Severe accident management at Paks NPP
The MVM Paks Nuclear Power Plant

- the only nuclear power plant in Hungary
- belongs to the MVM Hungarian Electricity Company Ltd.
- designed in the 70’s, commissioned in the 80’s
- 4 x VVER440/V213 reactors
- 30 years originally designed lifetime
- the largest and cheapest domestic source
### MVM Paks Nuclear Power Plant

The Paks Nuclear Power Plant is a nuclear power plant in Hungary, located in Paks. It is operated by MVM. The plant has four units, each with a capacity of 500 MW. The table below provides the start-up dates, capacity upgrade dates, and life times for each unit:

<table>
<thead>
<tr>
<th>Unit</th>
<th>Start up of the unit</th>
<th>Capacity upgrade</th>
<th>30-year life time</th>
<th>50-year life time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit 1</td>
<td>14/12/1982</td>
<td>19/07/2007</td>
<td>2012</td>
<td>2032</td>
</tr>
<tr>
<td>Unit 2</td>
<td>26/08/1984</td>
<td>05/12/2008</td>
<td>2014</td>
<td>2034</td>
</tr>
<tr>
<td>Unit 3</td>
<td>15/09/1986</td>
<td>13/11/2009</td>
<td>2016</td>
<td>2036</td>
</tr>
<tr>
<td>Unit 4</td>
<td>09/08/1987</td>
<td>28/09/2006</td>
<td>2017</td>
<td>2037</td>
</tr>
</tbody>
</table>
445,5 TWh electric power has been produced by MVM Paks Nuclear Power Plant since the date of the first connection of Unit 1 to the grid.
Continuous safety enhancement

- The enhancement of nuclear safety had been started in Paks already before the commissioning of Unit 4 in 1987.
- 1993–2002: Reactor Protection System Reconstruction
- 2011–2016: Targeted Safety Review (TSR) and corrective measures
Review of seismic hazards, plant reinforcement

During the technical design of Paks NPP, 0.025-0.05 g horizontal component was taken into account as earthquake intensity.

Pursuant to the results of a comprehensive geological assessment the design basis earthquake has been set to 0.25 g for the horizontal and 0.2 g for the vertical components taken at $10^{-4}$/year frequency level on the weighted mean hazard curve.

The reinforcement for design basis earthquake took place in the 1990s.
Plant reinforcement
Severe Accident Management (SAM)

The evaluation of the plant safety from the aspect of large discharges was completed by the end of 2004.

There are three key elements of the implementation of severe accident management:

- execution of technical modification belonging to SAM
- introduction of Severe Accident Management Guidelines
- modification of emergency preparedness
SAM technical modifications

External cooling of reactor pressure vessel

The approximate 1180 m³ water and the coolant from the primary circuit can be used to flood the 270 m³ reactor cavity.

Measurement system for severe accident

Certain primary circuit and secondary circuit parameters. Operable under severe accident conditions. Batteries and later mobile accident Mobile Diesel generator can supply electrical power to the measurement.
SAM technical modifications

Severe accident Diesel generators

Supply electrical power to measurement system and the actuation of certain valves. One for each Unit (100 kW, 0,4 kV). Two independent connection points at the outer wall of each unit.

Hydrogen management

Sixty (30 pairs) NIS type passive autocatalytic severe accident recombiners. The burning of H2 already starts at normal temperature.
SAM technical modifications

Reinforcement of cooling circuit of spent fuel pool

Reinforcement against loss of coolant due to pipeline rupture.

Prevention of containment long term over-pressurization

The slow overpressure is caused by steam produced during the external cooling of the reactor pressure vessel. Consequently, the relevant accident management guideline requires the reduction of the pressure in the containment.
Severe Accident Management Guidelines

Westinghouse severe accident management guidance documentation.

SAMGs cover different operational status of Unit
- under operation
- shut-down
- cooling pool severe accidents

Entry to the SAMG
- criteria in symptom-based operational instruction, shut-down symptom-based operational instruction and cooling pool instructions
- core outlet temperature
- dose rate (open reactor vessel with fuels)
- dose rate (cooling pool)
Creation of Technical Support Centre

TSC was established at Emergency Response Centre

Equipped with Severe Accident Monitoring System

Multiunits severe accidents
Targeted safety reassessment („stress test”)

In the frame of post Fukushima actions, MVM Paks NPP performed a targeted safety re-assessment taking into accounts ENSREG requirements.

Reassessment covered:

- design basis regarding external sources of hazards
- safety margins
- prolonged loss of electric power supply and ultimate heat skin
- severe accident management
- site emergency provisions
External natural hazards

Earthquake
Re-design, re-qualification of critical systems, and where necessary their reinforcement took place in the 1990s within the frame of a comprehensive review programme.

External flooding
The icy flood is 96.07 m, while the level of open river flood may be 95.51 m. The level of site is 97.15 m.

Low water level of the Danube
The value is 84.65 m. The essential service water pumps can be started and operated up to 83.5 m.

Other external hazards
The other external hazards do not challenge the safety of the plant more seriously than acceptable.
External natural hazards - conclusion

Paks NPP is safe and no further immediate action is necessary. However, further safety improvements are possible.

- Seismic reinforcement of conventional parts of the plant (400 kV and 120 kV substations, the fire brigade barrack, shelters).
- Appropriate fixing of tools and appliances, used during outages and stored at the units.
- External flooding may flood the pump rooms. Wall penetrations must be isolated in essential service water pump building.
- It should be ensured that the pipeline trenches are applicable to receive and drain the discharged water.
Electric supply and ultimate heat sink

From the aspect of assessment of beyond design basis margins the only external event that can be evaluated is the earthquake.

There is no certainty that the systems of electric power supply and ultimate heat sink functions will be impaired even after a beyond design basis earthquake, but the probability of loss of function is increased with the strength of the earthquake.
Electric supply/ultimate heat sink - conclusion

Alternative and justified off-site electrical power supply routes are available to supply electrical power to the safety consumers of the nuclear power plant. However, the assessment identified further alternative solutions.

- The existing mobile severe accident Diesel generators on the management of severe accidents, are not suitable. Independent accident Diesel generators have to be therefore installed.

- The high-voltage substations are non-safety systems and, therefore, they are not qualified seismically. Seismic qualification and/or reinforcement of the substations shall be carried out.

- Creation black-start capability to gas turbine (an off-site gas turbine located remotely).
The design of the Paks NPP provides a very low probability of such events; at most it might happen due to a beyond design basis external event or rather due to combinations thereof.

- The demineralised water tanks in Units 3 and 4 are installed alongside a laboratory and service building. The tanks must be protected against the impact of the falling wall.

- Alternate water supply from fire water system

- An appropriate solution might be the creation of mobile water extraction from the demineralised water tanks, the River Danube or from the fishing lakes near the plant.

- An appropriate design change must be implemented to access the additional cooling water at a quantity of ~2x2,000 m³ from the closed section of the discharge water canals of Units 3 and 4.
Emergency preparedness

The preparedness for emergencies is good, thanks to the earlier performed modifications in the frame of SAM. However some further improvements are possible.

- Radiation-shielded vehicles and other necessary tools
- A severe accident simulator must be built for training
- Extension of the functionality of the ERC and BERC
- Preparation for severe accidents involving several units simultaneously
- Emergency procedures for the management of liquid radioactive wastes resulting from a severe accident
## SAM - Tasks

<table>
<thead>
<tr>
<th>Modification</th>
<th>Unit 1</th>
<th>Unit 2</th>
<th>Unit 3</th>
<th>Unit 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>External cooling of reactor vessel</td>
<td>Implemented</td>
<td>Implemented</td>
<td>Implemented</td>
<td>Implemented</td>
</tr>
<tr>
<td>Measurement system</td>
<td>Implemented</td>
<td>Implemented</td>
<td>Implemented</td>
<td>Implemented</td>
</tr>
<tr>
<td>Severe accident Diesel generator</td>
<td>Implemented</td>
<td>Implemented</td>
<td>Implemented</td>
<td>Implemented</td>
</tr>
<tr>
<td>Hydrogen recombiners</td>
<td>Implemented</td>
<td>Implemented</td>
<td>Implemented</td>
<td>Implemented</td>
</tr>
<tr>
<td>Reinforcement of cooling circuit of spent fuel pool</td>
<td>Implemented</td>
<td>Implemented</td>
<td>Implemented</td>
<td>Implemented</td>
</tr>
<tr>
<td>TSC in Emergency Response Centre</td>
<td></td>
<td></td>
<td>Implemented</td>
<td></td>
</tr>
<tr>
<td>Introduction of severe accident management guidelines</td>
<td>Implemented</td>
<td>Implemented</td>
<td>Implemented</td>
<td>Implemented</td>
</tr>
<tr>
<td>Prevention of containment long term over-pressurization</td>
<td>2019</td>
<td>2019</td>
<td>2019</td>
<td>2019</td>
</tr>
</tbody>
</table>
# Targeted safety reassessment - Tasks

<table>
<thead>
<tr>
<th>Tasks</th>
<th>Ready and closed by HAEA</th>
<th>Ready and under review by HAEA</th>
<th>Ongoing</th>
<th>Ongoing with delay</th>
<th>Ongoing with expected delay</th>
</tr>
</thead>
<tbody>
<tr>
<td>46</td>
<td>33</td>
<td>1</td>
<td>6</td>
<td>4</td>
<td>2</td>
</tr>
</tbody>
</table>

- **Ready and closed by HAEA**
- **Ready and under review by HAEA**
- **Ongoing**
- **Ongoing with delay**
- **Ongoing with expected delay**
Summary

The safety improvements has a long history at Paks NPP. The enhancement of nuclear safety had been started in Paks already before the commissioning of Unit 4 in 1987. The core damage frequency decreased by one order of magnitude as a results of safety improvement projects.

The implementation of severe accident management was started and partly performed at Paks before Fukushima accident. By now, the elements of SAM have been performed, except of the prevention of containment long term over-pressurization.
Summary

The Targeted safety reassessment did not reveal any such deficiency at Paks NPP, which may question the adequacy of its design basis and may require any urgent intervention. Much of the tasks decided were met.

Some tasks delay mainly because

- their complexity; and
- long-lasting public procurement procedures
Thank you for your attention!