Oconee Simulator Upgrade:
Delivering a Challenging Project On Time and On Budget

Leo Veilleux
Proposals Specialist
Topics

• **Background**
• **Simulator Upgrade Project**
  – Contract Award Criteria
  – Project Scope and Details
  – Testing and Commissioning
• **Conclusions**
Oconee Nuclear Station

- Located on Lake Keowee in Oconee County, SC
- Three Units
  - Babcock & Wilcox 2-Loop PWRs
  - Once-Through Steam Generators
- Commercial Operation
  - Unit 1: Jul, 1973
  - Unit 2: Sep, 1974
  - Unit 3: Dec, 1974
- Second nuclear station in USA to have its license renewed by the NRC
- DOE: South Carolina ranks #1 for nuclear share of electricity generation
  - 58.1% (2017)
Oconee Nuclear Station Simulator History

- 1983: Original simulator built by Electronics Associates Inc. (EAI) on Gould 32/77 with MPX-32 OS
- 1990: RCS and Core models replacement by Westinghouse, upgraded to Gould 32/97
- 1993: Computer and Operating System upgrade to hybrid UNIX and reflective memory
- 1996: Addition of ICS part-task trainer and I/O replacement (EAI → RTP)
- 1996: Plant Computer Replacement (OAC)
- 1997: Platform Upgrade to PC/Windows NT, using home-grown Tools and Executives:
  - Executives written in C/C++
  - Tools/Utilities written mostly in Visual Basic
- 1999: Core model replacement to Studsvik
L3 MAPPS History with Oconee Simulator

• 2004: Turbine EHC and partial model replacement
  – Reactor Coolant System (RCS)
  – Balance of Plant (BOP) and Primary Auxiliaries
  – Electrical Distribution
  – Reactor Containment Building and Ventilation
    ▪ Legacy I&C models and in-house developed platform retained

• 2009: Reactor Protection System (RPS) replacement
  – Graphical simulation model implemented
Oconee Nuclear Station Second Simulator

• **2010: Second Simulator in service**
  – Named Simulator Bravo (First is Alpha)
  – Also referenced to Unit 1
  – CR panels built by Mauell, using TMI I/O

• **Partial replacement of Simulator Alpha I/O**
  – Mixed RTP I/O and TMI I/O
  – Part task trainers retain RTP I/O
    ▪ Standby Shutdown Facility (SSF)
    ▪ Integrated Control System (ICS)
Simulator Upgrade Project
Simulator Upgrade Contract Award Criteria

• **Contract Award Criteria**
  - Pricing and Payment Terms
  - Compliance with Aggressive Timeline
  - Duke personnel familiarity with the platform and models
    - Oconee and McGuire
  - Competence (capability and qualifications)
  - Risk Management

• **Key Dates**
  - Duke Energy awarded contract to L3 MAPPS in July 2017
  - Simulators Ready for Training in October 2018
Project Scope

• **Rehosted simulator platform**
  - New computers and software environment
  - Replaced Instructor Station
  - Upgrade of communication interfaces with External Systems

• **Instructor Control Graphic Pages**
  - New soft (virtual) panels
  - New instructor active schematics

• **Plant Models**
  - NSSS models upgrade
  - Reactor core neutronics 3D viewer
  - Graphical models to replace legacy exception-triggered I&C

• **Audiovisual System upgrade**

• **Partial I/O System upgrade**

• **Software replacement for Glasstop Simulators**
Rehost

• New operating systems and third-party software
• Replaced Oconee in-house developed platform with Orchid® simulation environment
• Replatformed ROSE® and legacy simulation software to Orchid®
  – Source code
  – ROSE® models transferred to Orchid® Modeling Environment
  – Database
  – Initial conditions
  – Training exercises (scenarios)
  – etc.
New Computer System

• Windows 10 and Windows Server 2016 Operating Systems

• New computers supplied by L3 MAPPS
  – Alpha, Bravo, SSF and Development servers
  – Instructor Station desktop and tablet PCs
  – ICS and Engineering workstations
  – Audio-Visual Recording workstations and playback PCs

• Other Equipment supplied by L3 MAPPS
  – Self-Powered Speakers and Subwoofers (simulation-driven immersive sound system)
  – Large Touchscreen Displays (enhancement of ICS using virtual panels)

• Other IT infrastructure retained or supplied by Duke (networking, racks, KVMs, domain controllers/DNS, etc.)

• New Servers for Emulation of VMS-based external systems supplied by Duke Energy
Orchid® Instructor Station

- Simulation control and maintenance functions (freeze, unfreeze, store, restore, speed-up, slow-down, DORT, etc.)
- Replay scenarios and operator actions (synchronized with the other systems such as Orchid® Multimedia Manager, etc.)
- Insertion of plant component and system malfunctions, instrument overrides and local operator actions
- Direct access to modeling schematics, active schematics and virtual (soft) panels
- On-the-fly creation of active schematics and virtual panels
- Multiple operating modes i.e. instructor, operator, engineer and student
- Built-in exam security

- Focuses on automation and data collection
  - Create/edit graphical scenarios
  - Monitor, record and trend any parameter
  - Monitor and track operator performance
  - Scenario-based Testing and Training (SBT²)
  - Generate training performance records and reports based on ANSI/ANS-3.5 requirements

- Control and monitor all aspects of simulator and trainee performance
- Fully graphical user interface with standard Windows features e.g. drag and drop, window resizing, zoom, pan, etc.
- Highly configurable (e.g. toolbars, plant parameters, feature behaviors, etc.)
- User-defined windows layout
- Client/server application
- On-line PDF user manuals

PowerPlantSim 2019
© 2019 L3 MAPPS Inc. All rights reserved.
Turbine Control (EHC) and Plant Control System (PCS)
- Stimulated in Simulators Alpha and Bravo
- OPC DA Servers (ICONICS and Top Server)
- OPC UA simulator-side communication interface
- Gateway between DA Server and UA simulator interface
External Systems – Operator Aid Computer (OAC)

• Alpha Server running VMS OS
  – Stimulated in Simulators Alpha and Bravo
  – Nine (9) OAC client PCs per Simulator (panel mounted and desktops)
  – TCP/IP communication interface

• Duke Energy lead concurrent project to emulate the Alpha Servers on Dell x64 servers and Linux OS
  – Emulated OAC available during Factory Acceptance Testing at L3 MAPPS
External Systems – Plant Monitoring Computer (PMC)

- **Alpha Server running VMS OS**
  - Stimulated in Simulators Alpha and Bravo
  - Two (2) PMC client HMI PCs per Simulator
  - TCP/IP communication interface

- **Duke Energy lead a concurrent project to Emulate the Alpha Servers on Dell x64 servers and Linux OS**
  - Emulated PMC available during Factory Acceptance Testing at L3 MAPPS
External Systems – Controllers and Recorders

• Siemens 353 Controllers (28 per Simulator)
  – Hybrid Stimulated HMI/simulated controls in full-scope simulators
  – Fully simulated on desktop/glasstop simulators’ virtual panels

• Eurotherm Chessel Chart Recorders (13 per simulator)
  – Stimulated in Simulators Alpha and Bravo
  – Fully simulated on desktop/glass top simulators’ virtual panels
Other External Systems

- **Reactor Vessel Level Indication System**
  - Simulated in Visual Basic on Simulators Alpha and Bravo
  - TCP/IP interface with simulator executive

- **Radiation Monitors**
  - Stimulated in Simulators Alpha and Bravo
  - Readouts only on soft panels

- **GARDEL**
  - Interface to stimulated system delivered
  - System not deployed in simulators yet
New Soft Panels

• Scope
  – Based on Sim Bravo
  – Main Control Room
  – Back Panels
  – Stand-by Shutdown Facility (SSF)
  – Integrated Control System (ICS)

• Accessible from
  – Orchid® Instructor Station
  – Glasstop Simulators
New Instructor Interactive Schematics

- 87 interactive schematics created with Orchid® Graphic Editor
  - Based on OAC HMI pages, and/or on Orchid® Modeling Environment schematics
  - Accessible from Orchid® Instructor Station
  - Used for system visualization and to insert/control instructor actions (LOA, Malfunctions, etc.)
NSSS Models Upgrade

• Improved accuracy of Steam Generator model
  – Finer meshing/nodalization
  – Higher execution frequency

• Correction of NSSS deficiencies

• ANTHEM™ Thermal-hydraulic model
  – Latest library code for upgraded secondary loop
  – Original library code for primary loop, to retain time-tested model
  – Same graphical library for both
Runtime Core Neutronics Viewer

- Inputs from retained Studsvik S3R Model
- Runtime animated 3D and numerical display parameters
  - Axial profiles
  - Horizontal slabs
  - Rod bank positions
  - Nuclear detectors
I&C Models Replacement

- Legacy FORTRAN I&C models replaced with Orchid® Modeling Environment graphical models
- ~60 subroutines controlling more than 380 components (valves, motors, etc.)
Upgraded A/V System

• Hardware
  – Retained 8 IP cameras (4 per simulator) and lapel microphone system
  – New A/V recording and debriefing computers

• Orchid® Multimedia Manager Software
  – A/V recording and playback
  – Time-synchronized with simulator for synchronized audio-video playbacks
  – Connectivity with debriefing room
  – Preview of all cameras in a mosaic display for monitoring at all times
Replacement of RTP I/O with TMI I/O

• **Problems**
  – Hardware obsolescence
  – Software to interface with 2 types of I/O systems on 4 simulators; difficult to maintain

• **Strategy**
  – Replace the TMI I/O interface software and database that auto-generates signal lists
  – Validate the Rehosted and Upgraded software on Simulator Bravo
  – Replace RTP I/O in SSF, then ICS, then chassis-by-chassis in Simulator Alpha
    - Duke Energy handled hardware replacement
    - L3 MAPPS performed software upgrade

• **Results:**
  – I/O replacement completed within a week (including validation)
  – Streamlined process to maintain I/O communication software across all simulators
Glasstop Simulators Upgrade

- Retained four (4) hardware platforms (steel structures, touchscreens and computers)
- Installed new Operating System and Orchid® Simulation Environment
  - Individual, standalone simulations, or grouped in any combination
  - Orchid® Touch Interface software and graphics
Testing & Commissioning

• Validation of rehosted software before integration of model upgrades

• Used automated testing features of Orchid® Instructor Station to compare responses with
  – legacy simulator -> rehost validation
  – plant data -> upgraded models validation

• External systems and devices available at L3 MAPPS during Factory Acceptance Testing

• On-site pre-validation of upgraded communication interface drivers (TMI, Siemens, etc.)

• On-site validation on Simulator Bravo, before switchover of I/O on Alpha, SSF, ICS

• Duke Energy actively involved at all stages
  – Collaborative atmosphere to successfully overcome challenges
  – On-the-Job training to complement formal training on Orchid® platform
Conclusions

• Oconee Simulators now on modern and easy-to-use/maintain Orchid® platform

• Enhanced instructor facilities with Orchid® Instructor Station, new instructor control graphic pages and upgraded A/V system

• Upgraded simulator sustainable until end of power station life

• Keys to success
  – Cooperation and Communications
    ▪ L3 MAPPS and Duke Energy were transparent with each other
    ▪ Duke Energy addressed queries in highly efficient manner
  – Dedication and Competence
    ▪ L3 MAPPS’ and Duke Energy’s teams commitment resulted in
      – Great project success and excellent product
      – Delivered on time and on budget
Thank You

2019 Power Plant Simulation Conference (PowerPlantSim’19)

The Society for Modeling & Simulation International™