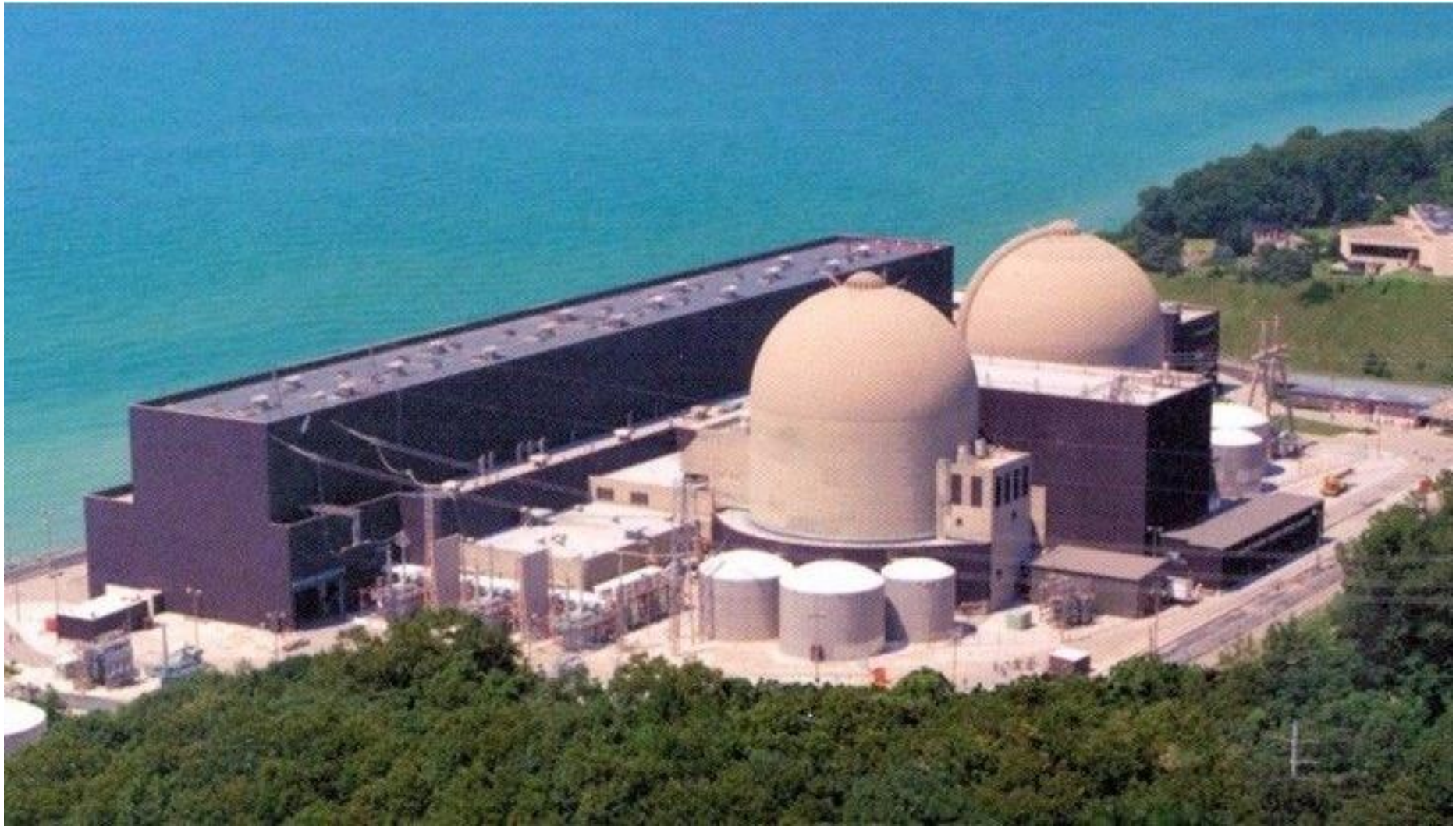
D. C. Cook Reactor Controls and Instrumentation Upgrade



D. C. Cook Reactor Controls and Instrumentation Upgrade

- **Replacement for digital controls installed early 1990's (which were replacements for original OEM analog controls)**
  - Taylor / ABB / MicroMod Mod30 platform
  - Driven by obsolescence issues with the Mod30 platform
- **System composed of four separate Control Groups, Control Group I through Control Group IV**
  - System performs, indication, control and alarming functions
  - Each RCS loop in a separate control group (Westinghouse 4-loop plant design)
  - Common indication / control / alarming functions distributed across the four control groups

RCI Indication Functions

MAIN CONTROL BOARD INDICATORS

- 4-20 mA or 10-50 mA current loop outputs
- Condensate Storage Tank Level
- Reactor Vessel Flange Seal Temp
- Reheater Coil Drain Tank Pressures (2)
- SI Pump Flows (2)
- SI Pump Pressures (2)
- RHR Flows (5)
- RHR Pressure (2)
- Boron Injection Flows (4)
- Accumulator Tank Levels (8)
- Accumulator Tank Pressures (8)
- RWST Level
- BAST Pressure
- Pressurizer Relief Tank Level
- Pressurizer Relief Tank Pressure
- Pressurizer Level
- RCS Wide Range Pressure
- Pressurizer Temps (4)
- Pressurizer Spray Temps (2)
- Pressurizer Liquid and Steam Temps (2)
- Upper Containment Wide Range Pressure (2)

RCI Indication Functions

MAIN CONTROL BOARD RECORDERS

- 4-20 mA or 10-50 mA current loop outputs.
- Converted to 1-5 V at Recorder inputs.
- RCS Wide Range Pressure
- RHR Temperatures (3)
- RCS TAVG and TREF
- SG Feedwater Flow (4)
- SG Main Steam Flow (4)
- SG Narrow Range Level (4)
- SG Pressure (4)
- Containment Pressure (3)
- Pressurizer Level

RCI Indication Functions

PLANT PROCESS COMPUTER (PPC) INPUTS

- 4-20 mA or 10-50 mA current loop outputs.
- Converted to 1-5 V at PPC inputs.
- Pressurizer Spray Valve Flows (2)
- Boron Injection Line Flows (4)
- SI Pump Flows (2)
- RCP Seal Leakoff Flows (4)
- Boric Acid Flow
- Primary Water Flow
- SG Wide Range Levels (4)
- Pressurizer Level
- RWST Level
- Steam Generator Pressures (8)
- Upper Containment Wide Range Pressure
- RCS Temperature
- RCS Delta-T
- RCS TAVG
- RHR Temperatures (3)

RCI Alarming Functions

- **Alarming Functions**
  - Main Control Room Annunciator
    - Process Alarms
      - ~160 alarms
    - RCI System Alarms
      - System Failure
      - System Trouble
  - Local Alarming
    - RCI System Alarms
      - Cabinet temperature
      - Cabinet door alarms
      - Deviation Monitoring

RCI Control Functions

- **Control Functions**
  - Steam Generator Water Level (CG 1-4)
  - Steam Generator PORV (CG 1-4)
  - Pressurizer Pressure Control (CG1)
  - Pressurizer Level Charging Flow Control (CG1)
  - Boric Acid Flow Control (CG1)
  - Primary Water Flow Control (CG1)
  - Steam Dump Control and Main Steam Turbine Bypass Header Pressure (CG1)
  - Feedwater Pump Speed Control (CG1)
  - Turbine Impulse Pressure (CG1)
  - TRef, TRef Lagged (CG2)

RCI Control Functions

- **Control Functions**
  - Pressurizer Level Control (CG2)
  - Pressurizer Level Charging Flow Control (CG2)
  - Upper Containment Narrow Range Pressure Channel 2 and Lower Containment Channel 1 Pressure (CG2)
  - Pressurizer Pressure Control (CG2)
  - Volume Control Tank Level (CG4)
  - Letdown Heat Exchanger Discharge Pressure (CG4)
  - Letdown Heat Exchanger Discharge Temperature (CG4)
  - Hi Auctioneered Tavg (CG4)
  - Hi Auctioneered Delta T % Power (CG4)
  - Rod Insertion Limits (CG4)
  - Rod Control (CG4)

D. C. Cook Reactor Controls and Instrumentation Upgrade

- **Originally designed as Phased Upgrade**
- **Phase 1 - Steam Generator Water Level Control (SGWL) only**
  - determined replacing SGWL only was not feasible
    - Equipment “intertwined”
    - Cannot maintain control group separation
- **Scope Expanded to all Control Group functions**

D. C. Cook Reactor Controls and Instrumentation Upgrade

- **Design Goals**
  - Replace obsolete equipment
  - Improve system redundancy
    - Equipment redundancy
    - Sensor redundancy
      - SG PORV Pressure channel selection
      - SG Narrow Range Level channel selection
        - Removed late in the project due to licensing concerns
      - Retain manual selection
    - Power Redundancy
      - Each control cabinet has independent protected power feeds

D. C. Cook Reactor Controls and Instrumentation Upgrade

Design Goals

- Improve plant reliability
  - "Hold last good value" capability
  - Replace Feedwater Regulating Value (FRV) actuator
  - Replace FRV solenoid valves (safety related)
- Maintain control group separation
- Minimi e the effect on the safety analysis and perform the work under 10C R50 59

D. C. Cook Reactor Controls and Instrumentation Upgrade

- **Original HMI Concept**
  - MCB Display screen technology
    - Replace existing MCB indicators
    - Replace existing MCB recorders
    - Replace existing MCB MOD 30 controllers
  - Remote display screen computers
  - 4 display screen sizes 6, 8, 10 and 21 inch

D. C. Cook Reactor Controls and Instrumentation Upgrade

Original HMI Concept

D. C. Cook Reactor Controls and Instrumentation Upgrade

- **Final HMI Concept**
  - Eliminate MCB display monitors and retain indicators and recorders
    - EMI / RFI considerations
    - MCB modification issues
    - Significant redesign of the I/O

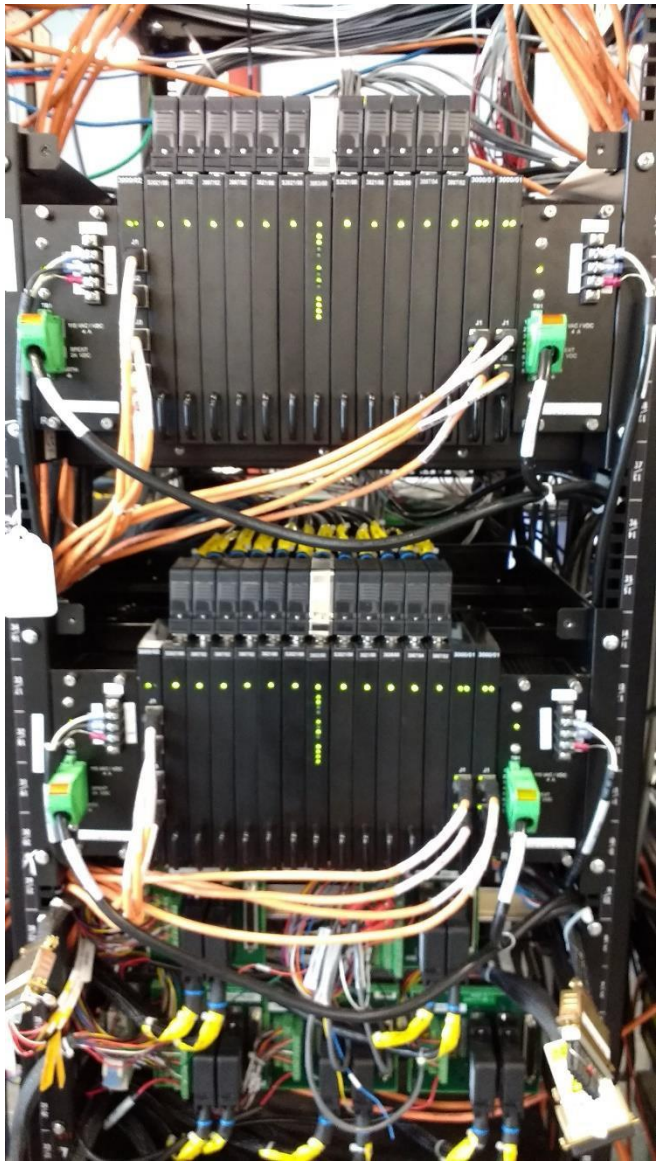
Configuration

RTP 3000 I/O Equipment

- Dual Redundant Node Processors
- Dual Redundant Chassis Processors
- Dual Redundant Power Supplies
- Dual Redundant I/O Cards
- Termination modules for all inputs and outputs
- Average of 4 I/O chassis per control group
- Node Processors directly connected to server computers to separate RTP I/O equipment by control group

Configuration

- RTP 3000 I/O Equipment

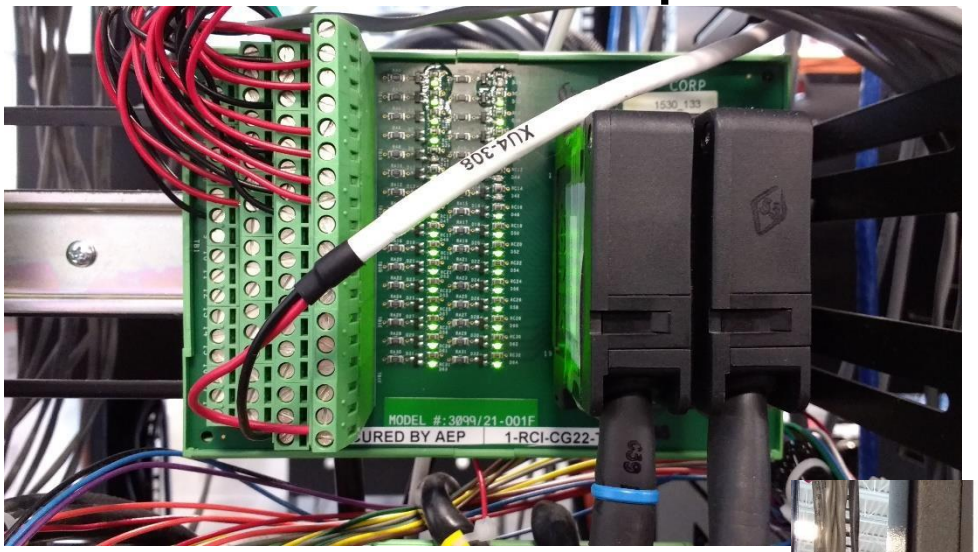


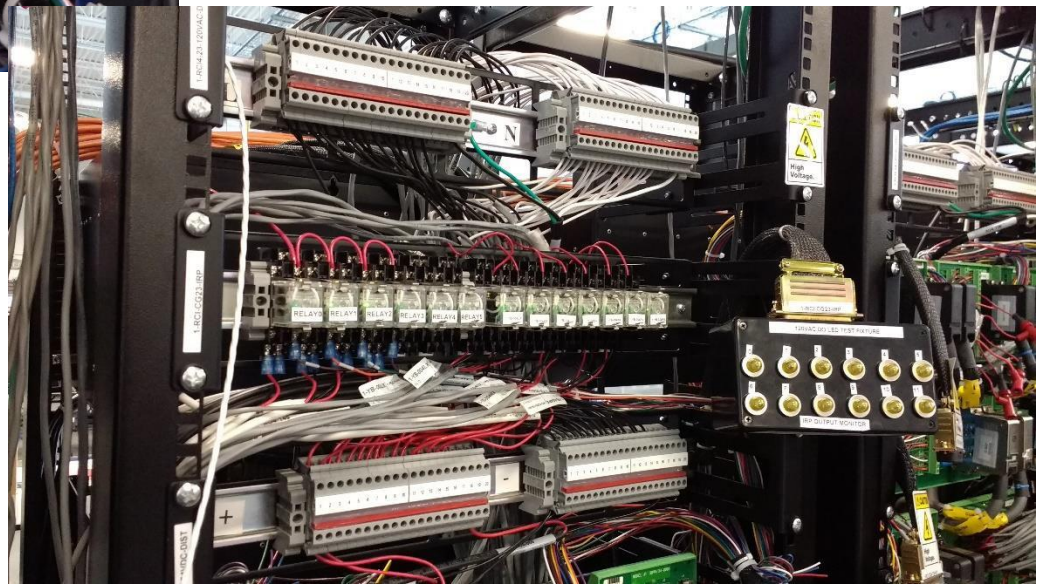
Configuration

- **RTP 3000 I/O Card Compliment**
  - 4-20 mA current loop analog input
  - 10-50 mA current loop analog input (new)
  - -10 to 10 VDC analog input
  - 100 Ohm RTD
  - 200 Ohm RTD (new)
  - 24 VDC digital input
  - 4-20 mA current loop analog output
  - 10-50 mA current loop analog output (new)
  - -10 to 10 VDC analog output
  - 24 VDC digital output
  - 120 VAC digital output

Configuration

RTP 3000 I/O Card Compliment





Configuration

Server Computers

- Two per control group (redundant pair)
  - Unable to use commercial grade servers (HP, Dell, etc.) due to the temperature requirements
- Industrial models from Crystal Rugged
  - Mostly equivalent to HP / Dell but some limitations in SNMP access to system status that limited NETMON implementation
- Each server computer had direct connection to RTP I/O equipment and a shared HMI network across all 4 control groups and the HMI workstations
- Final configuration does not include any server HMI equipment (monitor, keyboard and mouse) due to space limitations
  - Must be accessed via remote desktop from the EWS

Configuration

- **HMI Workstations (ALPC)**
  - Two Alarm Log PC (ALPC) for the system (redundant pair)
    - Unable to use commercial grade workstations (HP, Dell, etc.) due to the temperature requirements
  - Industrial models from Advantech
  - Shared HMI network to access all 4 control
  - Backup operator HMI device to the MCB MOD 30 HMI units
    - Supports Auto / Manual control from the workstation
    - Supports R*TIME system display functions
      - Operator Displays (Alarm Summary, SPAD, SPDD, Messages, Tabular, etc.)
  - Located on RO and BOP operator desks
  - Touchscreen Monitors

Configuration

HMI Workstations (EWS)

- One Engineering Workstation (EWS) for the system
  - Not considered part of the operational system so able to use commercial grade workstation (Dell) since the expanded temperature requirements did not apply
- Commercial model from Dell
- Final installation will share monitor with Turbine Control System due to space restrictions
- Connected to HMI network
  - Can only communicated with server computers
  - Cannot be used for RTP functions (NetArrays access)
- Used for I&C, Engineering and Maintenance functions

Configuration

HMI Workstations

Configuration

- **MCB MOD 30 HMI Units**
  - 29 for U1, 28 for U2
  - Replacements for existing MCB units
    - Supervisory control functions only, control functionality removed from MOD 30 units
    - Control functionality only performed by RTP system
  - Backed up by ALPC workstations
    - Functionality taken from MOD 30 at ALPC
    - Functionality returned to MOD 30 at ALPC
    - Functionality taken from ALPC at MOD 30

Configuration

MCB MOD 30 HMI Units

Configuration

Network Configuration

- Triple Redundant I/O Network Switches
  - B Network Switch and D Network Switch partitioned with A Network for server computer connection point
- Industrial model from Cisco
  - 100 MB support only
- No DAS network
- Shared HMI network
  - Servers and workstations
- Cyber Security Network Switch
  - SPAN of HMI network and I/O Network B & D switches
  - Connection point to D.C. Cook Layer 4 Centralized Cyber Security Network (CCSN)

Configuration

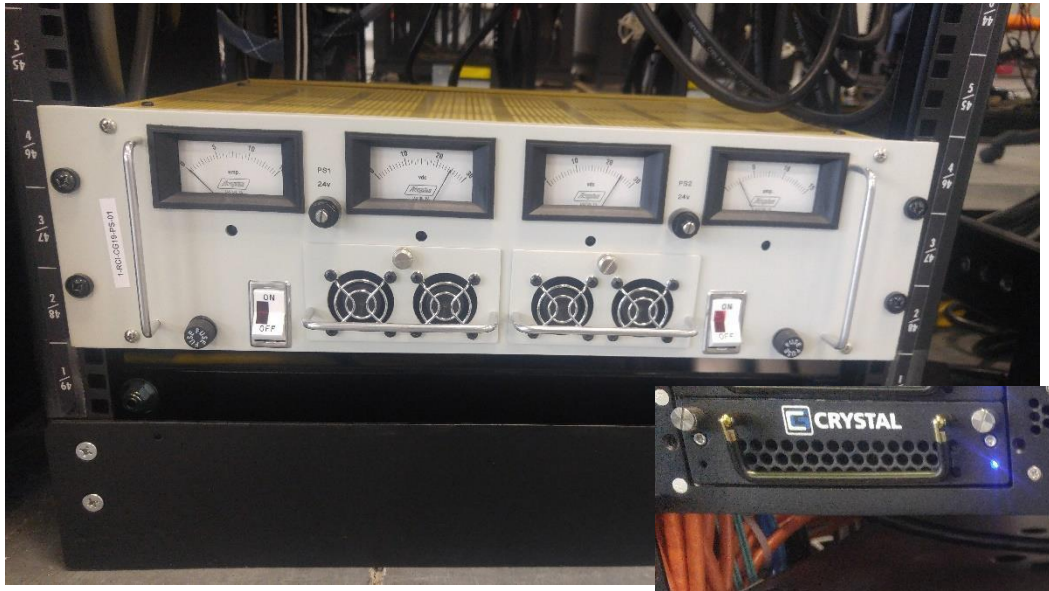
Network Configuration

Configuration

- **Power**
  - Redundant cabinet power feeds
    - Protected power from multiple independent sources
  - 80 VDC Power Supply for input current loop power
    - Combination of loop powered devices and RTP powered devices
  - 24 VDC Power Supply for whetting voltage and current loop outputs

Configuration

Power



Software

- **RTP NetSuite**
  - Installed on R*TIME Servers
    - Only machines with network connectivity to the RTP system
  - RTP NetArrays
    - Plant issues in PPC with V 8.0
    - RCI project upgraded to V 8.5 and 3 PGM model
      - V 8.5 required R*TIME Server changes because it implements a separate TCP/IP address for each Node Processor

Software

R*TIME Server

- D.C. Cook requested to use V 12.9 (same as PPC and CRA system)
- Changes required for RCI
  - RTP Non I/O Tags added quality tag
  - Configuration of all DO/RO and AO output cards as inputs to R*TIME
  - RTP message logging
  - RTP Interface changes to support RTP NetArrays V 8.5

R*TIME Viewer

- D.C. Cook requested to use V 4.10.5 (same as PPC and CRA system)
- RCI required multiple command line options and used V 4.10.8 (see R*TIME Viewer new features presentation)

Issues

- **But its not a PPC…**
  - Seismic **operability** testing
    - MCB equipment
    - Control cabinet equipment
  - EMI /RFI testing
    - MCB equipment
      - Issues with video extenders and serial (touch screen) extenders
    - Control cabinet equipment
      - Issues with RTP equipment and RTDs
    - Safety related standards
  - Station blackout environmental requirements
    - 122 deg for 4 hours
      - Significantly limited equipment selection
  - Fully dual redundant I/O

Issues

- **Control cabinet space**
  - Reuse existing seismically qualified control cabinets
    - Cabinet depth limitations
    - Cabinet height limitations
    - Cable routing limitations
      - Some RTP termination module to I/O card cables are 25’ in length

Issues

Functional Requirements Changes

- Due to D.C. Cook funding needs equipment purchased before HDD completion
  - Temperature requirement of 122 deg for 4 hours changed after HDD approval
    - Required significant equipment replacement

Issues

- **10-50 mA Current Loops**
  - Only a fraction of the original 10-50 mA current loops have been upgraded to 4-20 mA
  - Pursue new RTP 10-50 mA current loop analog input and analog output cards
    - Operational voltage issues
      - 36 VDC originally
      - 24 VDC final
    - Load range issues
      - 100 – 600 Ohm requested
      - 330-370 Ohm final
    - Dual redundant AO accuracy issues
      - RTP redesign to improve load sharing at low output current

Issues

- **200 / 235 Ohm RTDs**
  - Pursue new RTP 200 Ohm RTD card

- **Input Range**
  - Current allowed inputs in the range of -8% to 108% of scan (4-20 mA +/- 8%, 10-50 mA +/- 8%, etc.)
  - RTP defaults to a tighter range based upon TUV requirements for the SIL certification
  - Required RTP NetArrays change

Issues

- **RTP Chassis Fans**
  - Failure mechanism for the Node Processor
  - Particularly sensitive for Control Room equipment at DC Cook due to HVAC issues
  - Fan failure not monitored by RTP
  - D C Cook added undercurrent relays to detect fan failures
- **RTP Chassis Power Supplies**
  - D.C. Cook experienced RTP power supply issue due to RTP power supply component issues in their PPC and annunciator systems
  - RTP Power supplies modified by RTP and Scientech to automatically monitor voltage

Issues

- **PID Control**
  - Multiple PID controls in the system
  - RTP PID implementation had to match MOD 30 PID control response
    - Significant tuning and testing in the Simulator
  - Simulator Testing
    - Drive inputs and collect outputs from all 3 systems
      - Simulator Model
      - Actual MOD 30 units
      - RCI system
    - Compare results
    - Tune the RTP NetArrays PID configuration to the MOD 30 operation

Issues

- **MOD 30 HMI Units**
  - Static sensitivity if not properly grounded
  - Limited amount of Analog and digital communication between RTP and MOD 30 HMIs due to requirement to reuse e isting cabling

Issues

- **HMI Indication**
  - Digital values displayed on both the MOD 30 MCB HMI Units and the desktop ALPC units
    - Interface between MOD 30 units and RTP includes 4-20 mA analog inputs and 4-20 mA analog outputs.
    - Multiple A-D and D-A conversions meant digital value differences between MOD 30 and ALPC indications
      - Particularly sensitive for SG Pressure (indicated as xxxx.x)
      - Solution was to “calibrate” RTP AIs and AOs so that the digital values matched
- **HMI Control**
  - Auto / manual control from either the MOD 30 or the ALPC and the mechanism to switch between the two significantly complicated programming and testing

Issues

- **System Configuration**
  - RU-31 control functions removed during U2 FAT Dry Run
  - I&C Test Panel Displays added during U2 FAT
  - Lead Unit for installation changed multiple times

Implementation

- U1 / U2 Systems staged through FAT in Idaho Falls

Implementation

- **D.C. Cook created Digital Controls Staging Area (DCSA) in a building on the Turbine deck**
  - Large enough for U1 and U2 RCI systems to be simultaneously staged (13 cabinets each) plus two tables each
  - Physically and Cyber secure environment with protected power and HVAC
  - Includes a separate personnel work area
  - DCSA staging cabinets replicate control cabinets from field termination wiring forward
  - Wiring used in DCSA staging cabinets to be reused during final installation
  - Staged systems in DCSA used to verify plant procedure changes (I&C, Maintenance, Engineering, Operations) before final installation
  - 2nd EWS and 4 server heads were installed to facilitate easier access during installation and testing

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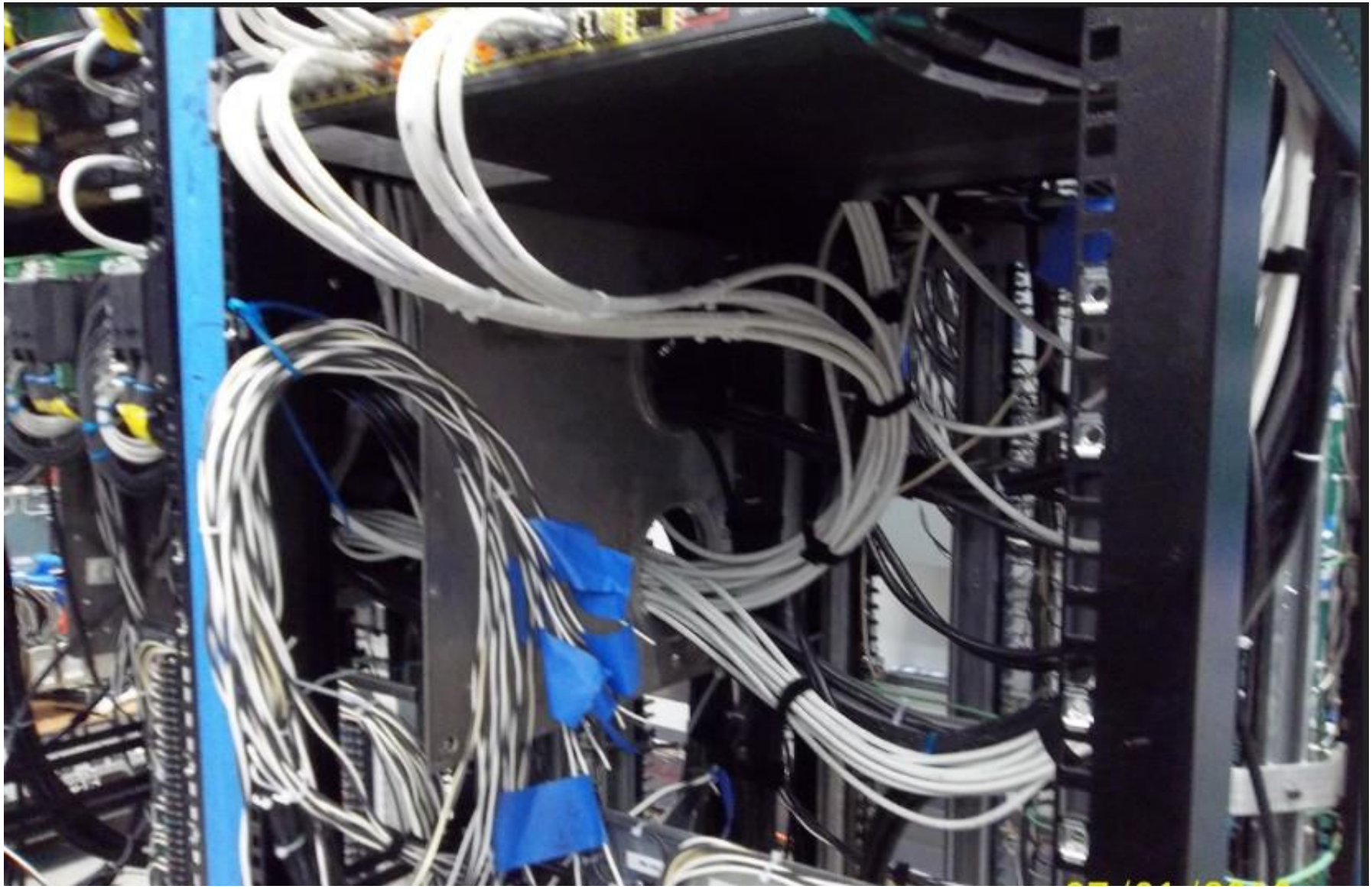

D. C. Cook Reactor Controls and Instrumentation Upgrade

- **Status**
  - U2
    - DC Cook 100% participation in FAT testing Fall of 2016
    - Pre-installation SAT testing performed in the “clean room” at DC Cook Fall of 2017
    - System installed Spring of 2018 during U2C24 refueling outage
  - U1
    - DC Cook 100% participation in FAT testing Spring of 2017
    - Pre-installation SAT testing performed in the “clean room” at DC Cook Fall of 2018
    - System installed Spring of 2019 during U1C30 refueling outage

D. C. Cook Reactor Controls and Instrumentation Upgrade

D. C. Cook Reactor Controls and Instrumentation Upgrade

Lessons Learned

- Changing of which unit would be lead installation due to prep, testing and outage planning time
- HMI EMC unacceptable reslts during development results in redesign
- Grounding issues (WSI cabinets and indicators)
- Interface with other Digital Control Systems (either grounding or sampling issues)
- Noise on analog outputs from Reactor Protection System
- Channel Deviation alarms received due to noise
- Engineering Workstation took control of a valve using an ALP screen
- Too many alarms caused Operator distractions; not everything is worth alarming

D. C. Cook Reactor Controls and Instrumentation Upgrade

Lessons Learned

- Current output of output cards does not go below 10ma and with card accuracy is above 10ma
- Overranging of 10-50ma input termination modules
- Retentive values in Netarrays
- PID changes due to full loop simulation
- Display changes due to changes to desired system operatoin