Scope of the upgrade

The project was done as two major, independent phases:

• N-1 phase
  – Updated a Unix based Ovation main turbine control to Windows based Ovation
  – Updated all of the Rod control logic cabinets to Digital Ovation logic
    • First time US upgrade of this type for rod control.
    • Second plant world wide for this upgrade.
      - The other plant was 3 loop vice our 4 loop

• N phase
  – Updates to the following control systems:
    • Reactor Temperature and Pressure control
    • Pressurizer level control (charging controls)
    • Makeup and VCT level control
    • Turbine driven feed pump speed control
    • SGWLCS
    • Steam Dump controls
    • Letdown pressure and Temperature controls
    • Turbine gas cooling control
    • Component Cooling system non-emergency level and makeup control
    • Residual heat removal system Temperature and flow controls.
    • Added auto-start of the motor driven main feed pump
Scope of the project Hardware:

The Main Control Board Changes:

• N-1 phase
  – Updated two existing Ovation drops from a Unix workstation to a Thin Client workstation
  – Removed several peripherals form the MCB including keyboards and a trackball
  – Rod control required new step counters that installed in existing mounts
  – All new hardware installed in existing slots/locations

• N phase
  – Added dual monitor Thin Client workstation to 1PM05J (Main board) and moved two existing monitors.
  – Added single monitor Thin Client workstation to 1PM04J (Feedwater panel)
  – Replaced 2 unitized feed pump control panels with a touch screen Thin Client drops 1PM04J
  – Rearranged or removed 16 control board meters
  – Removed 9 control selector switches for controlling channels
  – Replaced 28 Manual/Auto control stations with Ovation SLIM (small loop interface module) HMI controls. (Contractually required to fit into existing slots with no cutting or grinding.)
  – Added a desk top Thin Client at the NSO/operator’s desk
  – Removed 6 Yokagowa paperless recorders
Schedule issues

Simulator project started with the plant engineering behind schedule. There were some design items that were 4 months behind. The feed pump controls were the major system that lagged behind. The first cut of that logic was delivered on the week the Original schedule had us final accepting the load for training.

Some issues this lead to:
1. Simulator FAT was 2 full months prior to plant system FAT.
2. It was the norm to receive changes to the logic that were not tested yet.
3. Changes came out and we would have no idea what was in the change package.
4. Many times the testers had no idea how it was supposed to work......
5. The test schedule became rapidly useless.

Design issues plagued the project. We were still doing logic sheet changes in the control system up to the day of installation.

Is that how it’s supposed to work? Was a common refrain. There were a lot of weekends with Westinghouse engineers on site at the simulator making logic changes to the plant design and beta testing it in the simulator before going back to fix the plant design.
Post Outage: The trip

Braidwood has the ability to test the main feed pump trip circuits at power.

The system works by introducing a resistance in the trip circuit to lower the voltage to a low enough voltage to light a small indicator light, but it is low enough to not actuate the trip relay. Since the light is down stream of the relay, if it lights up during the test, you have verified continuity to the relay in the trip circuit.

Impedance in the old relay was not the same as impedance in the new Ovation trip relay. The ovation relay had a much lower threshold voltage where it would actuate the relay than the old relay had.

To compound the transient, the B loop feed line had a check valve that was restricting flow.

The end result was a completely preventable reactor trip due to the modification.
Post Outage: The Back-fit

As a result of the trip and some other system issues the station decided to perform a “back-fit” to unit 1 prior to the Unit 2 installation.

The Back fit was the response to all the issues found with unit 1 during the start up and testing and as a result of the trip experienced. It was decided to NOT install unit 2 until the unit 1 back-fit was completed and tested.

The delay in unit 2 created some training issues:
How do you maintain training and proficiency on two units that are no longer “similar” as far as control systems?

1. We are lucky to have a sister plant (Byron) within the utility.
2. Heavy use of the V-panels to leverage that technology for proficiency.
3. LOTS of training and explaining. (Use the training process, ADDIE is the savoir.)
Lesson learned:

1. Never forget that the simulator is first and foremost a tool for training. A project in the simulator has to be integrated into the whole training plan.

2. Involve the simulator group in the ADDIE process when it is needed. Scope and limitations of the simulation can be key.

3. One year standard warranty is probably no longer enough. With projects this large you will continue to find issues for some time after install. In particular, the increase in monitoring points and granularity the operators have with a fully digital system will show you flaws that may have existed for a decade without detection.

4. Two servers in use: Production and development. Due to the licensing issues and software constraints it is not possible to get development running right and then just “copy it”. It requires us to keep track of all the incremental changes made to get load running and the recreate them in order – exactly – to make the second server match the first server. How much stuff is done on the fly when integrating a load? Can you recreate the exact steps? How to test this?
Building’s on fire, can you come back in?

Remains of the transformer.
Outside the SWGR room and across the hall. The pressure from the arc flash blew through ceiling into hall and across the hall.
Back of switchgear. That fuzzy stuff was red melamine insulator.
Switchgear door

Notice the metal deformation/bulge
Examples of inside the switch gear.
The fireball went up. All the wiring in the overhead is melted inside the conduit.
Lesson learned:

1. Test and verify that your emergency power-down process is viable. Who knows enough about the simulator complex to shut it down fully in a controlled manner? What if they are on vacation? (We had to shutdown the whole simulator complex numerous times as they went back and forth to emergency power and repairs the system.)

2. Does your station have a plan for significant disruption in the training facility? (The sim was back on emergency, temporary power in 3 days. Full access to the building for training took over a week and a half for clean up and soot removal.)

3. Do you and your simulator group know how power gets to the sim? What is the backup? How long can you run on the battery/UPS before it crashes and you brown out the simulator computers and servers?

4. What powers the various parts of your simulator complex? For example maybe you have all of the simulator computers and peripherals on a UPS. Is your lighting and ventilation and other support systems on the same UPS or no UPS? Can you train if you don’t have ventilation? Can you train if you don’t have lighting? (They ended up powering the basic functions of the building off the simulator transformer while they did repairs. That was how we had lights and ventilation.)

5. What about network connectivity? Does a loss of network/LAN affect your ability to actually train?

PI hit: 46 hours of simulator unavailability went on the books. That drove us red for a full three months until it rolled off our average.
How to keep from dividing by zero....

During an NRC exam at Braidwood in June of 2019, we experienced a boron anomaly. The model calculated a boron concentration of 2.66 million parts per million boron concentration for the charging injection into the RCS loop. That is 2.66 parts of boron for every one part of boron and water solution. Which is physically impossible.

From ANSI 3.5, 2009

The response of the simulator resulting from operator action, no operator action, improper operator action, automatic reference unit controls, and inherent operating characteristics shall be realistic and shall not violate the physical laws of nature, such as conservation of mass, momentum, and energy, within the limits of the verification, validation, and performance testing criteria...

How did this happen?

\[
\text{Sum (individual flow x boron concentration)} / \text{sum_of_flows}
\]

As programmed, it also adds a small epsilon value (1e-6) to the sum of flows to guard against a divide by zero. But that VERY small denominator can yield HUGE final results.
Lesson learned:

1. Reinforce to your instructors to write issues or at least tell you about them. Getting the “Oh yeah it did that once a couple weeks ago, but did not repeat, so I didn’t tell anyone” after the fact is not the best issue resolution.

2. If you use an epsilon value to prevent dividing by zero, it can create its own issues.

3. SBT is NOT fool proof. This scenario had been run a number of times with no issue. As we incorporate “noise” into our models to create a more realistic simulator experience we also create additional interactions that can be randomized to some extent.
Questions??