3.7.4 Seismic Instrumentation

Appendix S to 10 CFR 50 requires that suitable instrumentation must be provided so that the seismic response of nuclear power plant features important to safety can be evaluated promptly after an earthquake. It also requires shutdown of the nuclear power plant if vibratory ground motion exceeding that of the operating basis earthquake (OBE) occurs or if significant plant damage occurs. The U.S. EPR seismic instrumentation system meets the relevant requirements of 10 CFR 50, Appendix S, as they relate to the capabilities and performance of the instruments to adequately measure the effects of earthquakes.

The seismic monitoring system (SMS) is not safety-related; nor does it have any effect on safety-related systems or equipment. The components of the seismic monitoring system are selected to emphasize accuracy and reliability, while at the same time minimizing the maintenance and surveillance resources required to support the system. The U.S. EPR seismic instrumentation program is described in the following sections.

3.7.4.1 Comparison with NRC Regulatory Guide 1.12

RG 1.12, Revision 2, describes seismic instrumentation that is acceptable to the NRC staff for satisfying the requirements of 10 CFR 20 and 10 CFR 50, Appendix S. The instrumentation described below is in conformance with the guidance of RG 1.12. Triaxial sensors at the locations noted below record accelerograms for which event analysis software provides a timely display of spectral content.

3.7.4.2 Location and Description of Instrumentation

The SMS produces a permanent record of the vibratory ground motion from various areas of the plant during an earthquake. The SMS or time-history accelerograph system consists of field-mounted sensors, recording and data storage equipment, central controller, power supply, and ancillary support equipment mounted in a system equipment cabinet.

All components of the SMS are qualified to the provisions of IEEE Std 344-2004[1] (Reference 3).

The system components are located in areas of the plant that are not affected by failure of pipes, vessels, pumps, and valves. The components are located in areas that are not generally affected by hazards such as explosions, fire, and internal flooding.

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1. Section 3.11 provides the justification for the use of the latest version of the IEEE standards referenced in this section that have not been endorsed by existing Regulatory Guides. AREVA maintains the option to use current NRC-endorsed versions of the IEEE standards.

Interconnecting cable between field sensors and the central equipment cabinet are routed in Seismic Class I raceways or conduits. The equipment cabinet is located in the computer room of Safeguards Building (SB) Division 2, which is a fully hardened building designed to provide protection from radiation, fire, chemicals, and internal missiles.

The in-structure instrumentation is placed at locations modeled as mass points in the building dynamic analysis so that the measured motion can be directly compared with the design spectra. Instrumentation that has sensors located in inaccessible areas contains provisions for data recording in an accessible location and provision for an external remote alarm to indicate actuation.

A COL applicant that references the U.S. EPR design certification will determine whether essentially the same seismic response from a given earthquake is expected at each of the units in a multi-unit site or instrument each unit. In the event that only one unit is instrumented, annunciation shall be provided to each control room.

3.7.4.2.1 Field Mounted Sensors

Field mounted sensors of the triaxial type (i.e., three-directional, x-y-z axes) are rigidly mounted at the following locations:

- Free-field.
- The primary containment structure (base foundation and two higher elevations).
- An independent Seismic Category I structure (foundation and higher elevation) not influenced by or connected to the primary containment structure.

A COL applicant that references the U.S. EPR design certification will determine a location for the free-field acceleration sensor such that the effects associated with surface features, buildings, and components on the recordings of ground motion are insignificant. The acceleration sensor must be based on material representative of that upon which the Nuclear Island (NI) and other Seismic Category I structures are founded.

The triaxial accelerometers (three elements supplied and mounted in a mutually orthogonal array) will produce a response that is proportional to the time varying acceleration at the location of the sensor. The accelerometers are chosen to respond to a maximum acceleration that is 1.2 times the SSE acceleration for the intended instrument location. The accelerometer outputs are then used by the seismic recorders to produce time-history accelerographs.

3.7.4.2.2 System Equipment Cabinet

The system equipment cabinet houses the seismic recorders, central controller, and power supplies. The equipment cabinet is located in the computer room of SB Division 2. All equipment except for the field-mounted triaxial accelerometers is located in this seismically qualified equipment rack. The cabinet equipment is of modular design.

3.7.4.2.3 Seismic Recorder(s)

Each seismic recorder (or data acquisition unit) is of modular design and mounted in the system cabinet. The recorders are able to accommodate the inputs from at least two triaxial accelerometers that possess a minimum of a 24-bit digital processor with 18-bit resolution. The sampling rate of the recorder is a minimum of 200 samples per second for each of the three directions (axis). Bandwidth shall be at least 0.20 to 50 Hz. The dynamic range of the recorder shall be at least 1000:1 zero-to-peak, and the instrumentation shall be able to record at least 1.0 g zero-to-peak. The trigger threshold is selectable from 0.01 to 100 percent of full scale with the trigger to be set 0.001g to 0.02g but not more than 0.02g. The recorders will record pre-earthquake data three seconds prior to the trigger actuation and continue to record the motion during the period in which the earthquake motion exceeds the seismic trigger threshold, and continue to record low-amplitude motion for a minimum of five seconds beyond the last exceedance of the seismic trigger threshold. Additional pre-event memory (for up to 30 seconds of pre-earthquake recording) is provided for “P” wave correlation. Each recorder is capable of operating autonomously for 25 minutes on its own backup battery power independent from other recorders. Seismic data is permanently stored on removable media.

The system interfaces and synchronizes with the plant master clock and employs a single backup global positioning system (GPS) receiver integrated with the entire system to provide timing for all of the system recorders.

3.7.4.2.4 Central Controller

The central controller (or computer) is used to provide control and monitoring of all of the recorders or data acquisition units, interfaces with external control systems and alarm functions. A single controller is able to support multiple recorder/data acquisition units. The controller supports custom software applications to provide a graphical user interface and event driven analyses that includes a generated response spectrum comparison with the design response spectrum, calculation of the cumulative absolute velocity (CAV), and also contains configurable built-in testing capability. The central controller utilizes the plant master clock for time related functions, but contains a GPS receiver for backup. Failure of the master clock will not degrade the functionality of the system. The controller includes the trigger and alarm functions. An independent threshold trigger setting is available for each channel.

Also, the controller supports a common trigger (when one recorder is triggered, all other recorders are triggered as well) and remote triggering.

The custom software application provides the user with an event driven analysis of the OBE, providing both a generated response spectrum comparison with the design response spectrum and application of the OBE Exceedance Criteria described in Section 3.7.4.4 to determine if the OBE has been exceeded in a potentially damaging frequency range.

The controller monitors the system health and provides immediate notification and alarms in the main control room (MCR) of component malfunctions or failures, power supply failures or similar events. Basically it monitors any system fault that would render the system incapable of performing its design function.

The controller provides two seismic triggered annunciations in the MCR; the first indicates a seismic event occurrence, and the second indicates exceedance of the OBE. The seismic event alarm is triggered by the digital recorders, and the OBE exceedance alarm is triggered by the centralized computer.

3.7.4.2.5 Power Supplies

The system components are powered from the plant-supplied, non-vital battery-backed uninterruptible power supply (UPS) to provide continuous operation following a station blackout. A backup battery system is provided for each recorder adequate to supply power to the equipment for a minimum of 25 minutes in a 24-hour period without recharging. The system equipment cabinet includes an internal UPS and charger capable of operating the central controller and support equipment.

3.7.4.3 Control Room Operator Notification

The SMS provides a status of operation to operators in the MCR. The operator receives two seismic triggered annunciation signals in the MCR. The first annunciation provided by the SMS informs the operator that a seismic event is being recorded. This annunciation indicates that seismic motion in excess of the trigger setpoint has been sensed and that the digital recorders are activated. The second annunciation signal is received later and is provided if the event-analysis software indicates exceedance of the OBE in a potentially damaging frequency range.

3.7.4.4 Comparison with Regulatory Guide 1.166

The operator uses input from multiple sources to determine the need for a controlled shutdown following the seismic event. The operator may validate the event by confirming that ground motion was sensed by plant personnel, that two or more channels have at least one measurement exceeding the seismic trigger threshold, and confirm the occurrence of the seismic event with the National Earthquake

Information Center. The decision for a controlled shutdown will be based primarily on an assessment of the actual damage potential of the event (available within four hours) and on the results of plant inspections (available within eight hours). The purpose of these actions is to perform a preliminary assessment of the physical effect of the earthquake on structures, systems, and components (SSC) and to determine if shutdown of the plant is warranted based on the observed damage or because both the OBE response spectrum and CAV limits have been exceeded.

The OBE response spectrum is exceeded if any one of the three components (two horizontal and one vertical) of the 5 percent of critical damping response spectra generated using the free-field ground motion is larger than:

1. The corresponding design response spectral acceleration (OBE spectrum if used in the design, otherwise one-third of the SSE spectrum) or 0.2g, whichever is greater, for frequencies between 2 and 10 Hz, or

2. The corresponding design response spectral velocity (OBE spectrum if used in the design, otherwise one-third of the SSE spectrum) or a spectral velocity of 6 inches per second (15.24 cm per second), whichever is greater, for frequencies between 1 and 2 Hz.

The CAV limit is exceeded if the CAV value is greater than 0.16 g-second as calculated according to the procedures in EPRI Report TR-100082 (Reference 4).

An assessment of the damage potential of the event is performed within four-hours following the event using the OBE Exceedance Criteria developed by EPRI in reports NP-6695, (Reference 1), and NP-5930 (Reference 2), and endorsed by the NRC in RG 1.166. This criterion is based on a threshold response spectrum ordinate check and a CAV check. The indication of damage potential is provided by event-analysis software installed on the SMS described in Section 3.7.4.2. The assessment of damage potential is based on the recorded motion from the free-field sensor also described in Section 3.7.4.2.

Inspections of SSC in accessible areas of the plant are performed within eight-hours following the seismic event using the general guidance in Chapter 4 of EPRI NP-6695, Reference 1. These inspections include a check of the neutron flux monitoring sensors for changes and an inspection of the containment isolation system for continued containment integrity. The inspection findings are compared to data previously obtained from baseline inspections in order to obtain a clear understanding of any seismic-induced damage.

Once the results of the inspection and the assessment of damage potential of the event are available, the operators will determine: 1) if a controlled shutdown is required, and 2) the condition of the equipment needed to safely achieve shutdown. If the assessment of damage potential indicates that the OBE exceedance criteria were not met, and the inspection results are favorable, the plant will continue to operate.

To satisfy the requirements of 10 CFR 50, Appendix S, paragraph IV(a)(2)(A), for applications that involve the use of a certified design, the application of OBE Exceedance Criteria is based on the following:

i. For the certified design portion of the plant, the OBE ground motion is one-third of the certified seismic design response spectra (CSDRS).

ii. For the safety-related noncertified design portion of the plant, the OBE ground motion is one-third of the site-specific SSE design motion response spectra, as described in Section 3.7.1.

iii. The threshold response spectrum ordinate criterion to be used in conjunction with RG 1.166 is the lowest of (i) and (ii).

Post-shutdown actions, including retrieval of data, recalibration of seismic instruments, and comparison of measured and predicted responses are based on the guidance in Chapters 5 and 6 of EPRI Report NP-6695, Reference 1, and RG 1.167. These activities address post-seismic event gap measurements: 1) between the new fuel racks and the walls of the new fuel storage pit; and 2) between the individual spent fuel racks, from the spent fuel racks to the spent fuel pool walls, and from the spent fuel racks to the equipment area, then appropriate corrective action is taken, if needed (e.g., repositioning the racks or analysis of the as-found condition).

3.7.4.5 Instrument Surveillance

The system components incorporate features for periodic maintenance, inspection and repair; the purpose of which is to minimize the occurrence of system failures and to increase the availability of the system.

The plant maintenance program for the equipment will provide reasonable assurance that seismic instrumentation is available during all modes of plant operation, including periods of plant shutdown. Maintenance procedures shall be developed that address maintenance in conjunction with the surveillance requirements. The system is modular and capable of troubleshooting, testing, and maintenance of a single channel or instrument without disabling the remainder of the system. Manufacturer recommendations shall also be evaluated and incorporated into maintenance and surveillance procedures as appropriate.

Surveillance intervals for activities such as periodic channel checks, functional tests, and channel calibration shall not exceed the following:

- Channel Check – Every two weeks for the first three months of service after startup. After the initial three-month period and three consecutive successful checks, monthly channel checks are sufficient. Battery checks shall be performed in conjunction with Channel Checks.

- Functional Test – Every six months.
- Channel Calibration – During fueling outages.

Surveillance procedures will include provisions that the CAV shutdown threshold is calibrated per the manufacturer recommendations of the instrument. In the event that an earthquake is recorded at the plant site, all calibrations, including that of the CAV, will be performed to demonstrate that the system was functioning properly at the time of the earthquake and to confirm calibration data used for the event-analysis software.

3.7.4.6 Program Implementation

A file containing seismic instrumentation information, such as instrument type, plan and vertical section views, service history and suitable earthquake time-history will be maintained onsite in conformance with RG 1.166, Revision 2. Operator responses to a seismic event including retrieval of data, recalibration of seismic instruments, comparison of measured and predicted responses, assessment of OBE exceedance, and post-shutdown actions are described in Sections 3.7.4.4 and 3.7.4.5. Responses to seismic events and post-shutdown actions are controlled by plant procedures developed prior to initial fuel loading. Alarm response procedures provide operators with guidance for immediate actions and follow up actions including determination of validity of the event and need for walkdowns and inspections; and post event actions based on magnitude of event and the severity of damage. Post event inspection procedures provide guidance for determining the extent of damage to vital plant equipment and provide acceptance criteria for determination of equipment acceptability for continued operation.

3.7.4.7 References

1. EPRI Report NP-6695, “Guidelines for Nuclear Plant Response to an Earthquake,” Electric Power Research Institute, December 1989.
2. EPRI Report NP-5930, “A Criterion for Determining Exceedance of the Operating Basis Earthquake,” Electric Research Power Institute, July 1988.
3. IEEE 344-2004, “Recommended Practices for Seismic Qualification of 1E Equipment for Nuclear Power Generating Stations,” Institute of Electrical and Electronics Engineers, 2004.
4. EPRI Report TR-100082, “Standardization of the Cumulative Absolute Velocity,” December 1991.

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