CONTROL AND INSTRUMENTATION FOR THE VEC SUPERCONDUCTING CYCLOTRON CRYOGEN DELIVERY SYSTEM

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Abstract

The cryogen delivery system for the superconducting cyclotron supplies liquid helium to the superconducting main magnet coil and three cryopanels. It also supplies liquid nitrogen to the thermal shield of the liquid helium chamber housing superconducting coil and the thermal shield and baffles surrounding the cryopanels. A suitable efficient piping network comprising vacuum jacketed cryogenic transfer lines, liquid nitrogen shielded transfer line and distribution manifold is used in the superconducting cyclotron for distribution of cryogens. A liquid helium pump ensures the required flow of liquid helium through the cryopanels. The cryogen delivery system is fitted with necessary field instrumentation and controllers to monitor and automatically control certain important process parameters. This paper presents the overall control and instrumentation for the cryogen delivery system.

INTRODUCTION

The importance of cryogen delivery system [1] in the context of a superconducting cyclotron is immense and critical. The superconducting coils of the cyclotron are immersed in a pool of liquid helium. Liquid helium is supplied to the magnet from the liquid helium plant/refrigerator. The accelerating chamber of the superconducting cyclotron has to be maintained at high vacuum for proper acceleration of particles. Vacuum in the accelerating chamber is obtained by three cryopanels placed inside the cyclotron. These cryopanels are cooled by liquid helium. Liquid nitrogen is used to cool the thermal shields of the liquid helium chamber for the superconducting coil and the liquid helium cooled cryopanels. The delivery of liquid helium (4.2K) and liquid nitrogen (77K) from liquid helium plant and nitrogen dewars to the cryostat and cryopanels requires extreme caution, continuous monitoring and finest control. Considering its safety and control aspects an intensive data acquisition and control instrumentation has been designed, installed and successfully operated.

INSTRUMENTATION SCHEME

The system takes care of as many as hundred parameters which are extremely critical for operation of the superconducting cyclotron main magnet. The system is designed to operate in a harsh condition, without loosing its performance or speed. Each hardware component is selected considering fast action, appropriate range, continuous run and fail-safe operation. From the control point of view, the system is centralised. It employs a centralized approach to the tasks of control, monitoring, data acquisition and machine protection. The heart of the instrumentation hardware is a Schneider make level 3 premium processor based PLC. It has a three layer hierarchy with PLC at its centre. All duties related to process control, interlock generation are performed in this layer. The first layer consists of mostly field instruments of different make which acts as the gateway between process signals and the PLC. The top most layer is a supervisory control and data acquisition software, operating in two different computers in two distant locations for controlling, monitoring and data acquisition. The PC-based consoles employ Wonderware SCADA software for cryogen delivery system monitoring and control.

Hardware Layout

The first layer (Fig. 1) consists of mostly field instruments, viz. pressure transmitters, level monitors, temperature transmitters, multi-channel strain gauge scanner, vacuum gauge controllers, dewar pressurisers, valve controllers and positioners of different make. Processed analog signals from each of these transmitters/ instruments are taken to/ from the second layer (PLC) for data acquisition and control. The web server facility of the PLC has enabled all the other workstations connected in the dedicated LAN to monitor some of the important parameters. Dedicated control logic was developed to process digital and analog input channels, operate various controls, generate interlocks and communicate with the supervisory control. The control parameters [2] are operated through control loops operating independently on the PLC. The PLC continuously monitors values of all the cryostat and cryopanels parameters and primarily uses these signals to control the cryogen delivery system. This also generates a “PLC_OK” signal if all the parameters are healthy. If anything goes wrong in the system, it takes necessary actions for the cryogen delivery system and also “PLC_OK” signal is withdrawn. The PLC is powered from the on-line UPS for reliable operation.

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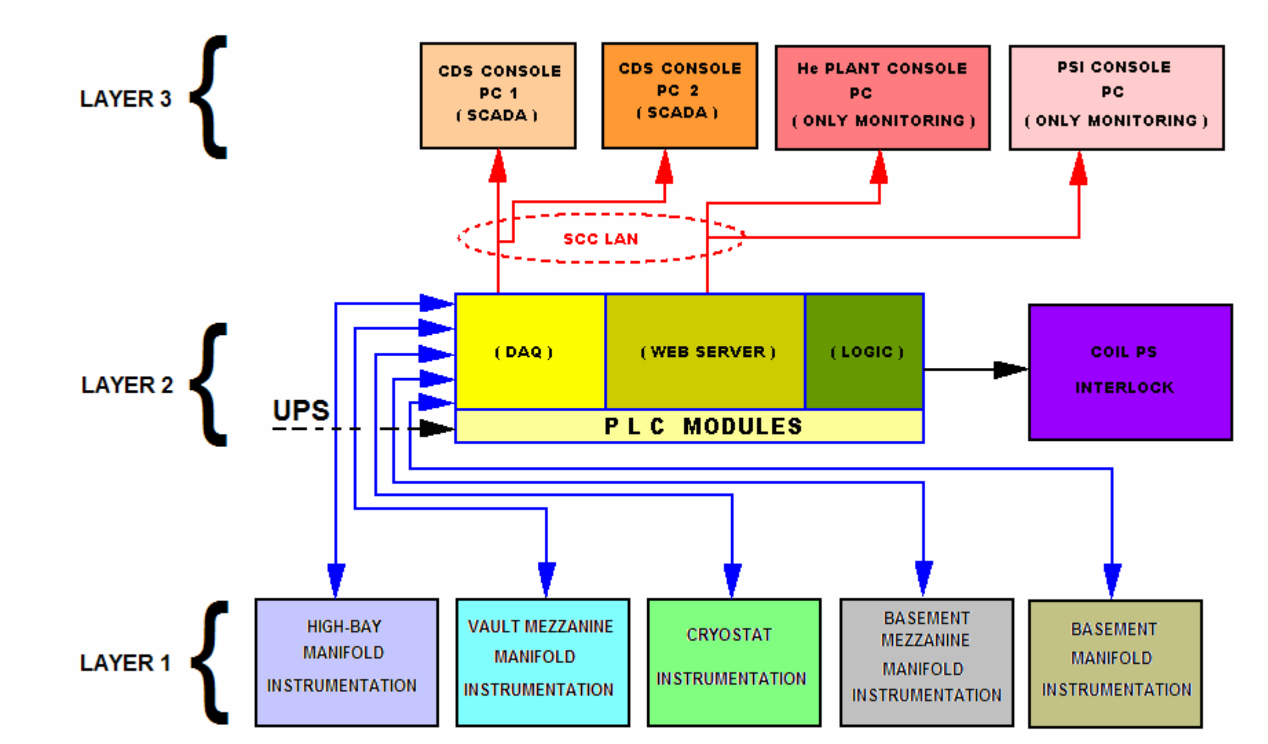

Figure 1: Hardware layout of cryogen delivery system instrumentation

Software

The supervisory control and data acquisition (SCADA) software monitors various system parameters, e.g. temperature, helium liquid level, condition of on-off valves, condition of control valves, etc. It has facility for remote control via Ethernet. It can control the parameters of the system by using PID or suitable control option. Special control panels for the different modes of operation are developed for the cryogen delivery system. The SCADA generates alarm on the console computer for the faulty conditions.

CONTROL SCHEME

The control system is a PLC based system. The SCADA communicates with the PLC through dedicated control LAN. It takes care of data acquisition and control in different operating modes through final control elements. In addition, this control system takes care of human as well as machine safety.

Monitoring and Data Acquisition System

Wonderware is used as SCADA. It allows the user to monitor, control, data logging and event monitoring. It also generates alarm as and when required and takes care of different mode of cryogen delivery system. Different access levels are provided for preventing unauthorised access. Modification is being carried out so that all the system requirements are met.

Control in Different Phases

This control system takes care of different modes of operation viz. cool down, steady state magnet standby, magnet ramp-up, steady state magnet energised, quench protection, magnet warm-up and power failure condition and generate alarm and interlock signals as and when necessary.

Safety features

Safety is one of the major aspects while operating with cryogens. Several safety interlocks, message displays and alarms are incorporated for human as well as machine safety.

- While energised, any reduction of helium level may cause severe damage to the superconducting magnet coils. To prevent this hazard, liquid helium level is constantly monitored and interlocked with the coil power supplies. Similarly, coil tank pressure and vacuum in the cryostat outer chamber are continuously monitored. ‘Slow dump’ and ‘fast dump’ interlocks are generated if any deviation is sensed.
- All the valves and actuators are installed such that they all remain in their respective fail-safe positions in case of any power or instrument air failure.
- Air-lock relays are used to maintain critical electro-pneumatic valves at their respective operating positions in case of sudden air failure.
- All the cryogen lines and dewars are equipped with safety valves, rupture discs to release the pressure in case of sudden pressure build-up.

CONCLUSION

The cryogen delivery system for the superconducting magnet was successfully commissioned in November 2004. It offered a hand full of complexities and technological challenges during the installation and commissioning. Cryopanel control was integrated with the magnet cryogen delivery system in the month of October, 2006. At present, this combined instrumentation and control system is running smoothly up to our satisfaction. Efforts are also being made to upgrade some of the field instruments with HART based smart transmitters.

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