DESIGN AND IMPLEMENTATION OF DISTRIBUTED CONTROL SYSTEM FOR PEFP 100-MEV PROTON ACCELERATOR*

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Abstract

The remote control systems and user interface for the Proton Engineering Frontier Project (PEFP) 100-MeV proton accelerator have been developed for the linac subsystems. The infrastructure of the PEFP control system is to provide a network based communication, distributed control system, and a standard communication protocol. To develop an extensible and reliable control system, we have chosen Experimental Physics and Industrial Control System (EPICS) as a standard development tool. The EPICS is a distributed architecture that provides several solutions such as independent programming tools for operating system, operator interface tools, and archiving tools. The advantage of EPICS is to support a wide range of solution from small test sites to large integrated facilities. The VME system was adopted as a hardware device of an Input Output Controller (IOC). The IOCs are connected with an Ethernet based control network which is a standard communication protocol for the distributed control systems. In addition, there are other types of networks, such as timing network and interlock network. In this paper, we will present the details for design and implementation of the distributed control system for the PEFP 100-MeV proton accelerator, which is based on distributed control system using EPICS and an integration management of the distributed data.

INTRODUCTION

The PEFP 100-MeV proton linac will be composed of several subsystems by their functions in the entire system [1]. The remote control systems for the local devices should be connected to local control network for an Ethernet communication. Control and monitoring for all accelerator subsystems is integrated using VME based IOCs which are distributed. The integrated operation will be realized by the network connections and by the interactions among control systems for all accelerator subsystems. The verified development tools, distributed control infrastructure, and efficient maintenance are requirements of the PEFP software development tool. The EPICS tool provides the Channel Access (CA) communication protocol to make TCP/IP connections and transfer process variables among controllers [2, 3]. Figure 1 shows the schematic layout for the PEFP control system including several control systems under the control network; interlock network, and timing network with EPICS software tool for the distributed control system.

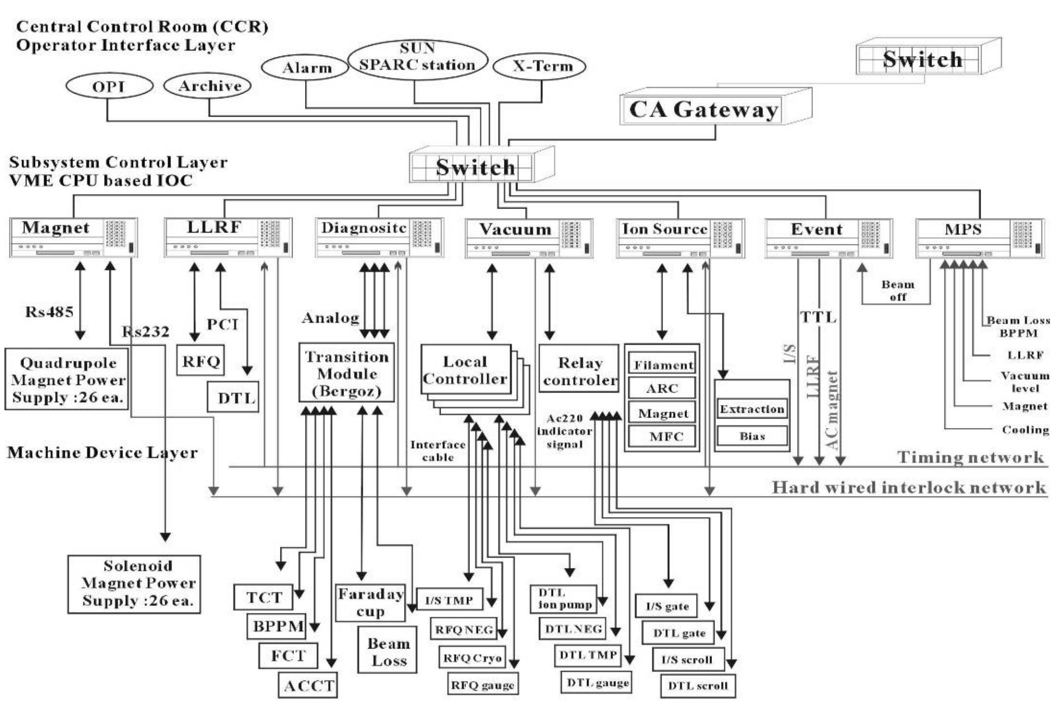

Figure 1: Layout of EPICS-based control system for the PEFP 100-MeV proton accelerator.

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IMPLEMENTASION OF CONTROL SYSTEM

The EPICS software tool provides the channel access communication protocol to make TCP/IP connections and transfer process variables among EPICS based IOCs. There are many tools that are used to make Graphic User Interface (GUI) for operators and to make an archiving system. We studied the IOC server architecture and hardware for the distributed control system and EPICS extension tools for user interfaces.

Design of Control System

The architecture for the accelerator control system is divided into the OPI (Operator Interface) layer and IOC layer. The OPI layer comprises operator console, alarm handler, the CA client programming, sequential programming, archive system, network management, general computing resources, and web monitoring system. The IOC layer consists of several local control stations including host-based Soft-IOC and micro-processor target IOC. The IOCs are implemented by EPICS application framework which provides a network-based EPICS CA for efficient access control of the distributed control systems. The IOCs are distributed for all accelerator subsystems such as radio frequency component, water cooling system, vacuum, magnet power supply, beam diagnostic, ion source, timing system, and interlock system. Figure 2 shows a block diagram of PEFP control network parts.

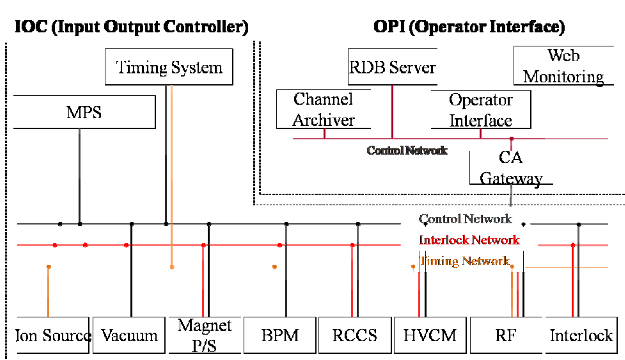

Figure 2: Block diagram of networked control system.

Hardware

We chose the station of Soft-IOC that runs in the same environment as which it was compiled consists of IBM x3650 server, HP xw6600 workstation, and Industrial Pentium 4 PC. This station is used for a graphic user interface, data archiving, and CA gateway between control system and operator interface. For the PEFP control system, we chose the station of the VME based target IOC that runs in a different environment where compiled. The Front-End layer as the IOC is built from VME crates, CPU boards, and I/O boards and runs a vxWork real-time OS. I/O boards support many standard field buses and interfaces like IEEE-488, RS-232/485, and Ethernet. Figure 3 shows VME board for the main control board. We use a cross-compile environment with Tornado for target architecture on SunOS 5.9 [4]. The VME-based IOCs are applied to vacuum units, magnet power supply, low-level RF, and ion source control system.

Figure 3: Input Output Controller (IOC) of VME system.

EPICS Software

We have studied how the EPICS software can be used for the PEFP control system and which features in EPICS can be used for specific control requirement. Figure 4 shows the distributed software architecture for design and implementation of the EPICS based IOC.

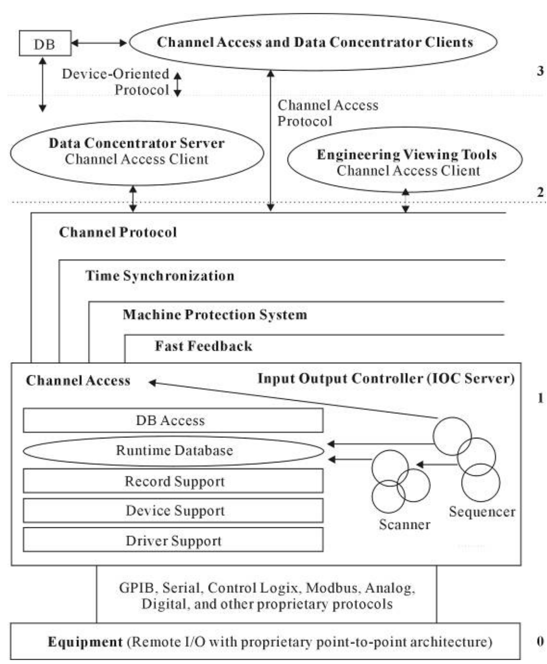

Figure 4: EPICS distributed architecture for the remote control system.

At the highest layer 3, access is provided for activities that do not involve moment-by-moment control or monitoring of the accelerator. Layer 3 includes high level physics modeling, making use of live data and data stored in the site relational database. Layer 2 contains accelerator operation and monitoring activities. Layer 1 contains dedicated equipment controllers, which in turn interface to specific equipment through point-to-point protocols in layer 0. The EPICS provides software architecture for realizing a distributed control system and supports software modules such as a standard communication protocol and processing database. The EPICS has the state notation language as a programming sequential operation that interact with EPICS process variables.

Control Room

The central control room must support several functions about system operation and entire management. The PEFP control room should be able to control and monitor a lot of control parameters though the distributed control systems, such as beam, radio frequency, vacuum, magnet power supply, cooling, and ion source, etc. To reduce communication traffic on the control network, OPIs and IOCs are connected by using the CA gateway. Internally the CA gateway makes a virtual connection to reduce the number of CA connections on the EPICS IOC. Operator interfaces for the integrated operation in the PEFP control room using EPISC extensions are shown in Fig. 5, 6, 7.

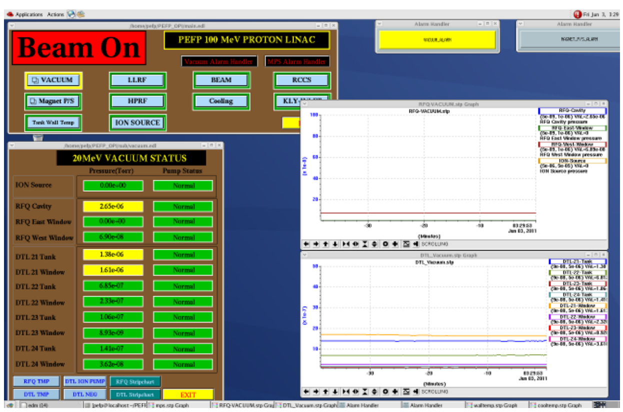

Figure 5: Operator interface using Extensible Display Manager (EDM) for vacuum control and monitoring.

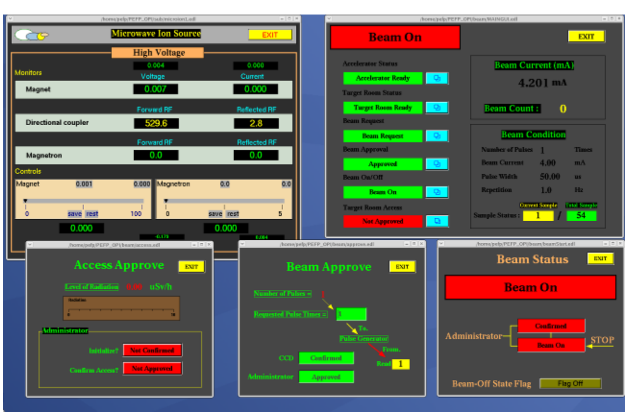

Figure 6: Communication interface for beam operation between users and operators.

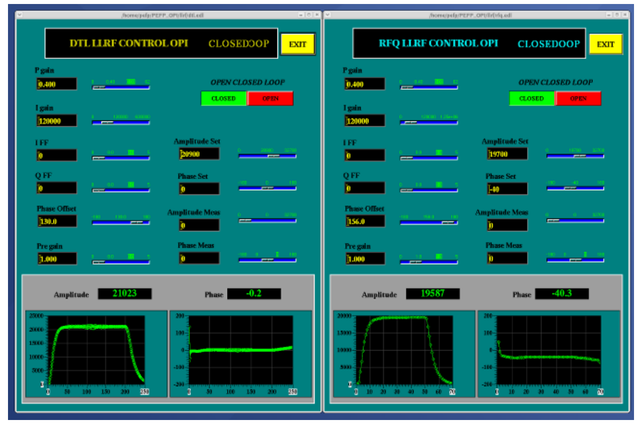

Figure 7: Operator interface for low-level RF feedback control.

The PEFP distributed control system adopting EPICS CA protocol makes operators of the control room focus accelerator operation and control management easily and efficiently.

CONCLUSION

The PEFP remote control systems have been developed with VME IOC and Soft IOC based on EPICS tool. We have developed EPICS supports to satisfy our system requirements. The EPICS CA protocol gave us networked software infrastructure on the distributed control system. For 100-MeV proton accelerator, some control systems are required to be upgraded such as low-level radio frequency feedback control system and to be applied by EPICS software for beam current and position monitoring that are operated by other programs. In the future, a machine protection system must be designed under the operation scenario of the proton accelerator. As a basic study, a preliminary interlock system by integrating a programmable logic controller and EPICS IOC will be studied.

ACKNOWLEDGEMENTS

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