GURALP SYSTEMS

Industry guide

Seismic instruments in the energy sector

The energy sector places unique demands on engineers, requiring both the construction of large structures and a guarantee of the safety of these structures, and of the equipment and personnel inside, when exposed to natural ground motion.

Before a power plant is built, and during construction, seismometers are used to study the level and type of local seismicity, helping engineers to design the structure to withstand ground motion with a high degree of tolerance.

Whilst the plant is operational, networks of accelerometers monitor the motion of the structure and can alert operators or automatically shut down systems if engineered safety margins are approached. This aspect is particularly important for nuclear power stations.

Data from these instruments and from free-field installations provide response information which can be compared against a dynamic model of the structure. As well as confirming the design parameters of the station and suggesting areas for improvement in seismic stability, studies of this kind lead to a greater understanding of the response of large structures in general.

Güralp Systems' accelerometers provide a truly cost-effective way to build dense strong-motion broadband arrays. Combinining these with our flexible digital hardware and telemetry systems, engineers and scientists now have access to a wider range of instrumentation options than has previously been possible.

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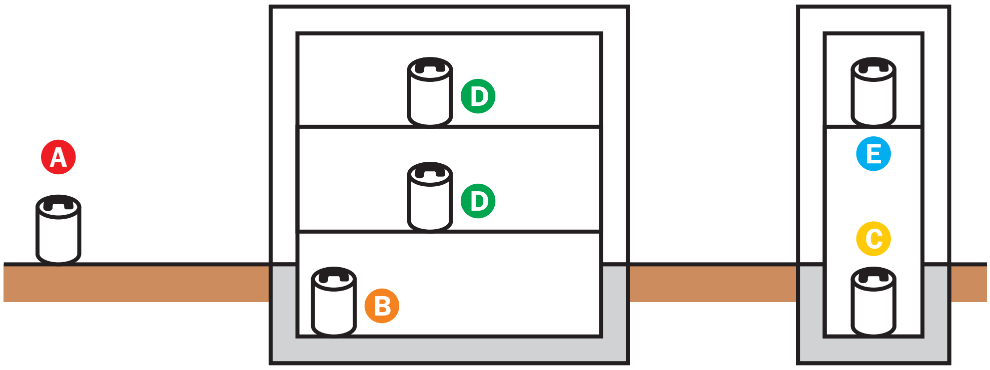
Array design within power plants

Similar design considerations apply to installations in power plants as to other large structures. Arrays normally combine free-field instruments with sensors in the foundations of the structure, and at one or several elevations.

The design of seismic arrays within a nuclear power plant may be subject to local regulation. For example, the US Nuclear Regulatory Commission requires the locations shown below to be instrumented as a minimum provision.



Free field: Location A measures the reference ground motion at a location distant enough that the effects of the structures are insignificant, but where the ground motion is still representative of that at the site.

Foundations: Ground motion is measured at the base of the containment (location B) and an independent second structure (location C). This represents the effective input vibration to the components of the plant.

Elevations: Finally, the vibrations of the containment (locations D) and the independent structure (location E) in response to the input motion are monitored.

All the locations should be chosen so that the results can be modelled by dynamic analysis, whilst avoiding areas of high radiation risk. Because of this requirement, instruments need to be as autonomous as possible so that maintenance is kept to a minimum.

Güralp Systems' digital sensors are highly robust and can be configured remotely using their normal communications links, including firmware updates.

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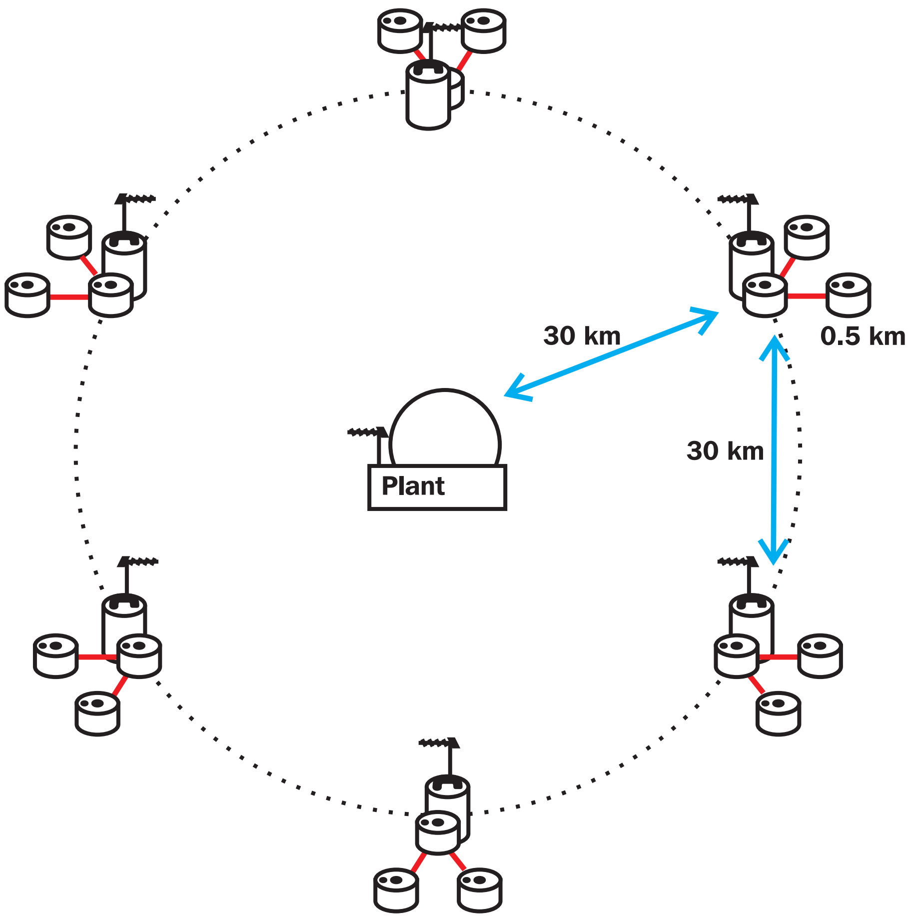
Array design for early warning systems

If the plant to be instrumented is already operational, it may be impossible to install seismic equipment to the latest standards. Safety monitoring in these cases can be performed using remote "early warning" systems which can shut down the station in the case of an earthquake.
For example, a plant in Lithuania was surrounded by six seismic stations at a distance of 30 km. When an earthquake is detected at one of these stations, it sends a shut-down signal over a radio telemetry link, which is received around 10 s before the seismic waves arrive at the plant. [Wieland *et al.*, 2000]



In this case, each station consists of one velocity sensor and three accelerometers. When two of any set of three accelerometers exceed their triggering threshold, the alert is given. Under normal conditions, continuous seismic data is recorded for basic research and monitoring purposes.

Güralp Systems' CMG-5TD digital accelerometers and DM24 digitizers include full support for triggering and low latency features.

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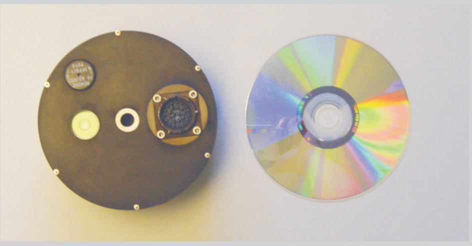
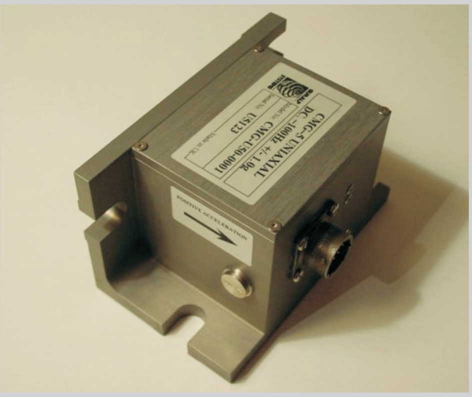
Güralp Systems’ strong motion range





Güralp Systems produce strong-motion broadband sensors suitable for a range of installation types.

Our latest surface strong motion instrument, the **CMG 5T Compact**, is a full three-component sensor housed in a case about the size of a standard CD.

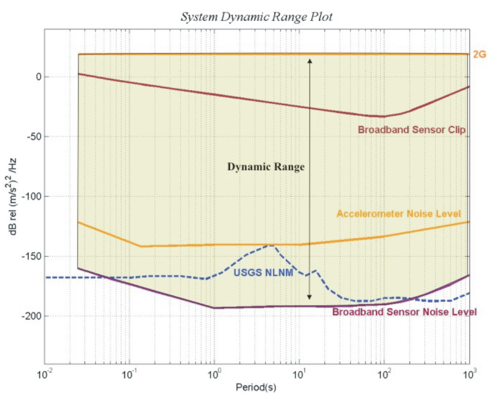
The uniaxial **CMG-5U** instrument is designed for simple installation in either vertical or horizontal orientation.

The well-regarded original design **CMG-5T** is also available. This instrument can also be fitted with an internal CMG-DM24 digitizer module to form the **CMG-5TD**.

The 5TD offers support for high sample rates and low latency data transmission, as well as direct data download over FireWire. At-a-glance status information is available on its optional LCD display as well as being transmitted with the data streams in GCF format. Full configuration and firmware updates can be carried out remotely over the standard serial interface.

Identical components to the 5T are also used in the **CMG-5TB** borehole accelerometer.

CMG-5TB components can also be fitted as part of a combined weak- and strong-motion borehole instrument, providing unsurpassed resolution and dynamic range for both local events and teleseisms. This instrument is particularly suited to autonomous free-field stations, especially in combination with downhole digitizers and data modules.



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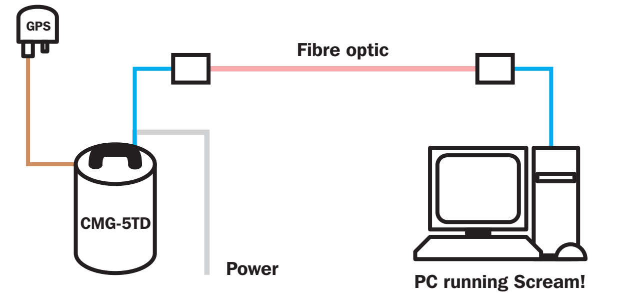
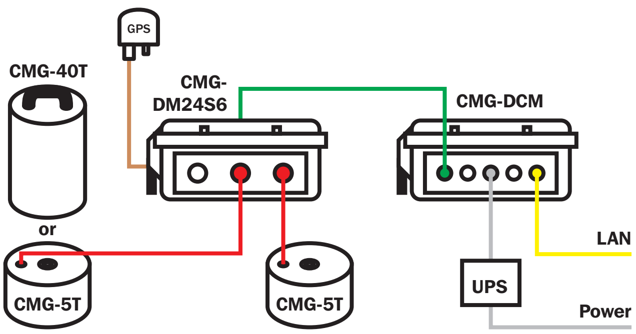
Telemetry and networking options

Güralp Systems' hardware forms a modular system using standard protocols, giving engineers the flexibility to design the network to their needs.
A single array can combine a wide range of technologies.



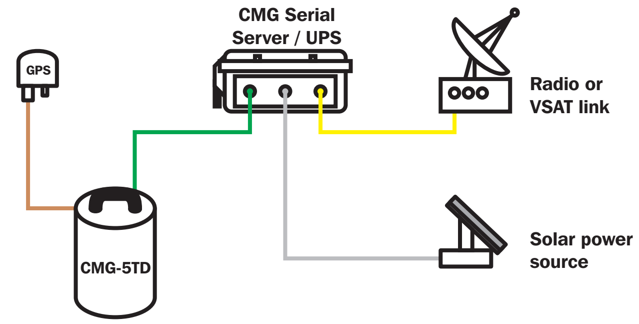
Example 1: A CMG-5TD installation
The digitizer outputs data streams over an RS232 or optional RS422 link using Güralp Systems' compact GCF format and block recovery protocol. Media converters or modems can be used to carry serial data over fibre-optic cables or telephone lines.

Streams are received by an acquisition PC running Scream! software, where they can be archived or retransmitted as desired.



Example 2: An installation using a six-channel digitizer connected to two analogue instruments. Velocity (CMG-40T or 6T) and acceleration (CMG-5T) instruments can be used interchangeably.

Data streams output from the digitizer are transmitted onto the network by a CMG-DCM data communications module.

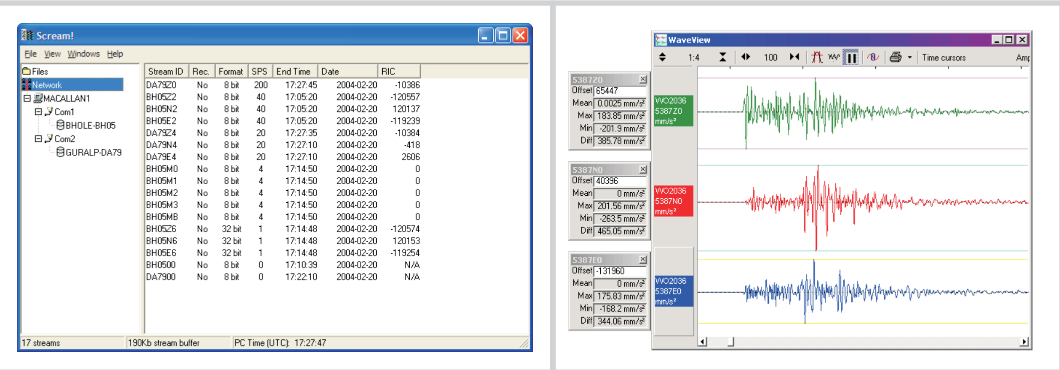


Example 3: A free field installation based on a CMG-5TD instrument. Power is supplied from a solar panel through a Serial Server / UPS.

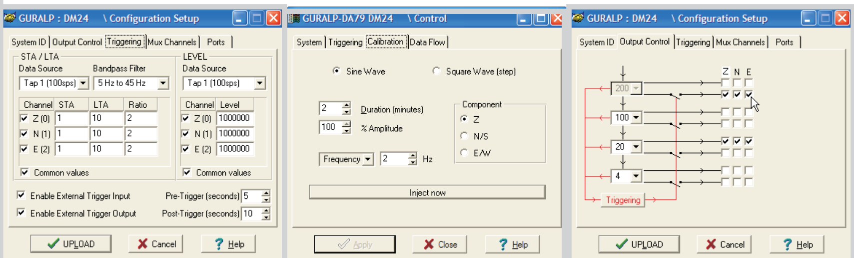
The Serial Server also receives GCF data from the 5TD's output port and transmits it to a central location across a local area network, in this case carried over a radio or satellite link using a spread-spectrum, FM radio or VSAT modem.

Scream!

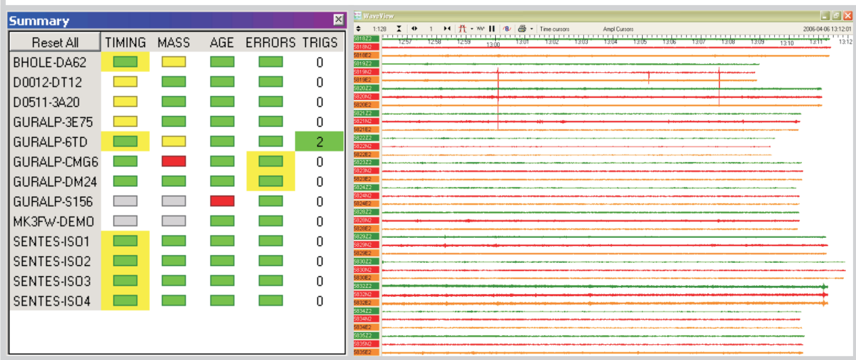
A PC running Güralp Systems' **Scream! software** can collect data from any number of sources and archive it to a local hard disk, or retransmit to a data centre further afield. Using Scream!, operators can view data streams in physical units, and apply filters to pick out events.



Scream! can **replay archived data** and **convert data** into a number of common formats, including MiniSEED and UFF. Güralp digitizers can also be fully **configured and controlled** using a graphical interface.



As well as displaying real-time data from any number of instruments side by side, Scream! provides features for **monitoring seismic networks.** Timing, mass position and data integrity information for the entire network is summarized in a convenient window.



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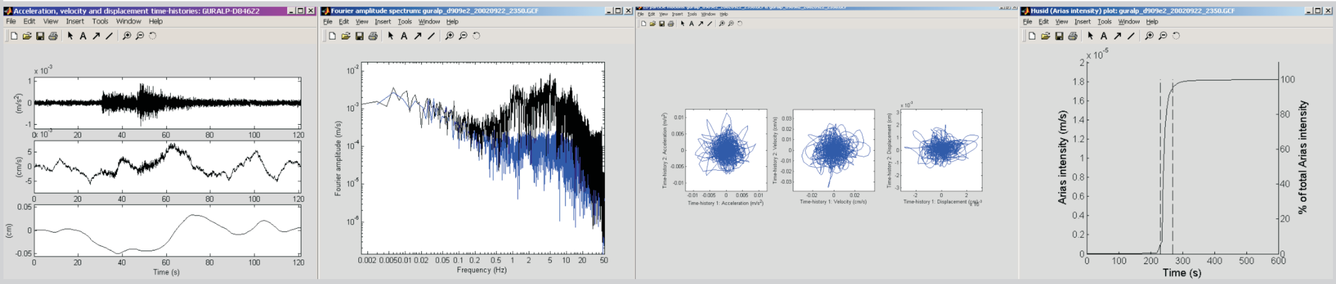
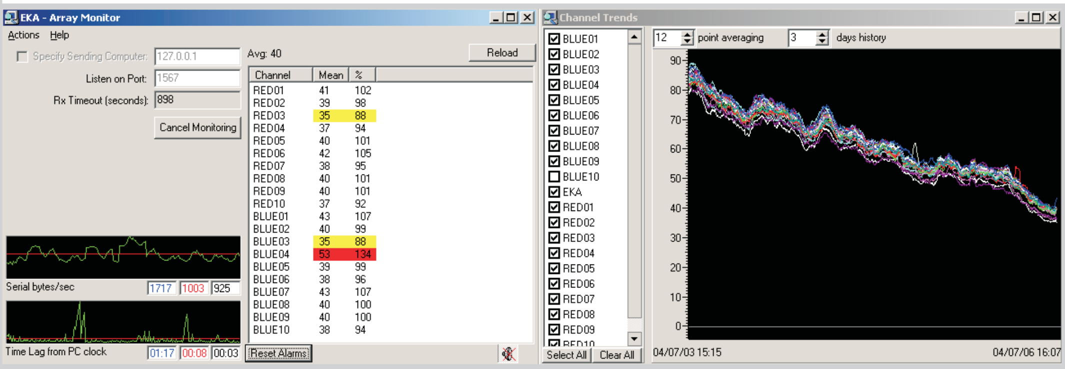
Monitoring and analysis software

Standard **extensions to Scream!** allow operators to generate instant PSD plots, and interpret calibration experiments.

Güralp Systems' strong-motion analysis tool, **ART**, extends Scream! still further. ART offers a wide range of commonly-used analysis techniques, including uncorrected and corrected response spectra, particle motion analysis, spectral intensity and Arias intensity plots.



Completing the suite of analysis and monitoring software, **ArrayMon** focuses on the **seismic network** as a whole. Developed for use at existing arrays operated by Güralp Systems, ArrayMon provides operators with constantly updated information on **state of health, instrument outputs and channel trends.** It can also alert operators to potential problems by SMS.



Güralp Systems' data formats are well supported by third party software. Import filters are provided in the standard distributions of **Earthworm** and **Antelope**; tools are freely available for importing data into **SeisLog** databases; and Scream! fully supports the file formats used by **ARTeMIS, PITSA, sac, PC-SUDS** and other packages.

Case study: monitoring a wind turbine

A group at Keele University, led by Professor Peter Styles, has deployed Güralp Systems' equipment to study the extent of ground vibrations caused by wind farms.

The group installed a DM24S12AMS acquisition and monitoring system in a wind turbine in Ardrossan, west Scotland. This is a complete digitizing and recording station with an on-board PC, which can gather data from up to 12 CMG-5U single-axis accelerometers and 6 additional CMG-5TD triaxial digital instruments.

For this experiment, four CMG-5U instruments were fixed to glass plates on the inside wall of the wind turbine tower. Two more uniaxial instruments were installed vertically on the floor.

The DM24S12AMS module was installed in the centre of the tower base and connected either to mains power via a 3-phase adapter, or to a 12V battery pack.

A CMG-5TD sensor was also deployed, buried in a shallow sand-filled pit a short distance from the tower. This sensor recorded free-field ground movements, whilst the 5U instruments monitored the motion of the tower itself.

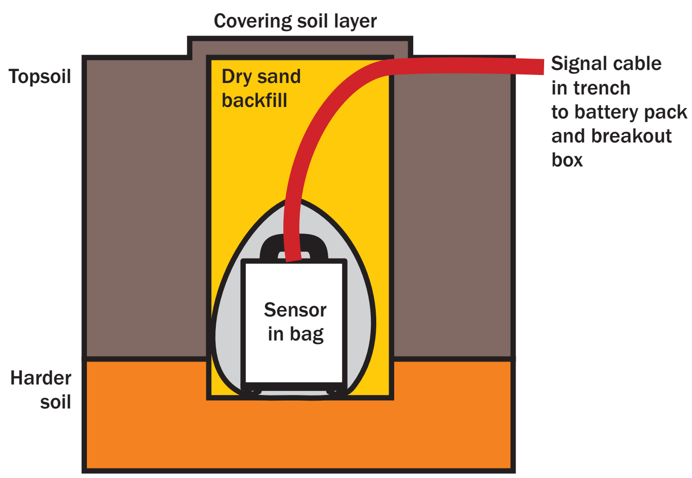
Data streams were automatically recorded by Scream! on the hard disk of the DM24S12AMS' built-in laptop PC. At the end of the experiment, data was retrieved over a local network.

Results

This experiment demonstrated that wind turbines do generate vibrations in the ground, at predictable frequencies related to the speed at which the blades rotate and the normal modes of vibration of the towers.

It also showed that wind turbines cause ground movements at a level proportional to the power output of the turbine. The scientists suggest that this could be improved by changing the design of the turbine foundations, so that they take into account seismic coupling as well as structural stability.

Case study: monitoring an entire wind farm



The first experiment used Güralp Systems' strong motion instruments to measure high-frequency structural vibrations near a turbine. At longer distances, these high frequencies are attenuated, so to study the effects of distant wind farms, the group used CMG-6TD medium motion velocity sensors. Velocity instruments are much more sensitive to ground motion at low frequencies than accelerometers.

In this experiment, 7 CMG-6TD instruments loaned from the sensor pool of SeisUK at the University of Leicester were deployed in a straight line at distances ranging from 1 to 17 km from the wind farm at Dun Law in the Scottish Borders, with an additional 3 forming a triangular array at a distance of 6 km. Cross-section of a typical pit installation.

Each instrument was set up to save all the streams it generated into its 3 Gb of Flash memory. This allowed the CMG-6TDs to run for approximately 55 days between visits to the site. At each visit, data was downloaded onto a 40 Gb Firewire disk. This was repeated for the 4-month duration of the experiment.

Results

This experiment demonstrated that seismic disturbances from wind farms travel as seismic surface waves which can be detected many kilometres away. The group also found that the ground motion generated by a group of turbines is proportional to the square root of the number of turbines.

The Keele group was able to use these results, together with a separate infrasound experiment, to suggest that turbines of current design cause significant ground vibration only within a restricted radius of the site.

References

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