DEWESoft®

MONITORING APPLICATIONS

CASE STORIES

Construction noise and vibration monitoring

By Rok Mesar, Business Developer, Dewesoft Monitoring Group
Advanced Construction Technology Services (ACTS), United Arab Emirates

CASE STUDY

Construction noise and vibration can be a nuisance to the neighboring community. Most often the builder has to comply with regulations defining threshold levels and limiting working hours. The consulting company ACTS set up a Dewesoft monitoring system during the construction of the large complex of Abu Dhabi Global Market to ensure there was excessive sound or vibration due to the ongoing construction.

Abu Dhabi Global Market (ADGM) is a financial center and a free zone located on Al Maryah Island in the heart of the UAE's capital city, Abu Dhabi. Finalized in 2018 the structure under investigation extending across the entire 114 hectares of the island, now houses an international arbitration hearing center and is part of a large complex of buildings established by the Abu Dhabi Chamber of Commerce in 2013.

According to Abu Dhabi's Environment Health and Safety Management System, any activity resulting in excess noise that can harm the peace of a neighborhood should be undertaken only between 7 am and 8 pm on working days, and between 9 am and 7 pm on weekends and public holidays unless developers have a special license from the municipality.

Noise pollution is defined as the "excessive, upsetting human, animal or machine-created environmental noise that disrupts the activity, balance or harmony of normal life".

In this case, the monitoring was carried out by ACTS, Advanced Construction Technology, Services on behalf of the customer. ACTS provides construction consultancy services specializing in the materials and geoengineering fields. ACTS currently operates throughout the Middle East, Africa, and Southeast Asia, headquartered in Beirut, Lebanon, and with a local office in Dubai.

The project scope was to check if the noise or vibration were excessive due to the ongoing construction. The consulting company set the threshold limits:

- the noise level and
- RMS acceleration value.

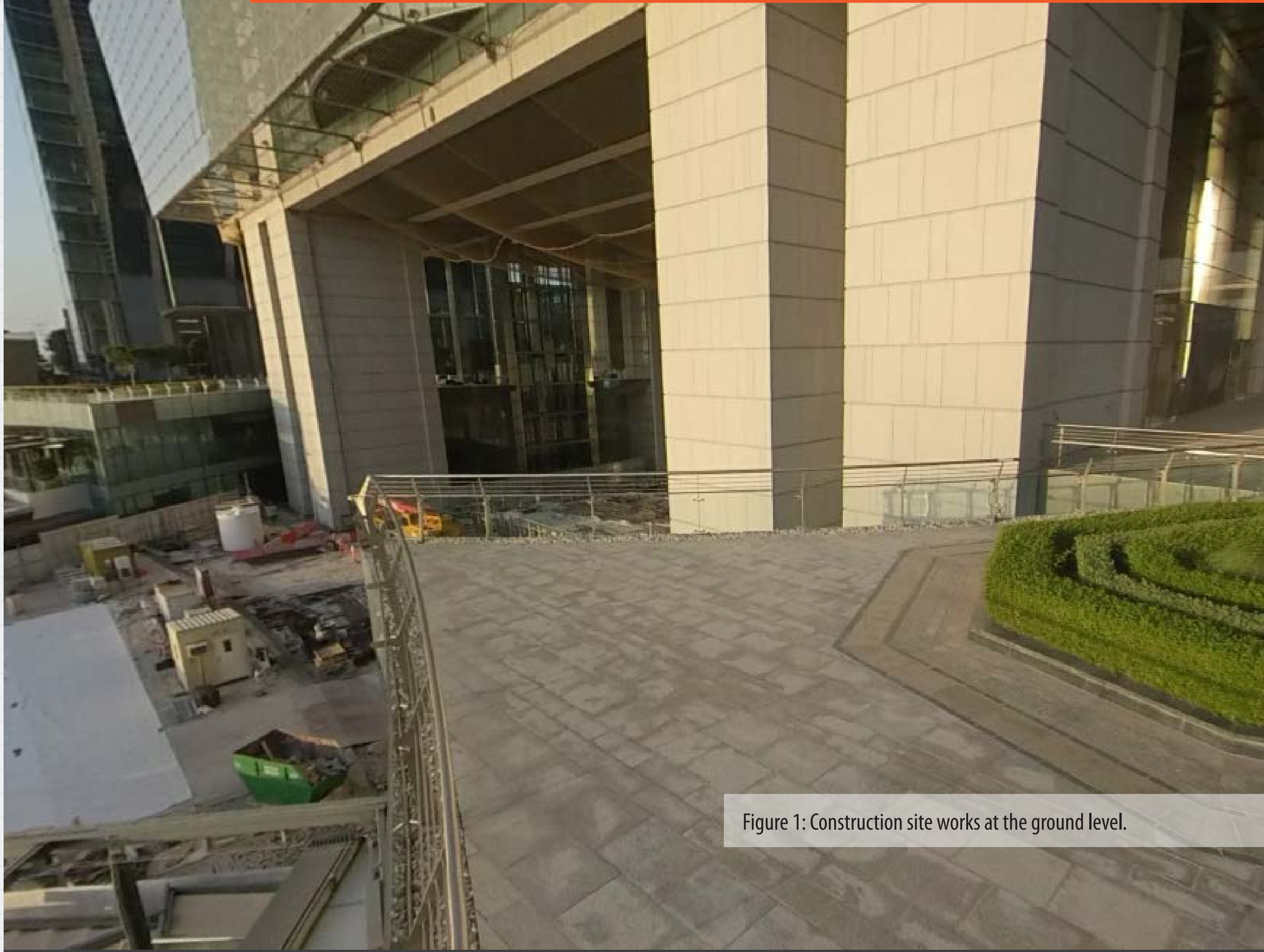


Figure 1: Construction site works at the ground level.

One of the goals was to evaluate the results any time the values passed these limits. This monitoring station enabled them to take initiatives to avoid getting into the high-level zones too often, e.g. by applying dampers or noise barriers.

The below are the threshold that was used during the investigation:

- High Average noise levels in the rating above 90 dBA.
- Moderate Average noise levels are for recorded values between 70dBA and 90 dBA
- Normal Average noise levels are for recorded values below 70dBA.
- The RMS acceleration value limit was set to 80 ug in all directions (X, Y, Z).

Measurement setup

To monitor the structure for vibration and sound levels, a state-of-the-art hardware device system was installed. The system includes the following:

- 1x data logging embedded PC
- 1x 24 V power supply (to power the PC)
- 1x IOLITE Power-Injector
- 1x 48 V power supply (to power the devices)
- 2x IOLITE-1xACC (in aluminium waterproof boxes)
- 4x IOLITEe-3xMEMS-ACC
- 2x GRAS 146AE microphone

To verify whether the ongoing works are affecting the surrounding of the building, the vibration and sound sensors were installed at different locations - see figure 2. The vibration was measured at four reinforced concrete columns while the sound levels were checked for two locations in the surrounding area.

Measurements

The consultants were monitoring the noise using the DAQ system and the microphones as a sound level meter - fulfilling the IEC 61672 requirements for Class I. The parameters measured were:

- LAF peak - the peak the Sound Level with 'A' Frequency weighting and Fast Time weighting, and
- LAF average over 1 min.

In LAF the "L" represents "Level", the sound pressure level. The "A" represents the frequency weighting which indicates that some frequencies within the audio spectrum are given a weighting. The A-weighting is the standard weighting of the audible frequencies - the range from 20Hz to 20kHz - and reflects the sensitivity of the human ear to noise.

The IEC 61672-1 standard on sound level meters describes two time types of weightings, Fast (F) and Slow (S). They both dampen the reaction of the displayed level to a sudden change in the sound level. Fast Time Weighting is generally the time weighting used for environmental noise measurements, where sound varies over time.

The Peak is the maximum pressure level value reached by the sound and is well-suited to measure impulsive sounds.

The vibration parameters used were:

- Root Mean Square value (RMS), and
- Peak-to-Peak (P-P).

The RMS value is the instantaneous value within a certain duration of time and relates to the power of the vibration. The RMS is generally a useful indicator to represent the vibration level in practice as it is directly related to the energy content of the vibration profile and thus the destructive capability of the vibration.

The peak-to-peak value has the benefit of providing the maximum excursion of the wave, which is useful when looking at displacement information.

The construction/demolition works started at around 7 am and were concluded at around 6 pm. The noise monitoring reports - see figure 3 - show that the highest LAF peak noise registered during the monitored period was 99dBA.

Overall, the vibration monitoring system did not detect any significant acceleration levels due to the construction works. However, a small earthquake was noted on the 31st of October 2020 - see figure 5.

Conclusion

The consulting company was very satisfied with the system due to its plug-and-play functionality and ability for automatic report generation for the final customer.

With the help of the DewesoftX software threshold setting tool and notification system by SMS and e-mail, the final customer-managed through proper work planning, maintenance of machinery, the use of acoustic barriers, etc. to conduct the demolition and construction works respecting all the country noise and vibration standards.

The Dewesoft noise and vibration monitoring solution helped the client to finish the project on time without any increase in the project costs due to delays or potential nuisance claims.

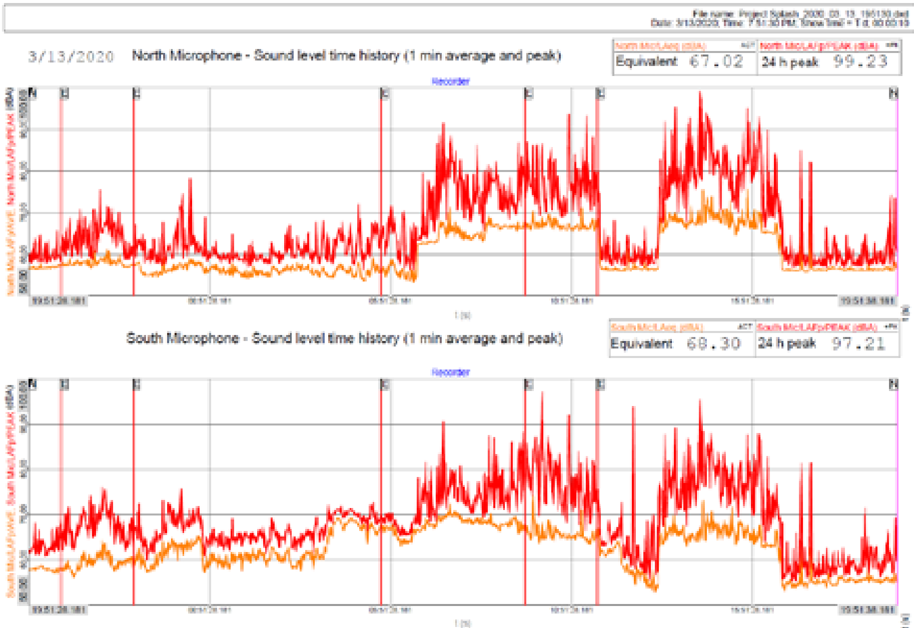


Fig. 3. Sample of the noise monitoring report.

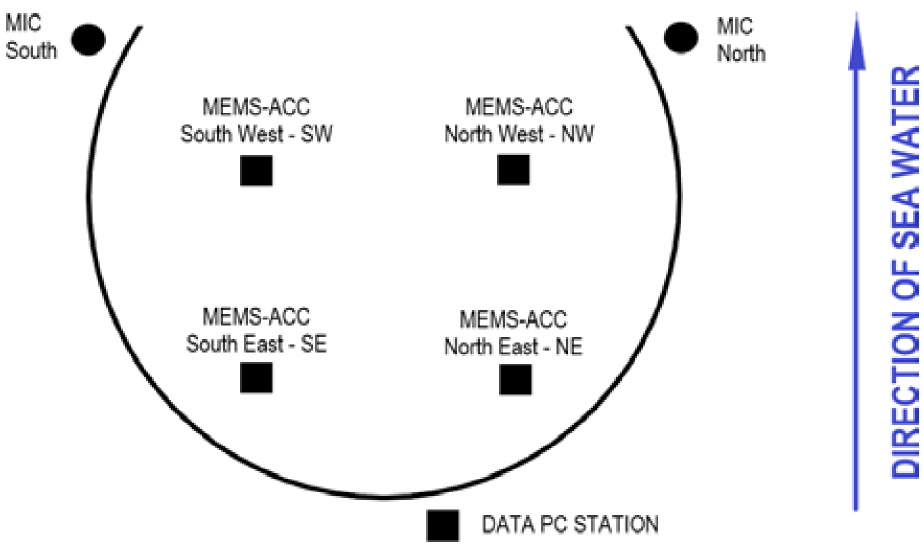


Figure 2. The locations of the sensors installed with their respective IDs.

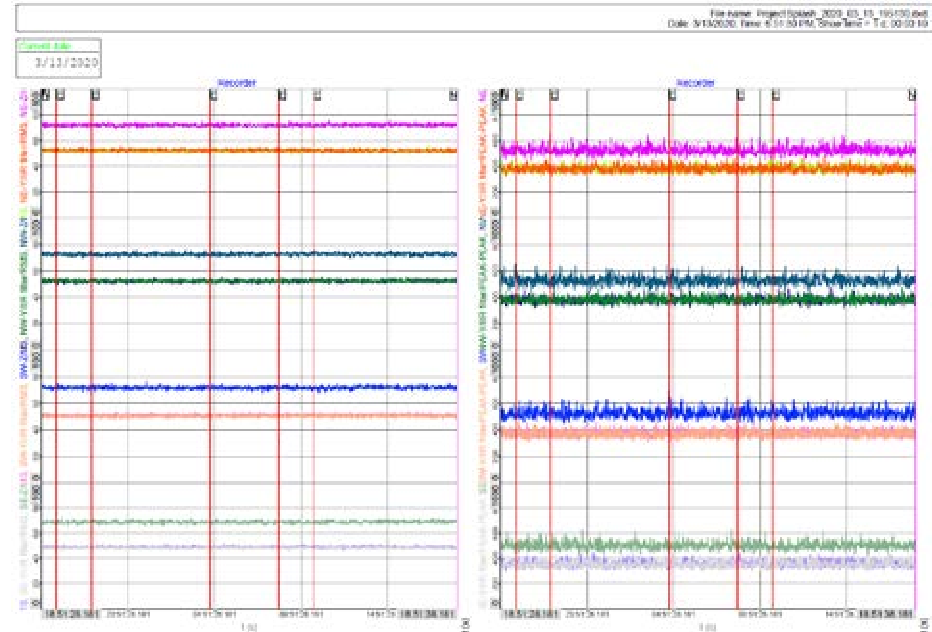


Fig 4. Sample of the vibration monitoring report.

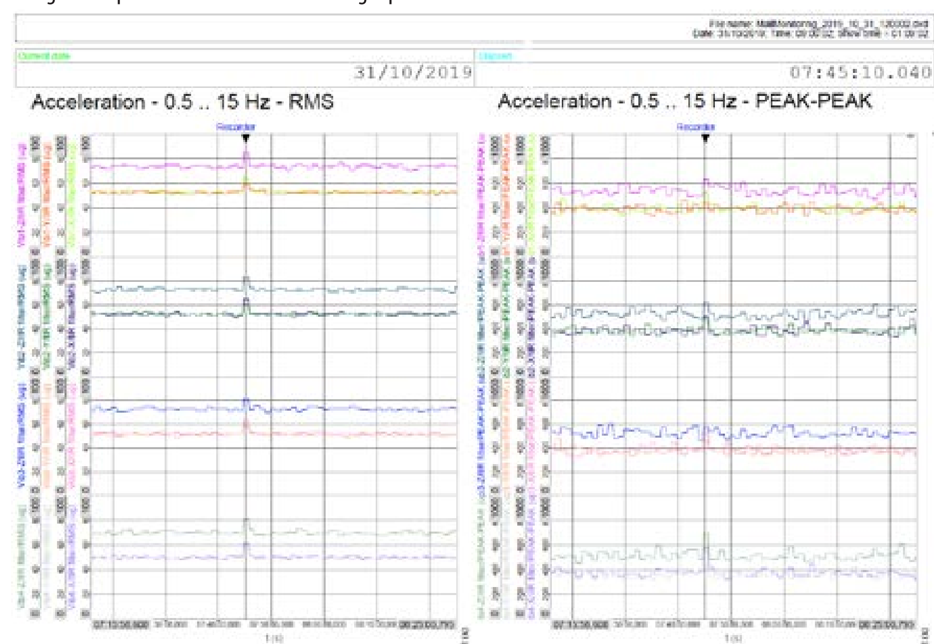
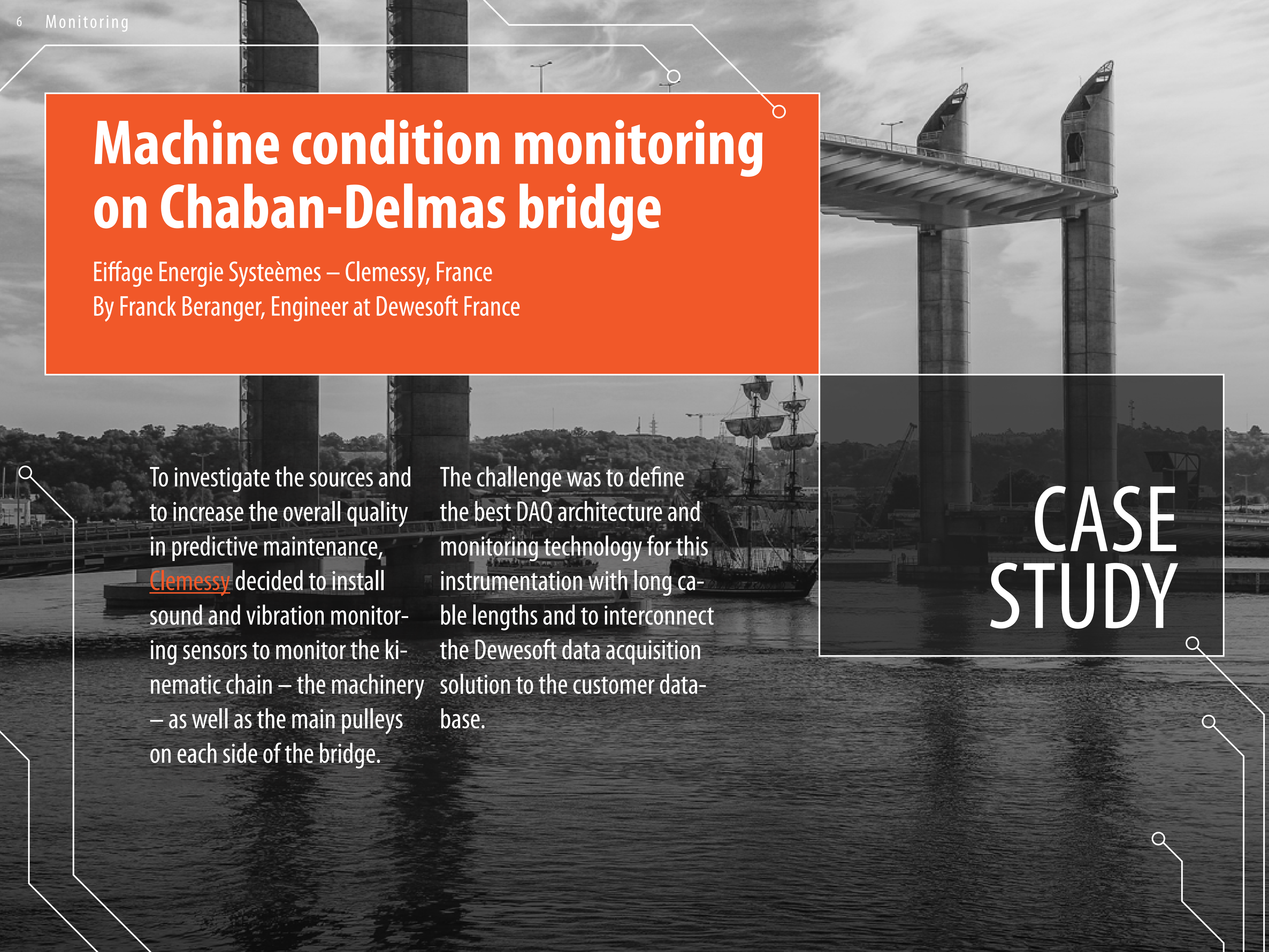


Fig. 5. The system registered a minor earthquake in October 2020.



Machine condition monitoring on Chaban-Delmas bridge

Eiffage Energie Systeèmes – Clemessy, France
By Franck Beranger, Engineer at Dewesoft France

CASE STUDY

To investigate the sources and to increase the overall quality in predictive maintenance, Clemessy decided to install sound and vibration monitoring sensors to monitor the kinematic chain – the machinery – as well as the main pulleys on each side of the bridge.

The challenge was to define the best DAQ architecture and monitoring technology for this instrumentation with long cable lengths and to interconnect the Dewesoft data acquisition solution to the customer database.

"Provide a crossing over the river Garonne for cars, pedestrians and bicycles, as well as, at a later date, a tram line" and "allow the passage of boats and, in particular, very large ships" – in 2003, these were the project requirements for a new bridge to cross the river in the city center of Bordeaux, France.

The result of the project is the Pont Jacques Chaban-Delmas, the longest vertical-lift bridge in Europe – its main span is 110 m (361 ft). The construction took place from 2009 to 2012 and the bridge was inaugurated in March 2013 - see figure 1.

Bordeaux in southwestern France, with almost 1,2 million inhabitants in the metropolitan area and hub of the famed wine-growing region, is a port city on the Garonne River. The Garonne has a length of 602 kilometers (374 miles) and flows into the Atlantic Ocean.

The bridge has been named in honor of Jacques Chaban-Delmas (1915-2000), a former prime minister of France and mayor of Bordeaux from 1947 to 1995. During World War II, his nom de guerre as a general in the underground resistance was Chaban, and after the war, he formally changed his last name to Chaban-Delmas.

Today, this fifth bridge over the Garonne within the city connects the eastern and the western parts of Bordeaux, the left bank city center near its wharves with the right bank of the city – the districts of Bastide and Bacalan. That is why the bridge also has been nicknamed "Le Pont Ba-Ba".

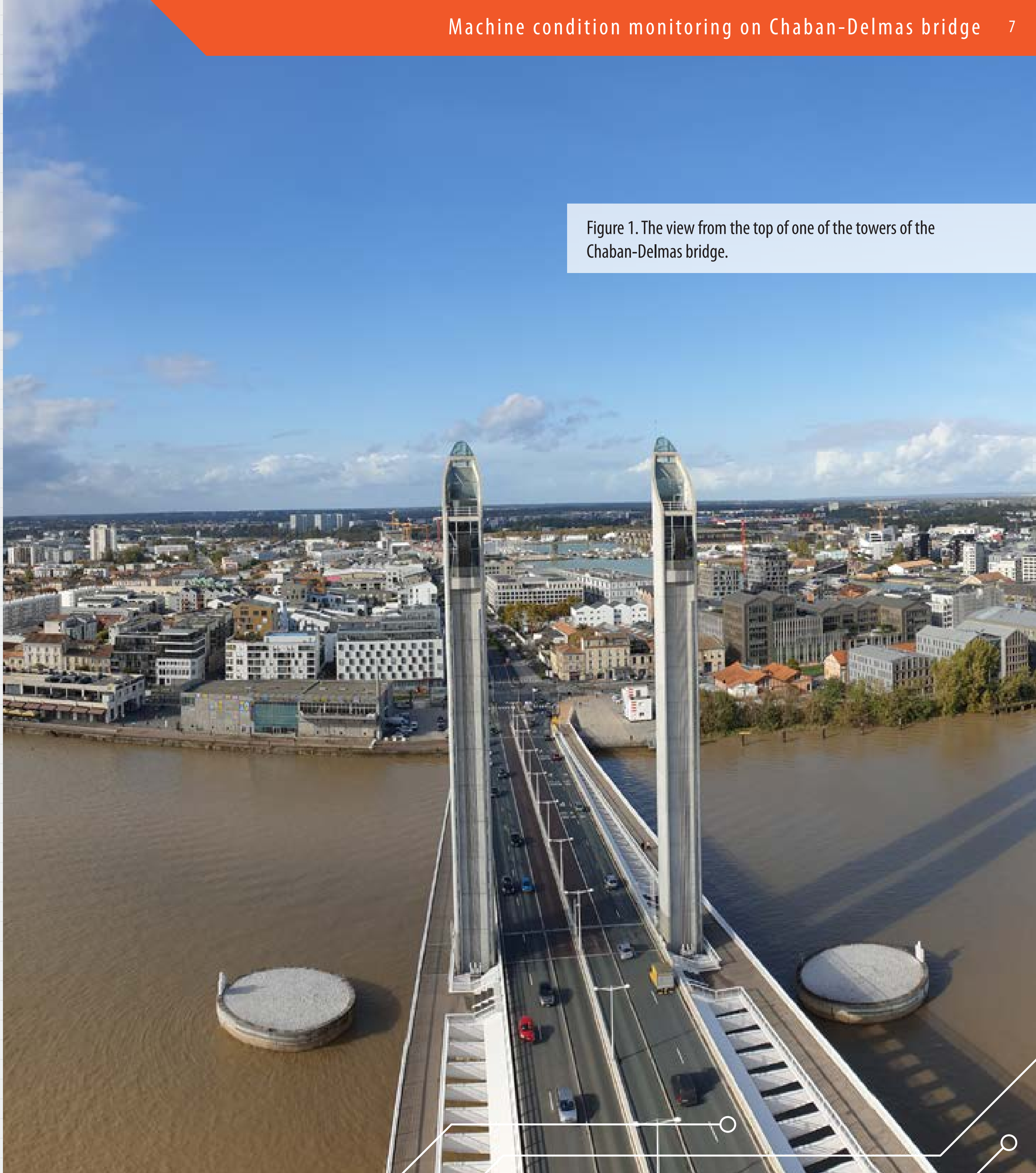


Figure 1. The view from the top of one of the towers of the Chaban-Delmas bridge.

The Chaban-Delmas bridge

Vertical-lift bridges are an uncommon solution to spanning a river used by large or tall ships, but such passage would allow the city to profit from the development of the cruise business. The structure, with a height identical to the Aquitaine Bridge downstream, had to be able to rise within 12 minutes maximum.

The architecture firm of the bridge is the SARL Architecture et Ouvrages d'art. The design of the work and the project management within the design-realization consortium led by the GTM company are carried out by Egis JMI, the architects Thomas Lavigne and Christophe Cheron, Hardesty & Hannover, and the design engineer Michel Virlogeux.

The bridge is 575m long (1421 feet): 433m of which is the main deck and 117m (387 feet) is the central lift span. The central section of the bridge remains in one piece but lifts vertically up by to 58m (190 feet) to let tall ships pass underneath. The height of the four independent towers, the pylons is 77 m (262 ft), and the distance between them is 110 meters (361 feet).

The weight of the lifted part of the bridge is around 2,600 tons. Forty ropes of 69 meters in length each connect to this center bridge segment, via deflection pulleys at the top of the four pylons using counterweights.

The width of the bridge varies depending on the different sections; from 32m (115 feet) at the abutments to 45 meters (148 feet) for the lift span. The usable width is 27 meters with 15 meters used by public transport in its own lane, pedestrians and two-wheelers and 12 meters for light vehicles and trucks. Bike and pedestrian paths are separated from motor vehicle traffic. Thus, this gentle circulation takes place outside the pylons of the bridge.

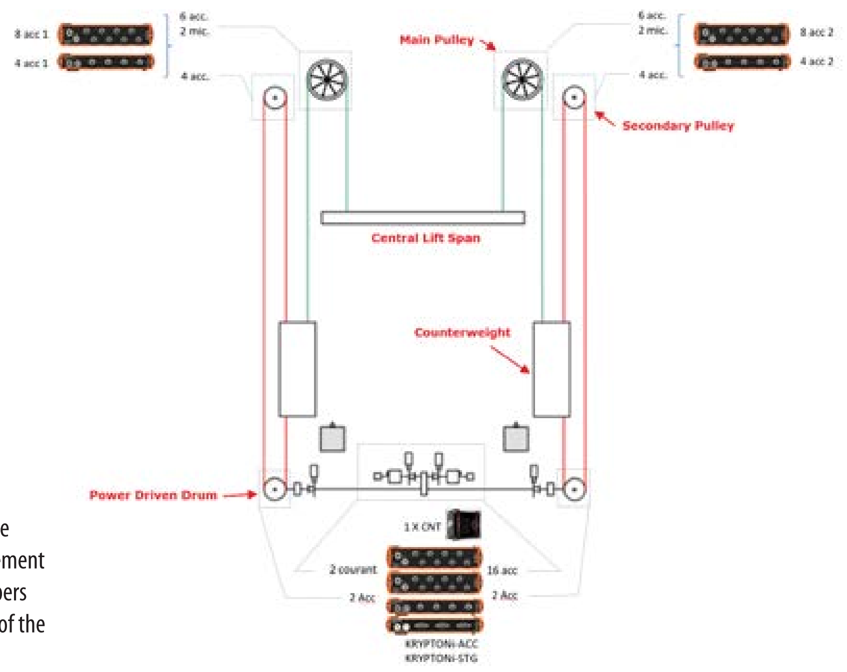


Figure 2. Overview of the instrumentation requirement in terms of sensor numbers and positions (one side of the bridge).

The bridge is configured for up to 43,000 vehicles a day. The bridge rises about sixty times a year, stopping traffic for about an hour to let larger vessels pass through. The bridge takes just 11 minutes to fully lift or lower into place.

Predictive maintenance - permanent monitoring

Operation and maintenance of the structure is the responsibility of the company Eiffage Energie Systemes - Clemessy, a branch of one of the top five biggest construction and concession companies in Europe, Eiffage. Clemessy is specialized in the engineering and implementation of industrial technical installations.

The Chaban-Delmas bridge is a structure capable of lifting a lifting span of 2,750 tons to a height of 53 meters in 11 minutes allowing the passage of yachts, ferries, or sailboats that will dock at the port of Bordeaux.

The lifting mechanism works on the principle of a giant elevator and requires the participation of a team of ten staff members. From a control tower, two operators manage the maneuver while the rest of the team is spread over the various strategic points in the foothills of the bridge. In addition to this, the team manages the maintenance of the vital machinery:

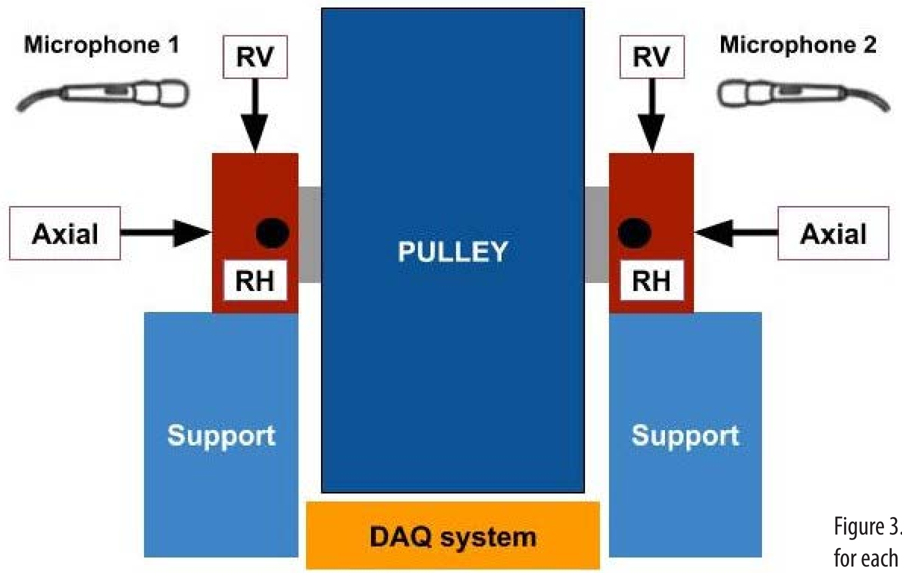


Figure 3. Measurement setup for each of the four bridge pulleys.

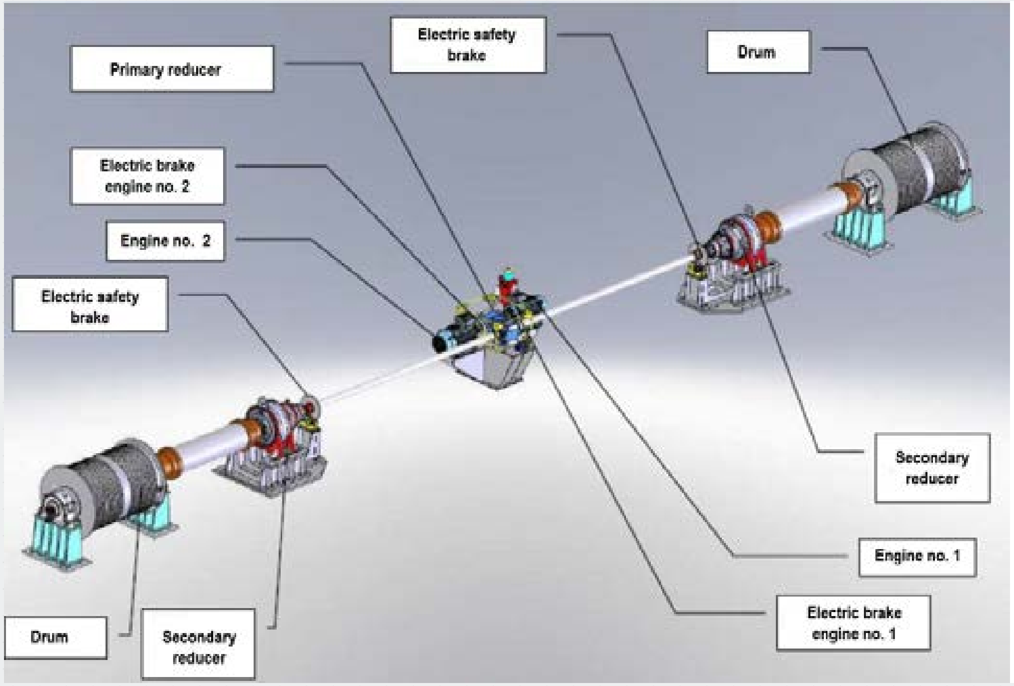


Figure 4. Bridge lifting machinery layout.

- motors,
- shafts,
- huge cables, and
- pulleys.

To increase the overall quality in predictive maintenance, Clemessy decided to install sound and vibration sensors to monitor the kinematic chain – the machinery – as well as the main pulleys on each side of the bridge.

This investment in the data acquisition instrumentation of the mechanical operation of the bridge has been the responsibility of the owner, the city of Bordeaux, while Clemessy was in charge of the project. The bridge is mainly instrumented with IEPE sensors – accelerometers and microphones, while current sensors and tachometers are only used in the machinery instrumentation - see figure 2 and table 1..

Measurement setup

Things to look out for can be vibration and inexplicable noise, such as knocks, which are phenomena below 10 kHz bandwidth, so the maximum required sample rate was 20 kHz which fitted perfectly with the maximum sample rate of KRYPTON, a rugged and distributed EtherCAT data acquisition system for field measurements in any environment.

KRYPTON DAQ systems have an IP67 degree of protection and can operate in the extreme temperature range from -40 to +85°C.

The whole instrumentation is 82 analog input channels separated in two sides of the bridge - 41 channels for each side with two pulleys - see figure 3:

- 1 x KRYPTON-8xACC module
- 6 x Accelerometers - BWD: 5kHz (SR=10kS/s)
- 2 x Microphones - BWD: 10kHz (SR=20kS/s)

Machine condition monitoring system for each side of the two sides of the bridge:

- 3 x KRYPTON-8xACC
- 1 x KRYPTON-3xSTG
- 1 x KRYPTON-1xCNT
- 1 x Rugged Computer
- Dewesoft X + OPT-NET + OPC UA server + DSA

This application required the math processing tools of Dewesoft X3 data acquisition software to calculate real-time statistical parameters on each vibration sensor. The point of interest for the investigation was not the time channels but from each input sensor the customer required to calculate statistical indicators to compare with alarm levels. An alarm counter was also implemented for this project.

The challenge was to define the best DAQ architecture for this instrumentation as some sensors are located on the top of pylons for the pulleys monitoring. Each side has two pylons, and these pylons are 77 meters high and no source of power is available on the top -see figure 5.

KRYPTON modules, based on EtherCAT protocol technology allow having a cable that can run up to 100 meters from module to module connecting amplifiers together. A single cable is used to transmit data, power, and synchronization between DAQ modules. Rugged DAQ module and EtherCAT were the two main reasons to select KRYPTON DAQ modules. These were the only solutions to place the data acquisition system on top of each pylon without a big investment.

The source measure unit (SMU) is capable of both sourcing and measuring at the same time. It can precisely force voltage or current and simultaneously measure precise voltage and/or current.

Table 1. Shortlist of indicators

Sensor type	Indicator	BWDTH	Averaging Time	Unit	Type
Machinery Accelerometers	Global Level Vel. (Low Frequency) (mm/s RMS)	[1-1000 Hz]	10 sec	mm/s	RMS
	Global Level Vel. (mm/s rms)	[3-1000 Hz]	3 sec	mm/s	RMS
	Global Level Acc. (g RMS)	[200-2000 Hz]	1 sec	g	RMS
	Global Level Acc. (g RMS)	[2000-8000 Hz]	1 sec	g	RMS
	Global Level Acc. (g cc)	[10-8000 Hz]	500ms	g	Peak-to-peak
	Shock counter from Acc. GLApkpk				
	Alarms with different levels for each indicator				
Electric Motor Current / Velocity	Current (A RMS)		0,5	A	RMS
	Velocity			rpm	RMS
Main Pulleys Microphones / Accelerometers	Global Level Microphone (dB cc)	[10-8000 Hz]		dB	Peak to peak
	Global Level Acc. (g cc)	[10-8000 Hz]		g	Peak to peak
	Shock counter from GLM				
	Max shock Level				

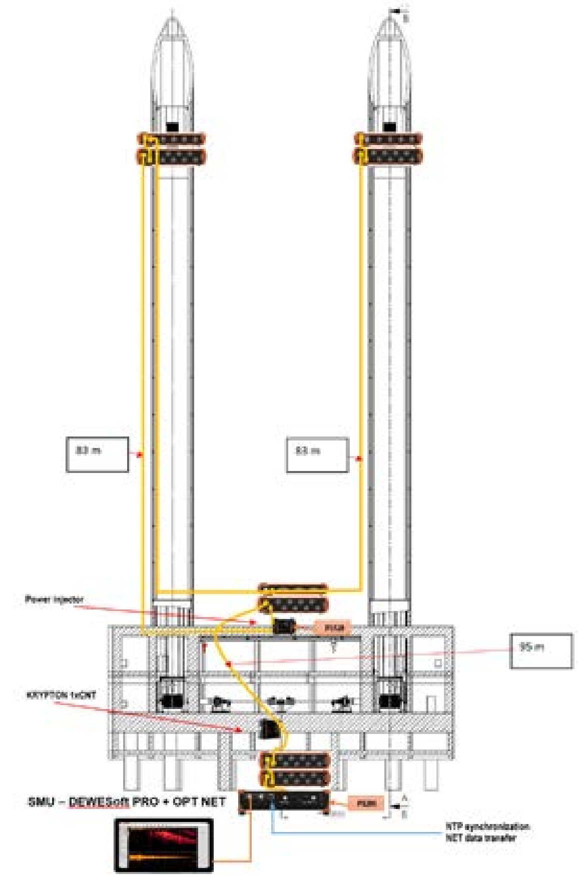


Figure 5. Overall measurement instrumentation setup on pylons and bridge structure.

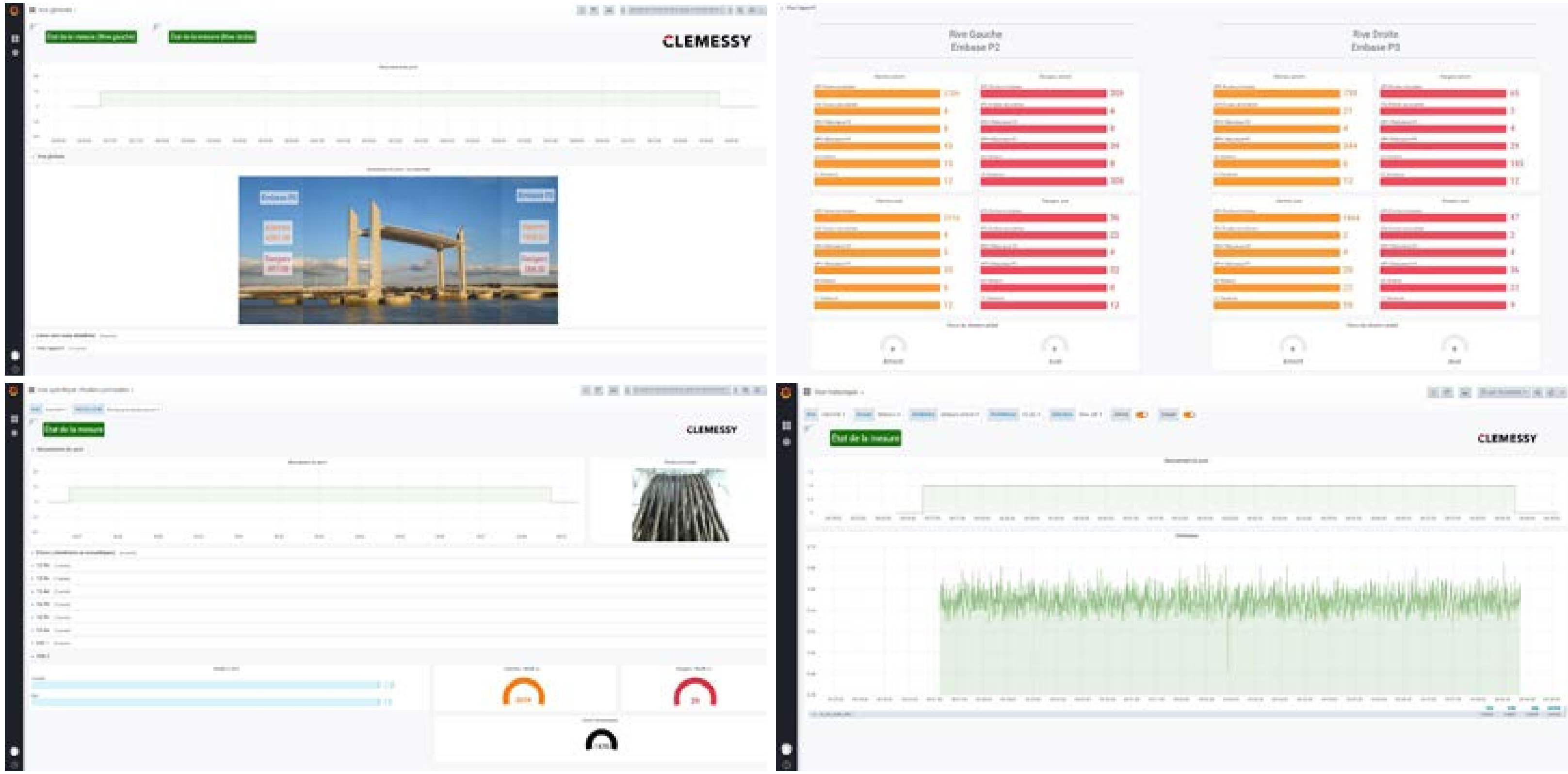


Figure 6, 7, 8 and 9. Operator screens on local web interfaces displaying values for alarm levels, alarm numbers, shock counting, statistic levels for accelerometers/ microphones, and DAQ status.

Connecting DAQ with existing database - OPC UA

Another challenge - and not the least - was to interconnect the Dewesoft data acquisition solution to the customer database over OPC UA to exploit the data in an Internet of Things (IoT) solution. The key to this application was the OPC UA server plugin. OPC Unified Architecture (OPC UA) is a machine-to-machine communication protocol for industrial automation developed by the OPC Foundation. This standard is frequently used in Industry 4.0 for communication and data sharing between different devices.

Dewesoft X3 offers two OPC UA options that can be included:

- OPC UA client: the client that can be connected and fetch data from any OPC UA server.
- OPC UA server: the server can serve Dewesoft X measurement data to one or more OPC UA clients.

During bridge lifts, the condition-based maintenance team members are not situated in front of Dewesoft but use a specific local web interface with only statistics and reports about the maneuver. The CLEMESSY database collects information from the Dewesoft OPC UA server such as alarm levels, alarm numbers, shock counting, statistic levels for accelerometers/ microphones, and DAQ status - see figure 6.

The Clemessy database solution is called Smart Forest. More than a single database, Smart Forest is a global solution, including:

- A "Big Data" software platform
- A multi-channel, multi-source interface for data collection
- An Artificial Intelligence engine
- A modular and user-friendly HMI

Conclusion

Dewesoft was capable of offering a complete hardware and software solution for the data acquisition and monitoring instrumentation of the whole bridge and as a proven partner of Clemessy France, our solution was preferred.

To optimize project deadlines the Dewesoft setup was initiated before the official delivery. When the hardware was delivered, the architecture was tested and the setup evaluated and improved – first in the laboratory, then during the on-site installation.

The Dewesoft X DAQ software is intuitive and very easy to use, however, to set up properly 82 AI channels, add 800 math calculations, set up 800 alarms, and create a nice display without errors, does take some time.

The proactive support and good communication helped the project to fly on time and to prevent any surprises and issues related to the dispersed DAQ architecture with long cable lengths. The first maneuver of the bridge with the Dewesoft solution was a success. Dewesoft setup was improved and a sequence was added to prevent maintenance Team actions on the instrumentation.

Dewesoft offers a range of DAQ solutions, combining innovative Hardware and Software DAQ technologies such as the OPC UA server plugin, that can fit the instrumentation needs of large engineering structures like bridges, tunnels, buildings, etc.

To have only one software to acquire analog data, do the online calculations, do alarm control systems, and transmit data using the latest IoT protocol is a major customer benefit and was a reason for success in this case. And the output: Reliable data presented in a smart user interface.

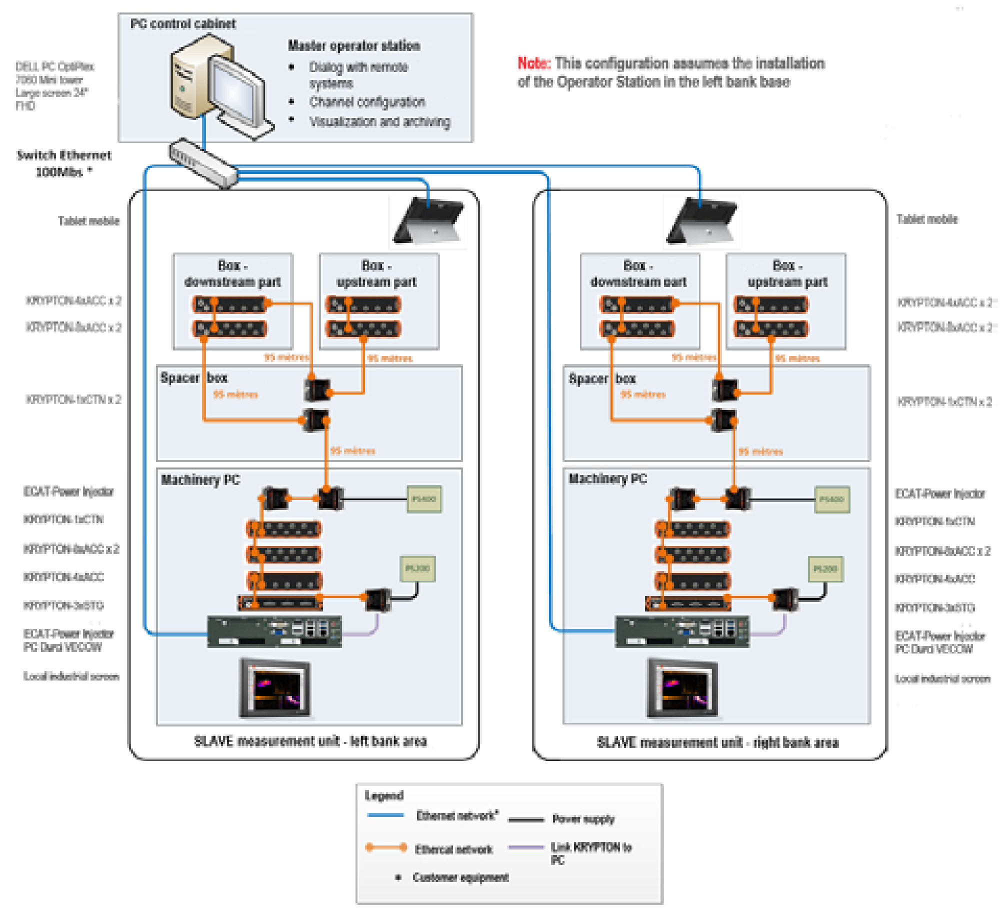
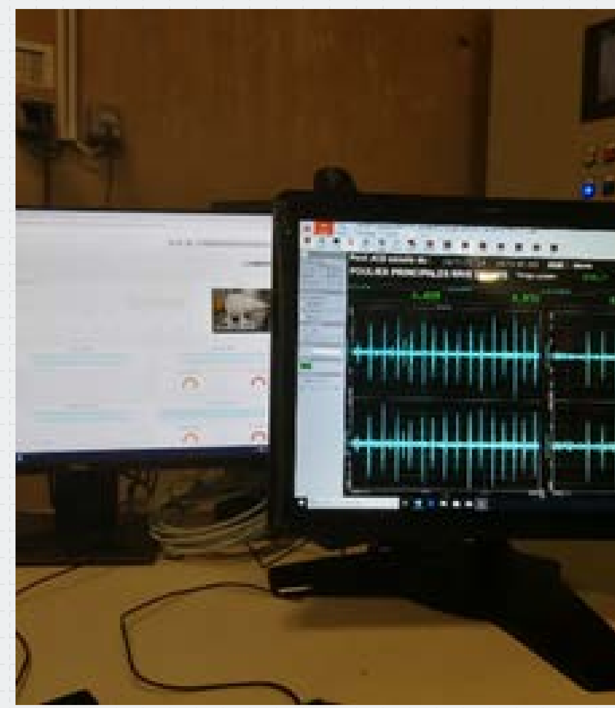


Figure 10. The architecture of the Dewesoft DAQ instrumentation.



Remote turbine monitoring at a geothermal power plant

ENEL Green Power, Italy

By Gabriele Ribichini, Managing Director at Dewesoft Srl, Italy and Marco Ramacciotti, Research & Application Manager at ISE Srl, Italy

CASE STUDY

In 2012, the modernized Rancia 2 geothermal plant in Tuscany, Italy, entered into service. Now the ongoing project, SmartGEO, has refurbished the plant to even include a remote diagnostics system.

In cooperation with ISE Srl, the Italian partner for Industrial Monitoring, Dewesoft has supplied field data acquisition and analysis through an innovative solution, a time series database perfectly integrated with Dewesoft X software. With a new storage architecture, it fulfills customer requirements in terms of performance, data safety, storage capability, and user interface.

Italy is the most important country in Europe for geothermal energy production, and ENEL Green Power, an Italian multinational renewable energy corporation, headquartered in Rome, is one of the most innovative companies in this field.

Larderello Enel site

Enel Green Power has operations in over 30 countries across the five continents. It generates energy from hydropower, wind, solar, biomass, and geothermal sources. In Tuscany alone, ENEL Green Power runs 35 geothermal power plants, with a total capacity of about 776,2 MW, that are able to meet more than 30% of the regional consumption.

The Larderello site in Tuscany has from ancient times been known for its hot springs and in 1818 a merchant of French origin, Francesco Giacomo Larderel, began work near the village of Montecerboli for the world's first plant capable of exploiting geothermal waters for the production of boric acid.

The exploitation of geothermal energy to produce geothermal electricity began in 1904 when Prince Piero Ginori Conti managed to channel the heat coming from the Earth into a dynamo capable of lighting five bulbs. The world's first geothermal power plant was completed in 1913 and was by 1916 able to produce many Kw, sufficient power to power the village of Larderello, the nearby town of Volterra, and the Italian electric railway system.

Today the Larderello site is a major global center of geothermal energy and supplies clean and sustainable electricity to around one million Italian households.

Geothermal energy production

Geothermal energy is generated and stored within the Earth. This energy of the Earth's crust originates from the original formation of the planet and from the radioactive decay of materials. The difference in temperature between the core of the planet and its surface drives a continuous conduction of energy in the form of heat from the core to the surface.

Geothermal power is considered to be sustainable and due to its low emissions also to have the potential for mitigation of global warming. The earth's geothermal resources are in theory more than adequate to supply all humanity's energy needs, but only a very small fraction is yet exploited. Although geothermal is a renewable energy source, eventually, the hot rocks below the surface will cool.

In 2012, the completely refurbished Rancia 2 geothermal plant entered into service at Larderello. The plant, which has a net installed capacity of 17 MW, is capable of generating about 150 GWh per year, thus avoiding the emission of many thousand tons of CO2 and saving many thousand TOE (Tons of Oil Equivalent) of fossil fuels per year.

Geothermal power plants

There are three main types of geothermal energy plants that generate power in slightly different ways:

- Dry steam plants,
- flash steam plants, and
- binary cycle plants.

Dry steam plants like Rancia 2 are the most common, accounting for about half of all installed geothermal plants. They work by piping hot steam from underground reservoirs directly into turbines, which power the generators to provide electricity. After powering the turbines, the steam condenses into water and is piped back into the earth via the injection well - see figure 1.

Flash steam plants differ from dry steam by pumping hot water, rather than steam, directly to the surface, into a "flash tank" with a much lower temperature, causing the fluid to quickly "flash" into the steam.

In the **binary cycle plants**, the water or steam from below is pumped through a heat exchanger where it heats a second liquid that is heated into steam, which powers the turbines.

The SmartGEO project

Currently, an innovation project embracing digital technologies and the Industrial Internet of Things and other reliability topics has been initiated at Rancia2 to monitor and predict plant performance.

The SmartGEO project aims to prototype, develop, and put into service remote diagnostics for geothermal plants. With the European financing program POR-FESR, the region of Tuscany brought together local companies and research centers and total financing, 3.3 million euros.

The project is a collaboration between the academic institutions, Scuola Superiore Sant'Anna (SSSA) and University of Florence (UniFI), and ENEL Green Power along with the leading Italian company in high-level industrial automation, SDI, and the engineering company, ISE Srl, that provides industrial plant maintenance services and solutions. A concrete example of synergy between Universities and Industries.

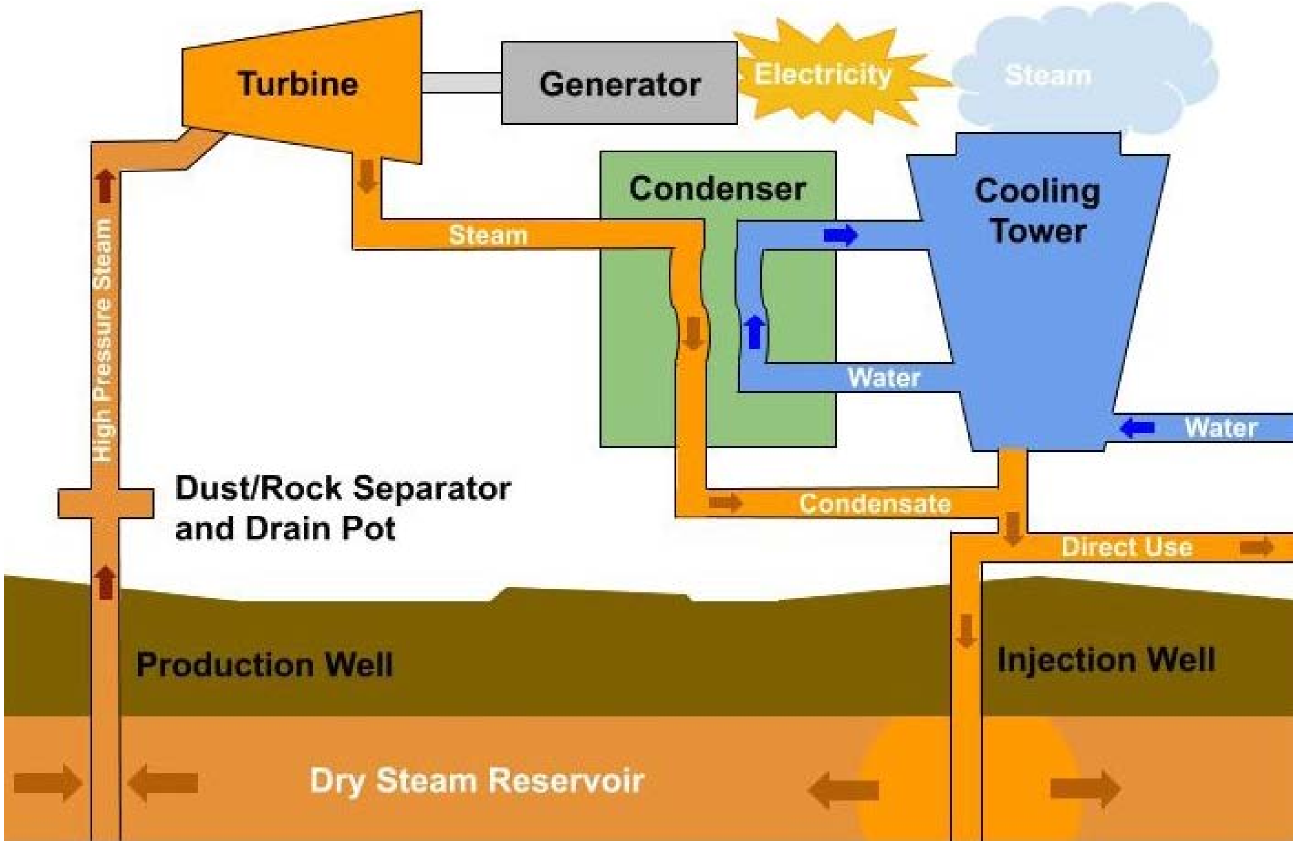


Figure 1. The principle and layout of a dry steam geothermal power plant.

Remote plant monitoring and diagnostics

The first phase of the SmartGEO project began in 2017, when the Rancia 2 geothermal plant saw the installation of sensors and systems in its most important units, from the wells, the steam collection network, the re-injection pumps, the pipelines to the steam cleaning systems and the AMIS system.

All to achieve important targets such as:

Warning prediction

- Avoid production freezes and losses.
- Diagnose dangerous disruptions in systems.

Real-time monitoring of the steam network

- Optimizing Steam Distribution.
- Environmental protection and diagnosis of possible ruptures.

Auxiliary predictive monitoring and maintenance

- Increased analysis capacity.
- Avoid breakages with predictive maintenance.

An ecosystem for development and execution of control and prognostic algorithms

- Scientist-friendly data platform.
- Possibility to perform thousands of optimization algorithms and prognoses in real-time.
- Native integration with OSIsoft Historian database used to store real-time data

The use of tools for remote diagnostics allows for the integration and simplification of the control, automation, and diagnosis systems already present in a plant, and also provides an opportunity to improve plant performance.

These diagnostics technologies include:

Monitoring
- New auxiliary sensors and innovative measurement techniques.

D&O platform
- Process Prognosis (Soft real-time) & Training.
- Power plant control (Hard real-time)

Research
- R&D of innovative algorithms (AI, machine learning, adaptive control).

App Interface
- Monitoring and configuration interfaces.

Dewesoft data acquisition

After an interesting comparison in the market, Dewesoft data acquisition technology was selected for field data acquisition (DAQ) and signal analysis. Several signals were requested both from the main turbines and auxiliary systems composing the geothermal power plant.

Finally, the complete Rancia 2 power plant was monitored using a combination of KRYPTON DAQ modules in the field for the cooling tower systems – fans and pumps – and SIRIUS HD modules for the main turbine and generator - see figures 2, 3, and 4.

This rotating machinery – the turbine and generator -- is controlled with first-class protection systems like the Bently

Figure 2. The main turbine.


Figure 3. The shaft between turbine and generator.

Nevada 3500 the vibration monitoring system suitable for protection and diagnosis. Such complex systems aim to monitor all the fundamental machine parameters and eventually stop the operation in case of danger.

Rotating machinery such as turbines and generators, belonging to the category of turbomachinery, are monitored with analog proximity sensors installed at each bearing and a key phasor for each rotating shaft. Although the transducers look very simple and robust, the signal processing is far from being obvious.

ENEL required a solution capable of reading signals at the Bently Nevada system inputs but using them in a more flexible environment, where well-known and innovative algorithms could be applied in combination for improved analysis of the plant status, to predict any machinery malfunction and thus optimize the power production and power plant efficiency.

At the time of the request, we had all technology needed except for a data infrastructure able to continuously collect data for decades, enabling comparison of data from different events, and allowing multiple technicians from the support team to interact with the analysis - all running on a strictly secure production network.

Time series database

Our best brains were involved in several meetings... and finally, we came up with an innovative solution: A time-series database perfectly integrated with the DewesoftX data acquisition (DAQ), data recording, and data analysis software.

Our systems have now been installed in the field, next to the Bently Nevada protection system, 3500 Vibration Monitoring Systems, acquiring the same signals. The data storage has been enriched through this new database architecture, able to fulfill all customer requirements in terms of performance, data safety, storage capability, and much more!

The database has been developed in our new real-time environment (Dewesoft RT) suited to be hosted on any hardware, in a scalable and distributed architecture, while data is acquired by Dewesoft X DAQ software and processed locally with state-of-the-art rotating machinery diagnosis tools.

Our partner for industrial monitoring and predictive monitoring applications, ISE Srl, took care of the smart data processing algorithms and developed some nifty setups in the Dewesoft software resulting in a range of clear and easily manageable user interfaces for asset monitoring:

- evaporator diagnosis,
- PAE pump monitoring,
- PAE pump bearings analysis,
- harmonics tracking,
- fan analysis,
- turbine and generator analysis,
- turbine analysis,
- turbine orbit analysis,
- generator orbit analysis,

Figure 4. The Sirius data acquisition system acquires a signal from the main turbine (picture above) and the generator.

- compressor FFT analysis,
- compressor and generator waterfall diagrams, and
- full production shaft waterfall analysis.

The choices of Dewesoft SIRIUS and Krypton DAQ hardware solution together with the high flexibility of Dewesoft technological software platform gave the possibility to create various front-end set up modules according to the ISE technical background and the specific needs of Enel technicians, who were not so used to this degree of flexibility on the Bently Nevada platform - see figures 5 to 16.

Conclusion

A key component of the project was to introduce an innovative human-machine graphic interface, which allowed operators to quickly identify the best corrective measures. Our dedication to the project, strong efforts from Dewesoft HQ in cooperation with the experience, and strong innovation from ISE brought an excellent solution to the market.

In the second stage of the project, the remote diagnostics model will probably be replicated in other additional twin units, for an overall production increase of 12 GWh a year. In the third phase of the project, with the acquisition of greater expertise and know-how, it will be possible to design a second generation of the system, which can be used even in plants powered by other renewable sources.

Shortly after installing the system, the engineers at ENEL Green Power were able to detect some potentially dangerous mechanical phenomena in the evaporation towers - a real success for our team.

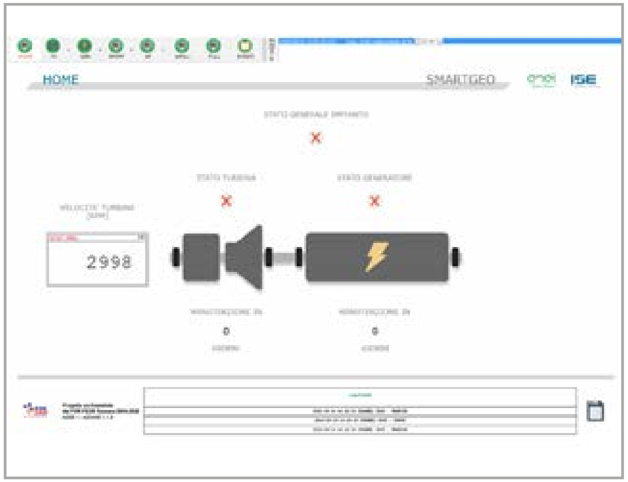


Figure 5. Main Dewesoft screen for evaporator diagnosis.

Figure 6. PAE pump monitoring screen

Figure 7. PAE Pump bearings analysis (using envelope detection algorithm).

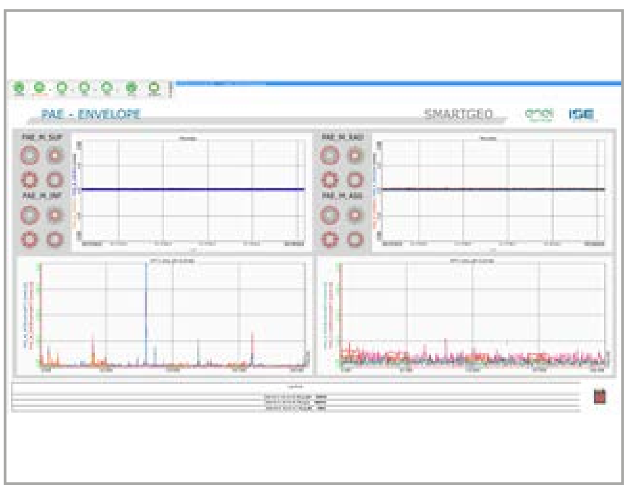


Figure 8. Harmonics tracking screen.

Figure 9. Ventilator analysis main screen.

Figure 10. Turbine and Generator analysis home screen.

Figure 11. Turbine analysis main screen.

Figure 12. Turbine orbit analysis screen.

Figure 13. Generator orbit analysis screen.

Figure 14. Compressor FFT Analysis screen.

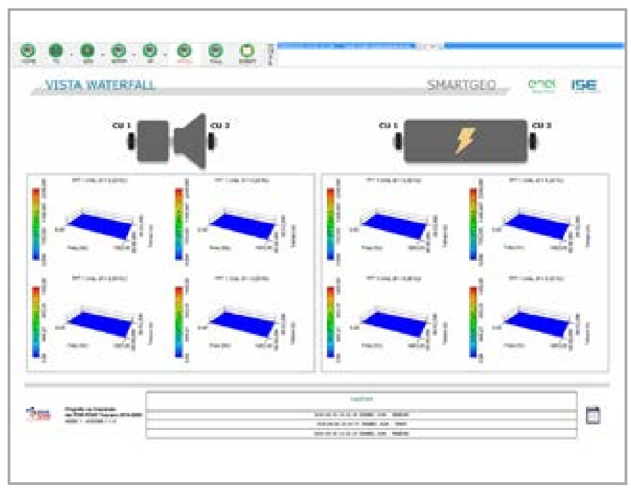


Figure 15. Compressor and generator waterfall diagrams screen.

Figure 16. Full production shaft waterfall analysis.

Structural health monitoring of a railway viaduct

By Rok Mesar, Business Developer, Dewesoft Monitoring Group
Advanced Construction Technology Services (ACTS), Saudi Arabia

CASE STUDY

A railroad bridge in Saudi Arabia was observed for around 80 hours to evaluate its structural health - the monitoring system was based on Dewesoft integrated sensing devices. The prime objective was to acquire measurements before, during, and after the crossing of trains on the bridge.

The obtained specifically quantified outputs allowed diagnostics to ensure that the bridge maintains its solid structural integrity while in use.

Structural health monitoring is a tool to ensure the integrity and safety of an engineering structure - detecting the evolution of damage and estimating performance deterioration. Sampled response measurements provide insights into changes to the materials and geometric properties and allow an analysis of the structure over time. The ongoing process of monitoring the mechanical state of structures provides useful maintenance input and can ultimately prevent disasters.

In this case, the monitoring was carried out by ACTS, Advanced Construction Technology, Services on behalf of a customer. ACTS provides construction consultancy services specializing in the materials and geo-engineering fields. ACTS currently operates throughout the Middle East, Africa, and Southeast Asia, headquartered in Beirut, Lebanon, and with three local offices in Saudi Arabia.

The Arabian desert is crisscrossed by rivers that are not really there - so-called wadis, dry water-formed ravines that only fill up with water during the rainy season. The Urayja Viaduct - also named OW8 (Over Wadi No. 8 Bridge) - is one of more such bridges crossing wadis found across the Kingdom of Saudi Arabia. It is located within the central Saudi Arabian desert in the region of Ḥāʾil near the small town Urayja - some 565 km or 351 miles North-West of the capital city, Riyadh.

OW8 comprises seven spans of four post-tensioned reinforced concrete girders capped with a reinforced concrete deck and parapet walls. Each span is 20 m long, there are six piers and two abutments. Bearings are bed stones/ plinths with anchor bars - see figures 1 and 2. The circular plates on the girder and bed stone are suspected to be of an elastomeric material but the details on the as-built drawings are not clear.

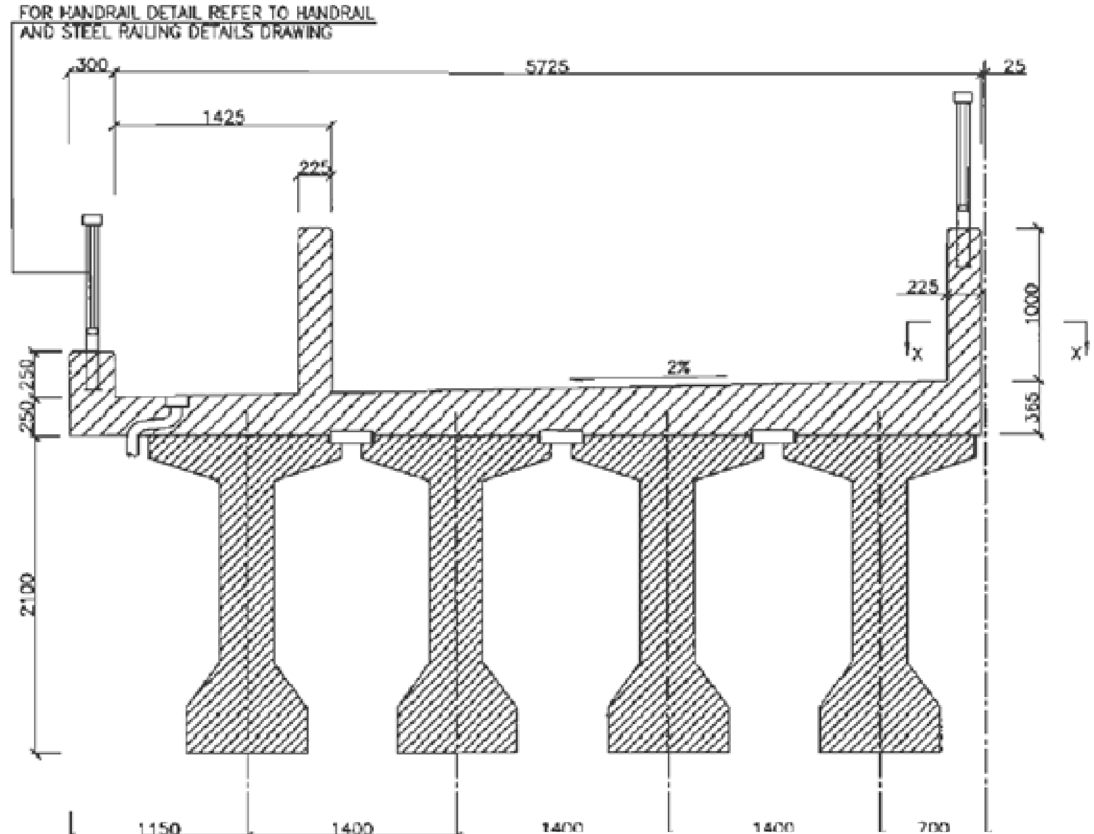


Figure 3. Cross-section of girders and deck – the bridge includes a reinforced concrete slab with a walkway (left).

The bridge was constructed in 2013, and the as-built drawings are dated January 2014. The section scrutinized for this study was the span between pier 4 (PRT 4) and pier 5 (PRT 5) where the sensors were placed on the soffit and the web of the girders.

The deck comprises a reinforced concrete slab with a walkway and there are two parapet walls cast into the deck along with a ballast retaining wall - see figure 3.

Measurement setup

To monitor the structure for the prescribed response metrics, state-of-the-art data acquisition hardware was installed. It included:

- control cabinet,
- data loggers, and
- measurement devices.

The data acquisition system was composed of the following sensors:

- 1 × data logging embedded PC
- 6 × Accelerometers - IOLITEdi-3xMEMS-ACC
- 6 × Tiltmeters - IOLITEdi-3xMEMS-ACC-INC
- 8 × Strain Gauges - IOLITEdi-1xSTG
- 3 × Power Injectors - IOLITEd-Power-Injector
- 1 × 24 V power supply - to power the PC
- 1 × 24 V power supply - to power the Data Logger

EtherCAT protocol allows the IOLITEd devices to be easily distributed across large structures. Devices can span 50m node-to-node with only one cable running between them for signal, power, and synchronization.

Devices are daisy-chained with a standard Ethernet network cable. It is recommended that the cable is shielded (SFTP, CAT5e) and has a minimum of 24 AWG wire thickness. The cable must have 4 wire pairs. The maximum distance node-to-node is 50 m.

A passive PoE (power over ethernet) power injector is necessary for merging the EtherCAT signal and power into a single cable.

Accelerometers

IOLITEdi-3xMEMS-ACC is an integrated sensing device. Acceleration is measured by a triaxial MEMS accelerometer inside the device that is tightly attached to the mechanical chassis. Analog to digital conversion is done inside the device, eliminating any noise picked up in analog cabling. A microprocessor inside the device transmits the acceleration samples over the EtherCAT protocol - see mounting in figure 4.

Low levels of vibration need to be measured which requires an accelerometer with extremely low noise. Even though low frequency is of interest, it must be possible to detect even small changes in the frequency of vibration.

Tiltmeters

IOLITEdi-3xMEMS-ACC-INC works as a two-axial inclinometer to measure the roll and pitch angles - about its X and Y axes - with the Z-axis positioned vertically. Tilt in two axes is measured by a 2-axis MEMS tilt sensor inside the device that is tightly attached to the mechanical chassis.

Analog to digital conversion is done inside the device, eliminating any noise picked up in analog cabling. A microprocessor inside the device transmits the angular data samples over the EtherCAT protocol -see mounting in figure 5.

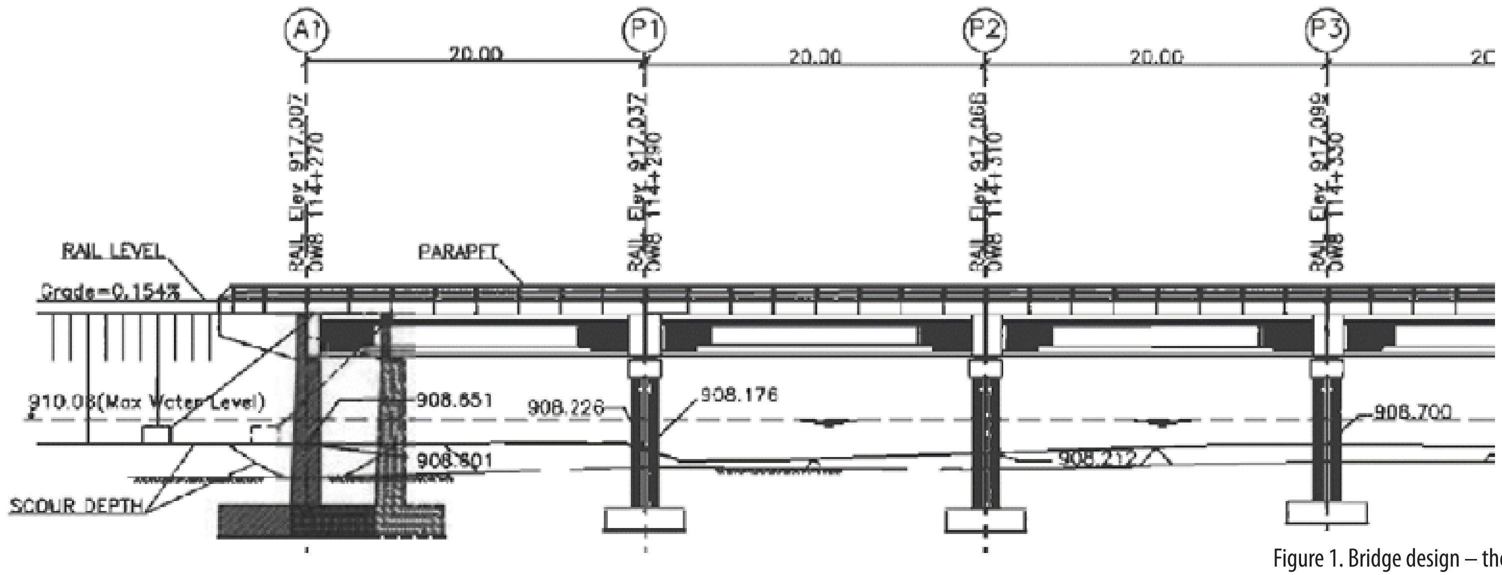


Figure 1. Bridge design – the Low Mileage Elevation.

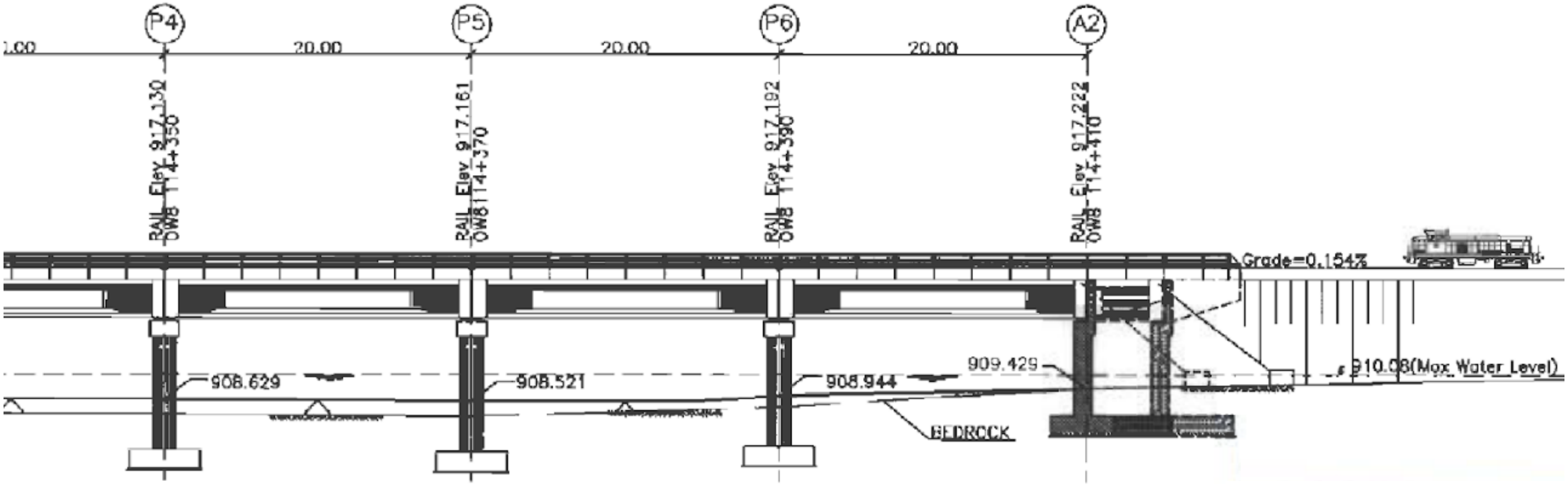


Figure 2: Bridge design – the High Mileage Elevation.

Strain gauge sensors

The SNS-STG is a bolt-on strain gauge sensor. It includes a strain gauge sensor integrated into a housing that is ready to be bolted on the structure. The rated output from the sensor is 1.5 mV/V for 1000 micro-strain.

The sensor is connected to the Data Acquisition device named IOLITEdi-1xSTG transforming analog data into digital and communication of the data over the EtherCAT protocol - see mounting in figure 6.

Data logging

All the monitoring devices were daisy-chained with a single CAT6 cable. This single cable delivers power, data, and synchronization to the DAQ devices. The data is delivered to an embedded data logging PC running DewesoftX data acquisition software - see the setup in figure 7. The software can present live recordings, store the data based on triggers and analyze the data files.

Advanced engineering methods can be implemented inside DewesoftX software with low set-up effort and no special programming skills. These include:

- Signal filtering
- Integration to velocities
- Integration to displacements
- Frequency domain analysis
- Complex statistics

The same is true for storing the data to a database, exporting to 3rd party software format, or sending the data using standard protocols such as OPC UA.

Data acquisition software

The scope of monitoring software is to:

- acquire signals from all sensors,
- perform a real-time visualization,
- give the alarm on abnormal stages,
- store data, and
- convert/store the data into a database server for further processing.
-

The graphs in figures 8, 9, and 10 are showing the responses over 1 minute and 29 seconds during the crossing of train #400120. The train passing the bridge is a phosphate carrier cargo train with 4 locomotives and a total of 124 wagons traveling in the downward direction at 100 km/h.

Video of the system configuration and software interface

Conclusion

"The selection of sensors, data acquisition devices, and system integration was completely done by Dewesoft. The company also tested the system before shipping it and built a user interface as well as set reports according to our client requirements. This saved us a lot of engineering time", says Mohamed from ACTS.

The IOLITEdi is a tailor-made data acquisition device for structural health monitoring solutions with an ideal price-performance ratio for permanent condition monitoring on structures such as bridges.

"Even though the system requires cabling, the RJ45 connectors enabled us to do the work very fast since it offers a possibility of on-site crimping. The CAT6 cables are also very inexpensive and can be easily purchased in any local store", Mohamed concludes.

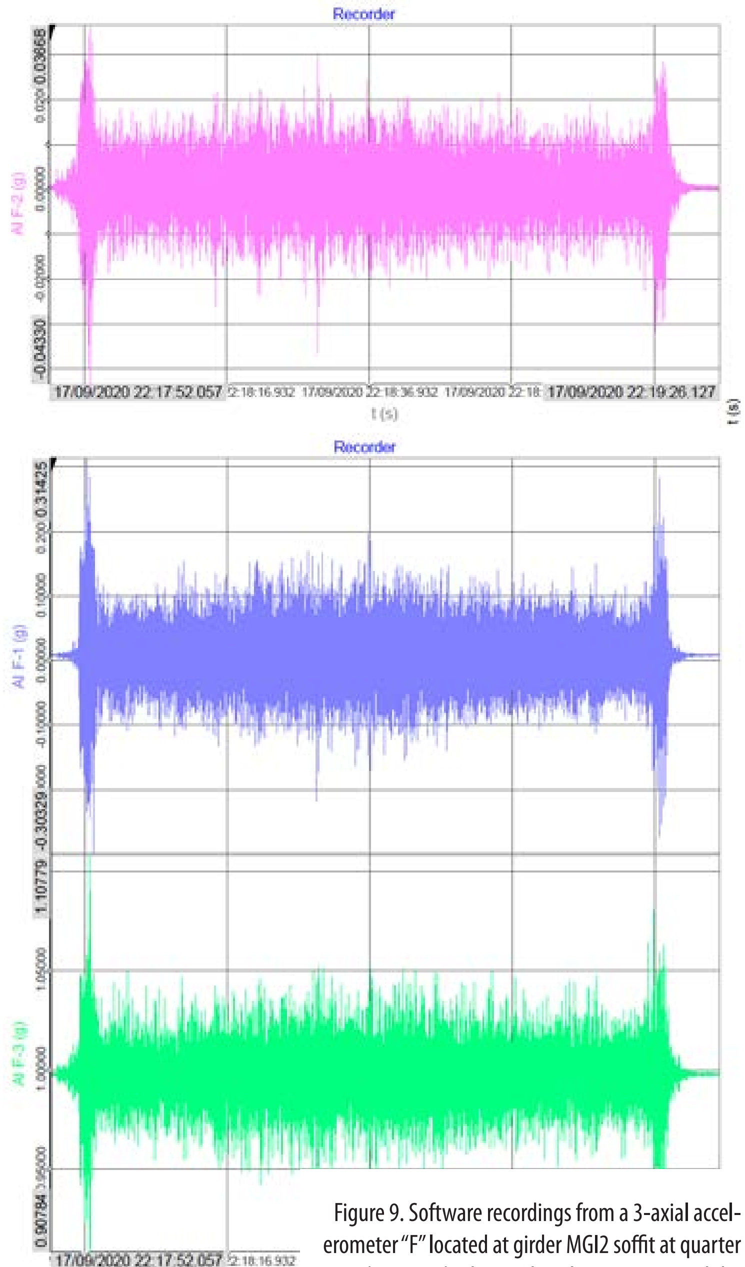


Figure 9. Software recordings from a 3-axial accelerometer "F" located at girder MGI2 soffit at quarter span (section 2) when a Phosphate Train passed the bridge on September 17th, 2020.

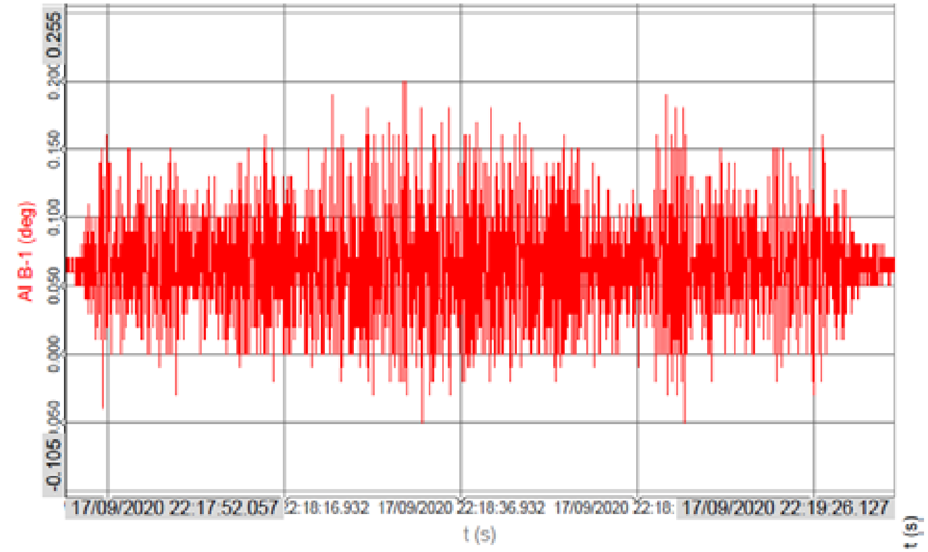


Figure 10. Software recordings from a tilt-meter monitoring tilt/inclination response for the sensor "B" located at the girder MGI2 soffit when a phosphate train passed the bridge on September 17th, 2020.

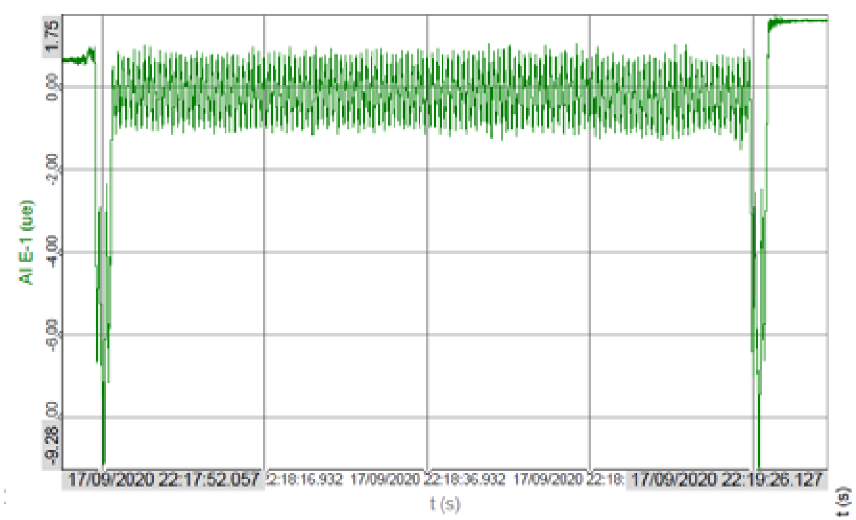


Figure 8. Software recordings from Strain sensor "E" located at the girder MGI2 soffit at quarter span (section 2) when a Phosphate Train passed the bridge on 17th September 2020. The y-axis presents the stain in "με" while the x-axis presents the evolution of time in "sec".

Structural health monitoring with MEMS accelerometers

ESSEBI S.r.l., Italy
By Giorgio Sforza, Technical Director, ESSEBI S.r.l., Italy

CASE STUDY

Structural health monitoring is becoming increasingly common as a valid predictive means to assess the state of structures and their need for conservation over time. This is due to the recent tragic events which were first triggered by the disastrous collapse of the Polcevera viaduct in Genoa and due to the overall high level of obsolescence of the Italian national road and railway heritage.

With the introduction of a high-performance MEMS-type accelerometer chip, the Dewesoft IOLITEd single-channel data logger developed a 3xMEMS-ACC DAQ device - an integrated signal conditioner with a built-in MEMS accelerometer.

ESSEBI now widely uses this tool in various applications in the fields of civil engineering and architecture. The first results have shown it to be the optimal solution among all in the market at the moment.

The main road and railway managing bodies in Italy - ASPI, ANAS, RFI, etc. - are publishing numerous tenders, related to **infrastructure diagnostics and structural health monitoring**, with the ultimate aim of covering the entire national territory of their competence with such services.

The context in terms of job opportunities in the sector is becoming increasingly effervescent and this is why many operators are taking action with all available means. Few with any experience, many improvised and often recycled from the most varied work activities, perhaps involved in the production crisis. In this scene, more than a dozen companies have thrown themselves headlong into the production of modular acquisition systems starting, very often, from previous experiences that are not very significant, especially in the field of controls and measurement.

The dominant feature of this nascent electronics, which is taken as a pretext and as a distinctive and indicative element of better performance, is almost always the wireless transmission of the signal. If it is good for static measurements, with a decidedly negligible amount of data involved, it is not at all suitable for dynamics.

Even with sampling rates that are not prohibitive, consumption is so high as to make grid power supply unavoidable and, at this point, the same power cable can be used to carry the signal with consequent greater safety in transmission, synchronization, and above all respect of the European Community indications.

ESSEBI S.r.l. has been operating in the monitoring sector for almost thirty years. They chose reliability and have turned to Dewesoft. Dewesoft did not have a product that would meet the specific market needs available at the time. But it has promptly launched a targeted development starting from similar solutions, which were already extensively tested on the market.

Since 1992 ESSEBI has been operating mainly in the structural engineering services sector. The company's specific competence is the implementation of static or dynamic monitoring systems on both civil structures and architectural works, but also the performance of general non-destructive testing and diagnostic activities on artifacts in reinforced and prestressed concrete, steel, masonry, and wood.

Initial overpass monitoring projects

At the end of 2017, ESSEBI was involved in the construction of dynamic monitoring systems on four motorway overpasses in Emilia Romagna. The design company LA SIA, was in turn, appointed by SITE (a telephone, and electrical system company, assigned by Autostrade per l'Italia ASPI) the leading European concessionaire for toll motorway construction and management.

The first of them was the overpass bridge in Val d'Enza, on the A1 highway - see figure 1. This was considered a pilot plant and was required to be built with extreme urgency. ESSEBI was forced to turn to those on the market who boasted equipment suitable for the monitoring purpose. Especially at decidedly competitive prices, capable of complying with the tight budget made available.

The quickest and apparently most effective solution was to contact a supplier - a company born as an outsourcing of the corporate branch dedicated to the production and marketing of a satellite anti-theft system for cars.

But the experience was completely unsuccessful due to the total unreliability of the instrumentation and the absolute lack of management software. That is always about to be finished, but was never really delivered.

The only positive aspect was that the bugs of the whole apparatus, fortunately, came out immediately (and there were many of them). This gave ESSEBI the possibility to immediately change course starting from the end of the installation of the first system and turn to other shores.

Faced with repeated attempts to intervene, with little success, all that remained was to turn to another supplier. The winning choice was to refer to Dewesoft. Dewesoft did not yet have any complete solution ready. But their indisputable corporate credibility, seriousness, and the possibility of setting up a dedicated development in a relatively short time gave them the edge to be selected.

The conception of the 3xMEMS-ACC

A working lunch settled a few steps away from the ESSEBI headquarters in Rome, was an opportunity to discuss the situation with the Dewesoft representative in Italy. Within a few days, the challenge was accepted with considerable enthusiasm and turned into serious prototype development.

Thus begins the adventure aimed at developing an accelerometric acquisition module, with a built-in MEMS transducer (MEMS - Micro-ElectroMechanical System) based on Dewesoft's general-purpose single-channel data acquisition device called MonoDAQ.

After a couple of months, a prototype with a chip from the renowned MEMS-chip manufacturer was prepared. Unfortunately, it was not enough to satisfy ESSEBI's requests in terms of the signal-to-noise ratio. New experimentation was started with a MEMS chip from an alternative semiconductor company, strongly supported by ESSEBI itself - see figure 3.

This time the results were excellent and within a further two months, we had the first working and tested prototypes satisfying the requirements set up with a spectral noise density not exceeding 25 µg/√Hz.

The requirements were imposed by ESSEBI and based on the assumption that the module should have identified the environmental noise to which buildings and infrastructures are subject to a good resolution.

The product was named MonoDAQ-E-gMeter, with the "E" denoting its EtherCAT interface and "g" standing for what it measures - acceleration in gees. Today the device is sold within the Dewesoft IOLITEd family of data acquisition systems (IOLITEdi-3xMEMS-ACC). The company decided this is the best strategy to take on the worldwide structural monitoring market.

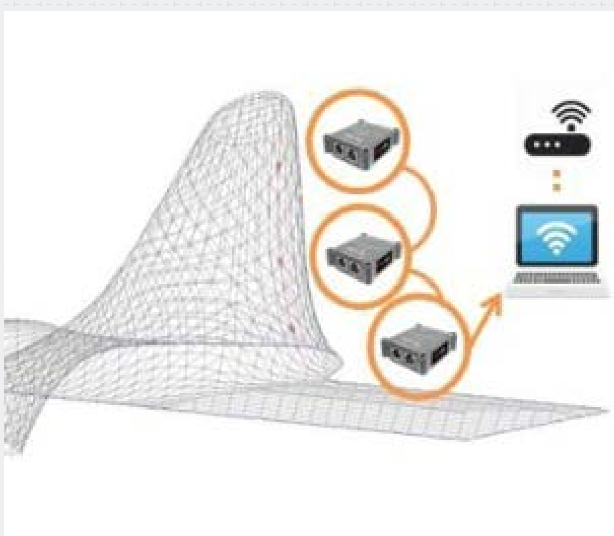
The splendid adventure finally begins with the installation of the DAQ systems in the remaining three overpasses on the Val d'Enza. The systems completely replaced the M3S system, which in fact never worked properly - see figures 4 and 5.

Since that time, many installations have followed and have involved the most disparate types of artifacts in the field of civil constructions, infrastructures, and architectural works.

The Milan Fair structural monitoring system

Monitoring systems installed in the Service Center and Pavilion 13 of the Milan Fair have the purpose of starting trigger recordings when severe atmospheric events occur (snow, wind, etc.). In this case, the transducers, suitably calibrated in high temperature, have the additional purpose of making static rotational recordings with accuracies of the order of a hundredth of a degree, acting in all respects as servo-inclinometers.

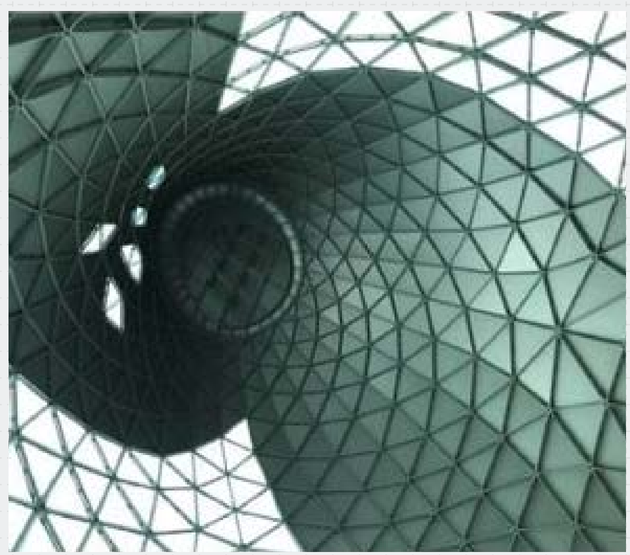
The Service Center structure being investigated consists of a 54,000 square meter covering wave of glass bolted to a steel reticular structure resting on a system of modular distance steel columns. The "sail" is over 30 m wide and a kilometer and a half long and cuts the central axis of the exhibition center by connecting the east and west doors of the Fair. The highest point reaches 35 m in height.



We have chosen to measure the accelerations of a rib of the steel frame that supports the entire structure. It is measured with three triaxial IOLITEd-3xMEMS-ACC MEMS devices. This choice is linked to the fact that the entire structure rests on a base that allows it to move in the plane - see figures 6 and 7.

Concerning Pavilion 13, the 3xMEMS-ACC modules are integrated into a larger system with different types of modules from the IOLITEd DAQ family, mostly the IOLITEd STG type for connection to strain gauge sensors.

A series of transducers have been installed on the lattice truss elements that constitute the beams of the roof to monitor the trends. The main source of dynamic excitation used during the measurements was that produced by the environment, in particular by the wind action.



The roof in question consists of steel trusses. The longitudinal beam is 224m long and distributes the load on 6 supporting pillars. The main beam is integral with 8 transverse trusses of equal dignity with extremal and central supports on the main beam.

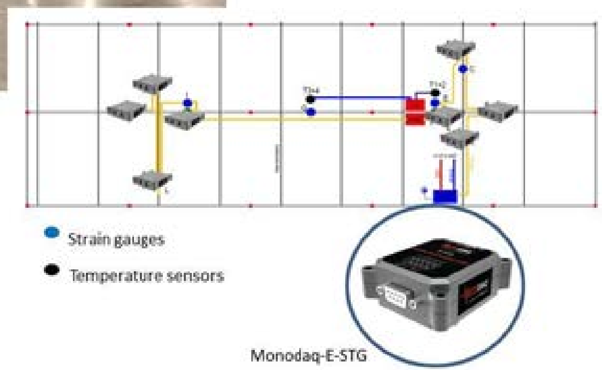
On the roof trusses, there are 9 acceleration measurement points along the 3 axes of a set of three references, arranged both along the main and secondary beams as shown in figure 8.

IOLITEd-3xMEMS-ACC MEMS accelerometers were used to measure accelerations and inclinations. Dewesoft X data acquisition software is used for:

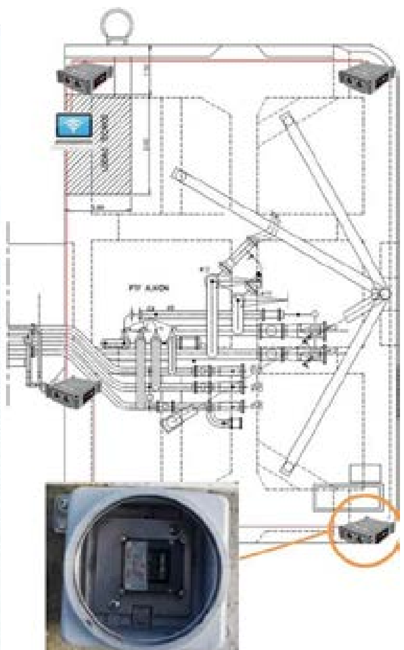
- managing the acquisition,
- setting the parameters for all the sensors,
- displaying the time history of the acquired signals,
- instantaneous FFT, and
- data saving.

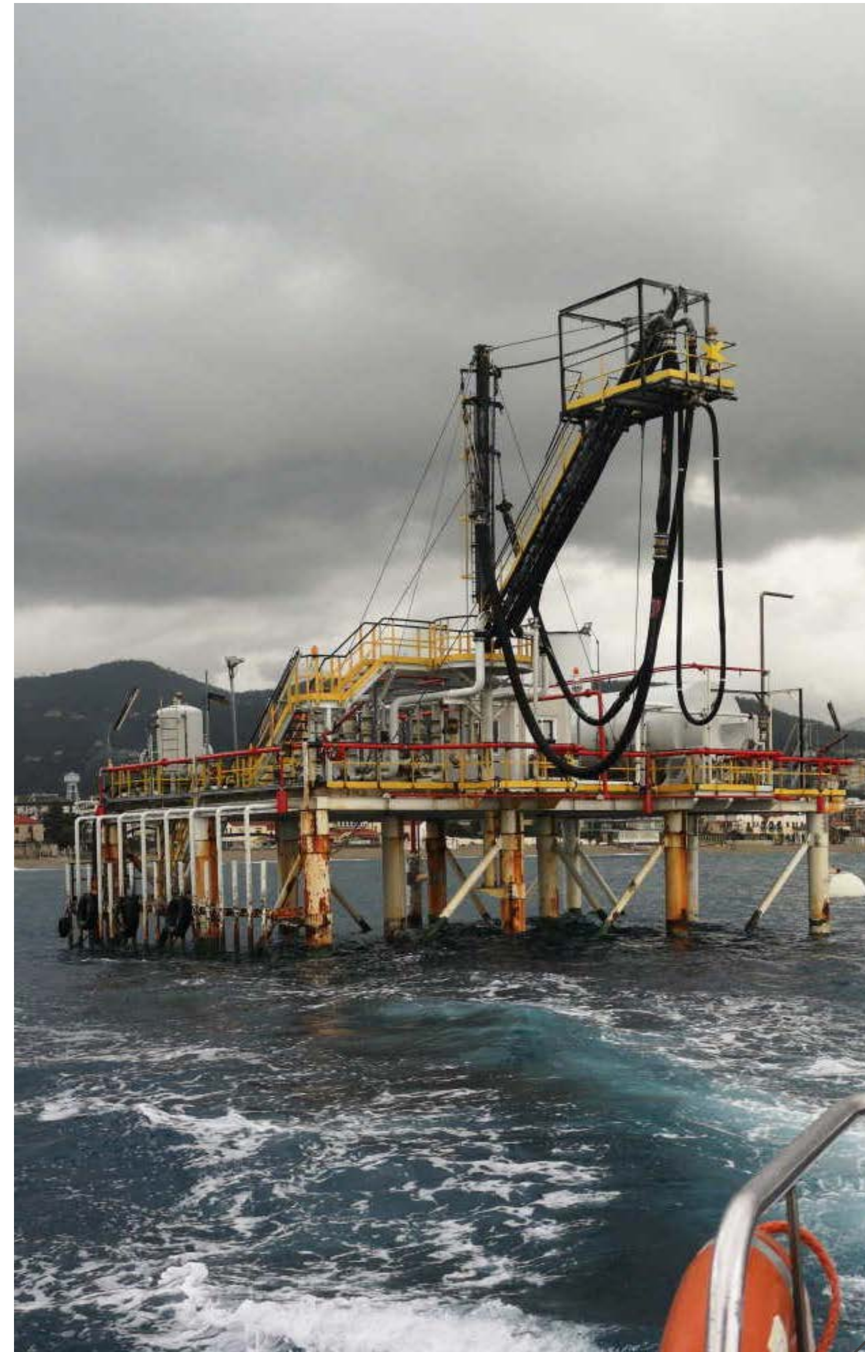
As regards the OMA surveys, the dynamic quantity chosen for the measurements consists of the frequency response of the structure in terms of accelerations in the defined points.


E-g-meter


Strain gauges
Temperature sensors
Monodaq-E-STG


Monodaq-U-X





The Vado Ligure offshore dock

The systems installed on a jetty in Vado Ligure and on an offshore platform in Savona have the aim of verifying the behavior of both structures when subjected to a significant wave influence - see figures 9 and 10.

In addition to some buildings in Rome, systems have been installed on some buildings of its property along the Apennine ridge, with the main purpose of identifying seismic events, of any entity, with triggered storage.

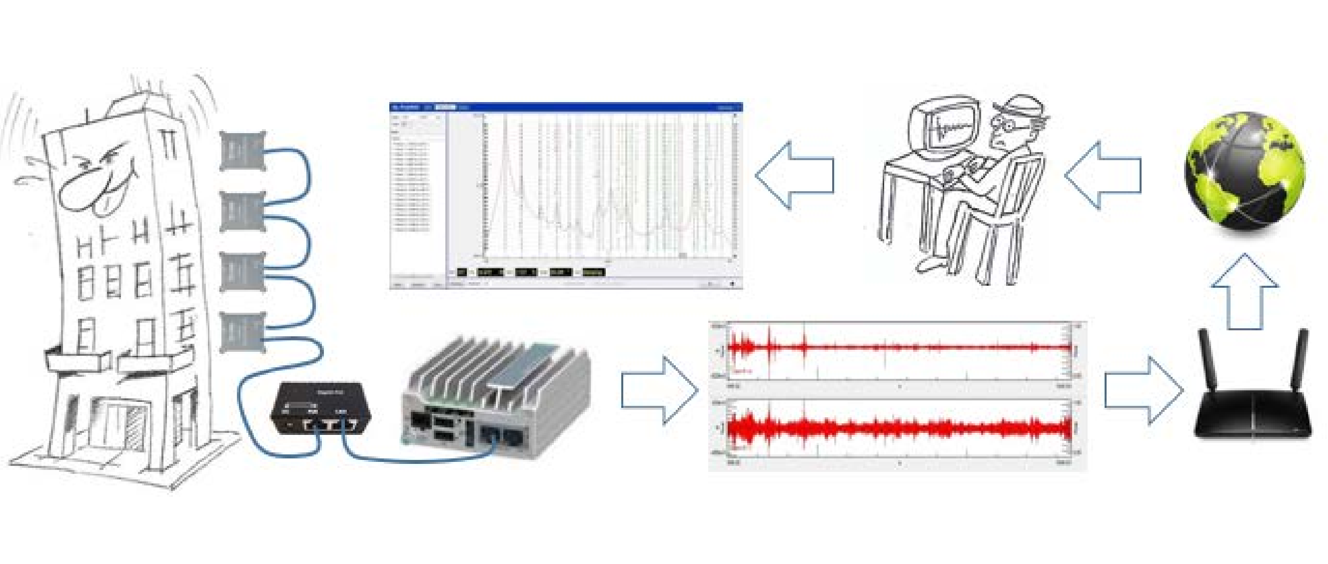
Passive seismic control

Considering the huge real estate assets of Poste Italiane, if this experimentation were to hit the mark, it would open up very interesting scenarios in the passive seismic control of countless artifacts located in seismically relevant areas - see figures 11 and 12.

With regard to a residential or monumental building, a typical modular dynamic monitoring system consists of a series of 3x MEMS-ACC DAQ modules appropriately distributed on the various floors and powered over Ethernet (PoE).

In the case of buildings that are regular in plan and height, minimal installations are required with a 3xMEMS-ACC at the foundation (zero seismic), as well as a couple arranged, for example, on the top floor. This is the hypothesis of shear-type floors and when you want to analyze only the first modal forms. As interest in higher modal forms increases, there is a progressive involvement of all the other floors, until they are all affected.

In the face of more complex buildings, the number of modules inevitably tends to increase as a function of the desire to obtain analysis that is more and more truthful. The acquired data is then stored following appropriate selective algorithms on the mass support of the industrial PC placed in a special panel together with a router. The router is used to provide an internet connection on the remote terminal. A system for sending messages is also usually active when previously set thresholds are exceeded - see figure 13.



Preventive control of building condition

The Italian territory is packed with architectural treasures. At the same time, it is often battered by seismic events, more or less significant, which cause serious damage. Hence a permanent and preventive control of the artifacts considered to be of greatest value, regardless of their actual conservation conditions, could constitute a serious opportunity in terms of future developments.

At the moment Palazzo Pamphilj and the Portico di Ottavia in Rome are under instrumental observation - see figures 14 and 15. The modular dynamic monitoring systems are installed with multiple 3xMEMS-ACC devices.

The monitoring system is important for two things:

- Allowing the trigger storage of seismic events with the possibility of evaluating the actual behavior of the building portion of interest when subjected to significant shaking.
- Enabling periodic modal analysis with the sole environmental excitement.

The IOLITEdi-3xMEMS-ACC modules, with their characteristic of very low spectral noise, are particularly suitable for carrying out modal analysis in operating conditions (OMA). In addition to the main purpose for which they have been installed, the whole series of artifacts reported above, have allowed arriving at dynamic characterizations, enabling to fully define the dynamic identity card of the artifact under consideration.

OMA - modal analysis on bridges

Considering the above, the E-gMeters (3xMEMS-ACC) were not only used in permanent monitoring installations but also as part of extemporaneous solutions for the dynamic characterization of different types of structures employing Operational Modal Analysis (OMA).

Here is an example of two city bridges - see figures 16 and 17:

- the famous Ponte del Risorgimento in Rome, with a span of over 100 m among the first reinforced concrete works built in Italy,
- and the metal pedestrian walkway called the Navetta in Parma.

With regard to Ponte della Navetta, an analysis before and after the intervention was carried out with tuned mass systems to evaluate its effectiveness in terms of vibration damping.

In the case of Ponte del Risorgimento, the OMA was compared with the measurement performed by the ESSEBI back in 2014. The overlap in terms of natural frequencies with the results obtained at the time, with multi-channel systems and high-sensitivity seismic IEPE piezoelectric accelerometers, was amazing. Even more surprising was the use of E-gMeters (five on each side edge of the bridge) to have obtained softer and more defined modal shapes.

Other OMA were performed on other artifacts. We just want to recall the testing of the two recently built overpasses in Novara and Palmanova (UD).

Monitoring nearby construction and demolition

An application that is becoming increasingly popular is vibration control in buildings. This is adjacent to an area with high-intensity vibrations that are artificially caused. At the moment ESSEBI is in fact engaged in checking four buildings around one - a former clinic - that is gradually being demolished - see figures 18 and 19.

The four autonomous systems, in the four buildings, are all made up of E-gMeter modules connected to PCs. By using a router and remote control, messages are sent whenever the threshold values derived from the available standards (DIN 4150, ISO 4688, etc.) are exceeded.

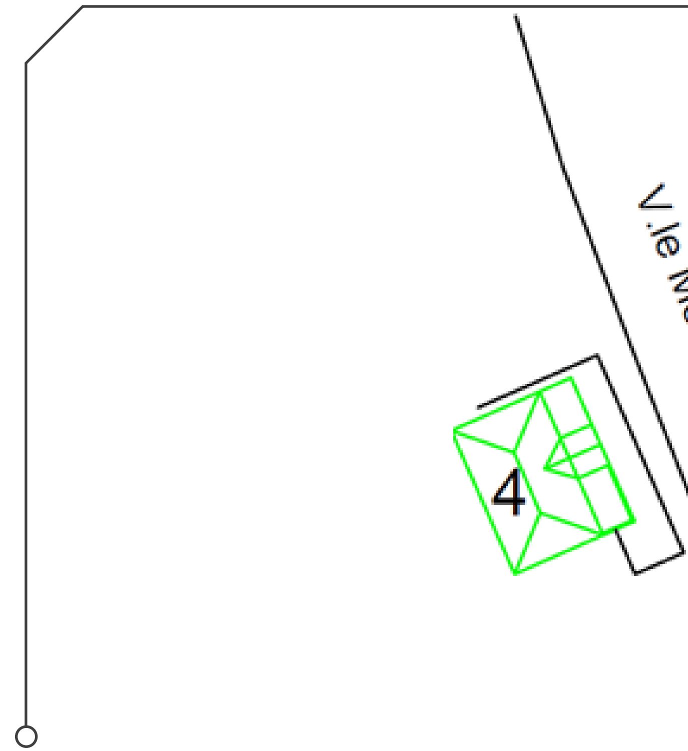
Conclusion

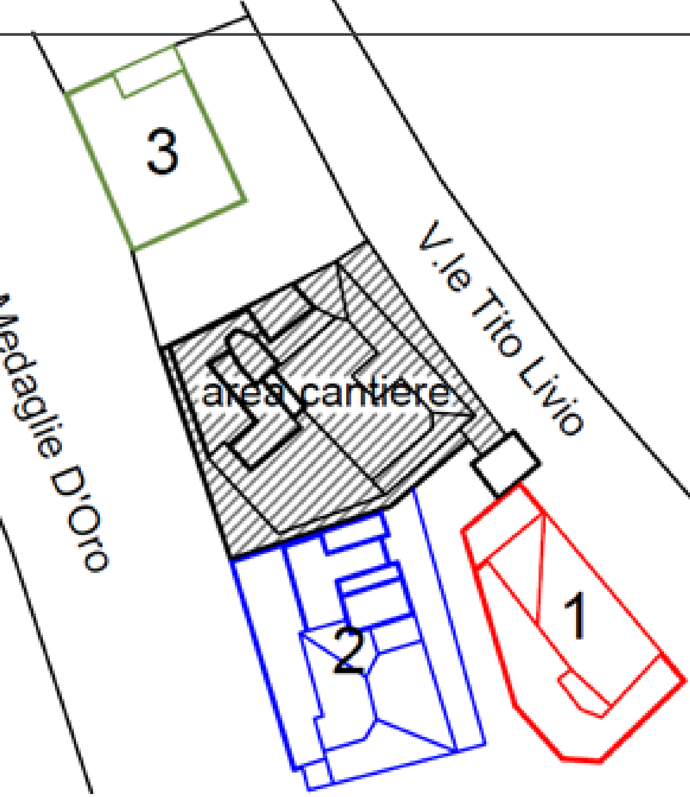
About two years after its birth, the IOLITEdi-3xMEMS-ACC is establishing itself as an optimal and versatile solution for dynamic monitoring of any kind. It is particularly suitable for applications concerning structural health monitoring.

Competing solutions proposed are always the same. They usually include many modules with a sensitive element consisting of accelerometer sensors or velocimeter connected via LAN or wireless networks. Such a solution is banned by many EU directives due to problems related to safety. It is fallacious for dynamic applications where the acquired data is huge, is high on battery consumption, and is highly risky when it is necessary to guarantee synchronous data acquisition.

These proposed modules refer to most often consisting of a PC or of some minimal process controller with the possibility of data storage and remote operation. At best these solutions are set up and assembled in some basement, without any industrial approach or testing.

The presence of a valid software platform, with the possibility of multiple uses at different levels of complexity, gives an extra kick to Dewesoft data acquisition instrumentation. It always represents an inevitable weakness of competition which, in a more or less amateurish way, tries to enter the sector of structural monitoring.

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Operational modal analysis and long-term structural monitoring of a jetty

By Giorgio Sforza, Technical Director, ESSEBI S.r.l., Italy

CASE STUDY

Modal analysis is vital to understanding and optimizing the inherent dynamic behavior of structures. The influence of sea waves on a jetty structure is now continuously monitored at the Italian harbor of Vado Ligure.

The system enables the control of its structural conditions over time, detecting its dynamic response employing a series of integrated signal conditioners with built-in MEMS accelerometers – IOLITEd 3xMEMS-ACC Dewesoft IOLITEd DAQ devices - all arranged on the structure and connected to constitute the measurement chain.

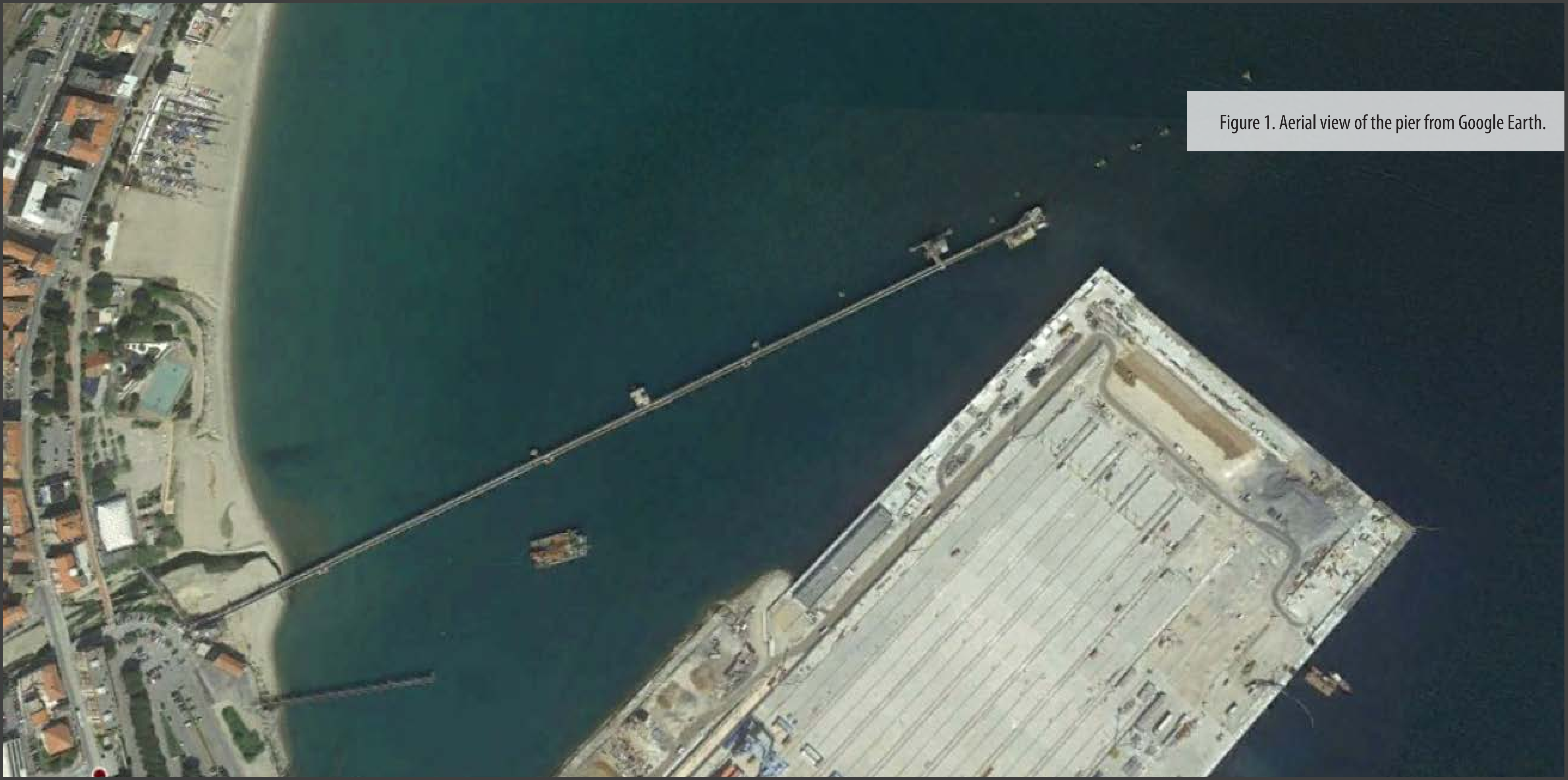


Figure 1. Aerial view of the pier from Google Earth.

The Italian port of Savona Vado or Vado Ligure in the North-Western Italian region of Liguria is located west of Genoa in the Northernmost part of the Mediterranean Sea. This large industrial and commercial port has piers for the loading and unloading of coal and oil, and a terminal that provides ferry services connecting Savonna Vado with the islands Corsica and Sardinia.

Here, the structural health monitoring systems are installed on an 800 meters long jetty in Vado Ligure to verify the behavior of the structure when subjected to the influence of significant sea waves.

The jetty is owned by Esso Italiana S.r.l. and allows tank ship loading and unloading. It connects via a pipeline to a berth from which base oils for blending purposes are pumped to a lubricant plant for manufacturing processes, packaging, storage, and distribution.

Modal analysis and OMA

Modal analysis is vital to understanding and optimizing the inherent dynamic behavior of structures. In structures, almost all vibration problems are related to structural weaknesses associated with resonance behavior, natural frequencies being excited by operational forces.

For many civil engineering and mechanical structures, it is difficult to apply excitation using either a hammer or shaker due to their physical size, shape, or location. Also, civil engineering structures are loaded by ambient forces, such as waves, wind, or traffic. These natural input forces cannot easily be controlled or correctly measured. However, in some cases, it is preferable to use this natural excitation of the structure under true operating and boundary conditions to determine its modal properties.

Operational Modal Analysis (OMA) is based upon measuring only the responses of test structures for accurate modal identification under actual operating conditions – with no artificial excitation – and is often used in situations where it is difficult or impossible to control an artificial excitation of the structure.

The methodology is known as OMA - Operational Modal Analysis, whose approach is also called "Output Only" as it is the only response of the structure to be analyzed without having forced nature or known trends generated on it. These data, treated with appropriate modal extraction algorithms, allow the proper modal parameter identification.

The complete dynamic behavior of a structure can be viewed as a set of individual modes of vibration, each having a characteristic natural frequency, damping, and mode shape. By using these dynamic properties of systems in the frequency domain,

Figure 4. Photos of the installed instrumentation

the modal parameters, to model the structure, problems at specific resonances can be analyzed and subsequently solved.

A modal identification determines the modal parameter's characteristics of a structure. These parameters are the specific frequencies of the structure with the related damping and modal forms. Knowing the modal parameters enables the prediction of the response of the structure as a function of external excitation.

The structure's vibration modes in fact provide information about the relative motion of the elements which make up the structure when it is stressed at that particular frequency. If the structure is subjected to an action that excites more than one frequency, the way the structure vibrates would result from the combination of exciting vibrating modes.

These parameters thus constitute a sort of dynamic "identity card" of the structure that can be used for the validation of calculation models, for their calibration, or diagnostic purposes – providing a baseline in long-term structural monitoring.

Figure 2. Dewesoft IOLITEdi 3xMEMS-ACC data acquisition device with integrated low-noise 3-axial MEMS accelerometer

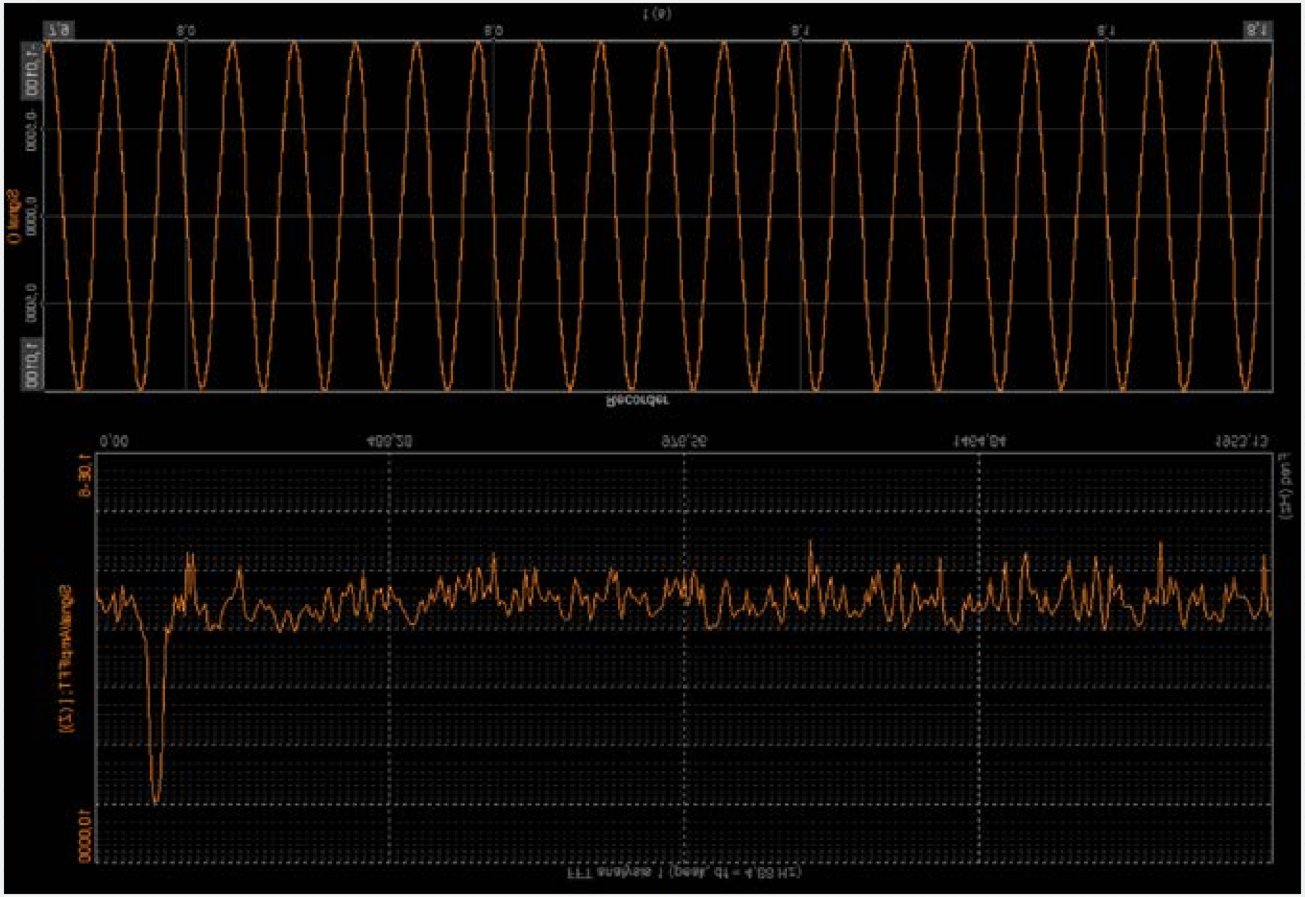


Figure 3. Dewesoft records vibration signals in the time domain while DewesoftX software converts the recorded signal into the frequency domain using Fourier transform

Measurements

The detection of dynamic parameters makes it possible to verify the persistence of the structural conditions with reference to a precise instant of time T0. Generally, this time T0 for new structures can be taken at the time of testing, whereas for existing structures it can be taken as the time instant in which an assessment of the structural safety conditions is carried out and in which the first measurements are made.

In this particular case, the data were recorded by the system on two separate days straddling the completion of repair work on one of the poles on December 28, 2018. This made it possible to evaluate the effects of the rehabilitation interventions and to have an up-to-date picture of the dynamic properties of the structure after the repair intervention. This picture was then used as a reference for the control of its state of preservation over time.

The dynamic magnitude chosen for the measurements is the response of the structure in terms of acceleration in some points arranged on the surface of the platform at the head of the pier. In particular, the points at the four vertices of the plan shape of the jetty platform, which were named with the letters A – D, were instrumented.

Each measurement point was instrumented with an IOLITEdi 3xMEMS-ACC, a three-axis accelerometer with axes XY oriented according to the directions of the horizontal plane and the vertical Z-axis - see figures 2 and 4. In particular, with reference to the plan layout of the platform, the X-axis is orthogonal to the development axis of the jetty and the Y-axis is parallel to the latter.

For the dynamic characterization of the structure, the accelerometric measurements acquired in two separate days were done on December 6, 2018, and January 4, 2019, before and after the rehabilitation of the B1 pole of the platform. For each day, the signal was acquired from the sensors for a 60-minute period and the modal characteristics of the structure were determined based on the accelerometric response within this interval.

The measurements were carried out with a sampling frequency equal to 100 samples/s. The appropriate anti-aliasing analog filter was used and a consequent bandwidth up to about 40 Hz. This allowed having a more than adequate frequency band concerning the expected frequencies for the investigated structure.

A simple geometric model, a single-line diagram, relative to the measurement points corresponding to nodes arranged in the space, and linked together by lines – makes the perception of the shape more immediate.

To improve the visualization of the modal forms additional points are added to the simplified single-wire diagram (wireframe) with the measured physical points A – D, simulating the base sections of the supporting poles - see figure 5.

The summary of the results of the measurements performed on 6 December 2018 and 4 January 2019 - see table 1, enables a quick comparison of the analysis attained in terms of frequency, damping, and prevalent direction of the associated modal form.

The frequencies determined starting from the measurement of the accelerometric response on 4 January, following the repair operation performed on the B1 pole, are higher than those determined on 6 December, with an increase of between 4 and 7%. The modal forms do not appear to change between the two elaborations. Therefore, the modal parameters of this study of the structure show an increase in rigidity following the restoration of the poles.

Form	f [Hz] 6/12/2018	f [Hz] 4/01/2019	z [%] 6/12/2018	z [%] 4/01/2019
Translational X	1,171	1,224	1,15	1,10
Torsional	1,303	1,385	1,22	2,27
Roto translational Y	1,453	1,514	1,69	1,85
Translational Y	1,717	1,845	2,24	1,78

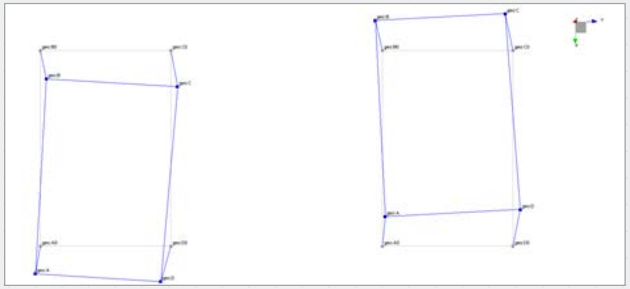


Figure 4. Translational modal form X

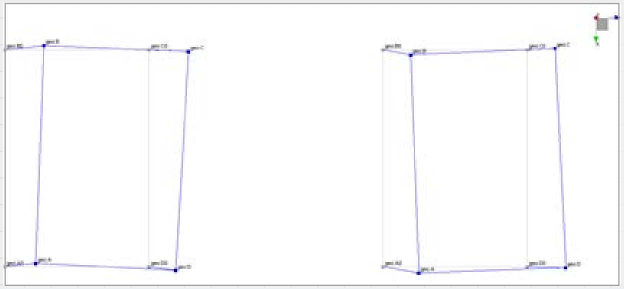


Figure 5. Torsional form

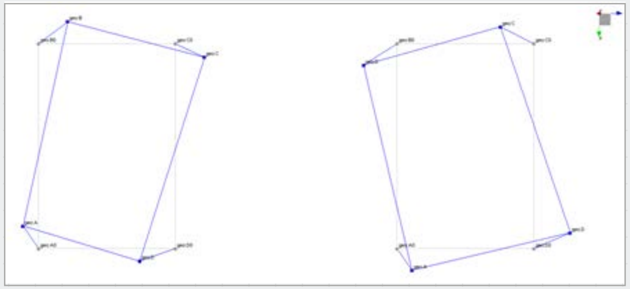


Figure 7. Translational modal form Y

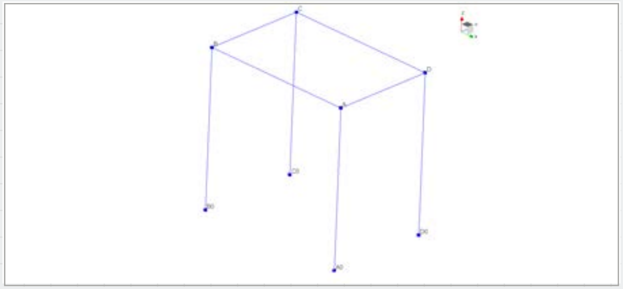


Figure 5. Wireframe geometric model of the pier

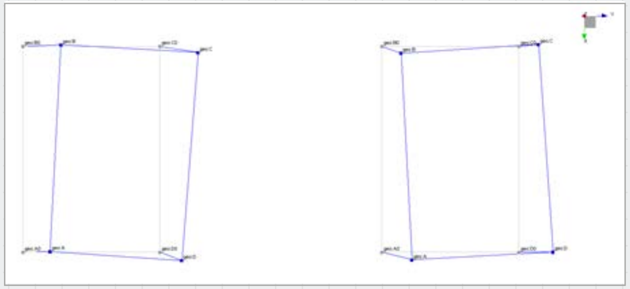
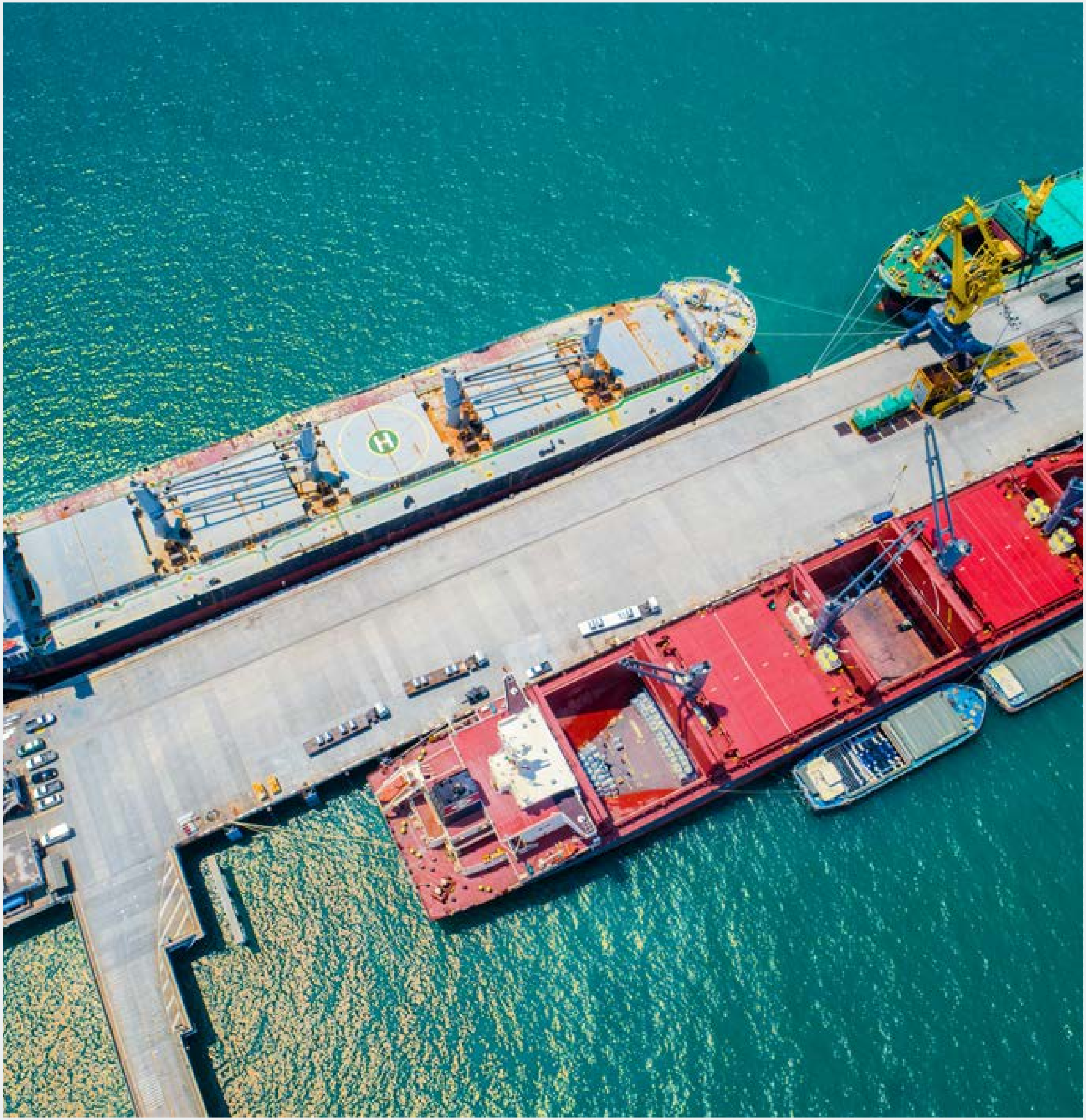


Figure 6. Roto translational modal form Y



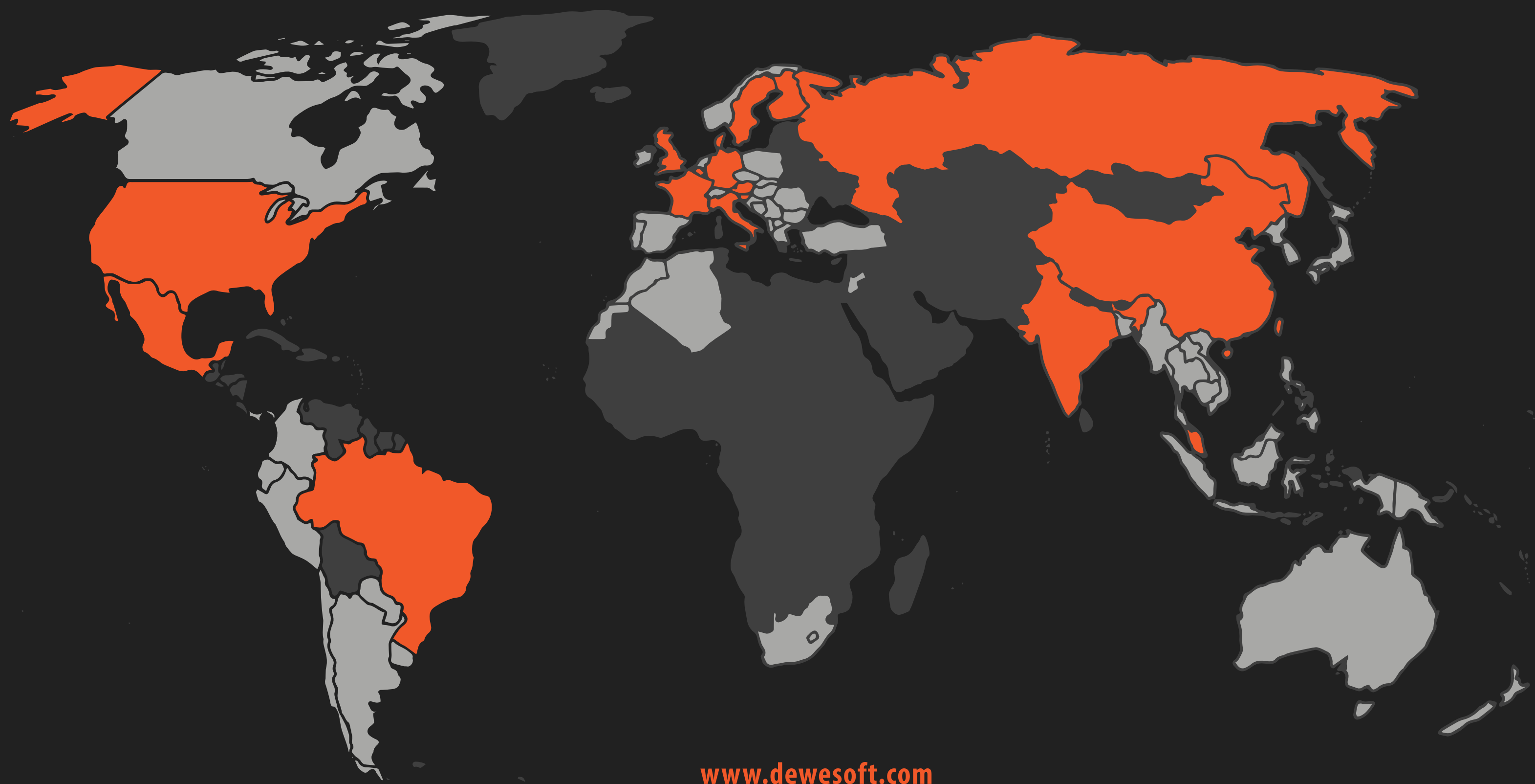
Conclusion

This method provides for the calculation at regular intervals of the specific frequencies of the structure and therefore the continuous structural monitoring and comparison with the data obtained at the initial time taken as reference.

Due to its very low costs and short realization times, the methodology of Operational Modal Analysis (OMA) is increasingly used in the civil engineering sector to characterize the dynamics of a structure.

Learn more:

- Dewesoft rotating machinery vibration testing solutions
- Dewesoft modal testing solutions (SIMO, MIMO, OMA, ODS analysis, ...)
- Dewesoft modal testing online training course



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