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Title: **Evaluation of Seismic Resistance of Low Voltage Switchgear, NNP V1 Jaslovské Bohunice, Slovakia**

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Date: **October 1997**

IAEA BENCHMARK STUDY FOR SEISMIC ANALYSIS AND TESTING OF WWER-TYPE NPPs

Evaluation of Seismic Resistance of Low Voltage Switchgear, NNP V1 Jaslovské Bohunice, Slovakia

Prepared for

Research coordination Meeting
October 13-17,1997
EQE, San Francisco, USA

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Introduction

During this year, company Stevenson & Associates took part in the project of evaluation of seismic resistance of NPP V1 Jaslovske Bohunice in Slovakia. We were responsible for a part of electrical equipment, mainly for the evaluation of low voltage switchgears.

There were four steps of the evaluation:

1. Detail Walkdown
2. Application of GIP-VVER Methodology
3. Developing of In Cabinet Response Spectra
4. Evaluation of Acceptance of Formerly Performed Relay Tests According to the Russian Standard OEG 130.003

Cabinet Description

Evaluated cabinets are located in Reactor Hall, Diesel Generator Building, Gallery and Auxiliary Buildings on elevation varying from -6.15 m to +14.7 m. These cabinet are originally Russian designed. Cabinets are welded of sheet metal, 2 mm thick. Side walls are reinforced with steel members. Cabinets are usually arranged in rows of four to six. Side walls of adjacent cabinets contain large cutouts to provide access to these cabinets. Relays are mainly fixed to panels located on the rear wall. A typical cabinet is shown on fig. 1,2

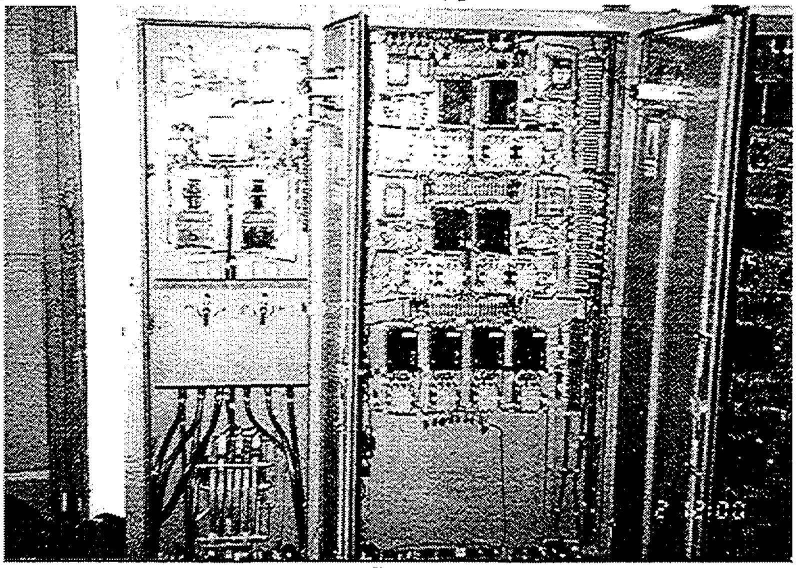

fig.1

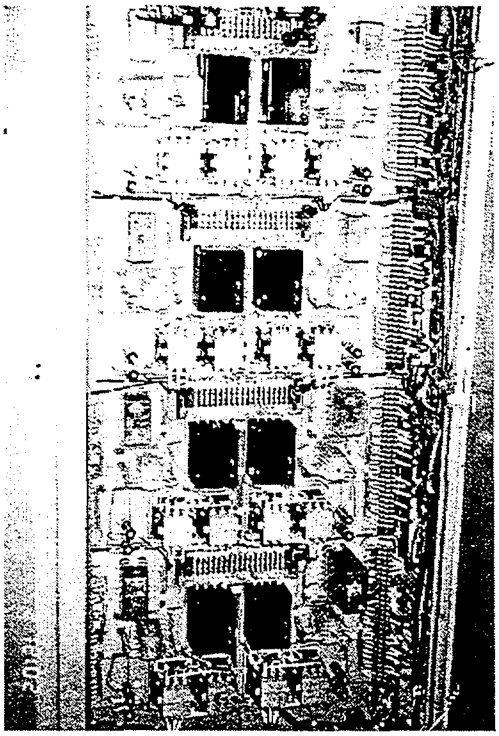

fig. 2

Application of GIP-VVER Methodology

1. Comparison with Bounding Spectra

First natural frequency was evaluated as above 8 Hz. Further detail analysis showed, under the assumption of rigid floor the value of first natural frequency to be 12.81 Hz.
Next two graphs show us:

a) comparison of GRS with Bounding Spectra (fig.3)
b) comparison of FRS for location Gallery elevation +14.7 m with 1.5 times Bounding Spectra(fig.4)

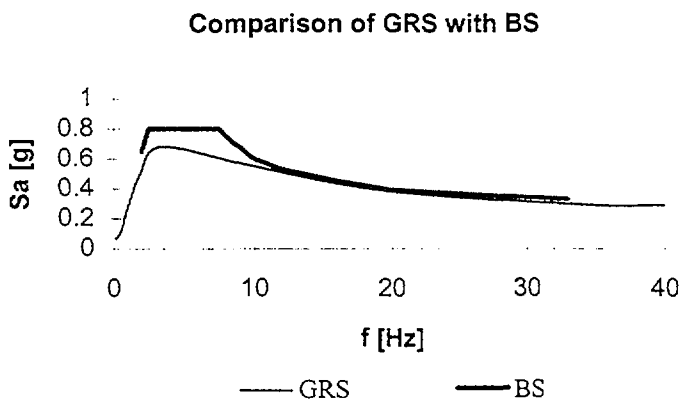

fig.3

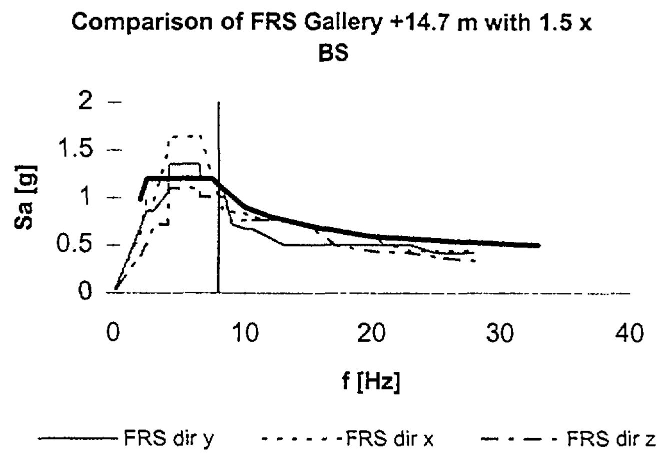

fig.4

2. Caveats

Generally there were no problems relating to caveats. The only problem found was that some adjacent cabinets did not bolted together.

3. Anchorage

The cabinets are mainly welded to the embedded structures. Some cabinets are welded to the floor composed of some free lying steel members (fig.5,6).

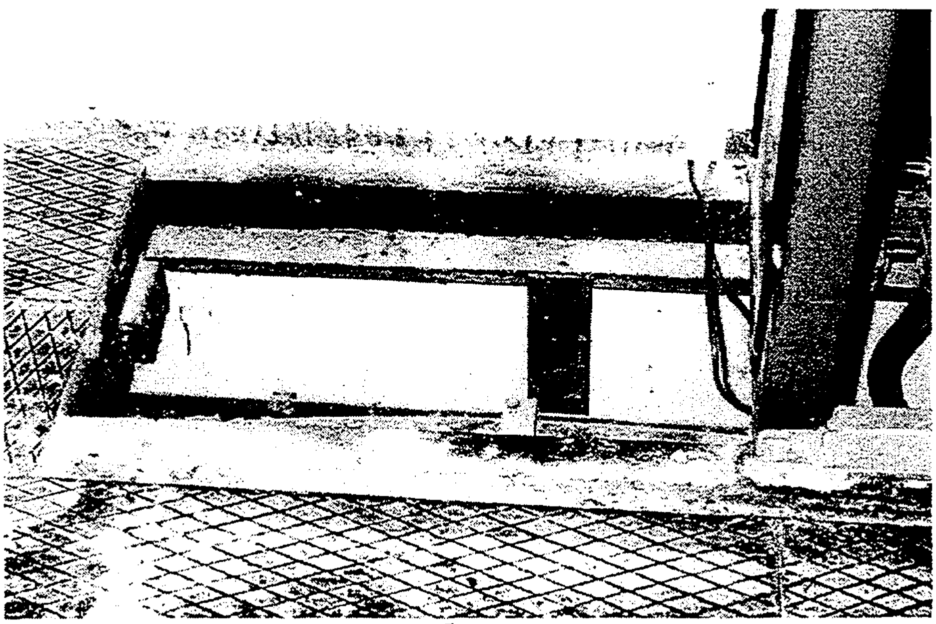

fig. 5

fig. 6

It caused a reduction of the value of the first natural frequency which consequently caused shifting of corresponding spectral acceleration to the peak spectral acceleration range. The in site modal properties tests of same type cabinets with approximately the same weight of content but standing on different floors were performed. The results varied from the value of 4.85 Hz for flexible floor to the value of 11.8 Hz for stiff floor.

Upgrading of flexible floors was recommended.

4. **Interactions**

The presence of brick walls was detected in some rooms in the auxiliary building. Reinforcement of these walls was recommended.

Development of In Cabinet Response Spectra (ICRS)

ICRS was developed for cabinets located in the Gallery on elevation of +14.7 m. In this location there is the most adverse seismic input. Amplification factors for location of fixation of relays were developed for particular directions on the base of knowledge of ICRS as a ratio between ICRS and FRS. These amplification factors were later used for determination of ICRS for other locations.

The finite element model of two adjacent cabinets was created as shown on fig.7. Relays were modeled as lumped masses.

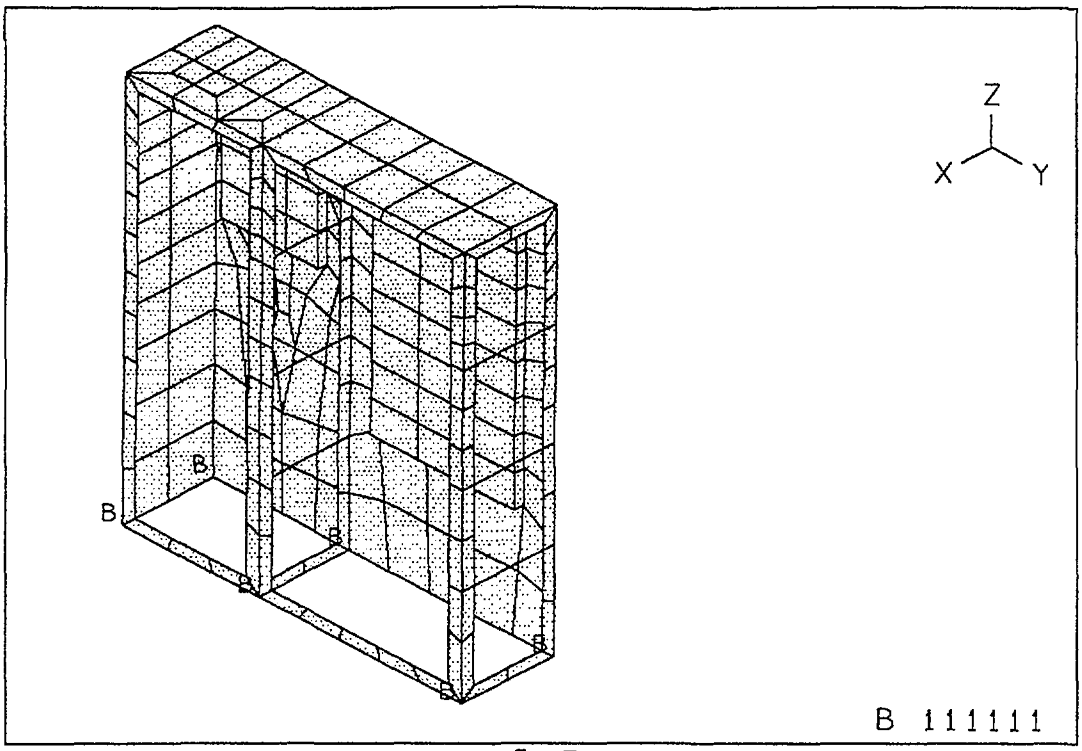

fig. 7

Three statistically independent time histories corresponding to the FRS were generated using program SPECTRA and used as an excitation.

The highest response in the location of fixation of relays was used for computing the ICRS. That means that the developed ICRS are maximum conservative. The comparison of ICRS with FRS for each direction is shown on fig. 8-10.

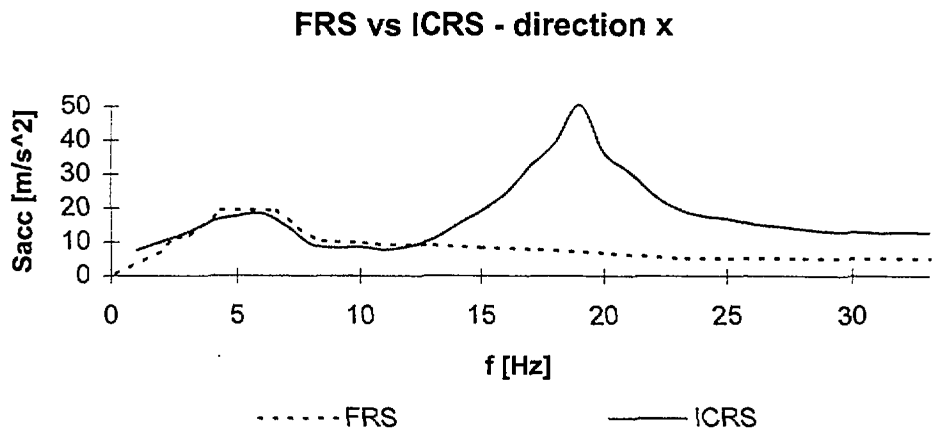

fig.8

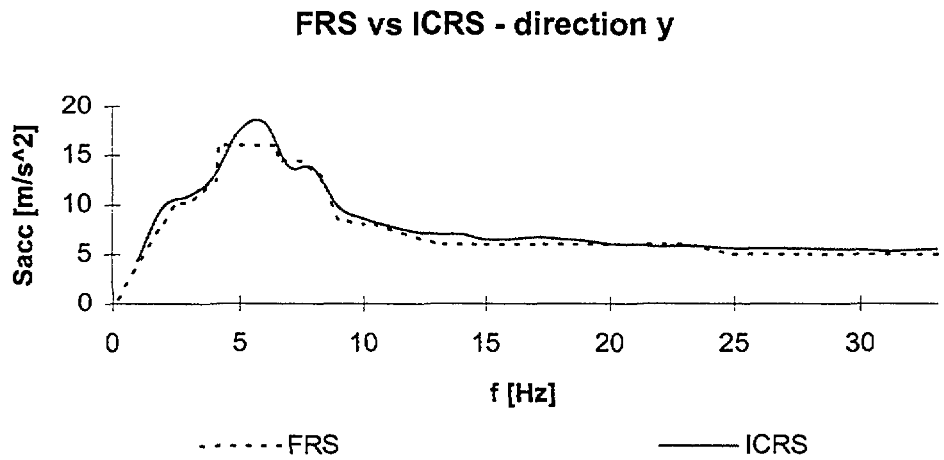

fig.9

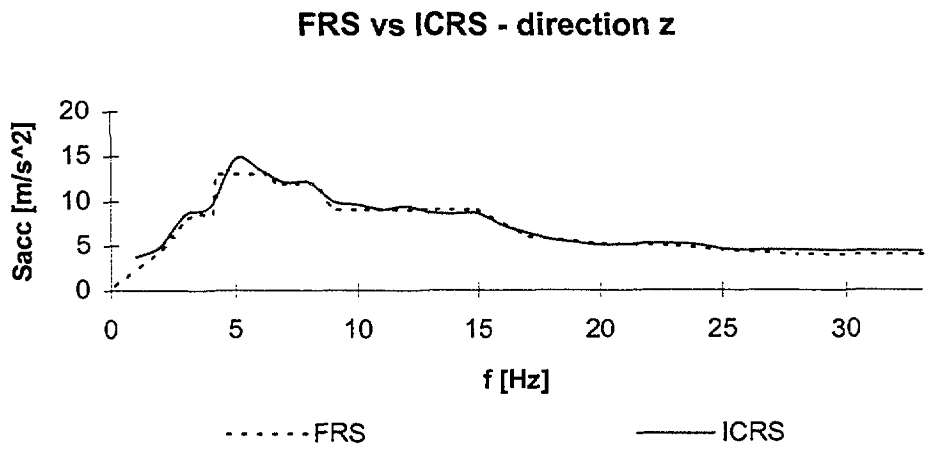

fig.10

Evaluation of Acceptance of Formerly Performed Relay Tests According to The Russian Standard OEG 130.003

Relays were tested in compliance with the Russian standard OAG 130.003. The excitation according to this code is assumed to be single frequency harmonic subsequently in the whole frequency range.

As mentioned above relays were excited by harmonic signal. In order to know the contribution of frequency content of time history equivalent to ICRS Fourier decomposition of signal was performed in form:

$$a(t) = \sum_{k=-\infty}^{\infty} c_k \cdot e^{ik\omega t}$$

where c_k are Fourier coefficients

The squares of particular Fourier coefficients give us an idea of energy contribution of individual harmonics to total energy associated with the signal. This dependence is called Energy spectrum (fig.11) and is expressed in form:

$$E_k = |c_k|^2$$

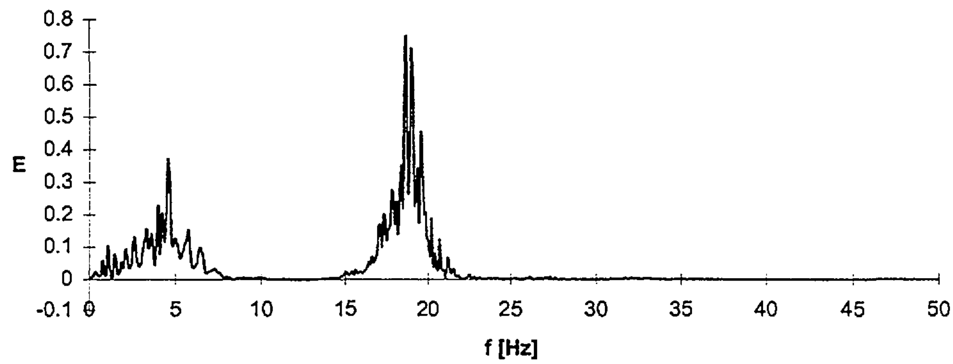

fig.11

The signal used for excitation should generally contain concurrently all harmonics in whole frequency range with amplitudes equal to particular Fourier coefficients. However only the one harmonic signal of particular frequency was used at a time. From the energy spectrum it is evident that only harmonics in range from 3 to 7 and 15 to 22 Hz have significant contribution to the total energy associated with the signal.

Multi-frequency tests based on the harmonic excitation can be generally replaced with a single frequency test when the response spectra of harmonic excitation signal envelopes the ICRS in the whole frequency range. From this it is obvious that when this demand is satisfied only for one arbitrary frequency it is possible to accept results of test according to the OAG 130.003 standard.

Now the question arises whether it is necessary to require enveloping in the whole frequency range.
If we have the knowledge of:

- distribution of energy of excitation signal
- first natural frequency of tested subject

it is possible to require enveloping only in the significant energy frequency range of excitation signal above the value of first natural frequency of the tested subject.

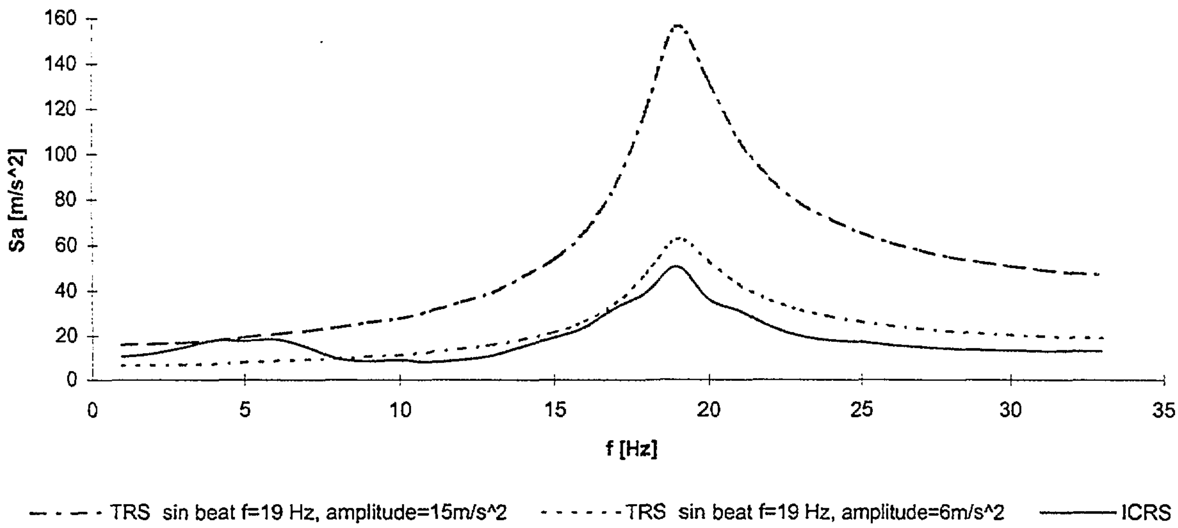

fig.12

An example of the required value of amplitude of harmonic signal necessary for enveloping is shown on fig.12. If the enveloping in the whole frequency range is required the amplitude should be 15 m/s^2 for the frequency of 19 Hz. Under the assumption that the first natural frequency of the tested subject is higher then 8 Hz the required amplitude should be only 6 m/s^2 which is the amplitude of harmonic signal according to OAG for elevation of +14.7 m.

Conclusion

Tests performed according to the Russian Standard OAG are acceptable only if the tested subject shows just one dominant natural frequency in the significant energy frequency range. If there is no knowledge of modal properties of the tested subject (that is a frequent situation because test reports usually contain only generalized Fourier loading spectrum) the enveloping of ICRS in all significant energy frequency ranges by RS of harmonic signal on one arbitrary frequency. This criteria is usually not satisfied because the shake tables used for the tests are not able to produce the sufficient level of excitation in the low frequency range. It may lead to the demand for test repeating.