Vacuum Control Systems of the Cyclotrons in VECC, Kolkata

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Abstract. VECC has undertaken the modernization of the K-130 Room Temperature Cyclotron (RTC) (operational since 1978) and commissioning of K-500 Superconducting Cyclotron (SCC) at present. The control system of RTC vacuum system has been upgraded to Programmable Logic Controller (PLC) based automated system from relay based manual system. A distributed PLC based system is under installation for SCC vacuum system. The requirement of high vacuum in both the cyclotrons ($1x10^{-6}$ mbar for RTC and 5×10^{-8} mbar SCC) imposes the reliable local and remote operation of all vacuum components and instrumentation. The design and development of the vacuum control system of two cyclotrons using the Experimental Physics and Industrial Control System (EPICS) distributed real-time software tools are presented.

1. Introduction

At VECC, Kolkata the K-130 Room Temperature Cyclotron has been delivering light heavy ion beams up to 15 MeV/nucleon since 1978. The K500 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 [1]. The vacuum systems of the two cyclotrons are entirely different from the point of view of requirement, construction and operational philosophy.

1.1. RTC Vacuum system

The main vacuum system of RTC (as shown in Figure 1) which maintains a vacuum level of $1x10^{-6}$ mbar inside 23 m^3 volume of Dee tank and resonator tank, was designed as two redundant sets of pumping system using oil diffusion pumps backed by rotary pumps and roots pumps. The oil (DC-704) diffusion pumps, having a pumping speed of 41000 litre/sec of air, are being operated with a fore pressure tolerance of $4x10^{-1}$ mbar. There are Freon cooled (approx. -60ºC) chevron baffles at the inlet of the diffusion pumps to arrest oil migration into the high vacuum chamber. The backing pumps i.e. two rotary pumps and a roots pump, of individual pumping systems are interconnected through twenty two electro-pneumatic Ultra High Vacuum (UHV) gate valves to ensure maximum availability of the system. Also, there are various vacuum gauges e.g. hot cathode gauge, cold cathode gauge and pirani gauge, to measure vacuum level at various points of the system. The individual pumping systems are capable to operate from 'Roughing' to 'Backing' mode. The beam line vacuum system of

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RTC comprises of several pumping modules. Each pumping module consists of diffusion pump backed rotary pump and associated isolation valves and gauges. The control system of main vacuum system is upgraded to PLC based system from initial relay based system to incorporate auto-operation and PC based remote monitoring and control of the system using Supervisory Control Software. A similar control system is under installation for beam line vacuum system.

1.2. SCC Vacuum system

The SCC vacuum system is divided into four sub-systems i.e. beam chamber, liner, cryostat outer vacuum chamber (OVC) and beam lines. In order to maintain 5 x 10^{-8} mbar inside the SCC beam chamber, several technically dry (oil-less) pumping modules and cryo-panels are used. Each pumping module of the system consists of a Turbo-pump, backed by a Scroll Pump integral with a VPI (Vacuum Pump Isolation) Valve. There are liquid Nitrogen and liquid Helium cooled cryo-panels installed within the median plane valley of the beam chamber. The liquid Nitrogen Cooled panels remove moisture and gas species with higher molecular weight. The liquid Helium cooled panels, protected by liquid nitrogen cooled chevron baffles, remove mainly Nitrogen, Oxygen and Argon. The bottom surfaces of the liquid cooled panels are bonded with activated charcoal for removing lightest gases, Hydrogen, Helium, and Neon, mainly by cryo-adsorption. The liquid Helium cooled panel is by direct heat source from room temperature surfaces.

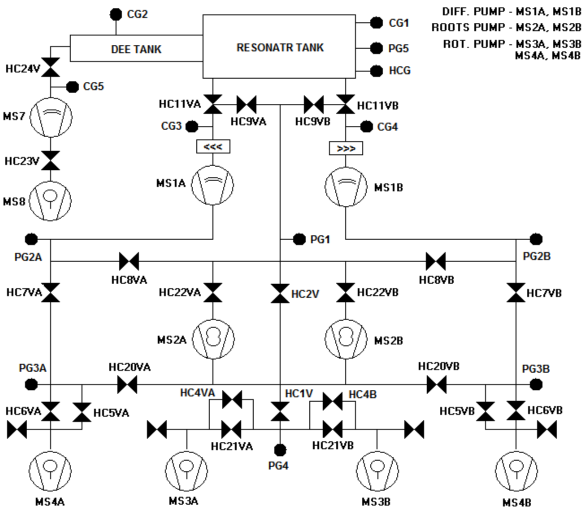

Figure 1. The schematic of Vacuum system of RTC

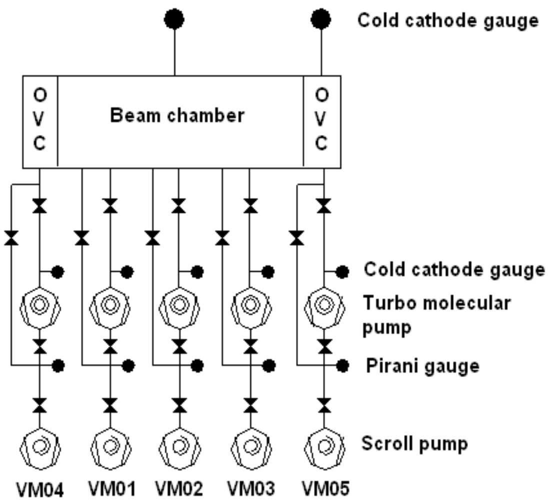

Figure 2. The schematic of Beam chamber and Cryostat OVC Vacuum subsystem of SCC

The liner vacuum system is comprised of two rotary pumps, four valves and four Pirani gauges to maintain a pressure in the order of 10^{-2} mbar inside liners. The OVC and beam line vacuum system consist of 23 pumping modules. All subsystems, except liner subsystem, are designed to have redundancy at pumping module level. The schematic of the beam chamber and cryostat OVC subsystem is shown in Figure 2.

2. Control System

The control systems of the vacuum system of two cyclotrons are comprised of several standalone PLC nodes. At present main vacuum system of RTC is controlled by a PLC node situated at the Pit area of the cyclotron. The control system for SCC vacuum which is also comprised of three standalone PLC nodes for main machine, vault beam lines and cave beam lines, is under installation.

2.1. Control hardware

The control systems are implemented using Schneider make PLC with integrated Modbus-TCP connectivity. The field components are distributed judiciously among the PLC input/output modules to overcome the single field component or PLC hardware failure. The systems are designed to incorporate 'auto', 'manual' and 'maintenance' mode of operations. Each PLC node contains a hardware local panel, consisting of indications and push buttons for in-situ operation in manual mode and maintenance mode. The Graphical User Interfaces (GUI) running on several PCs facilitate remote monitoring and operation of the system in manual and auto mode.

2.2. Supervisory Control System

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 [3]. The indigenously developed MODBUS-TCP based Input Output Controller (IOC), which communicates with PLC, is in the lowest layer. The Operator Interface (OPI), sitting on top of IOC, communicates with the IOC for monitoring and supervisory control. The OPIs (shown in Figure 3) are also developed in house using VB6 on Windows XP to include various common features of Windows and connectivity to Access/Excel used as local database. Several reusable ActiveX components e.g. text display, image display, alarm window, set-point input, button etc. are developed using the E-Z (Easy) Channel Access library to reduce OPI development time [2]. The OPIs incorporate the features e.g. system 'mimic' for ease of operation, on-line trending of selected parameters, audio-visual alarm, user authenticated secure mode for control of various components and modification of set-points etc [2]. The OPIs facilitate the user to operate the systems in manual and auto mode. The auto mode of operation is designed with a facility for user to select field components for particular run. This design philosophy reduces the operational complicacy and also includes the advantages of redundant field components. This operational philosophy has been tested satisfactorily in RTC vacuum system. In RTC vacuum system, the user selection is restricted to the choice of diffusion pump, roots pump and rotary pumps. The similar method is also being adopted in SCC vacuum system, though the user selection is restricted to the choice of pumping module instead of pumps. The OPIs also provide diagnostic views of control hardware. An indigenously developed MySQL based EPICS tool is used to log selected vacuum parameters for historic analysis.

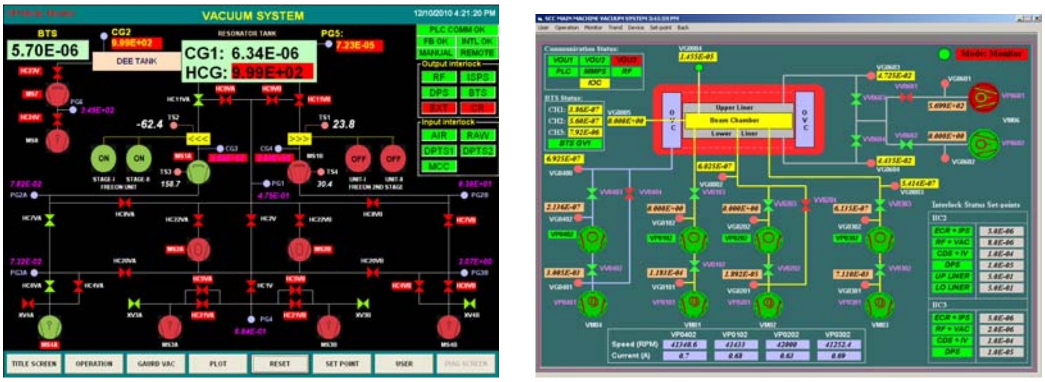

Figure 3. The operator interfaces of Vacuum system of RTC & SCC

3. References

[1] A. Sur, R. K. Bhandari, "Superconducting Cyclotron and its Vacuum System", Proceedings of the International Symposium on "Vacuum Science and Technology", TIFR, India, 2007.

[2] Anindya Roy, et. al., "Vacuum Control System of VEC", Proceedings of the Indian Particle Accelerator Conference, RRCAT, India, 2009.

[3] Anindya Roy, et. al., "Vacuum System of the Cyclotrons in VECC, Kolkata", Proceedings of XIIth IEEE IVEC, MTRDC, India, 2011.