SAFETY AND CONTROL SYSTEMS OF THE MVINIS ION SOURCE

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The mVINIS Ion Source, which is the heavy ion source of the TESLA Accelerator Installation, was assembled and tested in the fall of 1997, and it was commissioned in the spring of 1998. The role of its safety system is to protect personnel from high voltages, and sensitive equipment from damage in the cases of overheating, electric discharges or poor vacuum. A part of the safety system is dedicated to the vacuum system, enabling its manual start-up, and also preventing possible operator errors. Control functions of the mVINIS Ion Source are implemented via Honeywell Alcont 3000^x system, which is used as the main control system of the TESLA Accelerator Installation. All the vacuum pumps and the valves, DC and high voltage power supplies, microwave generator and ion beam diagnostic elements are controlled via a touch screen and functional keyboard. The major advantages of the control system are the user friendly environment, and the easy running of the machine.

1 Introduction

The main aim of the mVINIS Ion Source safety system is to protect personnel from high voltage and equipment from damage in possible accidental situations. Safety system is completely autonomous system that includes local and remote signalization as well as manual control of the vacuum system components (mostly vacuum valves). Two implementation variants have been considered in design phase, one based on relay technique and the other one based on PLC (Programmable Logic Controller), and the former has been accepted as simpler and cheaper one.

Initially, for the mVINIS commissioning, control functions were performed on an industrial PC based controller. This was done because the implementation of the control system was easier on such a small system, and because we wanted to understand and optimize the control of all mVINIS parameters. On the other hand, such a small system did not have enough capacity to support in total 176 I/O channels what was required for the complete control of mVINIS. Finally, our global plan was to realize control of mVINIS on the main control system Honeywell Alcont 3000^x, and thus integrate it into the TESLA Accelerator Installation control system. We have succeeded to implement only a part of the control functions on the Alcont 3000^x system. It is planed that complete control of mVINIS would be transferred to the main control system by August 1998.

2 mVINIS safety system

The main functions of the mVINIS Ion Source safety system are:

- Protection of personnel from high voltage
- Overheating protection of the ECR hexapole magnet
- Overheating protection of coils on the ECR source, solenoid lens and analyzing magnet
- Local LED signalization on synoptic board
- Alarm signals monitoring for the Alcont 3000^x control system

The basic principle of operation of one block of the safety system is presented in Fig. 1. Each sensor signal (e.g., cooling water flow, temperature, pressure) drives a

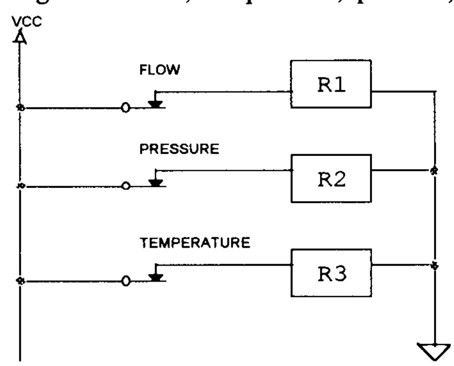

Figure1: Functional schematics of the safety system

relay, which is activated when the measured quantity is in normal range of operation, and deactivated when it is out of this range. Protection of the injection stage coil of the ECR ion source is taken as an example in Fig. 2. DC power supply Oerlikon 1000 A/125 V is automatically turned off if the cooling water flow (R1) or pressure (R2) in the injection coil falls below some minimal level, or if the temperature of the coil (R3) exceeds certain maximal value. Water flow is controlled by Eletta flow monitor switches, water pressure is measured by the pressure transmitter with 4 - 20 mA output signal, and injection stage coil temperature is controlled by thermal switches, opening their contacts at 70 °C. It is clear that the injection stage coils are protected by three levels of interlocks. The same principle of multiple protection is implemented in case of other devices and equipment. Safety system logic is based on Omron SPDT,

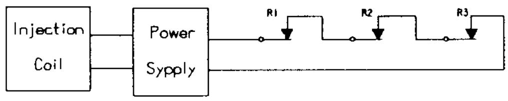

Figure 2: Principle of devices protection

DPDT and 4PDT relays. Local signalization is based on 24 V LEDs. Blue diodes are used for the flow, yellow for the pressure, and red for the temperature signalization. All diodes are turned off in normal operation, and turned on only in the case of alarm situation. Synoptic board of the mVINIS safety system is shown in Fig. 3.

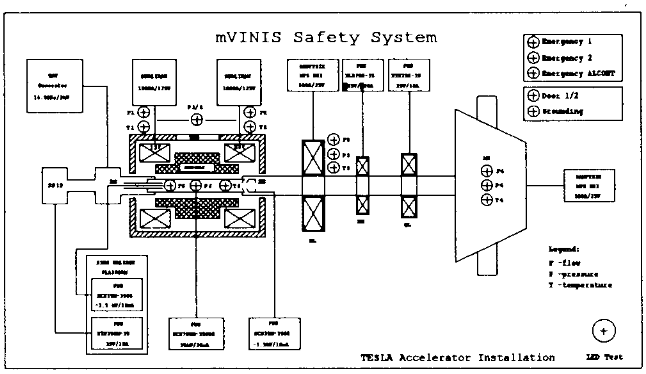

Figure 3: Local signalization of the mVINIS safety system

3 mVINIS vacuum safety system

The basic functions of the mVINIS vacuum safety system are:

- Manual control of the vacuum system
- Vacuum pump protection
- Local signalization on the synoptic board
- Generation of status and control signals for the Alcont 3000^x control system

The mVINIS vacuum system consists of five rotary pumps, four turbomolecular and three cryogenic pumps. Separation of vacuum sections and pumps is done by twelve electropneumatic valves. Control of one electropneumatic valve is presented on functional scheme in Fig. 4.

Selection between local (manual) and remote control is performed by LOC/REM switch. Decision block enables/disables local or remote control function. Requested command is stored in the latch block while opening and closing of valves is performed by the relay driver block. The open/close state of valves is shown on the synoptic board. This iformation is sent simultaneously to the main control system. If, for any reasons, vacuum in the system becomes too low, vacuum safety subsystem block will close relevant valves acording to the predefined algorithm. During local to remote switching, or vice versa, there are no unwanted arbitrary openings or closings of vacuum valves. In case of alarm situation, one can use reset button to close imediately all vacuum valves. Monitor and control signals leading to the remote control system are galvanically isolated by the optocouplers.

Figure 5 shows the mVINIS vacuum safety system synoptic board. Local signalization of the valves state is

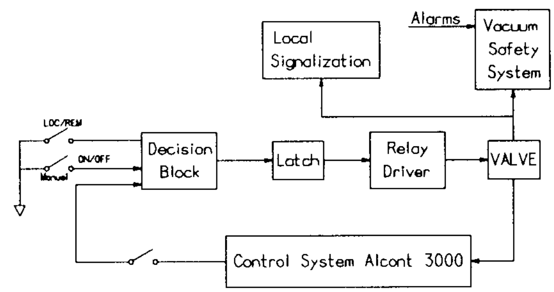

Figure 4: Functional diagram of the vacuum valve control

implemented by two-colour LEDs. The LED is red when the valve is closed, and green when it is open. The green LED turn on when the certain vacuum pump is on. In addition, blinking red LEDs are used for the alarm situations on the vacuum pumps. Test LED button is used to check the functioning of all LEDs simultaneously.

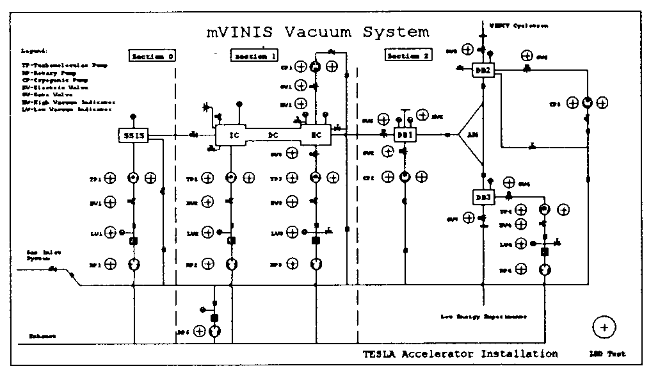

Figure 5: Vacuum safety system signalization

4 Controlling the mVINIS Ion Source with μR2D2 industrial controller

Control of the mVINIS Ion Source was initially implemented on μR2D2 industrial controller [1]. There were two basic reasons for that: (a) it was faster to develop control functions on the PC based control system; (b) it was easier to modify the application programs in order to optimize the mVINIS operation parameters and learn how to perform its overall control. μR2D2 is a PC based industrial controller (Electronic Design, Belgrade) having the following I/O boards:

- 16 channel, 12 bit ADC board
- 32 channel digital input board
- 32 channel digital output board
- 4 serial RS-232 ports
- one serial RS-422 port

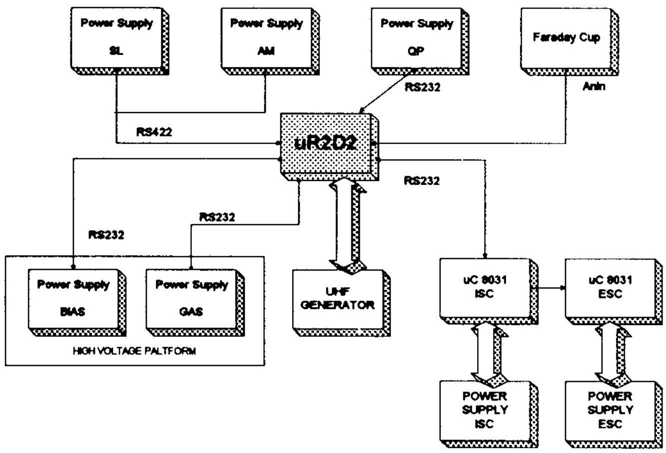

Figure 6: Control of the mVINIS Ion Source by the μR2D2 industrial controller

Serial ports [2] were used to control seven DC power supplies (supplies for ECR coils, solenoid lens, quadrupole lens, analyzing magnet [3], bias electrode, gas inlet system). Two DC power supplies located on the high voltage platform (25 kV) [4] required optically isolated serial lines. Control of the 14.5 GHz UHF generator was realized over digital I/O modules. Two old Oerlikon power supplies 1000 A/125 V used for the injection stage and extraction stage coils of the ECR source required special microcomputer modules. These modules were developed in our laboratory. They are based on 8031 microcontroller [5], with 8 KB of external ROM memory, 16 KB of external RAM memory, serial RS-232 interface and parallel 8255 interface. Each module directly controls Oerlikon power supply and communicates with the central control system over serial port. Control programs were written in C language for DOS enviroment. Recording of the ion beam spectra is performed by separate program written in LabWindows/CVI for Windows 95 [6].

5 Controlling the mVINS Ion Source with the Alcont 3000^{x} control system

Complete control of the mVINS Ion Source could not be accomplished on the μR2D2 because of its limited capabilities and insufficient number of I/O channels. The complete list of the mVINIS channels is given in Table 1. The final version of the mVINIS control system is under development on the Alcont 3000^{x}, latest version of the Honeywell control system. This robust and reliable industrial control system has been chosen for the main control system of the whole TESLA Accelerator Installation based on it's good performances at the Jyvaskila accelerator facility. Reliable work of the older version of Alcont system in this accelerator facility which is similar to our installation, as well as available support from their development team were crucial facts for us to decide to purchase Alcont 3000^{x} system.

Table 1: Complete list of the mVINIS I/O channels

Analog inputs	14
Analog outputs	4
Digital inputs	114
Digital outputs	32
Serial interfaces	12
Total number of channels	176

This control system is a classical three-layered system (Fig. 7). It consists of two touch-screen operator consoles, one UNIX workstation and one application design module (DM) on the highest, user-interface level. Two operator modules (OM) form the intermediate level, while three process modules (PM) with I/O cards are on the lowest, device-dependant level of hierarchy. Applications are developed on the design module and run on proces modules (PM). Applications run on PMs cyclically, with selectable run cycle range (0.1 sec is minimal interval). Each PM is based on one i80486 processor driving up to 19 I/O cards each. Process modules communicate over dual-redundant industrial bus called Upline, with throughput of 1 Mbps, sending only refresh and operator-demanded data, thus decreasing communication load.

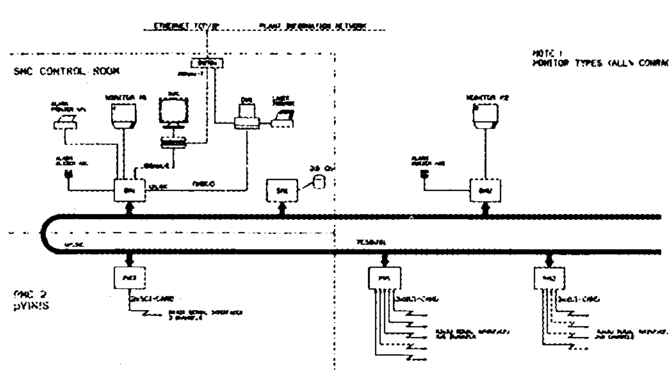

Figure 7: System structure of control system Alcont 3000^{x}

Design module, which is a Pentium PC computer connected to the Upline, has block editor for developing applications hierarchy and actual applications, graphics editor for screen definitions, system editor for system structure definitions and storage editor [7] for long term data storage applications. Appropriate library of ready-made blocks, each graphycally representing an executable Pascal program, is available in the system software. User can also develop his own blocks and save them for the future use.

Recently, we have implemented on Alcont 3000^x system all control functions that have been already installed and tested on the μR2D2 system. There are five control screens enabling complete control of the mVINIS Ion Source:

- ECRIS screen is used to adjust and monitor all parameters of the ECR ion source (ISC and ESC power supply currents, main high voltage, UHF power, bias electrode voltage, gas flow etc.);
- TRANSP screen is used to adjust focusing elements, analyzing magnet and diagnostic elements along the beam transport line (Fig. 8);
- DIAGN screen is used to record ion beam spectrum, beam profile and beam emittance (this application is not finished);
- VACUUM screen shows the status of the vacuum system ellements (pumps, valves) and pressure levels at certain points; it can be used also to open/close vacuum valves;
- SAFETY screen shows similar information to that presented on safety system synoptic board.

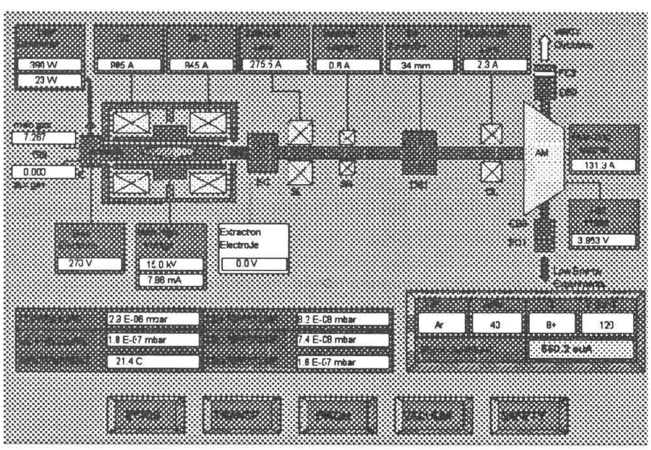

Figure 8: Display of the mVINIS beam transport

Control of mVINIS can be performed either from the touch screen operator console located near the ion source, or from the other consoles located in the control room. We have simplified control screens as much as possible, reducing the number of parameters presented at one time to the minimum, hiding less frequently used data under graphical press buttons. In return, we have obtained simple control scheme and user friendly environment. Running the mVINIS Ion Source using this control system is a real fun.

6 Conclusions

The safety and control systems of the mVINIS Ion Source were completely developed and implemented at the Vinča Institute. Testing and commissioning of the mVINIS Ion Source, that required uninterrupted functioning of the source in the period of several weeks, has proved that the safety system was functioning reliably. We have encountered some problems with noise generated by the plasma discharge effects, which have influenced proper functioning of the main high voltage power supply, ECR source DC power supplies as well as functioning of the safety system itself. After introduction of electronic filters on the high voltage line, and AC supply lines we have significantly reduced these effects.

Control of the mVINIS Ion Source is being developed on the Honeywell Alcont 3000^x main control system of the TESLA Accelerator Installation. Present experience shows that this is a reliable and flexible control system which fulfills it's basic requirements. User friendly environment and simple touch screen comunication with the mVINIS components and devices are one of its major advantages.

There are still a lot of functions that we plan to implement, specially regarding the ion beam diagnostics. Also, we plan to store main parameters for the most common regimes (beams) into a data base, that could be recalled by the control system alowing automatic adjustment of the source to the preset state.

7 References

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[3] Danfysik, Manual – Magnet Power Supply 853.

[4] Fug, Manual – NTN 350M – 35.

[5] Intel, MCS-51 Microcontroller Family User's Manual, February 1994.

[6] National Instruments Corporation, LabWindows/CVI User's Guide.

[7] Honeywell, Technical documentation of control system Alcont 3000^x.