SEISMIC INSTRUMENTATION OF POWER AND INDUSTRIAL FACILITIES IN MEXICO

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ABSTRACT

The Mexican Centro de Instrumentación y Registro Sísmico, A. C., (CIRES, A. C.), with the sponsorship of the Electric Power Research Institute, (EPRI) from the United States of America, is working on the project "Seismic Instrumentation of Power and Industrial Facilities in Mexico" with the objective of recording the response of structures and equipment under strong earthquake motions. The results of this project are applied to the procurement and qualification of equipment in existing and new nuclear electric power generating plants all over the world (Kennedy et al., 1992; Ravindra et al., 1992; Moore et al. 1992). Four different structures located on sites known for high seismic activity were selected. The sites are the steel smelter in the Lázaro Cárdenas steelworks plant; the thermoelectric power plant from Comisión Federal de Electricidad in Manzanillo Colima; the Portland cement plant CRUZ AZUL in Lagunas Oaxaca; and an industrial building in its final construction stage in Acapulco Gro.

KEYWORDS

Manzanillo 1995 Oct. 9 earthquake; Accelerograph networks; Seismic instrumentation; CIRES; EPRI.

THE EPRI STRONG MOTION ARRAY IN MÉXICO

In 1990 CIRES signed an agreement to install, operate and maintain for EPRI four networks of strong motion accelerographs along the southern coast of México. The instrumented sites are the Manzanillo Power Plant in the state of Colima, operated by the Comisión Federal de Electricidad; a steel smelter at the steelworks plant SICARTSA in Lázaro Cárdenas, Michoacán; an industrial seven level structure in its final building stage near Acapulco, Guerrero; and the Portland cement plant CRUZ AZUL in Lagunas, Oaxaca. Each array comprises a free field instrument and six or seven accelerographs located within the industrial structure. In each structure recorders were installed at several levels, in order to record data for evaluating the response of the structure to the seismic excitation. At each level recorders were installed at selected locations on the floor and within equipment cabinets to study the transfer functions from the cabinets to the respective floor. Where possible the axis of the sensors correspond to the axis of the cabinets and structures. At each site, all instruments are interconnected to start recording synchronously by a trigger signal, generally from the free field instrument. A common external time code signal is also fed to all instruments of the array to study the phase shifts of the structure under seismic activity. Fig 1 shows a schematic of the typical instrument distribution in a plant, corresponding to the steel smelter control building of SICARTSA. Instrument “8” is located on free field, about 200 m far from the control building; instruments “9”, “10” and “13” are located on the floors of ground level, first level and second level, respectively; instruments “11”, “12” are located
within cabinets of control equipment and instruments "14" and "15" are located on the process display boards of the control room.

Fig. 1 Typical instrument distribution in a plant

Equipment

The instruments selected are the Terra-Tech DCA-333-R with ±1g full scale range for the instruments installed on floors and ±3g full scale for instrument installed within cabinets. The free field instruments are the Terra-Tech DCS-302-R. Both instrument types have integrated cassette magnetic tape recorders and solid state RAM memories as storage media for data. The recording capacity of these instruments is about 20 minutes of data sampled at 100 samples per second from triaxial servoaccelerometer sensors. External time reference for each network is obtained from an integrated time source (ITS) model 1020 from Precision Standard Time, Inc. coupled to a model 9100A synchronized time code generator from Datum Inc. to produce a serial IRIG E TTL time code. This time coded data is recorded by the accelerographs together with the internal clock information and the three channel acceleration sampled. Each instrument is powered by a 12 v., 80 AH low maintenance battery held recharged by a marine battery charger connected to the AC power mains. In each instrument a special junction box is used to implement the interconnection of all network components.

At each site, the free field instrument was interconnected to the network within the instrumented building by special purpose half duplex radio trigger link because, generally, the cost of the interconnection via direct wiring was too high or might affect the plant operation during the installation work. The time reference is not
Fed to the free field instrument. Instead, the free field instrument trigger signal includes a 10 second long train of pulses which is recorded once on all instruments of the network on starting and permits to find a common time reference for all instruments, related to the external time reference normally recorded with each event.

**Initial Operation Problems**

After installation completion of the accelerograph networks on a site, an instrument calibration was done. The good operational status of each system was checked and a tuning up period of two months was started during which, the threshold trigger levels for each instrument were established to allow simultaneously the greater sensitivity and the ambient vibration not triggering the accelerographs. However it was found that most of the initial problems were produced by human activities such as plant maintenance, use of walkie-talkies, crane operations, quarry blasting, pressure relieving on the steel smelter, power dropouts, etc. These activities produced so many events that the storage media was used up completely, some times in less than a week. To get rid of these problems, the triggering schemes of the networks were changed so the free field instruments acted as MASTER triggering unit and all the rest of the instrument were left as SLAVE triggered units. In addition, all free field instruments were left powered by solar panels to overcome the power failures produced by the plant technicians disconnecting by error this circuit, some times during more than a month. The radio interference produced by walkie-talkies was eliminated by means of radio frequency filters installed on the time code signal, the trigger signal and the battery input lines.

In the Manzanillo power plant and in the CRUZ AZUL cement plant the free field instrument is located on the switch yard so varistors were installed on the solar panel power lines to absorb the transients induced during the operation of the high voltage disconnect switches. The triggering of an instrument due to human activities which induce some type of ground or cabinet movement was reduced by raising the threshold trigger levels of most instruments.

Still most of the triggering is produced by human activity such as the railroad train maneuvering, quarry blasting, maintenance work on instrumented cabinets and similar. Is for this reason that the maintenance visits to each site are required with an interval of three to four months, otherwise the data storage media might be completely full with useless data, with the risk of being unable to record the valuable data we are waiting for.

It was found that the gel-cell backup 12 v. 80 AH batteries need to be replaced before the five years period expected. The automotive, free-maintenance sealed type batteries have proved to be good replacements to them, besides of being less expensive.

**First Results**

The networks have been in operation since endings of 1992. Up to Oct. 12, the four networks have recorded more than 250 events in total, with an accumulated recording time of 6300 seconds. Most of these events correspond to small local events such as quarry blastings in CRUZ AZUL, steel smelter pressure relieves in SICARTSA or moderate earthquakes occurring at more than 100 km from the seismic networks. The recording of these events demonstrated the good operating conditions of the networks and the data was accumulated to a catalog of small events useful for characterizing the structure parameters. This information is interesting to the owner of the structure but for EPRI was of limited interest. After five years of operation, the EPRI seismic instrumentation program in México attained a big success (EQE International, 1995) when the northernmost site of the four EPRI accelerograph installations recorded the magnitude 7.6 ms earthquake of 1995 Oct. 9, near coast of Jalisco, Mexico: latitude 18.9 degrees north, longitude 104.1 degrees west, origin time 15:35:51.5 utc (NEIS Oct. 9 15:54 CST 1995). These records appear to be the only ones in the high-intensity region of the Manzanillo earthquake. The free field accelerograph recorded strong motion that lasted for a period approaching 30 seconds, see Fig. 2. In the most intense period of the recording, several cycles of motion of the order of 0.4g occurred. The data collected from this earthquake together with the cataloged data obtained from previous minor movements during the last three years have made of this the
most important site ever investigated in the EPRI program. The EPRI strong motion array in Mexico appears to be the only on-going program in the world for recording the actual strong motion amplification in structures and equipment relevant to the nuclear industry, the power industry or for that matter the industry at large.

**EPRI - CIERES NETWORKS OF ACCELEROGRAPHS**

![Graphs showing acceleration over time for different channels.]

- **Time:** 15:35:54 GMT
- **Date:** October 09, 1995
- **Station:** MZN01 (N1)
- **Name:** Substation

Max (m/s²) | Min (m/s²)
--- | ---
Channel 1: 3.02863 | -2.69838
Channel 2: 3.82828 | -3.87624
Channel 3: 3.81880 | -3.87124

Fig. 2. A section of the free field recording of the 1995 Oct. 9 Manzanillo earthquake

**REFERENCES**


