DESIGN AND IMPLEMENTATION OF CONTROL SYSTEM FOR 4MEV LIA

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ABSTRACT

A monitoring and control system for 4MeV electron linear induction accelerator capable of producing beams in burst mode is presented. The system is a distributed one based on local network using DataSocket. The hardware and software architecture of the system is described. Some methods to overcome the limitation of DataSocket and instrument driver are also given.

INTRODUTION

4MeV electron linear induction accelerator capable of producing beams (2.0kA, 60ns) in burst mode was established in 2003 to develop a full service facility for LIA research. The 4Mev LIA is composed of 2MeV injector, pulsed power system, beam transport, accelerator cavities and auxiliaries. In the control system, there are about 62 power supplies used to beam tune, and 5 power supplies to energize the pulsed power system. The operation of the 4MeV accelerator depends on the synchronized functioning of pulsed-power system and timing system. Furthermore, it is necessary to design safety system in order to protect device and personnel safety.

When design such a control system of high current LIA, the following requirements should be met well.

Reliability in the electromagnetic interference environment.

Device and personnel safety.

Operation scheduled and fault diagnosis.

Flexibility for system maintenance.

With respect to the requirements of the control system, we have implemented the control system based on commercial product (National Instruments, Labwindows/CVI) and designed a distributed system using DataSocket technology.

GENERAL ARCHITECTURE

The control system architecture is illustrated in figure 1. This architecture can be defined two levels: the control level which includes 3 PCs and the front-end level which constituted by the peripheral devices. The front-end level includes programmable AC power sources for pulsed-power, power supplies for beam tune, timing and safety system. The front-end level connected to the control level through Ethernet. The GPIB and RS485 communication bus is converted to TCP/IP protocol by GPIB-ENT and 485-TCP gateways. Through simple configuration, remote computers can transparently access to GPIB and RS485 instruments via Ethernet.

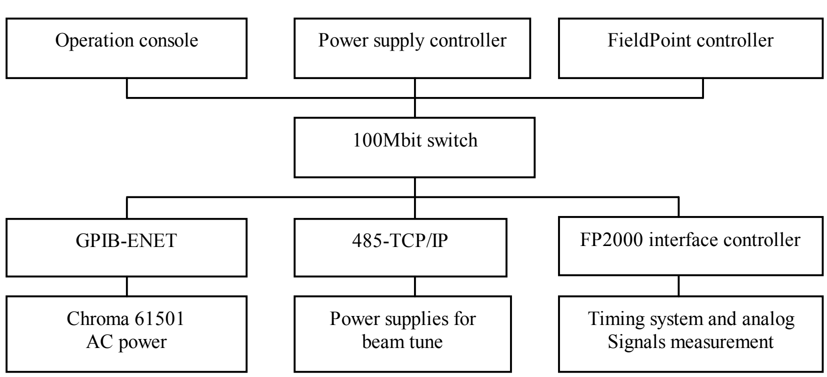

Fig.1 The hardware architecture of control system

In the front-end level, Chroma 61501 can provide sine wave output with low distortion and can control the transition waveform of output (slew rate of output and frequency), serving as power sources for pulsed-power system.

FieldPoint-2000 distributed system is modular I/O architecture and operates as stand-alone embedded real-time controller with Ethernet interface. This system is used to measure analog and digital inputs, and to provide synchronized trigger signal to timing system. With the LabVIEW Real-Time embedded system, the safety interlock is also implemented in the FP-2000 interface controller. The obvious advantages of FieldPoint system are the features of industrial specifications as PLC and the software functionality and flexibility as PC.

In the control level, operation console is responsible for operation schedule and status monitoring. As well known, it is essential to ascertain reliable LIA performance before experiment as well as to manage control parameters and settings. Considering the scale of pulsed power system, the management of Chroma power sources is integrated into operation console. All the control tasks of power supplies such as parameters setting, loading, status monitoring and unloading, are performed in the power supplies controller. To cooperate LabWindows/CVI and LABVIEW real time system well, it is necessary to design a FieldPoint controller to communicate between the control console and FP-2000 interface controller.

SOFTWARE

Software Model

The software model follows the so-called publisher/subscriber model. NI DataSocket is a kind of technology, which uses the DataSocket server to act as an intermediary to exchange data among applications running on different machines on a network. The traditional application of DataSocket is to exchange live data among applications. In our software model, we define two kinds of items: control command items and running data items, we also specify their publisher or subscriber roles. Therefore DataSocket server manages command and running data items meanwhile to act as a medium between operation console and subsystem controller. Control command items are published by operation console and are subscribed by power supply controllers or FP controller, accordingly, running data items are published by power supply controllers or FP controller and are subscribed by operation console. The software model can be illustrated in figure 2.

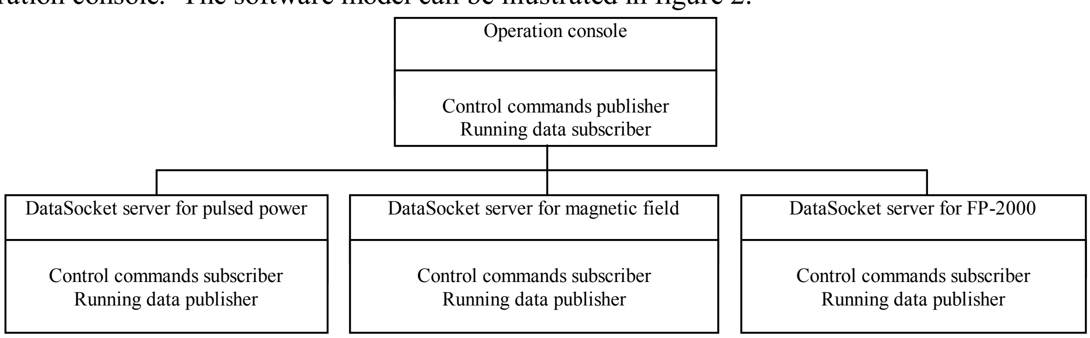

Fig.2 Distributed software architecture using Datasocket

The software system consists of the following components.

Operation console: Operation console includes user interface, parameter settings, control schedule and running data display. It is completely machine independent, with the DataSocket server medium. Because of the sequence feature of LIA control system, operation console coordinates all the data items of 3 DataSocket servers, sends out all the control commands as publisher, and receives results from DataSocket servers as running data subscriber.

DataSocket servers: Managing data items such as sever setting, writer, reader and items creator. Detecting the changes of data items. In order to simplify system architecture, three DataSocket servers don’t communicate with each other.

Devices control: Responsible for devices management, subscribing control commands and settings, performing the control tasks, transmitting the data values which have changed or a given time period has escaped.

Drivers: Drivers for power supplies of beam tune are written into DLL in the LabWindows/CVI platform. By using the IVI(Interchangeable Virtual Instrument) of FP-2000 and Chroma 61501, we save much time to develop effective application in spite of the low-level command sets of the different instruments.

Application Methods of DataSocket

When using the DataSocket transport protocol, there are two disadvantages: firstly, the DataSocket server by default publishers only sends the most recent value to all subscribers. When one client publishes values to the server faster than another client reads them, newer values overwrite older unprocessed values before the clients read them. This loss of unprocessed data can occur at the server or at the client. On the other hand, with the large number of items in a software system, it is difficult to handle the logical relationship of items and it is unavoidable to bring about the software complexity. Some recommendations based on the experience are as follow:

Taking into account of time delay during data transmission, the speed difference between publisher and subscriber, considering the time consumption of processing items. There should be a compromise between the speediness and the reliability of the applications.

Specifying reasonable, simple and fully functional items by analysing, abstracting and synthesizing requirements of control system. A good communication interface can be constructed on the basis of this kind of data items. For example, in pulse power DataSocket server, all the control commands such as setting, loading, unloading, can be written to one data item. By this way, it is helpful to decrease the item number, and also helpful to adapt to the data update mechanism according to DataSocket technology.

Applying data dictionary to describing the properties and the processing methods. The property part includes URL address, role, updating mode and data type. The processing part includes outer relation, corresponding process and data outputs.

Device Support

LabWindows/CVI provides a wide range of drivers for all sorts of NI's hardware, and another appreciated thing is that many companies such as Chroma provide IVI drivers for LabWindows/CVI. However, the IVI drivers for Chroma 61501 have some problems. For example, the function of chr616xx_VoltCurrPowerMeas which returns all the measurement parameters such as the frequency, voltage RMS, current peak and inrush at once, consumes about 5 seconds from receiving command to returning parameters. This time expenditure is not satisfied to the control requirement of pulsed power system. To avoid complexity, there are two ways to fix the problem: at first, one way is to modify the IVI drivers to return only two measurement parameters such as voltage and current values according to our requirements. Another way is to use the IVI drivers and low-level command sets by turns. In other words, the IVI drivers are used to initialize and control the Chroma instruments, and low-level command sets are applied to get the voltage and current values. This kind of low-level operation is based on a board or device descriptor, which is returned by OpenDev, ibfind, or ibdev in GPIB/GPIB488.2 library of LabWindows/CVI. One important thing is to manage the IVI's ViSession handle and the device descriptor well. In our design, by applying the latter one, the scan rate of 5 Chroma instruments reduces to 0.1 second.

FieldPoint Distributed System

LabWindows/CVI lacks for supporting Real-Time mechanism. In order to obtain the compatibility between LabWindows/CVI and the LabVIEW Real-Time embedded system in FP-2000 interface controller, it is necessary to design an application written in LABVIEW to carry out interaction between operation console and FP-2000 distributed I/O system. As well known, LABVIEW is very suitable for small subsystem, the time of writing and debugging the code is really low and the high performance could be obtained.

User Interface

The user interface is a graphical mode interface. In order to minimize both operator fatigue and the chance for human error, the program executes in presetting time schedule. The followings are typical functions that an operator can perform:

Define the control model according to the requirement of experiment.

Configure the setting parameters, and download them to DataSocket servers.

Energize pulsed-power system, monitor the voltage and current measurements.

Start up the time schedule. This process will continue to be performed until terminated by operator. The control schedules include turning power supplies of beam transport on, monitoring status, turning pulsed-power supplies off, triggering the timing system, and so on.

After accelerator shot, store the monitored data and status, accelerator tune, and analyse the off-line data.

Maintainability

Software or program maintenance is an important and yet sometimes challenging job. The system model based on DataSocket severs has good maintainability. The features of machine independence of operation console, and the easy modification of items of DataSocket severs, both are helpful for adding new functions, adapting to new hardware devices.

CONCLUSIONS

The 4MeV LIA distributed control system based on DataSocket can work reliably in electromagnetic interference environment. Configurable operation satisfies the needs of kinds operation mode of 4MeV LIA. Because of the loss of unprocessed data in DataSocket server, there must be a compromise between rapidity and reliability of application. Moreover, compared to traditional PLC, high-level development environment, flexible data logging and data transmission can be obtained by using the programmable automation controller such as FieldPoint. The application of FieldPoint system is a useful attempt.

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