SNS VACUUM CONTROL SYSTEM: SOFTWARE DESIGN STRATEGY AND COMMISSIONING EXPERIENCE*

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Abstract

The vacuum control system for the Spallation Neutron Source (SNS) has been designed by a multi-laboratory collaboration. The system is comprised of over 550 vacuum instrumentation devices, and the successful operation of SNS is dependent upon its reliable operation under high-intensity beam operating conditions [1]. The first parts of this subsystem have been commissioned since it was last described in this series of conferences. To maintain the necessary high reliability, availability and flexibility of the vacuum system, both Programmable Logic Controllers (PLCs) and EPICS Input and Output Controllers (IOCs) are used for controlling and monitoring these devices. Experience in commissioning the SNS Front-End and DTL vacuum subsystems has shown that their performance is heavily impacted by the PLC and IOC software design. In this paper, we discuss the software design strategy as well as the lessons learned from our testing and commissioning experience.

INTRODUCTION

The successful operation of SNS depends upon the reliable operation of the accelerator vacuum system under high-intensity beam operating conditions. Associated with the vacuum pressure levels are the availability and reliability requirements of the vacuum subsystems and their components. The different vacuum levels are required through out the entire accelerator (see Table 1). The design of the SNS vacuum system and its control system is done by a multi-laboratory collaboration effort [2]. The standardization for the vacuum control system architecture was established. To maintain the necessary high reliability, availability and flexibility of the vacuum system, both Programmable Logic Controllers (PLCs) and EPICS Input and Output Controllers (IOCs) are used for controlling and monitoring the vacuum devices. Experience in commissioning the first section of the machine has shown that their performance is heavily impacted by the PLC and IOC software design. In this paper, we will first describe our control system architecture and two different approaches of PLC-IOC software designs that we used in our Front-End vacuum control system and Drift-tube LINAC vacuum control system. We will discuss the advantages and disadvantages of these two software design strategies from our commissioning experiences.

Table 1: SNS Vacuum Level Requirements

SNS Subsystems	Vacuum Levels	Beam Energy	Length
IS/LEBT	1.0e-4 Torr	65 KeV	0.12 m
RFQ	1.0e-6 Torr	2.5MeV	3.76 m
MEBT	5.0e-7 Torr	2.5 MeV	3.64 m
DTL	1.8e-7 Torr	86.8 MeV	36.57 m
CCL	1.4e-7 Torr	185.6 MeV	55.12 m
SCL	1.0e-9 Torr	1 GeV	157.32 m
HEBT	5.0e-8 Torr	1 GeV	169.49 m
Ring	1.0e-8 Torr	1 GeV	248.0 m
RTBT	1.0e-7 Torr	1 GeV	150.75 m

ARCHITECTURE

The system is architected with three layers of classic distributed real-time control system: Device Control Layer, equipped with Allen-Bradley ControlLogix programmable logic controllers (PLCs) to monitor gauge and pump set point outputs and control valves; Global Control Layer, equipped with an EPICS Input Output Controller (IOC) to overlook multiple subsystems; and Operator Interface Layer, equipped with LINUX boxed to provide machine operation interface (see Figure 1).

PLC – Device Layer Controller

Allen-Bradley ControlLogix PLCs [3] are used to monitor gauge and pump set point outputs and control valves. The SNS project has selected the ControlLogix PLC as the standard PLC. The principal function of the PLC is to provide the sector gate valves that sectionalize the vacuum systems. The valve control logic will be fail-safe. A sector valve will close in case of:

- Vacuum conditions deteriorating to a specified limit;
- Power loss;
- Pump fails

The vacuum PLC will also provide interlock outputs to SNS subsystems such as the RF system and Machine Protection Systems, and receive interlock inputs from subsystems such as water system and the target system.

All vacuum system interlocks use 24 Vdc control power and converted into 10mA to satisfy the MPS specification.

*Work supported by the US Department of Energy under contract DE-AC05-00OR22725
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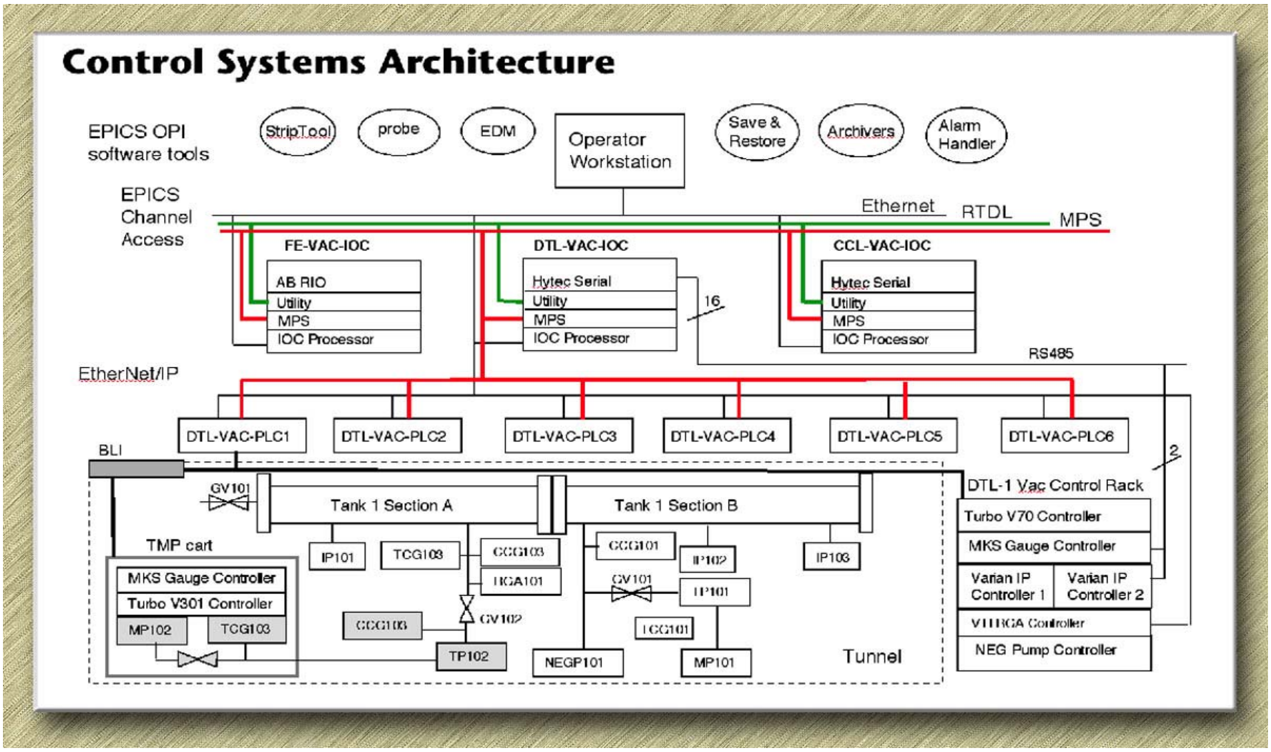

Figure 1: SNS Vacuum Control System Architecture

IOC – Global Layer Controller

The Input/Output Controller (IOC) is a VME controller or a Linux Soft IOC. The primary function of the IOC is to provide the supervisory controls among the vacuum subsystems and the interface to the other subsystems. It also acts as a gateway to OPI machines.

The interface between IOC and the PLCs is over Ethernet via EPICS Ether/IP driver [4].

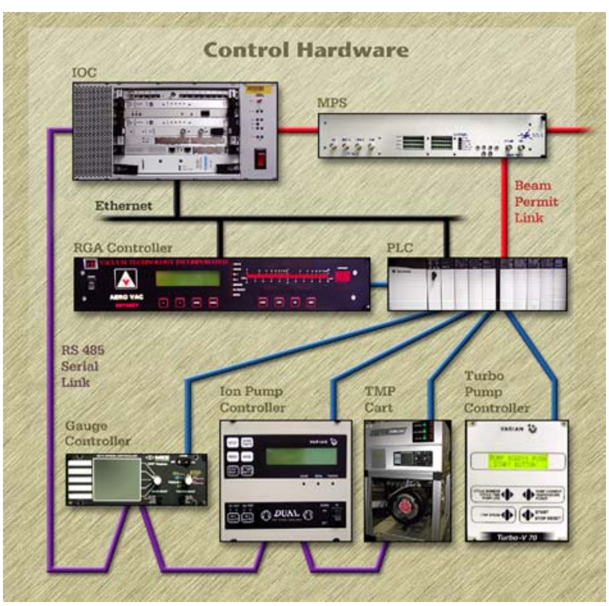

Figure 2: Vacuum system control hardware layout

To provide more detailed vacuum instrumentation controller information to operators, Hytec [5] VME 64x carrier and its serial 485 IP cards are used to link IOC to the gauge and ion pump controllers. Figure 2 shows a typical control hardware layout in DTL vacuum subsystem.

CONTROL SOFTWARE DESIGN

Up to now, we have successfully delivered beam to DTL warm LINAC. The first two parts of the machine include Front-End, designed by LBNL and DTL, designed by LANL. The two subsystems take two different software design approaches in terms of distribution of the functionality between PLC and IOC. The commissioning experience has shown that these two approaches have both advantages and disadvantages. The vacuum control subsystem design will be influenced based on the lessons learned from the commissioning of the early sections of the machine.

The Front-End Vacuum Control

The SNS Front-End consists of three subsystems: The Source/LEBT, RFQ and MEBT. The full system entails about 500 signals for valves, pumps and gauges. It uses one IOC and one PLC with Flex IO interface family. The IOC and PLC shares the responsibility of interlocks: the PLC performs through its ladder logic the basic validation of signals and the first level of interlocking. More complex interlocking is performed in the IOC, such as turning off pumps and closing valves depending on the status of nearby gauges or related devices and requiring valid status before energizing these devices. The IOC logic also enforces the inter-system constraints on the isolation valves. Special over-rides are provided to permit device testing when appropriate. Figure 3 shows one P&ID EPICS OPI display in Front-End vacuum system.

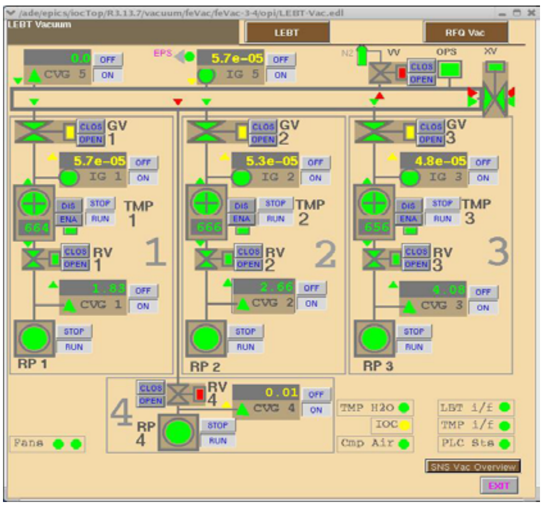

Figure 3: LEBT Vacuum P&ID in EPICS OPI

DTL Vacuum Control

The SNS DTL consists of six tanks. There are 19 devices in each tank and about 95 for the whole DTL. One IOC and six PLCs are used. Each PLC controls the vacuum instrumentation devices for each tank: Turbo cart control, RF window control, Ion Pump control, RGA control, valve control and external interlocks. The IOC serves for supervisory controls among the tanks.

Commissioning Experience

Both SNS Front-End and DTL vacuum systems have the similar number of instrumentation devices. Both use PLC and IOC for controlling and monitoring the vacuum devices. They, however, use a different software design methods. Our commissioning experience shows that the two different software design strategies carry both advantages and disadvantages on system performance as listed in the following:

- Modularity of the software design will ease for trouble shooting and save programming time
- It is more flexible to implement interlocks in IOC than PLC
- But, implementing the basic fail-safe interlocks in PLC will permit IOC hot reboot
- Using Linux soft IOC may have better cost effective when PLC is used

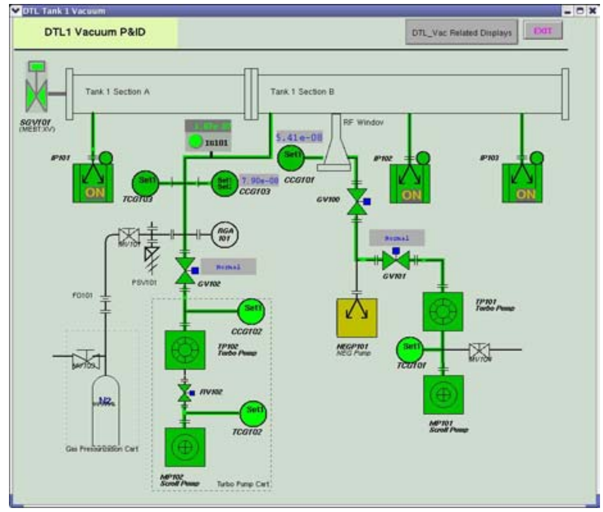

Figure 4: DTL tank-1 P&ID in EPICS OPI

SUMMARY

Our commissioning experience suggests us to be careful on the software design when using both PLC and IOC in a vacuum control system. To maximize both reliability and flexibility of the system performance, the function distribution between PLC and IOC has significant impact. Our lessons learned from our first part of machine commissioning will influence our system design for the other parts of the machine and future upgrading.

We have been successfully delivering our first beam in DTL tank in September this year. The commissioning continues and scheduled to have beam hit to target in 2006.

ACKNOWLEDGEMENT

The authors would like to acknowledge Steve Lewis and Keith Kishiyama of LLNL, Pilar Marroquin of LANL and Peter Cull of LBNL for their initial design efforts for the related vacuum control systems.

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