CONTROL SYSTEM OF 10-MEV BABY CYCLOTRON

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Abstract

For controlling all the equipment and services required for operating the 10 MeV baby cyclotron and optimizing various parameters, an extensive control system is used. Most of the control systems are located in the control room which is situated outside the biological shield. The control console in the control room has switches for all the power supplies like main magnet, radio frequency system, vacuum system, ion-source, deflector, etc. Several Programmable Logic Controllers (PLC's) which are located near the equipment control the whole system. A technique of Supervisory Control and Data Acquisition (SCADA) is presented to monitor, control, and log actions of the PLC's on a PC through use of I/O communication interface coupled with an Open Process Control/Object Linking and Embedding [OLE] for Process Control (OPC) Server/Client architecture. In order to monitor and control different part of system, OPC data is then linked to a National Instruments (NI) LabVIEW. In this paper, details of the architecture and insight into applicability to other systems are presented.

INTRODUCTION

As you are designing the cyclotron control system, some requirement must be considered:

• Control subsystems should be integrated into the control system easily.

• The programming system for application programs should be programmer-friendly.

• Incremental amendment and extension should be possible.

• To minimize man-power and efforts, the international collaboration or commercially available products should be applied.

- Easy data access and analysis
- Remote control/diagnostics based on Network
- High level security
- Well defined auto/manual control mode
- Practicable to local control in emergency
- Stable beam current
- Control various devices in real time
- Convenient operation
- Easy maintenance

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The control of Cyclotron is a typical complex real-time system. Generally, it is a hybrid system including both continuous control and dynamic discrete events. But for time response requirements, closed-loop controls are implemented by hardware such as PLC in most cases of cyclotron.

Supervisory control and data acquisition is the basic requirements for distributed control system of industrial process and large-scale equipment like cyclotron, which has high channel counts that demands for keeping track of a large number of data points. Normally, SCADA provides effective approaches to system's high-level monitor and control by combining real-time/historical data collection, logging and trending with friendly dynamic graphic indicators

Control architecture of system control is a three layer architecture comprising of device layer, server layer and user Interface layer. The device layer consists of PLCs which controls the automatic process sequence operations. The PLCs and the process components are configured to satisfy fail-safe operation [1].

The user interface layer consists of the control computers where the operators issue, the set points and the mode of operation commands. The alarm and historical archive are also running in this layer.

PLC OVERVIEW

Programmable Logic Controllers (PLCs) [2] are diskless compact computers including all the necessary software and hardware interfaces to the process. They are generally used for automation control application either standalone or connected to distributed inputs/outputs, to other PLCs and/or to supervision PCs. The connections are established by means of field buses such as PROFIBUS or Ethernet. An example of this connection is shown in Fig. 1.
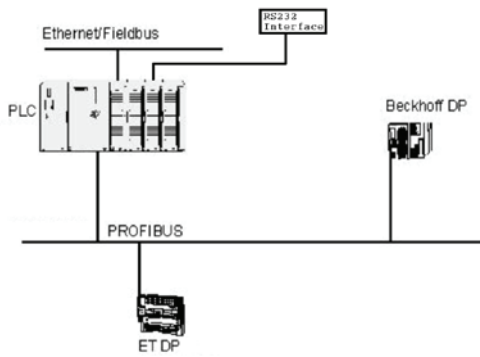
Figure 1: Typical PLC BUS communication.

The available I/O modules support a wide range of electrical interfaces

- Analogue module (+/- 10V, +/- 1V, 4-20mA, resistor, etc.)
- Temperature measurement (pt100, Ni 100, etc).
- Digital module (+- 24V, 220V, etc.)
- TTL module (Beck Hoff I/O module, etc.)
- RS 232 module
- Ethernet Modules

PLC-based solutions are well adapted to two-level control architectures where the front-end layer has to be autonomous and independent from the supervision layer. The process control does not depend on the network neither on a remote computer; it is more secure

RELATION BETWEEN LABVIEW AND S7-PLS

The S7 series of Siemens PLC system controls the whole process. A pc serves as the interface to the system for monitoring and control. The pc communicates with the plc system via serial port to the communication controller at plc side. LabVIEW is a graphical programming platform that helps engineers scale from design to test and from small to large systems. The DSC Module provides OPC Client I/O servers for communicating with any server implementing the OPC Foundation OPC server interface. This allows LabVIEW to communicate with any PLC that is interacting with an OPC Server. An OPC Client I/O server will list all available OPC servers that are installed and running on a local or network computer. Figure 2 shows the relationship of the components involved in communication between LabVIEW and a PLC.
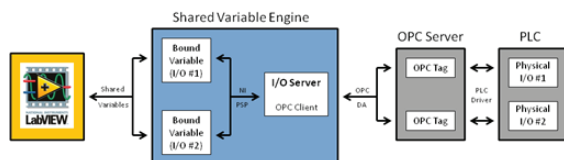

Figure 2: Communication of LABVIEW and SVE with PLC through OPC.

PLCs publish data to the network. An OPC Server program uses the PLC's proprietary driver to create OPC tags for each physical I/O on the PLC. National Instruments provides an OPC Server solution with NI OPC Servers. NI OPC Servers contains a list of drivers for many of the industry's PLCs. The OPC Client I/O servers provided with the DSC Module can connect to each OPC tag using the OPC DA standard. We can configure the multiple OPC Client I/O servers in the SVE with different update rates, dead band percentages, and reconnect poll rates. The SVE provides a PSP URL for each OPC tag that other Shared Variables can bind to by enabling aliasing. Once you deploy the Shared Variables in the SVE and the Shared Variables receive values, LabVIEW can easily read and write to the Shared Variables using a VI. The cyclotron status can be clearly graphically displayed on the monitor screen. As an example the vacuum system control display is shown in Fig. 3. This screen gives the real time dynamic messages by changing colour or positions. Different pages also assign different meanings to the function keys, according which the operator can choose appropriate instructions to the PLC.
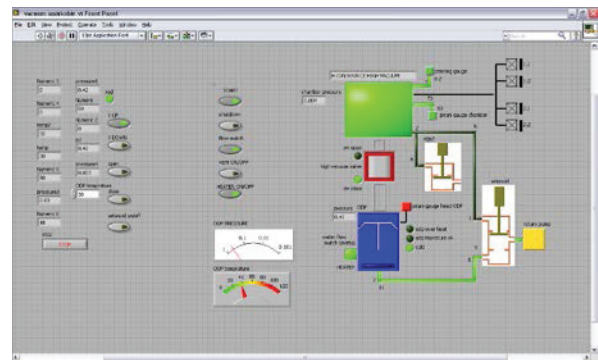

Figure 3: Cyclotron vacuum system control display.

INTERLOCK AND SAFETY SYSTEM

Control Logic and Interlocks is a regulation library interlocks that promise correct and safe system running and sequential logic for cyclotron routine operation such as system start-up and shutdown in automatic/manual modes. The interlock system will be operated in hierarchy depending on criticality and time scale of operation. The conventional interlock signals with response time of few tens of milliseconds, the interlock actions are handled through the local interlock control units, typically made up of Siemens S7 PLC. The state of component is conveyed to over the plant interlock networks (PIN) to different subsystems and over the central interlock network to other plant systems. There are many industrial solutions are available to communicate between PLCs but the cyclotron system shall adapt the IO recommended communication protocol to communicate the interlock events between subsystems [3]. Figure 4 shows the interlock system layout of 10 MeV baby cyclotron.
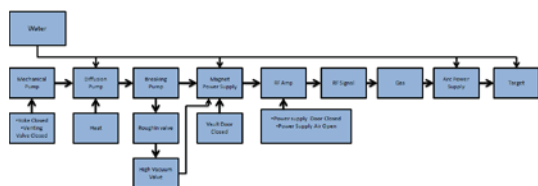
Figure 4: Interlock System Layout.

CONCLUSION

This paper introduces the framework design for the control system of the cyclotron. It can simulate processes during cyclotron running with well-designed HMI. The system is of flexibility and extensibility due to the easy program language. So it is really useful before lab experiment and hardware design for cyclotron. It gives a clear direction to the design of cyclotron control system and the entire optimum design of cyclotron system.

The PLC can operate in two modes: full automation or half automation. In the mode of full automation, the cyclotron can automatically start-up by pushing one function key, including turn on power supplies, cooling water, vacuum, set up the magnet, RF system, ion source step by step and, put the strippers into correct positions, until the desired beam is obtained on the target. In the mode of half automation, the PLC divides the whole sequence into different sections. At end of every section, operator interventions are required but, the operation sequence and safety interlock are also managed by the PLC. The full automation mode is suitable for routine production and the half automation mode is suitable for machine maintenance and equipment test. The two modes can be transferred at any time.

REFERENCES

[1] Farrands Controls, Valhalla, New York, USA.
[2] Siemens S7 series PLC programming guide for PLC user programming.
[3] Li Zhenguo, "PLC Application in the Control of CIAE-30 Cyclotron", APAC 2004, Gyeongju, Korea.