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Vladislav Gvozdev, external PhD candidate, Peter the Great St.Petersburg Polytechnic University, Civil Engineering Institute, St.Petersburg, Russia
vladgvosdev@gmail.com

INFLUENCE OF BUILDING ENVIRONMENTAL CONDITIONS ON PROCESS SYSTEMS

Abstract. In this article the V&V activities for the Environmental and Dynamic impacts qualification were described. The basic principles of Safety function assignments to the system were presented, as well as impacts and sources of various environmental conditions. Then, specific V&V measures, which can be used for confirmation of safety functions performance and consequently can be used as basis for the Environmental Qualification, were presented in the article.

Key words: validation & verification, Environmental Qualification, Dynamic impacts qualification, nuclear power plant.

Владислав Гвоздев, аспирант,
Санкт-Петербургский политехнический университет Петра Великого,
Инженерно-строительный институт, Санкт-Петербург, Россия,
vladgvosdev@gmail.com

ВЛИЯНИЕ УСЛОВИЙ СРЕДЫ НА ТЕХНОЛОГИЧЕСКИЕ ПРОЦЕССЫ

Аннотация. В этой статье были описаны действия по валидации и верификации для квалификации экологических и динамических воздействий. Были представлены основные принципы назначения функции безопасности системе, а также воздействия и источники различных условий окружающей среды. Затем в статье были представлены конкретные меры по валидации и верификации, которые могут быть использованы для подтверждения выполнения функций безопасности и, следовательно, могут быть использованы в качестве основы для экологической сертификации.

Ключевые слова: валидация и верификация, экологическая сертификация, сертификация на динамические воздействия, атомная электростанция.

1. Introduction

This article is concerning the Validation and Verification (V&V) activities for Nuclear Power Plant (NPP) Design and Construction is focused on the environmental conditions in the NPP buildings and rooms and their influence on the NPP safety functions and their performance as intended.

The construction-specific V&V process has not been deeply researched for complex civil structures such as nuclear power plants. Typically, nuclear power plant industry requirements for V&V are presented in the IAEA (International Atomic Energy Agency) safety standards as part of the management system [1,2].

In international practice, verification and verification activities are mainly governed by the discipline of quality, starting with general guidelines for the quality management system, such as [3–5], which represent a very general approach applicable to any type of activity. There are many ways that can be chosen to meet the requirements, and they mainly depend on the industry in which the verification and verification is applied. In general, V&V and their problems, including their interchangeability, differences in definitions, purposes, etc., have been researched quite extensively, and many publications and articles have been published in different industries, for example, more detailed industry studies regarding the application of the process verification and verification presented in [6, 7]. In project management, this issue was considered in [8], for example, for large industrial projects, a description and recommendations for the implementation of V&V can be found in [9].

Confirmation that safety functions of process systems which are allocated in buildings to be operated in accident environmental conditions as intended to be granted via the collection of V&V evidences can be named Environmental and Dynamic Impacts Qualification and should be performed throughout the different NPP construction phases, i.e. by defining and justifying qualification requirements to manage individual equipment qualification [10, 11].

The Environmental and Dynamic Impacts Qualification is the part of the Qualification discipline, which is focused on the obtaining the

evidences that qualification items are suitable to perform their functions [5, 6]. (functional operability and/or structural integrity will be maintained) in specified conditions (e.g. vibration, temperature, pressure, radiation, humidity, etc.) existing before, when and after they are required for the Plant entire design service life-cycle. [6, 11–13].

This issue was already presented in following articles, where general qualification process was presented in terms of systems, structures and components [14], and in terms of qualification context [15]. The correlation between different disciplines (such as quality control, system qualification and licensing) that use V&V outputs (sometimes similar results) in terms of a qualifying context is also presented in those publications.

2. Methods

In the course of this survey used in the NPP design and construction phases, the analytical method was applied.

3. Results and Discussion

The principle diagram for Environmental Qualification and Environmental conditions that affect the safety is presented in Figure 1.

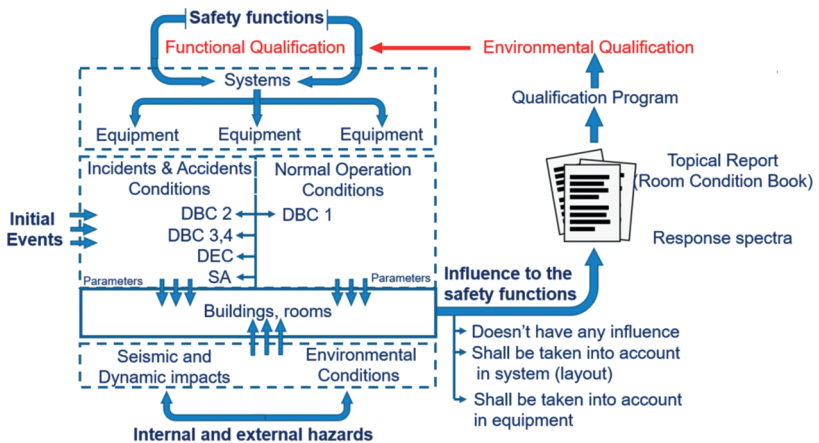


Figure 1. General principle of environmental qualification

The functions are assigned to the system (qualification item) by the System Designer, and during the system design development the functions will be broken down into specific components (qualification item) functions to overcome the initial events and make system able to perform function as intended [16].

The System Designer assigns the operation modes, including the events categories when the system shall perform its safety function, operation time during such events and the safety trains for the systems and for the equipment within those systems based on the Safety Concept [16, 17].

Environmental Qualification to be performed for the qualification items affecting the safety via the qualification measures (V&V activities) in accordance with the applicable industrial standards (e.g. IEC 60780 [18], IEC 60980 [19]; KTA 2201.4 [20]; KTA 3706 [21]; IEEE 323[22]; IEEE 334 [23], etc.), in this case the supplier of a qualification item shall provide all qualification evidences, which confirm that the qualification of items remains valid throughout the life-cycle of the NPP.

The System Designer shall specify the qualification requirements for the items to be qualified. Functional operability and/or structural integrity of safety relevant components shall be ensured.

4. Environmental conditions

Environmental conditions under which the functional operability and/or structural integrity shall be maintained may be grouped as follow:

- Initiating events, which will belong to the event categories, based on their probability,
- Hazards (internal and external) which will belong to the appropriate event categories if they affect the safety of NPP.

Apart from Normal Operation Conditions, Environmental Qualification considers the events (incidents and accidents) conditions.

These conditions are applied to the rooms and buildings where systems and equipment performing safety function are located.

The environmental and seismic condition to be analyzed against their impacts on the safety function performance. There are 3 main possibilities:

- no impact,
- impact on the safety function shall be considered in the building, system level,
- impact on the safety function shall be considered in the equipment level.

Analyses performed to define the environmental conditions shall be completed after the analysis variables have been finalized.

The System Designer shall identify the environmental and seismic conditions where the fulfilment of the system and equipment to be qualified:

- For seismic it is usually expressed in the form of a seismic response spectrum or time history from the analysis of a building or major sub-structures such as a control panel.

- Environmental conditions which have some influence to the safety functions include, but are not necessarily limited to, temperature, pressure, humidity, radiation, chemical spray, electromagnetic interference, ageing and submergence. Those parameters shall be listed in and specified for any buildings and rooms within the buildings, containing safety classified systems and equipment.

Synergy effects from combined parameters shall also be considered.

The excessive conservatism shall be removed from environmental analysis, and environmental envelope (conditions) shall be provided in accordance with the design conditions.

5. V&V measures for the Environmental Qualification

The choice of the qualification methods selected is largely a matter of technical judgement and availability of information that supports the conclusions reached.

The Environmental Qualification is to be performed based on following V&V actions:

- Testing, (incl. type tests),
- Analysis,
- Experience (incl. Qualification by analogy),

- Combination of the above-mentioned methods (depending on the particular situation).

Testing:

- When equipment is qualified by testing to demonstrate the structural integrity and functional operability, the test input (testing characteristics and parameters) shall be equal or exceed the minimum specified over the qualification requirements.

- When equipment is qualified by testing, the testing conditions shall reproduce equipment installation and operation (voltage, current, pressure, etc.).

- If testing is impracticable due to size or weight limitations, analysis may be acceptable for passive equipment, such as cabinets. Partial test data shall be provided to support the analytical assumptions and conclusions reached.

- Exceptions shall be addressed individually and justified in detail.

Analysis:

- Functional operability shall not be verified by analysis techniques alone.

- Therefore, qualification by analysis shall only be used on its own where demonstration of functional operability and structural integrity is adequate to assure the design intended function.

Experience:

- Experience data for environmental qualification shall be used for equipment qualification where it is cost-effective and is justifiable technically.

- Equivalence shall be demonstrated between the component(s) to be qualified and the previously qualified component(s) for which the experience data are representative such that the dynamic characteristics and material properties have a high degree of similarity.

- Also, the experience data qualification requirements shall not be less demanding than the specific qualification requirements for the qualification items of appropriate designed NPP.

- Experience data shall be drawn from previous test or test/analysis qualifications or other documented experience. The results of the previous

tests or analysis shall be comparable, the boundary conditions and acceptance criteria shall be comparable as well.

Combination of methods:

– The combination of physical test, experience and analysis may be also used, i.e., by demonstrating the similarity of the equipment to previously qualified equipment or to equipment which has been exposed to more severe environments.

6. Seismic Qualification

The seismic qualification shall demonstrate the ability of system equipment (passive and/or active) to perform its required safety role during and/or after the time it is subjected to the forces resulting from a Design Basis Earthquake when the operational functionality shall be demonstrated, considering all the equipment fulfilling the functions in such conditions (e.g. for motor-operated valves, etc.).

For components which functionality has to be ensured during dynamic events an experimental verification is preferred. Qualification by analogy may be acceptable for equipment of the same type.

7. Environmental Qualification

The mechanical, electrical and I&C equipment shall be qualified for use in the operating environment under which it will be required to perform its design function. Mechanical equipment qualification shall meet the requirements of applicable industry standards for the class of the equipment involved.

Electrical and I&C equipment shall be environmentally qualified in accordance with IEC 60780 or other standards provided they are demonstrated to be equivalent to IEC 60780 for the class of equipment involved.

8. Conclusions

Since the environmental parameters in buildings may differ in different states of NPP, it is necessary to highlight the parameters for

which the specified equipment must be qualified. Thus in addition to considering environmental parameters in normal operation (DBC1), environmental parameters in NPP operating modes other than normal operation (DBC2, DBC3, DBC4, DEC, SA) are subject to consideration. Consideration of the environmental impact in various modes of NPP operation and in the post-accident period is considered for each building separately, if building or the components and structures located in its premises are important for safety (safety class 1, 2 or 3 is assigned). In this case, an accident in which the environmental parameters have the most severe consequences in a given building is considered as an initiating event.

When designing equipment, it is necessary to take into account the qualification requirements came from analyses of internal and external effects of the environment. Protection against such hazards and ensuring od process system functions performance are ensured by fulfilling the requirements for independence and physical separation, as well as by using additional systems and additional qualification measures.

Thus, components important to safety must be qualified to demonstrate that they meet the environmental safety function requirements for the equipment over their design life. The effects of environmental parameters are taken into account when choosing the basic materials for components and structures and materials for their protective coatings. Qualification methods are depending on influence of such hazards to process systems and its components and shall be analyzed.

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