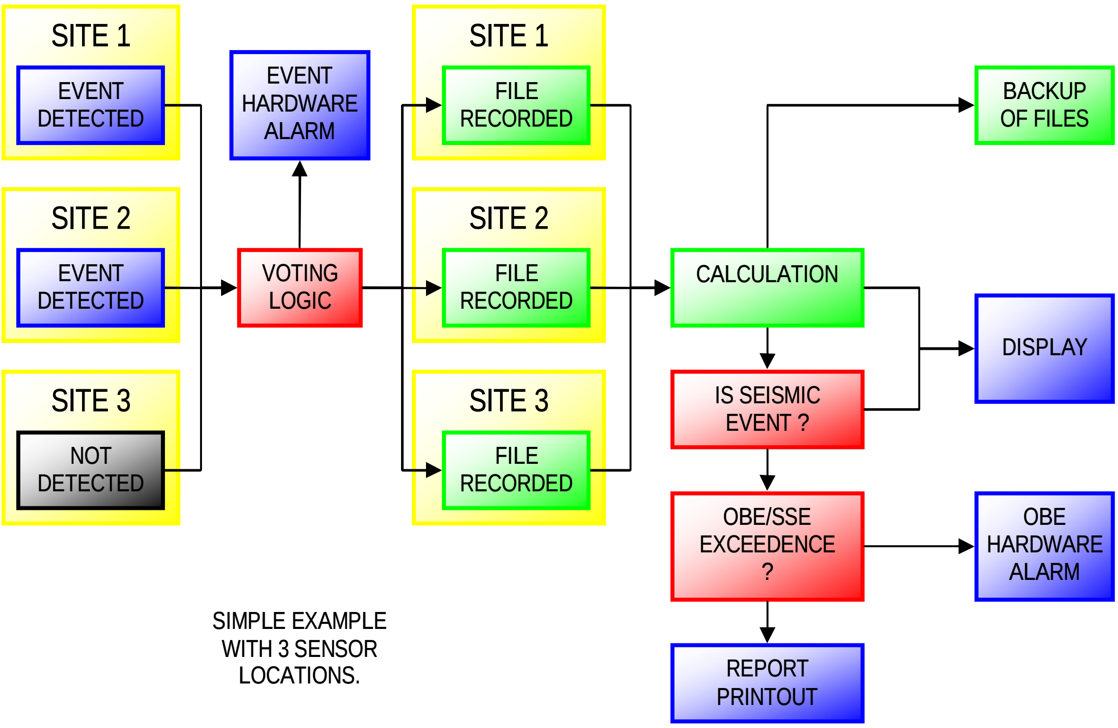
SEISMIC INSTRUMENTATION OF THE SWISS NUCLEAR POWER PLANTS

The share of Nuclear Power Plants in the overall electricity production in Switzerland is approximately 40 percent. Such important energy production assets require also lucid and up to date maintenance and operation procedures and facilities. Seismic instrumentation of most of the active Nuclear Power Plants in Switzerland have been upgraded to the state of the art technology as of June 2006. The upgrades were carried out within the framework issued by the Swiss Nuclear Authority, generally based on the regulations set forth by U.S. Nuclear Regulatory Commission. Gathering the experience gained during the upgrading of three out of four active plants, the typical approach of a distributed recording system is presented.

The purpose of the seismic instrumentation in an NPP is to provide the relevant information (recorded data, Operating Basic Earthquake “OBE” and Safe Shutdown Earthquake “SSE” alerts) so that the seismic response of the safety-significant plant features can be evaluated promptly after an earthquake. The state of the art instrumentation that have been deployed, offer to the operators additional benefits such as background noise supervision and seismic signal checks. Depending on the final sensor locations valuable information about response differences between installation sites can be determined.

As for a distributed system, data transmission is one of the major components of such a system. Therefore beside the standard industrial RS-422 interface also fiber optic data transmission is used.

Beside hardware aspects, as another key item in modern instrumentation, the software supplied with the system is designed for fully automatic operation.



The system is designed for fully automatic operation:

- Performs automatic event detection
- Checks whether the event can be declared as seismic
- Check whether it meets OBE and/or SSE criteria
- Activate alarms and provide report after an event

The software prints out the results of an entire check within a few minutes after an earthquake and displays the actual earthquake reports.

1. System implementation

Seismic Instrumentation in NPP are typically based on a or a mix of 2 basic groups:

- SMS: Seismic Monitoring System for the purpose of recording full time histories of acceleration at several points and provides several pre-determined calculation on the recorded files. The system can compare the results of these calculation with given limits and generate alarms accordingly.
- SAS: Seismic Alarm System for the sole purpose of generating alarms when a certain acceleration level is reached. It is usually based on the PGA (Peak Ground Acceleration). In such system, the purpose of the computer is only for maintenance and is not par of decision path.

A second design aspect for such instrumentation is the topology of implementation as shown bellow:

(1) SMS / SAS with De-Centralized Recording

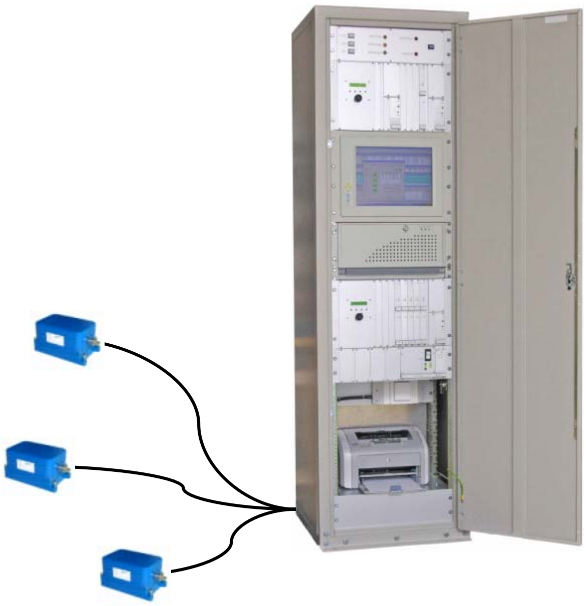
Advantages:

Independent recording units increase redundancy and reliability.

Digital transmission between remote and central locations.

Link from remote to central can use Fiber Optics.

(2) SMS / SAS with Centralized Recording



Advantages:

Simple devices in controlled area (analog sensors).

Simplified diagnostics and maintenance.

Higher compatibility for upgrade on existing systems based on central recording.

The selection of an implementation type is usually cost driven:

- For a system upgrade, the reuse of the existing cable would be a major cost reduction and would define the type of implementation.
- For a new system, both implementations are possible and one of the selection criteria is the expected level of radiation at sensor site. In De-Centralized (1) implementation sets of recorder / sensor have to be placed in the controlled area. In Centralized (2) implementation, only sensors have to be placed in controlled area.

The CPU is housed in the existing earthquake-safe cabinet, including specified accessories. GeoSIG supplies a comprehensive documentation and guarantees the training of the personnel of the NPP.

In Switzerland all the NPP have implemented a De-Centralized topology. So, a typical NPP seismic system as for Gösgen NPP consists of a CPU and several distributed DRUs located at various place in the plant.

2. System principle

A base configuration of a system consists of one free field and 5 in-house locations plus a spare unit. The typical DRU comprises of two instruments; one AC-23 triaxial sensor and one GSR-18 strong motion recorder. In order to guarantee a certain level of redundancy, the motion signals detected by the sensor are stored in the local recorder before being retrieved automatically by the CPU.

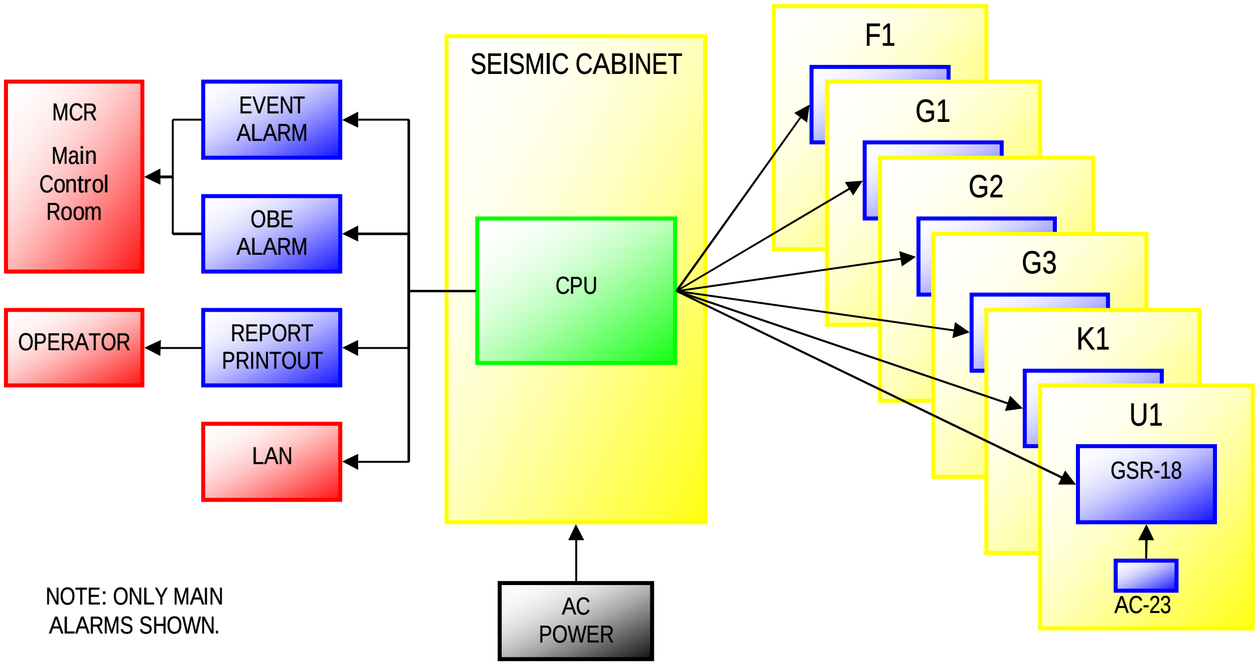


Figure 1: Overview of a typical NPP Seismic Instrumentation

During normal operation the seismic instrumentation is continuously running for checking the DRUs for event downloading. The key components of the system are equipped with emergency power supply (sensors and recorders) or redundant 24 VDC supplies provided by the NPP. Non-key components like printer and spare laptop are powered directly from an AC source. The triaxial measuring sensors and recorders have self-monitoring and testing facilities for periodic testing of the entire measurement chain.

For each measuring channel the recording threshold and the alarm limit values can be set individually. The GSR-18 has sufficient storage capacity for the complete recording of an event, i.e., pre-, main- and after-shocks. In order to analyse weak-motion signals as well, the data are acquired with a resolution of 1:131'000 (18 bits). The alarm transmission and communication between the GSR-18 and the CPU take place via RS-422 / Alarm cable except for the free field stations where fibre optic cables are taking place.

After an event, the CPU acquires the locally recorded data automatically. In addition, it is also possible to retrieve the data with a laptop computer directly from the recorder. As soon as recording starts, the system automatically initiates a pre-defined evaluation. The results of this automatic evaluation are stored in the computer of the CPU in pre-defined files and can be printed out automatically.

The recorded data from the DRUs, which was retrieved by the CPU automatically in case of an event, are stored on the computer of central unit, which are accessible over Ethernet by defining the GeoDAS_Data folder as a shared folder on the network. These file sharing allows anybody (with the necessary credential) to have access to the data of the seismic instrumentation from its local working place.

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3. Design of System

3.1. Seismic Sensor

The AC-23 accelerometer sensor is based on a standard exploration geophone mass-spring system with electronic feedback, forming a servo-accelerometer. This type of sensors yields very good stability versus temperature or aging because of the very simple principle. The AC-23 sensor package is a triaxial accelerometer sensor designed for strong motion and industrial applications where a high sensitivity is required. With the help of the test line, the sensor can be easily and completely tested. Full scale can be typically set to 1 or 2 g full scale.

The AC-23 accelerometer is directly compatible with the GSR recorders designed for strong motion measuring and applications where high sensitivity is required. The system is so build that the recorder will immediately detect a broken sensor channel or disconnected cable.

3.2. Recorder

GSR-18 is used as a recorder for the seismic instrumentation system of NPP. The GSR is a data acquisition system representing the state of the art technology in earthquake monitoring. It provides data with a much higher resolution than what is required in the norms.

At each of the six DRUs, the recorders continually store data from their dedicated accelerometers in their pre-event ring buffers and check whether a trigger condition is fulfilled. When a movement occurs and acceleration values above the predefined trigger level are experienced, a trigger alarm is set off and the event is recorded.

3.3. Examples

Figure 2: DRU site

Figure 3: CPU

Figure 4: Typical cabinet

The CPU computer utilising GeoDAS then retrieves the event from all DRUs, checks whether it is a seismic event or not and calculates the RSA and the CAV based on free-field recorder data. Based on this, further alarms are set.

Event-data recorded by each DRU are analysed for OBE/SSE, whereas only station F1 is used for generation of OBE/SSE alarms.

4. GeoDAS Software for NPP Seismic System

The GeoSIG Data Acquisition System (GeoDAS) is a graphical windows based application running under Windows 9x/2000/NT4/XP.

The software GeoDAS manages all the data processing tasks after an event is declared. Event declaration, recording and alarming are the tasks of hardware independently of the computer and its software.

As option, a LAN connection can be used to link the system with existing local network.

As time source, LAN time server could be used, GPS time receiver or existing serial time code.

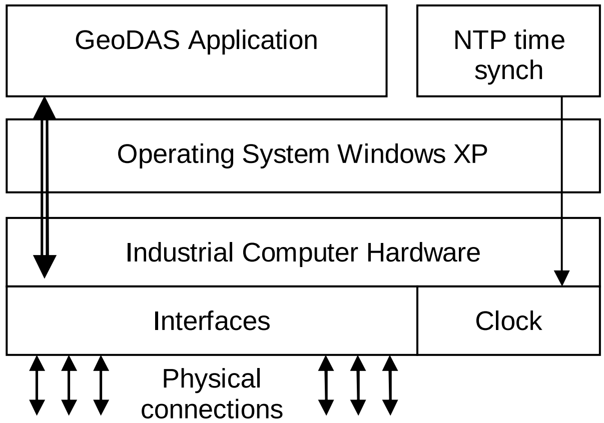

Figure 5: Software overview

The program is used for setup and data retrieval of the DRUs. It is configured to continuously check the recorders for new event recordings. As soon as there is new data, it is downloaded automatically, as well as left in the recorders memory for redundancy purposes.

Thereafter, data is analysed by means of seismic and OBE/SSE checks. GeoDAS also checks the recorders SOH (error status) and can be used to analyse the detailed cause of any malfunctions.

The program is communicating with all stations in parallel, as a result of the dedicated serial communication links that are provided by the system hardware. This means that downloading of all DRUs' data in case of a common trigger takes place promptly.

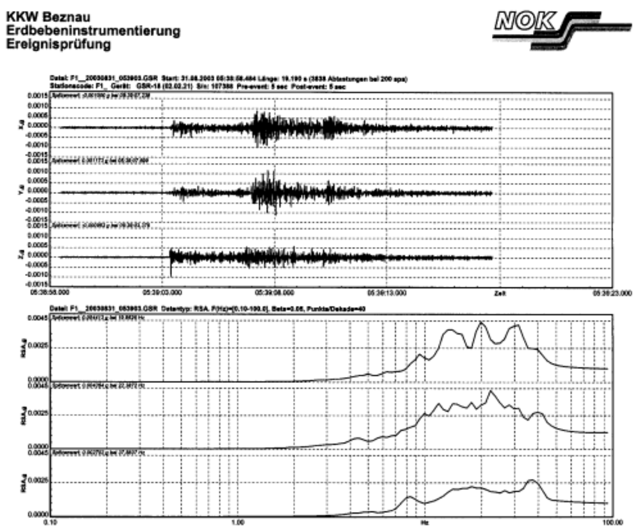

Figure 6: Extract of a report

The software has two modes of operation:

- Standard, where the software is in the so-called “autodownload-mode”, downloading and analysing automatically any events
- Extended, where the user can stop the autodownload-mode and login to the DRUs manually

General Tasks of GeoDAS

- Setup of an instrument. One can change any parameters of an instrument with GeoDAS.
- SOH monitoring. GeoDAS performs permanent or periodical monitoring of the instrument status.
- Downloading of the event files from the recorder(s)
- Off-line event data view and data analysis
- Logger features. GeoDAS keeps important messages in a log file.
- Analysis of the event recording files for seismic and OBE/SSE criteria

An example of the main GeoDAS screen is shown in the figure below. The figure indicates also the basic elements of this screen: the main information windows, main menu, toolbars, context menus, etc.

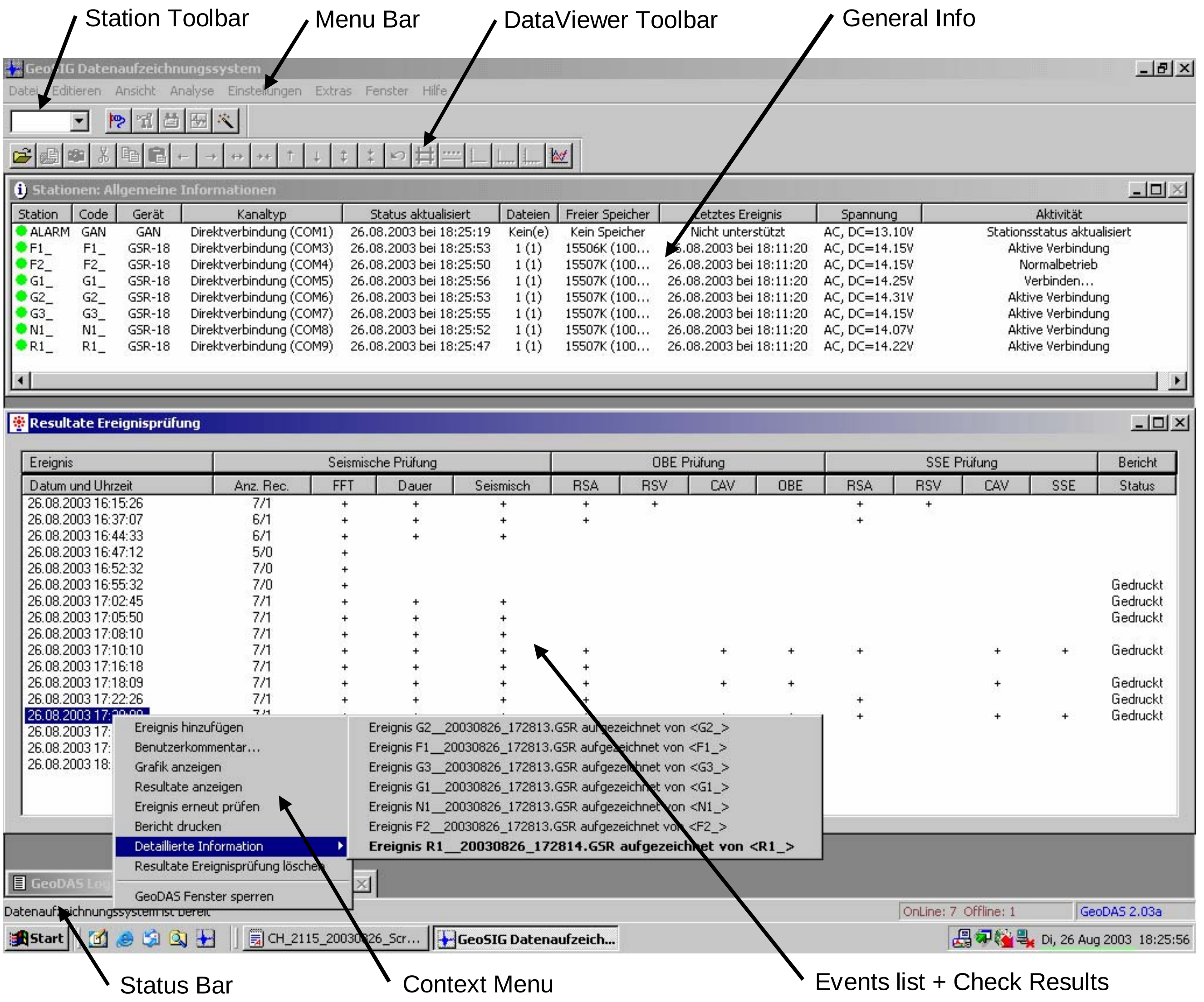

Figure 7: Main window of GeoDAS

5. Conclusions

- An upgrade of an NPP seismic monitoring system is influenced by many frame conditions.
- Every NPP seismic monitoring system has to fulfill user specific requirements.
- Excellent project planning and a close contact between supplier and customer is required.

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