Qualification of Safety-Related Equipment for Severe Accident Conditions – completion of Mochovce NPP in Slovakia

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1. Brief information - Mochovce NPP (MO34)

Mochovce NPP (utility SE-ENEL)
PWR plant Russian design type VVER 440 model V-213

- Four units with original design electric power output 440 MWe, each
- 2 units in operation and 2 units under construction
- Design Lifetime: original 30 year, extended +10 year
- Seismic hazard: Reviewed design value PGA = 0.15g SSE for 1x10E4 years

COMPLETION PHILOSOPHY FOR UNIT 3 AND 4:
UPGRADE ORIGINAL DESIGN OF GENERATION II NPP INTO GENERATION III NPP
2. Severe Accident Equipment Qualification – 4 cases

During preparation of **Qualification Specification** and **Qualification Program Reports** a four specific cases of „equipment qualification“ have been discovered.

**Case 1:** Equipment placed in Mild Environmental Zone to be exposed to extreme condition caused by Severe Accident scenario

**Case 2:** Plant transients and equipment performance characteristics for demands of Severe Accident management

**Case 3:** Qualification for Harsh Environment for Severe Accident Conditions (postulated)

**Case 4:** Special issues (non-postulated)
3. CASE 1 - Equipment placed in Mild Environmental Zone exposed to Severe Accident Conditions

Environmental conditions change only as consequence of Severe Accident scenario.

Equipment originally designed/qualified for mild environment.

An example; the asynchronous motor of the pump assembly exposed to radiation doses exceeded 100 Gy (see limit in IEEE 334), i.e. 30 kGy.

Solution: qualification performed as either design requirement for applied materials or the qualification test sequence shall refer to Mild Environmental test sequence followed by separate radiation test after seismic testing.
4. CASE 2 – Plant transients and equipment performance characteristics

Plant transients (e.g. transition between battery to diesel supply) affect the functional characteristics and even damaged equipment.

Example: assynchronous motor for water supply pump unit experienced a drop of voltage to 65% Un, design recovery interval only 7 second.

Solution: Robust design and overloading protection. Generally, the approach followed IEEE 627 requirements to Design Qualification of equipment.
4.1 Specific example – Capability of electric motor

- Special designed electric motor in accordance of pump performance characteristics
- Radiation resistance of winding insulation material – MICALASTIC tested for 1x10E7 Gy

Motor type: 1AJ4 450ZX-2
Insulation class / Utilization: F / B
Altitude: ≤ 1000 m a.s.l.
Ambient temperature: ≤ 40 °C
Type of construction: B 3
Degree of protection: IP 55
Cooling type: IC 81W
Water inlet temperature: ≤ 33 °C

Rated output: 500 kW
Voltage: 6000 VY
Speed: 2981 1 / min.
Frequency: 50 Hz
Current: 56 A

Standard: IEC 34 - 1
Starting current: 600 %
Starting power factor: 0,22
No load current: 10,5 A
No load power factor: 0,08
Material rotor cage: Cu
• Loading moment of the pump exceed the moment of motor, i.e. at moment equality the start-up of motor is stopped in this point, however the current will be 180 A – 3.2 times of nominal value

• The issue should be the time during standby regimes where is postulated interval of voltage drop to value of 65% Un.

• In Technical Specification of the motor is a allowable period of refreshment 7 sec.

• What happened if period of voltage refreshment is longer?
5. CASE 3 – Qualification for Harsh Environment for Severe Accident Conditions

Generally, equipment cannot be qualified because qualification principles shall follow the appropriate jurisdiction of law and standards. Therefore, it shall be assessed by different procedure, so called Survivability Assessment.

A baseline rules are described in EUR for LWR. No other public available procedure relating to evaluation of equipment required for Severe Accident management.
5.1. Severe Accident Equipment Adequacy Assessment: Qualification vs Survivability Assessment

**BASIC ASSUMPTION**

- Equipment shall be subject to an assessment to demonstrate that its design provides a reasonable level of confidence that it shall operate in the environment under which it is required to perform its functions in **Design Extension Conditions** and it shall be able to operate over the timespan for which it is needed.

- Qualification of components and systems, as required for those coping with **Design Basis Conditions**, does not necessarily apply.

- Demonstration of equipment survivability does not require the same rigorous demonstrations and the same conservatisms as a true qualification process.
Design Basis Conditions (LB LOCA)
- Thermo-dynamic profiles (peak temperature 127 °C, pressure 0.25 MPa (gauge))
- Post-accident duration (5h – 100 days),
- Radiation conditions: dose, dose rate, TID (0.37 MGy)

Temperature profile of Design Basis Accident LOCA inside containment of Mochovce NPP

Pressure profile of Design Basis Accident LOCA inside containment of Mochovce NPP

Design Extension Conditions (SA defined in Basic Design)
- Temperature peak (primordial): 139°C (duration < 30 min.)
- Pressure peak (primordial): 350 kPa (duration < 30 min.)
- Post-accident duration (primordial): more than 1 year,
- Radiation conditions (primordial): cca 0.3 MGy
- Humidity: 100%

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6. CASE 4 – Special issues

Special issues cover the specific considerations relating to Beyond Design Basic Events

Examples of special cases of equipment (design) qualification:

**Hydrogen burning:**
- Peak temperature 1600 °C
- Pressure wave

**Prolonged after accident temperature**
- Permanent temperature 139°C – 1 year

**SCIENTIST’S APPROACH VS ENGINEER’S APPROACH**
DECISION SHALL BE BASED ON ENGINEERING JUDGMENT BECAUSE FEASIBILITY
7. Comments to application of equipment adequacy assessment for SA conditions

Distinction accordingly environmental zones
- MILD environmental zone
- HARSH environmental zone

RULES FOR MILD ZONE
- Applied for equipment with existing qualification documentation and equipment to be tested
- SA ageing is not considered in line with equipment conditioning followed by simulation of postulated event (seismic, accident …)
- SA is considered as design requirements (radiation resistance, degree of protection – IP, anti-explosion design etc.)
- No safety margins are considered
7. Comments to application of the equipment assessment for SA conditions (cont‘d)

RULES FOR HARSH ZONE
- Applied for equipment with existing qualification documentation
- Not combine Design Extension Conditions (SA) with Design Basis Conditions (LB LOCA); an assessment for environmental parameters is made separately
- Definition of target values: TD environmental extreme peak
- SA radiation dose should not be considered as a contribution to TID (accident dose)
- No safety margins are considered
7. Comments to application of equipment adequacy assessment for SA conditions (cont’d)