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Modernization of the PS19 seismic station

Torsten Grasse[1], Gernot Hartmann[1], Erwin Hinz[1], Mathias Hoffmann[1], Marian Jusko[2], Lukas Menke[1], Ralf Schönfelder[1]

P4.4-134

POSTER

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ABSTRACT

After 25 years of reliable operation, PS19 (GERES) was modernized in 2017/2018. It was the first major upgrade since the station was certified as primary seismic IMS station in 2002. The German NDC operates PS19 remotely. The required data availability is ensured by preventive maintenance twice a year. The station consists of 25 array elements within an aperture of about 4 km. During the modernization, a total of 200 km cables for power supply and data transmission, connecting the array elements with the central facility, were replaced and the infrastructure was refurbished. A new system for overvoltage protection was installed in order to reliably operate the array in future. The GCI between the central facility and the IDC was changed from satellite connection to internet based VPN routing. All GERES GS13 seismometers underwent on-site reference calibration against a set of GS13s tested at CEA, France and SNL, USA in order to validate each seismometer's response against the values configured in the IDC. Data authentication has been successfully transitioned from DSA to ECDSA on both CD1.1 frame and sub-frame level. An additional broadband seismometer was installed for increasing the station's mission capability. PS19 was successfully revalidated in its new configuration.

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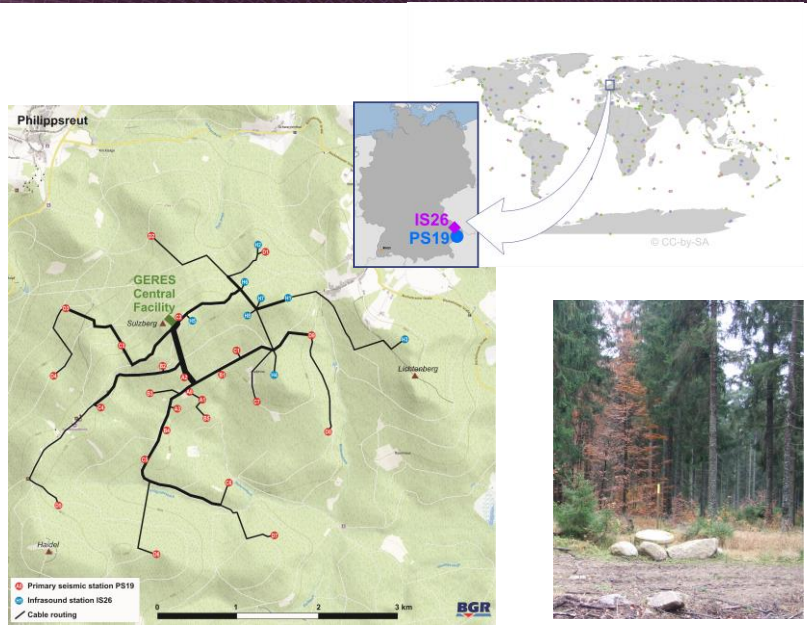
INTRODUCTION

PS19 (GERES) is the only primary seismic station of the IMS in Central Europe. It was installed in 1989 and certified as IMS station in 2002. The German NDC operates PS19 remotely. The required data availability of 98% is ensured by preventive maintenance twice a year.



The station consists of 25 array elements within an aperture of about 4 km. Each site is equipped with a vertical short period GS13 seismometer. Horizontal GS13 seismometers are installed at four array elements. Additionally, two 3-component broadband seismometers complete the array configuration.

The equipment is installed in vaults and connected with the central facility by power cables and fibre optic communication cables. Together with eight infrasonic array elements of the co-located infrasound station IS26 the data will be assembled in the central facility and prepared for transmission to the IDC.

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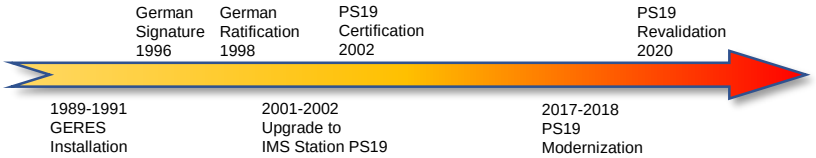
CABLING



The cabling of the GERES array was often affected by lightning strikes in more than 25 years of operation. The reliability of power supply was decreased. Consequently, a general modernization was carried out in 2017-2018. This major upgrade comprised the replacement of the cabling connecting the array elements with the central facility and the improvement of the overvoltage protection. The infrastructure of the central facility was refurbished. A total of 200 km cables for power supply and data transmission were replaced. It was necessary to shut down the data acquisition of the seismic array for 18 months.

A temporary seismic array with ten elements was set up in compensation to sustain the detection capability of the IMS seismic network. Local power supply by fuel cells and mobile communications for data transmission have ensured uninterrupted operation. (For more details see O4.4-135.)

Cables for power supply, data transmission and backup communication lead to each seismometer vault in a star-shaped layout. All cables are merged in the main cable duct to the central facility.

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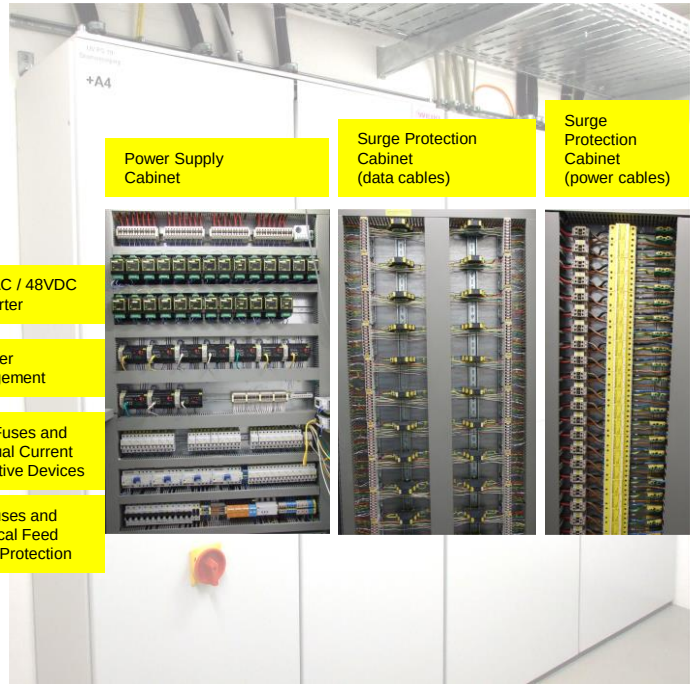
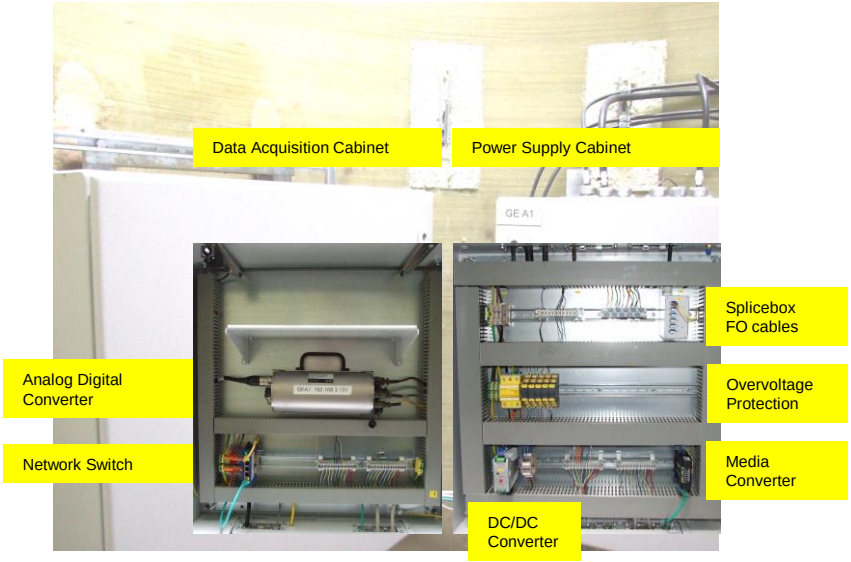
POWER SUPPLY



The power supply unit for the 25 array elements is installed in a separate room of the central facility. It is equipped with a two-stage surge protection.



About 60 km underground power cable were necessary to connect the central facility with the vaults at all array elements, where another overvoltage protection prevent any damage of the data acquisition devices.
Earthing electrodes above the cable routes provide protection against lightning strikes.

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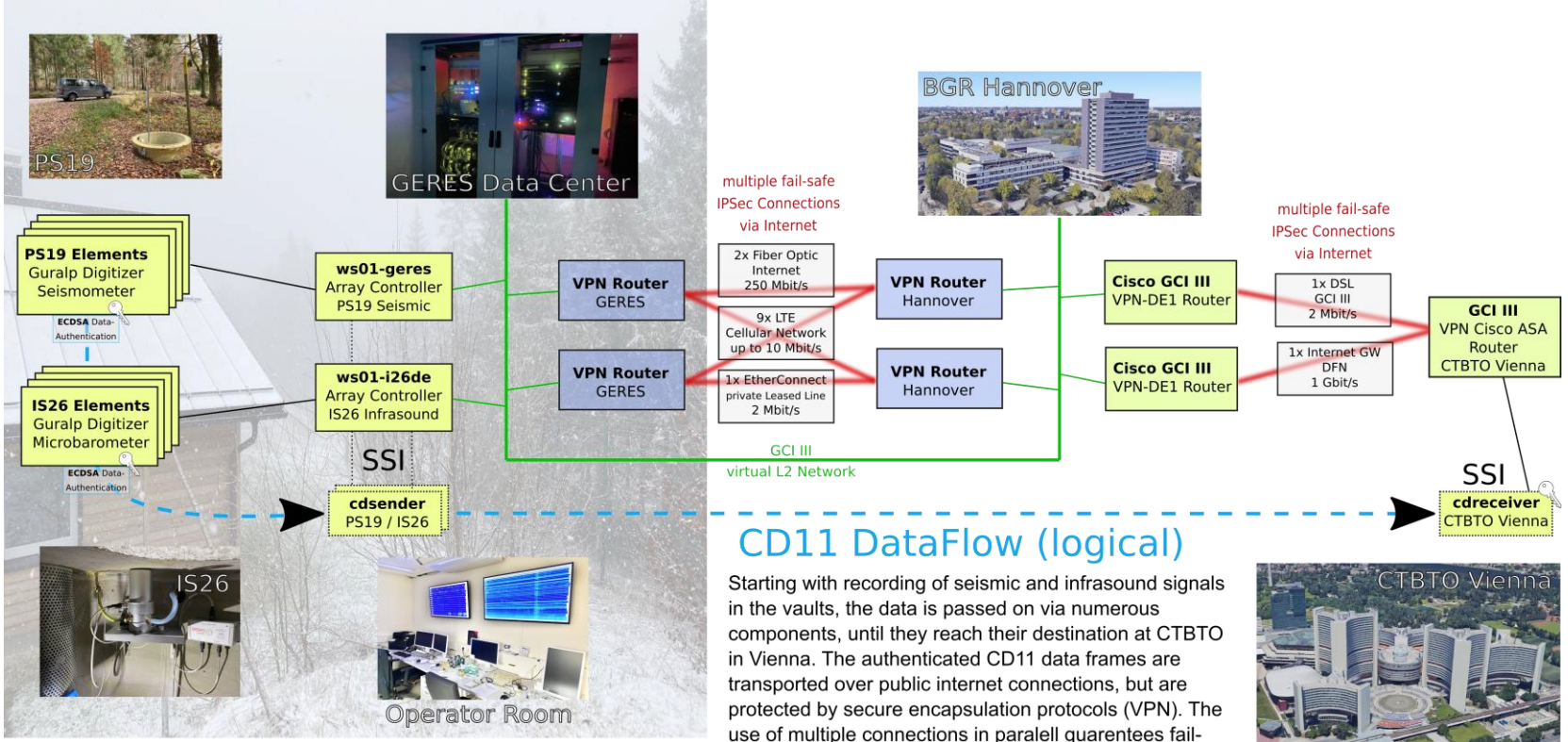
DATA FLOW



CD11 DataFlow (logical)

Starting with recording of seismic and infrasound signals in the vaults, the data is passed on via numerous components, until they reach their destination at CTBTO in Vienna. The authenticated CD11 data frames are transported over public internet connections, but are protected by secure encapsulation protocols (VPN). The use of multiple connections in paralell guarentees fail-save operation.

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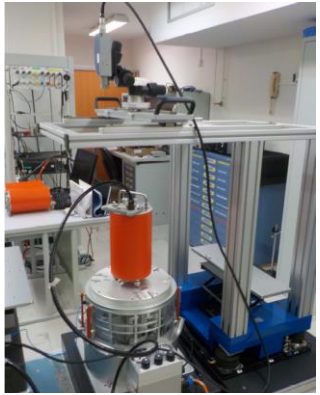
CALIBRATION



Calibration of GS13 vertical axis on shaking table

Digitizer Testbed with Signal Generator and Reference Meters

Objective

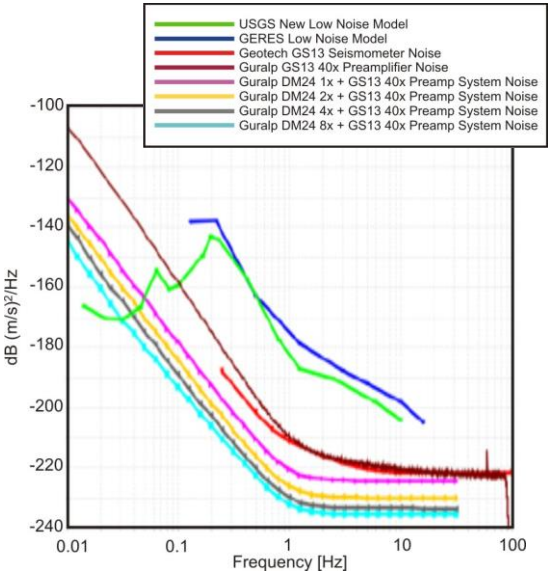
The upgrade of PS19 comprised the replacement of the old digitizers by Guralp DM24. New preamplifiers for their connection with Geotech GS13 seismometers had to be built. The combination of all device in a verified data acquisition system needed an independent calibration procedure.

Step 1

8 Geotech GS13 seismometers were sent to Sandia National Laboratories, USA (SNL) and French Alternative Energies and Atomic Energy Commission (CEA) to quantify their characteristics in controlled lab environment with predefined and common test procedures utilized by both laboratories.

Fully calibrated horizontal and vertical air bearing shaking table and laser vibrometer were used to ensure traceability of all measurands.

In addition, the new GS13-to-DM24 preamplifiers were evaluated and calibrated at SNL to measure and quantify their performance characteristics, including power consumption, input impedance, sensitivity, full scale, self-noise, dynamic range, system noise, response, passband, and timing (Ref: SAND2017-10485 Report).



The system noise conditions of the individual components of the GERES seismic system. The USGS New Low Noise Model and the Low Noise Model for the GERES array is given for comparison.

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CALIBRATION

The reference sensors were setup in a huddle test to directly validate the consistency of their calibrations.

The remaining sensors were deployed around the reference sensors, recording background seismic signals, for comparison determination of their responses.

Step 2

With the characteristics of the 8 Geotech GS13 reference sensors, Güralp DM24 digitizers, and the GERES preamplifiers measured in the lab-controller environment, the performance evaluation of the full fleet of the GERES instruments was conducted at the stations central facility.

Geotech GS13 seismometers

- Verification of lock/unlock functionality
- Balancing of springs supporting the seismometer mass on the vertical seismometers
- Measuring of signal coil impedance
- Measuring of calibration coil impedance

Güralp GS13-to-DM24 preamplifiers

- Measuring the digitizer signal output impedance
- Measuring the seismometer signal input impedance
- Measuring the DC Gain of the preamplifier signal line

Güralp DM24 digitizers

- Measuring the digitizer's bit-weight

The seismometer sensitivities were determined at 2 Hz, a frequency at which the instrument response is relatively flat, with good coherence, and where the recorded seismic signals had minimal local noise disturbance. The equivalent sensitivities at 1 Hz and 5 Hz were then derived by adjusting for the relative amplitude difference using the nominal Geotech GS13 response model.

All components were calibrated individually prior to combining them into their final and pre-determined sets of seismometer, preamplifier and digitizer, each destined for its specific array element.

To validate the accuracy of the measurements, two equipment sets were also calibrated at the final site location in the underground seismic vault, to correlate and validate the calibration results.

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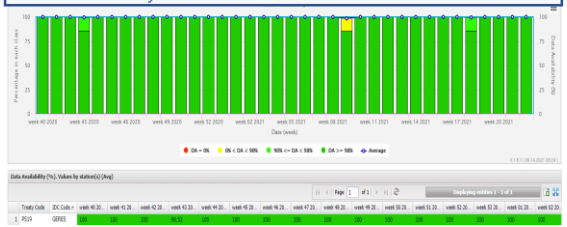
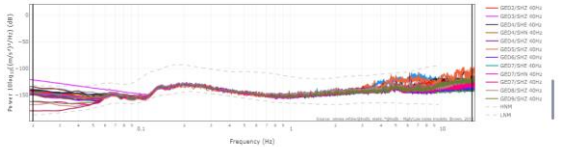
REVALIDATION

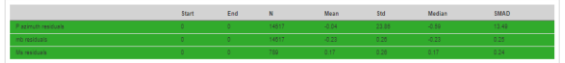
Data Availability



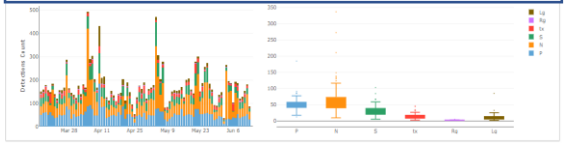
Power Spectral Density



Residuals Summary



Detection Rate



On-site revalidation tests at all GERES sites and the Central Recording Facility were successfully conducted in September 2020 by BGR, and since validated by the PTS.

All previously scheduled PTS on-site visits to inspect the delivery of the recapitalization works were impacted by the Corona pandemic.

Formal PS19 revalidation is planned after the PTS on-site inspection visit, which is tentatively scheduled for Q3 2021.

Routine monitoring of relevant station characteristics at the IDC examine the performance of PS19:

- The overall data availability meets the specifications for IMS stations.
- The power spectral density reveals the good seismic recording conditions at each array element.
- The correctness of array analysis is proved by the estimation of several residual values and detection rates.

Continuous monitoring tools quickly detect any operational irregularity.

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CONCLUSIONS

The complete systems of data acquisition in the seismometer vaults, the cabling for intra-site power supply and data transmission and the equipment in the central facility were renewed.

The system for overvoltage protection was improved to the current state-of-the-art technology. Since the restart, no outages due to the impact of lightning strikes were observed.

The GCI between the central facility and the IDC was changed to internet based VPN routing. Several backup lines are configured for a fast switchover in case of any communication failure.

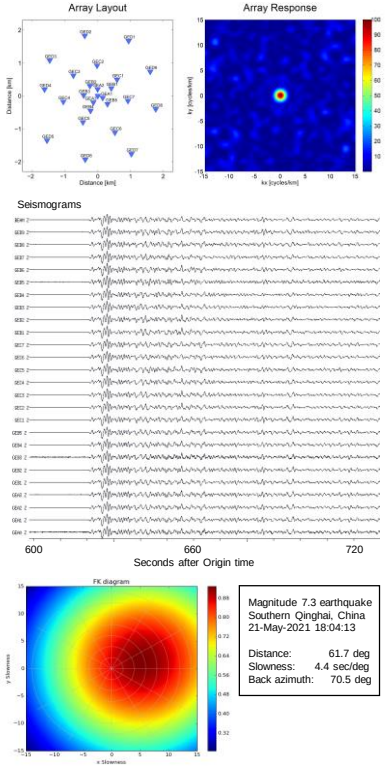
The GS13 seismometers in combination with Güralp DM24 digitizers were comprehensively checked and recalibrated before their reinstallation at the 25 array elements.

A second broadband seismometer was installed for increasing the station's mission capability.

The data streams are authenticated with ECDSA on both CD1.1 frame and sub-frame level.

PS19 returned to full array operation in December 2018 after 18 months of construction work. Revalidation tests finalized the modernization project in September 2020. Since then, GERES fulfills again the requirements for data availability of 98% every month.

GERES is an example for a successful major upgrade of a primary seismic IMS station.



Example of PS19 seismic recording and analysis

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