CONTROL SYSTEM OF THE TESLA ACCELERATOR INSTALLATION

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I. INTRODUCTION

Control system of the TESLA Accelerator Installation present link between the operator, users of the facility and the machine itself. It is one of the most important systems from the user point of view, because it integrates the whole installation and enable performing automatic procedures for optimal functioning of accelerator systems. Our cyclotron is a multipurpose machine and the whole installation can operate in different regimes. In that sense, the control system should provide simple and reliable switching between regimes in a short period of time. The optimal values for several tenths of parameters and appropriate procedures will be stored in main accelerator data base for each regime, assisting even inexperienced operators to run the accelerator easily and safely.

There are several possible approaches in solving the overall control of the TESLA Accelerator Installation. We are considering the two global solutions for realization of the control system: one based on distributed network of PC controllers and the other based on a distributed network of industrial programmable controllers (PLC). In case of PC based control systems we are considering the following manufacturers: National Instruments, Burr Brown, Advantec and Electronic Design. In the case of industrial control systems based on PLCs, we are considering SIEMENS Simatic S5/S7, HONEYWELL Alcont 3000^{X} and DANFISYK ControlNet.

In this paper we will describe the control system of the TESLA Accelerator Installation based on the network of PC computers and intelligent instrumentation for control and data acquisition. The basic principles and organization of the control system will remain the same irrespective of the control hardware and software.

From the control level, we can distinguish the following accelerator systems:

- Magnetic structure of the VINCY Cyclotron,
- Radiofrequency system,
- Injection system,
- Extraction systems (foil stripper or electrostatic deflector),
- Vacuum system of the VINCY Cyclotron,
- Ion beam diagnostic system,
- mVINIS ion source,
- pVINIS ion source,
- Transport lines (low energy and high energy transport lines),
- Cooling system of the TESLA Accelerator Installation,
- Safety system

Each of these systems will have dedicated Front End Computer (FEC) with access to the hardware for control and measurements, enabling its autonomous operation. Console computers will integrate all FECs into the local area network (LAN) enabling global supervision and control of the whole accelerator installation from the main control room.

Prior to defining the conceptual solution of our control system we have studied the control systems of the existing cyclotrons in the world. Control systems of CERN-ISOLDE[1] and Jyvaskyla - K130[2] have been of a special interest for us.

II. CONTROL SYSTEM ARCHITECTURE

Control system is divided into three logical layers:

- Top layer (console and computing layer) consisting of several powerful PC computers located in the control room. It will perform overall control of the TESLA Accelerator Installation.
- Middle layer consisting of FECs PC computers controlling data acquisition and control equipment.
- Bottom layer consisting of intelligent instrumentation and different types of transducers, signal conditioners and control devices.

Schematic presentation of the control system of the TESLA Accelerator Installation is shown in Fig. 1. It is based on PC compatible computers at all levels. They are connected in the local network based on Ethernet protocol, using fiber optics cable which enables high data transfer rates and minimizes the influence of electromagnetic noise.

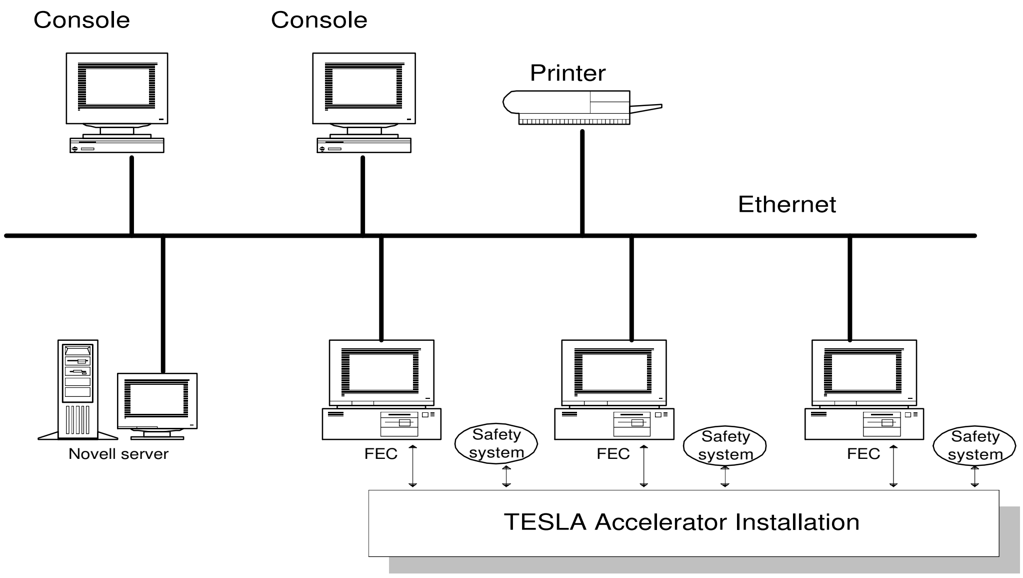

FIG. 1. TESLA Accelerator Installation control system architecture

In order to achieve reliable and safe operation of whole accelerator facility we will introduce additional safety systems (interlocks) wherever it is necessary. Safety systems will work in parallel with the FECs, but will be completely independent in their operation. They will be realized using simple and reliable hardware.

In case of accidental loss of electricity the vital functions of the control system will be preserved using battery backup supplies (Uninterrupted Power Supplies) carrying out the regular shut down procedure.

The control system network will be connected to the local computer network of the TESLA Accelerator Installation (AIT). The control applications will be developed on AIT network stations and afterward downloaded into the control computers.

III. TRANSDUCERS AND INTELLIGENT INSTRUMENTATION

We estimate that the control of whole accelerator installation will require approximately 1500 control channels. In general, there are three types of channels:

- Input channels carrying signals from different transducers (e.g. water temperature and pressure)
- Output channels carrying signals for control devices (e.g. open/close vacuum valve)
- Bidirectional channels for connecting intelligent instrumentation (e.g. RS232 and GPIB for control of power supplies)

All these channels are connected to the input/output cards of the FEC computers. All input/output channels have to be optically isolated in order to protect FECs from high common mode voltages. FEC computers will be located close to the controlled systems so the length of the signal lines will be minimized, reducing the possibility of noise induction.

IV. FRONT END COMPUTERS

The FEC computers are based on the Intel compatible processor board and several input/output modules. They are installed onto the PC bus and mounted into the industrial chases. The control channels carrying signals from transducers and external devices are introduced into the FECs via 8-bit/16-bit I/O modules. I/O modules are mostly compatible with ISA bus (Industry Standard Architecture). Due to the large number of analog and digital signals in certain cases it will be necessary to extend PC bus or introduce a new control computer.

The following types of I/O modules will be used: analog to digital converters, digital to analog converters, digital input and output registers, relay input and output registers, timers, counters, serial RS232/RS422 and parallel GPIB modules. It is preferable to use RS422 serial interface because it enables reliable communication up to 1300 m with transfer rate of 10 Mbaud. Using RS422 interface it is possible to control up to fifty power supplies via one serial port, thus eliminating the need for the external serial multiplexer or the internal multichannel serial interface. We estimate that the control system will handle in total 1500 input/output lines. These signals will be distributed on 10-15 FEC computers.

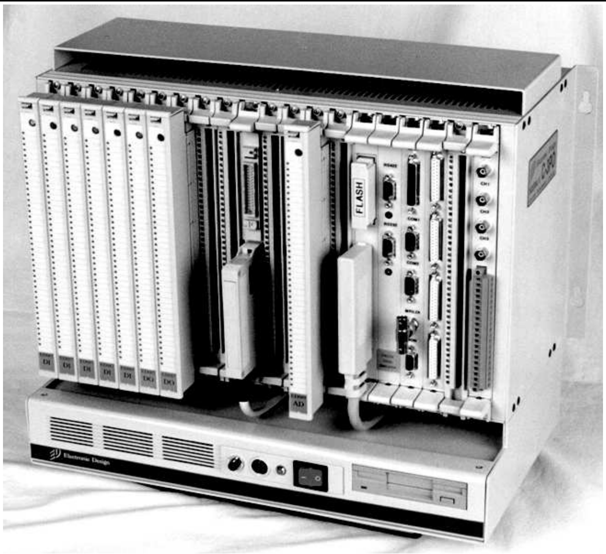

FIG. 2. C3PO Controller

As FEC computers we plan to use industrial PC controllers R2D2, C3PO and C3PO II produced by Electronic Design from Belgrade. R2D2 is based on PC architecture and 386, 486 or Pentium processor (see Fig. 2). It has seven slots for I/O modules in a form of double Euro card. Each controller has graphic card, standard IDE disk, diskette or optional 2MB PROMDISK. The C3PO controller has a passive board with 16 slots for I/O modules. The C3PO II is actually composed of two C3PO controllers having seven I/O module slots each. These two controllers can work independently or in parallel. In parallel operation if one controller fails, the other one continue to execute all the functions and at the same time send information to monitoring system about the failure.

V. FILE SERVER

The Pentium computer with 1 GB hard disk is used as a file server of the local control network. It will work under the Novell Netware operating system, characterized by relatively high speed and reliability. Server will enable sharing of application software and databases of general importance (containing relevant parameters for running the accelerator systems), as well as peripheral sharing (printers, plotters) throughout the control network.

VI. CONSOLE SYSTEMS

Console systems are based on powerful Pentium computers with 21″ color monitors and fast graphic adapters. At least two console systems will be located in the control room and additional one in the vicinity of mVINIS ion source. They will work in parallel enabling monitoring of different systems. Separate console enables independent operation of mVINIS ion source when used in experiments with low energy ion beams. Software packages for virtual instrumentation will be used for writing the application programs. These programs support DDE protocol as well as enable data exchange with other windows applications that are being simultaneously performed on console computers.

VII. SOFTWARE

There are two options for the system and application software for the FEC computers: DOS and Windows environment.

A. DOS environment

The qualities of this solution are simplicity, speed and higher reliability of the DOS comparing to the Windows. Anyway, DOS standards do not support NetDDE (Network Dynamic Data Exchange) so it will be necessary to develop or to buy special software tool to enable data transfer between the FECs and console computers. In CERN, special interpreter NODAL was developed for the ISOLDE control system, enabling FECs to run procedures sent by console systems and at the same time to perform the local control.

The application software must be independently developed on one of the high level programming languages C/C++, Pascal or Basic. The possibility to use special software tools substantially enlarge program productivity (LabWindows - National Instruments[4]).

B. Windows environment

In the case of Windows environment the software tools for so-called virtual instrumentation (VI) have been developed. They enable simple and quick realization of data acquisition, analyses, display or control. These programs contain libraries of elements used for simple and quick realization of user interfaces and instrument control panels. Instead of classical programming, resolving of a certain task is performed through the flowchart or block scheme, called FlowGram. On the bases of the FlowGram executable code version FlowCode is generated. Relatively simple data acquisition and control programs might be written within 30 minutes using VI software. Typical examples of virtual instrumentation programs are Visual Designer (Burr-Brown)[4], LabVIEW (National Instruments), Labtech Control (Labtech). Because of their simplicity and flexibility, virtual instrumentation software tools, enable high productivity.

Virtual application programs require PC computers based on 80386/80486 or better processors, VGA graphic cards with graphic accelerator, at least 8 MB RAM memory and 20 MB disk space.

Systems based on the windows environment are less reliable comparing to DOS systems (system might crash when several applications work concurrently). The advantage of the virtual instrumentation programs is that they support NetDDE and DDE protocols for data exchange between FECs and console systems.

Regardless the DOS or Windows environment, the FEC computers can perform data exchange with the console systems through common files located on the file server.

VIII. CONTROL OF THE MAGNETIC STRUCTURE

First application of control hardware and software will be related to the magnetic field measurements of the VINCY Cyclotron. The main coils of the cyclotron magnet will be connected to the main DC power supply DANFYSIK MPS 8000/853 delivering maximum 1000 A and 150 V. The power supply will be controlled via RS232 line using elaborate set of instructions. On the other hand, main coils will be cooled by demineralized water from the main cooling system. The main coils are consisting of 16 segments (pancakes), which form 16 separate cooling loops, each containing PT100 temperature transducer and ELETTA flow monitor. In addition, there will be one pressure transducer on the main water collector and one water flow monitor on the power supply cooling line. In total, we will control one power supply trough RS232 line, and monitor 16 temperatures, 17 flow monitor switches and one pressure transducer. As a FEC computer we will employ R2D2 controller with two 16 channel A/D modules, 32 bit digital input register module and one RS232 line.

This system will enable operator to set up the desired current through the main coils and continuously monitor all signals from transducers. The execution time of one cycle of the program will be less than one second. If the temperature of water flowing through any of coil segments exceeds the limiting value (50° C) or the flow through any of the coil segments drops below the predefined level, the R2D2 controller has immediately to switch off the magnet power supply. At the same time it will present the information on the display about the cause initiating the power supply shut down.

The control program of the magnetic structure is already realized using Visual Designer program. This application was developed in 2-3 days thanks to the high productivity of the virtual instrumentation program. Magnetic structure FlowGram is presented in Fig. 3 while the real time application display is shown in Fig. 4.

IX. CONCLUSION

Presented control system is reliable, inexpensive and uniform system, based on PC compatible computers. All console and control computers are connected to the local Ethernet network. All the computers have installed the same operating system (DOS, Windows). The uniformity of the applied hardware and software will largely simplify the maintenance of the system.

Virtual instrumentation software minimizes the time required for the development of supervisory and control applications. It does not require knowledge of higher programming languages or detailed knowledge of control hardware.

Since there is large number of outstanding manufacturers of PC computers and input/output modules all over the world, such control system will be less expensive than the corresponding industrial control system.

The number of control parameters supported by this system is practically unlimited. If needed, new control and console systems can be easily added. It is estimated that the complete control of the TESLA Accelerator Installation will require about 10-15 PC computers.

Control system which is presented in this paper is one of the possible solutions. We will define in the nearest future the most convenient control system for our installation. The basic criterion in choosing the control hardware and software will be reliability, availability, easy programming and the overall price.

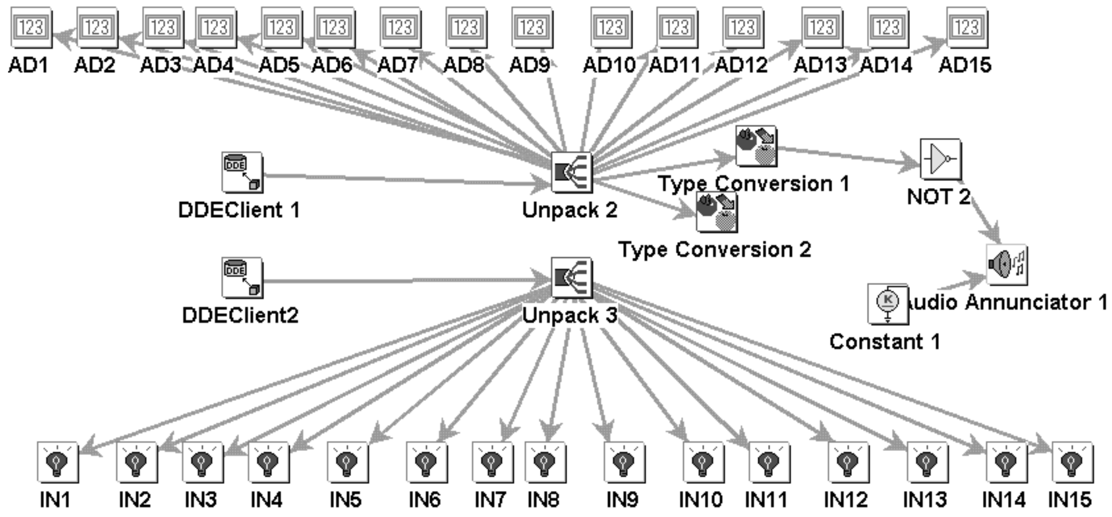

FIG. 3. Magnetic Structure FlowGram

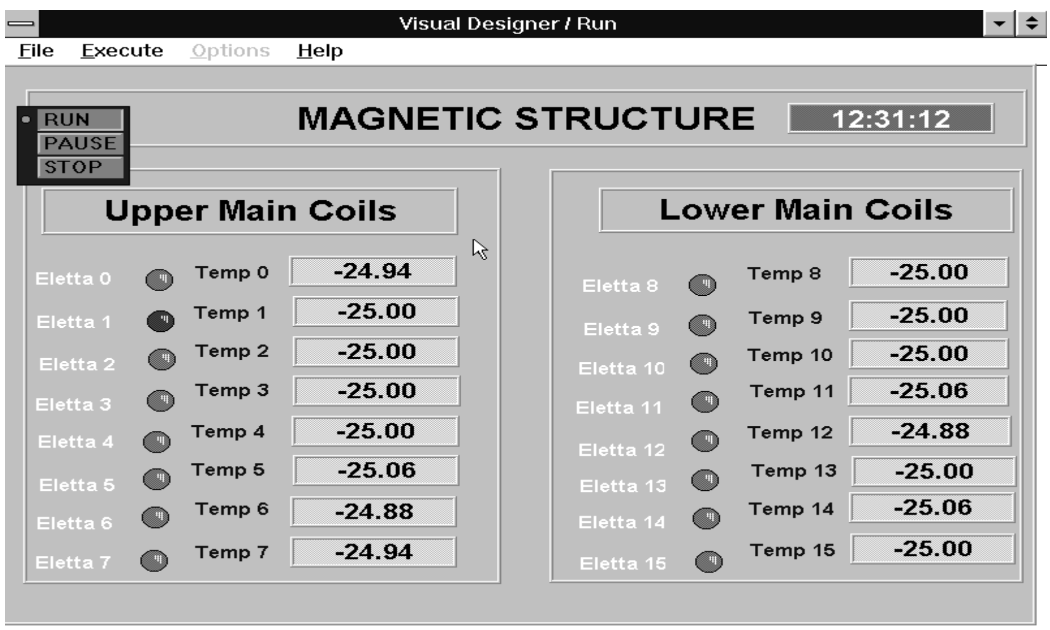

FIG. 4. Magnetic structure run time display

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