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STATUS OF THE TPS VACUUM CONTROL SYSTEM

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Abstract

The Taiwan photon source (TPS) is a 3 GeV photon source. For the vacuum system NI CompactRIO controllers with embedded real-time processors and programmable FPGAs were selected to design the interlock system to maintain ultra-high vacuum conditions and protect vacuum devices. The vacuum pressure protection function and component protection logics worked well during the past years of operation. Besides, basic function and other applications such as TCP/IP Modbus communication and real time message APIs were developed. The architecture of the vacuum control system is presented in this paper.

INTRODUCTION

The Taiwan Photon Source (TPS), a low-emittance 3-GeV synchrotron ring, started in December 2014 and is now currently operated in top-up mode at 400mA for users. During the past years of operation, the vacuum system worked well [1], the dynamic pressure per beam current continuously decreased. Until the last machine shutdown in August 2019 and reached a value of $1.10\text{x}10^{-10}$ Pa/mA with a 6417Ah accumulated beam dose.

In the TPS vacuum control system, Compact-RIO (C-RIO) real time controllers from National Instrument serve for vacuum data acquisition, monitoring and safety interlock. All programs were developed in the LabVIEW language, which offers a graphical programming approach that visualizes the application. EPICS channels were built via embedded EPICS I/O client and server in the LabVIEW project to connect vacuum system with the TPS control system. In addition, distributed EtherCAT I/O modules were chosen to expand temporary monitor signals.

One real time message system, combining EPICS, LabVIEW, python and LINE APIs, was developed. Real time messages could be received on cell phones by inquiry and message push functions. The hardware architecture of the vacuum control system, data archive system, safety interlock logic and real time message API will be presented in this paper.

HARDWARE ARCHITECTURE

The design of the 518.4m circumference TPS storage ring is divided into 24 sections and each section is assigned to one control instrument area (CIA). In each vacuum section, NI CompactRIO (C-RIO) controllers are used to control the vacuum system, serving as data acquisition, numerical transfer and interlock protection function. Between the C-RIO and vacuum system, the interface of the I/O communication is used by an I/O port or terminal for the vacuum components, such as vacuum gauges, pumps and vacuum valves. A total of eight I/O modules, including three analogue inputs (AI), three digital inputs (DI) and two digital outputs (DO), are used and installed and one CIA serves 1/24 of the vacuum sections as shown in Fig 1. Analogue signals, like pressure readings of vacuum gauges and pumps are taken as the basic logic signals for safety interlock and cooling water flow rate as a vacuum component protection issue. Digital input and output signals provide the status, set-point, logic trigger and remote control of the vacuum system.

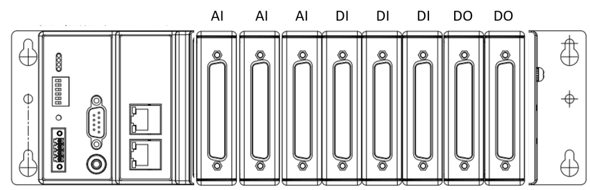

Figure 1: The C-RIO controller with modules.

All vacuum C-RIO controllers are operated under vacuum private network. In each C-RIO, an EPICS server was built to publish shield variables in the LabVIEW project to process variables (PV) in the TPS control network. The setting page of the EPICS server is shown in Fig. 2. Furthermore, one additional C-RIO was assigned as the EPICS client to communicate with the TPS EPICS server, which acquires machine information, such as operating beam current. The architecture of the vacuum control system is shown in Fig. 3.

During the past operations period, few events occurred. Temporary signals built and monitored were necessary. An EtherCAT I/O module was chosen to communicate by TCP/IP Modbus protocol. All EtherCAT modules are administrated by one TCP/IP Modbus server built into a C-RIO. In the TPS vacuum system, several RTD modules were used to monitor the temperature distribution near beam position monitors (BPM) which reach a higher temperature during machine operation.

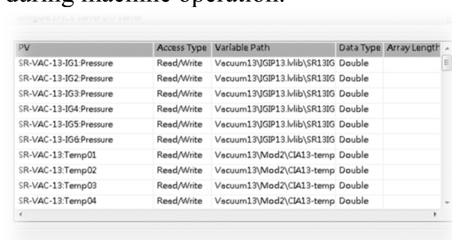

Figure 2. Embedded EPICS server in the LabVIEW project.

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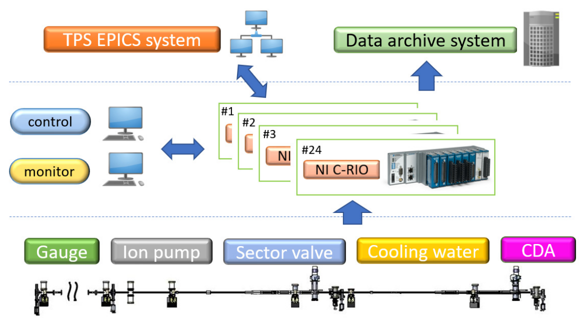

Figure. 3: Hardware architecture of the TPS vacuum system.

DATA ARCHIVE SYSTEM

In the TPS vacuum system, including storing ring (SR), booster ring (BR) and transport lines, all signals are collected and recorded in a data acquisition (DAQ) system for analysis and monitoring. About 8000 signals including vacuum pressure readings, pressure trigger set-points, pump status and temperature readers etc., were connected to servers via Ethernet for recording and monitoring. The data archive system developed by the NSRRC utility group is extensively used recording, analysis and tracing [2]. Figure 4 displays the operations page of the archive viewer software. The vacuum signals are listed and a maximum of eight signals can be selected for comparison or analysis. In the history function, it is used for long term data tracing, a trend function is used for real time monitoring such as during the vacuum baking process.

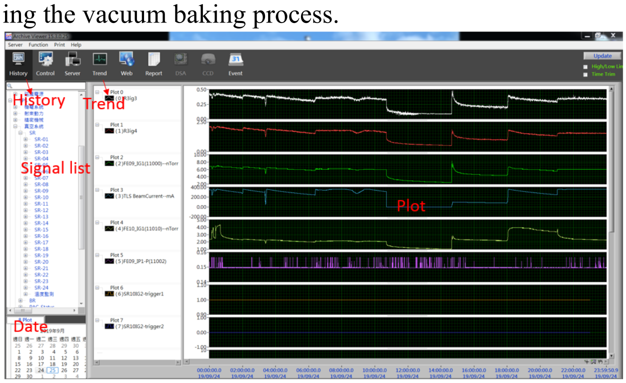

Figure 4: The operations page for the archive viewer software.

The Labview languaue is a system engineering software, which offers a graphical programming approach that visualizes the application. The graphical interfaces is flexible and easy to use. Web publishing tools, shown in Fig. 5, was used in the TPS vacuum monitor system. It transfers LabVIEW front panel pages to web pages, which display snapshot updates continously. Figure 6 displays one example of the front pannel page for the overall vacuum logic signal, which collects machine operations current and machine protection system (MPS) status as accessed from the TPS EPICS system and vacuum logic signals bindings from 24 C-RIO controllers. Web publishing tools allow it to becomea web URL, which is easy to view on a PC or cell phone. One disadvantage is that it can be browsed only at the NSRRC due to network security.

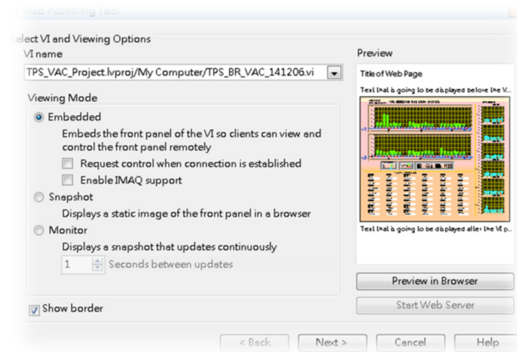

Figure 5: Web publishing tool of the LabVIEW program.

Figure 6. Monitoring page for overall vacuum logic signals.

Different from signal records in the data archive system, the monitoring pages are also recorded as image files, which are used for comparison under different operation condition. The front panel image method of invoke node functions as shown in Fig. 7, was used to return an image of the front panel as a flattened pixmap. The overall distribution of the vacuum pressure and chamber temperature on is recorded and compared for different operation conditions or used for long time tracing of the TPS vacuum system.

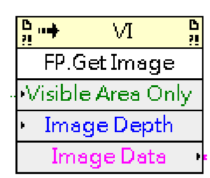

Figure 7: Front panel image method to invoke node functions.

INTERLOCK SYSTEM

The protection of ultra-high vacuum (UHV) conditions and components is the main goal of the interlock system. In the UHV protection system, vacuum valves are on manual only when the vacuum pressure on both sides is satisfied and is switched off automatically as soon as the set points of the vacuum gauges at either side are triggered. Furthermore, the open status of valves is monitored by the MPS to avoid irradiation by synchrotron radiation. The normal status of the cooling water and compressed air are also connected to the MPS to make sure the vacuum system is ready for machine operation.

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During the past years of operation, the vacuum interlock system was optimized. Bursts of vacuum pressure randomly occurred during initial high current operation and temperature sensors located near high radiation zones were malfunctioning often due to radiation damage. The ageing of electronic components was also needed to be considered. Countdown and rest functions were added to avoid a machine trip by a single signal source [3].

REAL TIME MESSAGE API

A task-oriented chatbot application as an interactive interface for monitoring was developed and applied in NSRRC [4, 5]. It is developed with python, EPICS, LabVIEW and LINE API [6]. Signal inquiry, reply and push methods are the main functions. The chatbot architecture is shown as Fig. 8.

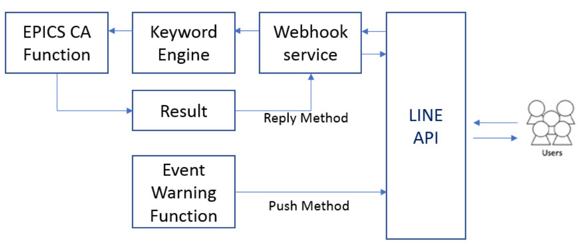

Figure 8: Chatbot architecture.

For signal inquiry, the message from the user is filtered by a keyword engine first, through EPICS channel access functions and then send back to the user by message reply method of the LINE message API. A rich menu which accesses the keywords was built for the inquiry functions and the users only need to click buttons to obtain signal options. Although remote control functions are feasible in this API, control commands are excluded due to safety issues.

Event and warning messages sent by e-mail or SMS was widely used in the data archive system at the NSRRC. SMS message functions were replaced by the LINE notify API, which saves the extra cost of SMS message sending. The signal was sent out by the push method of the LINE notify API when the signal exceeded the lower or upper limits. It is convenient when a warning occurred and the message is pushed to your cell phone immediately.

From work experience, it is not easy to understand what happens when serial messages are pushed in a short time. Images of a reply method were developed and was implemented by python web crawler combined with the LabVIEW web publishing tool. The screen shot of chatbot message push and inquiry functions are shown in Fig. 9.

CONCLUSIONS

The current status of the TPS vacuum system is described above. The vacuum pressure protection functions and component protection logics worked well during the past years of operation. The DAQ system is used to monitor, analyze and improve vacuum performance. All vacuum signals are displayed on web pages which are easy to monitor. The vacuum interlock system was optimized. Countdown and rest function were added to avoid a machine trip by a single signal source directly. A chatbot real time message API, including signal inquiry and message push functions are implemented. More applications such as machine learning will be developed in the future.

Figure 9: Screen shot of chatbot message push (right) and inquiry (left) functions.

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