

Integration Challenges and Solutions for Low Level Controls Systems at the FRIB

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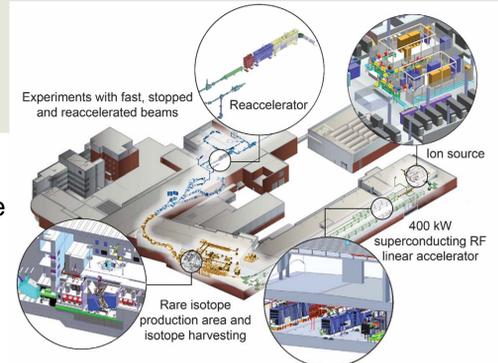


Figure 1: FRIB Layout

Abstract

- The FRIB under construction at Michigan State University, is a new heavy ion accelerator facility being built to provide intense beams of rare isotopes. The low level controls system integrates a wide variety of hardware into an EPICS/PLC based control system. This paper will present the challenges encountered with resulting hardware interfaces, and lessons learned that can be applied to future projects. These challenges include both technical design and project management challenges that are encountered when integrating hardware from other departments.

Project Management

Concurrent Design and Construction

- Challenges**
 - Building design input ahead of 60% design
 - Including # of racks, electrical requirements
- Solution**
 - Built test setups of rack rows/cable tray
 - Developed easily expandable flexible designs
 - Additional design iteration cycles
- Results**
 - Early completion of building Front end
 - Technical equipment installed ahead of BOD
 - Beam produced ahead of baseline schedule
- Lessons Learned**
 - Increased labor due to iterations on design

System Requirements

- Challenges**
 - Control designs dependent on interfacing systems
 - Interfacing hardware different from expectation
- Solution**
 - Easily expandable controls designs
 - Utilized tools such as
 - Interface documents
 - Requirements documents
 - Design documents
 - Adapted designs to accommodate changes
 - Weekly meetings with interfacing groups
- Results**
 - Minimize additional control resources required due to late design changes
- Lessons Learned**
 - Final procurement selection needs controls input

R&D Test Stands

- Challenges**
 - FRIB baseline did not include controls support
- Solution**
 - Hired additional permanent/contract labor
 - Use of PLC controls common in local industry
- Lessons Learned**
 - Dedicated engineer per test stand
 - If underutilized, resource can assist elsewhere

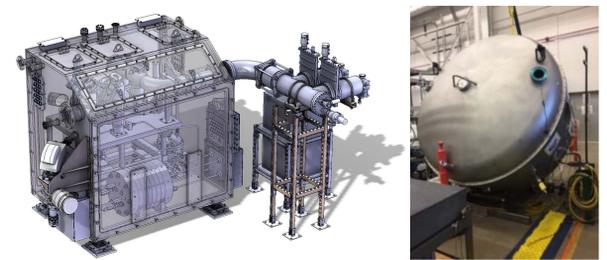


Figure 2: Lithium Charge Stripper & Target System Rotation Test Stands

Controls Process Improvements

The FRIB Cryoplant Control System

- Challenges**
 - Maximum possible uptime
 - Largely analog in nature
 - Complex series of feedback loops
- Solutions**
 - Controlled by Allen-Bradley ControlLogix PLCs
 - Use of ControlLogix PIDE instruction
 - Velocity form of the PID control equation
 - Independent gains
 - Many tunable parameters
 - Operates on percent error instead of absolute error
 - Gains applied against known scaling
 - Gains used in multiple instances, different process conditions
 - Developed in-house control blocks
 - Allows switching process variables
 - Bumpless transfer between operating modes
 - Split range rate limiting
 - Integrated override and interlock support
 - Allows development of templated faceplates
- Results**
 - Flexibility for more complex situations
 - Standard control panels
 - Reduces overall implementation effort

FRIB Superconducting Radio Frequency (SRF) Cavity Automated High-Pressure Rinse System [1]

- Challenges**
 - HPR system very labor intense
 - Multiple fixtures per cavity
 - Potential for cavity damage & contamination
- Solution**
 - Commercial, flexible automation
 - Reduced labor
 - Reduced re-processing rate
 - Adds flexibility for future projects
- Results**
 - Saved estimated 2500 labor hours for project
 - Lower cost than previous solution
 - Robot easily reprogrammable
 - Decreased contamination

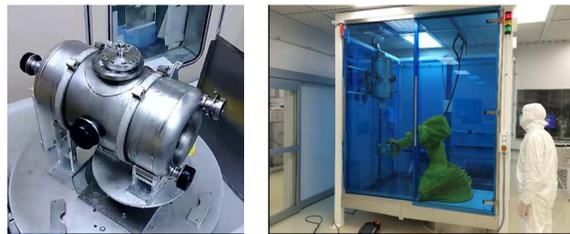


Figure 4: Old HPR fixture versus Robotic high-pressure rinse system installed at FRIB

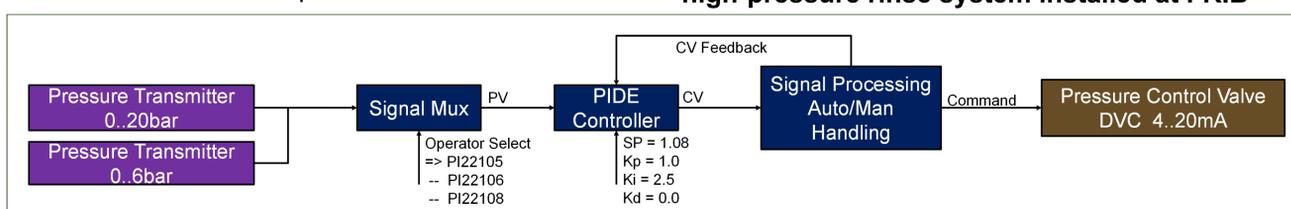


Figure 3: Example PIDE implementation for FRIB Cryoplant



Figure 5: Instrumentation Box utilizing 5B Modules

Superconducting Cryomodule Instrumentation

- Challenges**
 - Interface to a high number of raw signals
 - Solution for up to ~128 channels per cryomodule
- Solution**
 - Use commercial 5B isolated signal conditioners
 - Interfaces with a variety of instrumentation
 - Temperature sensors
 - Strain gauges
 - Superconducting magnet lead drop voltages
 - Superconducting magnet coil voltages
 - Potentiometers
 - Custom 16 channel connector boards
 - Compact design
 - Package allows 48 channels in 4U box in 19" rack
 - Output compatible with PLC voltage levels
 - Custom modules can be developed
- Results**
 - Low cost per channel solution
 - High density packaging – 48 channels in 4U space
 - Can accommodate late design additions

References

- [1] I. Malloch, et al., "Design and Implementation of an Automated High-Pressure Water Rinse System for FRIB SRF Cavity Processing*", in Proceedings of LINAC2016, East Lansing, MI, Sept. 2016, paper TUPRC024, p. 468.