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Typical Design/Qualification Acceptance Criteria for Newly Installed Pipelines and Equipment Components of VVER-Type NPPs

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ABSTRACT

This paper describes in general the typical design/qualification acceptance criteria and seismic acceptance criteria in particular that are applicable for important to safety newly installed pipelines and equipment components of VVER-type already existing NPPs, specifically during the design verification phase of this newly installed equipment. These criteria are currently used for VVER 440-213 and VVER 1000 NPPs in Czech Republic and in Slovakia. The similar criteria are also used in Hungary.

KEY WORDS: design, qualification, seismic, environmental qualification, EMC, acceptance criteria, newly installed pipelines, newly installed equipment, replacement of equipment, VVER

INTRODUCTION

Once NPP is completed and approved for operation, its operation needs to comply with all applicable regulations and standards and other relevant safety requirements [1]. Throughout its lifetime, the plant should be regularly inspected, tested and maintained, in accordance with approved procedures, to ensure that it continues to meet the design requirements and remains consistent with the assumptions and results of the safety analysis [2,3].

However, over its lifetime, NPP may undergo various changes on the basis of the feedback of operational experience, the findings of periodic safety reviews, regulatory requirements, advances in knowledge and/or improvements in technology [4]. Structural and equipment modifications due to seismic upgrading are typical for almost all VVER-type NPPs [5,6]. In some cases modifications may be necessary for economic reasons, in other cases to ensure recovery from an identified fault condition or a plant failure.

The most often plant modification means the replacement of some of pipelines and equipment components due to their aging, insufficient ability to perform their operational and/or safety functions and to withstand environmental conditions and seismic in particular. The detail design of newly installed pipelines and equipment components should specify requirements for construction, installation, commissioning, qualification, testing, and maintenance during operation. This paper shows briefly the typical design/qualification acceptance criteria and seismic acceptance criteria in particular that are applicable for such important to safety newly installed pipelines and equipment components of already existing VVER-type NPPs, specifically during the design verification phase of this newly installed equipment. These criteria are currently used for VVER 440-213 and VVER-1000 NPPs in Czech Republic and Slovakia and mostly also in Hungary. They are based on internationally well-recognized codes, standards and other similar documents since no national documents of this type have been developed and are available.

EQUIPMENT QUALIFICATION

A qualification procedure shall be adopted to confirm that the newly installed pipelines and equipment components important to safety are capable to meet (throughout their design operational lives) the demands for performing their functions while being subject to the operational and environmental conditions (vibration, seismic, temperature, pressure, irradiation, humidity, electromagnetic interference, jet impingement etc.). The environmental conditions to be considered shall include the variations expected in normal operation, anticipated operational occurrences and design basis accidents. In the qualification program, consideration shall be given to ageing effects caused by various environmental factors, such as vibration, irradiation and temperature) over the expected lifetime of the equipment.

The design verification phase is qualification in the narrowest sense, when the equipment design is verified or qualified. This phase includes the development, collection, analysis, review, and acceptance of equipment qualification data. During this phase, qualification of equipment is established using analysis, tests, and experience information. Activities in this phase must also identify the installation, maintenance, and replacement requirements or limitations necessary to ensure that equipment remains qualified during the all implementation and preservation qualification phases.

The inputs of the design verification phase for newly installed pipelines and equipment components include:

- the qualification requirements developed in the plant design phase (i.e. scope of equipment, normal, abnormal, and accidental operational and environmental conditions, performance requirements etc.),
- detailed information on the equipment configurations based on conceptual designs, design drawings, or installed equipment inspections,
- the collection of referenced qualification reports, analyses, material data, and other related qualification information,
- the design/qualification acceptance criteria (i.e. regulations, standards, codes, including specified provisions to be applied, licensing commitments etc.) applicable to the particular equipment installation.

Then the outputs of the design verification phase usually include:

- an overall conclusion stating the level of qualification achieved for the evaluated equipment,
- the installation configuration requirements and limitations necessary to apply the qualification conclusions,
- the maintenance, surveillance, and parts replacement requirements necessary to apply the qualification conclusions,
- the installed or qualified life for the equipment,
- details of the evaluation, including reference to applicable source data.

TYPICAL DESIGN/QUALIFICATION ACCEPTANCE CRITERIA FOR NEWLY INSTALLED PIPELINES AND EQUIPMENT COMPONENTS OF VVER-TYPE NPPs

Table 1 Summary of Design/Qualification Acceptance Criteria for Newly Installed Pipelines and Equipment Components of VVER-type NPPs in Czech Republic and Slovakia [1,2,3]

Equipment Class	**Service Requirements**			
	Operational Requirements	**Environmental Requirements**		
		Seismic [4)]	**Non-seismic [5)]**	**EMC [6)]**
Mechanical Equipment				
Pipelines, Pipe Supports and Penetrations	ASME BPVC Section III [7)] (analysis) [7,8], anchorage (e.g. [9])	ASME BPVC Section III [7)] (analysis) [7,8], anchorage (e.g. [9])	no specific requirements	no specific requirements
Small Bore Pipes, HVAC Ducts	ASME BPVC Section III [7)] (analysis) [7,8], specific screening approaches [10,11]	ASME BPVC Section III [7)] (analysis) [7,8], specific screening approaches [10,11]	no specific requirements	no specific requirements
Valves (motor, fluid and hand operated)	ASME BPVC Section III [7)] (analysis) [7,8], OTT-87 [15]	ASME BPVC Section III [7)] (analysis) [7,8], IEC 980-1989 [14], IEEE Std 344-1987 [16], ASME QME 1-1994 (2000) [12,13], OTT – 87 [14]	IEC 60780 [19], IEC 60068-1 to 5 [19], IEEE Std 323-1983 [20], ASME QME 1/1994 (2000)[12,13], OTT – 87 [15]	IEC 61000-1 to 6 [22], IEEE Std 384-1992 [23], US NRC RG 1.180 [24]
Valve Actuators	related IEC/IEEE design standards, OTT-87 [15]	IEC 980-1989 [14], ASME QME 1-1994 (2000] [12,13], IEEE Std 344-1987 [16], IEEE Std 382-1985 (1996) [17,18], OTT-87 [15]	IEC 60780[19], IEC 60068-1 to 5 [20], IEEE Std 323-1983 [21], ASME QME 1-1994 (2000] [12,13], IEEE Std 382-1985 (1996) [17,18], OTT-87 [15]	IEC 61000-1 to 6 [22], IEEE Std 384-1992 [23], US NRC RG 1.180 [24]

Table 1 Continued

Equipment Class	Service Requirements			
	Operational Requirements	Environmental Requirements		
		Seismic [4)]	Non-seismic [5)]	EMC [6)]
Pumps	ASME BPVC Section III [7)] (analysis) [7,8], anchorage (e.g. [9])	ASME BPVC Section III [7)] (analysis) [7,8], anchorage (e.g. [9]), IEC 980-1989 [14], IEEE Std 344-1987 [16], ASME QME 1-1994 (2000) [12,13]	IEC 60780 [19], IEC 60068-1 to 5 [20], IEEE Std 323-1983 [21], ASME QME 1-1994 (2000)[12,13]	no specific requirements
Tanks, Heat Exchangers, Filters	ASME BPVC Section III [7)] (analysis) [7,8], anchorage (e.g. [9])	ASME BPVC Section III [7)] (analysis) [7,8], anchorage (e.g. [9])	no specific requirements	no specific requirements
Diesel and Motor Generators	ASME BPVC Section III [7)] (analysis) [7,8], anchorage (e.g. [9])	ASME BPVC Section III [7)] (analysis) [7,8], anchorage (e.g. [9]), IEC 980-1989 [14], IEEE Std 344-1987 [16],	IEC 60780 [19], IEC 60068-1 to 5 [20], IEEE Std 323-1983 [21]	IEC 61000-1 to 6 [22], IEEE Std 384-1992 [23], US NRC RG 1.180 [24]
Ventilators, Air Handlers, Chillers	ASME BPVC Section III [7)] (analysis) [7,8], anchorage (e.g. [9]), related IEC/IEEE design standards	ASME BPVC Section III [7)] (analysis) [7,8], anchorage (e.g. [9]), IEC 980-1989 [14] IEEE Std 344-1987 [16],	IEC 60780 [19], IEC 60068-1 to 5 [20], IEEE Std 323-1983 [21]	IEC 61000-1 to 6 [22], IEEE Std 384-1992 [23], US NRC RG 1.180 [24]
Supporting Platforms	codes for capacity evaluation of steel structures	codes for capacity evaluation of steel structures	no specific requirements	no specific requirements
Cranes, Transport Devices	codes for capacity evaluation of steel structures	codes for capacity evaluation of steel structures	no specific requirements	no specific requirements
Electrical Equipment				
Switchgears (low and medium-voltage) and Distribution Cabinets/Panels	related IEC/IEEE design standards, anchorage (e.g. [9])	IEC 980-1989 [14], IEEE Std 344-1987 [16], codes for capacity evaluation of steel structures, anchorage (e.g. [9])	IEC 60780 [19], IEC 60068-1 to 5 [20], IEEE Std 323-1983 [21]	IEC 61000-1 to 6 [22], IEEE Std 384-1992 [23], US NRC RG 1.180 [24]
Motor Control Centers	related IEC/IEEE design standards, anchorage (e.g. [9])	IEC 980-1989 [14] IEEE Std 344-1987 [16], codes for capacity evaluation of steel structures, anchorage (e.g. [9])	IEC 60780 [19], IEC 60068-1 to 5 [20], IEEE Std 323-1983 [21]	IEC 61000-1 to 6 [22], IEEE Std 384-1992 [23], US NRC RG 1.180 [24]
Transformers	related IEC/IEEE design standards, anchorage (e.g. [9])	IEC 980-1989 [14], IEEE Std 344-1987 [16], codes for capacity evaluation of steel structures, anchorage (e.g. [9])	IEC 60780 [19], IEC 60068-1 to 5 [20], IEEE Std 323-1983 [21]	IEC 61000-1 to 6 [22], IEEE Std 384-1992 [23], US NRC RG 1.180 [24]

Table 1 Continued

Equipment Class	Service Requirements			
	Operational Requirements	Environmental Requirements		
		Seismic [4]	Non-seismic [5]	EMC [6]
Batteries and UPS	related IEC/IEEE design standards, anchorage (e.g. [9])	IEC 980-1989 [14], IEEE Std 344-1987 [16], codes for capacity evaluation of steel structures anchorage (e.g. [9])	IEC 60780 [19], IEC 60068-1 to 5 [20], IEEE Std 323-1983 [21]	IEC 61000-1 to 6 [22], IEEE Std 384-1992 [23], US NRC RG 1.180 [24]
Battery Chargers and Inverters	related IEC/IEEE design standards, anchorage (e.g. [9])	IEC 980-1989 [14] IEEE Std 344-1987 [16], codes for capacity evaluation of steel structures anchorage (e.g. [9])	IEC 60780 [19] IEC 60068-1 to 5 [20], IEEE Std 323-1983 [21]	IEC 61000-1 to 6 [22], IEEE Std 384-1992 [23], US NRC RG 1.180 [24]
Cables with Accessories	related IEC/IEEE design standards	no specific requirements	IEC 60216-1 to 5 [25] IEC 60332-1 to 3 [26] IEC 60811-1 to 5 [27] IEEE Std 383-1974 [28], IEEE Std 572-1985 [29]	IEC 61000-1 to 6 [22], IEEE Std 384-1992 [23], US NRC RG 1.180 [24]
Cable Supporting Structures	codes for capacity evaluation of steel structures, anchorage (e.g. [9])	codes for capacity evaluation of steel structures anchorage (e.g. [9])	no specific requirements	no specific requirements
Cable Penetrations	related IEC/IEEE design standards	IEC 980-1989 [14], IEEE Std 344-1987 [16],	IEC 60780 [19], IEC 60068-1 to 5 [20], IEEE Std 323-1983 [21], IEC 60772 [30] IEEE Std. 317/1983 [31]	IEC 61000-1 to 6 [22], IEEE Std 384-1992 [23], US NRC RG 1.180 [24]
I&C Equipment				
I&C Cabinets and Panels	related IEC/IEEE design standards, anchorage (e.g. [9])	IEC 980-1989 [14], IEEE Std 344-1987 [16], codes for capacity evaluation of steel structures, anchorage (e.g. [9])	IEC 60780 [19], IEC 60068-1 to 5 [20], IEEE Std 323-1983 [21]	IEC 61000-1 to 6 [22], IEEE Std 384-1992 [23], US NRC RG 1.180 [24]
Sensors on Mechanical Components	related IEC/IEEE design standards	IEC 980-1989 [14], IEEE Std 344-1987 [16],	IEC 60780 [19], IEC 60068-1 to 5 [20], IEEE Std 323-1983 [21]	IEC 61000-1 to 6 [22], IEEE Std 384-1992 [23], US NRC RG 1.180 [24]
Transmitters on Racks	related IEC/IEEE design standards, anchorage (e.g. [9])	IEC 980-1989 [14], IEEE Std 344-1987 [16], codes for capacity evaluation of steel structures, anchorage (e.g. [9])	IEC 60780 [19], IEC 60068-1 to 5 [20], IEEE Std 323-1983 [21]	IEC 61000-1 to 6 [22], IEEE Std 384-1992 [23], US NRC RG 1.180 [24]
Relays, Contactors, switches etc. (detached)	related IEC/IEEE design standards	IEC 255-21-3 [32] ANSI/IEEE C37.98-1987 [33]	IEC 60780 [19], IEC 60068-1 to 5 [20], IEEE Std 323-1983 [21]	IEC 61000-1 to 6 [22], IEEE Std 384-1992 [23], US NRC RG 1.180 [24]

Notes: 1) Table 1 presents only general design/qualification acceptance criteria in term of codes and standards that are commonly accepted by National Regulatory Authorities in Czech Republic and Slovakia and mostly also in Hungary. The detail acceptance criteria are given in the relevant design/qualification specifications.

2) Basically, the IEEE standards are accepted for equipment designed, fabricated and tested under the IEEE jurisdiction. Otherwise, the relevant IEC standards are generally preferred in all European Community. Almost all IEC standards are currently adopted as EN standards (Euronorms) and as such they are mainly accepted also as national standards (e.g. Czech CSN standards, Slovak STN standards etc.).

3) Equipment that was already designed and qualified in accordance with some previous versions of the standards shown in Table 1 may be also accepted under the condition that the same level of performing of its specified safety functions is clearly demonstrated in the relevant design/qualification documentation.

4) Seismic design and qualification is required for all seismic category 1 pipelines and equipment components [5,6] based on the "Seismic Scenario" of the plant.

5) Specific non-seismic (environmental) qualification procedures are strongly required namely for equipment located in so called "harsh" conditions (under the containment - VVER 1000, or inside the hermetic zone - VVER 440) .

6) EMC qualification is required only for sensitive equipment located in areas with potential non-negligible electromagnetic or radio-frequency interferences.

7) The basic material characteristics (the yield limit, the ultimate strength limit etc) that are necessary to determine the allowable stress values / stress intensity values must be reliably verified when the ASME BPVC is used. Also the manufacturing and inspection quality is anticipated to be on the same level as assumed by this code. ASME BPVC Section III is generally accepted as an internationally recognized code for design, analysis, fabrication, examination, testing and preparation of reports for equipment components important to nuclear safety.

8) These codes are: CSN 73 1401 (Czech Republic) and STN 73 1401 (Slovak Republic) for the design of steel structures. They are both based on the Eurocode 3 for steel structures.

SEISMIC DESIGN/QUALIFICATION ACCEPTANCE CRITERIA FOR NEWLY INSTALLED PIPELINES AND EQUIPMENT COMPONENTS OF VVER-TYPE NPPs

Table 2 Seismic Design/Qualification Acceptance Criteria for Newly Installed Pipelines and Equipment Components of VVER-type NPPs in Czech Republic and Slovakia

Equipment Class	**Verification Requirements**		
	Structural Integrity [1)]	**Seismic Functionality** [2)]	**Verification as Built** [3)]
Mechanical Equipment			
Pipelines, Pipe Supports and Pipe Penetrations	analysis required [7,8,9] for an each system	no requirements	final inspection using the GIP-VVER procedure [5]
Small Bore Pipes, HVAC Ducts	analysis [7,8] or specific screening approach [10,11] required for an each system	no requirements	final inspection using the GIP-VVER procedure [5]
Valves (motor, fluid and hand operated)	analysis [7,8] or indirect verification required for an each valve model	testing or indirect verification [12,13,14,15,16] required for an each valve model	final inspection using the GIP-VVER procedure [5]
Valve Actuators	no requirements	testing or indirect verification [12,13,14,15,16,17,18] required for an each actuator model	final inspection using the GIP-VVER procedure [5]
Pumps	analysis [7,8,9] or indirect verification required for an each pump model	testing or indirect verification [12,13,14,16] required for an each pump model	final inspection using the GIP-VVER procedure [5]
Tanks, Heat Exchangers, Filters	analysis [7,8,9] or indirect verification required for an each component model	no requirements	final inspection using the GIP-VVER procedure [5]

Table 2 Continued

Equipment Class	Verification Requirements		
	Structural Integrity [1)]	**Seismic Functionality [2)]**	**Verification as Built [3)]**
Diesel and Motor Generators	analysis [7,8,9] or indirect verification required for an each generator model	testing or indirect verification [14,16] required for an each pump model	final inspection using the GIP-VVER procedure [5]
Ventilators, Air Handlers, Chillers	analysis [7,8,9] or indirect verification required for an each component model	testing or indirect verification [14,16] required for an each pump model	final inspection using the GIP-VVER procedure [5]
Supporting Platforms	analysis or indirect verification required for an each platform	no requirements	final inspection using the GIP-VVER procedure [5]
Cranes, Transport Devices	analysis or indirect verification required for an each platform	no requirements	final inspection using the GIP-VVER procedure [5]
Electrical Equipment			
Switchgears (low and medium voltage) and Distribution Cabinets and Panels	analysis or indirect verification required for an each cabinet/panel housing structure	testing or indirect verification [14,16] required for an each component model	final inspection using the GIP-VVER procedure [5]
Motor Control Centers	analysis or indirect verification required for an each cabinet/panel housing structure	testing or indirect verification [14,16] required for an each component model	final inspection using the GIP-VVER procedure [5]
Transformers	analysis or indirect verification required for an each transformer housing structure	testing or indirect verification [14,16] required for an each transformer model	final inspection using the GIP-VVER procedure [5]
Batteries and UPS	analysis or indirect verification required for an each transformer housing structure	testing or indirect verification [14,16] required for an each component model	final inspection using the GIP-VVER procedure [5]
Battery Chargers and Inverters	analysis or indirect verification required for an each transformer housing structure	testing or indirect verification [14,16] required for an each component model	final inspection using the GIP-VVER procedure [5]
Cables with Accessories	only proper attachment to the cable supporting structure	no requirements	final inspection using the GIP-VVER procedure [5]
Cable Supporting Structures	analysis or indirect verification required for an each typical cable supporting structure [34]	no requirements	final inspection using the GIP-VVER procedure [5]
Cable Penetrations	no requirements	testing or indirect verification [14,16] required for an each penetration model	final inspection using the GIP-VVER procedure [5]

Table 2 Continued

Equipment Class	Verification Requirements		
	Structural Integrity [1)]	Seismic Functionality [2)]	Verification as Built [3)]
I&C Equipment			
I&C Cabinets and Panels	analysis or indirect verification required for an each typical housing structure	testing or indirect verification [14,16] required for an each component model	final inspection using the GIP-VVER procedure [5]
Sensors on Mechanical Components	no requirements	testing or indirect verification [14,16] required for an each component model	final inspection using the GIP-VVER procedure [5]
Transmitters on Racks	analysis or indirect verification required for an each typical rack	testing or indirect verification [14,16] required for an each component model	final inspection using the GIP-VVER procedure [5]
Relays, Contactors, Switches etc. (detached)	no requirement	testing or indirect verification [30,31] required for an each component model	final inspection using the GIP-VVER procedure [5]

Notes:
1) Structural integrity means herein the structural integrity under the seismic loading.
2) Use when seismic functionality is specifically required.
3) The main purpose of this final inspection is to verify seismic adequacy of the equipment as built (mounted) with an emphasis on proper anchorage, connections and seismic interactions in particular.
4) The GIP-VVER procedure [5] is a specific modification of the well-known GIP procedure for verification of seismic adequacy of nuclear power plant equipment [35,36].

CONCLUSION

The described herein typical design/qualification acceptance criteria and seismic acceptance criteria in particular are applied for important to safety newly installed pipelines and equipment components of VVER-type already existing NPPs, specifically during the design verification phase of this newly installed equipment. They are currently used for VVER 440-213 and VVER 1000 NPPs in Czech Republic and in Slovakia and approved case by case by the National Regulatory Authority upon the utility request. The similar criteria are also used in Hungary.

USED ABBREVIATIONS

ASME American Society of Mechanical Engineers
BPVC Boiler and Pressure Vessel Code
EMC Electro-Magnetic Compatibility
GIP Generic Implementation Procedure
IAEA International Atomic Energy Agency
IEC International Electrotechnical Commission
IEEE Institute of Electrical and Electronics Engineers (USA)
NPP Nuclear Power Plant
NRC Nuclear Research Commission (USA)

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