Directions with Extremely Short Lines of Sight

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Abstract

During the revitalization aggregates on hydropower plant and shipping sysytem »Djerdap 1« upon a Danube the need for precise measurements appeared. For realization this requirements it was necessary to perform geodetic measurements in extremely tight area. As a consequence it was necessary to use theodolite which has possibility to measure on short distances. Extremely short line of sight is considered the line of sight shorter than standard lenghts i.e. shorter than 1.8 m.

Key words: precise measurements, extremely short line of sight

1 INTRODUCTION

Hydropower plant and shopping system "DJerdap 1" upon a Danube is in the middle of revitalization process. During the process of revitalization some sophisticated activities are undertaken for operation of system improvement. During these activities the need for geodetic measurements constantly exists. The requirements of accuracy are often extreme and the conditions for performing measurements are extreme too (Nestorović et al., 2011). The extreme conditions usually means that measurements shall be performed in tight area, that time interval for providing measurement is often limited and short, that vibrations exist, that other people working simultaneously in the same area, poor light etc. Figure 1 shows the panoramic view of "DJerdap 1" upon a Danube.

Figure 1 Panoramic view on HPPSS „Djerdap 1“

In this paper the determination of dimensions of connection between shaft and rotor of aggregate is described and obtained results are given. The used method of measurement is also described.

2 DESCRIPTION OF THE TASK

The rotor is one of the crucial parts of aggregate both of its role in generating electrical power and its mass which is almost 700 t. That fact has a consequence in very high requirements in fulfilment geometrical relationships between it and other connected parts especially the shaft. This is very important because if it is not, the forces which appear during the operation (rotation) could damage the aggregate. The figure 2 shows the rotor in his position.

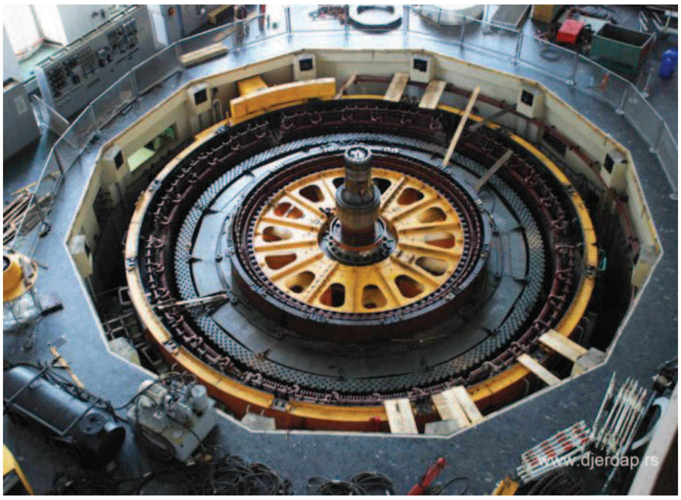

Figure 2 The rotor in its position in aggregate

In this paper the focus is on the connection between the rotor and shaft which is on the bottom of the rotor and which could be seen on fig. 3. The connection is smallest circle on the bottom of the rotor.

Figure 3 The rotor during its transport

The main characteristic of the connection is that its diameter is smaller than 2 m and measurements, because of efficiency must be performed from inside of it. Because of the importance of connection the geometry is to be determined in 40 points and with as high as possible accuracy.

3 MEASUREMENTS AND RESULTS

Because of very high requirements of needed accuracy for determining the geometry of connection (higher than it is possible to measure with total stations) the intersection method was chosen for determining the coordinates of connection. The scale was provided by precise levelling rod which was calibrated i accredited laboratory. Also because of short lines of sight it was necessary to choose the appropriate theodolite which allows visibility of points with extremely short lines of sight even smaller than 0.5 m. Figure 4 shows the conditions, under which the measurements, for determining the geometry of confection between rotor and shaft, were performed.

Figure 4 The conditions for measurements

The measurements were performed by using the motorized theodolite which has standard $\sigma_d = 0''.5$ for directions and possibility of very short sighting. Because of stability the industrial tripod was used. Every point was measured from 5 positions. The coordinate system and scale was provided by two precise levelling rods. On the figure 5 the drawing of geodetic network is shown.

The main characteristics of measurements were:

- Every point was provided with 5 directions (both points on the connection and points on the rods);
- On the levelling rods 9 points were measured;
- It was measured 229 directions;
- Minimal line of sight was 0.5 m, maximum was 1.5 m and average line of sight was 0.94 m;
- Measurement of directions were performed in 2 sets of angles and
- Measurements were performed under poor light.

Adjustment of geodetic networks was done using following least squares model (Ninkov, 1989), (Ninkov, 1989), (Caspary, 1987) and (Pejović, 2005):

$$v = Ax + f \quad (1)$$

With conditions

$$[Pvv] = minimum \quad (2)$$

$$x^T x = minimum \quad (3)$$

Stochastic model is

$$M(\varepsilon_i) = 0, \quad (4)$$

$$M(\varepsilon_i^2) = \sigma^2. \quad (5)$$

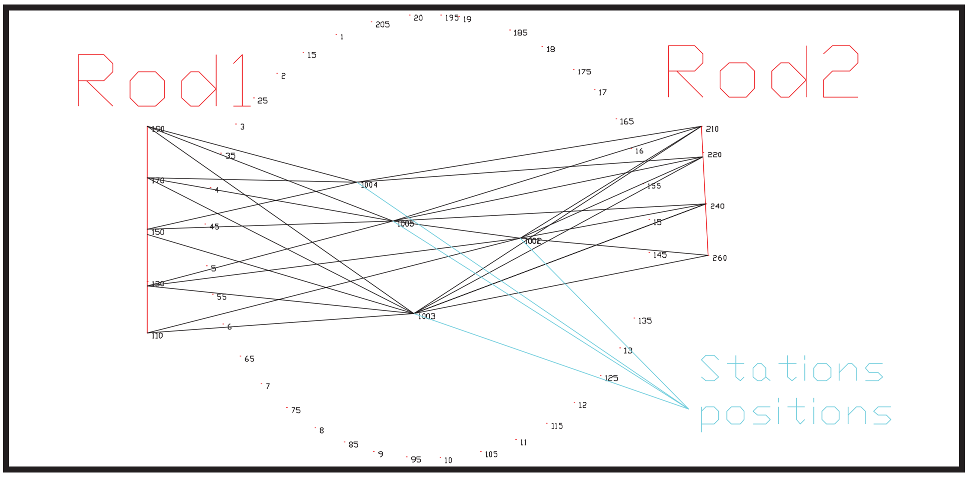

Figure 5 Position of stations points, levelling rods and points of connection

These models were accepted because all points were considered as stable during the measurement process. Gross errors were detected by data snooping method (Caspary, 1987). After data processing the following results were obtained:

- Total number of unknowns in adjustment was 111;
- Maximum semi-axes of error ellipses are: a=0.058 mm and b=0.010 mm;
- Average semi-axes of error ellipses are: a=0.036 mm and b=0.007 mm;
- Minimum semi-axes of error ellipses are: a=0.029 mm and b=0.006 mm;
- Number of degrees of freedom is $f = 129$;
- Unit standard deviation from adjustment is $\sigma_0 = 3''.25$ and
- Only 2 directions were eliminated by data snooping method.

4 CONCLUSION

According the obtained results it is possible to state that intersection method is adequate for highest requirements of accuracy as well as efficiency, in mechanical engineering tasks even in very limited and difficult conditions. Even though the new technologies have been developed (especially laser trackers) it is possible to solve some problems successfully by using classical intersection method and motorized theodolites with possibility for extremely short sighting.

REFERENCES

NESTOROVIĆ, Ž., GOSPAVIĆ, Z., BOŽIĆ, B., DELČEV, S.: Geodetic Networks of Special Purposes in Hydropower Industry, INGEO 2011, Brijuni, Croatia, September 22-24, 2011.

NINKOV, T.: Optimization of Geodetic Networks Projecting, Belgrade, 1989 (Optimizacija projektovanja geodetskih mreža, Naučna knjiga, Beograd, 1989)

CASPARY, W.F.: Concepts of network and deformation analysis, School of surveying, The University of New South Wales, Kensington, N.S.W., Australia,1987

PEROVIĆ, G: Least squares, Faculty of civil engineering, University of Belgrade, 2005.