

Ensuring Dam Safety with the KMIDam Platform



CASE STUDY

Critical infrastructure such as dams must be operational, stable, and in good structural health as they meet the demands of a community or region. However, severe events like earthquakes, floods, or terrorist attacks pose a significant threat to the safety and integrity of these dams.

The consequences of a dam failure can be catastrophic, not only for the regional economy, but also for people living downstream. In addition, gradual damage accumulates due to numerous factors including aging, cyclic environmental loading, debris blockage, overtopping, settlement, and more. Long-term monitoring of these critical structures is indispensable.

In recent years, improved availability of data has enabled engineers to improve their understanding of the impact of earthquakes on dams, especially where related to peak accelerations experienced by these structures. During the 1994 Northridge event (Mw 6.8), the extensive instrumentation installed at the Pacoima dam in Southern California recorded peak acceleration at the crest that exceeded 2g. Until this time, many engineers questioned the validity of this kind of impact.

The evidence collected helped engineers to accept the reality of higher accelerations and re-evaluate design loading for these critical structures. Data from many studies has also had a positive impact on dam safety, as the analysis of data obtained through long-term monitoring has led to the incorporation of water-structure dynamic interaction and generalized damping in Finite Element Models.

It's clear that placing data in the hands of those who need it has a profound effect on dam safety.

Kinematics, the global leader in seismic platforms and instrumentation, is expanding the reach and usefulness of this data by delivering it to those who need it in real-time before, during, and after earthquakes.

KMIDam Enhances Dam Safety

The KMIDam platform integrates smart sensing technology, real-time processing, and predictive computations to ensure the safe and compliant operational continuity of dams. It serves the needs of stakeholders by delivering actionable information at the time and in the format most useful to the decision-maker in question.

- *Immediately helps operators understand the impact of seismic events while eliminating the guesswork to support better-informed decision-making*
- *Highlights gradual changes occurring in the structure so that problems can be rectified before they become costly or result in a serious incident*
- *Monitors and analyzes the impact of reservoirs on the seismicity of surrounding regions*
- *Assists in achieving and maintaining compliance with local regulations*

KMIDam integrates ASPEN technology, Smart IP-ware seismic stations, Real-time data acquisition and processing technology while making use of Commercial off the shelf (COTS) communication and Cloud enterprise grade data centers or on-site servers. This ensures the delivery of high data availability and performance while valuable information is disseminated in real-time through automated reports and alarm alerts.

Four primary modules are outlined below to demonstrate how KMIDam enhances dam safety through integrated actionable information.

- *Reservoir Induced Seismic Monitoring (RIS)*
- *Earthquake Impact Alerts (EIA)*
- *Structural Health and Performance Monitoring (SHPM)*
- *Multi-Asset Command and Control System (CCS)*



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Reservoir Induced Seismic Monitoring (RIS)

KMIDam Reservoir Induced Seismic Monitoring (RIS) provides the ability to monitor the seismicity beneath and around the dam and correlate it to reservoir level variations. The system leverages seismic stations located on the dam and in the surrounding region to provide a comprehensive view of how changing water levels influence regional seismic activity, and helps operators more completely understand the impact to the surrounding region.

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Figure: An example layout of seismic stations for KMIDam RIS.

Due to the multi-asset nature of the KMIDam Platform, RIS data from multiple dams can be monitored via the same data center and intuitive interface.

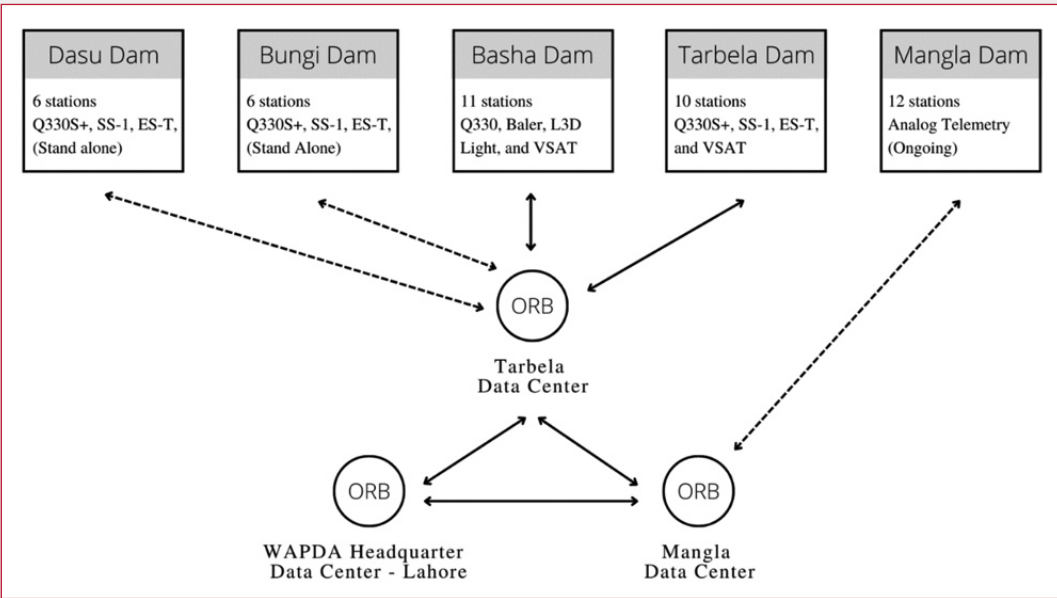


Figure: A multi-reservoir implementation of RIS in Pakistan with data sent to a single concentrated data center.

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Earthquake Impact Alerts (EIA)

The use of reference earthquakes based on site-specific Design Earthquake Spectra is well-established in dam design, as is the correlation of structural damage with Peak Spectral Acceleration (PSA) and Cumulative Absolute Velocity (CAV) during an earthquake.

KMIDam Earthquake Impact Alerts (EIA) enhance emergency response by triggering alarms for damaging ground motion exceedance at the dam site associated with two different predetermined levels of earthquakes: Operating Basis Earthquake (OBE) and Safe Shutdown Earthquake (SSE).

This empowers emergency response leaders by converting strong motion data into actionable information to support immediate informed decision-making during an event. KMIDam EIA maximizes operational continuity since it not only reduces the risk of overreaction, but also guides appropriate emergency response through immediate and accurate information.

A combination of real-time data analysis views and automated reports are used to deliver this timely information to decision-makers just when it is needed most.

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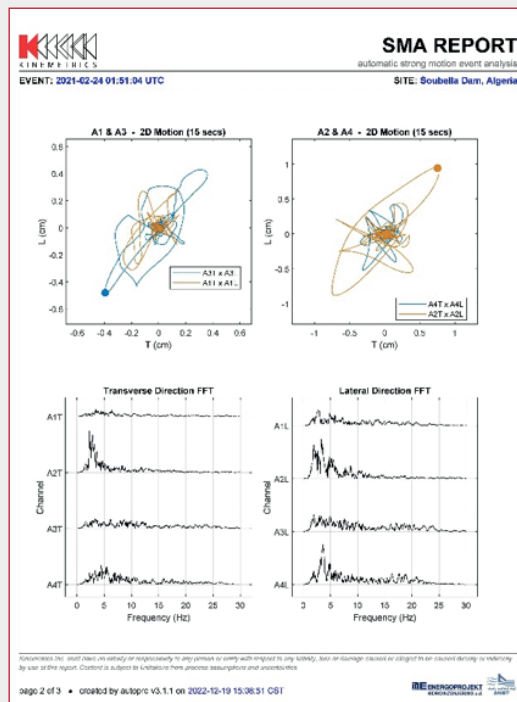
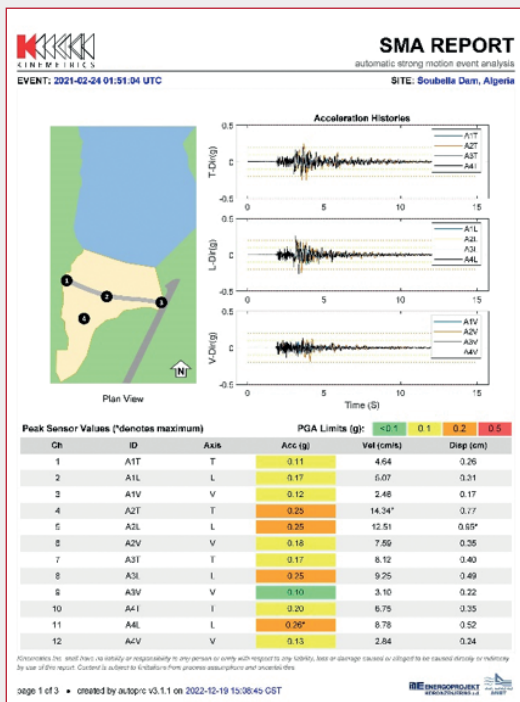
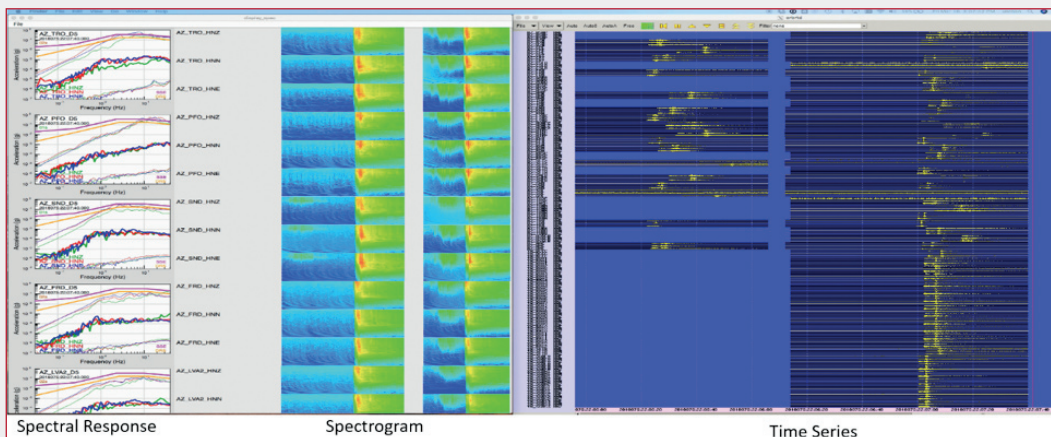


Figure: Examples of Real-time and automated report views.



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Structural Health and Performance Monitoring (SHPM)

KMIDam Structural Health and Performance Monitoring (SHPM) delivers permanent surveillance of structural performance by leveraging comparison of the system identification (natural frequencies and mode shapes) of the dam through the recorded data with finite element modeling results. A digital twin of the real-life structure can also be integrated to continuously update real-time measurements and monitor the static and dynamic response.

KMIDam SHPM provides information on the occurrence, location and severity of structural damage, along with the effects of this damage on structural performance, which has been proven to have a positive effect on decisions relating to continued dam operation.

This ensures increased confidence in dam safety and supports informed decision-making for regular maintenance and emergency situations.

Multi-Asset Command and Control System (CCS)

Operation of critical facilities like a Dam can be difficult, as it involves a variety of systems and sensing technologies that must be operational and continuously monitored. The importance of operational efficiency requires an intuitive and effective multi-asset command and control system.

KMIDam Command and Control System (CCS) is a redundant high-end data center that brings all the functions and tools delivered by the KMIDam Platform under one roof. Highly intuitive tools for monitoring the state-of-health of all the deployed hardware, real-time data acquisition, and software systems are delivered via this robust CCS and can be easily integrated with other existing systems.

KMIDam Delivers a Complete Dam Management Platform

The KMIDam platform delivers relevant, actionable information to the stakeholders who need it most before, during and after earthquakes. This robust dam management platform enhances the safety of dams throughout their entire lifecycle, and is built upon the history of quality, trust, and innovation delivered by Kinemetrics.

Information for this article was sourced from the following:

El-Idrissi M., Saifullah M.K., Ciudad-Real M., Skolnik D., Spassov E. Operations and Dam Safety with the KMIDam Platform; Proceedings of the 10th International Conference on Experimental Vibration Analysis for Civil Engineering Structures, EVACES 2023; Milan, Italy. 30 August – 1 September 2023.

