TECHNICAL INFORMATION

PREDICTIVE MAINTENANCE SYSTEMS

SENSONICS LTD

Seismic Technical Note

SEISMIC PROTECTION & MONITORING SYSTEM FOR NUCLEAR INSTALLATIONS

1. Introduction

This system has been designed to provide the following primary functions:-

i) A secure and extremely dependable alarm to the plant operational staff when a seismic event of greater magnitude than a predetermined level occurs, thus allowing the rapid shutdown of plant processes in a controlled manner.

ii) To record the seismic event and allow playback of time waveform, level and spectral data to establish the likely effect of the event on the plant structure.

The Seismic detection system comprises of a minimum of three triaxial seismic switches mounted at least 10m apart on the superstructure of the building to be monitored. The seismic detectors are wired to a central equipment cubicle located close to the control room.

The seismic detectors provide a seismic event alarm at the operating base eartquake (OBE) level that should be set above the anticipated background vibration level. However, to protect against spurious trips, the following precautions have been taken.

- Three sensors operating in a two out of three logic are employed
- The sensors are spaced at least 10m apart from each other
- The sensors are placed in positions where personnel access is not normally required, and is restricted anyway

2. General Functions

The following are the principle functions of the system.

2.1 Primary Functions of the System

The primary functions of the systems are:

a). To provide plant operational Staff with immediate warning of a Seismic event which exceeds a predetermined intensity (amplitude) to enable them to bring the reactor to a safe condition in a controlled manner.

b). To record the time history of any such Seismic event and allow post-event playback of frequency and amplitude data to determine the likely cause of the alarm and to estimate the extent of damage to the reactor and its surroundings

2.2 Other Features of the System

Whilst providing as effective monitoring as possible it is also necessary to reduce spurious alarms to an acceptable level.

The most likely cause of spurious alarms is local activity e.g. movement of vehicles, maintenance activities etc. Therefore to eliminate these non structure-threatening incidents three widely dispersed seismic switches are employed and a 2 out of 3 voting system utilised. The seismic detectors are set to trip at the Operating Basis Earthquake (OBE). The OBE level has in turn been chosen to give an adequate margin over and above the background ground vibration level.

In order to ensure correct operation of the system, a facility is provided to allow frequent functional checks to be made with the minimum loss of seismic event monitoring.

The seismic detectors are to be rigidly mounted to the main foundations of the reactor building where the structure is directly connected to the bedrock below.

The equipment supplied is based on a seismically qualified standard monitoring system.

The replay software runs on a portable PC which can be stored away from the system in a protective case and so does not require Seismic qualification. The portable PC can be connected to the data recording system when required via an RS232 link.

Failure Mode and Effect Analysis, Reliability Analysis and Availability Analysis are to be produced for the system.

The supplier recommends a proactive maintenance regime for the correct operation of the system.

2.3 System Installation Requirements

2.3.1 Physical

The seismic equipment cubicle measures 800mm wide, 950mm deep, and 1925mm high (excluding the removable eyebolts). The cubicle will stand on a plinth that may be up to 250mm high. Access is required to the front and the rear of the cubicle. The cubicle should be securely bolted to the floor, and located in a position where it will be adequately protected against secondary seismic hazards.

2.3.2 Electrical

The seismic equipment cubicle requires a 110V ac, 50 Hz, supply rated at 10A or greater. The incoming/outgoing cables may enter via either the top or the bottom of the cubicle.

3. General System Description

3.1 General

Ground motion is detected by means of 3 ‘Seismic Switches’ distributed around the site. Each switch comprises three orthogonally mounted seismic pick-ups together with electronic circuits which amplify and filter the signals produced by the pick-ups and compare these with a pre-set, adjustable threshold. If any signal exceeds this threshold, then a relay changes state. The relay contacts remain in the changed state for a (factory) pre-set length of time (0<10 sec) after the ground motion signal falls below the pre-set threshold. When this time period has elapsed, the relay and its contacts return to the original state ready for the next event.

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The relay contact outputs from each of three 3-axis seismic switches are cabled to a central monitoring cabinet where a voting logic system assesses the individual alarm situation. If two seismic switches have tripped the voting system considers that a genuine seismic event has occurred and initiates the seismic event alarm output. The seismic event alarm is indicated in the Central Control Room.

The analogue dynamic signal from each of the 9 (total) seismometers is transmitted via a BS5308 armoured, individually screened, twisted pair cable to the central monitoring cubicle. The cables are sheathed in LFH material.

Each equipment assembly within the overall system contains detection circuits for 'equipment failure', and provide relay contact outputs for indication within the central monitoring unit. All the equipment fault alarm relay outputs from all the individual units are connected in series. A failure in any one of the units will cause a relay to open that will bring up a group system fault alarm on the master annunciator rack and provide a relay output for remote indication of the fault on the Group Warning system.

The system operates from a 48V dc power supply rack that is powered by a 110V, 50 Hz floating ac supply. In the event of mains failure the system will continue to operate for up to 3 hours on rechargeable batteries associated with an Uninterruptable Power Supply (UPS) located in the equipment cubicle.

3.2 Test/Calibration Facilities

Routine calibration checks of the seismic monitoring system are achieved by means of a reference signal generated in the seismic equipment cubicle and connected via switches to the input of each seismic switch unit in turn.

It is a requirement that during calibration checking the system should not be taken off-line. The seismic switches can therefore be calibrated individually, while the system continues to function from the other two switches.
During this period the seismic event alarm will be initiated if either of the other two switches trips (i.e. the voting system will continue to operate on 1 out of 2 logic).

The 2 out of 3 alarm voting system is duplicated and a facility to switch from one voting system to the other provided. In this way each individual voting system can be functionally tested whilst the other remains on-line.

Following calibration a system test will be performed. This is the only time that the system will be 'off-line' and should be limited to no more than 2 minutes.

4. Plant Mounted Seismic Switches

Each of the three 3-axis seismic switches should be mounted on a vertical surface that is an integral part of the building structure. Each unit is to be held rigidly to the building structure by means of three anchor studs set into the concrete walls.

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The housing for each seismic switch is identical and comprises a painted steel enclosure attached to a plated steel mounting plate provided with three mounting holes. The housing has a hinged lid held closed by a pair of wing nuts. The wing nuts, when tightened, pull the lid and housing together into a captive gasket which maintains the sealing of the enclosure to IP66 rating. The lid is to be padlocked to prevent unauthorised access during normal operation. A 10 pair, LFH cable enters the housing via the lower gland plate and is terminated at Klippon terminals mounted within the enclosure.

Power for operation of the seismic switches is supplied, via the 10 screened twisted pair cable, from the 48V dc power supply unit located in the seismic monitoring equipment cubicle.

5. Seismic Monitoring Equipment Cubicle

The cubicle is 800mm wide by 950mm deep and 2.075m tall (when on 150mm plinth) and fitted with an armoured-glass-panelled front door and a sheet steel rear door. It is firmly anchored to the floor by six anchors inserted through the base into the floor. Both front and rear doors have key-lockable handles and provision for padlocks.

All the seismic monitoring equipment is located at the front of the cubicle such that all operational visual indicators are visible through the glass door (additional fault diagnostic indicators are viewable via the rear door). The operator is directed to the diagnostic indicators at the rear by the 'System Failure Alarm' indicator visible through the glass front door.

Access to the cubicle via the front door is necessary during normal operation for the 'acceptance' and 'resetting' of any alarms.

Access to the cubicle via the rear door is necessary during installation and maintenance.

6. Voting Alarm System

6.1 System Description

The alarm voting logic system is duplicated. A two-way switch directs all alarm signals from the 3 seismic switches to either voting system. The duplicated voting systems normally operate in parallel with each other. Either voting unit may be defeated for test purposes while the second voting system remains fully functional.

The system as a whole consists of:

- 2 off master annunciator (2/3 voting) racks RA8119 (drawing SK.4987B)
- 1 off slave annunciator (diagnostic) rack RA8120 (drawing SK.4988B)
- 1 off switching/inhibitor rack
- 1 off repeater rack
- 1 off 48V dc PSU rack

Each of the above is in the form of a 19 inch wide x 1U high rack fitted with front panel indicator windows and legends.

The voting system is powered from the 48V dc PSU rack (see Section 7).

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6.2 Principles of Operation of the Voting Alarm Systems

a). Alarm Voting

Under normal operating conditions (i.e. calibration check not selected), when two seismic switches trip nearly-simultaneously (i.e. within the delay period of 0 to 16 seconds pre-set within the seismic switches) the voting system will deem that a seismic event has occurred. A 'Seismic Event' Alarm will be initiated together with the appropriate 'Seismic Switch Activated' alarm(s). The Event Alarm will remain activated until manually reset by the operator.

b). Seismic System Fault Alarm

This group alarm will be initiated by any of the alarms indicated on the slave annunciator rack. These alarms will in turn be initiated by a group of faults indicated by diagnostic LED's located on the originating racks. This will provide a diagnostic chain of failure indicators from overall system fault down to specific failures.

Each main circuit board within the local alarm voting and diagnostic system has a PSU integrity alarm indicator (a green PSU OK LED) which is visible via the rear door. If such a failure occurs within the alarm voting and diagnostic system, an additional fault relay initiates a Seismic System Fault alarm.

7. Functional Check System

7.1 General Description

The seismic monitoring system is designed so that each of the three seismic switches and both of the two out of three alarm voting systems can be individually checked for correct functionality while the system remains operational.

There is also the facility to check the system function as a whole, from signal injection at the seismic detectors to the indication of a seismic event alarm. The system will be off-line for the duration of the test. The two out of three voting system can be checked in 2 minutes using a single combination of two tripped sensors, but a full check involving all combinations of tripped sensors may take up to 10 minutes.

The Calibration Rack RA.8124 is located in the seismic monitoring equipment cubicle, provides facilities for generating and switching the calibration signals required for functionally checking the triaxial seismic switches.

The front panel contains one key operated switch and three rotary selector switches. The key operated switch enables an authorised person only (keyholder) to operate the calibration unit. The key can only be removed when the system is in the 'normal' position. This eliminates the possibility of a seismic alarm signal being generated accidentally by an unauthorised person.

In the 'normal' position the seismic monitoring system remains in normal operation and the calibration signal will not interfere with the seismic detectors.

The rotary switches select the calibration signals to the detectors. Each switch has seven positions: off, X Lo, X Hi, Y Lo, Y Hi, Z Lo, and Z Hi, and is allocated to an individual seismic triaxial detector.

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With this rotary switch arrangement the user is able to select one or more seismic detectors for activation at the same time. The alarm voting systems can be checked when two or more seismic detectors are activated.

The reference sine wave generated in the central calibration unit is conducted to the seismic detectors via individual buffer amplifiers. The reference signal level is constant and the actual calibration level in each seismic detector is factory set to the OBE level.

The X, Y, Z and Hi, Lo selection is achieved by BCD-coded digital signals transmitted to the three seismic switches via the 10 screened twisted pair cables.

The front panel keyswitch also operates a relay providing a signal to the master annunciator rack, indicating that the seismic switches are not in normal operation. The 'seismic calibration check' indicator on the master rack front panel will illuminate.

7.2 Calibration Rack with Alarm Defeat

An alarm voting switch rack allows each of the voting systems to be functionally checked off-line whilst the other system remains on-line. The voting system undergoing test has its alarm output defeated.

7.3 Calibration Checks

These checks will be carried out at the following intervals (to be confirmed by the availability/reliability analysis).

Trip levels	- Weekly
2 out of 3 Voting	- Monthly
System Check	- Monthly

8. 48V dc Power Supply Units

This unit is located within the Seismic Monitoring Equipment Cubicle and powered by 110V, 50 Hz from the Uninterruptable Power Supply.

The 48V dc PSV rack is a dual, diode-interconnected, PSU system. Each half of the system is capable of taking the full system load.

The output from this unit is used to power the seismic switches, the voting alarm system, and the calibration rack.

9. Uninterruptable Power Supply (UPS)

9.1 System Description

This unit is to supply uninterrupted AC power to the Seismic Monitoring System for a period of three hours following the loss of the primary power source (110V, 50 Hz, single phase). In principle the mains input is used to charge a battery bank, which in turn powers a static inverter. The latter generates 110V, 50 Hz which continuously supplies the full system load under normal conditions and will continue to do so for up to 3 hours following loss of mains power.

10. Seismic Recording and Replay System

All nine of the dynamic analogue signals (amplitude/time waveform) are continuously recorded on to a rolling buffer memory, with a time period of 1 hour. On the raising of a seismic event alarm the vibration data for 1 to 9 seconds leading up to the seismic event, and for 10 to 20 seconds after the event is automatically recorded to non volatile memory on a silicon drive disk. The time periods before and after the seismic event are user selectable. The seismic acceleration level at which the transfer of data to the silicon disk is initiated is capable of being set independently of the seismic event alarm level.

A facility is also provided via the laptop PC to manually initiate the transfer of data, at any time, to the non-volatile memory.

The data recorded in the non-volatile memory is accessible via a parallel data port and RS232 or other link to a replay software programme loaded onto the portable PC. The software is capable of displaying the recorded data in time/level and spectral formats.

The data is 'time stamped' by the system as it is acquired and transferred, with its 'time stamp', to the replay software.

11. Equipment List

The following list covers all the items supplied by Sensonics.

Table 1 Equipment List

Item	Part No.	Description	Quantity
1	SA-3	Seismic Switch	3 off
2	TBA	Seismic Monitoring Cubicle	1 off
3	RA8119	Master Alarm Annunciator Rack	2 off
4	RA8120	Slave Alarm Annunciator Rack	1 off
5	RA8124	Calibration Rack	1 off
6	TBA	Calibration Rack with Alarm Defeat	1 of
7	TBA	Seismic Recorder Rack	1 off
8	TBA	Repeater Rack	? off
9	RA8118	110/48V PSU Rack with Back-up	1 off
10	TBA	Uninterruptable Power Supply	1 off
11	TBA	48V Battery Pack	1 off
12	TBA	Seismic Recording Software	1 off
13	TBA	Replay Software to be installed on a portable PC supplied by Sensonics	1 off
14	TBA	Protective storage box for PC	1 off
15		10 screened twisted Pair armoured instrumentation cable to BS5308	Length to be advised

12. Environmental Performance/Withstand

Temperature - 40^{o}C for 24 hours
Humidity - 90% non condensing
EMC - To be advised
Earthquakes - The equipment has been seismically qualified (see GEC ALSTHOM report ETC(M) C.91.205: March 1990).

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13. Documentation

Full documentation will be supplied with the equipment.

14. Design Life

The design life of the equipment will be 20 years.

15. Abbreviations

AIR	Auxiliary Instrumentation Room
LED	Light Emitting Diode
LFH	Low Fire Hazard
NSRP	Nuclear Steam Raising Plant
OBE	Operating Basis Earthquake
PC	Personal Computer
PSU	Power Supply Unit
STF	Shore Test Facility
UPS	Uninterruptable Power Supply
VDU	Visual Display Unit

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