

# Using Wire Rope Isolators for Seismic Protection

Claude Prost and Joshua Partyka, Vibro/Dynamics LLC, Broadview, Illinois

The application of wire rope shock and vibration isolators to protect sensitive equipment from seismic events is presented. Dynamic analyses of protected equipment subjected to typical seismic excitations are reviewed using a proprietary software program. The analyses for wire rope isolators and typical undamped spring isolators with snubbers for a circuit breaker and backup generator set are compared.

Wire rope isolators (WRI) are well known for shock and vibration protection of sensitive equipment in defense applications. Their unique features and predictable response by means of numerical simulations have made them a standard solution for many shock and vibration problems.

Less known are their capabilities in seismic applications, although the same equations and methodology apply. Through extensive studies over the years, a vast amount of data on earthquakes has been gathered. Accordingly, the shock and vibration community, including involved governmental entities and contrac-

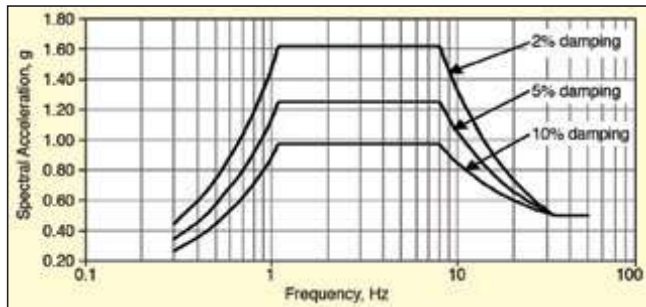


Figure 1. Typical earthquake shock response spectrum from IEEE693-2005.

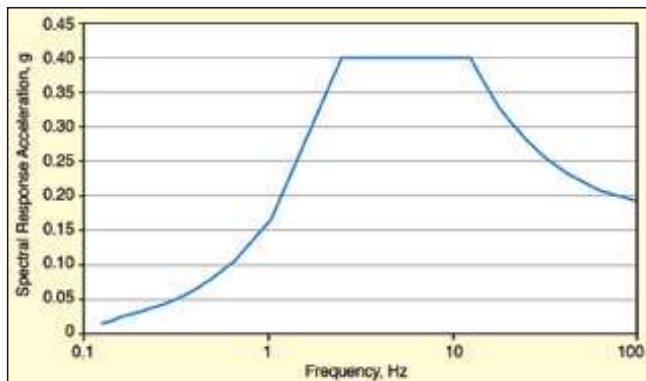


Figure 2. Typical design response spectrum per ASCE7-10.

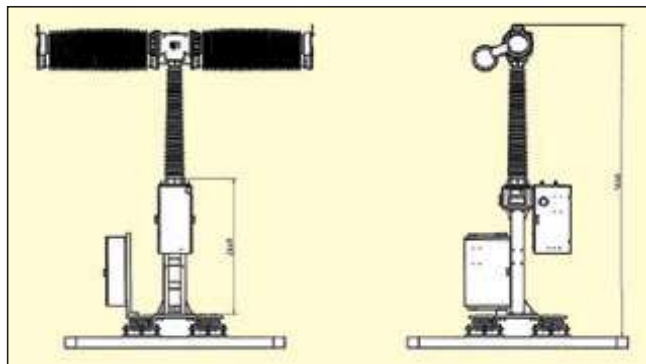


Figure 3. Schematic of typical circuit breaker.



Figure 4. Physical testing setup of a circuit breaker with wire rope isolators

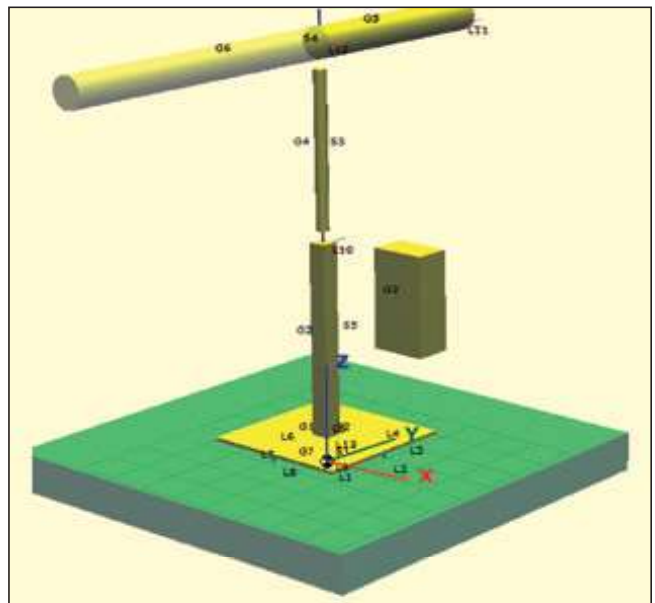


Figure 5. SYMOS representation of circuit breaker.

tors, is becoming increasingly aware of the need for better isolation products against such hazards, among which wire rope isolators are gaining popularity.

One widely accepted design consisting of undamped springs with snubbers in seismic applications may result in substantial magnification of the seismic input when the snubbers are engaged. This is not an issue in terms of safety but may lead to special reinforcement of the equipment at high cost, which is contradictory to today's approach of reducing cost with the use of off-the-shelf components (COTS). The advantage of coil springs is the capabil-

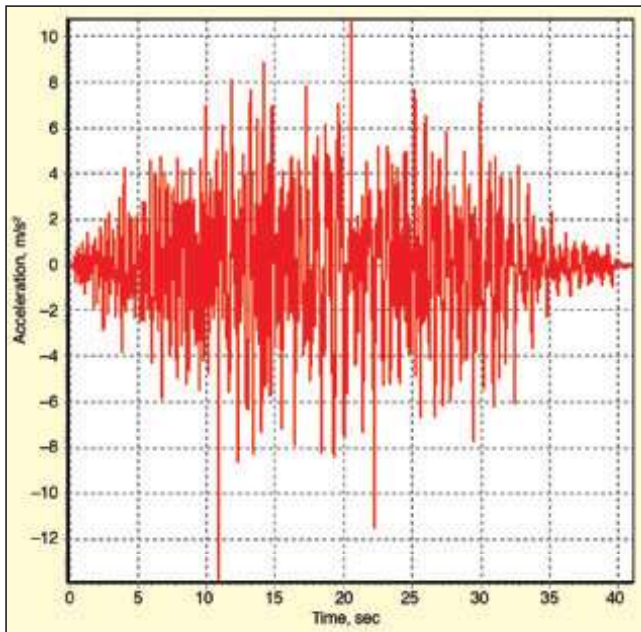


Figure 6. Acceleration time history of seismic input.

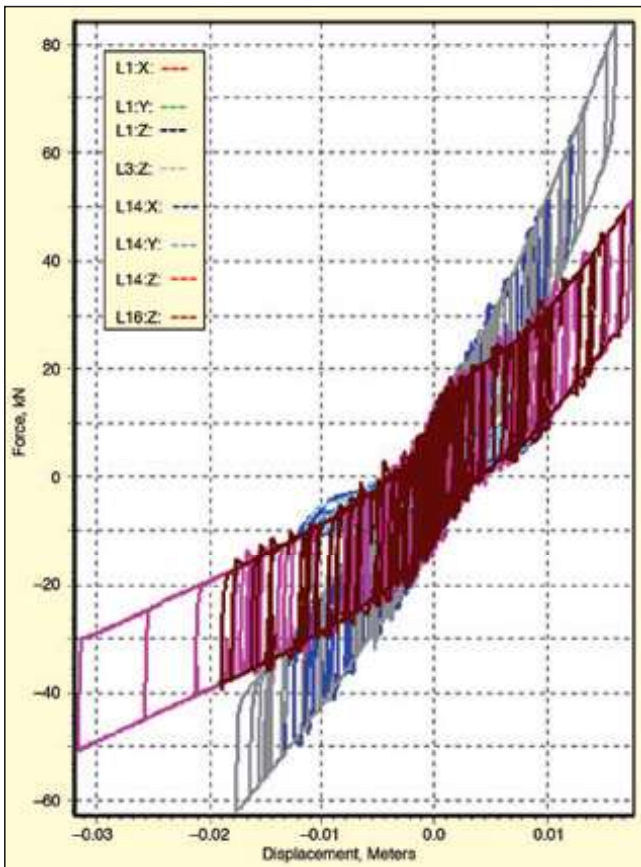


Figure 7. Dynamic load deflection curves with large areas, reflecting high damping properties of WRI.

ity to offer better vibration isolation, which makes them suited for generating sets, pumps, and compressors. Another solution is to reinforce the equipment to avoid the earthquake frequencies, which is impractical or at least very costly in most cases.

Wire rope isolators offer substantial damping, which reduces the unavoidable magnification of seismic input at low frequencies. The shock response spectrum is a widely used concept and clearly shows that damping is of paramount importance for seismic protection but doesn't provide enough insight into the dynamic behavior of a system under seismic conditions. Therefore, it is ideal to conduct a dynamic analysis using time histories and a nonlinear numerical model.

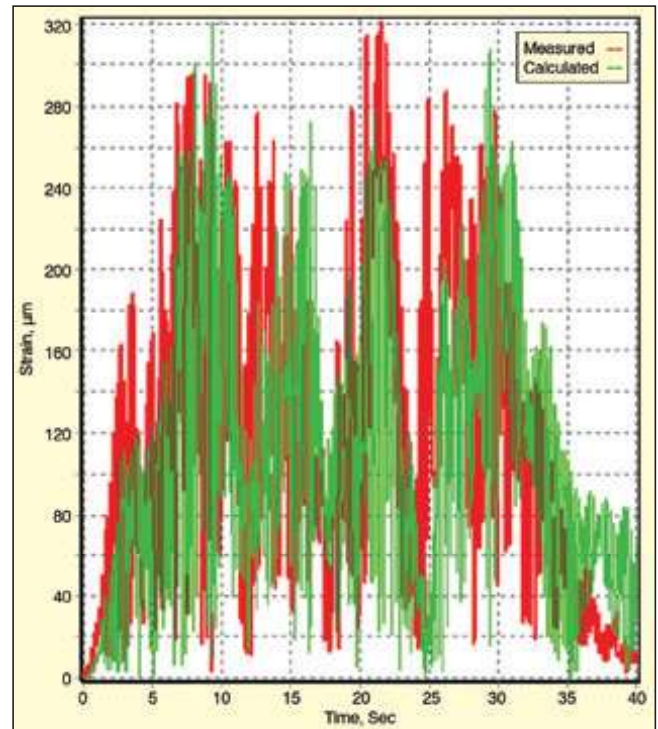


Figure 8. Measured vs. calculated strain values at bottom of porcelain.



Figure 9. Typical wire rope isolator.

This article presents two physical case studies from the Socitec Group's large application track record with wire rope isolators, a circuit breaker and a generator set. Both cases have been installed by highly known international contractors. Input/output diagrams are presented along with comparisons of calculated response with experimentally measured data.

### Shock Response Spectrum

An earthquake is usually specified for analytical methods as a shock response spectrum, giving the computed response of an elastic linear system under a complex input. This spectrum is adjusted with severity parameters defined by the seismicity of the region and often represented on a log scale so that the response zones are represented by straight lines for various viscous equivalent-damping ratios. Several conservative standards are in use and are based on the compilation of many different measurements. Among these well-known standards are the IEEE and the ASCE7-10; an example of each is shown in Figures 1 and 2, respectively.

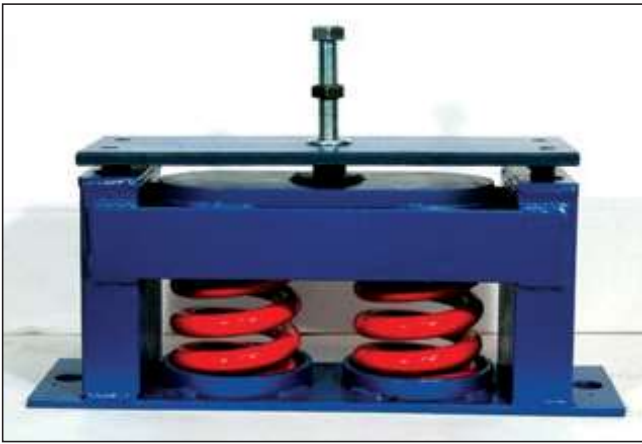


Figure 10. Typical restrained spring isolator.

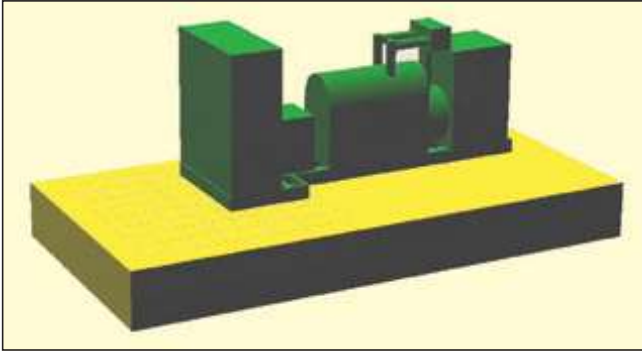


Figure 11. SYMOS representation of genset.



Figure 12. Physical test setup of genset.

The shock response spectrum technique is useful and allows a relatively easy selection of the resilient elements. In many cases, however, it is an over simplification not compatible with the nonlinearity of the elastic mountings and certainly with wire rope isolators. Therefore using a time history input together with an adequate nonlinear software package such as the Socitec Group's proprietary program SYMOS is the optimal method to predict system response. This time history input can be measured, supplied by the standard, or computed back from the shock response spectrum.

### Circuit Breaker Case Study

Circuit breakers such as the unit shown in Figure 3 are used to separate portions of an electrical distribution network for maintenance or energy balancing purposes. They control high voltage overhead power lines, which require insulation for safety as well as to prevent leakage. Fragile porcelain is often used as the insulation material.

*IEEE 693-2005: Recommended Practice for Seismic Design of Substations* is a typical specification for seismic design of electrical equipment and recommends a minimum quasistatic load resistance. This specification also suggests a resonance search of the equipment to assess stiffness and damping properties by use of the SRS or static pull test. This gives a better idea of system behavior under large deflection of the isolation system. A dynamic

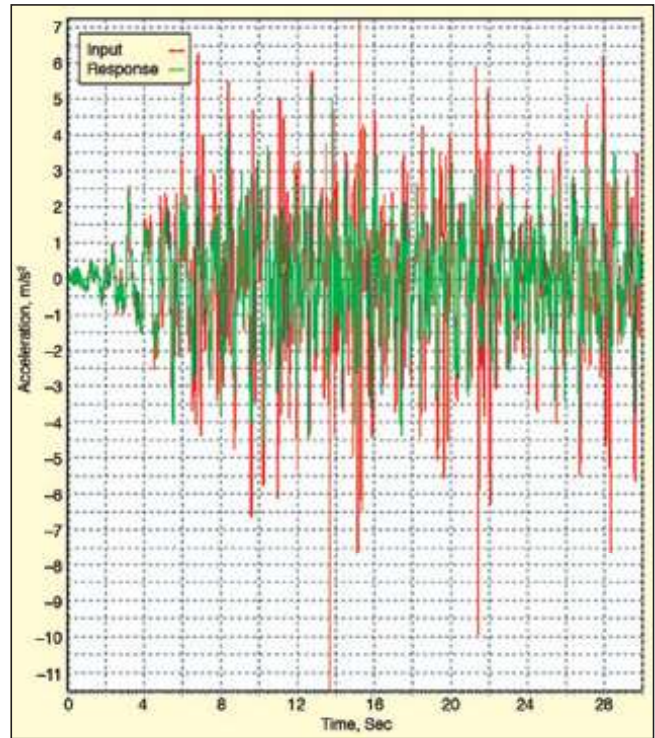


Figure 13. Input acceleration vs. response acceleration with WRI.

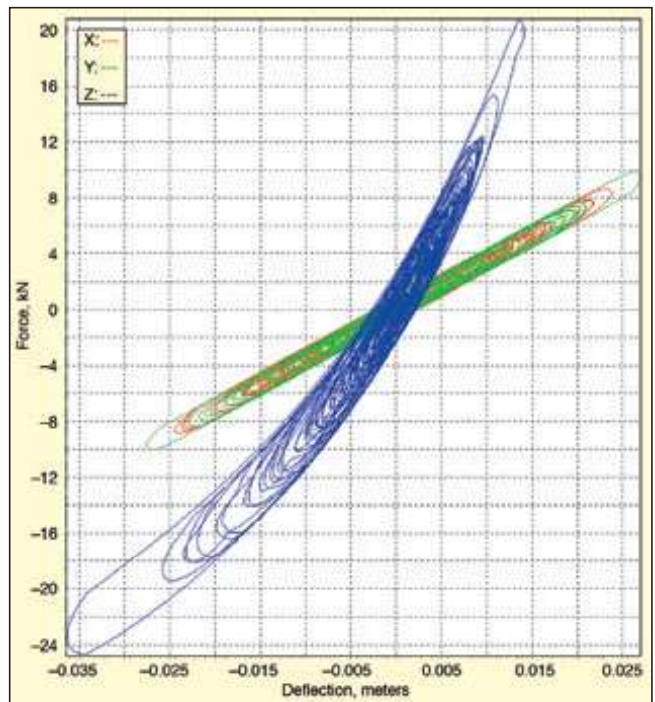


Figure 14. Dynamic load deflection curves in WRI.

test shown in Figure 4 was conducted on a 3D seismic table.

The dynamic test and analysis combined method is preferred by Vibro/Dynamics. This requires the use of a nonlinear analysis program capable of properly representing the system, such as SYMOS. The circuit breaker is divided into a number of rigid bodies with nonlinear connections as shown in Figure 5. Before inserting the wire rope isolators, the model was validated through modal analysis, matching the circuit breaker's lowest eigenmode, which was provided by the customer from previous finite-element analyses of the structure.

Items  $L_1$  to  $L_8$  represent the wire rope isolators. The acceleration time history input of Figure 6 was applied to the ground ( $S_g$ ), and the calculation was executed. The maximum strain at the base of the circuit breaker was measured by strain gages and calculated by the program. Dynamic load deflection curves are shown in Figure

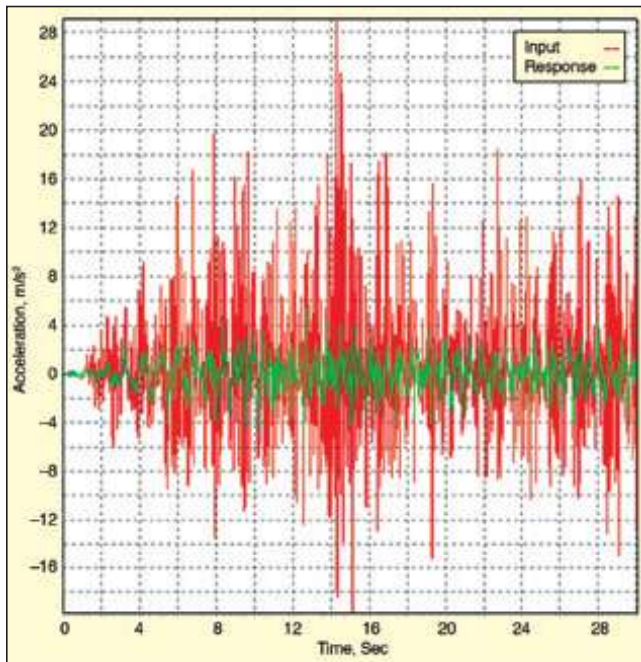


Figure 15. Input acceleration vs. response acceleration with restrained springs.

7 and measured vs. calculated strain for the porcelain insulators is shown in Figure 8.

**Summary.** Without WRIs, the stresses at the bottom of the circuit breaker exceeded acceptable levels. The installation of the WRIs decreased stress levels to acceptable levels. In addition to the main benefit of reducing seismic accelerations, the WRI has further advantages for a variety of installation types:

- Ruggedness
- High damping ratio, particularly with the proper cable selection
- Predictability using proper analysis software
- Extremely high ultimate strength
- Maintenance-free design
- Unlimited lifetime
- Wide application temperature range

They are particularly useful if the equipment to be protected exhibits an eigenmode below 5 Hz, which is the case for most large tower-shaped structures. When this is the case, the excellent damping properties of the WRI increase the overall damping ratio in system, which reduces the response acceleration (see SRS of Figure 1).

### Generating Set Case Study

Backup generating sets (gensets) are used in power plants to provide energy when all other safety systems have failed. While a genset is rather robust, it is critical to reduce forces at the attachment points so that the genset can function if necessary. Another factor of lesser importance is to isolate the internal vibration

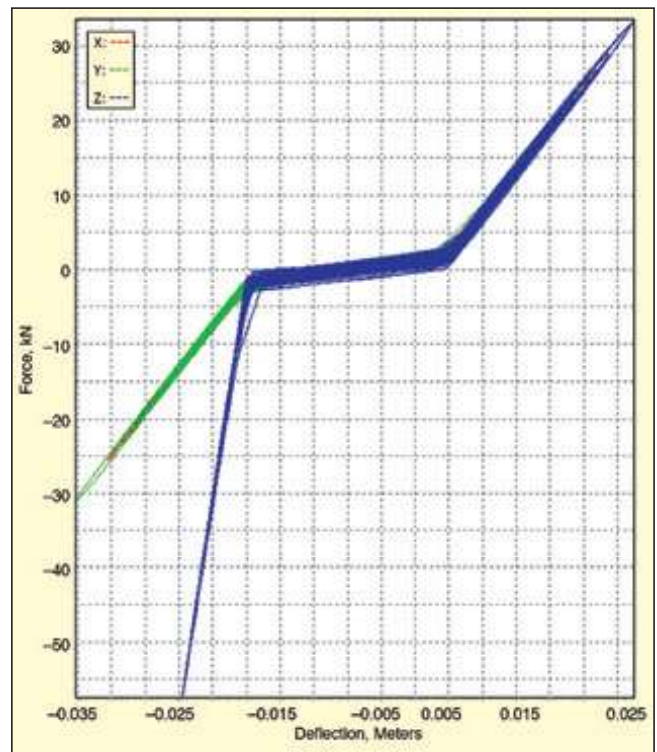


Figure 16. Dynamic load deflection curves of restrained spring.

produced during the weekly functional test run. Two technical solutions were considered – wire rope isolators (see Figure 9) and conventional coil springs with snubbers (see Figure 10).

*IEEE 693-2005: Recommended Practice for Seismic Design of Substations* is representative of a typical input for this application and was used for this case study. The SYMOS model is shown in Figure 11 and the experimental test setup is shown in Figure 12. Input vs. output measurements are shown in Figure 13 for the wire rope isolators and Figure 14 for the spring isolators. Dynamic displacement curves are shown in Figures 15 and 16 respectively.

**Summary.** WRIs offer a good alternative to conventional restrained spring isolators:

- Extremely high ultimate strength.
- Satisfies seismic building code requirements.
- High damping without the need for additional devices.
- Response can be reliably calculated with appropriate software.
- Offers mitigation or reduced magnification of seismic inputs.
- Modularity allows for customized solutions.
- Versatile mounting attitudes.
- Insensitive to environment (temperature, fluids, etc.).

While the WRI, with its superior seismic performance, does allow more displacement, it should not be an issue if accounted for in the planning and design stages of the installation. **SV**

The author can be contacted at: [cprost@vibrodynamics.com](mailto:cprost@vibrodynamics.com).