Diamond Light Source Machine Protection

12 Years of Operation (2019)

Diamond-II (2025/26?)

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- UK National Synchrotron Light Source, located near Oxford
- Operating with external users since Jan 2007
- 3 GeV 561.6 m 24 cell electron storage ring
- DBA lattice - 2.7 nm.rad emittance
- 300 mA operating current routinely (350 mA max)
- 500 MHz superconducting RF (+ normal conducting from 2018)
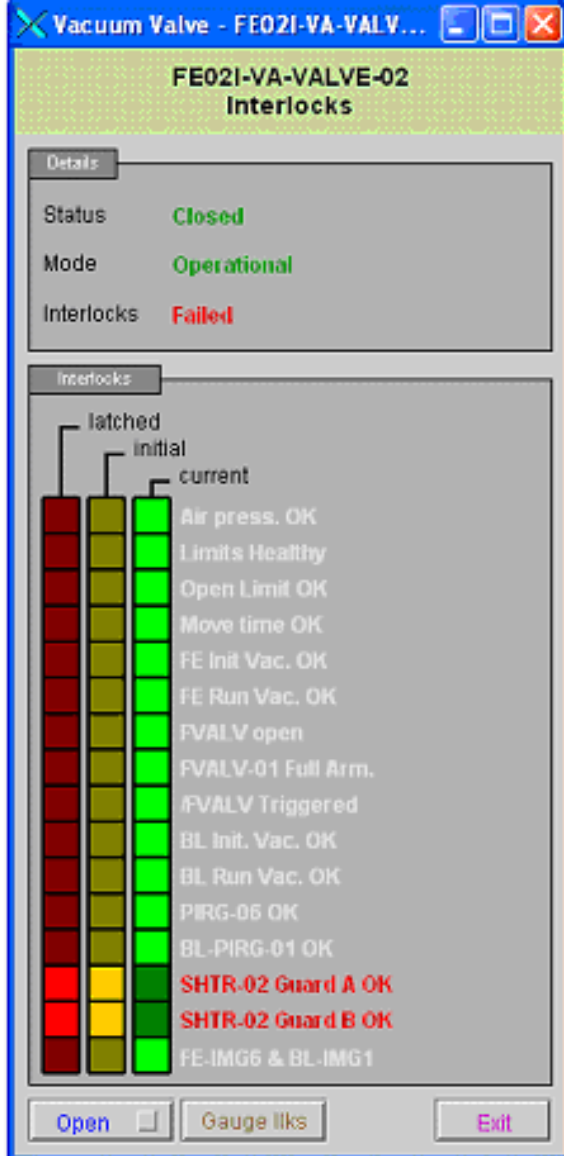- ≈ 33 beamlines in operation, construction or design

- Small team of 4 for all of machine protection

- Over 650 different PLC related applications (PLC/HMI etc)

- Work closely with other teams: Engineering, Controls, Vacuum, ID, RF, IFM, Diagnostics, Beamlines, Suppliers …..

- Some services we offer:

  – Design advice (the earlier the better!)

  – Hardware testing

  – Commercial equipment evaluation

  – Vacuum controls and interlocks

  – Installation, testing, commissioning, fault finding, maintenance

  – Operations support

  – Build and test of bespoke PLC solutions

  – PLC solutions including motion, vision systems, robot integration
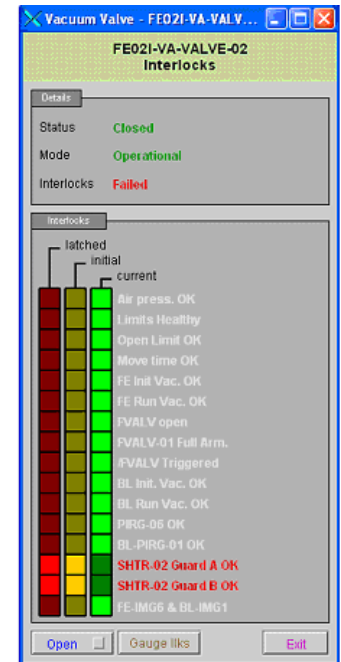
- Majority of PLC hardware is supplied by OMRON
  - Initial CPU hardware was OMRON CJ1 series
  - Later hardware was replaced with CJ2M series bringing built in Ethernet capability

- Standard PLC solutions are supplied in 3U 19" Rackmount box
  - Standard products used wherever possible
  - Standardization allows quick deployment and repeatable code
  - 180+ Valve Crates deployed
  - 40+ Temperature Crates deployed

- Remote I/O used on site on 66 PLCs
  - >99% uses Profinet with Omron controllers

Our PLC Solutions

- Standard solution means all staff are familiar with EPICS/PLC interface

- Majority of interlocks displayed with 3 sets of "traffic lights" for each bit

- Green showing current interlock status

- Yellow showing which bit failed first

- Red showing what has failed since last reset

- As many interlocks as possible are configured to have 2 states for starting and running, start conditions are most stringent, run conditions are less stringent and are used to prevent spurious beam trips

- Application management through 3rd party supplied software "Autosave"
  - Software stored on dedicated server
  - User permission controlled, allow electrical designers access to symbol table to compare I/O but no write access
  - Reduced time looking for and verifying applications are current

- Currently use hardwired interconnects between PLCs and other devices
  - Now starting to see problems with limited I/O
  - Issues with number of point connections and wiring
  - Future projects likely to require greater interconnection for interlocking

  Solution: Greater use of ethernet comms

- Linac and RF systems use Siemens S7 series
  - Turnkey solutions from external suppliers in early 2000's
  - Not written to our standard (there wasn't one when they were made)
  - Systems are using obsolete parts and software
  - Very little documentation and understanding of applications

  Solution: Project underway to convert application to run on our standard Omron hardware

- Code similarity between legacy system (CJ1) and later hardware (CJ2M) and identical EPICS integration means little progress made on addressing:
  - All code requires specific addressing for EPICS to access
  - Memory can be used incorrectly causing overwrites and deletion
  - No direct interface to EPICS, ie 100 words are read and then EPICS uses data from that block, no data types are allocated (FLOAT, UINT, DINT etc)

  Solution: Tag based addressing, for future consideration

- Remote I/O
  - Omron Profinet solution not robust enough for critical interlocking
  - Interface module dedicates large memory area for I/O
  - This memory area is flexible and can lead to clashes with hard coded memory in some code
  - All of the I/O modules can be allocated memory in the PLC, in any order, large networks quickly become confusing

  Solution: Tag based addressing, for future consideration

- Diamond-II upgrade planned for 2025/26

- 99% of PLC hardware will not be supported for planned lifetime of Diamond-II

- Investigations ongoing for new hardware solution
  - Remote I/O as a standard function not an optional addon
  - Tag based to eliminate aforementioned memory addressing problems and to improve interface with EPICS
  - Ethernet/IP comms between systems for greater interconnection and less reliance on hardwired I/O
  - Greater emphasis on beamline automation
  - Robotic hardware to be used requires FSoE for communication to PLC
  - Greater implementation on metrics such as valve open/closing times

- Our PSS system is also under review to replace their aging solution with safety PLC hardware