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SHAKING TABLE TESTING OF ELECTRICAL EQUIPMENT IN ARGENTINA

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ABSTRACT: This paper describes the testing facility, the methodology applied and the results obtained in the seismic qualification tests of diferent types of electric equipment. These tests were carried out on a shaking table that was developed and built at the Earthquake Research Institute of the National University of San Juan, Argentine.

The equipment tested consist of 500 KV and 132 KV current transformers, a 500 KV voltage transformer, a 145 KV disconnecter and a relay cabinet. The acceleration response of the tested equipment was measured at several locations distributed along its height, and strains were measured at critical points by strain gauges cemented on the base of the porcelain insulator. All the information was recorded with a data acquisition system at a sampling rate of 200 times per second in each channel.

The facility developed at this Institute is the largest one in operation in Argentina at present and the equipment tested is the highest, heaviest and more slender one which has been seismically qualified on a shaking table in this country.

These tests have been a valuable experience in the field of structural dynamic testing applied to equipment of hydroelectric and nuclear power plants.

1. INTRODUCTION

Earthquakes have often affected the electric power systems causing the interruption of power supply to industries and homes, which sometimes has extended during several days. Some components of high voltage substations have shown to be very sensitive to the shaking of strong earthquakes. Measurement transformers,disconnec-ting switches, circuit breakers and other similar substation equipment of 220 KV or larger voltage have been severely damaged on the 1978 Miyagi-Oki, Japan earthquake (Katayama 1980), on the 1987 Bay of Plenty, New Zealand earthquake (Rutledge 1988) and on the 1989 Loma Prieta and 1995 Northridge, USA earthquakes (EERI 1990, 1995).

The restoration of the operation of this equipment demands time which produces important economic losses that are larger than the reposition cost itself. Also, some equipment could be essential for assuring the security of power plants.

With the purpose of carrying out dynamic tests on full scale substation electric equipment subjected to seismic motion, the Earthquake Research Institute of the National University of San Juan, Argentina, has designed, built and put into operation a shaking table. With this testing facility the seismic qualification tests of two 500 KV measurement transformers and other equipment have been recently performed (Figures 5 to 9).

2. THE SHAKING TABLE

The shaking table mentioned above has one horizontal degree of freedom and was designed and built keeeping in mind that the electric equipment to be tested are slender and have normally the centre of gravity in such a position that generates a very important seismic overturning moment at its base. The testing facility is located in San Juan City which, with its mild and very dry climate, allowed the facility to be built outdoors. This fact also simplifies the erection of the equipment to be tested which has, in the case of 500 KV current transformers, a total height a little larger than 10 meters.

The shaking table motion is produced by a PC computer controlled electro-hydraulic actuator.

The operation limits of this facility are shown in Figure 1. The installation has also a data acquisition system to measure and record the cinematic variables which correspond to the motions of the shaking table and the equipment under testing.

The whole installation has been designed by the authors of this report, including the frame and supports of the table, the actuator, the transducers and electronic circuits of the data acquisition system and its software.

3. SEISMIC QUALIFICATION TEST MOTIONS

The electric and mechanical equipment seismic qualification tests are the experimental approach to demonstrate the ability of the equipment to perform its required functions during and after the occurrence of earthquakes.

About the seismic activity in Argentina, the most destructive earthquakes have occurred at the centre of the western part of its territory, (Volponi 1962). For example, in November 23, 1977 the city of San Juan was shaken with Mercalli Intensity VIII by one Ms = 7,4 earthquake from an epicentral area at a distance of 60 km. Figure 4 shows the acceleration record obtained in San Juan city on that occasion with a maximum acceleration 0,17g whereas one Wilmot seismoscope with a period 0,7 sec and 10% of damping located on the same site recorded 0,26g as spectral acceleration. (Carmona 1978).

The 500 KV measurement transformers tested will be installed in substations of hydroelectric power plants located at Limay River in Comahue Region, one thousand km. to the south of San Juan City, where the seismic activity is lesser than in this place.

To seismically qualify these equipment Hidronor, the owner at the time of these tests, specified the spectral response accelera-tion curve shown in Figure 2 with a maximum value of 0,26 g. The shaking table motion that was specified to fulfill this require-ment was a sine-beat type acceleration. It was specified a sequence of 5 sine-beats separated by quietness intervals, each sine-beat having five complete sine waves with amplitude modulated by a half sine wave and period equal to the fundamental natural period which has the equipment under testing in the direction of the shaking table applied motion (Figure 3).

An example of another motion applied with this shakinq table is shown in Figure 12. This accelerogram was derived from the record obtained in San Juan City in 1977 and aplied to a 5 tons structural model.

4. PERFORMED TESTS ON 500 KV MEASUREMENT TRANSFORMERS.

To perform the seismic qualification test, the transformers were mounted on the shaking table with its bolted steel tower support rising to a total height of 10,5 m. It is very important to properly reproduce the service condition since the tower support changes the dynamic response of the device (Figures 5-6).

The instrumentation includes 6 accelerometer transducers distributed along the height of the device under testing and 2 strain gauges cemented on the base of its porcelain insulator (Figure 9), all of them connected to the data acquisition system in which the information was measured and recorded as digital data at a sampling of 200 times per second in each channel.

The tests carried out on the shaking table have had two stages. In the first stage one sloped step and sinusoidal scanning motions were applied in order to determine the natural periods, mode shapes and damping of the electric device under testing.

After the identification of the dynamic parameters the required motions for the equipment qualification were applied. The amplitudes were successively increased until the response spectral acceleration of the equipment tested was equal or larger than that specified on Figure 2, which was 0,26g for both transformers as a consequence of their natural frequencies. In the current transformer the maximun response spectral acceleration obtained during the test was 0,30g whereas in the voltage transformer it was 0,38g, both larger than the required value given in Figure 2. Figure 11 shows the acceleration-time curve measured in the upper part of the current transformer during one of the strongest sine-beat shaking table motions and also it is shown with a dotted curve the response calculated using the modes and frecuencies obtained by a minimization output error method (Zabala,1993) . The 2,5 and 3% damping acceleration response spectrum curves of the motion applied are shown in Figure 10.

Finally, it must be pointed out that after the shake neither through visual inspection nor through electric measure tests any disturbances or damage on the measurement transformers tested have been detected. In this way, the seismic qualification test of these electric devices has been successfully completed.

5. FINAL REMARKS.

It should be pointed out that the testing facility built is at present the largest one of its type in Argentine and the equipment tested is the highest, heaviest and slenderest one which has been seismically qualified on a shaking table in this country.

Furthermore, even though this shaking table has only one degree of freedom, the tests performed have been a valuable experience for a better understanding of the seismic behavior of special electric devices. In the near future other degrees of freedom will be added to this testing facility in order to be able to better represent earthquake motions.

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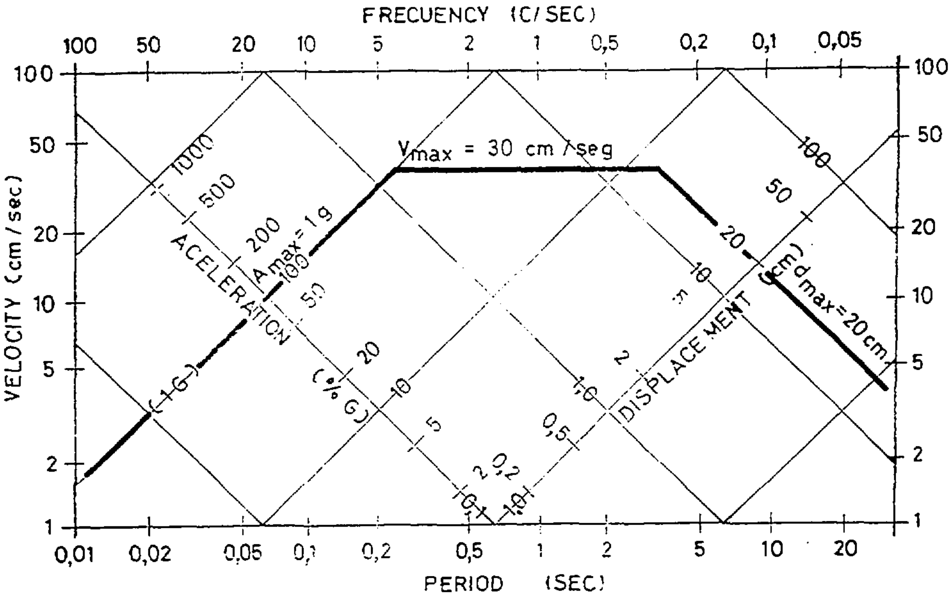

FIGURE 1. Shaking table operation limits.

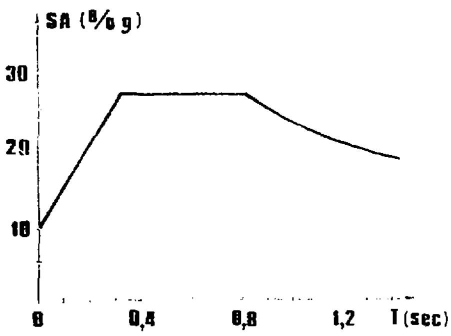

FIGURE 2. Acceleration response spectrum required by Hidronor.

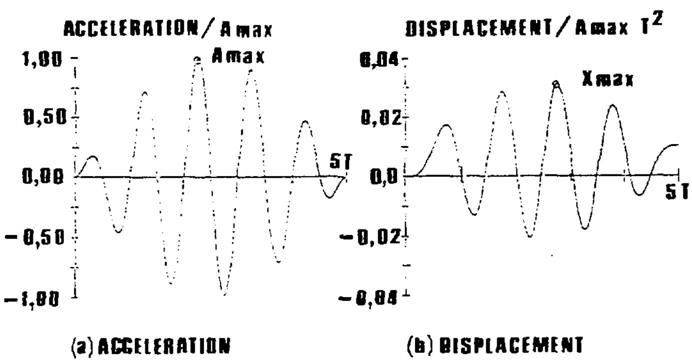

FIGURE 3. Sine-beat type shaking table motion required by Hidronor.

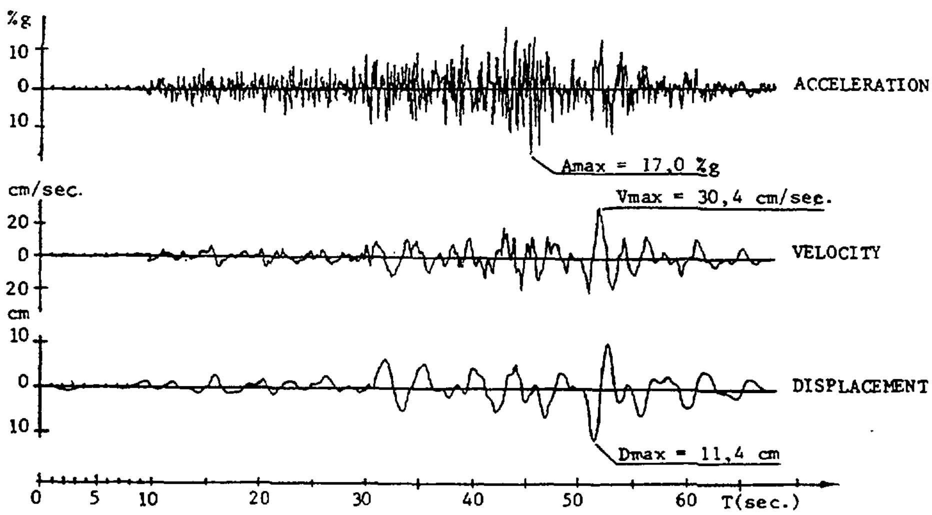

FIGURE 4. Acceleration record of San Juan (Argentina), Nov.23,1977 earthquake.

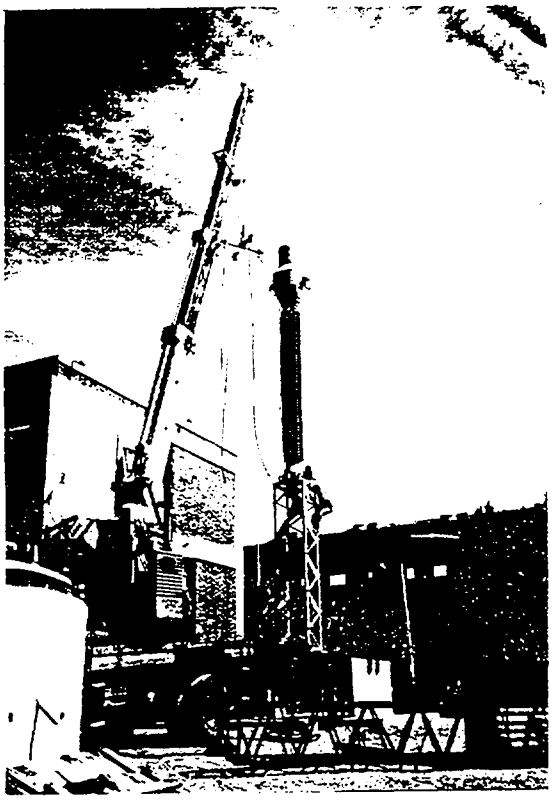

FIGURE 5. 500Kv current transformer with its supporting tower.

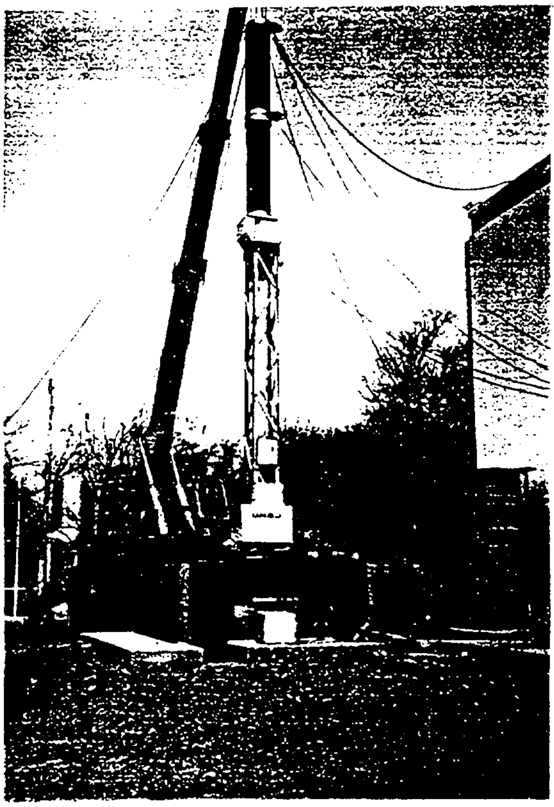

FIGURE 6. 500Kv voltage transformer ready for the test.

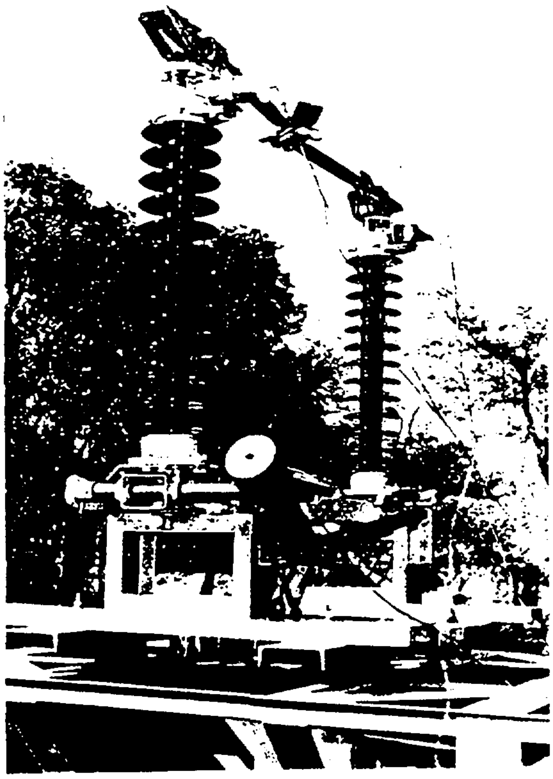

FIGURE 7. 145Kv disconnectors with acceleration transducers.

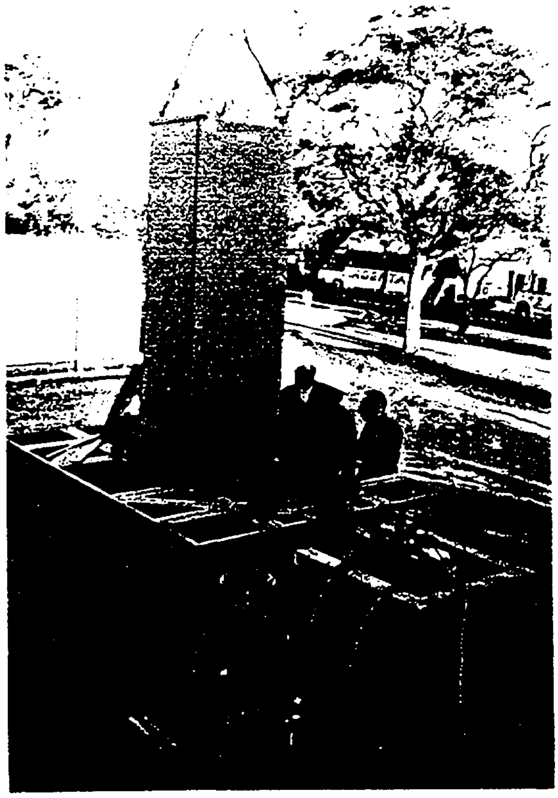

FIGURE 8. Relay cabinet mounted on the shaking table.

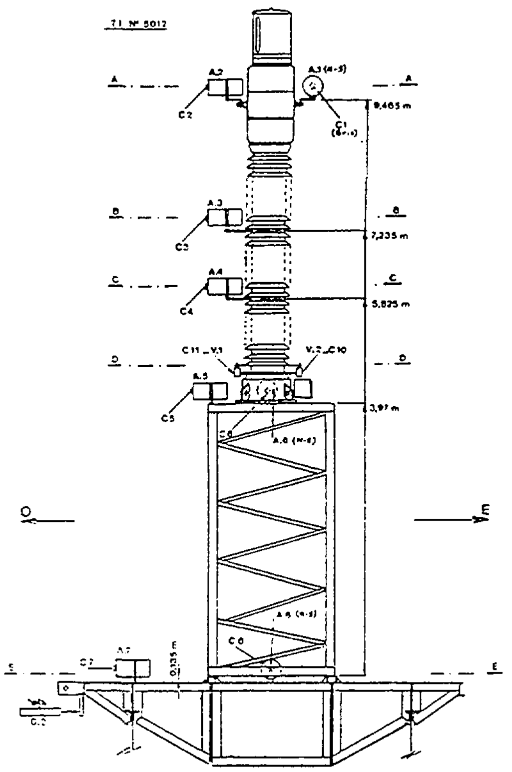

FIGURE 9. 500Kv current transformer test instrumentation.

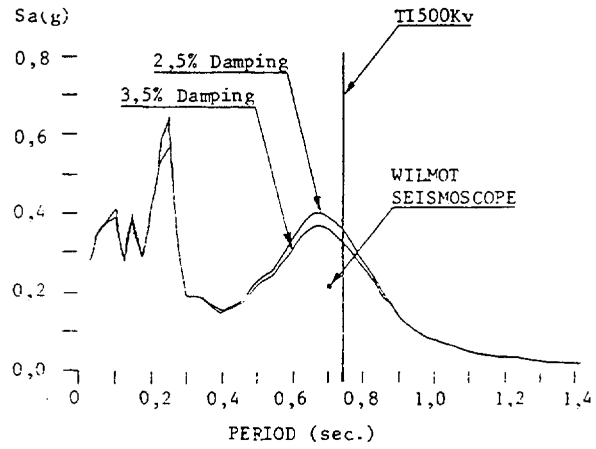

FIGURE 10. Qualification movements response spectrum.

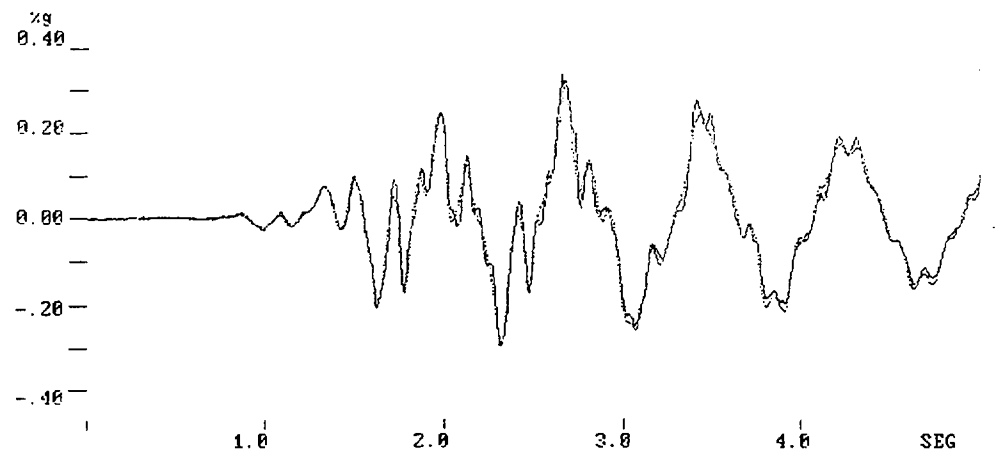

FIGURE 11. Acceleration history measured at the top of the 500Kv current transformer.

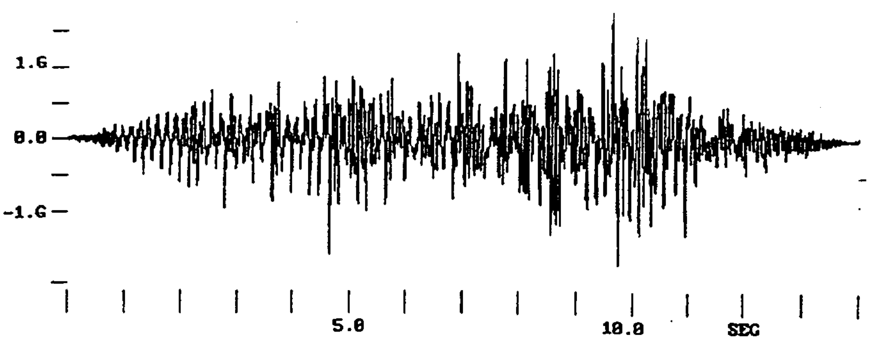

FIGURE 12. Example of shaking table applied motion.

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