New Power – Challenges and Lessons Learned from PSE's Lower Baker Unit 4 Powerhouse

2014 Northwest Hydro Operator's Forum Spokane, Wa

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5/21/2014

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PSE Lower Baker Unit 4 Powerhouse

Presentation Overview

- Introduction
- Lower Baker History and Features
- FERC License
- New Powerhouse Project Scope
- Unit 4 Principal Features
- New Control System Objectives/Features
- Challenges, Considerations, and Lessons Learned

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Lower Baker, Concrete, Wa

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Lower Baker's Lake Shannon

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Gravity-Arch Dam   285 ft high

Lower Baker Dam 550 ft long

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Original Powerhouse, Units 1, 2, and 3

Rebuilt Powerhouse, Unit 3

Unit 3 Generation Components

- 22 ft ID, Concrete-Lined Penstock from Reservoir to Surge Chamber
- 16 ft ID, Steel-Lined Penstock from Surge Chamber to U3 Powerhouse; 4550 cfs
- Vertical Francis Turbine, 80 MW - 13.8kV Generator
- Woodward Hydro-mechanical Cabinet Governor

FERC Re-Licensing

- The original FERC license to expire in April 2006
- License renewal process began in 2001
- A Settlement Agreement with 23 other parties completed in 2004; new license issued in 2008

License included Stringent Constraints

- New Licensing Constraints Added:
  - Reservoir Elevation Requirements
  - Maximum Generation Flow Constraints
  - Minimum Inflow Requirements (MIF)
  - Tightly Constrained Downramping Rates

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MIF Drives New Powerhouse Option

- The MIF requirement increased from 80 to 1,200 cfs
- Lower Baker Facility water conveyance capacity allowed extra 1500 cfs (previous Units 1 and 2)
- 1500 cfs allows for 30 MW Generator size
- “Lower Baker Unit 4” conceived

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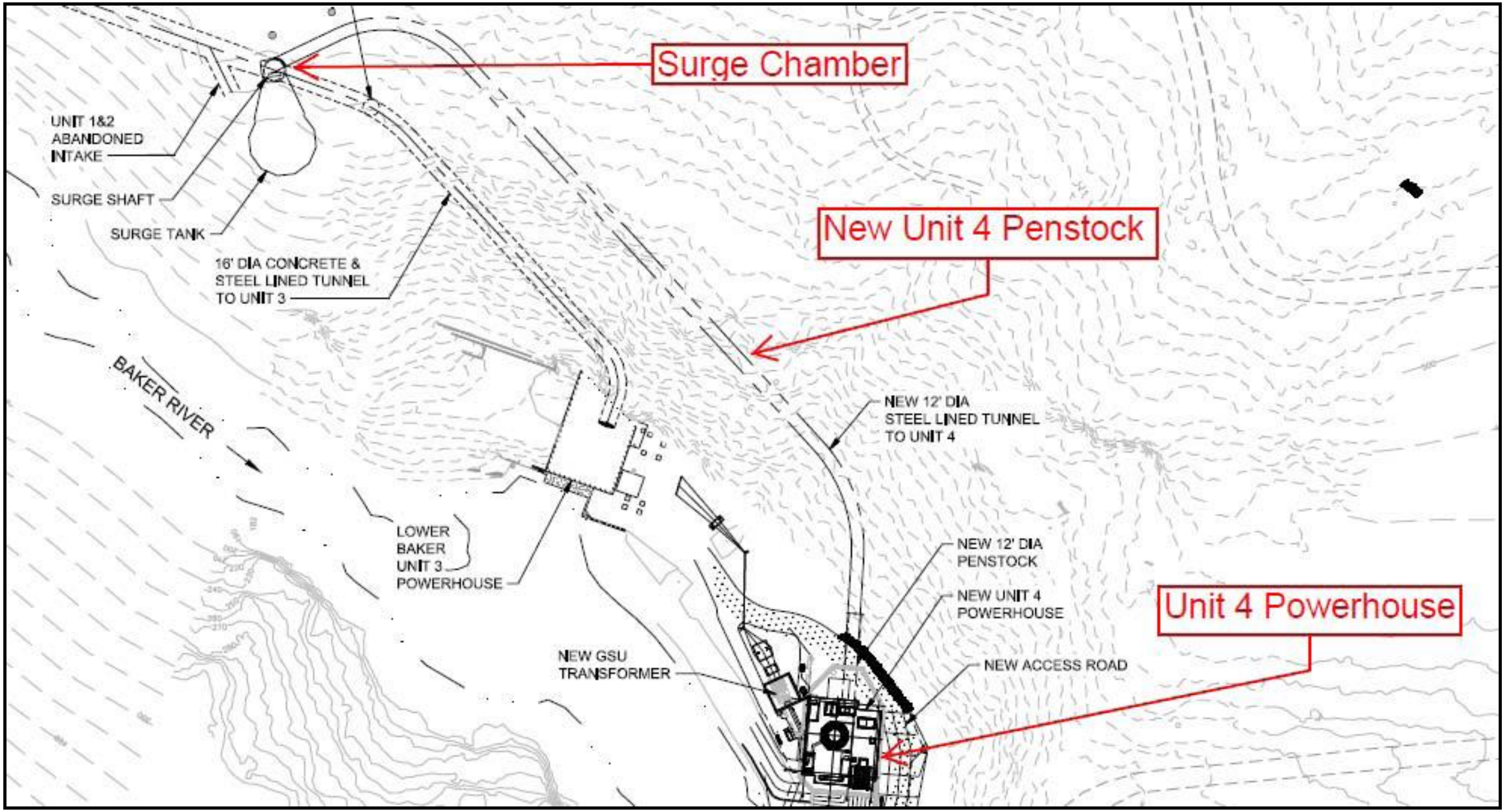
New Powerhouse Project Scope



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New Powerhouse Project Scope

- 1000 ft tunnel bored to surge tank

- 12 ft dia steel-lined penstock installed

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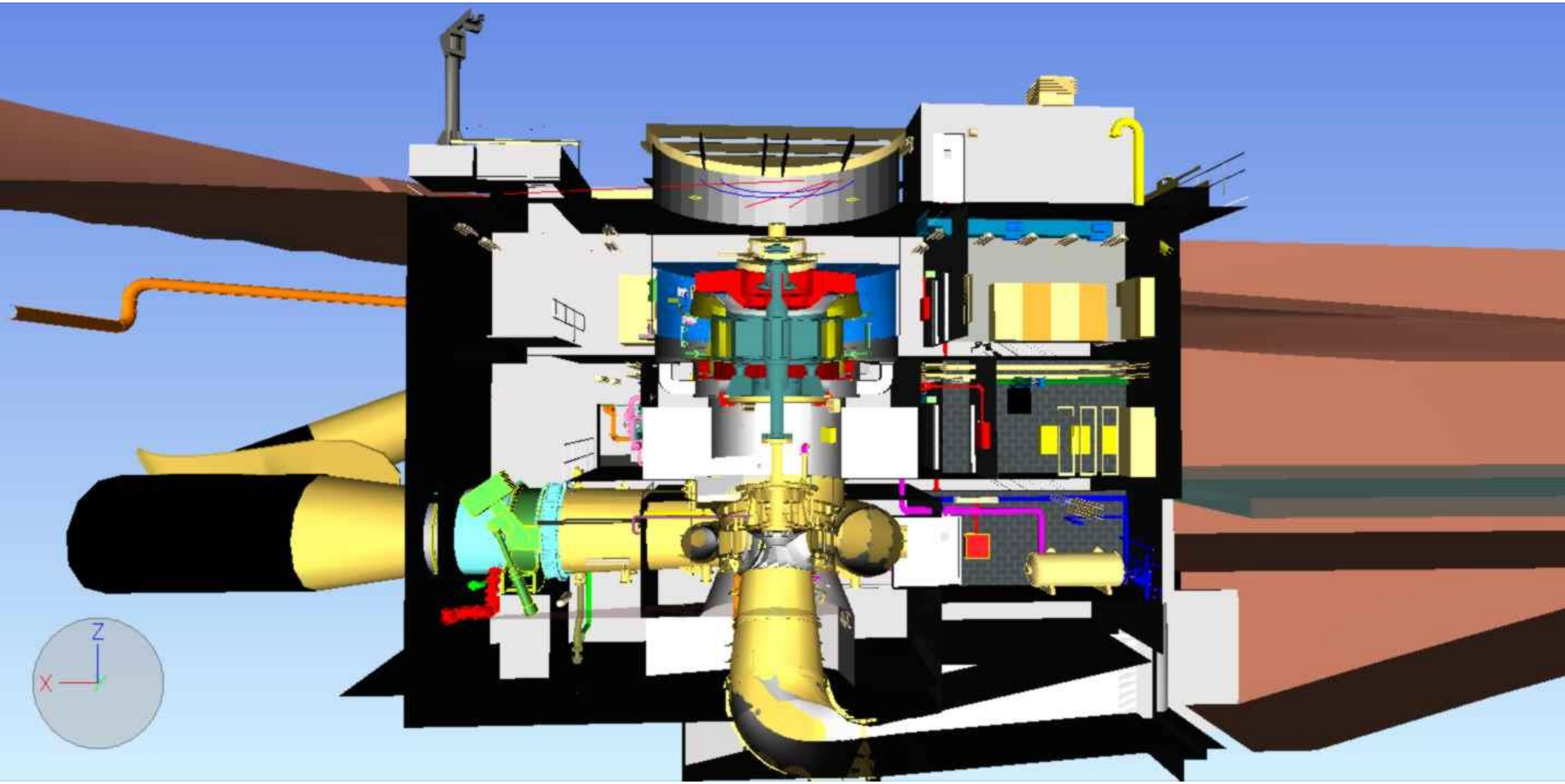
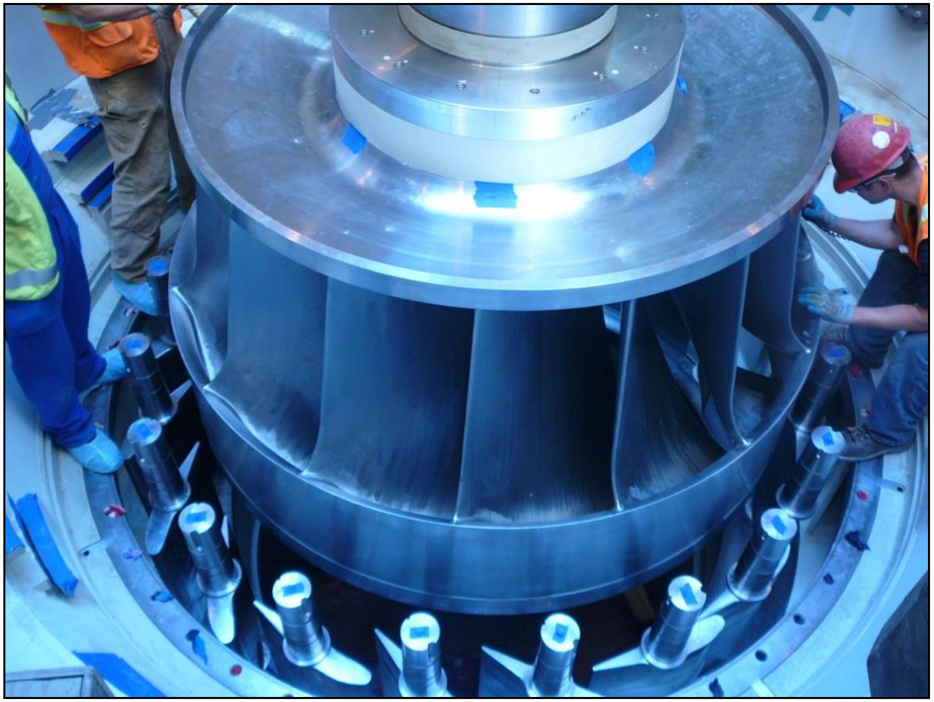
New U4 Powerhouse Cross-section



Unit 4 Turbine

- 30 MW Vertical Francis Turbine
- Litostroj Power, Ljubljana, Slovenia
- Nominal 1500 cfs Capacity



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Unit 4 Generator

24-Pole, 300 RPM

34 MVA at 0.95 pf

Končar Generators
Zagreb, Croatia

Assuring 1200 cfs MIF Capability

- 5-ft dia,1500 cfs energy-dissipating bypass valve

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Completed Unit 4 Powerhouse

Unit 3 and Control System Additions

- New Licensing Constraints Added:
  - Reservoir Elevation Requirements
  - Maximum Generation Flow Constraints
  - Minimum Inflow Requirements (MIF)
  - **Tightly Constrained Downramping Rates**

More Automation Needed!

	Original license	Interim license (IPP)	New license
	Minimum Instream Flows (cfs)		
August 1- October 20	80	80	1000
October 21-July 31	80	80	1200
	Maximum Generating Flows (cfs)		
September 10 – October 20	no limit	Best Effort	3200
April 1 – May 31, August 1 – September 9, October 21 – December 31	no limit	no limit	3600
January 1 – March 31, June 1 – July 31	no limit	no limit	5600
	Downramping Rates		
February 16 – June 15	no limit	<2000 cfs / hr	0 day, 2 night **(in/hr)**
June 16 – October 31	no limit	<2000 cfs / hr	1 day and night **(in/hr)**
November 1 – February 15	no limit	<2000 cfs / hr	2 day and night **(in/hr)**

Table 1: Lower Baker license operation constraints (past to present)

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Digital Control Components Added

- Unit 3 Digital Control System Upgrade (UCS, Governor)
- Unit 4 Digital Control System (UCS, Digital Governor)
- Facility Controller (FCS PLC), Operator Work Stations (OWS)

Control System Objectives

- Automated Downramping to meet added constraint
- Integrated Facility Operation to Meet new MIF
- Bypass Valve (SBV) Control Designed to insure MIF
- License Compliance Monitoring / Alarming
- Economic Unit Dispatching
- Unit Dispatching to Avoid ‘Rough Load Zones’

Operating Modes - Who and Where?

Manual Mode: Local Control at GCP

Auto Modes:

- OWS in Control Rooms
- Remote operation at Load Office

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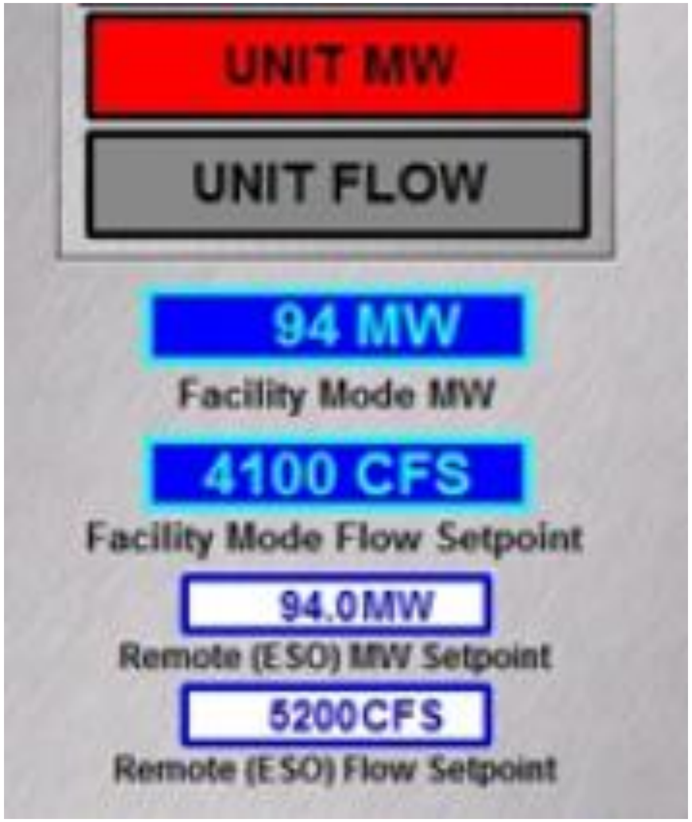
Control Modes – What should be controlled?

- Unit Flow (CFS)
- Unit Load (MW)

- Facility Flow (CFS)
- Facility Load (MW)

- U4 Synchronous Condense



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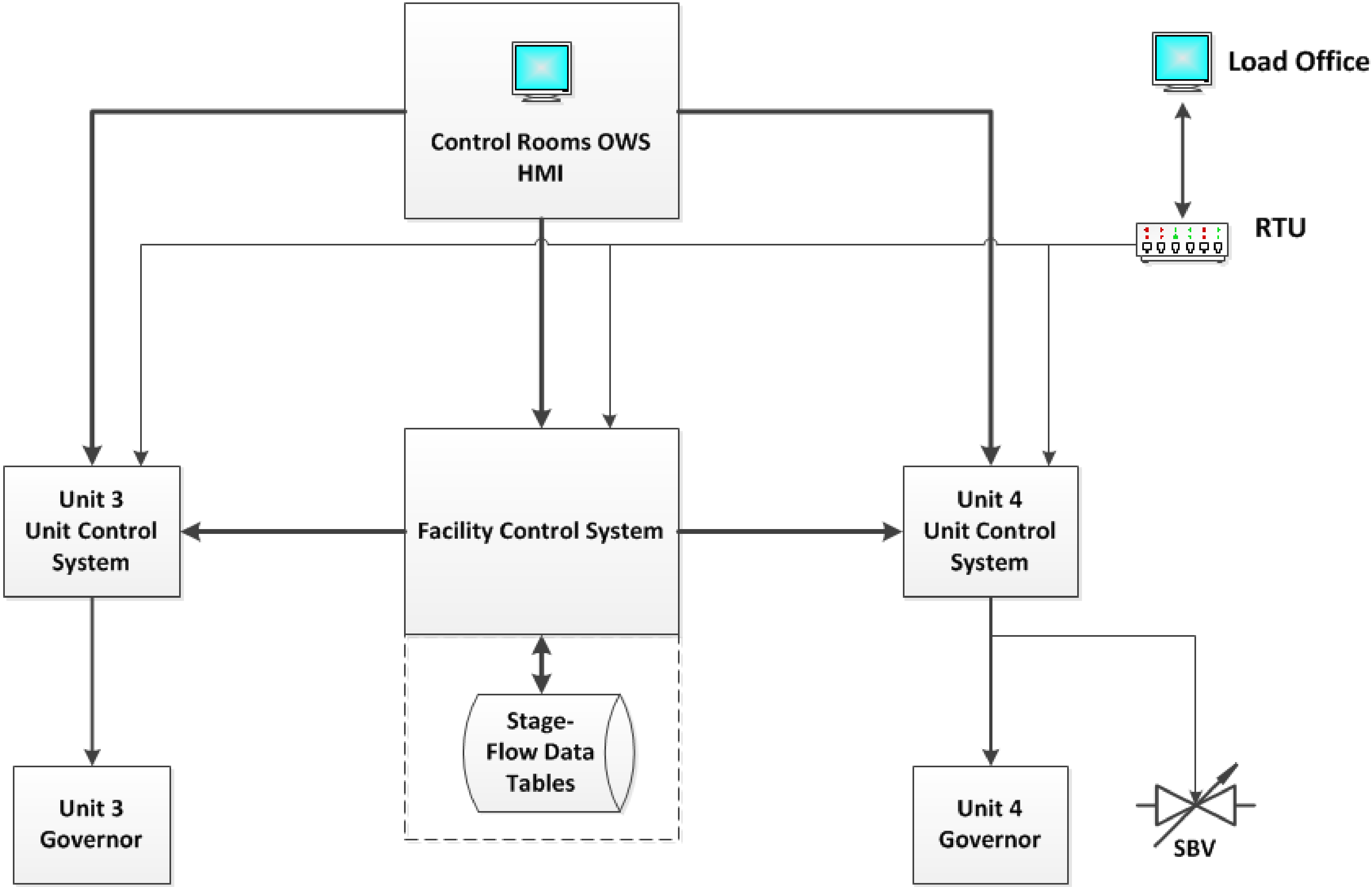
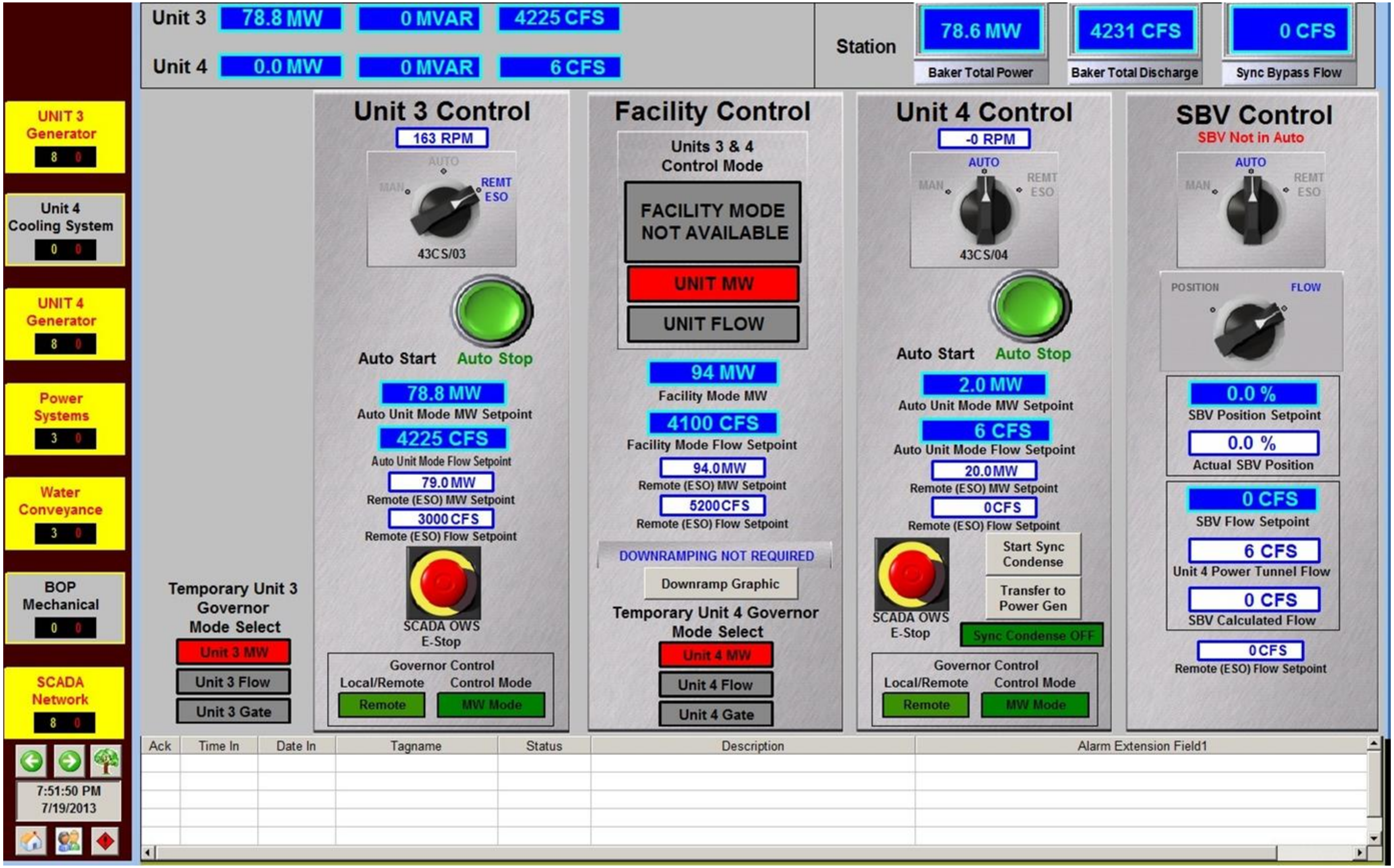
Control Hierarchy



OWS Control Mode Graphic



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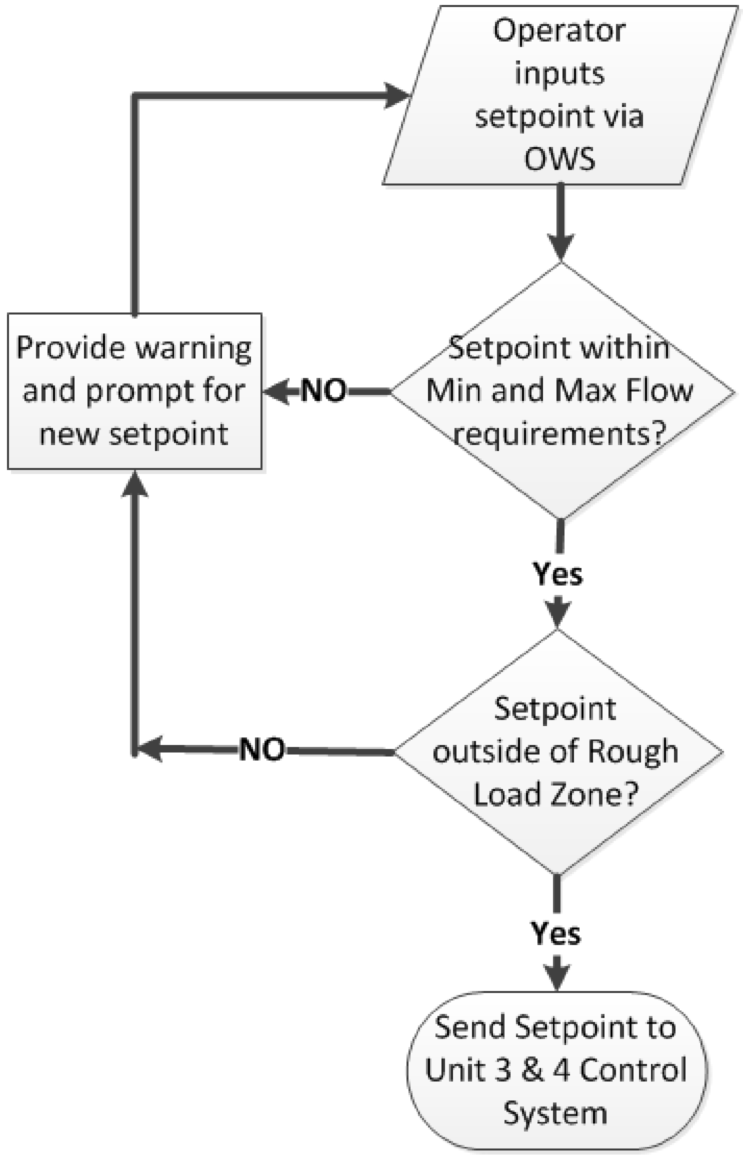
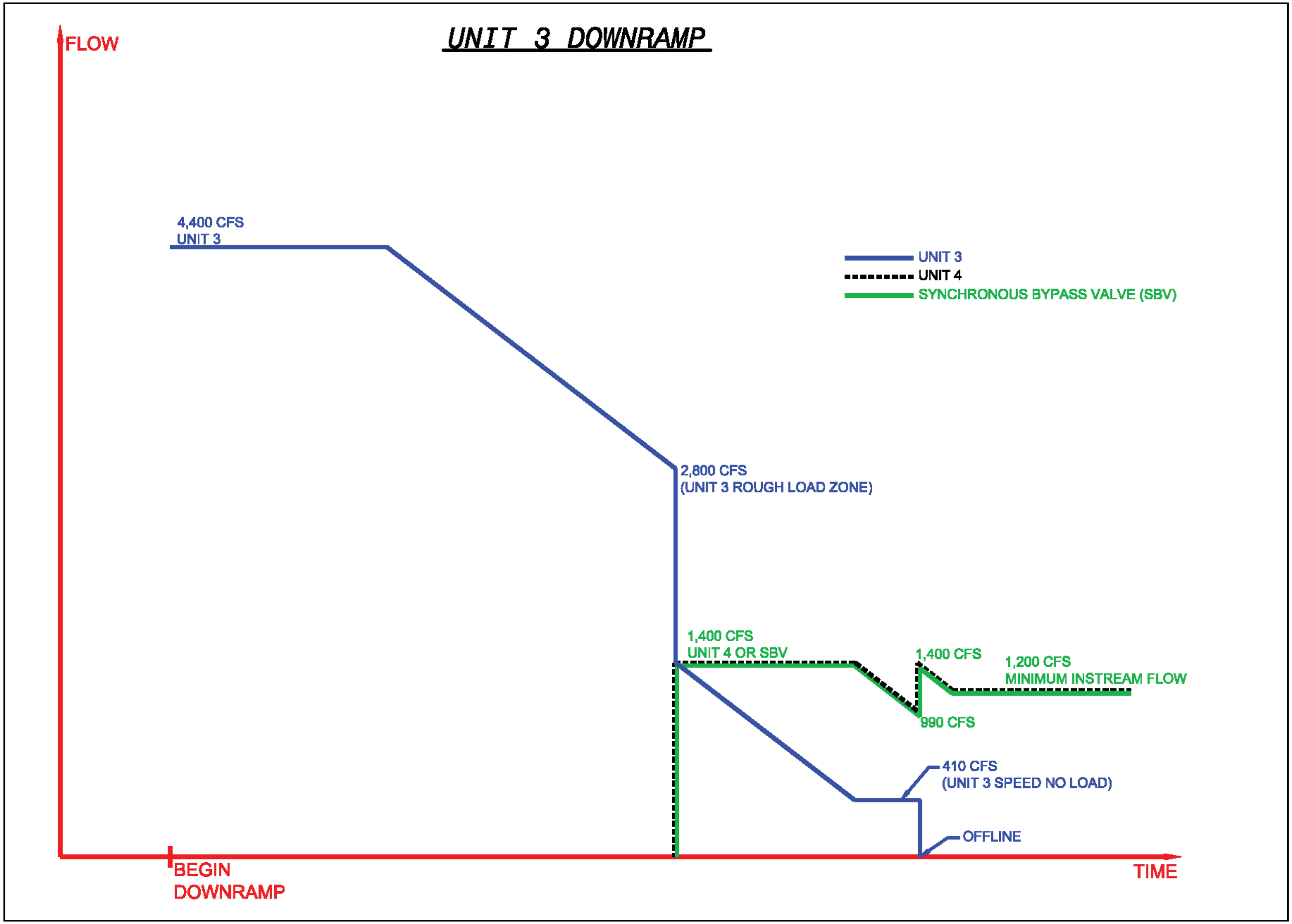
Operator Setpoint Validation



The Control System provides validation for operator requested setpoints

Automatic Downramp Control



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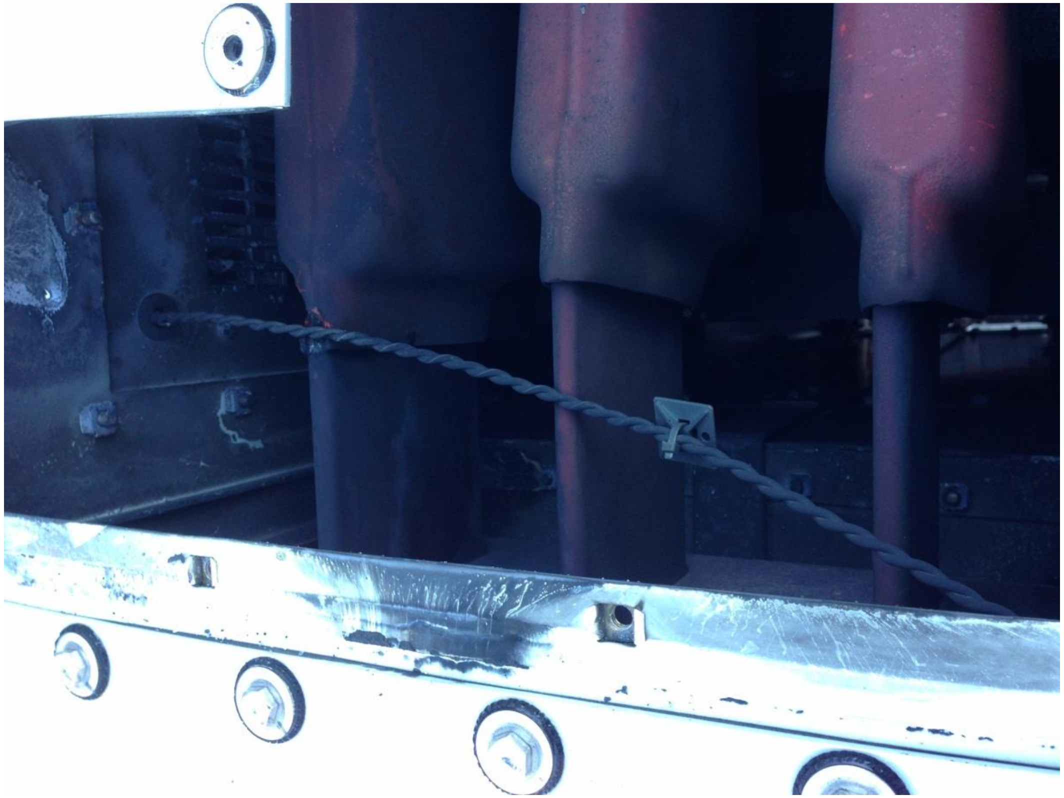
Challenges - Vibration

- During commissioning the turbine experienced wicket gate vibration – a resonance caused by vortex shedding forming downstream of stay vanes above 27MW

- Provider re-shaped the stay vanes to reduce the vortex formation. The attempt was unsuccessful, shifting the start of the vibration down to 23MW   (75% gate position)

- Provider is designing new runner/vane components to correct problem in early spring 2015 (following new CFD modeling and flow scale tests)

Challenges – Bus Ground Fault



- Improperly installed bus duct heater wiring caused ground fault on 13.8 KV bus leading to GSU
- Duct work was cleaned-up and sheet metal repaired under warranty

Challenges – Control System Testing

- The vibration issue, bus fault, along with follow-up outages and lake level considerations have restricted the amount of operational testing possible on the FCS logic

- Controls provider will be brought in to correct several punch-list items associated with Communications, FCS, and UCS programming

Lessons Learned from this Project

- Computer Modeling doesn't guarantee proper machine behavior
- Control System Testing and Debugging can be delayed by mechanical and operational issues
- Don't economize on Instrumentation – buy the best!
- A New Hydro Powerhouse is a once-in-a-career event – budget and schedule for more Engineering involvement

Why choose redundancy of PLC CPU Modules?

- Allen-Bradley PLC Processor Modules estimated at > 500,000 hrs MTBF
- Is Facility Controller PLC the place to provide redundant processors?
- What about I/O? Instrumentation? Software?

Let’s Talk about Redundancy!

- Computer Redundancy is an old concept going back many years

Triple Modular Redundancy (TMR – 2/3 voting)

Saturn V moon rocket used both TMR and Simplex computer systems on-board

What could be done in one case couldn't be done in another!

TMR Processing requires TMR measurements!

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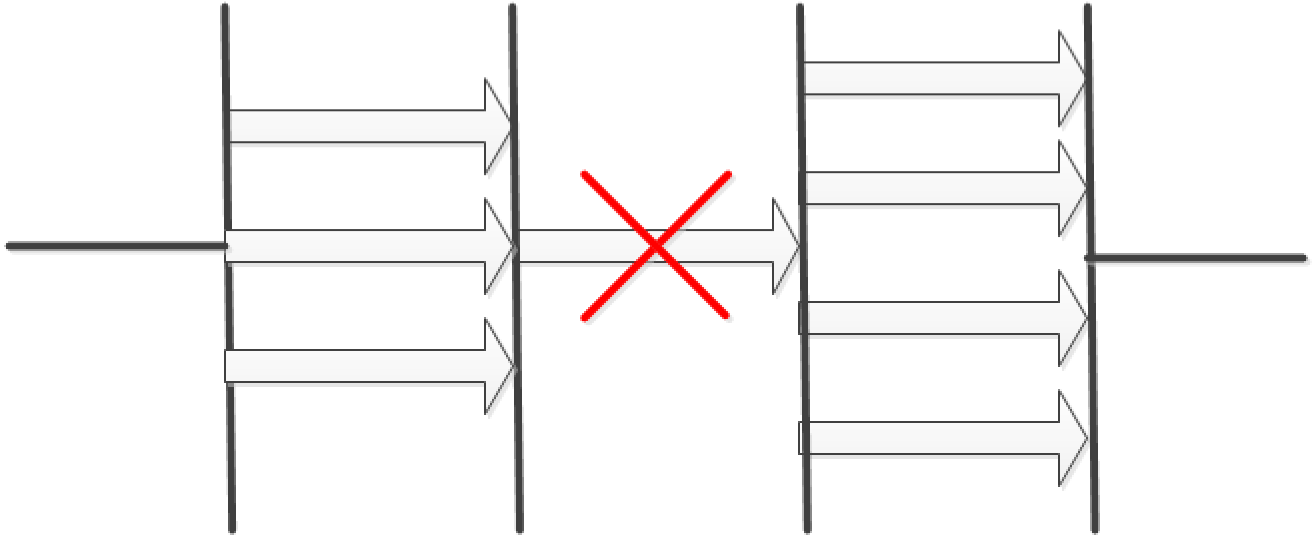
Redundancy Protection Choices

The 60-cent fuse will blow to protect the
$100 picture tube!



Redundant Hardware, Bad Software:

- Software Faults means synchronized Dual-Redundant Processors will fault together

- Bad logic means synchronized Dual Redundant Processors will both redundantly give wrong answers

- Independently implemented Hardware and Software provide a means to greater non-common redundancy

Control System Considerations

Desirable Notions of:

- Simplicity
- Reliability
- Maintainability

Simplicity – *nothing left to remove*

- What is meant by "Simplicity"? KISS?

Characteristics:

- Discoverable – Your people have access
- Transparent – Straightforward solutions
- Leverage – Doing a lot with little; reusable
- Clarity - Create useful mental models

Who does the Maintaining?

DIY → MIY Ownership

1. “*Do It Yourself*” means easier “*Maintain It Yourself*”

2. *“Who are you going to rely on?”   “Who owns it?”*

3. *Great opportunity to correct and update the drawings*

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Questions?