Earthquake resistance of VX25 enclosure systems

White paper IE 7

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1 | Introduction

Natural forces have always posed a threat to humans and are the cause of numerous fatalities and serious damage to property. Earthquakes are one of the natural disasters which remain difficult to predict. The thirteen natural disasters (see Table 1) with the most fatalities between 1990 and 2023 included more than eight earthquakes [Mun24].

Date	Incident	Magnitude	Region	Fatalities
12 Jan 2010	Earthquake	7.0	Haiti	222,570
26 Dec 2004	Earthquake, tsunami	9.1	Sri Lanka, Indonesia, Thailand, India, Bangladesh, Myanmar, Maldives, Malaysia	220,000
2-5 May 2008	Cyclone Nargis, storm tide	–	Myanmar	140,000
29-30 Apr 1991	Tropical cyclone, storm tide	–	Bangladesh	139,000
8 Oct 2005	Earthquake	7.8	Pakistan, India, Afghanistan	88,000
12 May 2008	Earthquake	5.8	China	84,000
Jul/Aug 2003	Heat wave	–	Europe	70,000
Feb 2023	Earthquake	7.8	Turkey	60,000
Jul/Sep 2010	Heat wave	–	Russia	56,000
20 Jun 1990	Earthquake	7.4	Iran	40,000
26 Dec 2003	Earthquake	6.6	Iran	26,200
11 Mar 2011	Seaquake, tsunami	9.0	Japan	18,537
25 Apr 2015	Earthquake	7.8	Nepal	9,000

Table 1: Fatalities from natural disasters, 1990 to 2023

Earthquakes occur as the result of processes in the earth's core. The plates that make up the Earth's solid crust move over the molten interior, a process known as plate tectonics. The edges of the plates are in constant motion, colliding, separating and sliding over each other. During the course of these movements, the plates may become stuck together, creating huge stresses. If this stress is discharged suddenly, it creates an earthquake, and the resultant damage may extend over long distances, depending on the strength of the earthquake.

The bulk of earthquake damage is structural damage to buildings and transport infrastructures, which may in turn trigger damages caused by secondary events such as landslides and tsunamis. Equipment inside buildings can also suffer extensive physical damage. Depending on the severity of the earthquake and the population of the affected areas, the levels of damage to equipment and systems may be similar to that inflicted on buildings and infrastructures. In the aftermath of an earthquake, there is often a shortage of electricity, drinking water and gas, at the very time when they are urgently needed for aid.

To prevent such earthquake-related damages, the buildings, transport infrastructure and technical infrastructure in earthquake-prone regions should be of an "earthquake-resistant" design wherever possible. However, the required measures differ widely depending on the area (buildings, technical infrastructure) and local earthquake risks. This White Paper will outline what we mean by the term "earthquake-resistant" specifically in the area of electrical infrastructure.

In earthquake-prone regions, technical facilities must be designed as earthquake-resistant to guarantee human safety and minimise failures and downtime.

What needs to be done?

Switchgear manufacturers who need to consider earthquake-resistance requirements may face issues outside the scope of their regular areas of expertise. What should we do if a customer needs an earthquake-resistant switchgear system, for instance? This guide provides advice for this and similar scenarios to help switchgear manufacturers gain a general understanding of the issues involved.

What needs to be considered?

Which factors should be considered when constructing electrical switchgear systems in potentially earthquake-prone regions? This is the key question. To provide a clear insight into the problems involved, this White Paper begins by explaining the basic principles of earthquakes, how they are measured and the different scales applied. The next section examines the effects an earthquake can have on electrical switchgear systems and the damage it can potentially cause.

Which standards apply?

There are a number of standards and regulations relating to earthquake resistance. The safety of buildings is often a priority, and approaches may differ significantly between different disciplines, such as structural engineering, electrical engineering and information technology. This White Paper will summarise the various standards that are relevant to the electrical infrastructure.

2 Intensities, magnitudes and earthquake zones

In terms of physics, an earthquake is a shock wave that emanates from the epicentre of the earthquake. This shock wave causes the Earth's crust to vibrate with a complex frequency spectrum, both horizontally and vertically. It is described in terms of the corresponding amplitudes and frequencies on the Earth's surface. Because the energy released by an earthquake cannot be measured directly, we use various scales to describe the strength of an earthquake, and differentiate between scales of intensity and scales of magnitude.

Subjective scales of intensity

Scales of intensity are based on the macroscopic effects of an earthquake – such as the severity of damage to buildings – and the subjective impressions of the people who feel or hear the earthquake. The Mercalli Scale developed in 1902 is still widely used to indicate intensity (see Tab. 2).

Scales of intensity are of limited use in sparsely populated areas with few buildings to become damaged and not many people to report their experiences.

JMA		**Mercalli**			
Category	**Ground acceleration**			Description	Category
	Gal	Gal	g (9.81 m/s^2)		
0	< 0.8				
		< 1.0	< 0.001	Not felt	I
1	0.8–2.5				
		1.0–2.1	0.001–0.002	Weak	II
2	2.5–8.0	2.1–5.0	0.002–0.005	Weak	III
		5.0–10	0.005–0.01	Light	IV
3	8.0–25	10–21	0.01–0.02	Moderate	V
		21–44	0.02–0.05	Strong	VI
4	25–80				
		44–94	0.05–0.1	Very strong	VII
5	80–250				
		94–202	0.1–0.2	Severe	VIII
6	250–400				
		202–432	0.2–0.5	Violent	IX
7	> 400				
		> 432	0.5–1	Extreme	X
			1–2	Extreme	XI
			> 2	Extreme	XII

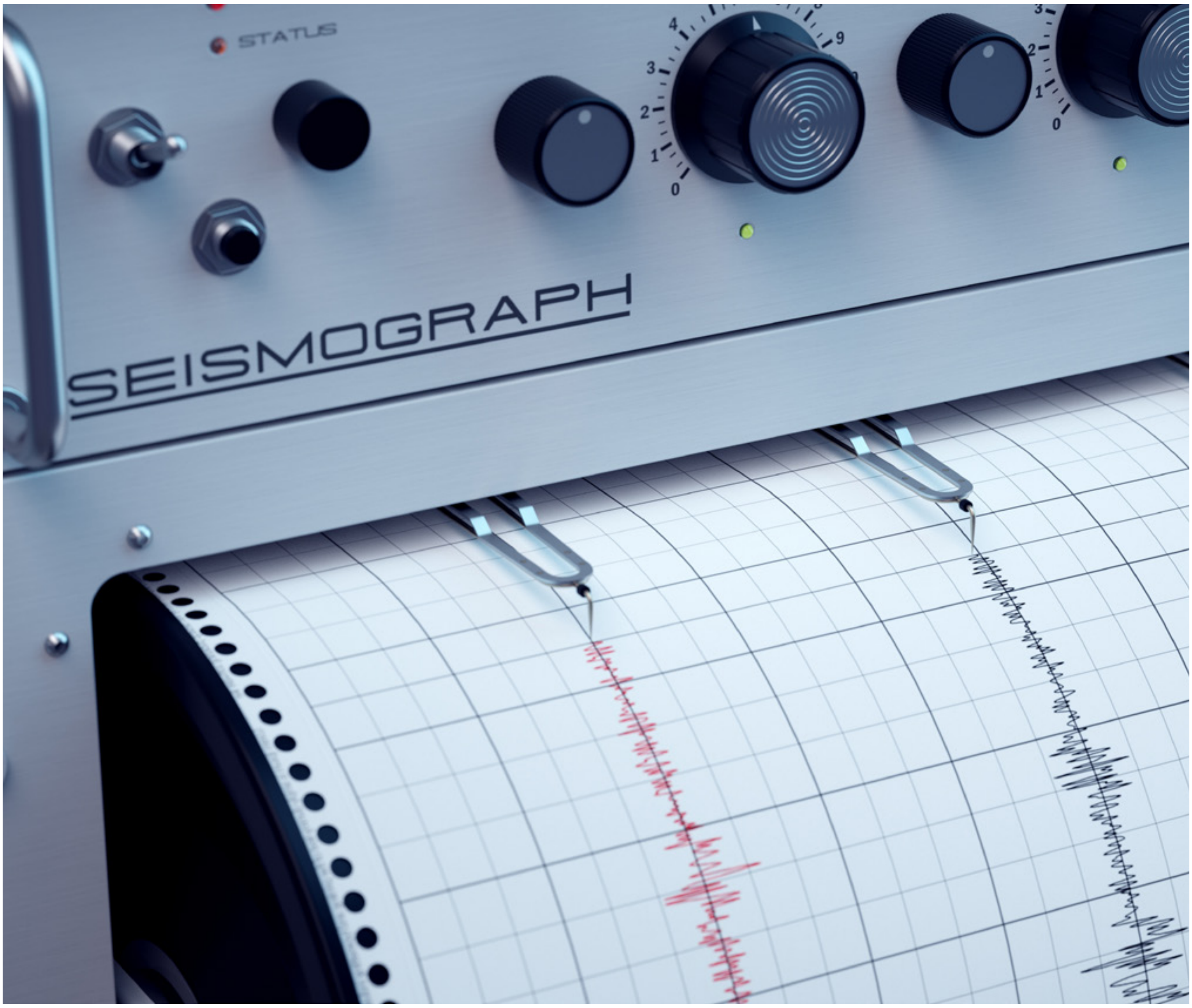
Table 2: The Mercalli Scale compared to the Japanese JMA Scale

Note: Seismic intensity is not regulated solely by ground acceleration. This table is only intended for reference purposes.

Scales of magnitude

Scales of magnitude are based on measurements by seismometers, which measure local vibrations of the Earth's surface in the form of velocity, acceleration and deflection. These measurements are then used to calculate the strength of the earthquake. The best-known scale of magnitude is the Richter Scale, which was developed in the 1930s and is still often cited in conjunction with earthquakes. The Richter Scale calculates magnitude from measurements in the immediate vicinity of the earthquake's epicentre, and is therefore often referred to as a local magnitude scale. The Richter Scale was defined using measurements from a certain type of seismometer at a distance of 100 kilometres from the epicentre.

As Charles F. Richter originally developed and calibrated the scale with a particular type of seismometer for local earthquakes in California, strictly speaking it is only suitable for that region and becomes imprecise at magnitudes above 6.5. Higher magnitudes, often referred to in the media as being on the "open-ended Richter Scale," are actually values on the Moment Magnitude Scale, a more recent refinement of the Richter Scale. The most powerful recorded earthquake to date was in Valdivia, Chile, in 1960, with a magnitude of 9.5. By way of comparison, the 2011 earthquake in Japan that caused the nuclear reactor disaster in Fukushima had a magnitude of 9.0.



Earthquake probability and earthquake zones for the purposes of risk assessment

As well as classifying earthquakes according to their strength (i.e. their intensity or magnitude), another crucial aspect is the likelihood of an earthquake with a certain intensity occurring. Earthquake risk zones have been defined to enable expedient risk assessment. For example, in the United States, the UBC (Uniform Building Code) defines five earthquake zones. Zone 0 means that powerful earthquakes almost never occur in this zone, whereas in Zone 4, higher-magnitude earthquakes are probable. Parts of the state of California are typical examples of Zone 4. The earthquake resistance requirements for IT and telecoms installations as well as electrical infrastructure equipment are often based on these earthquake zones. However, the classification into zones and related criteria vary from one country to another. Some European countries, including Germany, use a classification based on zones 0 to 3 using different figures from the US (see Table 3). As such, there is no direct comparability between national standards in terms of zones. In regions with a high earthquake risk, suitable protective measures must be taken, which usually entail additional costs. As such, particular caution should be exercised with international use, and a fundamental understanding of the different systems is important.

Country	**AT**	**DE**	**CH**	**FR**	**IT***	**GR**	**USA**
Standard	ÖN 1998-1	DIN EN 1998-1	SIA 261	NF EN 1998-1	OPCM 28	Gna 1998-1	1997 UBC
Zone 0	a < 0.035 g	0.0 g					0.0 g
Zone 1	0.035 g < a < 0.05 g	0.04 g	0.06 g	a < 0.07 g	a < 0.05 g	a < 0.16 g	0.075 g
Zone 2	0.05 g < a < 0.075 g	0.06 g	0.1 g	0.07 g < a < 0.11 g	0.05 g < a < 0.15 g	0.16 g < a < 0.24 g	0.15 g
Zone 3	0.075 g < a < 0.1 g	0.08 g	0.13 g	0.11 g < a < 0.16 g	0.15 g < a < 0.25 g	0.24 g < a < 0.36 g	0.3 g
Zone 4	0.1 g < a		0.16 g	0.16 g < a < 0.3 g	0.25 g < a < 0.3 g		0.4 g

* Italy uses a reverse sequence of zones.

Table 3: Ground acceleration in Europe and the USA

Recently, and partly because of the aforementioned difficulties, we have noticed that many local earthquake standards have chosen not to use fixed earthquake zones but instead use generally comparable values such as Peak Ground Acceleration (PGA). However, for individual applications, these must be linked to local and project-specific conditions. Some standards make reference to national Internet platforms showing all the required values on a map.

3

Earthquake damage to electrical infrastructure

As previously mentioned, many standards prioritize the safety of buildings in conjunction with earthquake resistance. This is understandable, since most earthquake-related deaths are attributable to damage to buildings, and this is also where the greatest material damage occurs. Nevertheless, it is also important to provide effective earthquake protection for technical infrastructure equipment such as electrical switchgear and data centres. This is not just a requirement for critical installations, for example in power plants or chemical production plants, but also plays a pivotal role in the general supply system.

To assess the earthquake resistance of electrical installations, you first need an overview of their location and possible stresses. Consideration must also be given to the consequential damages that may arise if an electrical installation fails. Depending on the type of building, stricter requirements often apply to the technical installations than to the supporting components themselves. Hence, earthquake damage not only affects the safety of the building; the technical equipment must also be designed to withstand an earthquake.

Maintaining the proper functioning of systems even during a high-magnitude earthquake is particularly crucial for critical, safety-relevant infrastructures such as nuclear facilities. This requires very extensive measures which are outside the remit of this White Paper. Particularly in the areas of telecommunications and IT, high system availability and hence a high level of earthquake resistance are crucial. At the same time, maintaining function for a specified period and/or rapid recommissioning following an earthquake are key considerations.

The vibrations associated with an earthquake are generally in the frequency range between 0.3 Hz and 50 Hz. The stresses acting on switchgear may cause both functional impairments and structural damage to the system as a whole. Some functional impairments can be resolved with minimal effort to quickly restore switchgear operation in the aftermath of an earthquake. One typical example would be a loose contact or temporary short-circuit interrupted by the installed fuses.

More serious types of damage might include a component breaking loose from a support rail or mounting plate inside the enclosure. More severe damage to the switchgear generally results in a longer-lasting interruption to the power supply. This occurs when an enclosure moves due to the earthquake, potentially breaking free from its anchor or even falling over.

This category also includes structural damage to the enclosure. In all cases, the housing or enclosure plays a decisive role. If the enclosure does not withstand an earthquake, the entire system will fail. The earthquake resistance of enclosures is a key aspect of all relevant standards but cannot be considered in isolation. The surrounding building and built-in components must also meet the relevant requirements. Simply installing a suitable enclosure will not suffice if it is necessary to maintain function after or even during an earthquake. The built-in components must also meet the requirements of the relevant standard, and the function of the overall system must be verified by testing.

In an **earthquake, vibrations** of up to **50 Hz** can occur.

4 Overview of current standards

Earthquake resistance calls for different standards in different disciplines and geographical markets.

Earthquake resistance is relevant to many different sectors. As a result, different standards apply depending on the technical discipline. Standards may be roughly divided into the areas of structural engineering, IT and telecommunications, and electrical engineering. The applicable standards also vary depending on the target geographical market.

As electrical systems tend to be installed in buildings, structural standards do not usually apply directly, but they do have an indirect influence. Standards in the construction sector often focus on the base mounting of the enclosure. However, verification of the base mounting requires a knowledge of the local on-site conditions and must be provided by a building surveyor.

Some electrical engineering and IT & telecommunications standards are based on construction standards but translated into specific requirements governing the relevant technical equipment. Buildings may amplify the effects of an earthquake, so the amplitudes and accelerations acting on an electrical installation may actually be higher.

For switchgear and other electrical engineering and IT infrastructure, the three main standards are EN/IEC 60068-3-3, IEEE 693 and Telcordia GR-63-CORE. Other standards such as those used in the construction industry are not relevant for switchgear manufacturing but tend to be more widely used. We must assume that the structural engineers ensure compliance with these standards. It is only the interface between construction and electrical engineering – i.e. the link between the structure and the enclosure/housing – which is important. As such, the various standards also include references to the relevant construction standards.

DIN EN/IEC 60068-3-3

IEC 60068-3-3, known in Europe as EN 60068-3-3 [Beu93], is essentially a guide to the seismic testing of electrical devices. The standard distinguishes between a general seismic class and a specific seismic class. The specific seismic class should be used when the seismic movements are known, for example due to geographical location or the properties of the building where the equipment is to be installed.

IEEE 693

Standard 693 [IEE05], published by the Institute of Electrical and Electronics Engineers (IEEE), defines recommended practice for the earthquake resistance of switchgear as well as individual components. Alongside test methods, the standard also includes seismic design guidelines for switchgear, including structures, foundations and the floor anchoring of enclosures. As such, they also contain references to standards from the construction sector.

Telcordia GR-63-CORE

The Generic Requirements GR-63-CORE [Tel02] originally developed by Bellcore (now Telcordia) for the telecommunications industry is not strictly speaking a standard, but in the United States in particular, it is widely used as a requirement for tenders. The basic concept is that a system such as a data centre should have exceptional statistical availability. It encompasses a wide range of criteria for resistance e.g. to humidity, fire, contaminants and earthquakes. It refers to the US classification into zones (Zone 0 to Zone 4), with Zone 0 representing a minimal risk and Zone 4 a very high earthquake risk (see Table 3). These requirements are set very high to ensure high system availability, and are therefore also included in other standards (such as IEC 60068-3-3, EN 61587-5 (RRS for single-axis acceleration), ETSI EN 300019-1-3).

5 | Typical test methods

There are essentially two approaches when designing systems in earthquake-prone regions: The first entails testing the entire system in its desired configuration, i.e. including all components built into the enclosure, in a suitable test laboratory. However, this approach is very costly and time-consuming, and in Rittal's experience, is only chosen by a few users.

The second option is for the panel builder or switchgear manufacturer to use components (including the enclosure) whose fundamental suitability for use in earthquake-prone regions has been verified.

For verification purposes, Rittal has had samples of its VX25 enclosure models tested by recognised laboratories. Using a defined process, the enclosures were tested for their fundamental suitability for use in earthquake-prone regions. Below, we give a detailed account of a typical test process for determining an enclosure's earthquake suitability. The vast majority of users opt for this far less time-consuming approach.

All relevant standards stipulate testing with a vibration table to verify an enclosure's earthquake resistance. The aim is to simulate the effects of an earthquake (vibrations and shocks) in the laboratory.

During the test, the enclosure is secured to a vibration table and undergoes a defined testing program. There must be no structural damage to the enclosure, i.e. no load-bearing parts may be damaged or broken.

Furthermore, all key connections must remain intact. The same generally applies to enclosure doors, hinges and locks. Functional tests are also carried out after loading to determine whether the system still functions correctly.

Earthquake resistance calls for different standards in different disciplines and geographical markets.

Different frequency spectra in the standards

The precise test requirements vary between standards, particularly regarding the exact frequency spectrum and related accelerations. The test method specified in Telcordia GR-63-CORE is outlined here as an example. First, the enclosure is mounted on a vibrating table and fitted with accelerometers and displacement sensors at the centre and top. The test should simulate a real installation by running a specified movement program that must reach the stipulated acceleration values at frequencies of between 1 Hz and 50 Hz (the required response spectrum (RRS)).

The key parameter here is the spectrum that strikes the test piece – the test response spectrum (TRS). This varies depending on the test structure and the mass and geometry of the test piece. The displacements of the test piece, measured at the centre and top, must not exceed 75 mm (3 inches) at any point during the test.

The vibration table tests described above are performed in all three dimensions. The RRS stipulated in GR-63-CORE results in a test duration of 31 seconds in each dimension. The loads exerted on the enclosure during these tests are approximately equivalent to those experienced during an earthquake with a strength of 8.3 on the Moment Magnitude Scale.

Very similar test spectra

To be able to compare the requirements of the vibration table tests for all three relevant standards, the required RRS may be entered in an acceleration/frequency diagram (see Fig. 1). From this, we can see that the spectra of the individual standards are similar, but have different acceleration values in the relevant areas. It is also evident that certification to Zone 4 in accordance with GR-63-CORE is almost entirely consistent with the requirements of the other standards. To meet further requirements, Rittal deliberately increased the test spectrum for its VX25 system, so the RRS of IEEE 693 is always covered (see Fig. 1, Horizontal (TRS) and Vertical (TRS) with earthquake kit Zone 4).

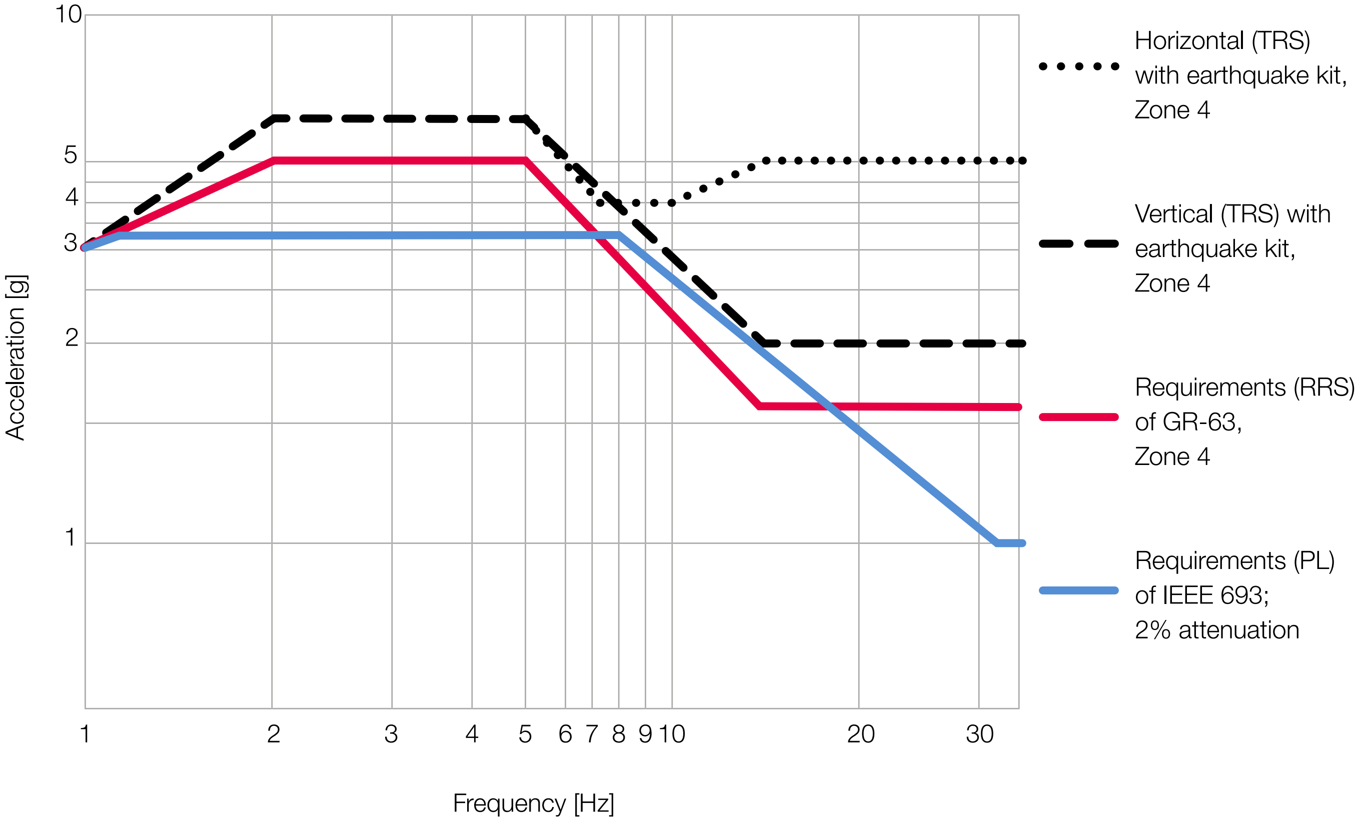


Figure 1: Acceleration/Frequency Diagram

6 Earthquake-resistant enclosure design

Since ancient times, one method has proven effective for building stable, vibration-resistant mechanical structures: Timber frame construction. Timber framing is comprised of wooden beams whose ends are joined together in a triangular shape, so that only compressive and tensile forces act on the beams. This makes the overall structure very resilient while also reducing the weight. This construction principle is used successfully to build houses, bridges and other supporting structures. With buildings today, the aim is to achieve the maximum possible rigidity, for example with solid concrete structures. Another option, mainly used in tower blocks, is to use a pendulum as an active element. The movements of the earthquake cause the pendulum to vibrate and absorb the energy almost completely, so that the structure of the building is not damaged. A third option is to disconnect the object you wish to protect from the earthquake. For example, a building or piece of equipment may be placed on shock absorbers that cushion and absorb the shocks from the earthquake. However, the weight to be absorbed must be precisely known, and there must be sufficient spring deflection/damping distance available.

Rittal also applies the timber framing principle to its VX25 large enclosures (see Fig. 2) to make them earthquake-resistant. These robust enclosures are distinguished in particular by their flexibility and efficiency as well as their high quality. An optional earthquake extension accessory pack can be used to reinforce the structure of the enclosure frame so that it meets even the exacting requirements of Zone 4 to GR-63-CORE. This “earthquake kit” is comprised of struts which are screw-fastened into the sides of the enclosure frame to significantly increase rigidity. Gusset plates in the corners of the frames provide yet more stability. An earthquake-resistant base/plinth is also available to secure the enclosure to the base and keep it stable even under significant stress.

Figure 2: Earthquake extension accessories for the VX25 large enclosure

When fitted with the earthquake kit, the VX25 satisfies the high demands of Zone 4 to GR-63-CORE.

The VX25 large enclosure has been tested by independent institutes to verify compliance with GR-63-CORE Zone 4. For Zone 4 certification, equipment weighing 500 kg was installed on a mounting plate with side panels and special earthquake accessories (earthquake kit, base/plinth and comfort handle). Furthermore, certification was issued stating that configurations with a lower weight meet the requirements of the lower zones without any special accessories (see tables below).

Based on Rittal's many years of experience in the large enclosure sector, the VX25 is generally assumed to be of a suitable construction, provided certain peripheral conditions are adhered to.

- The standard and/or frequency spectrum must be comparable (see Fig. 1).
- Even distribution of weight
- Built-in mass equal to or less than that used in the tested variants
- Footprint equal to or greater than the tested variants (a larger footprint improves stability)
- Height no more than 2,000 mm (or centre of gravity no more than 1,000 mm)

Because siting an individual enclosure is considered the least favourable case, several enclosures may be bayed together. Connecting the vertical sections increases rigidity compared with individual sections.

Tested VX25 variants

Dimensions (W x H x D) [mm]	Measures	Model No.	Tested installed weight [kg]	Standard, level
800 x 2000 x 600	**Standard enclosure** ° 4x screw-fastened on the inside with 40 Nm to the base plinth ° Mounting plate screw-fastened **Comfort handle** **Side panels** **Base/plinth (2024)**	**8806.000** 8618.200 8106.245 8660.003 8660.033	200	Telcordia GR-63-Core **Zones 1 & 2** (2g peak between 2-5 Hz)
800 x 2000 x 600	**Standard enclosure** ° 4x screw-fastened on the outside with 40 Nm from the base/plinth ° Mounting plate screw-fastened **Comfort handle** **Side panels** **Base/plinth (2024)**	**8806.000** 8618.200 8106.245 8660.003 8660.033	200	Telcordia GR-63-Core **Zone 3** (3g peak between 2-5 Hz)
800 x 2000 x 600	**Standard enclosure** ° 8x screw-fastened with 45 Nm from the base/plinth ° Mounting plate screw-fastened **Comfort handle** **Side panels** **Earthquake-resistant base/plinth** **Earthquake kit (VX)**	**8806.000** 8618.200 8106.245 8601.860 8618.600	500	Telcordia GR-63-Core **Zone 4** (5g peak between 2-5 Hz)

Table 4: VX25 overview

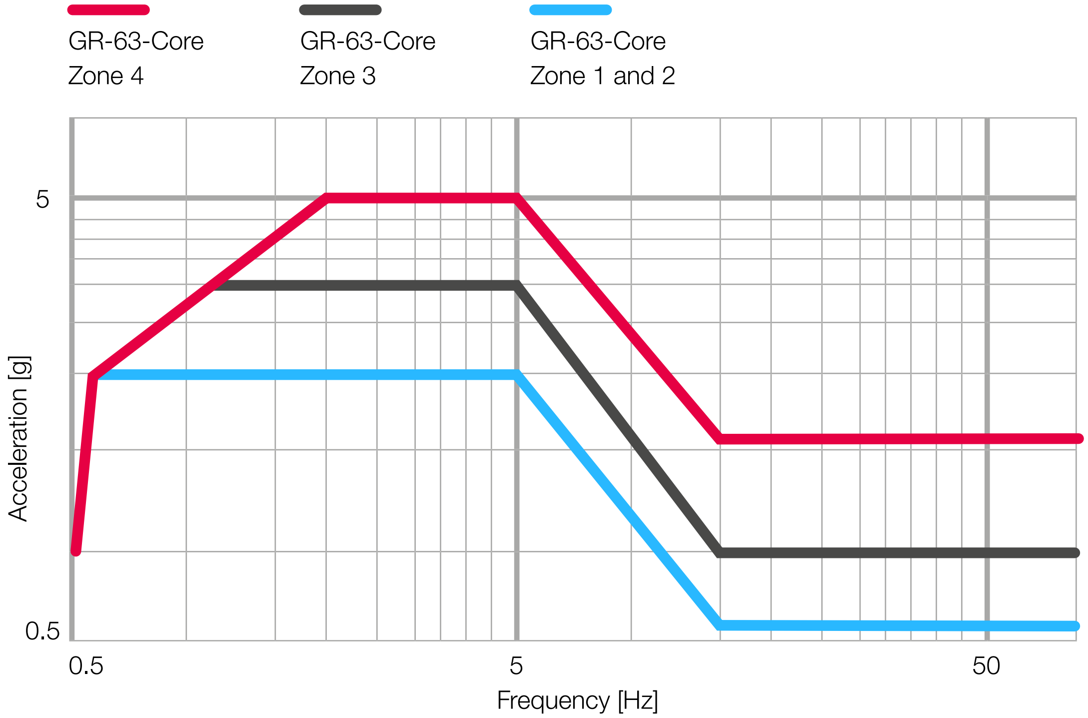


Figure 3: Comparison between Telcordia GR-63-Core Zones 1 & 2, Zone 3 and Zone 4

Rittal will be happy to advise you. In fringe zones, we collaborate closely with the customer to find a qualified solution.

7 Specific approach

A specialist guide assists switchgear manufacturers with implementation of the requisite safety measures and compliance with the relevant standards.

While there is plenty of information available about earthquakes, potential damages and the situation with standards, one question remains: How do I handle a specific enquiry about an earthquake-resistant switchgear? First, it is important to clarify the geographical situation, i.e. in which country, which earthquake zone or which areas with ground acceleration will the switchgear be used? Next, identify the applicable underlying standard. The individuals in charge of construction and structural engineering should consider all requirements relating to buildings or securing the switchgear within the building. If no applicable standard is available for the enclosure itself, only a construction standard or regulation, it may be useful to compare the ground acceleration in the available standard against the values for the US zones shown in Table 3. For example, if it requires a ground acceleration of 0.1 g, this would be within the requirements of Telcordia Zones 1 & 2. An enclosure configuration authorised for that zone could also be classified as suitable for such requirements.

The above examples of application standards must distinguish between structural integrity and functional integrity. If the sole concern is structural integrity, then a certified enclosure, such as the VX25 enclosure fitted with the appropriate earthquake accessories, as described in the previous section, will generally suffice.

Of course, an enclosure cannot guarantee the functional integrity of a system, which is sometimes also required. This will require extensive testing. Finite-element-method structural calculations can be performed in preparation. During this process, it is important to test the switchgear with the installed equipment that will actually be fitted. Ultimately, the distribution and weight of the installed components can influence the vibration behaviour of the enclosure. The type of installation – whether on mounting plates, top hat rails or busbar systems – can also affect behaviour. For this requirement it is therefore advisable to test earthquake-resistant enclosures for the specific intended scenario, with the actual installed equipment in situ.

8 Summary

Earthquakes can poses a very serious threat to people and property in certain geographical locations. Electrical switchgear systems and data centres are not just valuable assets; their key role in the technical infrastructure makes them particularly vital – hence the need to ensure their resistance in earthquake-prone regions. Enclosures – generally those containing switchgear and servers – play a key role in safeguarding the functional integrity of such a system in the event of an earthquake. After all, if these suffer serious structural damage, then this will undoubtedly disable the system.

With the correct accessories, the VX25 large enclosure system meets the highest earthquake requirements of Telcordia Zone 4. The earthquake resistance of enclosures is very important. Various standards define the conditions such enclosures must meet to be considered earthquake-resistant. Depending on the application and geographical market, various different standards must be taken into consideration. Although they use different approaches, one key similarity is that they all use one important test: Vibration testing on a vibration table which simulates the accelerations produced by an earthquake. The precise frequency and acceleration spectrum of the vibration table test may vary, however.

Rittal's VX25 large enclosure system is tailor-made to meet the various earthquake standards up to the highest requirements of Telcordia Zone 4.

Rittal's VX25 large enclosure system is tailor-made to meet the various earthquake standards up to the highest requirements of Telcordia Zone 4.

9 Annex, list of figures, tables and sources

Terminology, abbreviations

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List of figures

Tables

List of sources

[Mun24] Munich Re, NatCatSERVICE, 2024 03
[BEU93] IEC 60068-3-3:1993-09 Environmental testing; seismic test methods for equipment, Beuth-Verlag 09
[IEE05] IEEE Standard 693 – IEEE Recommended Practice for Seismic Design of Substations, 2005 09
[TEL02] Telcordia GR-63-CORE Issue 2, 2002 09

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