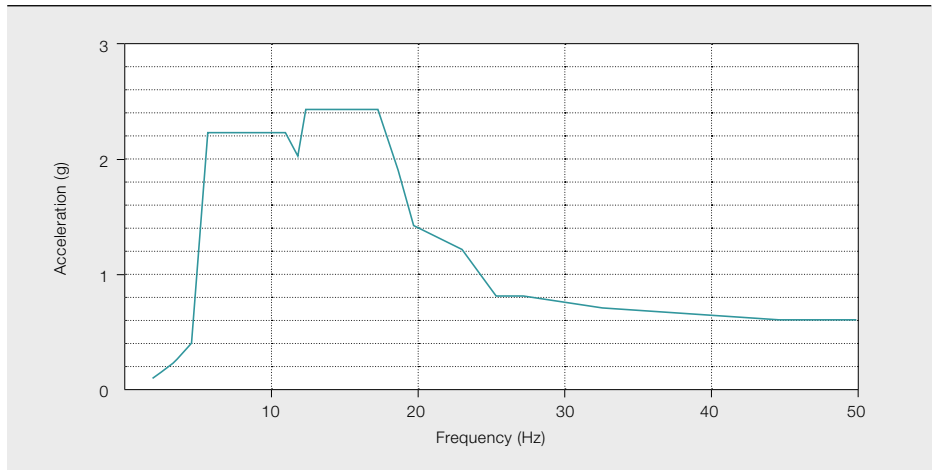


A seismic switch

Certified switchgear for nuclear power plants is providing a critical link in the chain

RENATO PICCARDO, ANNUNZIO REGANTINI, DAVIDE CATTANEO, LUCIANO DI MAIO – A nuclear power plant must be able to manage an enormous amount of energy in extremely safe conditions. All system functions must be controlled with absolute reliability and guaranteed operation. The equipment used must be able to withstand degradation over time caused by exposure to environmental extremes of temperature, pressure, humidity, radiation and vibration, including earthquakes. ABB has developed the UniGear ZS1 medium-voltage certified switchgear with the aim of satisfying all critical requirements.

1 Example of required response spectrum (RRS)



operating basic earthquake (OBE) or, in case of a very strong earthquake, it must be able to shut down the reactor, known as a safe shutdown earthquake (SSE). An additional requirement is verifying the functionality of each component under very intense environmental conditions in terms of temperature/humidity and after a thermal/radiation aging process.

and vibration, can hasten common-cause failures of qualified equipment. For this reason it is necessary to establish a “qualified life” for equipment with significant aging mechanisms. Qualified life is the period of time before the start of a design basis event for which equipment has demonstrated that it meets the design requirements for the specified service conditions [1].

People working on nuclear projects know that attention to detail and only using equipment that has been certified is crucial: It is never acceptable to turn the key of a nuclear plant until it is certain that every component playing a safety function has been fully tested and certified. Detailed parameters for certification are specified in American IEEE¹ and European IEC² standards.

The qualification process

Every supplier of products for the safety chain of a nuclear power plant (NPP) must go through a specific qualification process, the purpose of which is to verify and certify complete reliability of system components.

Some of the equipment in a NPP may also be required to operate under very intense conditions. This is why the main purpose of a qualification process is to verify the ability to operate during various and well-defined environmental settings.

The critical scenario is the possibility of a seismic event: The system must be able to continue functioning during a so-called

According to both IEEE and IEC standards the following methods can be used to qualify system components (alone or in combination):

- Type testing: A type test subjects a representative sample of equipment, including interfaces, to a series of tests, simulating the effects of significant aging mechanisms during normal operation.
- Operating experience: Performance data from the equipment in question or from equipment of similar design that has successfully operated under known service conditions may be used in qualifying other equipment under equal or less severe conditions.
- Analysis: Qualification by analysis requires a logical assessment or a valid mathematical model of the equipment.

Climatic qualification (cyclic damp heat)

The purpose of climatic qualification is to prove that the switchgear will continue to perform its safety function before, during and after variation of the humidity and temperature levels in the environment where the equipment will be installed. The test determines the suitability of equipment under conditions of high humidity combined with cyclic temperature changes and production of condensation on the

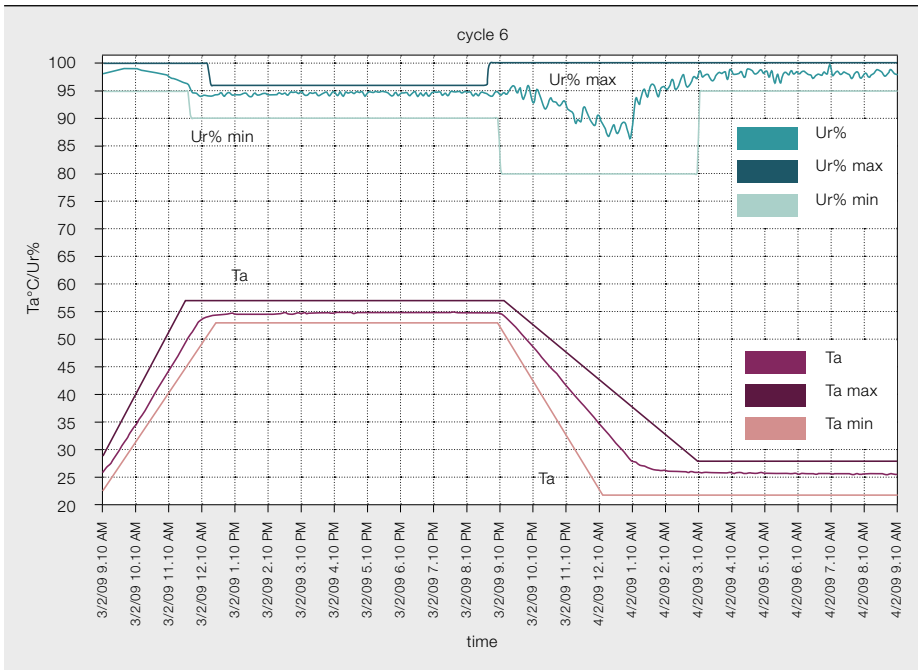
The system must be able to continue functioning during a so-called operating basic earthquake (OBE) or, in case of a very strong earthquake, it must be able to shut down the reactor

surface of the equipment being tested. In medium-voltage (MV) switchgear, condensation produced during humidity-temperature cycles can cause a reduction in the isolating properties.

Degradation over time, along with exposure to environmental extremes of temperature, pressure, humidity, radiation

Footnotes

- 1 Institute of Electrical and Electronics Engineers
- 2 International Electrotechnical Commission



The ABB Competence Center located in Dalmine, Italy, has several recent references for medium voltage switchgear for nuclear plants in Europe: Tihange and Doel in Belgium, Cernavoda in Romania, Oskarsham in Sweden and Leibstadt in Switzerland.

Seismic and airplane impact test qualification
IEC 60980 [2] and IEEE 344 [3] standards represent the two main reference standards for the seismic qualification of safety electrical equipment for nuclear power stations. The response spectra are not defined in either standard, since they can vary depending on the geographic area and building structure. They are therefore normally defined in technical project specifications.

A time-history seismic test usually consists of a tri-axial independent multifrequency test performed on the basis of time histories (plots of the acceleration as a function of time) artificially synthesized from a given required response spectrum (RRS). The RRS takes into account the characteristics of the geographic location and of the supporting structure or building → 1. The time-history method is considered the best way to simulate seismic loads during the qualification of equipment.

During the seismic test the following earthquakes are simulated:

OBE/S1: an earthquake that produces accelerations where features for continued operation without risks to public safety are designed to remain functional.
SSE/S2: an earthquake that produces accelerations for which certain structures, systems and components necessary to ensure the integrity of the reactor coolant pressure boundary as well as the capability to shut down the reactor and

maintain it in a safe shutdown condition, are designed to remain functional.

EMC qualification

The equipment must also be qualified to ensure full availability of the safety function in case of high electromagnetic stress, which may occur during accident conditions. Two types of testing, which reproduce the actual configuration of the instrumentation and control (I&C) devices installed in the primary equipment, including wiring, are performed on all of the equipment.

Immunity testing: Electromagnetic compatibility (EMC) qualification tests are performed in order to verify the level of immunity of the equipment from electromagnetic disturbance in a broad frequency range.

Emission testing: Electromagnetic emissions radiated and conducted on the wires by each piece of electrical equipment are measured over a broad spectrum.

Detailed functional tests are performed on all of the I&C functions, such as protection or control functions integrated into a single piece of equipment. The software qualification process follows IEC standards specifically developed for NPPs; these are described in IEC 60780 [4].

The ABB answer

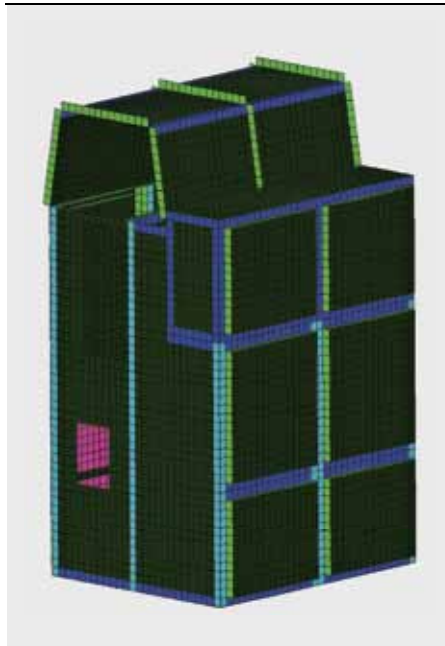
ABB has the products, the expertise and the technical means to ensure that all NPP requirements are met. The ABB Competence Center located in Dalmine, Italy, has several recent references for MV NPP switchgear in Europe: Tihange and Doel in Belgium, Cernavoda in Romania, Oskarsham in Sweden and Leibstadt in Switzerland. For each of these projects, ABB's products underwent a rigorous qualification procedure. This process verified equipment functionality in the case of seismic events and severe environmental conditions.

In addition to ABB's own products, laboratories and know-how, the company also can rely on a dedicated partnership with state-of-the-art laboratories located nearby containing, for example, a triaxial shake table; in addition, ABB can call on a team of experts on structures for seismic events. Software simulations of seismic events can provide many advantages for nuclear projects since no prototype is

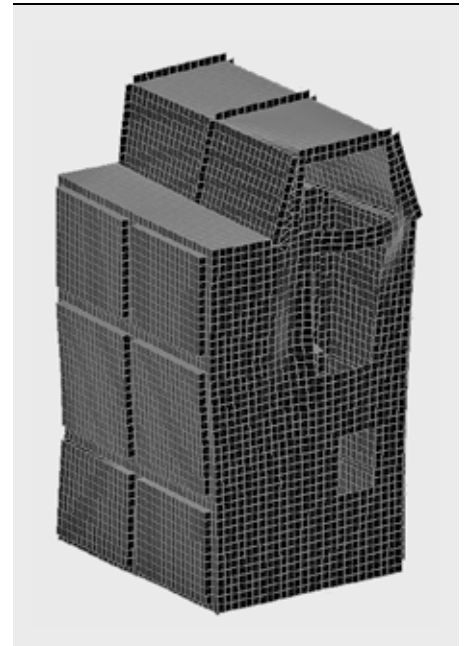
3 Seismic test arrangement on UniGear ZS1 during Doel NPP qualification



4 Example of numerical evaluation of the structure used for analytical seismic qualification



5 Example of amplified deformation on UniGear ZS1 structure



needed, therefore achieving shorter scheduling times and a reduction in costs.

In 2009, Areva NP, an engineering, procurement and construction (EPC) leader in NPPs, certified that the ABB Competence Center satisfies the conditions for “planning and production of medium voltage switchgear for nuclear power plants.”

MV Switchgear – UniGear ZS1

Medium-voltage switchgear is one of the most important links in the power distribution chain. ABB has developed the UniGear ZS1 switchgear with the aim of satisfying all users’ requirements. UniGear ZS1 is a combination of consolidated solutions and innovative components from ABB. The MV switchgear is suitable for indoor installations. Metal partitions segregate the compartments from each other and the live parts are air-insulated. The range of apparatus for UniGear ZS1 switchgear is the most complete available on the market, and includes vacuum and gas circuit breakers and vacuum contactors with fuses.

Industry applications

Doel is one of two large-scale NPPs in Belgium. The Belgian energy corporation Electrabel, part of the GDF SUEZ group, is its largest stakeholder. In 2009 ABB supplied MV switchgear comprising 18 UniGear ZS1 panels with 12kV / 1,600A / 50kA ratings and equipped with ABB HD4 SF₆ insulated circuit breakers. ABB equip-

ment is used for distribution of energy supplied by diesel emergency generators.

The equipment supplied was qualified according to IEEE 323 and 344 standards and customer specifications, which included a request for climatic and seismic tests → 2. A specimen switchgear was identified so that all of the characteristics that were part of the supply were included. A qualification program was implemented on these prototypes → 3, achieving a successful outcome.

The Tihange Nuclear Plant is the other large-scale NPP in Belgium. The primary stakeholder in the plant is again the Belgian energy company Electrabel. The plant has three pressurized water reactors (PWRs), has a total capacity of 2,985 MWe and makes up 52 percent of the total Belgian nuclear generating capacity.

ABB has retrofitted 344 breakers made by CEM Gardy, with HD4 SF₆ breakers. On site there are 354 circuit breakers (including 35 spares) and 34 VT trucks (including seven spares). A VT truck is a

piece of equipment that has voltage transformers fitted onto removable trucks. As required in the contract, the replacement of all circuit breakers and VT trucks took place within 2010; the site activity was performed along two years, during the annual routine maintenance shut-downs.

The qualification process was conceived in two different steps. Industrial and nuclear qualifications were based on IEC

Medium-voltage switchgear is one of the most important links in the power distribution chain. ABB’s UniGear ZS1 switchgear is a combination of consolidated solutions and innovative components from ABB.

and IEEE standards for MV apparatus and switchgear, as well as on the customer’s technical specifications. Seismic tests were performed according to IEEE standards at CESI-ISMES laboratories.

The Oskarshamn nuclear power station is one of ten active nuclear power stations in Sweden. With three reactors, the



In addition to ABB's own products, laboratories and know-how, the company also can rely on a dedicated partnership with state-of-the-art laboratories.

plant produces about 10 percent of the electricity needs of Sweden and its reactors use boiling water reactor (BWR) technology.

In 2009 ABB supplied four MV switchgear installations, each of them comprising seven UniGear ZS1 panels with a 12 kV / 1,600 A / 50 kA rating and equipped with ABB HD4 SF₆ breakers. As at Doel, ABB equipment is used for power distribution supplied by diesel generators for emergencies and the equipment supplied was qualified according to IEEE 323 and IEEE 344 standards, as well as the customer's specifications, which required seismic qualification.

Seismic qualification of the MV switchgear was performed by both analytical and testing methods. Both of these were carried out in collaboration with the CESI-ISMES laboratories located a few kilometers from the ABB MV switchgear factory → 4, → 5.

Modernization of existing NPPs

Retrofitting is the implementation of modern components (primary switching devices and digital protection/control technology) in existing MV installations. The aim of this modernization is to replace only those components that are planned for replacement according to their expected life cycle.

Because circuit breakers operate opening and closing currents, as opposed to other switchgear components that are static, in most cases breakers are the equipment most prone to aging. Therefore breakers are the components that are generally in the worst condition and replacing them with new ones is the best solution.

ABB has already performed retrofits on its own as well as competitors' breakers. The most extensive job was performed at the Tihange NPP where ABB retrofitted 344 CEM Gardy breakers with HD4 SF₆ breakers.

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References

- [1] IEEE 323 IEEE standard for qualifying class 1E equipment for nuclear power generating stations.
- [2] IEEE 344 Recommended practices for seismic qualification of class 1E equipment for nuclear power generating stations.
- [3] IEC 60780 Nuclear power plants – Electrical equipment of the safety system – Qualification.
- [4] IEC 60980 Recommended practices for seismic qualification of electrical equipment of the safety system for nuclear generating stations.

Further Reading

EN 61000-4 Series Electromagnetic compatibility – Testing and measurement techniques.

Title picture

Seismographs are used to record both real earthquakes and to monitor shake-table testing.