Spallation Neutron Source LLRF Systems

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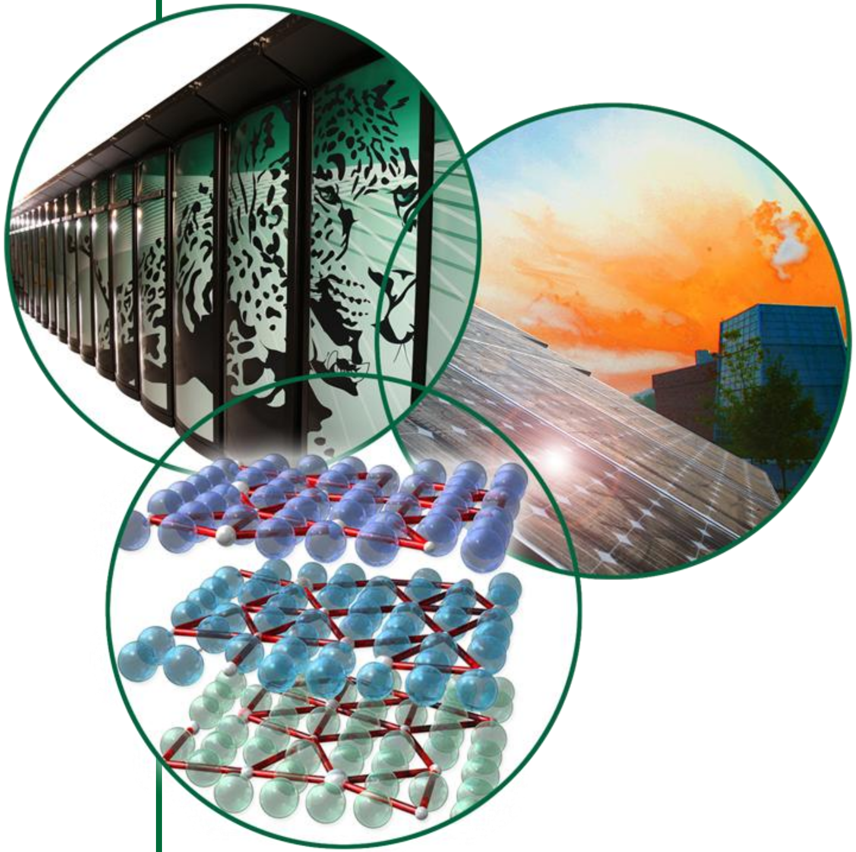

U.S. DEPARTMENT OF ENERGY

OAK RIDGE NATIONAL LABORATORY

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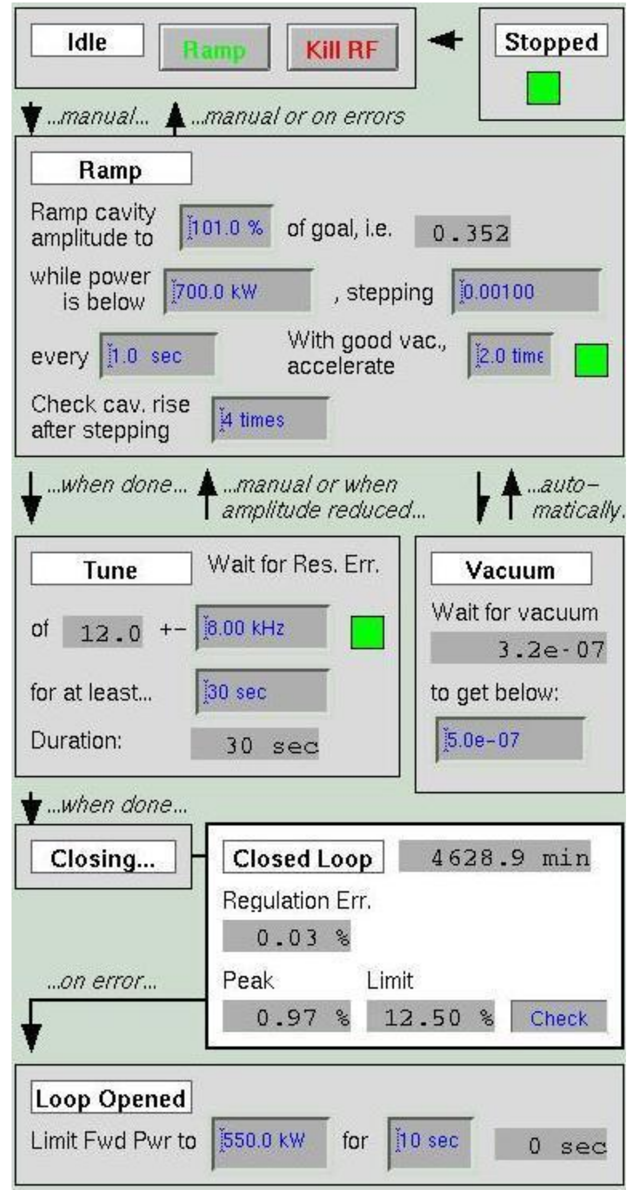
LLRF Automation

- **The startup of the RF systems is automated with the use of a sequencer**
- **Systems can be started or stopped using two buttons**
- **The ramp feature provides the following features:**
  - **Ramp cavity to a user selectable percentage of goal**
  - **Verifies vacuum stays below a set value – halts the ramp if exceeds the value, resumes after recovery**
  - **Tunes cavity prior to closing loop**
  - **Finishes ramp to operational settings in closed loop**



LLRF additions to address Superconducting Cavity issues

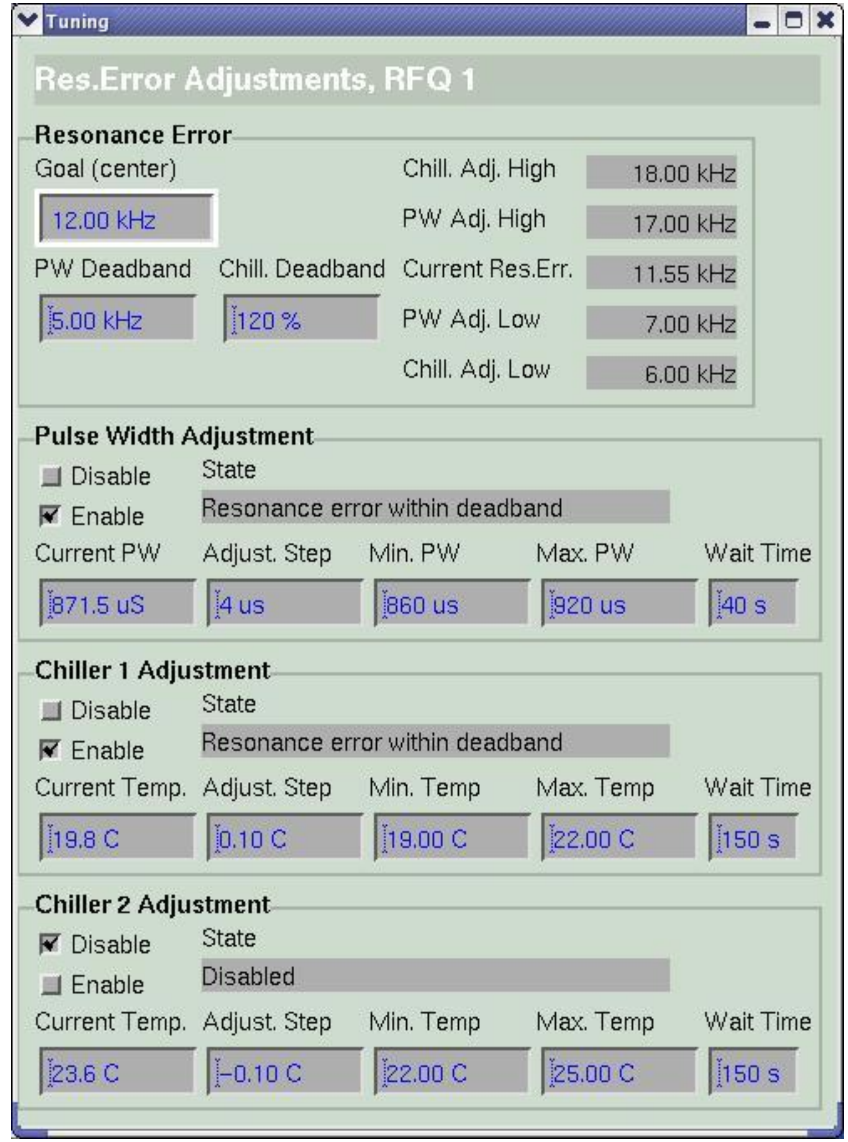
- Quench detection
  - Quench detection was included in the original LLRF package but didn't function properly
  - We now have two functional quench detection schemes
    - Hardware quench detection implemented in HPM module for detection during beam
    - Software based detects the onset of a quench and shuts off RF preventing the quench over full pulse
- Heater control
  - Heaters are provided to keep the thermal load on the cryogenic system constant
    - LLRF enables these heaters when RF power is disabled
- Monitor electron probe current
  - Cold Cathode vacuum gauges go to sleep and can leave us unprotected
  - We installed pico-ammeters to monitor electron current in the couplers
  - Provided electron current display and interlock
- Chatter Fault Protection
  - Inhibit RF after preselected number of successive faults
  - Require manual reset

LLRF additions to address RFQ Issues

- As we increased the pulse length toward full beam power operation we began experiencing RFQ tuning issues
  - With the RFQ operation stable something would disturb the operation and require much effort and time to recover
    - Observed that excessive Ion Source gas flow reduces structure Q over time
      - Now monitor gas flow
    - Structure cooling seemed marginal
      - The RFQ is cooled by a pair of chillers
      - The chillers operate at a fixed temperature set point
        - » One chiller cools the vanes
        - » A second chiller cools the body and MEBT cavities
        - » Replaced the water manifolds
      - Replaced chillers
  - We observed that a minor adjustment of RF pulse length prior to losing control would correct the problem
    - We added a slow pulse-length adjusting feedback loop to the LLRF control software
    - We also added slow control loops for the chiller temperature

RFQ Software Control Loops

- Issues discovered with high duty, long pulse operation of RFQ
- Software loops added to enable up to 1 mS pulse operation
- Adjust pulse width for fine adjustment
- Adjust chiller temperatures to center pulse width



Beam Blanking

- Downstream RF must be disabled during beam tuning
- Initially the LLRF was shifted in time to simplify tuning process
  - Time shift is limited by HV Pulse Width
  - More time consuming to perform
- Beam blanking allows for turning RF off during beam pulse
  - All RF stations remain on
    - Those not yet in use are not gated on during beam pulse
    - Allows physics team ability to turn on entire Linac and step through each cavity in sequence
    - No need to stop tuning process to turn on the next cavity