ANO 2 Service Water Upgrade and Mutual Exclusion

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What is Mutual Exclusion?

- A program object that prevents simultaneous access to a shared resource.
- This concept is used in concurrent programming with a critical section, a piece of code in which processes or threads access a shared resource.
Why We Upgraded

• The Service Water (SW) model is a original model that was delivered with the simulator.

• Ops requested SW casualty training that was beyond anything we had done previously.

• Limited plant data available to validate response.

• Instructors questioned accuracy of response.
Simulator Upgrades

- Fall of 2016, Arkansas Nuclear One signed a contract with Corys to build new Service Water/Chilled Water (CHW) module using Thunderflow (TFlow).
- Factory Acceptance testing was completed in April of 2017. Using glass panels at Corys office.
- Site Acceptance testing was completed in August of 2017 on the simulator.
Factory Acceptance Test

Max LOCA

P5602-2 - Containment Pressure

Minutes

New SW Model
Before SW Model
Nodal with TFlow
What happened

- During cycle 18-01 (Aug/17) an instructor called stating pressure in A Steam Generator went to 1200 PSI. Pressure went from 1020 PSI to 1200 PSI in one frame.
- The instructor made a snap of the condition.
- Then the instructor reported they back tracked 3 minutes and everything worked properly after the back track.
When we Reset to the Snap this is What we Saw

SG A

10010.0 F
13080.0 F

10375.7 F
1202.6 PSI

-23351.6 F
1202.8 PSI

-23351.6 F
1202.8 PSI

-23351.6 F
1202.8 PSI

527.6 F
1203.6 PSI

561.2 F
1203.6 PSI

527.6 F

SG B

7811.5 F
7383.3 F

548.3 F
1028.8 PSI

548.2 F
1029.1 PSI

548.3 F
1028.8 PSI

548.2 F
1029.1 PSI

548.2 F
1029.1 PSI

517.0 F
1029.7 PSI

517.0 F
What could have caused this?

- This could not happen thermodynamically.
- We know it's not something with the IC or with the code, because after backtracking three minutes it ran fine.
- THOR is the program that is responsible for the Steam Generator calculations. THOR was installed in 2009. THOR has run for years without any problems. THOR can’t be the problem since it hasn’t changed in years.
- What changed this load? SW/CHW was installed. The problem shows up on RCS (THOR) not SW/CHW (TFlow).
Solution

• Both RCS (THOR) and SW/CHW (TFLOW) were calling the same subroutine (VPT1N), and they are in different threads. When THOR and TFLOW call VPT1N at the same time, you would see numbers that did not make sense in one of the programs.

• Renamed the VPT1N called from TFLOW to ANO_VPT1N. Have not had a problem with RCS/Steam Generators (THOR) or SW/CHW (TFLOW) since the change.
Original Setup

```
CPU 1
THOR

THOR
THPRPR
VPT1N

CPU 2
All other Models

TFlow
TFGetProp
```
Modified Code

CPU 1
THOR
THOR
THPRPR
VPT1N

CPU 2
All other Models
SW
TFlow
TFGetProp
ANO-VPT1N
Other things that happened after original incident

• Service Water Pressure went to zero with two Service Water Pumps running. SW Pressure is calculated in TFlow program.

• Pressurizer pressure went to 2500 psi for a second. Pressurizer pressure is calculated in THOR program.

• Both of the above incidents happened during non-training times. After seeing the above issues we got approval from the simulator review board to build new load during training cycle.
Not the first time we have had this problem

• DR 12-0082: Near the end of training session with small LOCA and small SGTR, containment temperature instantly changed from 131 to 580 degrees F. Snapped the failure in IC244. Snapped a backtrack 2 minutes before failure into IC245. Same session ran that morning with no issues.

• Action Taken: Discovered violation of Mutual Exclusion involving calls to the scientific subroutine library from outside of Models CPU 2. In THOROUT, steam table subroutine calls were being made for calculations of steam flow venturi differential pressures SGPD1030 and SGPD1130.
Lessons Learned

• Test on the simulator as much as possible. A lot of the testing was done on the glass panels or standalone desktop.

• Let the simulator run several hours without a reset. When we tested the fix we let it run over night for several nights.
Questions?