Automated Geodetic Monitoring Systems in new Hydropower Plants

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Abstract

Large dams are critical infrastructures for water supply and energy generation, in which the early detection of structural problems is a priority to assure dam safety. Integrating hydropower plants, EDP-Energias de Portugal owns more than 50 large dams, almost all of them being concrete structures, and a few rockfill or masonry ones. In order to avoid and prevent structural problems and to fulfil the Portuguese legislation and international recommendations, each of them is monitored by various different and complementary methods, including geodetic ones. These latter methods, in the scope of Precision Topography / Applied Geodesy, are essential to provide the integration of point sets, not only representing the main structure but also the surrounding area, inside and outside the influence zone. Therefore, the Geodetic Monitoring Methods, being able to quantify both relative and absolute displacements, and being independent from the other observation instruments/methodologies, provide a way of relating them all, mutually evaluating and validating each other. Given the recent technological developments, the current challenge for the near future is to look for innovation that will bring higher efficiency and increased reliability, always based in the best cost-benefit ratio. Not only for the design of the newborn geodetic systems in implementation for the newly constructed dams, but also for the systems already in exploitation. After the conclusion of the new Hydropower Plants of Baixo Sabor (with two dams) and Foz Tua, all the three dams are outfitted with Geodetic Monitoring Systems, in which the implementation has been a good opportunity to tackle new challenges and to move forward in reliability, economy and robustness.

Key words: Geodetic Monitoring Systems, Structural behaviour and dam safety, Precision Topography, Applied Geodesy, Quantifying horizontal and vertical displacements, Geodetic measurements, Geodetic surveys, Geodetic observations / observables, Dam monitoring.

1 INTRODUCTION

Approaching the end of the construction recently achieved, each of the three new dams was provided with a tailor-made Geodetic Monitoring System: Baixo Sabor Upstream (BSU), Baixo Sabor Downstream (BSD) and Foz Tua (FT). Geographically located at the north-eastern continental Portugal, at the end section of two tributaries of the right embankment of the Douro River, the greatest drainage basin in the Iberian Peninsula, they increase the number of EDP dams monitored by geodetic methods to more than fifty.

Those new systems reflect a very important technological modernization, allowing, for the first time in Portuguese dams, an automatic, remote and continuous geodetic monitoring. Thus providing, in almost real time, the quantification of the precise absolute displacements of the structural points chosen to represent the dam behaviour, named Object Points (OP).

2 BAIXO SABOR

The geodetic monitoring system implemented on the Baixo Sabor Hydropower Project is a technological breakthrough and a major achievement compared to the past. For the first time in Portugal, a dam is continuously observed by methods of spatial geodesy through the use of Global Navigation Satellite System (GNSS). In each of the two dams were materialized three Object Points (OP) by GNSS antennas (*Fig. 1*) and a reference station outside the influence area of the project (*Fig. 2*), with good foundations, excellent spatial visibility and (located/situated) less than one kilometre (far) from the monitoring structure. Based on differential GPS (DGPS) techniques, the reference station enables the correction of the continuous spatial observations of the dam's OP. Thus, the displacements are quantified as absolute values, with adjustable observation intervals, where the 24 hour solutions provide displacements with submillimeter horizontal tendencies and millimeter measurement accuracy at vertical component.

Fig. 1 Object Point at Baixo Sabor Upstream dam

The high frequency observations supplied by this solution, gives the possibility to configure alarm scenarios that enable the early detection of an anomalous behaviour of the structure.

Fig. 2 Reference Station at Baixo Sabor Upstream dam

This GNSS monitoring project integrates a broader project of Automated Data Collection, with the scientific cooperation of LNEC (National Laboratory for Civil Engineering) and LEICA (equipment provider), became operational in May 2016.

It is important to note that the implemented geodetic systems in use also includes geodetic high precision EDM traverses at the inspection galleries and precise leveling lines (inspection galleries and crest).

3 FOZ TUA

Even though based on a different technique, the Foz Tua Hydropower Plant has been given the most recent innovation in the specific field of geodetic monitoring systems applied to EDP dams. It is an automatic and continuous three-dimensional geodetic monitoring solution, composed of 25 OP on the downstream face of the dam (Fig. 3).

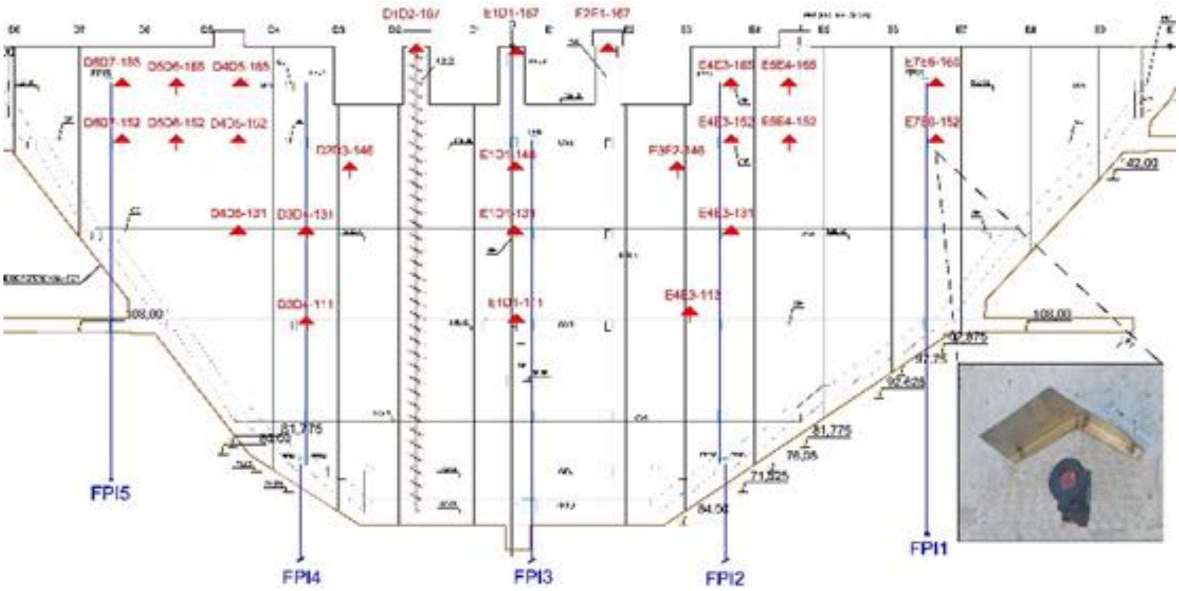

Fig. 3 Object Points at Foz Tua dam

These OP, materialized by reflector prisms, are observed from a robotic total station (RTS) at a dedicated survey pillar, PEJ (Fig. 4), whose stability is controlled by four stable reference points installed on the downstream slopes of the valley.

Fig. 4 Robotic Total Station on dedicated survey pillar

This automatic deformation monitoring system, in operation since May 2016, is configured to read the OP with an hourly frequency, the displacements being calculated both in horizontal and vertical components. These displacements are quantified with respect to a reference epoch - which defines the reference frame - and where the network points (both reference and

object) are, for the first time, computed in coordinates using suitably selected measurements, actually referring to the date of 21 September 2016.
This monitoring system allows the publication of automatic reports, weekly sent to a specialized group of technicians, including structural analysts. It is also possible to access online to the acquired measurements, or request a non-scheduled observation, from a webpage that delivers almost real time updates.

The comparison between the radial and tangential displacements resulting from this system and the values stemming from the Inverted Pendulums (IP), when referring to points on the same construction block and similar heights, reveals a strong correlation (Fig. 5). This proves the reliability of this monitoring system, that when referring to the horizontal component, presents a submillimeter accuracy of the quantified displacements.

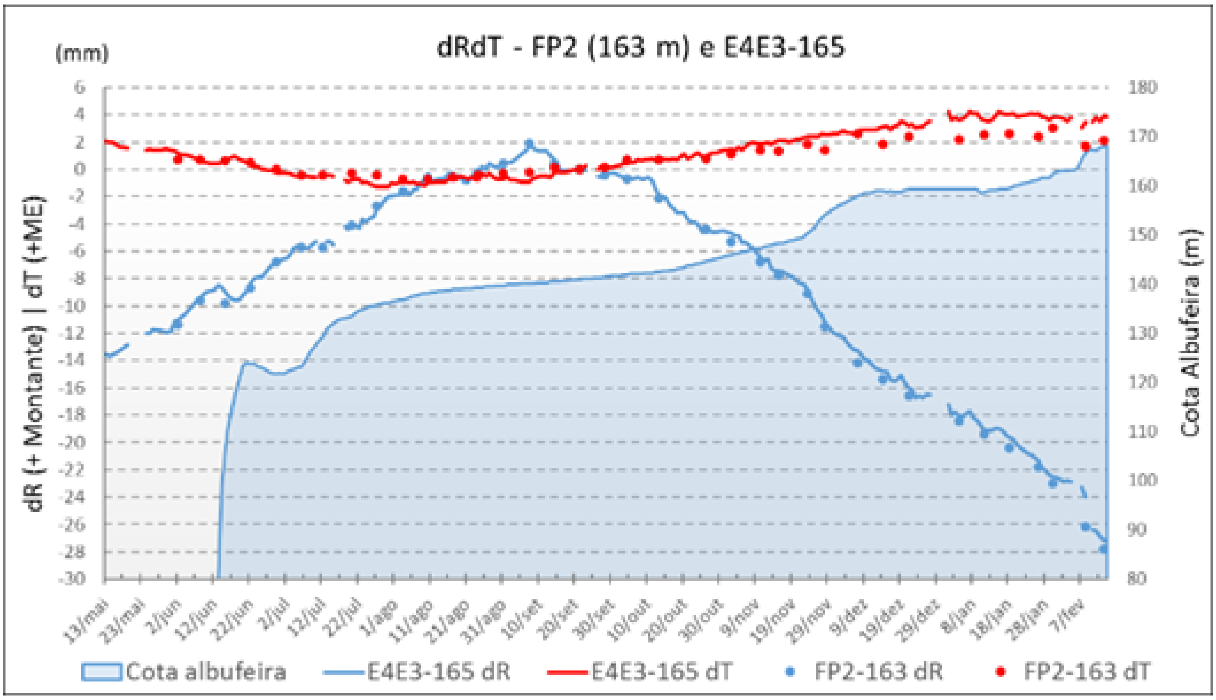

Fig. 5 Comparison between Geodetic vs Pendulum deformations

In addition, it is also an advantage of this technology to quantify the vertical component with a millimeter accuracy. This is only possible because of the high repeatability in this surveying continuous technique, which, in practice, results in a very large number of observations. And this is a relevant innovation in EDP dams, as it is the only case in which a vertical component is not observed by means of precision spirit leveling, a slow and labor-intensive geodetic technology.

In Foz Tua dam, as in Baixo Sabor, there are other geodetic technologies in use for the deformation monitoring systems, as precision traversing and differential leveling.

4 CONCLUSIONS

These new automatic systems, in addition to enable a continuous and remote follow-up of the dam behaviour, present high reliability mainly due to the observation frequency they deliver. These advantages give confidence in the analysis of the deformations, ensuring valuable results which are nowadays of utmost importance, namely when considering such a critical dam's life phase like the first filling of the reservoir.

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