The Cryogenic Control System of BEPCII

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Outline

- Preamble
- Cryogenic control system
  - Control system overview
  - Exchanging data between S7-400 and IOC
  - Control system of superconducting devices
  - Commissioning
- Conclusion
- Acknowledge

Preamble

- In order to increase the luminosity of the BEPC, the project BEPCII was constructed.
- Three kinds of superconducting devices are used: superconducting RF cavity (SRFC), superconducting solenoid magnet (SSM) and superconducting quadrupole magnet (SCQ).
- The cryogenic system produce cooling helium for SRFC,SSM and SCQ.

Preamble

- Two 250W compressors are installed in cryogenic plant: One compressor for SRFC, the other for SSM and SCQ respectively.
- The compressor system comprises a main compressor, a refrigerator, a subcooler and transfer lines.
- Superconducting SRFC consists of two SRFCs, one valve box and one 2000L Dewar.
- Superconducting magnets are composed of two SCQs, one SSM, three valve boxes and one 1000L Dewar.

Cryogenic control system

- Control system overview
  - The cryogenic control system is divided into compressor control and superconducting control according to the front-end devices.
  - Two cryogenic compressor systems were purchased from the vendor-Linde Company, which performs the compressor control through S7-400 PLC, Profibus and WinCC software.
  - The control system of superconducting devices was developed by IHEP, using AB-PLCs, ControlNet and VME IOCs(See Fig1).

Cryogenic control system

- Control system overview

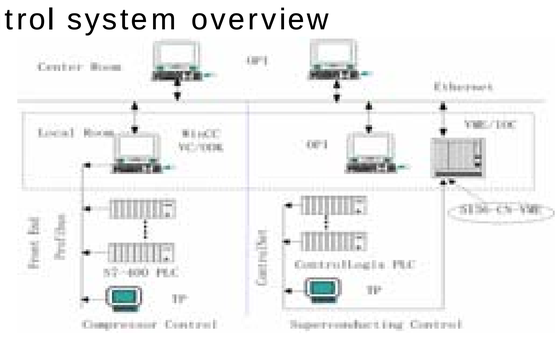

Fig1 the cryogenic control structure of BEPCII project

Cryogenic control system

- Exchanging data between S7-400 and IOC
  - It is required to integrate the compressor signals into EPICS.
  - The open development kit (ODK) is a software package, which provides open C application program interface (C-API).
  - The data of WinCC can be accessed or changed by EPICS via C-API of the ODK (See Fig2).

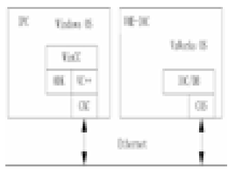

Fig2 the communication between S7-400 PLC and EPICS IOC

Cryogenic control system

- Control system of superconducting devices
  - The cryogenic control system supplies the 4.5k liquid helium to the SRFC, the 4.5k two-phase helium for SCQ and SSM of the BEPCII.
  - The cryogenic control system is expected to run continuously and steadily.
  - It is very important to design the control logic, control PID loops, the low level interlock and sequence.

Cryogenic control system

- Control system of superconducting devices
  - Design of Control Function (See Fig3)
    - The control logic and control loops often need to be modified during the commissioning stage.
    - Generally the loops running on the PLCs must work continuously, even momentary interruptions can not be tolerated.
    - A short interruptions can be tolerated in IOC side.
    - All high level control algorithms, control PID loops and automatic sequences reside in IOCs under the EPICS.
    - Only the low level interlocks and device I/O of the pivotal equipments run in PLCs.

Cryogenic control system

- Control system of superconducting devices
  - Design of Control Function

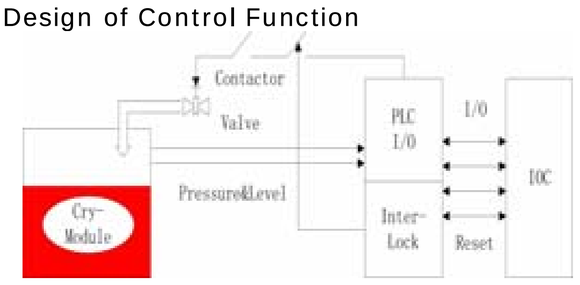

Fig3 Design of Control Function of Superconducting Devices

Cryogenic control system

- Control system of superconducting devices
  - PID Control Loop
    - To keep the cryogenic system operation best with a fairly constant load, a lot of PID control loops are designed and used in cryogenic control system.
    - Here is the example which shows how to control the level of liquid helium in superconducting cavity (See Fig4).
    - The power of the electrical heater is used to compensate the dynamical load of the SRFC.
    - Two PID control loops are designed to keep the balance of the liquid level in vessels.

Cryogenic control system

- Control system of superconducting devices
  - PID Control Loop
    - The output power formula: PHeater=PState+PRF+PPID
    - PState stands for static state power of electrical heater.
    - PRF means dynamic load power from RF system.
    - PPID is compensating power of electrical heater.
    - SetpL_H and SetpL_V stand for the setpoint value of the level-heater and the level-valve PID control loop respectively.

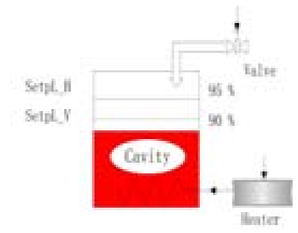

Fig4 Two PID Control Loops

Cryogenic control system

- Control system of superconducting devices
  - Interlocks in the PLC
    - In order to protect the key devices from damage, a lot of interlock conditions need to be taken into account to force actuators at a safe position.
    - All interlock actions are performed automatically as soon as one of interlock conditions is available.
    - The recovery of the interlock status must be enabled by the operator.
    - Of course, these interlock programs reside in the PLC, which is independent from the IOC.

Cryogenic control system

- Commissioning of the cryogenic control system

Conclusion

- Two-layer control structure is adopted in cryogenic system.
  - The high level control is on the EPICS IOC, where all control algorithms, PID control loops and sequences reside.
  - The low level control is on the PLC, which performs data input output and the important and necessary interlocks.
- The control system of SRFC has been in operation for more than one and a half years without any problem.
- The improved cryogenic control system was put into operation in May 2007 and it is working well.

Acknowledge

- The control system of superconducting systems was designed, constructed and is commissioning successfully at BEPCII.
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