UJV Rez, a. s.

HRA Data Collection Projects in Czech Republic

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- Current data collection project
  - NPP Dukovany and Temelin data collection (III) - 2017-2020

Czech Power Plants

Czech Nuclear Power Plants

Dukovany NPP (EDU)

- In operation since 1985(-1987)
- Four VVER-440/213 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 pressurized water 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 - 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

- 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
- OSC Company developed special software for collection of selected data
- Analysis and evaluation of collected data performed by UJV experts in 2012-2013

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

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**
  - 28 crews at Dukovany NPP (4 reactor units)
  - 14 crews at Temelin NPP (2 reactor units)
- **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**
  - 2017: Development of data collecting modules (software)
  - 2018: Data collection at EDU and ETE NPPs (**1st run**)
  - 12/2018: Analysis of data: preliminary 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: Update of collecting modules
  - **10/2020: Final results & recommendations** (based on all runs)

Current Simulator Data Collection (III)

- Dukovany NPP (28 shifts for each task)
  1. LOCA (65 t/h) and SGTR (17 t/h)
  2. LOCA followed by flooding of hermetic rooms
  3. Main steam collector break (50 t/h)
  4. Loss of offsite power (LOOP)
  5. Loss of heat removal from the secondary side – **F&B**

- Temelín NPP (14 shifts for each task)
  1. **SGTR** with subsequent rupture of the steam line
  2. **SGTR** with ATWS
  3. Steam line rupture outside the containment
  4. Power decrease to house load consumption after LOOP

Simulator Data Collection III - Requantification of HEPs

- **DT+ASEP** used for original **quantification**
- **THERP** method used for **error factor assessment**
- **Bayesian** approach used for **HEPs modification**
  - **Approximation of original Log-normal distribution to Gamma distribution**
  - **28 trials (14 crews during 2 different excercises)**
- **SGTR/SGCR** are **risk dominant scenarios** in PSA model for Temelin NPP
- Values of **9 HFEs related to SGTR** scenarios were **modified** (more HEP updates will follow)
- Average **HEP decrease** by approx. **35%**

Simulator Data Collection III - Requantification of HEPs

#	HFE	Description	Original HEP	New HEP	Change [%]
1	**HEP3-E3A-S2-3**	**Identify the faulted SG and to perform the initial steps of the procedure E3-A: close and de-energize atmospheric steam dump valve (SDV), isolate steam header from steam consumers.**	**2,00E-02**	**1,46E-02**	**-27%**
2	HEP3-E3A-S4	Set up the FW flow into the damaged SG.	4,60E-02	2,47E-02	-46%
3	HEP3-E3A-S4T10	Set up the FW flow into the damaged SG (large break - shorter time).	3,00E-01	1,25E-01	-58%
4	HEP3-E3A-T10	Identify the faulted SG (large break) and to perform the initial steps of the procedure E3-A: de-energize ASDV, set condenser SDV pressure, isolate steam header from steam consumers.	5,10E-02	2,61E-02	-49%
5	HEP3-E3-S12	Identification of damaged SG and preparation of cool down and depressurization of PC.	2,70E-03	2,51E-03	-7%
6	HEP3-E3-S3	Isolate the intact SGs and to maintain FW level in faulted SG.	1,59E-02	1,10E-02	-31%
7	HEP3-ECA-3_1	Cooldown and depressurize PC to minimize loss of PC coolant. A maximum cooldown rate of 60°C/hour is allowed.	2,15E-02	1,53E-02	-29%
8	HEP3-ECA-3_2	Cooldown and depressurize PC to minimize loss of PC coolant. A maximum cooldown rate of 60°C/hour is allowed. SGTR combined with PC loss of coolant.	4,80E-02	2,53E-02	-47%
9	HEP3-FR-C	To take any action to guarantee core cooling: rapid depressurization through SC or opening of paths among top segments of PC.	1,32E-02	1,06E-02	-20%

Simulator Data Collection III - Requantification of HEPs: Example (1)

- **HEP3-E3A-S2-3: Identify faulted SG** and to perform initial steps of procedure E3-A: **close and de-energize** atmospheric steam dump valve (**SDV**), **isolate steam header** from steam consumers
  - **Original value of HFE** (HEP3-E3A-S2-3): **2.00E-02 (DT+ASEP)**
  - **Prior distribution: Lognormal** - error factor **EF = 5**
  - **Number of simulator runs: T = 28**
  - **Number of observed human errors: r = 0**
  - **Approximation of prior distribution to Gamma distribution**
    - Degree of freedom **N = 3** (based on EF, derived from tables)
    - Mean value of Gamma dist: **E** = p1/p2 = **0.02** (original HEP)
    - Parameter p1 = N/2 = 1.5
    - Parameter p2 = p1/E = 1.5/0.02 = 75

Simulator Data Collection III - Requantification of HEPs: Example (2)

- Parameters of posterior distribution:
  - q1 = p1 + r = 1.5 + 0 = 1.5
  - q2 = p2 + T = 75 + 28 = 103
- Final mean of posterior distribution = q1/q2 = 1.46E-02
- Original HEP 2.0E-02, updated HEP = 1.5E-02
  - 27% decrease

Simulator Data Collection - Recommendations to HRA Quantification

- **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 - 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 - 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 - 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)

Thank you for your attention!