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Seismic Tests According to New Specifications

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SUMMARY

1 - SEISMIC SIMULATION METHODS AND FACILITIES

1.1. General considerations

The concept of seismic simulation was considered from the beginning part and parcel of Nuclear Power Plant equipment qualification. The seismic withstanding of equipments is considered by specifications, and may be found out either by analysis or by testing. The actual trend is to prefer testing, whose results are undeniable and who allow testing of the functional part of the equipment (which is not always possible by analysis). According to this scheme, the laboratory plays a prominent part in setting up of testing methods, facilities and developments.

1.2. New requirements of standards

In the field of specification standards and concerning the use of these specifications, we also noticed an evolution. Main reference for seismic testing remains IEEE STD 433-1975, which considers several possible testing methods. However, the choice of a method tends more and more to relieve testing of technical restrictions, i.e., multiaxis tests with input signals as synthetized time histories. This trend was also followed in Europe, and nowadays the more generally used type of test is biaxis test with synthetized time history, which appears the most suitable for taking into account of eventual resonant frequency couplings or axis couplings of test specima.

1.3. Seismic simulation by "synthetized time history"

The completely synthetized time history method offers the advantage of freeing the testing of everything but the Required Response Spectrum. In this view, we are using HEWLETT PACKARD 5451 B systems, i.e., Fourier analysers, presenting all adequate software. Directions for use are to be found as follows. The fully synthetized time history is obtained from a mixture of discrete components (decaying sine) judiciously shared out in the time domain. Damping and shape of the RRS are then put into the system and computing and iterating processes lead to get time history in accordance with the RRS. The time duration of the signal is obtained by a randomization process. A correction relative to test table transfer function is done, then the driving signal is applied to the shaker. A synthetized time history is made up for each test axis (usually, one vertical axis and one horizontal axis, combining two orthogonal directions) and for each severity level (OBE and SSE). The duration of each seismic simulation is of about 30 s.Biaxis tests are performed by proceeding to a 90 degree rotation of the specimen on test table in order to investigage all directions. This program is fully agreed by IEEE STD 344. However,as far as appropriate testing facilities exist,triaxis tests should be more suitable.

In consideration of the future, we are working out improvements of the test program such as a fully computed share of discrete components allowing to match some particular effect, easy adjustment of a time domain signal duration, and optimization of computing duration. This sort of program, as well in its actual state as it should be when improved, seems most suitable to most required test occurences. Another advantage is given by the flexibility of use and by the possibility of modulating either the whole signal level, or part of the RRS shape, with help of the Fourier analyser.

1.4. Test facilities

To perform these programs and to take into account the variety of equipments to be tested as well as size evolution and equipment configuration, a laboratory must have at hand a range wide enough of testing facilities, i.e., in this case, seismic test tables. For seismic simulation, these tables have to be driven by hydraulic shakers allowing large displacements at low frequencies and running within a frequency range of approximatively DC to 100 Hz.
Several shakers are necessary for a multiaxis running of the table, which may be driven by a mechanical system for the biaxis configuration. For the triaxis configuration, hydraulic shakers will ensure both motion and driving. Small biaxis test tables with an approximate dimension of 1m x 1m and a 4000 daN dynamic thrust, allow testing of small and medium equipments within a weight range of up to 500 kg, such as electrical equipments and components or devices, mechanical equipments, small panels, pipes, valve elements, and so on. On a larger scale, large biaxis test tables measuring 3m x 3m and with a dynamic thrust of 30 000 daN plus a vertical static compensation thrust of 10 000 daN, allow the testing of large equipments within a weight range of up to 20 000 kg. These equipments enclose panels, cells or electric frames of large size, large electromechanical equipments such as cooling units, emergency diesel structures, motors, fans, valve operators, valves and so on. In some cases, particular auxiliary frames shall be needed to ensure anchoraging at top of rear face of tested equipment.

Measurement facilities, mainly based on accelerometric measurements, shall allow to fit out the tested equipment, as well as be able of measuring and recording motions and of computing dynamic responses and local response spectra. For this we use the same kind of digital H.P. system with tape recorder and graphic plotter. The multiplexer technique allows simultaneous recording of up to 64 or 128 channels. Improvements are also to be expected in this field with the use of new computers and Array processors.
Moreover, and even if not absolutely specified by specifications, a three-axis test table allows to obtain optimal test conditions or to match particular conditions in which a specific triaxial motion is really of importance for the dynamic behavior of an equipment. This may be the case of an equipment with sensitive

parts along three axes and tested in operational conditions or, for instance, in the case of an equipment fitted with an anti-seismic device.

All these testing facilities together with their monitoring and control systems which shall be described later on, allow to meet most of customers and specificators requirements. This may be completed by modal analysis systems and by test benches with hydraulic shakers directly connected to the equipment frame, in the case of particular requirements or large equipments.

2. MONITORING AND CONTROL FACILITIES ASSOCIATED WITH SEISMIC SIMULATION TESTS.

2.1. General considerations

The scope of this second part is to present the monitoring and control facilities connected with the test tables as seen before for carrying out of seismic withstanding tests. Since the origin of these tests, specificators and laboratories tried to test electrical equipments in operational conditions as close as possible to actual service conditions. However, the extent of electric control resulted from particular specifications which where set up according to existing facilities.
With the issue of IEEE Specifications STD 649 and 650 as well as NUREG 0588, it is now doubtlessly specified that tests have to be performed on nominal voltage or intensity loaded electric equipment and while keeping a very close control of accidental chatters which may possibly appear on electric circuits. These specifications led SOPEMEA to develop and use suitable facilities allowing, on one hand, to monitor equipments under specified conditions and, on the other hand, to control their function. As the equipment tested is drawn from its functional line, facilities developed by laboratories have to replace this line. However, considering the complexity and variety of test specima, this is not always possible. For instance, in insuffiecent power conditions, it may be necessary to choose between nominal voltage and intensity. The control shall therefore be taken according to the most important parameter to take account of to keep good service conditions of the equipment during the test.

We shall now introduce some examples of facilities used this way.

2.2. Monitoring facilities

Let us first consider monitoring and power supplies.

2.2.1. Medium voltage power station.

For motor and rotating machine tests, we set up a medium voltage power station with a total power capacity of 800 kVA, allowing a voltage supply within the range of 3,3 kV to 11 kV and which may be fitted to the required value.
Voltage supply is delivered by means of cables and standard ELASTOMOLD connectors. Moreover, a movable panel allows monitoring and control of the station and of main parameters during the test. Last but not least, a protection

rack fitted with adjustable electronic cards ensures an immediate reaction to any possible error, such as phase error, unbalance, flockated rotor, ground defect..., which should let appear a malfunction and bring the test to a stop. Other protections can be proceeded to on request. This medium-voltage station allowed SOPEMEA to test in rotating conditions a wide range of medium-voltage motors for pumps implanted in french, belgian and south african power plants. It may obviously be used as well for any other electric equipment requiring a medium voltage supply (for instance, motor control center panels).

2.2.2. Current supplies

To match specified high intensity values, we developed three panels delivering intensities within a range of 50 to 2600 amperes. The value of intensity is adaptable and delivered under a voltage of about 2,5 V. Each electric channel is fitted with its own protective device. A variation of the intensity value may be performed during the test.
These conditions meet with IEEE requirements as concerns load current application during testing.

2.2.3. Voltage supplies

These supplies complete the standard voltage supplies of the town mains which present the drawback of delivering unadjustable values of voltage. They cover a voltage range from 0 to 450 V for A.C., and from 0 to 250 V for D.C, with a maximum intensity of about 8 amperes. The advantage of such supplies is a great flexibility of voltage values and, more particularly, the possibility of performing a seismic test with an equipment supplied with some percentage of the nominal voltage value. As in the case of current supply, each line, be it monophase or triphase, is protected.

2.3. Control facilities

We shall now consider the control facilities, allowing to ensure whether energized equipments can withstand seismic tests with electric functions staying within the limits given by specifications. The main problem we meet when dealing with electric equipment concerns the detection of chatter or accidental state changes on the circuits. Why is this a problem? Because the limits of error duration as admitted by specifications are very low, usually of about a few milliseconds, and commercial equipments able to deal with such problems are quite unexistent. SOPEMEA electronic services therefore developed and built chattering detectors for this purpose. These detectors are built on a rack with microprocessors according to the latest electronic techniques, and they are able of delivering simultaneously 20 control channels.
Control is done under three conditions :

- circuit out of any supply : in this case, the detector itself delivers an intensity of approximatively 20 mA through the circuit.
- circuit with a specified intensity value.
- circuit with a specified voltage value.

In the two last occurences, the detector is used with interface modules. Normally open or closed circuits may be controlled with identification of state. Moreover, two successive and opposite states may be controlled as the detector is neutralized when inducing the change of state. Results are registered on printer. They reveal the identity of controlled channel, duration of error, as well as occurence frequency or time, whether it applies to a sine sweep test or to a synthetized time history test. Error detection may be done within three measurement ranges, the complexive range being from 1 μs to 10 s. Detection is operational during the whole time of the test. Interface racks allow electric fitting with shunts for intensity and adjustable resistances for voltage. Each channel is electrically insulated from the others. As for other types of electric control, we resort to specific equipments of manufacturers, such as mini-computers, or to standard facilities such as magnetic or galvanometric recorders, in order to control parameters which vary slowly with time.

3 - CONCLUSION

In conclusion, techniques and specification evolution on one hand, the care of our laboratory to provide an always growing range of services to our customers on the other hand, led us to develop test facilities and peripherals in the scope of a maximal representativity of seismic testing.
