

June 2021

Case study

Strong motion monitoring of the **Angeghakot dam, Armenia**

Case study - Angeghakot dam strong motion monitoring

Introduction

This case study highlights the strong motion instrumentation of the Angeghakot dam reservoir, situated in a high seismic hazard region of Armenia. A seismic monitoring system is installed on the dam for structural monitoring and safety measures. The installation was conducted during Q2-2021 and it is now fully operational.

This specific dam is part of the Vorotan Cascade. A major refurbishment program lasting at least 6 years was undertaken since 2015 in order to modernize the HPP and improve the operational performance, safety, reliability and efficiency of the whole cascade.

SHA - Seismic Hazard Analysis map

The Angeghakot dam is located inside a triangle formed by Yerevan, Tabriz and Baku, refer to Figure 2. In this Caucasus region, a probabilistic map of PGA - Peak Ground Acceleration expected with a 10% exceedance probability in 50 years (return period of 475 years) is computed and displayed.

The PGA is expected to be between 0.2 to 0.3 g in the present dam location.

Vorotan Cascade (ContourGlobal Hydro Cascade) - key facts

Country:	Armenia, Syunik Province
Construction:	Began in 1961
Purpose:	Hydropower and irrigation reservoirs
Owner:	ContourGlobal since 2015
Cascade:	3 Hydro Power Plants (HPP) and 5 reservoirs
Cascade head:	1123 m total
Installed capacity:	404.2 MW, average power generation of 1.15GWh annually

Angeghakot dam reservoir - key facts

Type of dam:	Concrete spillway dam
Height:	23.4 m
Capacity:	3'400'000 m ³
Highest water level:	1'677.4 m a.s.l (above sea level)
Lowest water level:	1'664.5 m a.s.l



Figure 1. Dam location

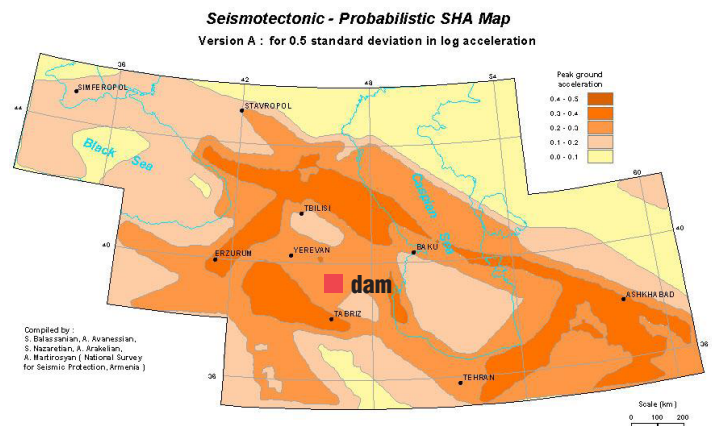


Figure 2. SHA Caucasus map

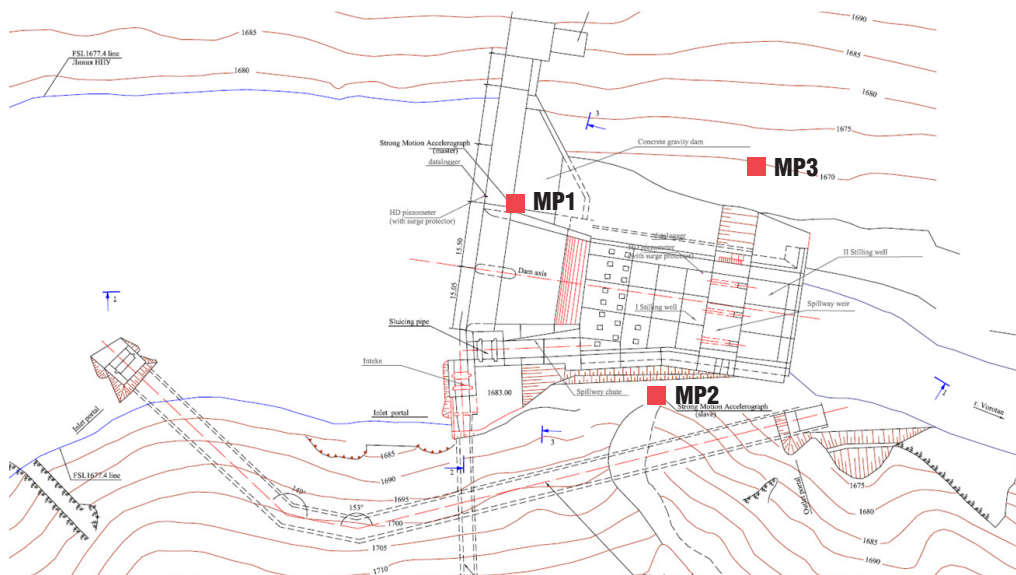


Figure 3: MR3000DMS locations, MP1 master device on-structure, MP2 slave on the rock-structure interaction and MP3 slave as free-field

Monitoring setup

The dam is equipped with 3 SYSCOM MR3000DMS - dam monitoring system for strong motion monitoring. These devices are interconnected and synchronized using fiber optics in a LAN network. The distributed architecture is a key aspect of the instrumentation, providing best reliability, remaining operational in case of network or single component failure.

One of the LAN network purpose is to be able to configure alarm voting logic, typically in a 2oo3 (2 out of 3) logic in this case, enabling highest confidence in alarming raised by the automated system. The voting logic is also key to ensure no false activation of the system in case of spurious event (for example during maintenance), detected by a single device.

The devices are protected against external conditions by cabinets and properly grounded. In order to measure the ground/structure motion without alteration, a concrete pedestal is built on-site, especially for the free-field location, as displayed on Figure 6.

The MPx (Measuring Points) in Figure 3, refers to:

MP1: master device on the dam concrete structure

MP2: slave device on rock soil - structure interaction

MP3: slave device as free field for input motion monitoring



Figure 5. Leveling and sensor orientation (typically one axis of each accelerometer facing the same direction) are important aspect during installation process.



Figure 4. MR3000DMS MP1, master device on-structure, protected by the dam road bridge with a suitable device axis orientation.



Figure 6. Protective housing for MP3 with concrete pad for proper coupling to the ground. The housing is grounded and therefore well protected against lightning.



Figure 7. Downstream view of the Angeghakot dam



Figure 8. Spillway view of the dam

Instrumentation

Syscom MR3000DMS are tailored for the dam structural health monitoring. It integrates in a unique housing all required features of the most advanced and modern accelerographs for best communication capabilities, reliability and ease of installation.

The usage of MEMS sensing technology also achieve the lowest cost of ownership of the monitoring system as it requires no periodic calibration over time. In addition, the MR3000DMS device continuous auto-test features will instantly alert the owner in case of system trouble.

Main characteristics of MR3000DMS devices:

- ± 4 g triaxial acceleration sensor
- 24 bits A/D converters and WebUI for easy setup
- OVP - Over Voltage Protection, type I & II
- Fiber optics communication
- GPS time synchronization
- Industrial cable glands and internal terminals (no additional junction box needed)



Figure 9. Syscom MR3000DMS - dam monitoring system

Refer to MR3000DMS datasheet for the complete specifications

Typical 3 devices wiring diagram, using fiber optics, fully protected against lightning surge, in a star network architecture.

The distributed intelligence system provides the best reliability and the MR3000DMS relays output can automatically and instantly trigger on-site safety actions post earthquake.

The seismic system alarming can be setup based on OBE (Operating Basis Earthquake) and SSE (Safe Shutdown Earthquake) RSP (Response Spectrum).

Wiring diagram

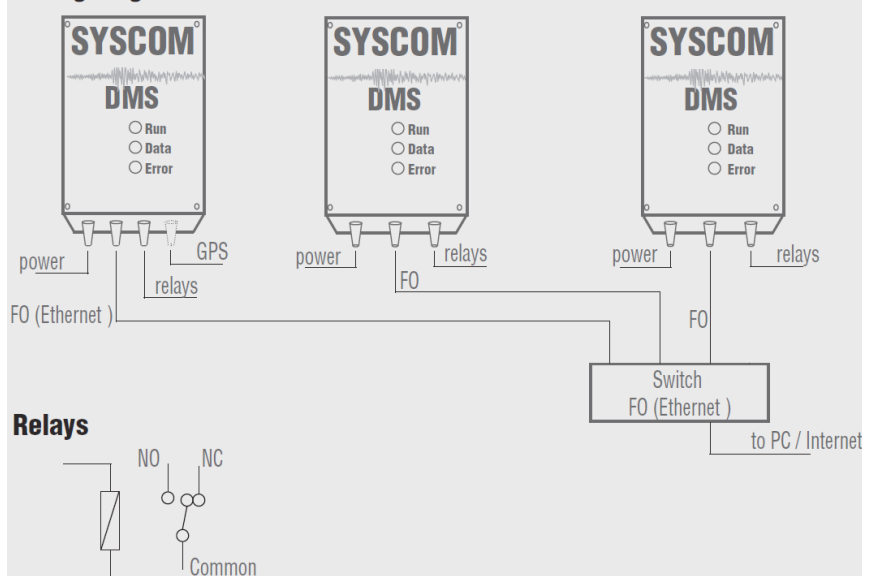


Figure 10. Syscom MR3000DMS - LAN network wiring diagram

Conclusion

The Angeghakot dam, part of the Vorotan Cascade, is now continuously monitored and the structural response of the dam will be recorded during the next earthquake induced ground motions. This will provide critical insights for SHM - Structural Health Monitoring and safety assessment of the reservoir over time.

For more information about the study and the instruments, please contact Hydro Solutions or directly SYSCOM at the contact details below.

We are grateful to our partner Hydro Solutions LLC for allowing us to write this case study.

<http://hydrosolutions.am/>



About SYSCOM

SYSCOM Instruments SA is a subsidiary of BARTEC GROUP, a multinational company that manufactures industrial safety equipment. SYSCOM Instruments SA is a leading supplier of vibration and seismic monitoring equipment for the civil engineering and safety markets, in particular for nuclear power plants and LNG plants. The reputation of SYSCOM Instruments SA is based on the reliability of its products, resulting from a meticulous control of all aspects of design and production.