ARCHITECTURE AND MAIN HARDWARE COMPONENTS OF THE FEL CONTROL SYSTEM

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Abstract

This article considers the architecture of the control system of the free electron laser of the Siberian Center for Photochemical Research, describing its general structure and listing the main features and hardware of individual components. Comparative characteristics of different communications standards used in the FEL control system are given as well as the reasons for choosing certain standards. Main issues of the future development of the control system are also considered.

INTRODUCTION

A high-power free electron laser on the base of accelerator-recuperator is now under construction at Budker Institute of Nuclear Physics. The full-scale FEL is based on the multi-turn accelerator-recuperator with electron energy as high as 50 MeV. This laser will generate average radiation power up to 50 kW in the wavelength range from 5 to 20 microns. The first FEL stage has been constructed and commissioned and coherent radiation has been generated by now [1].

According to usual practice, a specialized distributed control system has been developed for the first stage of the FEL. It was created with both standard and dedicated equipment. Besides, the choice of the system architecture depended on several factors specific to both the facility itself and the control equipment used.

ARCHITECTURE OF THE CONTROL SYSTEM

The full layout of the control system is presented in Fig.1. It can be seen that the system consists of 5 IBM-PC computers forming a local network with a rate of 100 Mbit. Each computer works under 1 or 2 monitoring programs, each controlling an individual subsystem. All control programs can work independently and have a low rate of integration with each other. Remote control, diagnostics of parameters of subsystems and other interprogram communication are performed via the protocol Epics Channel Access [2], which is portable to various operational systems. That allows usage of different operational systems in the FEL control system. Now the control computers are working under operating systems Windows, Linux and LynxOS. Control programs communicate with the control hardware via a number of communication interfaces with a relevant hardware standard (CAMAC and CAN-BUS [3]). The standards used are:

- PPI-6, IPS-6 – for communication with a CAMAC crate controller.
- Gateway CAN-Ethernet, IXXAT iPC-I 320/PCI CAN-Controller – for communication with the CAN network.

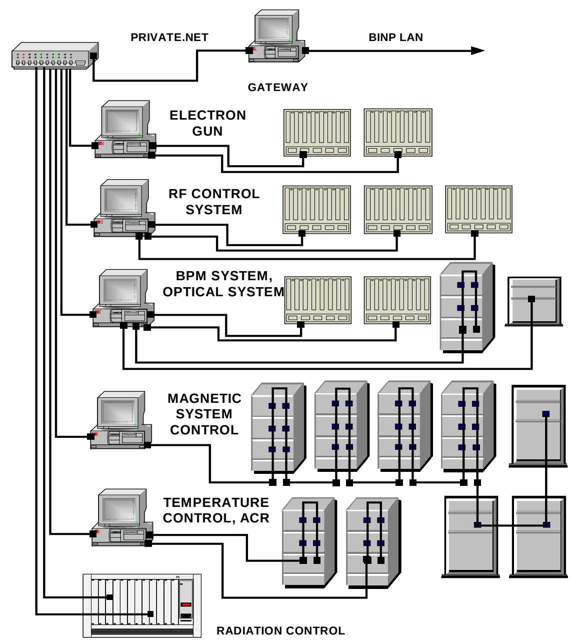

Figure 1: FEL control system.

HARDWARE COMPONENTS OF SUBSYSTEMS

It was mentioned above that the FEL control system consists of a number of independent subsystems, each controlling certain hardware and using relevant control equipment and communication interface. In table 1 presented a summary table of main subsystems, their parameters and characteristics. In total, the FEL control system comprises more than 1700 control and diagnostic parameters.

It is seen from the table that the FEL control subsystems use several communication standards, which can be grouped in the following way (by their application):

1. Systems using the CAMAC standard.
2. Systems using the CAN-BUS protocol.
3. Systems using other standard IBM-PC interfaces or their derivatives - RS-485 and Ethernet.

Table 1 : FEL control subsystems and their parameters

Subsystem	Number of items under control	Communication interface	Number parameters	Number of control devices
RF system	5 RF generators	CAMAC	700	3 CAMAC crates, 28 modules
Magnetic system	~165 DC power supplies	CAN-BUS	500	1 CAN-BUS link, 27 CAN devices
Electron gun	Electron gun control	CAMAC	120	2 CAMAC crates, 10 modules
Beam diagnostics system	28 BPM stations	CAMAC	150	2 CAMAC crates, 33 modules
Temperature control system	Up to 160 thermo-sensors	CAN-BUS	140	1 CAN-BUS link, 4 CAN devices
Anode power supply checking system	States of 100 thyristors	CAN-BUS	100	1 CAN network, 5 CAN devices
Radiation control system	16 radiation probes	Ethernet	16	2 TINY controllers
System for optical radiation diagnostics and control	Up to 15 step motors, radiation detectors.	CAN-BUS, RS-485	60	1 CAN-BUS link, 2 CAN devices, 10 Step motor controllers.

Table 2 : Communication standards used

Communi-cation standard	Operation speed, data transmission unit	Examples of application, traffic, and relative load
CAN-BUS	250 Kbit/sec 1 packet - ~100 bits	**Magnetic system:** Standard mode - 13 Kbit/sec, network load ~ 4% Mode of diagnostics of power supplies - up to 120 Kbit/sec, network load ~ 45% **Temperature control system**: 32 packets per second, network load ~1%.
CAMAC	2 Mbit/sec 1 NAF ~20 bit	**Beam position monitoring system:** Standard mode - 400 Kbit/sec, channel load ~20% Mode of beam pulsation measurement - up to 1.6 Mbit/sec (depending on the beam repetition frequency), channel load - up to 80 %
RS-485	19.2 Kbit/sec 1 command ~90 bit	**Step motor control:** 20 command/sec(1.8 Kbit/sec), channel load ~10 %

Relative communication interface load (traffic) and approximate amount of data transmission are among characteristics of a control system using a certain communication standard. Comparison of these characteristics and application of communications standards are presented in Table 2.

Choice of communication and control standards was defined by the following factors:

- Required amount of information per time unit. For instance, in the case of the beam position measurement system, pick-up stations shall be interrogated with maximal possible speed. Moreover, it should be possible to measure temporary stability, which requires measurements with the beam repetition rate, which makes it impossible to use such interfaces as CAN-BUS and RS-232, which are very slow. In the case of the magnetic system, the maximal amount of data transmission is 130 (normal mode) to ~1200 values per second (for oscillographic measurements of source currents), which allows application of serial interfaces (CAN-BUS and RS-485).
- Availability of unique hardware that has been developed for certain subsystems. For instance, a number of unique devices in the CAMAC standard has been developed to control the electron gun and to measure beam position – time-delay lines, Timer G0608, and ADC with frequencies as high as 100MHz and external triggering. The necessity to use

exactly these devices does not allow one to change to another standard.

- Spatial arrangement of the system. For instance, the magnetic system consists of a large number of power sources scattered over an area, which makes it advantageous to use the embedded controllers with some serial interface (CAN-BUS).
- Availability (or absence) of hardware for a certain subsystem of the control system, compatible with a certain standard.

It is clear from the above that different communications and control standards suit different subsystems as well as allow one to use diverse control equipment. Availability of corresponding communications standards allows one to use them together with IBM-PC computers. The main reasons why these communications standards have been chosen are as follows:

- CAMAC – availability of a lot of control devices developed during the last 30 years. High speed of operation and throughput of transmission link.
- CAN-BUS – much more freedom in placement of control devices and the entire system. Simplicity of organization of the control process and programming. Possibility of usage of one CAN line from different programs and computers. The range of available control devices is wide and a lot of devices to control (power sources) are supplied with embedded CAN-BUS interface.
- RS-485, Ethernet – standard IBM-PC interfaces (or their derivatives - RS-485). They are used for connection of a certain device exactly with a specific interface. Besides, it is possible to connect a large number of industrially-developed devices.

Thus, application of several hardware standards in the FEL control system is quite reasonable and gives a number of advantages.

DEVELOPEMENT OF THE CONTROL SYSTEM

This version of control system is not a final one. We can note a few issues that will define development of the control system and modernization of its individual units:

1. The construction of the second FEL stage. With that, some control subsystems will stay unchanged (the RF system and electron gun control) and the rest systems will be modernized mostly via increasing the number of elements to control. So, the number of elements in the control systems for magnetic elements, beam position measurement and temperature control will be more than 2 times increased.

2. Integration of user experiments into operation of the microtron-recuperator, which comprises the following:

- Organization of continuous measurement of wavelength and radiation power and transmission of this data both to the FEL console and to computers at user stations.
- Organization of radiation wavelength control, i.e. setting of a required wavelength or organization of a wavelength scanning cycle.
- Providing of the possibility of transmission of some parameters of accelerator operation, e.g. energy and average beam current, to computers at user stations.

3. The increasing of stability of FEL operation. The ability of continuously operation of FEL for many hours and stability of its main parameters (electron energy, wavelength and radiation power) are very important for user experiments at the present time. For that the development of new components and some modification of existing ones may be required. For example, development of software for archiving of all FEL parameters for the entire period of its operation and further analysis of them. Analysis of time behaviors of parameters of all FEL subsystems during its operation can be useful in improvement of stability of its operation as well as in detection of defective units.

CONCLUSION

The FEL control system is based on computers of the IBM-PC type with application of several communications standards. Application of each of the standards results from particularities of the corresponding system and control equipment applied. The operational experience of this system from the year 2002 has shown high reliability of the system and has confirmed correctness of the choice of hardware components – different hardware standards were used to control different hardware to manage a certain subsystem.

The future upgrade of the FEL control system is related mainly with providing of integration of user stations with control system of FEL, and commissioning of the second stage of the FEL.

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