Technical Meeting on Effective Utilization of Nuclear Power Plant Simulators as Introductory Educational Tools

Nuclear Power Plant Training for the Next Generation
Overview

• WSC Company Introduction
• Generic Nuclear Full Scope PWR Simulator
• 3KEYITS - Intelligent Tutoring System
• 3KEYSTUDENT - Web-Based
• Users & Classrooms
• Demo
WSC Company Overview

- A Multi-National Company founded in 1995
- Employees: ≈ 95; Multidisciplinary team of nuclear, mechanical, electrical, chemical engineers, physicists and computer scientists, 30% with advance degrees.
- Research Oriented – over 20% of gross profit goes into R&D
- Headquarters in Frederick, Maryland, USA
- Main Business - Power Plant Simulation
  - Nuclear Power Plant Simulators 40%
  - conventional Power Plant Simulators 30%
  - Simulation Assisted Engineering 20%
  - Navy and Marine Simulation 5%
  - Process and Pipelines 5%
- ISO 9001:2008 Certified
3KEYMASTER™ Simulation Platform and Modeling Tools

3KEYRELAP5-RT™ – Adaptation of INL’s RELAP-3D©, including NESTLE, providing real-time visualization and engineering grade modeling for Thermal-hydraulics and Neutron Kinetics

3KEYSAA - Adaptation of NRC’s MELCOR 2.1 Severe Accident Analysis code to run in real-time with visualization, interfaced with 3KEYRELAP5-RT™

3KEYDCS™ –that provides accurate emulation for Distributed Control System Logic and Man-Machine Interfaces, including trend and alarm displays

3KEYSAFE™ – Configuration Management Solution from reference plant design through all stages of plant design evolution

3KEYSTUDENT/ITS™ – Web based, & Classroom Intelligent Tutoring System
Nuclear Simulator Clients

- KHNP, Shin Kori 3&4 APR 1400 PWR
- APS, Palo Verde PWR
- BNFL: Magnox Simulator Upgrades
- ENTERGY, Vermont Yankee BWR
- FP&L, Seabrook, St. Lucie & Turkey Pt PWR
- Southern SNC, Hatch BWR
- Luminant, Comanche Peak PWR
- Toshiba, STP 3&4 BWR
- TVA, Sequoyah PWR
- INER, Taiwan BWR
- U.S. Navy Bettis/NNS/GD
- WCNOC, Wolf Creek PWR
- KSU (Sweden), R3 PWR
- GE, ESBWR
- Progress, Robinson PWR
- TPC/GE/ADT, Lungmen ABWR
- TPC, Chinshan BWR
- Bruce Power, Bruce B Candu
- PPL, Susquehanna BWR
- OPG, Darlington, Candu
- KHNP, Shin Kori 1&2, Kori 1 PWR
- CNPSC, Ningde & Yang Jiang CPR 1000 and HTR
Recent nuclear new builds and next generation reactors using WSC technology:

- Korea Hydro Nuclear Power, Shin Kori 3&4 APR 1400 PWR
- China Guangdong Nuclear Power Company, Ningde, Yang Jiang & Fangchengang CPR 1000, CNRSC Generic CPR 1000 with Severe Accident Modelling
- Emirates Nuclear Energy Corporation (ENEC) in UAE for Barakah NPP GPWR Classroom Simulator and Full Scope Simulators
- GE-Hitachi, ESBWR Simulation Assisted Engineering
- Toshiba ABWR, South Texas
- Taiwan Power Company TPC, Lungmen ABWR
- TerraPower Traveling Wave Reactor
- Holtec SMR
- Chinergy China HTR SMR
WSC Simulation Environment and Modeling Tools

SCADA/DCS/PLC Systems

Flow Systems

Instructor Station

Wiring/Protection

Electrical

Logic & control
Generic PWR Simulator
✓ Need to educate, recruit and maybe most importantly attract the next generation of engineers to the nuclear industry

“I need technology to excite the engineers that has the functionality he or she has in their mobile phone” Director of Training for the STARS Alliance in the US
• Attributes for the Generic PWR:
  - A modern look and feel for the Human Machine Interface (HMI). (panels are confusing to students)
  - Generic high fidelity models that require no third party software. Meets ANSI3.5 standard.
  - Self-paced learning software that complements or can be independent of classroom instruction.
Generic PWR Features and Capabilities

• The GPWR simulator is based on a two loop Pressurized Water Reactor Similar to the APR1400 with 1400 MWe output

• The simulator includes over 75 graphic control screens capable of operating the power plant from cold shutdown to full power with 10,000 supervised points

• The simulator includes an alarm and event system to aid in the operation and fault analysis

• A full featured trending system complements the plant controls to allow for supervision of one or multiple points to evaluate plant behavior and transients

• A full featured Instructor Station capable of inserting 100s of malfunctions
Plant Overview

✓ See the whole plant
✓ Select & Click System of Interest

Plant System Menu

✓ Easy access to plant systems
Learn

- How the nuclear plant works
- Purpose of safety and non-safety systems
- How each system works
- Controls & Feedbacks

Do

- Plant Operation (normal, abnormal, transients and malfunctions)
- What if, Engineering studies
- Control the plant thru transients
Sample HMI Screens

Reactor Rod Control

Main Generation

Main Turbine Generator
## Alarms, Events and Trends Screens

### Alarms

<table>
<thead>
<tr>
<th>NAME</th>
<th>TIME</th>
<th>DESCRIPTION</th>
<th>SYSTEM</th>
<th>STATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALM RCS 875</td>
<td>00:00:00</td>
<td>TREE FAULT TR</td>
<td>RCS</td>
<td>ACTIVE</td>
</tr>
<tr>
<td>ALM RPS 2555</td>
<td>00:00:07</td>
<td>TEMPERATURE IN CALIBRATION LINE POWER</td>
<td>RPS</td>
<td>NOT ACTIVE</td>
</tr>
<tr>
<td>ALM MBP 6445</td>
<td>00:00:36</td>
<td>SG 1 FLOW MISMATCH</td>
<td>MBP</td>
<td>NOT ACTIVE</td>
</tr>
<tr>
<td>ALM MBP 8441</td>
<td>00:01:56</td>
<td>SG 1 FLOW MISMATCH</td>
<td>MBP</td>
<td>NOT ACTIVE</td>
</tr>
<tr>
<td>ALM RCS 2494</td>
<td>00:03:00</td>
<td>BORON DILUTION PERRMED</td>
<td>RCS</td>
<td>ACTIVATED</td>
</tr>
<tr>
<td>ALM RCS 2494</td>
<td>00:03:00</td>
<td>P 13 HP (UP)</td>
<td>RCS</td>
<td>ACTIVATED</td>
</tr>
<tr>
<td>ALM RCS 2412</td>
<td>00:03:00</td>
<td>P 9 (N-N9)</td>
<td>RCS</td>
<td>ACTIVATED</td>
</tr>
<tr>
<td>ALM RCS 22125</td>
<td>00:03:00</td>
<td>C 9C HP COND AVAILABLE</td>
<td>RCS</td>
<td>ACTIVATED</td>
</tr>
<tr>
<td>ALM RCS 2208</td>
<td>00:03:00</td>
<td>C 9A LP COND AVAILABLE</td>
<td>RCS</td>
<td>ACTIVATED</td>
</tr>
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</table>

### Events Log

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
<th>Description</th>
<th>Location</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>00:02:06</td>
<td>ALM MPR 4350</td>
<td>SG 1 LEV DRY</td>
<td>ACTIVE</td>
<td></td>
</tr>
<tr>
<td>00:02:06</td>
<td>ALM MPR 4350</td>
<td>SG 1 LEV DRY</td>
<td>ACTIVE</td>
<td></td>
</tr>
<tr>
<td>00:06:33</td>
<td>P 1055A</td>
<td>SG 1 APT FW REG CVY GREEN LAMP</td>
<td>OFF</td>
<td></td>
</tr>
<tr>
<td>00:06:33</td>
<td>P 1055A</td>
<td>SG 1 APT FW REG CVY GREEN LAMP</td>
<td>OFF</td>
<td></td>
</tr>
<tr>
<td>00:06:33</td>
<td>P 2065B</td>
<td>SG 1 APT FW REG CVY GREEN LAMP</td>
<td>OFF</td>
<td></td>
</tr>
<tr>
<td>00:06:33</td>
<td>P 2065B</td>
<td>SG 1 APT FW REG CVY GREEN LAMP</td>
<td>OFF</td>
<td></td>
</tr>
<tr>
<td>00:06:33</td>
<td>P 1055A</td>
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<td></td>
</tr>
</tbody>
</table>

### Simultaneous Trip of all Feedwater Pumps

- **Trip Conditions**
  - Trip due to low feedwater flow
  - Trip due to high feedwater pressure
  - Trip due to high feedwater temperature
  - Trip due to feedwater pump failure

- **Trip Sequences**
  - Pump trip sequence
  - Pump trip confirmation
  - Pump trip reset

- **Trip Indicators**
  - Feedwater flow gauges
  - Feedwater pressure gauges
  - Feedwater temperature gauges
Reactor Graphics

Pressure, Temperature, Void, Neutron Flux
Controls

Pop-up Controls
A full featured Instructor Station aids Instructor control over the system.
VVER 1000
Intelligent Tutoring System
What is Intelligent Tutoring System

- **Intelligent Tutoring System (ITS):**
  - Automated training development tool to augment Training

- Using Experience and Knowledge, Instructors can create lessons for all levels of Student use, from Beginner to Advanced
Intelligent Tutoring System

- Self-paced and effective learning
  - Students can run a lesson plan without an instructor
  - Students can opt for lower level course until ready for the next level
  - On-line and context-specific tutoring at time of need
- Promote in-depth learning — lesson plans can be created that describe the inner workings of systems and not just common operating scenarios. Deeper understanding promotes better response in abnormal situations
- Effective utilization of instructors’ time — freed from tasks that can be automated, instructors can focus on observing and interacting with students
- Enables a high-quality and structured training program
- Speech recognition and voice synthesizer feature allows interaction with the simulator without the distraction of writing or reading
- Simulator-based lessons can be made available organization-wide to promote learning, e.g., to engineering

Learning centrifugal pump theory and do an exercise on the simulator using ITS
Multi-Tier ITS Lessons

- **1-01 ITS Lesson**
- **1-02 HMI Introductions**
- **2-01 Generic PWR General Description**
- **2-02 Generic PWR Primary Systems**
- **2-03 Generic PWR Balance of Plant Systems**
- **2-04 Generic PWR Generator and Electrical Systems**
- **3-01 Heat Exchanger Lesson**
- **3-02 Swap Running Feedwater Pump**
- **3-03 Steam Turbine Startup**
- **3-04 Generator and Main Power**
- **3-05 Reactor Protection**

Heat Exchangers theory Lesson & simulator exercise

Lesson on HP & LP Turbines with simulator exercise
# Three-Tiered Learning Approach

<table>
<thead>
<tr>
<th>Show Me</th>
<th>Mentor Me</th>
<th>Test Me</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Provide the learner with:</strong>&lt;br&gt;• Guided demonstration&lt;br&gt;• Operational fundamentals (‘why’)</td>
<td><strong>Provide the learner with:</strong>&lt;br&gt;• Access to the plant simulator&lt;br&gt;• Guidance from the Intelligent Tutoring System (ITS)</td>
<td><strong>Provide the learner with:</strong>&lt;br&gt;• Access to the plant simulator&lt;br&gt;• Operational/procedure steps</td>
</tr>
<tr>
<td><strong>Learner will:</strong>&lt;br&gt;• Complete a lesson&lt;br&gt;• Practice the procedure and learn operations fundamentals&lt;br&gt;• Answer review questions (reinforce knowledge)</td>
<td><strong>Learner will:</strong>&lt;br&gt;• Perform actions in the simulator&lt;br&gt;• Complete lessons in a specified timeframe&lt;br&gt;• Receive instructions and advice throughout the lesson</td>
<td><strong>Learner will:</strong>&lt;br&gt;• Perform operational steps in the simulator&lt;br&gt;• Demonstrate ability to properly and efficiently run the plant</td>
</tr>
</tbody>
</table>
Lunch a Lesson

- Simulator is integrated with a full featured ITS to provide instructions and procedures visually and verbally.
- Different modes of operation based on “show”, mentor” and “test” modes.
- ITS Control Box for student to manage the lesson.
- Provides time and score functionality compliant with SCORM LMS Systems.
The Simulator, integrated with a full featured ITS provides instructions and procedures visually and verbally.
° Continue, Pause the lesson
° Cancel the Lesson
° Message
° Advice: call the HMI, highlight the operation
° Graphics: supporting graphics, Video
° Repeat step
° Next Step
° Silence the narrative

Placing the A main feedwater pump control in manual allows the operator the ability to slowly reduce the pump speed while the B pump increases to maintain steam generator water level.
ITS Advice

Takes student to HMI page; Hints with graphical highlights to aid student in understanding the lessons; Provides more information
3KEYITS Advice

Hints with graphical highlights to aid students
Create Basic to Advance Lessons with ITS

Record Features to improve the efficiency of generating lessons
Lesson Scripts

Reset to IC

Power Point

Steps

Messages

Advices

Trends

Reset 1
Trend
Scn open main screen
Step 1 Introduction
Description 1 Introduction
Timeout 30
Advice First the lesson will cover the objectives and know the message This lesson will apply the principles of heat transfer Execute Heat exchangers.ppsx
Trend trends\Feedwater Heater 7A Temperature Profile.tnd
Step 2 Increase Feedwater Heater 7A Level for Performance Check
Description 2 Increase Feedwater Heater 7A Level for Performance Check
Timeout 30
Message In this exercise the field operator will slowly raise the temperature of the feedwater heater 7A during
Scn FW HTR 7A Level Increase
Step 3 Monitor Heater 7A Performance
Description 3 Monitor Heater 7A Performance
Timeout 30
Message Monitor Heater 7A Performance@SSM.mp3
Advice Note the initial drop in heater drain temperature with the opening of the feedwater heater 7A level increase with dump opening
Scn FW HTR 7A Level Increase
Step 4 Feedwater Heater 7A Level Increase with Dump Opening
Description 4 Feedwater Heater 7A Level Increase With Dump Opening
Timeout 30
Message Now the level is raised above the dump opening post advice with the emergency drain open, the heat contained in the feedwater heater will increase
Scn FW HTR 7A Level Increase
Step 5 Monitor Heater 7A Performance
Description 5 Monitor Heater 7A Performance
Timeout 30
Message Monitor Heater 7A Performance@SSM.mp3
Advice Note the opening of the 7A Feedwater heater alternate operating with a low FW heater level
Scn FW HTR 7A Level Decrease
Step 6 Monitor FW Heater 7A Performance
Description 6 Operating With a Low FW Heater Level
Timeout 30
Message Now the 7A Feedwater heater level control will be advice on a low heater level, flashing will occur on the heat exchanger.
Scn FW HTR 7A Level Decrease
Step 7 Monitor FW Heater 7A Performance
Description 7 Monitor FW Heater 7A Performance
Timeout 160
Message Monitor FW Heater 7A Performance
Advance As the level drops, the drain temperature starts to increase, and the heater performance when the water level is too low,
Reset 23
Trend
Trend trends\Feedwater Heater 7A Temperature Profile.tnd
Step 8 Feedwater Heater Venting
Description 8 Feed Water Heater Venting
Timeout 60
Message Another condition that can reduce the heat transfer after the main Feedwater HMI, compare the 7A and 7B Condition System.ClickTest
Step 9 Check The Feedwater Heater Water Level
Description 9 Check The Feedwater Heater Water Level
Timeout 30
Message Check the Feedwater Heater Water Level Message from the FW Heater Exclusions, Drains and Vents (Note Alert since an abnormal Feedwater heater level can affect Alert)
Alert A field operator has been dispatched to verify the shell side...
Access Simulator & ITS Lessons via organization Intranet or Internet

3KEYSTUDENT™ Web-based Learning System Solution
ITS & WebITS

Local ITS (development computer)

- Local ITS
- 3KM Engineering Station
- 3KM Simulation Server
- Drawings
- Copy Lessons
- 3KM To Silverlight Converter
- Lessons

Web ITS

- 3KeyStudent
- Web ITS
- Drawings
- Lessons
- 3KM Simulation Server
- Web Server
3KEYSTUDENT - GPWR & Lessons runs on organization Intranet or Internet
Examples of Educational Classrooms
Layout & Network
Web-Based Computer Complex
Bismarck State College

Server Room – Web Farm

- KVM Switch
- Simulation Server #1
- Simulation Server #2
- Simulation Server #3
- Simulation Server #4
- Web Server

Web-Based Simulation Clients

- Home Desktop
- Home Desktop with 2 LCDs
- Home Laptop
- Office Laptop with 2<sup>nd</sup> LCD
- Office Laptop
- Office Desktop with 2 LCDs

Internet

Connect via Industry Standard Web Browser

Local Area Network

Classroom or Meeting Room
IAEA NAEC Layouts of Delivered Classroom Simulator
Classrooms

ENEC GPWR & 3KEYITS Training Simulator Classroom
TRCC college Lab Platform

- GPWR full scope simulator model
- Two GlassTop (touchscreens)
- Configurations:
  - One Power plant
    - Student 1 controls the Reactor
    - Student 2 controls the Turbine
  - Two individual plants
- Full functional Instructor Station
- Intelligent Tutor System (ITS)
  - Automated training lessons
Current Users

3KEYITS with GPWR:

- Emirates Nuclear Energy Corporation (ENEC)
- Khalifa University
- Bismarck State College
- IAEA – NAEC
- Three River State College

The 3KEYITS for non-Nuclear:

- EPRI – Generic CC
- EEI – Joppa
- ATCO – Battle River
- NRG – Keystone
- Bismarck State College
- General Physics
- LADWP: Haynes, Harbor, Valley CC
Demo: Example of a lesson in Intelligent Tutoring System

a. Review types of Heat Transfer with equations
b. Review Feedwater Heat Exchanger function
c. Simulator Exercise
THANK YOU!

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