TRIM COIL TEMPERATURE CONTROL SYSTEM FOR SCC

R. B. Bhole, Anindya Roy, Joydeep Mishra, Sarbajit Pal
Variable Energy Cyclotron Centre, DAE, 1/AF Bidhannagar, Kolkata 700 064

Abstract

The thermal stress developed between the pole tip and the magnet yoke, due to dissipation of heat (maximum 150kW) by the trim-coils of Superconducting Cyclotron (SCC) may damage the magnet. A dedicated Trim Coil temperature Control System for SCC has been implemented to reduce the thermal stress by maintaining the difference between the average trim coil temperature and yoke temperature with in a predetermined value. This system also maintains the conductivity of the cooling water below 1.0 μS. The control loop is implemented using a set of stand-alone redundant controllers. The supervisory control is implemented using EPICS architecture, a standard open-source dual layer software tool for designing distributed control system. This paper describes the control process comprising of the essential elements e.g. sensors, controlling elements and the supervisory control architecture of the system.

INTRODUCTION

The K_{bend}=520 Superconducting Cyclotron, under commissioning activity at the centre, is expected accelerate heavy ion beams to energy up to 80 MeV/A for fully stripped light heavy ions and about 10 MeV/A for heavy ions. A set of eighteen trim-coils, wound around the pole tips, and the superconducting main magnet are used to achieve the desired the magnetic field profile at median plane in this accelerator. A large amount of heat, approximately 150 kW during operation, dissipated across the trim-coils creates a temperature difference between pole-tips and main magnet yoke. The thermal stress developed due to this temperature difference may damage the magnet structure. A dedicated low conductivity water (LCW) system is commissioned to reduce the temperature difference by controlling the supply LCW temperature into the trim-coils. Chilled water (8±1ºC) is used for removing the heat from return LCW from the trim-coils. The system operates in a closed loop consists of storage tank, circulating pumps, plate type heat exchangers, control valves and associated process instrumentation. The conductivity of the system is maintained below 1.0μS by purifying part of LCW using mixed beds ion exchange column of LCW plant of SCC, through bleed/feed mechanism. A redundant set of stand-alone controllers and a scanner are used for remote monitoring and automatic control of the loop.

SYSTEM CONTROL LOGIC

Three key control objectives of this system, schematically shown Fig 1, are as follows: (1) Maintaining average pole-tip temperature with in ±1.0ºC of the magnet yoke temperature; (2) Maintaining LCW conductivity below 1.0μS by bleed/feed mechanism and (3) Tripping of circulating pump by sensing low level in the LCW surge tank.

Since direct measurement of the pole-tip temperature (T_p) is not possible in SCC, it is assumed as the average of the supply temperature (T_s) and return temperature (T_r) of the trim-coil cooling LCW. The temperature of LCW at various points in the loop e.g. supply header, return header of individual sector are measured by redundant Pt-100 type resistance temperature detectors (RTD). The temperature (T_m) of the magnet yoke is also measured by a redundant pair of RTD's. The difference (ΔT) between the pole tip temperature (process temperature) and the magnet yoke temperature (set point) is used by a PID controller to control the chilled water inlet flow through a control valve (CV1). This control action maintains ΔT within ± 1.0°C by manipulating the supply temperature of the trim coil cooling LCW. There are HIGH and LOW alarms on ΔT more than ± 2.5°C.

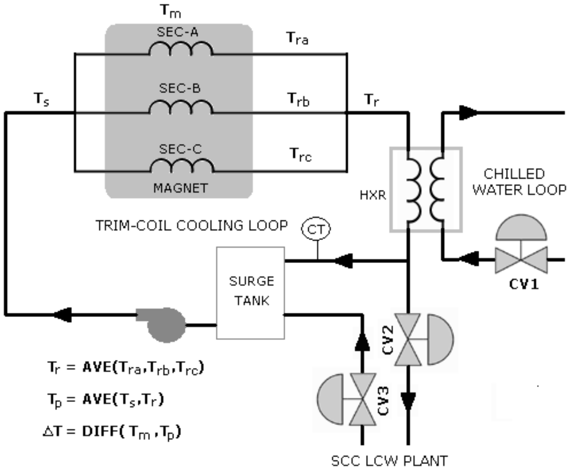

Figure 1: Schematic of the control loop.

As this system is a separate closed loop LCW system, the conductivity of the water may change with time. To maintain the conductivity below 1.0 μS, one automatic bleed and feed mechanism is implemented. In this control action, the controller measures the conductivity (C_m) of the water using conductivity meter (CT) and compare with the reference value (C_r) i.e. 1.0 μS. The positive difference ($\Delta C = C_m - C_r$) is used to open both the bleed control valve (CV2) and feed control valve (CV3) in proportional mode to compensate the conductivity through SCC LCW plant. The control loop also measures various process parameters e.g. surge tank level, LCW flow rate, pump discharge pressure, chilled water supply & return temperature and chilled water flow rate.

CONTROL SYSTEM

The control system is comprised of stand-alone process controller, data acquisition unit and PC based supervisory control software for remote monitoring and operation over control LAN.

Control Hardware

The control system (as shown in Fig 2) is implemented using a pair of stand-alone Siemens Moore PAC353 programmable controllers and a universal process parameter scanner. The controllers are programmed to operate in redundant mode for controlling the pole-tip temperature and automated feed/bleed mechanism. The process signals (4-20mA) are multiplied using three port isolators to feed both the controllers to maintain the outputs of stand-by controller in the same phase as operating controller. The scanner is used to monitor the other process parameters e.g. flow rate, level, pressure and chilled water temperatures. The control and monitoring hardware, communicate in MODBUS-RTU protocol, are connected to PC based supervisory system using control LAN through protocol converter.

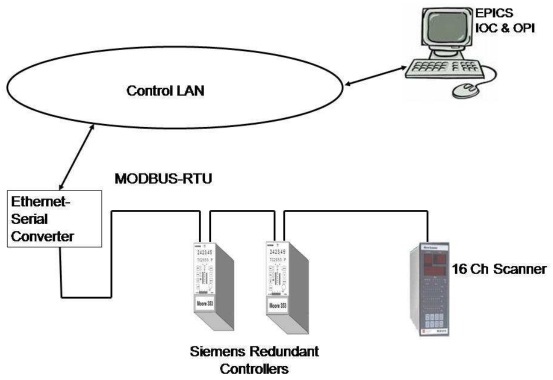

Figure 2: Schematic of the control system

Supervisory Control System

This system is connected to the dedicated control LAN commissioned in SCC building. The operators' console is provided in one PC connected to this LAN for online monitoring of all control loop parameters. The Experimental Physics & Industrial Control System (EPICS), a standard open-source dual layer software tool for designing distributed control system, is adopted to implement the supervisory control software. The indigenously developed, MS Windows based, Input Output Controller (IOC), which communicates with control & monitoring hardware, is in the lowest layer.

The OPerator Interface (OPI, as shown in Fig 3), developed in-house using MS Visual Basic, communicates with the IOC for monitoring and supervisory control. It incorporates the features e.g. system 'mimic' for ease of operation, on-line trending of selected parameters, audio-visual alarm. This program also archives data in MS-Excel format at regular interval on daily basis.

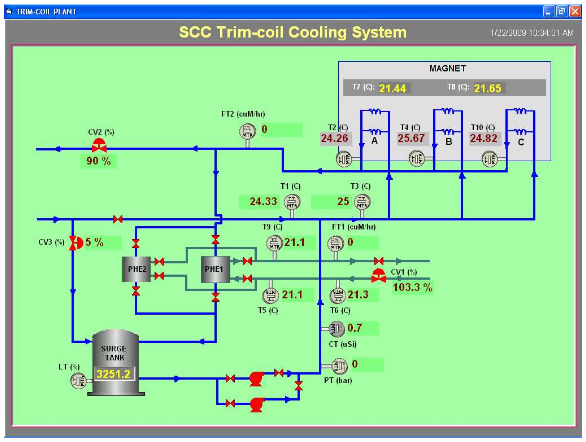

Figure 3: The operator interface

CONCLUSION

The system is installed and tuned to meet the requirement. The availability of the system is increased by placing redundant controllers and temperature sensors at critical points e.g. magnet yoke, LCW supply line etc. The system is designed to operate in MANUAL mode and AUTO mode. The MANUAL mode of operation is incorporated in this system to facilitate troubleshooting during maintenance.

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