Suspension of a surge arrestor using wire-rope isolators adapted to seismic conditions

SUMMARY:

To protect a surge arrestor in a nuclear power station against earthquakes, SOCITEC devised an isolation system using wire rope isolators and justified its choices with calculations and characterisation tests. The full set of equipment was qualified for seismic resistance by SOPEMEA in February 2018. This article presents the results of the measurements and their correlation with the design calculations.

INTRODUCTION:

The Fukushima nuclear disaster in 2011 resulted in stricter seismic response spectra for nuclear power stations, in particular when calculating the behaviour of electric equipment to ensure that the cooling circuit operates correctly. The upwards revision of these levels, sometimes to 10g or 15g, now prohibits rigid mounts or mounts on flexible elements such as the spring units generally used. The lifespans of these spring units are not guaranteed to satisfy nuclear regulations (i.e. over 50 years).

An alternative solution was therefore needed which could protect the equipment in nuclear power plants from earthquakes and stand the test of time. This article describes the process of how a solution was put in place using an elastic suspension to isolate a surge arrestor manufactured by RIELLO UPS, from the selection of the suspension model through to the seismic testing.

I – CHOOSING THE APPROPRIATE SUSPENSION

The solution selected for this application was the wire rope isolator. Its coiled cable possesses significant elastic and damping capabilities. The coils have high deflection capacities and damping is ensured by internal friction of metallic strands. This 100% stainless steel product has an identical lifespan to the equipment and does not react to temperature, humidity or chemicals.

Figure 1 – Model HH16-70

These isolators can considerably filter seismic shocks and limit the accelerations transmitted to under 1 or 2 g, thus guaranteeing that equipment will continue to operate after an earthquake. This kind of mount does however generate significant displacements of several centimetres. As a result, calculations need to consider non-linearities in the behaviour of the isolators. A time based approach is indispensable because harmonic calculations cannot take non-linearities into account.

The wire rope isolator selected was the HH16-70 model at a 45° angle. This rotation serves to increase the displacement capacity in the suspension and obtain identical stiffness characteristics on the Y and Z axes (figure 1).

II – NON-LINEAR MODELING OF THE SUSPENSION

The dynamic model of the suspension of the surge arrestor was produced using SYMOS software; this program can model equipment mounted on isolators represented by elastic connections with non-linear stiffness and damping properties. Different types of isolator models (viscous, dry friction, structural, etc.) can be integrated to obtain highly elaborate models relatively easily.

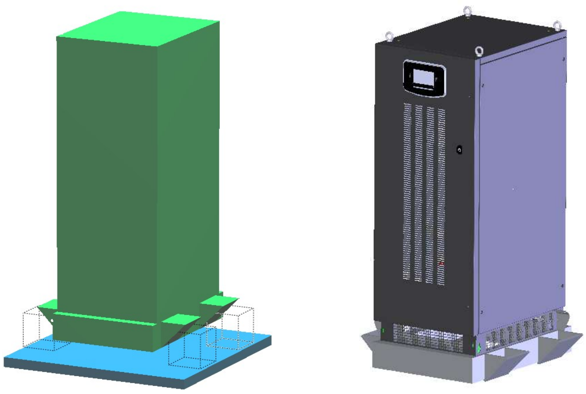

Figure 2 - SYMOS modeling (left) - 3D model (right)

Wire rope isolators were integrated using non-linear stiffness characteristics resulting from measurements and a dry friction model whose parameters were also identified using experimental characterisations. The model used was the Dahl model, which is often employed and adapted to friction thanks to its simplicity and robustness. The dynamic characteristics of an isolator are thus decomposed into an elastic component and a damping component dependent on the displacement in the isolator.

Figure 3 – Characterisation test on isolators

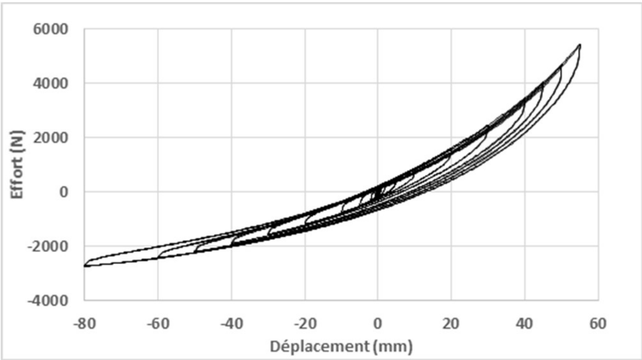

Figure 4 – Force-deflection curves

III – TEST CAMPAIGN AND CALCULATION VALIDATION

The surge arrestor designed by RIELLO UPS was qualified in February 2018 on an electrohydraulic exciter at the SOPEMEA laboratory located in Vélizy-Villacoublay, France. The first step is to identify resonance frequencies using sine-sweep testing. This is followed by two seismic tests: the first at a reduction of 50% and the second at a nominal level. Each test is carried out following two configurations: the OX and OZ axes are excited simultaneously for the first, and the OY and OZ axes for the second (figure 5).

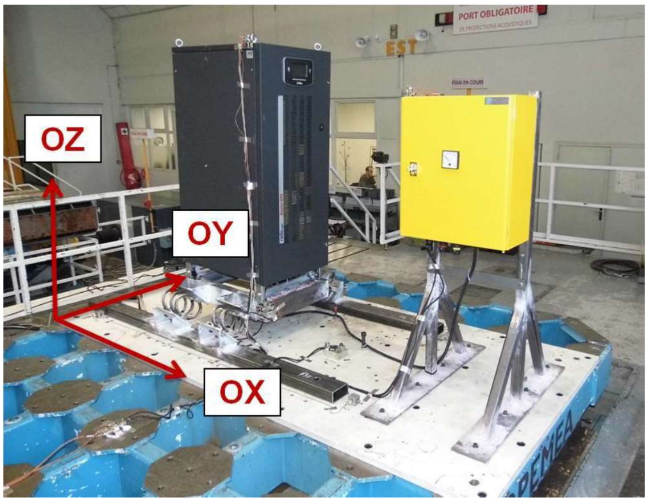

Figure 5 – Testing apparatus

The process used to identify resonance frequencies is sine-sweep testing at a frequency of 1-55Hz with a constant amplitude of 0.2 g. This research was also carried out numerically using SYMOS by producing a transient calculation for each frequency studied. Figure 6 shows the calculation-measurement superposition to find the vertical frequency.

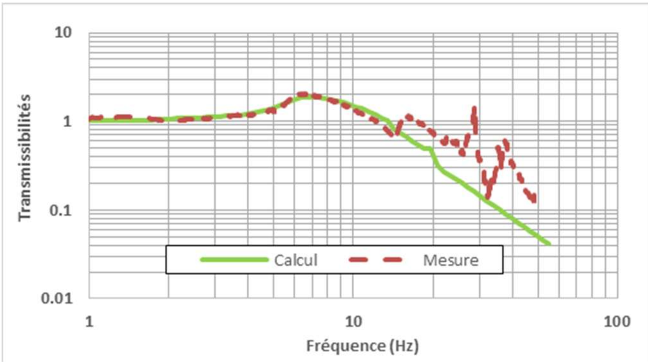

Figure 6 – Identification of vertical frequency

A good correlation at the frequency identification stage demonstrates the validity of the model in terms of stiffness and isolation. Time-history signals synthesised from seismic spectra (figure 7) were used as input for the SYMOS model.

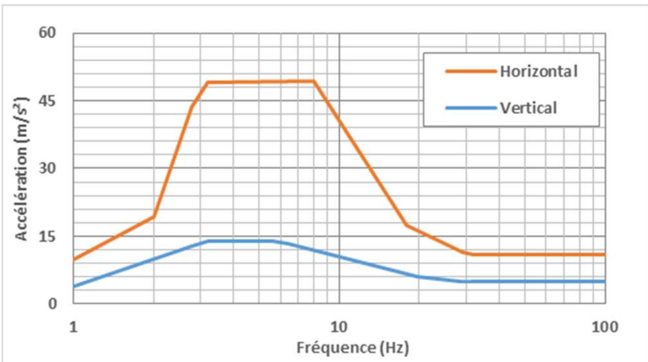

Figure 7 – Specified seismic response spectra

The graphs in figures 8 and 9 show the robustness of the model and its capacity to reproduce accelerograms on complex signals.

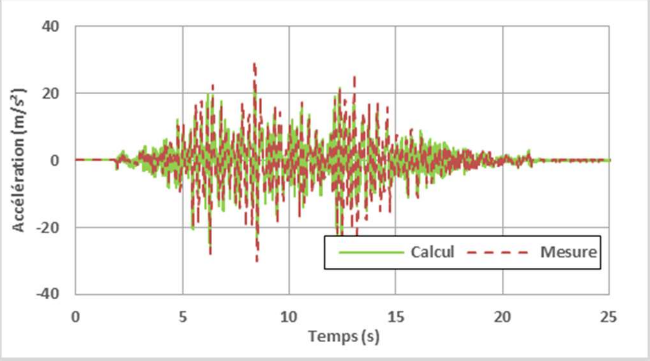

Figure 8 – Seismic tests – complete signals

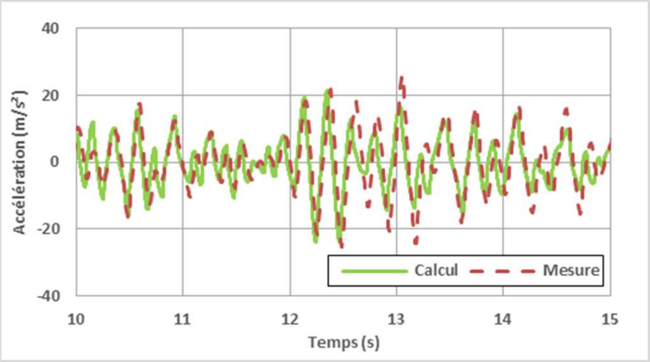

Figure 9 - Seismic tests – close-up of 5 seconds

IV – SUSPENSION PERFORMANCES

One of the objectives of the suspension is to filter some of the frequencies present in the input spectrum. To validate the performance of the isolators in reaching this objective, the seismic response spectra of the input and output signals were calculated. The result shown in figure 10 corresponds to the measurements carried out following the Y axis; the input is taken from the excitation table and the output at the level of the centre of gravity of the suspended unit.

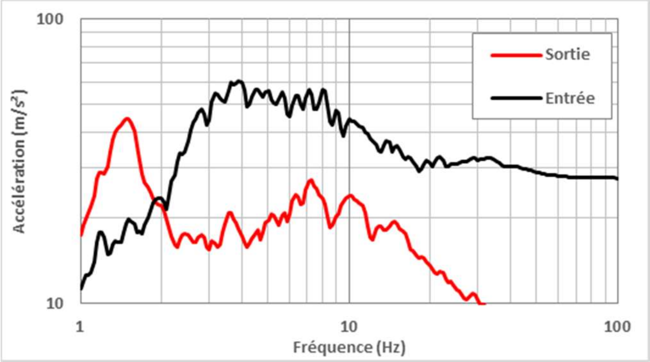

Figure 10 - SRC of input and output signals

The graph above shows that the intersection frequency is about 2Hz. This means that the suspension significantly reduces vibration levels corresponding to frequencies above 2Hz, illustrating the wire rope isolator's capacity to attenuate seismic shocks.

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