Engineering Note

Date: 2020-10-21

Project: DUNE Detector Safety System
Doc. No: CERN EDMS# TBD
Team: T. Nichols

Subject: DDSS Logic Requirements

1 OVERVIEW

1.1 Purpose

This document provides the logic requirements to be implemented by the DUNE Detector Safety System, which provides equipment safety interlocks for DUNE detector 1 at the LBNF far site at SURF.

1.2 Applicable Documents

CERN EDMS# 2xxxxxx	TPC Electronics Cable and Fibre Plant on the Top of the Cryostat
ANSI/ISA-88.00.01-2010	Standard, Batch Control Part 1: Models and Terminology

1.3 Abbreviations

AI	Analog Input
AO	Analog Output
APA	Analog Plain Assembly
DA	Derived Analog
DDSS	DUNE Detector Safety System
DI	Discrete Input
DO	Discrete Output
DUNE	Deep Underground Neutrino Experiment
EDMS	Engineering & Equipment Data Management Service
Fermilab	Fermi National Accelerator Laboratory
HMI	Human-Machine Interface
I/O	Inputs/Outputs
LBNF	Long-Baseline Neutrino Facility
PCO	Process Control Object
PLC	Programmable Logic Controller
PTC	Power and Timing Control
RTD	Resistance Temperature Detector
SURF	Sanford Underground Research Facility
TPC	Time Projection Chamber
WIEC	Warm Interface Electronics Crate

2 INPUTS/OUTPUTS

2.1 Common I/O

I/O Type	Tag Name	Device Type	Common Name
AI	TT0010I	Temp. Transmitter	Ambient Temperature
AI	AT0010I	RH Transmitter	Relative Humidity
DA	TY0010I	N/A	Dew Point (derived from TT0010I & AT0010I)

2.2 TPC Low Voltage Rack I/O

These I/O are duplicated 150 times across 25 racks (6 per rack). The naming convention is based on EDMS# 2xxxxxx. Tag names include a string mxxav where:

m = 1, 2 detector module (i.e. 1 is detector 1)
xx = 01..25 position of APA doublet in north, central, or south array. East to west. Equals rack number
a = N, C, S position of array (north, central, or south)
v = U, L upper (U) or lower (L) APA

I/O Type	Tag Name	Device Type	Common Name
DI	CEFAN_mxxav1_Sts	Fan	Cold electronics fan 1 status
DI	CEFAN_mxxav2_Sts	Fan	Cold electronics fan 2 status
DI	CEFAN_mxxav3_Sts	Fan	Cold electronics fan 3 status
DI	CEFAN_mxxav4_Sts	Fan	Cold electronics fan 4 status
DO	CEFAN_mxxav1_En	Fan	Cold electronics fan 1 enable
DO	CEFAN_mxxav2_En	Fan	Cold electronics fan 2 enable
DO	CEFAN_mxxav3_En	Fan	Cold electronics fan 3 enable
DO	CEFAN_mxxav4_En	Fan	Cold electronics fan 4 enable
DO	CEHEAT_mxxav1_En	Heater	Cold electronics heater 1 enable
DO	CEHEAT_mxxav2_En	Heater	Cold electronics heater 2 enable
DO	CEHEAT_mxxav3_En	Heater	Cold electronics heater 3 enable
DO	CEHEAT_mxxav4_En	Heater	Cold electronics heater 4 enable
AI	CERTD_mxxav1	RTD	Cold electronics flange temperature 1
AI	CERTD_mxxav2	RTD	Cold electronics flange temperature 2
DO	CEPS_mxxav_INLK	Power Supply	Cold electronics power supply interlock
Comms	Multiple	Custom	PTC Board EtherCAT

2.3 Bias High Voltage Rack I/O

These I/O are duplicated 150 times across 5 racks (avg. 30 per rack, varies rack to rack). The string mxxav is the same as §2.2.

I/O Type	Tag Name	Device Type	Common Name
DO	AP_mxxavX_INLK	Power Supply	Anode plane X bias voltage power supply interlock
DO	AP_mxxavY_INLK	Power Supply	Anode plane Y bias voltage power supply interlock
DO	AP_mxxavZ_INLK	Power Supply	Anode plane Z bias voltage power supply interlock

3 GENERAL APPROACH

The general approach is to follow the guidance in ANSI/ISA-88 by organizing code into a hierarchy of objects with modes and schemes. This keeps the code organized, eases duplication of desirable features, and provides the operator great flexibility for manipulating the system.

If an operator needs to take a large portion of the system offline to perform an intervention, they can do so by putting the corresponding PCO into Manual mode and setting the scheme to Off (or equivalent). The lower objects will fall into line with that scheme and do not need to be manipulated individually.

Alternatively, if an operator needs to intervene on a specific part of the system, they can do so by putting a lower object into Manual mode and manipulating it while leaving the higher objects as is.

4 LEXICAL

4.1 Terminology

Object	unit of code tasked to perform a certain control function or set of control functions
Mode	manner in which an object is manipulated, typically Automatic or Manual
Scheme	mutually exclusive process actions executed by the same object, e.g. Cooling, Filling
Logic Request	Order coming from the logic in the PLC
Operator Request	Order coming from the operator via the HMI

4.2 Object Layers

Objects are divided into three layers. From lowest to highest, they are I/O, Field, and Control.

I/O objects are standardized and correspond to individual inputs and outputs connected to physical devices. These objects provide common features useful for all I/O, such as simulation and error detection.

Field objects are standardized and correspond to common field devices with multiple I/O. For example, the Analog object connects to one AI object and one AO object in the I/O layer such that it can send an analog command signal and monitor the feedback to verify execution, which is useful for control valves. Likewise, the OnOff object connects to one DI and one DO in the I/O layer.

Control objects perform higher level functions. These include control loops (e.g. PID) and process control objects.

4.3 Process Control Objects

Process control objects (PCOs) reside in the control layer and coordinate the actions of other objects. They are customized to the process. They include a status, which indicates if the overall process is good based on feedback from lower objects. PCOs may be tiered such that higher PCOs direct the actions of lower PCOs.

4.4 Common Resources

Common resources are objects that can provide input to multiple other objects. They are not subordinate to other objects. Analog inputs, digital inputs, and objects producing values derived therefrom are common resources.

4.5 Modes

All objects have modes, typically Automatic and Manual. Modes are used to determine orders, such as setpoint and scheme. In Automatic mode, an object acts upon logic requests, orders provided by a higher object. In Manual mode, an object acts upon operator requests, orders provided via the HMI.

4.6 Schemes

Objects in the control layer have schemes. Typical schemes for a control loop include Regulation and Fixed Position. Schemes for PCOs vary, but may be On/Off or Run/Stop for a simple process or Cooling/Filling/Steady State/Emptying for a more complex process (e.g. cryostat operation).

5 COMMON RESOURCES

5.1 Dewpoint

Dewpoint is derived from temperature and relative humidity.

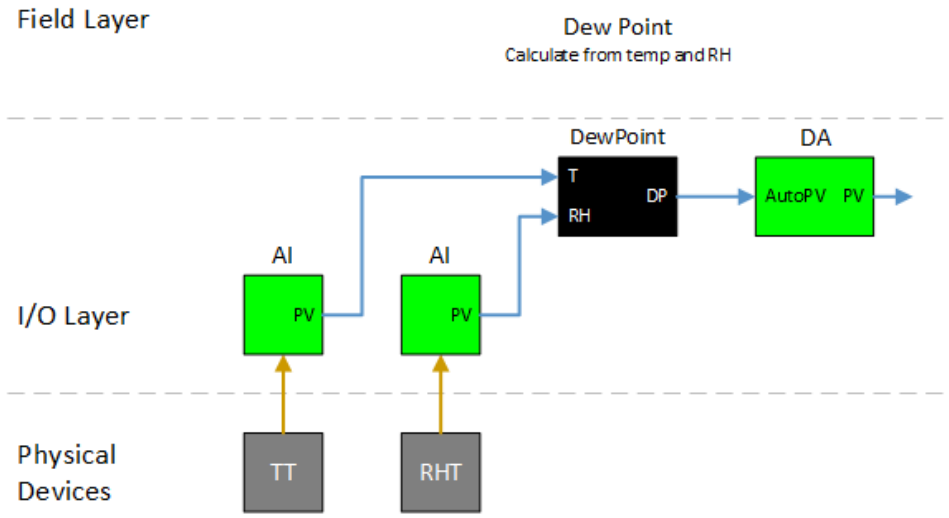

Figure 1 – Dewpoint Object Structure

5.2 Flange Temperatures

Flange temperature for a given flange is the minimum of the temperatures from the RTDs on the flange.

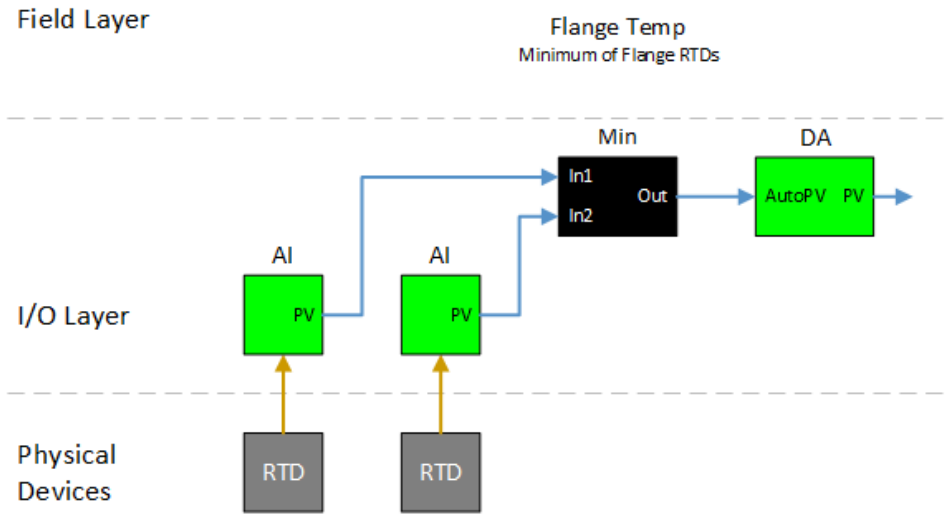

Figure 2 – Flange Temperature Object Structure

5.3 WIEC Internal Status

The Power & Timing Control (PTC) board on each WIEC reports the status of the Frontend Motherboards (FEMBs) and Warm Interface Boards (WIBs). [what this includes is TBD]

6 TPC Low Voltage

6.1 TPC Low Voltage

This is the highest PCO in TPC low voltage interlock system with control over the whole system. It has three schemes, On, Heat Only, and Off. It simply orders subordinate PCOs to have the same scheme as itself. The status is good if each of the subordinate PCO statuses are good.

Object		Scheme		
Type	**Name**	**On**	**Heat Only**	**Off**
PCO	APA Row N	On	Heat Only	Off
PCO	APA Row C	On	Heat Only	Off
PCO	APA Row S	On	Heat Only	Off

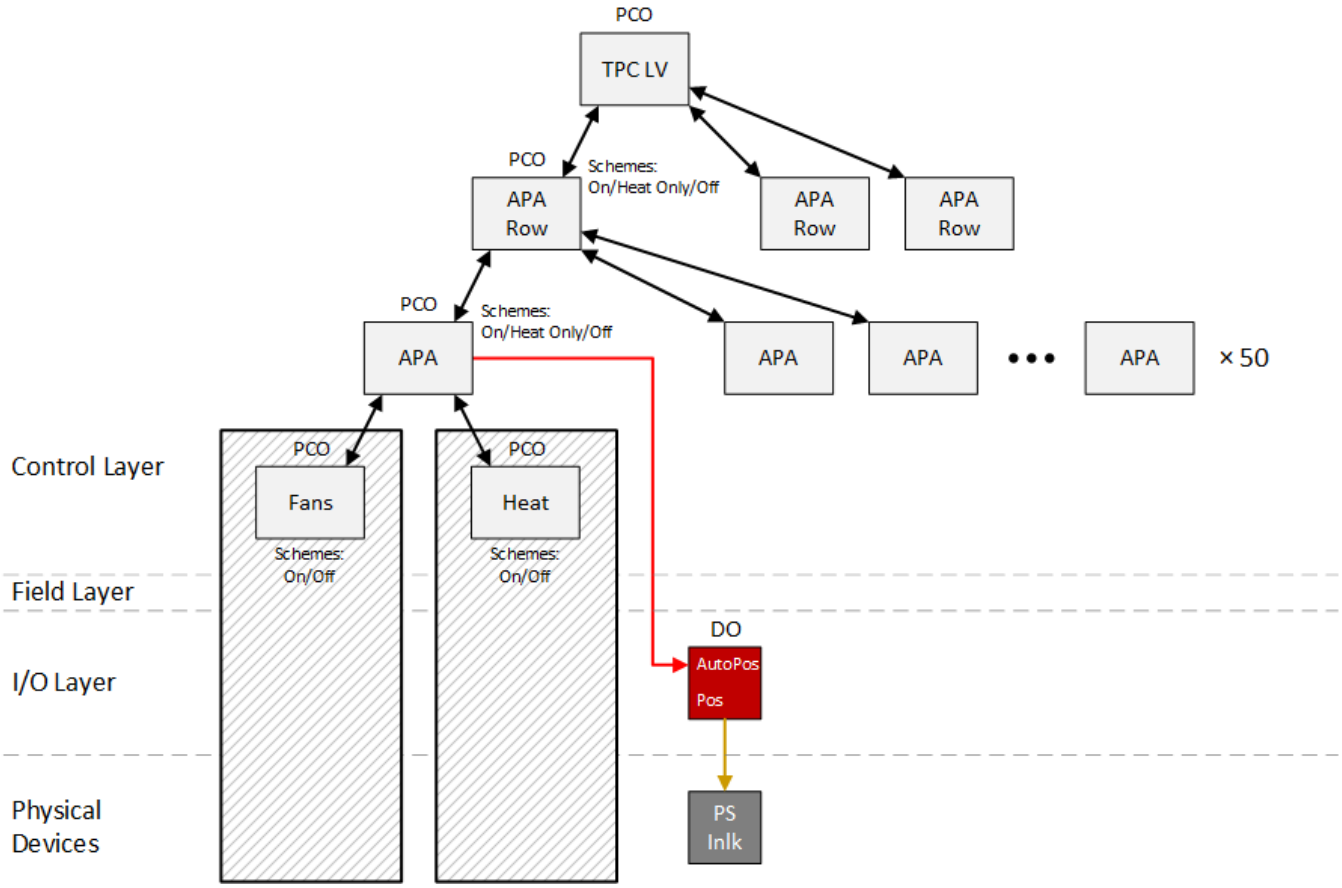

Figure 3 – TPC Low Voltage PCO Structure

6.2 APA Row

The APA Row PCO is subordinate to the TPC low voltage PCO and exhibits control over a single row of APAs. It has three schemes, On, Heat Only, and Off. It orders subordinate PCOs to have the same scheme as itself. The status is good if each of the subordinate PCO statuses are good.

Object		Scheme		
Type	**Name**	**On**	**Heat Only**	**Off**
PCO	APA m01aU	On	Heat Only	Off
PCO	APA m01aL	On	Heat Only	Off
PCO	APA m02aU	On	Heat Only	Off
PCO	APA m02aL	On	Heat Only	Off
⋮				
PCO	APA m25aU	On	Heat Only	Off
PCO	APA m25aL	On	Heat Only	Off

6.3 APA

The APA PCO is subordinate to an APA Row PCO and exhibits control over a single APA. It has three schemes, On, Heat Only, and Off. The status is good if both subordinate PCO statuses are good.

The On scheme is intended for normal operation. Fans run to prevent overheating of the WIEC. Heaters provide heat to the flange as necessary to prevent condensation. Given the fans and heaters are okay, the corresponding power supply interlock is enabled.

The Heat Only scheme is intended for maintenance, such as swapping a board in the WIEC. The fans are stopped and power supply interlock disabled, but heat is maintained as necessary to prevent condensation.

In the Off scheme, the fans and heaters are off and power supply interlock is disabled.

Object		Scheme		
Type	**Name**	**On**	**Heat Only**	**Off**
PCO	Fans mxxav	On	Off	Off
PCO	Heat mxxav	On	On	Off
DO	CEPS_mxxav_Inlk	If Fans & Heat good, enable. Else, disable.	Disable	Disable

6.4 Fans

The Fans PCO is subordinate to an APA PCO and exhibits control over the four fans on a WIEC. It has two schemes, On and Off. The status is good if in the On scheme and X out of 4 fans readback that they are running.

Object		Scheme	
Type	**Name**	**On**	**Off**
OnOff	CEFAN mxxav	Enable	Disable

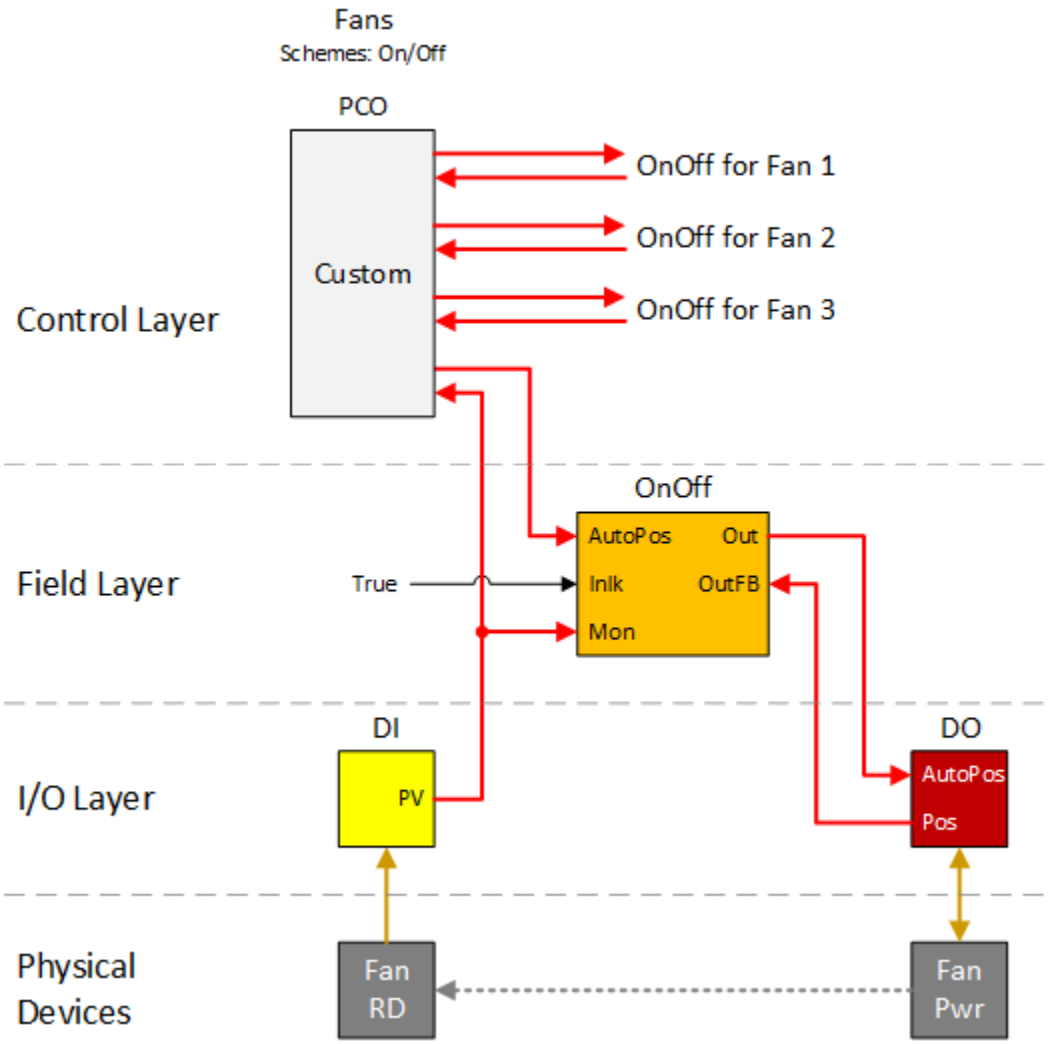

Figure 4 – Fans Object Structure

Each fan is individually enabled and has its own status. An OnOff object that provides the enable signal and verifies it is running.

6.5 Heat

The Heat PCO is subordinate to an APA PCO and exhibits control over the heaters on the corresponding feedthrough flange. It has two schemes, On and Off. The status is good if flange temperature is X°C above dewpoint.

Object		Scheme	
Type	**Name**	**On**	**Off**
DO	CEHEAT_mxxav (heater power)	If temp < 5°C + dewpoint, enable If temp > 6°C + dewpoint, disable	Disable
DO	CEHTLH_mxxav (low/high select)	If temp < 3°C + dewpoint, enable If temp > 4°C + dewpoint, disable	Disable

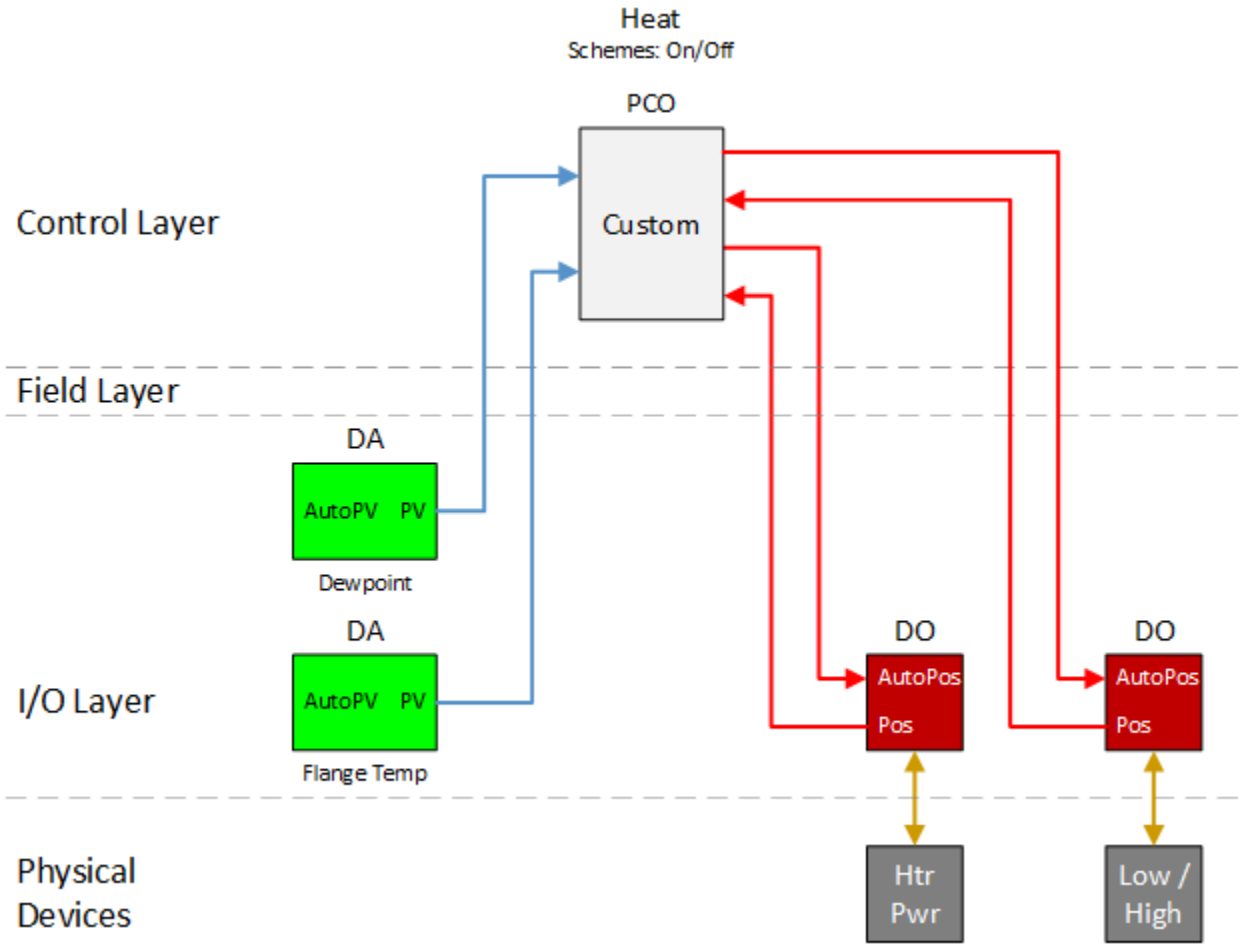

Figure 5 – Heat Object Structure