UJV Rez, a. s.

Simulator Data Collection in Czech Republic

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Outline

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  - Czech NPPs: Temelin and Dukovany
  - Introduction of UJV Rez
- Previous data collection projects
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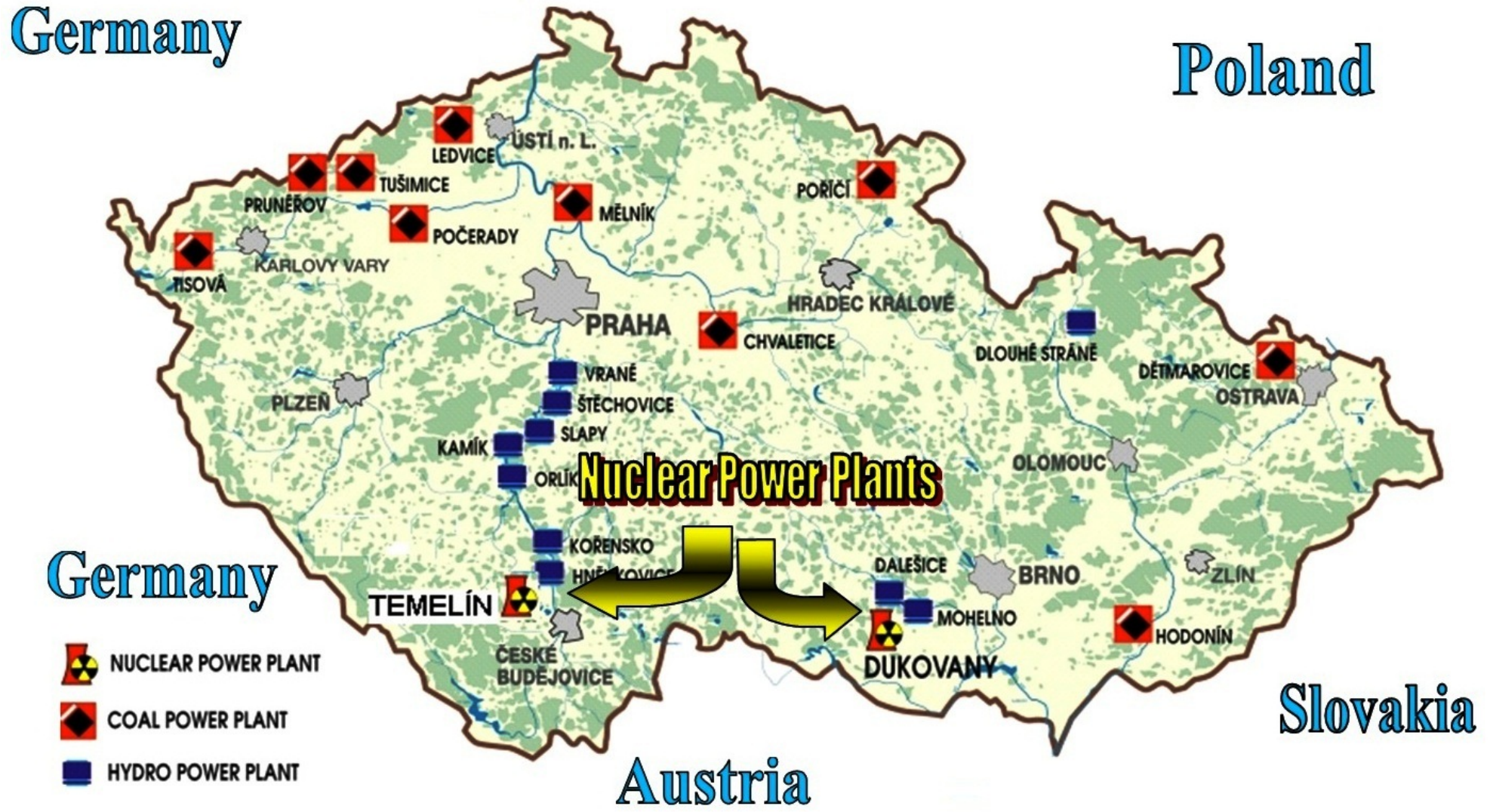
  - NPP Dukovany simulator data collection (II) - 2010-2012
- Current data collection project
  - NPP Dukovany and Temelin data collection (III) - 2017-2020

Czech Power Plants



Distribution of power sources

- **Gross power generation: 82 TWh (2017)**
  - Coal power plants: 37,6 TWh (45,8%)
  - **Nuclear power plants: 28,0 TWh (34,2%)**
  - Gas power plants: 5,1 TWh (6,3%)
  - Hydro power plants: 2,9 TWh (3,5%)
  - Solar power plants: 2,2 TWh (2,6%)
  - Biomass: 2,0 TWh (2,5%)
  - Wind power plants: 0,6 TWh (0,7%)
  - Other (renewable energy): 3,6 TWh (4,4%)

- **Total installed electrical capacity: 21 GWe (2014)**
  - Thermal power plants: 10,9 GW (52%)
  - **Nuclear power plants: 4,3 GW (20,5%)**
  - Hydro power plants: 2,3 GW (11%)
  - Solar power plants: 2,1 GW (10%)
  - Gas power plants: 1,3 GW (6%)
  - Wind power plants: 0,3 GW (1%)

Information source: http://oenergetice.cz/energostat/

Czech Nuclear Power Plants

Dukovany NPP (EDU)

- In operation since 1985(-1987)
- Four VVER-440, Model 213 pressurized water reactors
- 2 turbogenerators per reactor - Skoda: 250 MWe each
- Installed capacity increased up to 4 x 500 MWe during modernisation process in 2005-2012

Temelin NPP (ETE)

- In commercial operation since 2004
- Two VVER 1000/320 reactors
- Pressurized water reactor with 4 loops
- 1 turbogenerator per reactor - Škoda: 1000 MWe

UJV Rez – General information

- **UJV Rez (=Nuclear Research Institute) established in 1955**
- **UJV is a leading subject in research and development activities in nuclear technologies in the Czech Rep.**
- **UJV operates:**
  - 2 research nuclear reactors,
  - hot cell facility,
  - research laboratories,
  - radionuclide irradiators,
  - technology for radioactive waste management, etc.
- **Research activities are mainly targeted at assisting the**
  - power plant operator,
  - regulatory body and
  - nuclear facilities contractors

Number of employees – cca 1000

The first full-scope simulator data collection at Trnava

- Performed in time period 1998-2000
- Sponsored by DOE (U.S. Department of Energy)
- Coordinated by PNNL - Pacific Northwest National Laboratory
- Cooperation with NPP Dukovany, PNNL, VEIKI Budapest and VUJE Trnava
- Project divided into 15 Tasks (steps)
- Every task documented in comprehensive report written in Czech and English
- 18 crews from NPP Dukovany went through 18 different scenarios (each crew passed 6 different scenarios) -> 108 simulator runs

Simulator Data Collection I - Goals

- Basic goal: to obtain information for **re-quantification of human failure events** of PSA model
- Extended goal: to provide plant with **feedback** regarding factors influencing operators‘ work, particularly concerning **new symptom based procedures**
- Potential goal: to help to advance control room staff training

Simulator Data Collection I (Tasks 1-5)

- Task 1, 2 - preparation, organization and control of the project (carried out by PNNL)
- Task 3 - revision of available worldwide experience with simulator data collection (in cooperation with VEIKI)
- Task 4 - selection and preparation of appropriate methodology of data collection
- Task 5 - preparation of accident scenarios for first series of data collection

Simulator Data Collection I (Tasks 6-10)

- Task 6 - preparation of manual data collection tools
- Task 7 - development of data collection procedure
- Task 8 - first series of simulator data collection (Autumn 1998, 6 crews in 7 accident scenarios), qualitative data analysis
- Task 9 - development of specific methodology for quantitative data analysis, quantitative analysis of data
- Task 10 - development of tools for semi-automatic data collection (bar code sheets, configuration of bar code readers)

Simulator Data Collection I (Tasks 11-15)

- Task 11 - preparation of scenarios for second series of data collection
- Task 12 - second series of simulator data collection (Spring 1999, 6 crews in six 5 accident scenarios)
- Task 13 - qualitative and quantitative analysis of data from second series of data collection
- Task 14 - transfer of methodology to VUJE Trnava, Slovak Republic
- Task 15 - third series of data collection, data evaluation and quantitative analysis (Spring 2000, 6 crews in 6 accident scenarios, re-qualification finished)

Simulator Data Collection I - data evaluation

- Control room crew performance of every crew in every individual step of symptom based procedures analyzed and described
- Average score of every crew in every procedure as well as every simulated accident scenario derived
- Statistical hypotheses about importance of factors influencing operators work formulated and tested
- Some human error probabilities in PSA modified

Simulator Data Collection I - classification of individual procedural step

- Score 0 - step performed without problems
- Score 1 - hesitation, small problems, but the result OK
- Score 2 - significant failure not influencing accident scenario as a whole
- Score 3 - serious failure, simulator instructor intervention necessary

Simulator Data Collection I - some qualitative insights

- **Communication** was found to be key factor when working with symptom based procedures
- Many types of deficient communication - some measures related to **training** as well as work in accident conditions proposed
- Another key factor is **psychological profile** of shift supervisor
- Quality of the process of **selection of candidates** for operators and particularly shift supervisor function is very important

Simulator Data Collection I - some qualitative insights (2)

- No significant difference between performance of reactor and turbine operator confirmed
- Negative influence of failure of performance in next steps not confirmed
- Significant difference between crews performance during re-qualification and after it confirmed on high confidence level (conclusion: the crews are well trained, the training process was effective)

Simulator Data Collection I - requantification of HEP

- HEP adjustment approximately in order of 20-30%
- Positive adjustment made in most cases (cooling down by pre-defined trend)
- Negative adjustment in two cases (crew work with primary circuit charging system)
- Highest positive adjustment - fast loop isolation after SGTR - HEP value went down by 32.5%

Simulator Data Collection I - requantification of HEP

Action	Full-scope simulator statistics	Original value	New value
Operator opens the control valves of feedwater lines.	6 trials, without significant problem	2,03E-02	1,81E-02
Operator starts auxiliary feedwater pump manually.	24 trials, without significant problem	9,00E-03	7,40E-03
Operator opens the valves on emergency feedwater lines manually.	6 trials, without significant problem	2,96E-02	2,51E-02
Operator performs high rate cooldown (60°C, SGTR scenario).	12 trials, without significant problem	2,00E-02	1,60E-02
Operator performs isolation of hydroaccumulators.	18 trials, without significant problem	2,00E-02	1,47E-02
Operator performs isolation of the primary circuit loop with interfacing LOCA by main isolation valves.	12 trials, without significant problem	2,40E-02	1,86E-02
Operator performs isolation of steam generator from the secondary circuit side.	12 trials, 1 problem	4,10E-02	5,50E-02
Operator starts main feedwater pumps manually.	24 trials, without significant problem	9,00E-03	7,40E-03
Operator performs isolation of the primary circuit loop with damaged steam generator in the SGTR scenario.	**12 trials, without significant problem**	**4,00E-02**	**2,70E-02**
Operator starts primary circuit charging pump manually.	36 trials, 2 problems	3,03E-02	4,35E-02

Simulator Data Collection I – conclusions

- Simulator data collection and evaluation methodology transferred, modified and extended
- The methodology was used to gather and analyze data within more than two years of full-scope simulator exercises
- Using of methodology is restricted to analysis of crews working with symptom based procedures
- Significant increasing reliability of NPP Dukovany control room crews when working with new symptom based procedures was confirmed (by using of "objective" formal statistical methods)

The Second Simulator Data Collection at Dukovany NPP

- **Facility: Dukovany NPP full-scope training simulator**
- **24-34 crews involved (depended on scenario)**
- **Time period 2010-2013**
  - 2011: **24 crews** involved in **4 scenarios** - corresponds to 96 simulator runs
  - 2012: **34 crews** involved in **5 scenarios** - corresponds to 170 simulator runs
  - 2013: **30 crews** involved in **2 scenarios** - corresponds to 60 simulator runs
- **Mode of collection – combination of offline (automatic software) and online (personal observation) collection**

Simulator Data Collection II – Main Goals

- **Basic goals:**
  - to obtain information for better quantification of human failure events included in PSA model
  - to provide feedback and recommendations for improvement of symptom based procedures and training
- **Extended goal: to provide plant with feedback regarding factors influencing operators‘ work:**
  - available time windows
  - task complexity
  - stress level, etc.

Simulator Data Collection II - Schedule

- **2010: Preparation of the project**
  - UJV Rez prepared methodology for data collection
  - 120 important parameters and indications of equipment status (running x stand-by pumps, open x closed valves,…) appointed for collection

- **2011: Data collection**
  - OSC Company created special software for collection of selected data
  - Training instructors in cooperation with UJV experts appointed **4 training scenarios for collection**
  - Simulator runs started in October 2011

Simulator Data Collection II - Schedule

- **2012: Analysis and evaluation of collected data + data collection**
  - **6 training scenarios** appointed for collection
  - Simulator runs started in September 2012
  - Analysis and evaluation of data collected in 2011-2012

- **2013: Analysis and evaluation of collected data + data collection**
  - **2 training scenarios** appointed for collection
  - Simulator runs started in January 2013
  - Analysis and evaluation of data collected in 2012-2013

Simulator Data Collection II - Scenarios

- **2011** (bold scenarios analysed in detail)**:**
  1. Leakage on seal lines related to main reactor coolant pump
  2. **Rupture of main feedwater collector (3000 t/h)**
  3. **Steam generator collector rupture (300 t/h) and PORV stuck open**
  4. **Fire at RRCS system (Reactor Rod Control System) leading to ATWS (Anticipated Transient without Scram**)

Simulator Data Collection II - Scenarios

- **2012** (bold scenarios analysed in detail)**:**
  1. Failure of generator breaker followed by automatic switchover to standby power assured by 110 kV switchyard
  2. Inadvertent closure of main steam isolation valve (MSIV)
  3. **Steam generator collector rupture (400 t/h) combined with stuck closed main isolation valve in a cold leg followed by pressurized thermal shock (PTS)**
  4. **Pressurized thermal shock caused by stuck closed main isolation valve in combination with high pressure injection**
  5. **Steamline break into containment (30 t/h) – without ESFAS (Engineered Safety Features Actuation System) actuation**
  6. Leakage from system US20 outside containment
- **SGCR + PTS scenarios trained together as one session**

Simulator Data Collection II - Scenarios

- **2013** (bold scenarios analysed in detail)**:**
  1. **Hot leg rupture (250 t/h)**
  2. Rupture of SG1 followed by feedwater leak into SG compartment (1200 t/h)...

Simulator Data Collection II - Recommendations

- Results and recommendations summarized in EPRI Report:
  - Use of Simulator Data to Support HRA: A Case Study from UJV Rez. EPRI, Palo Alto, CA: 2013. 3002001038.

- The main findings of the project were presented to CR crews during special education lessons

Simulator Data Collection II - Recommendations

- **Recommendations to HRA Quantification (Failure Mechanisms, PSFs)**
  - Changed quantification of some human failure events included in PSA (using Bayesian approach)
  - Take into account „group setting“ control of some components (plant specific factor)
  - Confirmed some qualitative assumptions:
    - Negative dependence between operator errors
    - Need to consider
      - experience of operators
      - length of step,
      - number of negations,
      - step logic,
      - etc.

Simulator Data Collection II - Recommendations

- **Recommendations to Training**
  - Pay more attention to the instructions stated in the Conditional Information Pages
  - Too fast or imprecise (too silent) reading of procedure text by the unit supervisor
  - Observed deficiencies related to knowledge of some specific terms
    - *Cool down at maximum allowed rate*
    - *Six different types of reactor power*
  - Using three-way communication during phone calls **with local personal only**
  - Enable operators to observe performance of other crews

Simulator Data Collection II - Recommendations

- **Recommendations to Procedures**
- **Goal: Identify shortcomings in ergonomy of symptom based procedures related to human factors aspects (design, formulations, logic, step length,...)**
- **Scope of analyzed procedures:**
  - Procedures for abnormal conditions – LOCAs (type A)
  - Emergency operating procedures (type E)
  - Procedures for function restoration (type FR)
  - Procedures for low power and shut down states (type SD)

- Note: Czech symptom based procedures are based on Westinghouse logic of procedures

Simulator Data Collection II - Recommendations to Procedures

- **Generally, quality of the procedures was assessed as very high**
- **Several recommendations were formulated, e.g.:**
  - Problems with NOT logic -> eliminate if possible
  - More accurate formulations (parameter is stable, pressure is normal, the value of parameter X “trends” to the value of Y,...)
  - Adding or removing some definitions of important terms (3 types of levels in SGs or pressurizer, 6 different types of reactor power)
  - Some procedural steps were too complicated or long -> divide into more steps
  - Different shading of rows in case of long tables
  - Missing logic operators (-AND-, -OR-, -IF - THEN-,...) -> rigorous using of logic operators + highlight all the operators (in bold)

Current Simulator Data Collection (III)

- **Time period 2017-2020**
- **Funded by Technology Agency of the Czech Rep.**
  - TACR provides financial support for R&D from national budget
- **Facility:**
  - **Dukovany NPP (EDU)** full-scope training simulator (FSS)
  - **Temelin NPP (ETE)** full-scope training simulator (FSS)
- **Crews involved**
  - 32 crews at Dukovany NPP
  - 16 crews at Temelin NPP
- **Mode of collection – combination of offline (automatic software) and online (personal observation) collection**
- **Cooperation with Czech universities**

Current Simulator Data Collection (III)

- Goal of the project is development and testing of NPP control room simulator data collection methods and results, with focus on abnormal and emergency operation.
- The main areas of interest are:

1. searching of priorities in human factors treatment for CR crew, including support of HRA as a part of PSA
2. improvement of control room operators training
3. improvement of ergonomics of symptom based and other procedures used by CR crew
4. improvement of simulation runs, searching for problems occurred during simulations

Current Simulator Data Collection (III)

- **Schedule**
  - **09/2017: Development of collecting module (software) for EDU**
  - **12/2017: Data collection at EDU (1st run)**
  - **03/2018: Development of collecting module (software) for ETE**
  - 06/2018: Data collection at ETE (1st run)
  - 12/2018: Analysis of data: results & recommendations (1st run)
  - 2019: Continuation of data collection at EDU and ETE NPPs (2nd run)
  - 12/2019: Analysis of data: results & recommendations (2nd run)
  - 2020: Continuation of data collection at EDU and ETE NPPs (3rd run)
  - 10/2020: Final results & recommendations (based on all runs)

Current Simulator Data Collection (III)

- **Scenarios selected for collection at Dukovany NPP:**
  - Main Steam Collector Break (50 t/h)
  - Large Loss of Coolant Accident Followed by Flooding of Hermetic Rooms
  - **LOCA (65 t/h) and Steam Generator Tube Rupture (17 t/h)**

- **Analysis of data from these scenarios started in March 2018**
- **Scenarios for collection at Temelin FSS will be selected in April 2018**

Thank you for your attention!