SPECIFIC FEATURES OF AUTOMATIC CONTROL SYSTEMS FOR APPLIED CYCLOTRONS

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Abstract

A distributed automatic control system for the MCC-30/15 compact medical cyclotron has been built on the hierarchy principle. The lower hierarchical level consists of controllers for various systems of the cyclotron, which are networked on the basis of Profibus.

An industrial Advantech-type computer has been chosen as the host computer of the system. The upper hierarchical level also contains computers to control the RF system of the cyclotron and operator workstation.

Computers of the upper hierarchical level are networked on the basis of Ethernet. The number of computers for the operator workstation is limited only by the Ethernet bandwidth and the speed of the host computer.

To measure the beam current, a multi-channel high-precision measuring current amplifier has been developed, signals from which are sent to a high-speed ADC. It is possible to view current pulse oscillograms, which makes much easier the adjustment of the cyclotron modes.

A distributed automatic control system built on the hierarchy principle has been developed for the MCC-30/15 compact medical cyclotron [1].

The lower hierarchical level consists of controllers for various systems of the cyclotron: water cooling system, vacuum system, external injection system, power supply systems for the main electromagnet and ion guide magnets and system for control of mechanical devices of the cyclotron and ion guide. Controllers of the lower hierarchical level are networked with the host computer of the automatic control system via the Profibus DP. Controllers of the external injection system are networked with the host computer via the RS-485 interface. Programmable logic controllers (PLC) of the FX3U series (Mitsubishi) and ADAM-4501controllers (Advantech) are used as controllers of the lower hierarchical level.

A high-powered industrial Advantech-type computer with a 2.4 GHz Pentium 4 Celeron processor was chosen as the host computer of the automatic control system. In addition to the host computer, the upper hierarchical level also contains a computer to control the RF system of the cyclotron and computer(s) of the operator workstation. As the RF system is one of the most complicated and important system of the cyclotron, an industrial computer similar to the host computer is used for its control.

Any PC-compatible computers with the Windows XP operational system or higher may be used as the operator workstation computers. Computers of the upper hierarchical level are networked on the basis of Ethernet, for which purpose an industrial 8-port Ethernet-switch is applied. The number of operator workstation computers is limited only by the Ethernet bandwidth and the performance of the host computer. The use of the Ethernet network allows the operator workstation to be located both in the direct vicinity of the cyclotron and in any place, provided a computer network is available. The software of the automatic control system also allows several copies of the program for the operator workstation to be executed simultaneously on one and the same computer, which makes operation of the control system much more comfortable if several monitors are connected. The host computer performs arbitration of commands and transfer of the data on the status of the cyclotron systems to the operator workstation.

Fig.1 shows a simplified structure of the automatic control system.

The information is displayed on the operator workstation monitor(s) in the form of pages; each of these pages displays status of one of the cyclotron systems. The operator can arbitrarily choose a page to be displayed. If the operator workstation contains several monitors or computers, the operator can display several different pages simultaneously. The page shown in Fig.2 is the control of the vacuum system.

The software allows all the systems of the cyclotron to be controlled in two modes. In the "Manual Remote" mode, the operator performs on/off operations and adjustment of the cyclotron devices' parameters from one of the operator workstation computers on the basis of his own experience and design parameters of the mode. The "Choose and Control" principle is applied. By clicking the mouse, the operator chooses one of the cyclotron sub-systems on the mnemonic diagram displayed on the monitor and a panel to control this system is visualized. Current operating parameters and controls of this particular device are shown on the panel. The operator can either turn on/off the device or change the adjustment of its parameters (for example, the current of the main electromagnet or radial position / angle of the stripping device, etc). In so doing, the available ACS interlocking system does not enable any unallowable operations to be done. This ACS operating mode is used at the initial stage of the cyclotron operation until the data on the cyclotron operating modes has not been stored. Parameters of the actual mode can be stored in the data base. The second operating mode of the ACS is the automatic mode. In this mode, the operator chooses an operating mode among the modes previously stored in the data base and starts automatic procedures of turning on/off the sub-systems of the cyclotron. These procedures include production of the working vacuum in the cyclotron, external injection

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system and beam transport system, bringing to the working mode the main electromagnet and mechanical devices (shims and stripping devices) of the cyclotron, ion injectors, the RF system and the beam transport system. Operating parameters of all the devices are read from the chosen mode stored in the data base and are set automatically. Further an insignificant tuning of several parameters by the operator can be needed to optimize the operating mode. Sequence of the automatic procedures is defined by the system of ACS interlocks.

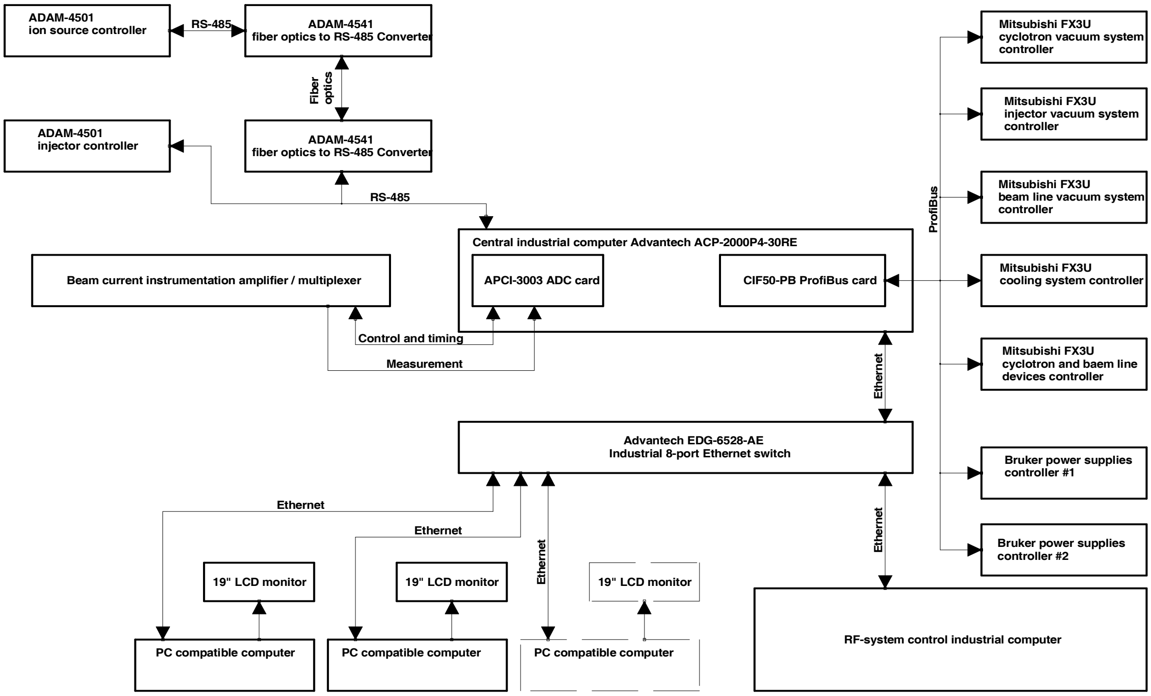

Figure 1: Automatic control system of the MCC-30/15 cyclotron. Structural diagram

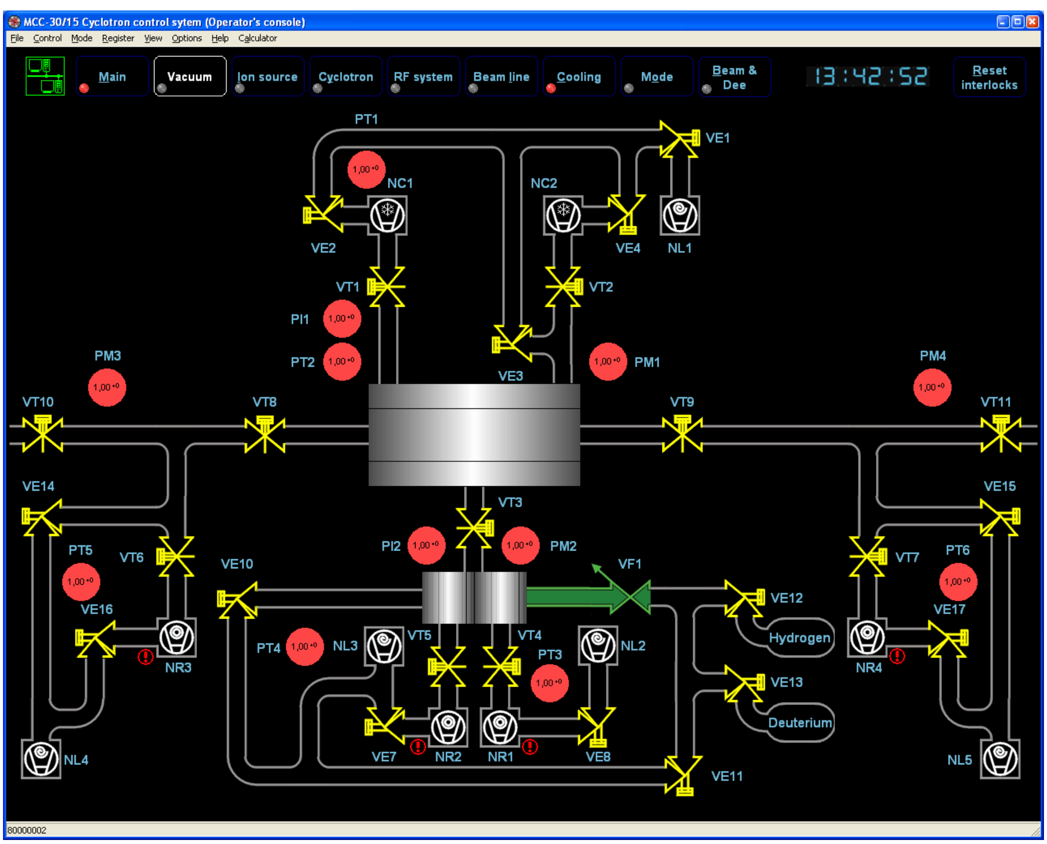

Figure 2: Control of the vacuum system of the MCC-30/15 cyclotron

To measure the beam current, a multi-channel high-precision beam current instrumentation amplifier has been developed, signals from which are sent to a high-speed ADC. An ADC card is installed in the host computer. The ADC is started by a synchro-pulse generated in the synchronization unit of the RF system. The software of the beam current measuring system allows both average and amplitude values of current to be measured; real-time display of the current pulse oscillogram is also possible, which makes much more easier the adjustment of the cyclotron sub-systems to the mode chosen by the operator. In addition, the oscillogram of the beam current allows the cyclotron modes to be adjusted at a low pulse repetition rate and high duty cycle, that is, at a very low average beam current and as a result low radiation intensity. On completion of the mode adjustment and beam extraction to a target/Faraday cup, a necessary intensity can be easily obtained by varying the pulse repetition rate and duty cycle.

Fig.3 shows the monitor of the operator workstation with the beam current oscillogram displayed.

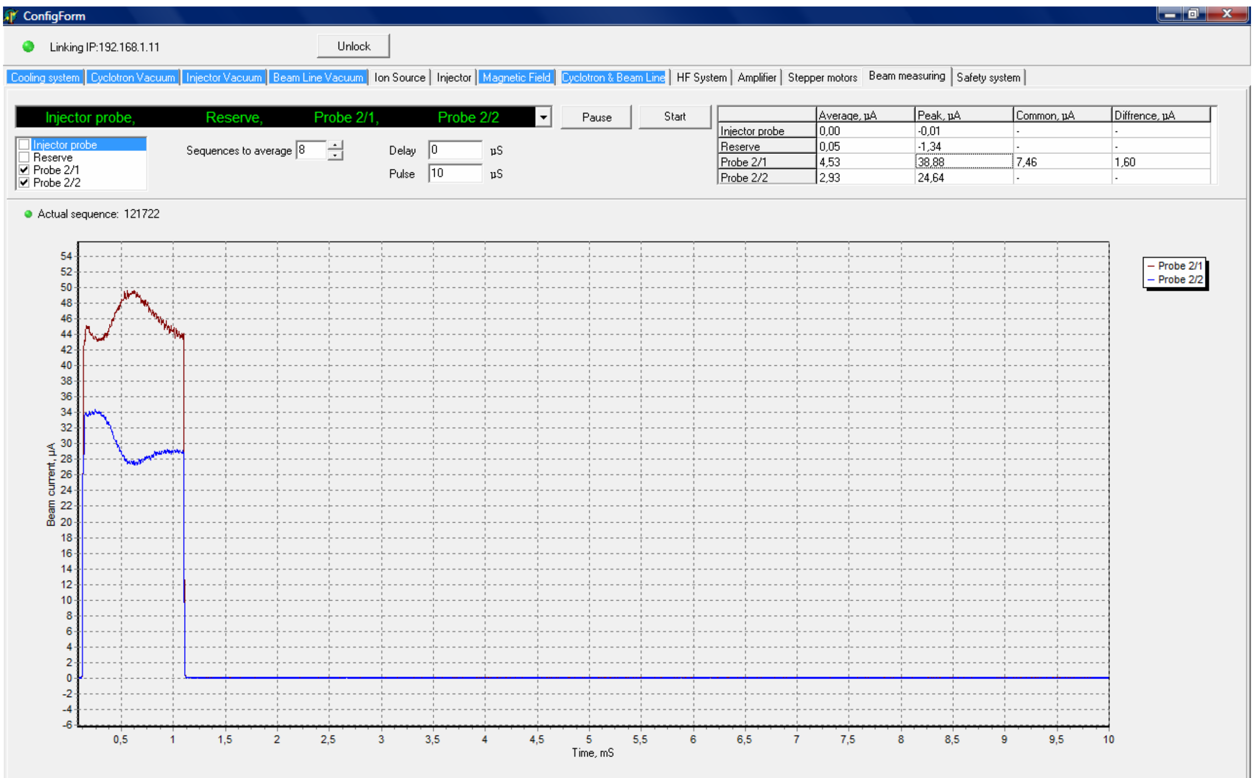

Figure 3: Oscillogram of the beam current pulse

To ensure passage of the beam through the ion guide with minimum losses, beam density scanners are used. By using these scanners, the ACS measures the beam density distribution along two coordinates of the ion guide cross-section, and a two-dimensional image obtained on the basis of two distribution curves is displayed on the monitor. Proceeding from this image, the operator can estimate necessary variation of parameters of correcting and focusing magnets of the ion guide and correct the position and size of the beam if necessary.

REFERENCES

[1] P.V.Bogdanov, M.F.Vorogushin, A.V.Galchuk, V.G.Mudroljubov, A.P.Strokach "The MCC-30/15 Cyclotron, parameters, adjusting works and their results" RuPAC-2010, Protvino (2010); http://www.JACoW.org