CONTROL SYSTEM OF A HIGH-POWER INFRARED FREE ELECTRON LASER

E.I. Gorniker, B.A. Gudkov, Yu.A. Evtushenko, A.A. Kondakov, G.Ya. Kurkin, A.D. Oreshkov, B.K. Ovchar, T.V. Salikova, M.A. Scheglov, S.V. Tararyshkin, A.G. Tribendis, N.A. Vinokurov
Budker Institute of Nuclear Physics, Novosibirsk, Russia
630090, Prospekt Lavrenteva, 11
Salikova@inp.nsk.su

The control system of the high power infrared FEL is built on the base of a two-level distributed system. The system includes the operator interface at the upper level and Input/Output Controllers under supervision of the real time operating system at the lower level. All hardware for the control system of the FEL is produced by our institute, which solves several problems of hard real time and reduces cost of equipment.
PACS numbers: 41.60.Cr

1 INTRODUCTION

The first stage of the FEL (Free Electron Laser) complex [1] consists of a 1.5 MeV injector, one-track microtron-recuperator with accelerating RF system, and submillimeter FEL (Fig. 1). The particle energy is 14 MeV. The bunch repetition rate is 0.022-22.5 MHz, and the average current is 10-50 mA. The FEL produces radiation of a 1-10 kW average power with a wavelength of 100-200 mm. The pulse duration is 20 to 100 psec. The first stage of the FEL is aimed to test the recuperation of the beam power and to obtain the high power terahertz radiation.

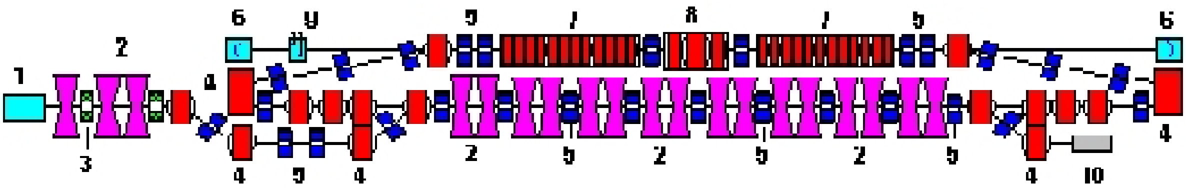

Fig. 1. First stage of FEL: 1 – electron gun, 2 – RF cavities, 3 – solenoids, 4 – bending magnets, 5 - quadrupole lenses, 6 – FEL optical resonator mirrors, 7 – undulators, 8 – buncher, 9 – outcouple, 10 – beam dump.

The FEL control system is a classical two-level distributed system consisting of the operator interfaces (OPI), network, and interfaces to the hardware IOC (Input/Output Controllers) created on the base of EPICS (Experimental Physics and Industrial Control System) [2].

At present time, the FEL complex can be divided to four autonomous parts for automation (Fig. 2). The first IOC controls the Radio Frequency (RF) system. The second IOC controls the gun, the third IOC – the magnetic system of the microtron, the fourth IOC – the diagnostic equipment.

2 SOFTWARE

Software of the control system of the FEL complex is built on EPICS. EPICS is a set of software tools and applications for developing of distributed control systems. The initial EPICS was jointly developed by Argonne National Laboratory and Los Alamos National Laboratory for the purpose of controlling Particle Accelerators and Large Experiments. At present time, the EPICS collaboration includes more than hundred laboratories and universities in USA, Europe and Asia, which allows development of EPICS at the base of new computer technologies.

The basic components of EPICS are:

The Operator Interface is a UNIX-based workstation, which can run EPICS tools for control over a large experimental complex. Usually it is set of control programs with operator's panels, editors for creation of the IOC database and other applications. The OPI level of the FEL control system contains computers with UNIX platforms such as Solaris, Linux and LynxOS. X11-Window, Motif and Tcl/Tk tool kits are used as the Graphical User Interface (GUI).

The Channel Access (CA) is the mechanism that provides network-transparent access to the IOC databases. CA is based on a client-server model. Each IOC server supports communication with an arbitrary number of clients. Also OPI or IOC client can communicate with an arbitrary number of servers. The Local Area Network supports TCP/IP protocols, and Ethernet is used at the physical level. All computers of the FEL control system are connected to a private subnet, which allows a minimal traffic of the network segment.

IOC is a computer under supervision of a real time operating system. A standard IOC contains a VME/VXI crate with embedded computer and various Input/Output devices. It is governed by the real time operating system

VxWorks. The FEL control system uses the ported version of EPICS. IOC includes personal computers (Intel x86 clone) under supervision of the real time operating system LynxOS/x86 and governs CAMAC and CANbus equipment produced by our institute.

The core IOC software consists of a memory-resident database together with memory-resident structures describing the contents of the database as well as a set of processes for monitoring the database. A record is a description of a physical parameter and equipment that corresponds to it. A record has fields determining when the record will be processed. The ported EPICS supports periodic scanning, program events that were defined by the user, and passive scanning as a result of external requests such as CA operations or processing of a linked record. The FEL control system uses 14 record types only. Each record type has a set of device support routines. The FEL control system uses up to 20 device support routines, which were written for optimization of exchange with equipment. All exchange with devices is executed by a standard mechanism, driver, which supports synchronous and asynchronous requests.

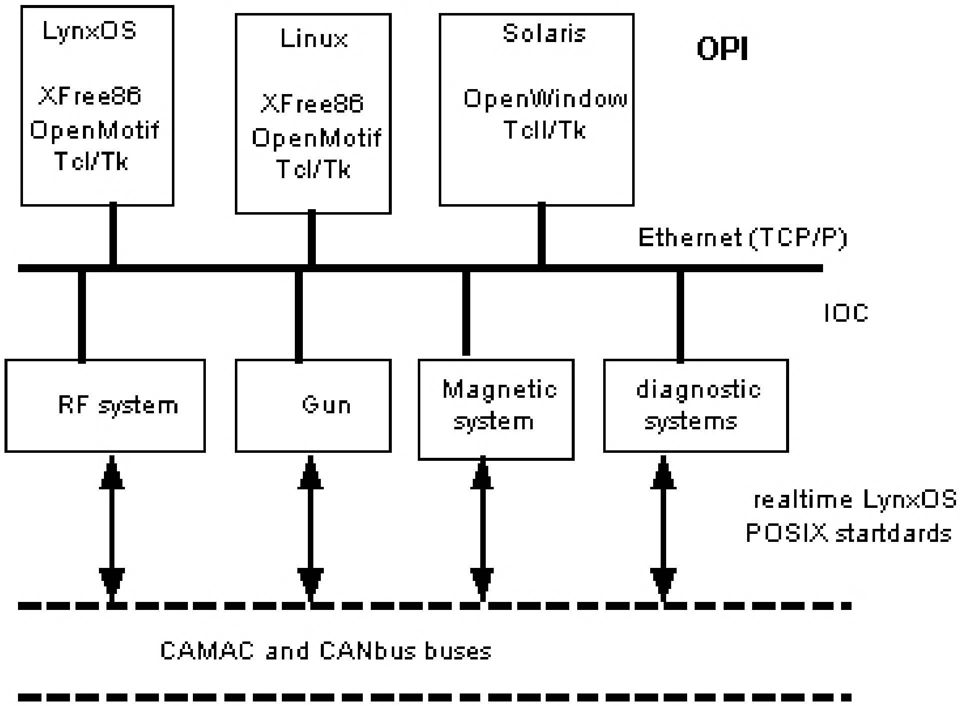

Fig.2. Layout of FEL control system.

Records with unique names are prepared at the OPI level by the Database Configuration Tool (DCT). This database is loaded to IOC, and user's applications monitor the equipment via records. EPICS has a miscellaneous tool kit for data processing and packages for graphical interface.

3 HARDWARE

The FEL control system is built on personal computers with Intel x86 processors under supervision of the real time operating system LynxOS, and hardware in the standards CAMAC and CANbus produced by our institute, which reduces cost of automation.

The buses used have low performance, since the time of full execution of NAF reaches 16 microseconds. Bit-rate of CANbus depends on the length of cable and reaches hundred microseconds and more. The whole control of crash conditions is executed by the hardware. That is a historical approach of our institute to solution of hard real time problems via creation of special hardware. A set of devices was created for the FEL control system: devices for control over propagation of beam in the injector, a gun driver, devices for control of locks of doors of the accelerator hall, a driver for monitoring temperatures, etc.

Fast data exchange between control programs and equipment is realized with application of CAMAC hardware such as ADC, DAC, digital Input/Output registers, etc. Slow exchange is made with the help of CANbus devices, which monitor temperature and currents of solenoids, lenses, bending magnets and undulators, and other elements of the magnetic system.

4 STRUCTURE OF THE CONTROL SYSTEM

At present, we update the software of the injector control system, which was created on the base of Windows95 with LabWindows/CVI tool kit. Two variants of software for the RF control system are being developed: the first variant uses LabWindows/CVI, the second variant is built on the base of EPICS. The control program under Windows95 executes a range of technological tasks and all functions of the control system. The UNIX variant of software executes functions of the control system and supports features of the distributed system.

At the OPI level, the RF control program has seven panels for monitoring parameters of the generators of the injector RF system and the main RF system as well as control panels for monitoring three cavities of the injector and sixteen cavities of the main accelerating structure. RF IOC supports 481 records.

The gun system includes the electrostatic gun, which emits bunches with frequency up to 22.5 MHz, and devices of the electron-optical beamline of the injector. The gun's IOC supports about 250 records. The OPI program includes a mnemonic diagram of the injector, where each element is linked with its own control panel. A click to a mnemonic element generates a window containing all control information. Now this work is in progress.

The accelerator-recuperator magnetic system consists of solenoids, quadropole lenses, bending magnets, undulators, a buncher, and beam correctors in vertical and horizontal directions with 150 power supplies. The control of magnetic system requires 150 input channels and 150 output channels. All data exchange between the OPI control program and magnetic equipment is slow. Similarly with the gun program, the OPI control program of the magnetic system has a mnemonic diagram.

The OPI programs of the RF system, gun and magnetic system log all updates of physical parameters to the cyclical buffer, which is periodically written to a file, which helps in analysis of failures of equipment.

The diagnostic IOC includes records to govern the diagnostic equipment and 150 records to control temperature. The diagnostic system is a set of constantly-modified applications. At present time, it is being debugged. The control of temperatures is a slow process, built on CANbus hardware. The OPI program polls all temperature channels and waits for program events indicating reaching of the lower or upper limit. Temperature monitoring hardware turns off the electron beam if any channel reaches the upper limit.

CONCLUSIONS

The EPICS tool kit provides environment for development of the FEL control system in the modern state of computer technologies. The ported version of EPICS allows utilization of hardware made at our institute, which reduces cost of hardware and software. The average performance of IOC at Pentium III (550 MHz) is equal to 4000 records per second, which is enough to make a good control system.

REFERENCES

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