Interface to Slow Control and Interlocks

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Outline

- Yesterday: discussion of changes to PTC to enable connection between WIEC and Dune detector safety system (DDSS)
- Today: interactions with Slow Control (SC) and DDSS, details about the interfaces with DDSS

- In defining our communications with SC and DDSS we suffer from the fact that these two systems are not yet well defined, this will be clear in some of the slides
- Will make some assumptions, may need to make slight changes in design
- Cryogenic controls based on OPC Unified Architecture (OPC-UA), the DAQ consortium is planning to use the same solution for SC
  - TPC consortium made aware of this only Monday last week (March 2), this may make us reconsider some parts of the design of the interface to the DDSS

Slow Control (i)

- Requirements (SC side): every system that needs to be controlled from SC should have Ethernet interface
- ProtoDUNE:
  - Warm Interface Board ✓
  - Low voltage power supplies ✓
  - Bias voltage supplies ✓
  - Power and Timing Card 🛑 (not needed)
  - Supplies for heaters and fans 🛑

ProtoDUNE

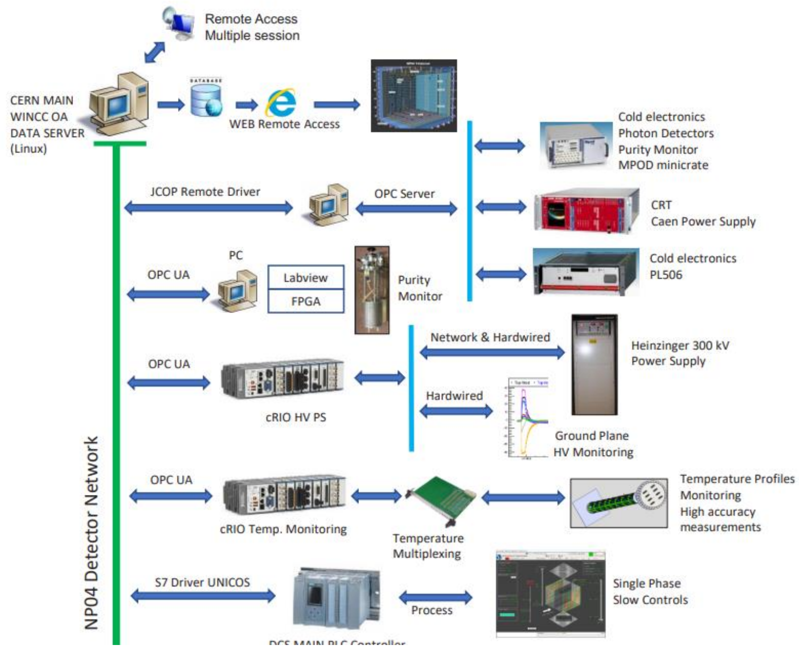
- Fans supply
  - Not remotely controlled, very minimal interlock system with low voltage power supply to WIEC
    - Goal: if the fans are not cooling the crate, turn off (or prevent from turning on) the LV to the WIEC
    - Initial realization: via software (using RTD on the WIBs and turning off the LV power supply)
    - Later realization: use current drawn by the fans to check whether they are running, feed this into an hardware inhibit signal sent to the LV power supply
- Heaters supply
  - Controlled by RTDs installed on the warm side of the flange, but not used (i.e. always powered off)

SC Interface - WIEC

- For each WIEC will have 6 SC connections:
  - Five WIBs plus PTC
  - Each will have a SFP+ transceiver, connected with two LC fibers to MTP12 patch cord going to patch panel on photon detector minirack
  - From there another MTP12 ribbon goes into network switch on the detector mezzanine
  - This is the same infrastructure used by the CCM to communicate with the WIBs
- WIBs talks both to the CCM (DAQ configuration) and to SC (low voltage power control and monitoring, monitoring of environmental quantities)
- PTC talks only to SC
- With additional I2C bus between PTC and WIBs we could route all the SC traffic exclusively to the PTC, that would then relay commands to the WIBs and relay monitoring data from the WIBs
  - Advantage: reduce the number of open SC connections

SC Interface – LV/bias supplies

- LV power supplies: 25 (one per row of detector), each powering six PTCs / WIECs (WIENER PL506)
- Bias voltage supplies: 5 WIENER MPOD crates with 45 ISEG modules (35 provide –HV, 10 provide +HV)
- Both implement OPC Data Access (OPC-DA) protocol (older than OPC-UA, requires additional Windows PC in the network)
- Giovanna says that the OPC-UA interface is now available (to be tested at ProtoDUNE soon)



- It is unclear that there are other supplies on the market that meet the same specifications as the WIENER ones and have OPC-UA interface

Fans: SC or DDSS ?

- Improve on the most recent ProtoDUNE design
  - Make power supplies remotely controllable via Ethernet
  - Provide additional inputs to the DDSS (main variable for inhibit to the LV to the WIBs comes from the RTDs on the WIBs, goes to DDSS via the PTC)
  - Fans: can make very simple custom board (remote power control via Ethernet or OPC-UA, use fan control chip, provide signal that indicates that the fans are spinning to the DDSS) or can become fancier (use the actual RTD measurements on the WIB to control the speed of the fans, temperature measurement goes from WIB to PTC to DDSS to the fans control)
  - Sits at the border between SC and DDSS, need to understand the design of both to choose optimal solution (reliability / cost / safety)

Heaters: SC or DDSS ?

- System was not used in ProtoDUNE, however we cannot delay its design / implementation until the last minute (i.e. the cryostat is full and we are ready for data taking)
  - Need to put the system in place even if we may not use it
  - Unless we have very solid simulation results that convince us that this is not needed
- System includes RTDs on the warm side of the flange and heaters
  - Also in this case we can make a simple custom board with remotely controlled power (enable/disable) plus RTDs controlling the power to the heaters. It would be nice to have feedback (heaters on/off, actual RTD readings) available in SC/DDSS. Fancier solution would include reading of humidity in the cavern to decide whether heaters are needed or not.

Fans / Heaters

- These are simple systems that require few weeks for design / prototyping
- Will start design activities when the details of SC and DDSS are clearer, but still need to make sure that prototypes are available for 2nd run of ProtoDUNE at the end of next year
- This is not a major cost (~$200k)

What is monitored /controlled by SC ?

- For TPC electronics SC will control ~45k quantities (see complete list in the backup material)
- ~4k channels to be turned on/off (in most cases all channels of a given type are turned on/off at once)
- At 1 KHz this is probably in the 100 MB of data being transferred to the SC
- Data can be split on configuration parameters that change very unfrequently plus monitoring voltages and currents
- For voltages and currents try to get data into SC computer as quickly as possible compatible with the entire system (not clear where the limitations are: OPC-UA, computer, network, supplies)

Archival of SC information

- We are not going to log data at the same speed as we are collecting it
  - In most cases should have just small fluctuations around stable value
  - Allow online display (on request) of a few channels at the maximum speed
  - Record all the data in a ring buffer at full speed (time window ? 10-30s)
  - If there are no problems only a fraction of the data gets stored in database
  - In case of trips dump the entire ring buffer to the slow controls archiving database

SC and DAQ configuration databases

- Both SC and DAQ configuration databases will have an area where we define the settings for the detector that are under the control of SC and CCM respectively
- The CCM (Control, Configuration, and Monitoring) and SC record every action taken in the archiving part of the two databases
- A fraction of this information migrates to the offline conditions DB for use in reconstruction / analysis
- Expect that TPC consortium is responsible for the definition of the tables that contain the information of the TPC electronics in agreement with infrastructure / conventions set up by DAQ/computing

Hardware Interlocks (i)

- Unless we decide to implement all interlocks in software (inside OPC-UA) we are going to have hardware interlocks:
  - Prevent bias voltage from being on if no power to the FEMBs (could restrict to no power to the FE amplifier)
  - Prevent PTC/WIB from being turned on if the fans are not active
- Full action matrix of DDSS not defined today
  - Try to design interface between TPC electronics hardware and DDSS in such a way that we have maximum flexibility in designing action matrix of DDSS

- Reminder: interlock system is not responsible for personnel safety (but can be used in part for this purpose during detector assembly / integration / installation)

Hardware Interlocks (ii)

- Inhibits from the DDSS
  - Prevent power from being provided to PTC/WIBs
  - Prevent bias voltages from being turned on
  - Turn off power / bias voltages in case of issues elsewhere in the detector
  - Try to prevent damage to detector components
- Inputs to the DDSS (over 1,100 channels)
  - Status of low voltage and bias voltage supplies (150+658 channels)
  - Status of fans / heaters (300 channels)
  - RTDs inside the WIEC, RTDs on the warm side of flange, other environmental monitors (T, humidity in the cavern)
  - Inputs from other detectors

Key assumptions

- Today, there is no design for DDSS today, have to make assumptions on how it will look like
- Use industrial components for DDSS, not relying on SC network connections
- Industry standard for PLC assumes that digital “true” is ~24V, this requires having a lot of custom boards to convert signals from our detector components to the PLC and viceversa
- This does require a lot of custom conversion modules (translate digital levels, remap channels on standard DSUB connectors, translate optical fiber links from WIB)
- The alternative is to develop custom boards where interlock logic is either pre-programmed or programmable via FPGA
- In the end the cost of the two systems (including development) is probably similar, prefer the industry standard based solution for long term maintenance reasons

Translation Cards (i)

- From the detector to the DDSS
  - 150 duplex fibers from PTCs, require optical to digital conversion and then input into the DDSS (via dedicated network, avoid network used for CCM/SC)
  - Connections from fans and heaters power and control system (from SC or from custom board)
  - Unclear how to get input from low voltage power and bias voltage supplies (from SC ?)
- From the DDSS to the detector
  - 150 duplex fibers to the PTCs
  - Low voltage power supplies (6 channels) can have inhibit on individual channels via DSUB25 connector
  - Bias voltage module (16 channels) requires two DSUB9 connections
  - Connections to fans and heaters power and control system

Translation Cards (ii)

- Example of translation card for placing inhibit signals on individual bias voltage cards (need 45 of these, one per bias voltage module)
  - Need digital output component for PLC system, assume sends out 0-24V signal on DSUB25 cable with a certain pin assignment (channel 1-channel16, ground)
  - Translation card receives 16 signals (plus ground) from PLC, reduces the voltage to the TTL range, reroutes them to two DSUB9 cables with a different pin assignment (channel1-8, ground, channel 9-16, ground)
  - The design of the board is trivial, need to make it compatible with rack mounting
- Similar design for translation card for placing inhibit signals on the low voltage power supplies (25 for LV, 25 for fans, 25 for heaters)

Translation Cards (iii)

- Inventory:
  - Optical I/O – 150 components (off the shelf), plus possibly a few network switches
  - Digital outputs – 70 components (more if also include fans and heaters), 70 translation boards
  - Analog inputs – RTDs, fans status ?
  - Digital inputs – Unclear we can get signal from LV/bias supplies
- Most probably this is at least 80% of the overall DDSS
  - Other detector components probably have much simpler systems
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Interface to DDSS

- Desire to have interface to DDSS has triggered design changes for the PTC
- I think we can interface all other systems to DDSS via appropriate choice of components (different model of supplies, with interlock on individual channels) plus interface cards to industry standard, without any changes to the components (except for translation cards)
- DDSS for TPC electronics needs to be distributed along the detector mezzanine (5 locations for bias voltage supplies, 25 locations for everything else)
  - This calls for distributed DDSS system (how many PLCs ? What structure ? What protocol for communication ?)
- Need to have discussions with controls engineer(s) who will take responsibility for design of overall DDSS to understand details of technical solution (i.e. choose components, choose protocol used by DDSS, ……)
  - Not a lot of expertise inside the consortium, will need guidance / help from technical coordination

Conclusions

- SC and interface to DDSS are the areas that are least well defined within TPC electronics consortium deliverables
- It's clear that we need to work with SC / Technical Coordination to understand how system will be implemented
- TPC electronics is probably the most demanding "customer" in terms of channels for both SC and DDSS
- Custom components that are required for DDSS are most probably very simple, as long as industry standard solutions are used for PLC

Backup Material

- Complete list of variables to be monitored by SC for TPC consortium

What does SC control / monitor? (i)

- Preliminary table in the appendix of the DAQ/TPC interface document
- WIBs (750 WIBs per detector, plus 30 for the cold boxes)
  - Temperature on the WIB, Firmware version, Status flag for each FEMB
  - FEMBs (4 FEMBs per WIB, 3,000 FEMBs per detector)
    - Turn on/off each FEMB individually
    - V,I for each power line (2-5 per FEMB, to be determined)
- PTCs (150 PTCs per detector, plus 6 for the cold boxes)
  - Temperature on the PTC, Firmware version, turn on/off each WIB individually, status flag for each WIB
  - V,I for the power lines to each individual WIB (5 total)

What does SC control / monitor? (ii)

- Low voltage power supplies (25 creates, 150 channels)
  - Status flag
  - Turn on/off each individual channel (6 per supply)
  - I,V for 6 channels
  - Status of interlock for each power line
  - Internal configuration of the power supply (ramp speed, thresholds for alarms, target voltage, operations to be executed when there is an alarm condition)

What does SC control / monitor? (iii)

- Bias voltage supplies (5 crates per detector, each with 9 modules, mostly 15 channels per module)
  - Status flag for the bias voltage supply
  - List of configured bias voltage modules, and list of active channels in each module
  - Individual bias voltage channels (658 channels total, 450 for the APA wires, 208 for the field cage termination electrodes)
    - Status of each channel
    - Turn on/off the bias voltage on each channel
    - V,I for each channel, status of interlock on each channel
    - Internal configuration of the bias supply for each channel (ramp speed, thresholds for alarms, operations to be executed whenever there is an alarm condition)

What does SC control / monitor? (iv)

- Fans power supplies (25 total, each controlling 6 WIECs)
  - Status of each channel (6 or 24 channels per power supply)
  - Turn on/off the power to each channel
  - V,I, fan speed for each channel (6 or 24 ?)
- Heaters power supplies (25 total, each controlling 6 WIECs)
  - Status of each channel (6 per supply)
  - Turn on/off power to each channel
  - Voltage and current for each channel
  - Temperature measurement on the flange for each WIEC

What does SC control / monitor? (v)

- Cold boxes (duplicate of cryogenic controls ? 3 cold boxes) “?”
  - Status of the cold box (open, closed, with GN2)
  - Humidity and temperature in the cold box (how many measurements ?)
- DDSS “?”
  - Record all the times when one of the inhibits for the systems under the responsibility of the TPC electronics consortium is active (record transition time and channel name)
- Rack monitoring “?”
  - Status of all the racks with TPC electronics components (power and bias supplies, number of racks to be determined)
  - T,V,I from each rack monitor interface