Overview of the NEK Equipment Qualification Programs
• Owners: GEN Energija 50%  HEP 50%
• Operator: NEK
• NSSS Supplier: Westinghouse
• Reactor Type: PWR
• Construction Permit: 1975
• Commercial Operation: 1983
• Operating Licence: 40-60 years
• Gross Plant Output: 727 MW
NEK share in Slovenia in production of electrical energy

- HE (Hydro Power) = 4.293 GWh
- TE (Fossil Power) = 4.400 GWh
- NEK = 5.423 GWh *
- Total = 14116 GWh

* Total Krško NPP Production

Construction design requirements:

- **Environmental Qualification of Electrical and I&C (EQ) Reactor Building**
  DBA equipment shall be qualified to IEEE 323-1971 and IEEE 323-1974 – NO FORMAL PROGRAM

- **Seismic Design** – Seismic Category I mechanical and electrical equipment for the KRSKO Nuclear Power Plant shall meet seismic performance requirements during and following the OPERATING BASIS EARTHQUAKE (OBE), SAFE SHUTDOWN EARTHQUAKE (SSE)
NEK Environmental Qualification program for Electrical and I&C equipment:

- First Periodic Safety Review (PSR1) – 2005 action plan
- Slovenian Nuclear Regualtory Body rule JV5 „Rules on radiation and nuclear safety factors“
NEK EQ Program document:

1. ED-12 consistent with 10 CFR 50.49

2. ED-12 defines methodology and criteria for EQ conditions determination (EQ zones)

3. ED-12 methodology and criteria for EQMEL in EQSEL lists

4. Program defines qualification process:  
   • Methods for qualification and documentation  
   • Process control (design changes, maintenance, purchasing)
NEK DBA EQ conditions:

Environmental conditions during and after DBA:
- LOCA
- MSLB (Main Steam Line Break)
- HELB (High Energy Line Breaks): \( T > 93.3^\circ C \) or \( p > 2.0 \) MPa
  (for example CVCS letdown, SG BD)

Analyses:
- \( T/H: \) RB, IB, AB: \( T, p \) and \( RH \)
- Dose rates and TIDs: RB, AB (for example RH sump recirculation), IB

Harsh conditions significantly more severe than normal operating conditions:
- Temperature: \( 8,3^\circ C \) (15°F) above normal/design \( T \)
- Pressure: 10% above normal/design (10kPa – 1.47psi)
- RH: 100%RH with condensation
- Chemical Spray - exposure
- Submergence – exposure
- Radiation TID > 100 Gy; > 10 Gy for electronics
EQ Zone Maps document

- Defined Harsh/Mild locations and corresponding enveloping EQ zone:

<table>
<thead>
<tr>
<th>BUILDING</th>
<th>ELEVATION</th>
<th>LOCATION</th>
<th>ENVIRONMENT</th>
<th>ZONE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auxiliary building</td>
<td>82-91</td>
<td>AB001</td>
<td>MILD</td>
<td>AB-M-02</td>
</tr>
<tr>
<td>Auxiliary building</td>
<td>82-91</td>
<td>AB002</td>
<td>HARSH</td>
<td>AB-H-05</td>
</tr>
<tr>
<td>Auxiliary building</td>
<td>82-91</td>
<td>AB003</td>
<td>HARSH</td>
<td>AB-H-05</td>
</tr>
<tr>
<td>Auxiliary building</td>
<td>82-91</td>
<td>AB004</td>
<td>HARSH</td>
<td>AB-H-05</td>
</tr>
</tbody>
</table>

- EQ conditions defined for every evaluated room:
**EQ equipment list**

**EQ Master Equipment List (EQMEL) components:**
- Electrical and I&C equipment:
  - Safety-related;
  - Non-safety-related that affects safety-related;
  - Certain post-accident monitoring (RG 1.97 Category 1 in 2)
- Located in Harsh environment and perform DBA safety function

<table>
<thead>
<tr>
<th>Equipment</th>
<th>System: RH</th>
<th>Status: ACTIVE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type: E</td>
<td>Diag: 1</td>
<td>Cat:E</td>
</tr>
<tr>
<td>Parent:</td>
<td>Sub Cat:</td>
<td>Parent Equip:</td>
</tr>
</tbody>
</table>

**Vendor information**

Model: /  Serial No: N31733
Vendor: ULTRA ELECTRONICS, ROUND ROCK, TX (787 JEFFERY WAY, ROUND ROCK, 78628)
MFG Id: U61
Manufacturer: ULTRA ELECTRONICS-UNI-10 - ULTRA ELECTRONICS NUCLEAR SENSORS/PROCESS INSTR.
SGDR: Part No: 170-18-0-C-0500-01  Instl. Year: 21.03.2013

**Determinants**

|----------|-------|-------|------|-------|-----------|---------|-------|-----------|--------|

**Location**

Buildings: A8  Rooms: 055  Equip Elev: 103.05

NEK EQ programs, UJV Rež, 2019
**EQMEL equipment list (typical):**

- Pumps electric motors
- VA fan coolers electric motors
- MOVs
- Limit switches
- Electrical penetrations
- Pressure transmitters (LT, PT, FT)
- RTDs, TCs
- Pressure switches
- RM detectors/monitors
- Solenoid valves
- MCCDs
- H2 recombiners (replaced with PARs)
- Transformers,
- Selector switches
**EQ Supporting Equipment List (EQSEL)**
- entire functional loop shall be qualified

Typical supporting equipment:

- Cables – BIW, Rockbestos, Okonite, General Cable
- Wires – FWIII SIS, FLAMETROL
- Heat-shrink in-line cable splices – TYCO/RAYCHEM
- Terminal blocks – MARATHON
- Sealing Tapes – Graphoil, Locktite
- Connectors – EGS Qualtech, Conax
- Sealing Compounds – DOW CORNING, NAMCO
Qualification documentation – EQMS

- Test reports (Environmental Qualification Report)
- NEK Qualification evaluations - EPRI EQ management Software (EQMS):
  - EQ Environments
  - EQMEL
  - GQE
  - PQE + SCEW
Qualification documentation – EQMS Plant Qualification Evaluation Module (PQE):

Thermal Aging – qualified life calculation:

<table>
<thead>
<tr>
<th>Normal Area Name</th>
<th>Ambient Temp (°F)</th>
<th>Basis</th>
<th>Temp Rise (°F)</th>
<th>% Energized</th>
<th>Aging Time (yr)</th>
<th>Aging Temp (°C)</th>
<th>Activation Energy (eV)</th>
<th>Notes</th>
<th>Qualified Life (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>IB-H-06 Zone</td>
<td>114.80</td>
<td>Bounding</td>
<td>0.00</td>
<td>100.00</td>
<td>3.072.00</td>
<td>98.61</td>
<td>0.7800</td>
<td></td>
<td>19.40</td>
</tr>
<tr>
<td>RH-I-01 Zone</td>
<td>120.20</td>
<td>Bounding</td>
<td>0.00</td>
<td>100.00</td>
<td>3.072.00</td>
<td>98.61</td>
<td>0.7800</td>
<td></td>
<td>14.90</td>
</tr>
<tr>
<td>Plant Temperature Monitoring</td>
<td>98.42</td>
<td>Measurement till 98.04: EQR 30-3-TR-1</td>
<td>0.00</td>
<td>100.00</td>
<td>3.072.00</td>
<td>98.61</td>
<td>0.7800</td>
<td>See Reference 20.</td>
<td>44.60</td>
</tr>
<tr>
<td>Plant Temperature Monitoring</td>
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<td>Measurement till 100.30: EQR 30-3-TR-1</td>
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<td>100.00</td>
<td>3.072.00</td>
<td>98.61</td>
<td>0.7800</td>
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<td>26.81</td>
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<td>Plant Temperature Monitoring</td>
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<td>Measurement till 107.06: EQR 30-2-TR-1</td>
<td>0.00</td>
<td>100.00</td>
<td>3.072.00</td>
<td>98.61</td>
<td>0.7800</td>
<td>See Reference 20.</td>
<td>33.40</td>
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<tr>
<td>Plant Temperature Monitoring</td>
<td>112.45</td>
<td>Measurement till 115.55: EQR 30-3-TR-1</td>
<td>0.00</td>
<td>100.00</td>
<td>3.072.00</td>
<td>98.61</td>
<td>0.7800</td>
<td>See Reference 20.</td>
<td>21.78</td>
</tr>
</tbody>
</table>

PAOT profiles area comparison – margin calculation:

PAOT Calculation Results

\[ t_1 / t_2 = e^{\frac{Q}{E(T_2-T_1)}} \]
Other qualification documents:

EQ block diagrams:
Other qualification documents:

EQ Workmanship standard (EQWS):

**EQ Field Configuration Drawings**

- EQ Field Configuration Parts List

NEK EQ programs, UJV Rež, 2019
**EQ activities:**

- Temperature
- Gamma and neutron radiation

**EQ labeling:**

**Control over plant processes:**
- Design changes
- Preventive Maintenance
- Procurement
EQ overall process

Qualification Inputs:
- Equipment:
  - Location (Normal and DBA environment)
  - Safety function
  - PAOT
  - Manufacturer/Model
  - EQ Master Equipment
  - EQ Supporting Equipment
- Qualification test report (Manufacturer/Model)

Qualification Evaluation:
- EQMS qualification (PQE):
  - Qualified Life
  - EQ configuration
  - EQ maintenance
  - Procurement requirements

Qualification Outputs:
- EQ Block Diagram
- EQ Workmanship Standard
  - Configuration requirements (orientation, sealing, etc.)
  - Maintenance requirements (periodic replacement equipment or part, periodic inspections, etc.)
- EQ Label, Plant Information system equipment EQ designation (EQ=YES)

EQ group is involved whenever EQ equipment is affected:
1) Replaced
2) Modified
3) De-installed
4) New EQ equipment installed
5) Environmental conditions affected
Second Periodic Safety Review (PSR2):

1. Qualification to Severe Accidents – Equipment Survivability Program

2. Active Mechanical Equipment Environmental Qualification – Mechanical Qualification Program

3. Electromagnetic Compatibility Qualification – EMC Program
**REGULATIONS:**

**Slovenian legislation:**
„Rules on radiation and nuclear safety factors“ requires Equipment Survivability (ES) assessment to show that there is reasonable assurance that the equipment and instrumentation used to mitigate and monitor Design Extended Accident Conditions (DEC).
Act is in accordance with IAEA, WENRA requirements.

**IAEA Safety Standard SSR-2/1 „Specific Safety Requirements“**
Requirement 20 - Design extension conditions:
„These design extension conditions shall be used to identify the additional accident scenarios to be addressed in the design and to plan practicable provisions for the prevention of such accidents or mitigation of their consequences“.

**WENRA Safety Reference Levels for Existing Reactors (2014)**
Issue F - Design Extension of Existing Reactors:
„There are two categories of DEC:
• DEC A for which prevention of severe fuel damage in the core or in the spent fuel storage can be achieved;
• DEC B with postulated severe fuel damage“.
„... DEC have the capacity and capability and are adequately qualified to perform their relevant functions for the appropriate period of time ...“
NEK WENRA approach:

IAEA and WENRA plant states defines environmental qualification and equipment survivability → NEK Safety Upgrade Projects (SUP) requirements:

<table>
<thead>
<tr>
<th>Operational States</th>
<th>Accident conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal operation (NO)</td>
<td>Design basis accidents (DBA)</td>
</tr>
<tr>
<td>Anticipated operational occurrences (AOO)</td>
<td>Design extension conditions</td>
</tr>
</tbody>
</table>

- without significant fuel degradation
- with core melt

**SUP Concept**

- Design Basis (current regulatory requirements)
- Transients
- Design Basis Accidents
- Extended Design Basis Accidents - DECA
- Extended Design Basis Accidents - DECB
- Beyond Design Basis Accidents
- Additional AM & SM Equipment SAMG

- Existing Plant Systems
- General & Transient Operating Procedures (GTO, AOP)
- USAF
- Existing Safety Systems
- Emergency Operating Procedures (EOP)
- USAF
- Additional Preventive Safety Systems
- Extended EOP's + FLEX
- SAM Systems, DAMG + FLEXG (Watergun Control, Filtration vent Systems)
- Mode equipment

**Environmental Qualification**

- EC/DBA classified equipment
- ES/DEC A classified equipment
- ES/DEC B classified equipment

NEK EQ programs, UJV Rež, 2019
DESIGN EXTENSION CONDITIONS DEC B

1) The limiting scenario is SBO sequence with PCFV, PAR actuation, mitigation actions at 24h: reactor core damage, Ex-Vessel core relocation; Accident mitigation scenario using AHX in severe accident (spray, recirculation from containment sump during ex-vessel event): conditions in AB, IB building at ARHR equipment /piping locations

2) SGTR: radioactive release to environment - conditions in BB1, BB2, Yard

3) SFP accident: scenario per Industry Guidance NEI 12-02 - conditions in FHB
Equipment Survivability Elements

Equipment Safety Function and Location Assessment DEC classification:

- Detailed safety function description - in which specific plant state equipment will be used (normal operation, abnormal operation, DBA, DEC) – If DEC than candidate for DEC classification

- Location of equipment – is equipment located in Harsh environment – If Yes than candidate for DEC classification
  - Temperature: 8,3°C (15°F) above normal/design T
  - Pressure: 10% above normal/design (10kPa – 1,47psi)
  - RH: 100%RH with condensation
  - Chemical Spray - exposure
  - Submergence – exposure
  - Radiation TID > 100Gy; > 10Gy for electronics

DEC PAOT timing is determined: 1hour, 1day, 1month, 1year

DEC Qualification standards:
- Electrical and I&C: IEEE 323-1974 or later edition, IEEE EQ daughter standards (317, 334, 382, 383, ...)
- Mechanical: ASME QME-1, or qualification of non-metallic materials
DEC systems and qualification

Various post-Fukushima Safety Upgrade Projects under development:

- Independent third DEC Diesel Generator additional to two 100% redundant DBA DGs – DEC B equipment
- Flood protection upgrade
- New Emergency Control Room in DEC Bunkered Building
- Passive Containment Filtering & Ventilation system (PCFV) – DEC B equipment
- Passive Autocatalytic System (PAR) – DEC B equipment
- Containment accident instrumentation - DEC A&B
- Various instruments located in systems in containment building (including new neutron flux instrumentation channels) – DEC A&B
- Independent system for the RCS pressure relief (alternate PORV) - DEC A system
- Reactor Coolant and Containment alternate cooling (ARH-ACI) system DEC A&B
- Alternate SI and AF (ASI, AAF) systems DEC A&B
- Alternate cooling of the SFP (Heat Exchangers, Spray System) – DEC A systems

Equipment Survivability (under development) performed to required level of conditions (DEC A or DEC B conditions).
Active Mechanical Equipment Qualification

- New qualification program based on:
  - EPRI EQ Reference Manual
  - EPRI NP-3877 Qualification of Active Mechanical Equipment for Nuclear Plants
  - NUREG 0800 Standard Review Plan Ch. 3.11
  - RG 1.100 Rev.3 (SEISMIC QUALIFICATION OF ELECTRICAL AND ACTIVE MECHANICAL EQUIPMENT AND FUNCTIONAL QUALIFICATION OF ACTIVE MECHANICAL EQUIPMENT FOR NUCLEAR POWER PLANTS) endorsing ASME QME-1 (Qualification of Active Mechanical Equipment Used in Nuclear Power Plants)
- MEQMEL development: DBA and DEC equipment; Safety function; PAOT; Location (Normal and Harsh environment conditions)
- Qualification assessment: Based on available qualification test reports or based on evaluation of non-metallic materials (EPRI reports and Curtiss Wright Power Suite EQ applications)
- Documentation packages (similar approach as EQ); corrective actions
- Preserving qualified status: control of maintenance, modifications and procurement processes
EMC Qualification Program

- New qualification program based on:
  - USNRC Regulatory Guide 1.180
    - Guidance applicable to all new safety related systems or modifications to existing safety related systems containing analog, digital or hybrid (combined) electronics equipment
  - EPRI TR-102323
    - Detailed technical report providing details from historical background to recommended generic EMI susceptibility and emissions test levels to be used in establishing equipment electromagnetic compatibility for nuclear power plant applications
- Provides definition of equipment under EMC scope:
  - EMC zones: high emissions (E); sensitive equipment (S) including exclusion zones
  - SR I&C equipment located in EMC zones
- Provides guidelines and practical examples for EMC-related documentation

- **Zone mapping** has been performed to capture an emission profile of the selected area.
- **Administrative measures** – defines exclusions area for welding, use of portable transceivers
- Implementation of **practical noise reduction design considerations**
- **Qualifications process** required and started for new equipment/systems (including SUP)
• EQ program / Plant Life Extension from 40 to 60 years (2023 to 2043)
  • Electrical Penetration Assemblies, Cables, Cable Splices and other commodities qualified life extension (Reanalysis per NUREG-1801, qualification testing for life extension)
  • Obsolete equipment – new qualifications

• To complete Equipment Survivability
• To complete MEQ program
• To complete EMC program

• PSR3???
Thank you!

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