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CONTROL SYSTEM OF A MINIATURE 12 MEV RACE-TRACK MICROTRON*

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Abstract

A simple control system has been developed for the commissioning of a compact 12 MeV race-track microtron which is under construction at the Technical University of Catalonia. It is of modular structure and is based on LabView programs at a conventional PC and ATmega microcontrollers. Apart from modules to monitor different RTM systems it also includes an Automatic Frequency Control of the magnetron frequency and interlocks. The architecture and main features of the modules are described and results of their operation are reported. Further developments of the control system and interfaces are on the way.

INTRODUCTION

The Technical University of Catalonia in collaboration with the Skobeltsyn Institute of Nuclear Physics of the Lomonosov Moscow State University and CIEMAT (Madrid) is building a miniature electron race-track microtron (RTM) which is intended for applications in the intraoperative radiation therapy and can also be used a source in radiography and inspection complexes. This compact accelerator was proposed in [1], its schematic view and the status of work on the RTM are described in Ref. [2]. Main parameters of the machine are given in Table 1.

Table 1: RTM Parameters

Parameter	Value
Beam energies	6, 8, 10, 12 MeV
RF operating frequency	5712 MHz
Synchronous energy gain	2 MeV
Pulsed beam current at the exit	5 mA
Pulse repetition frequency	1 – 250 Hz
Pulse duration	3 μs
End magnets field	0.8 T
Injection energy	25 keV

The RTM consists of an electron gun, an accelerating structure (linac), two end magnets and a focusing quadrupole. These elements are precisely fixed at a common rigid platform placed inside a steel box which plays the role of the vacuum chamber. The beam can be extracted from any of the four last orbits with one of the four dipoles. These extraction magnets are moved orthogonally with respect to the orbit plane by means of a motor situated at the external surface of the vacuum chamber and transmitting its rotational motion through a feedthrough. In all the RTM magnets the magnetic fields is created by blocks of Rare-Earth Permanent Magnet (REPM) material.

The RF source of the RTM is a C-band CPI magnetron SFD-313V. It is powered by a ScandiNova M1 solid state switch modulator. The modulator-magnetron assembly provides about 1MW/1kW pulsed/average RF power at 5712 MHz in 3 μs length pulses following with a repetition rate up to 250 Hz (see Ref. [3] for details). The vacuum inside the vacuum chamber is created by turbomolecular (at the initial stage) and ion pumps and is measured by a vacuum gauge. A water circuit run by a chiller is used for cooling the modulator and linac and stabilization of the temperature of the REPM blocks of the end magnets.

CONTROL SYSTEM ARQUITECTURE

According to the initial RTM conceptual design [1] and its further versions the control system must provide a complete control of the accelerator systems and ensure a safe machine operation both for the personnel and the RTM subsystems, and also offer a convenient interface for the operator.

The RTM control system architecture is shown in Fig. 1. It is of modular structure and includes the following components:

- Main PC with a Graphical User Interface (GUI)
- Interlock system
- A set of controllers communicating with the main PC and input/output devices

The accelerator controller plays a special role supervising the state of the interlock relays and the rest of the controllers (system controllers). The modulator, E-gun filament heating power supply (EGFHPS) unit, vacuum pumps and vacuum gauge have their own controllers which communicate either with the main PC (modulator and EGFHPS) or with the corresponding microprocessor of the control system. All the communications between the system controllers and PC are via Ethernet using the TCP/IP protocol. The control system program at main PC is written in LabView.

The microprocessor that receives temperature readouts from sensors placed at the magnetron body and the inlet and outlet of the cooling circuit is ADAM-6015 ADC. The rest of the microcontrollers are based on the ATmega328 technology [4]. The RTM control system allows the operator to supervise all main machine devices mentioned above and shown schematically in Fig. 1. In the present design the chiller is not supervised by the control system and is operated separately.

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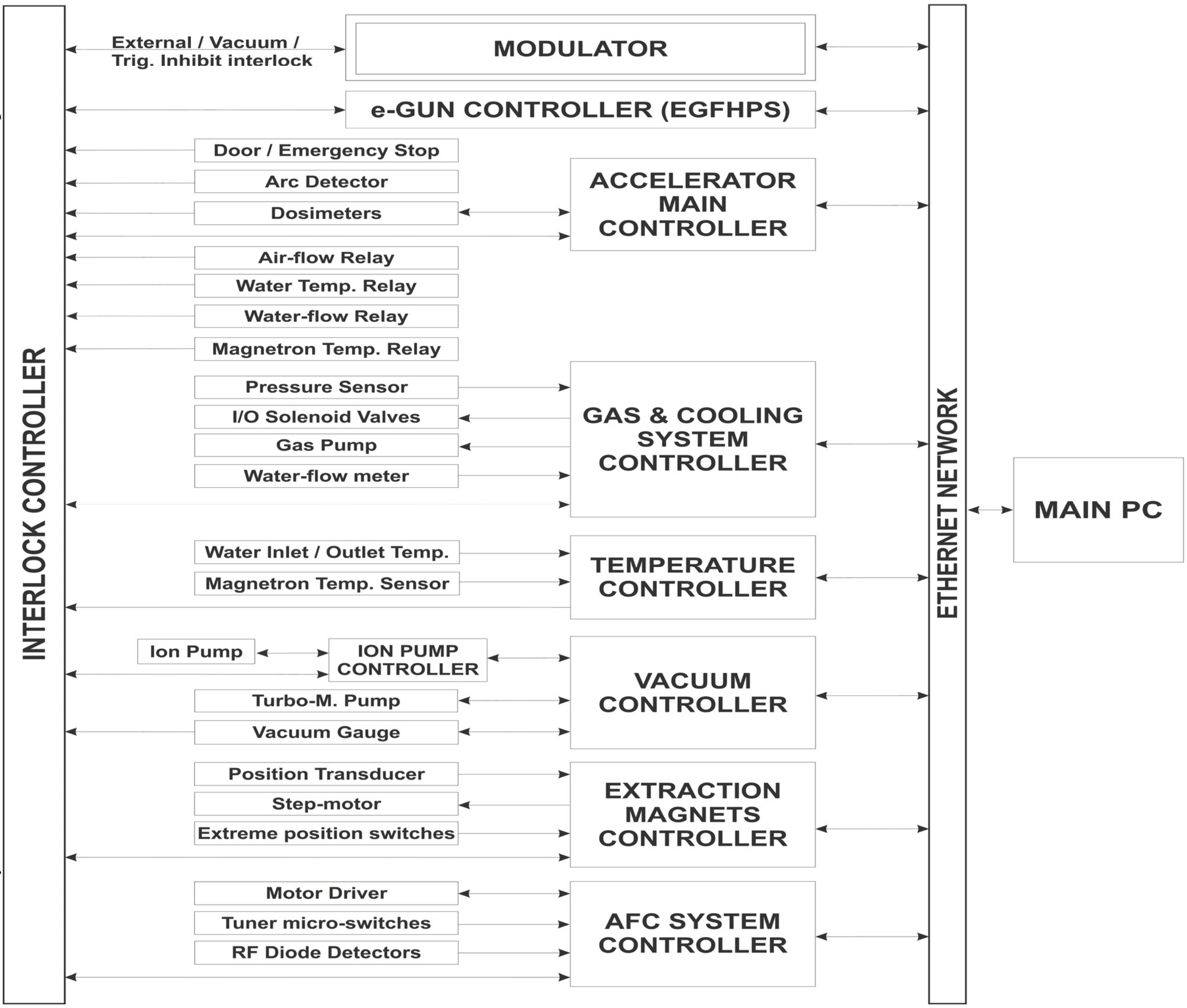

Figure 1: 12 MeV RTM control system architecture.

For each controller we defined a safe "Emergency stop" state and normal operation "Ready" state of the devices that it controls. For example, in case of the system, which fills the waveguide with the isolating gas SF_6 in order to prevent arc discharges and controls the gas pressure, the "Emergency stop" corresponds to the all valves closed and the SF_6 gas pump switched off. Each system microcontroller checks the communication with the main PC and the accelerator controller. In case of communication timeout it goes to the "Emergency stop" state and produces an interlock signal. It performs this operations also by a direct order from the main PC or the accelerator controller.

The accelerator controller (see Fig. 1) supervises the state of the interlocks and microprocessors and checks the communication with them and the main PC by sending ping messages with a certain period. In case of a timeout the controller sends an interlock signal to stop beam generation and orders all microprocessors to shift their systems status to the base one. Fig. 2 shows the main screen of the GUI of the machine.

In the following sections we describe details of two the control system modules that recently have been developed and tested.

INTERLOCK SYSTEM

The function of the interlocks is to ensure that certain regimes of operation of the RTM (beam generation, high voltage on, etc.) will only be possible if personnel safety and equipment protection criteria are met.

In the machine conceptual design rules for automatic stopping of the accelerator or some of its subsystems were defined. In most of cases of deviation of the machine parameters from their nominal values it is sufficient to stop the beam generation or disable the high voltage state of the modulator. For this the external and vacuum interlock lines, respectively, provided by the modulator itself are used. These lines are normally active (+24 VDC) and pass to low state (0 V) as a result of a genuine alarm condition or equipment fault.

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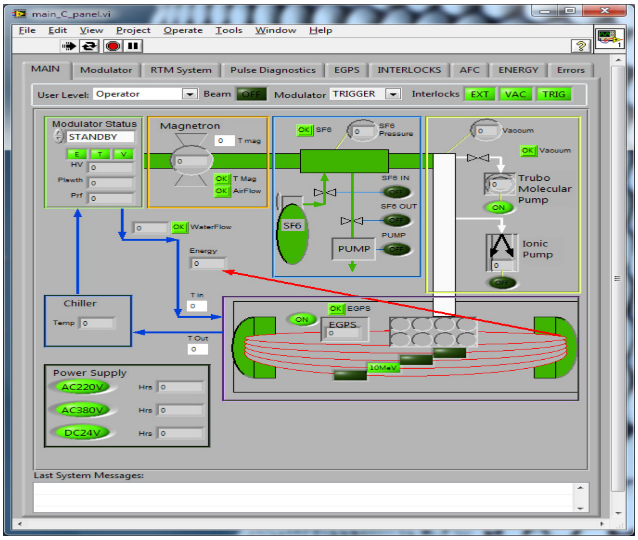

Figure 2: Main screen of the GUI.

To ensure maximum safety and protection it was decided that most of the connections with equipment generating signals of faults or hazards are hardwired. Only in certain cases, when a comparison with a certain preset value, like in the case of the SF_6 gas pressure or vacuum pressure, the interlock relays are open by the corresponding microcontroller. The interlock circuit provides the self-locking of the relays so that the interlock line cannot return to the active state even if the fault signal has disappeared. The restarting of the normal operation can only be done from the operator console after the status of the alarm is cleared. The accelerator controller is responsible for the supervision of the state of the interlock relays and processing of the reset order. The logic implemented in this microcontroller ensures that the beam generation is only possible if all the system controllers are in the "Ready" state, all the machine parameters are normal and an authorization from the main PC has been received.

A part of the interlock system, not shown in Fig. 1, disables the high voltage supply to the RTM in case of certain alarms, like opening of a door of the accelerator hall, pushing one of emergency stop knobs or direct order from the operator console.

The personnel safety is also ensured by monitoring of the accelerator hall and adjacent area with a number of dosimeters. Since the RTM generates pulsed radiation with pulses of 3 µs duration following each other with a minimal period of 2.5 ms (see Table 1) dosimeters able to measure the average dose rate of the radiation of these characteristics will be used. If the dose rate exceeds a preset value the interlock relay becomes open and an alarm signal to the operator console is sent.

ARC DETECTOR SYSTEM

The arc detector protects the circulator and vacuum window from a damage that can be produced by dielectric discharges inside the RF waveguide. The detector used in the RTM is an ATM 187-ARCE-A-1-2 opto-electric device which can detect visible arcs. It is armed by +15 VDC at 25mA and in this state develops TTL '1' (3.5 volts typical) on one of its output pins. In response to a visible arc in the waveguide the output changes to TTL '0' and remains at this level until the arc is no longer present, i.e. the detector re-arms automatically when the waveguide is no longer illuminated.

For certain regimes of the RTM operation (testing, commissioning) the system should be equipped with a self-locking mechanism to prevent its return to the normal operation once the arc has disappeared. We have designed and implemented a unit that can detect short signals and that includes a latch (also called flip-flop) circuit with two logical states. The self-locking unit determines the state of a relay that opens/closes the trigger inhibit interlock line of the modulator. The unit was built using a Philips IC HEF4001B and a transistor. It is connected to the accelerator controller and is placed inside the interlock system housing box.

Tests of the arc detector and self-locking unit operation and their communication with the controller and interlock were performed. It was checked that the response time of the arc detector is below 1 µs and the minimum duration of a detectable arc is 60 ns. The detector enters into the fired state with a 0.97 µs delay and remains in it for about 0.9 µs. The maximum response time of the whole module (including the self-locking circuit) is about 1.1 µs. The microcontroller and the interlock relay introduce an additional small delay depending on the circuitry. The test results show that the arc detector module of the control system fulfils the design specifications.

CONCLUSION

The control system of the 12 MeV RTM was designed and assembling and testing of the main part of its modules have been carried out. After finishing the programming of the microcontrollers the system will be integrated into the accelerator.

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REFERENCES

[1] B.S. Ishkhanov et al., "Conceptual design of the miniature electron accelerator dedicated to IORT", RuPAC'04, Dubna, 2004, pp. 474-476 (2004).
[2] Yu.A. Kubyshin et al., "Current status of the 12 MeV UPC race-track microtron", PAC'09, Vancouver, 2009, pp. 2775-2777 (2009).
[3] Yu.A. Kubyshin et al., "RF and accelerating structure of 12 MeV UPC race-track microtron", IPAC'11, San Sebastian, 2011, pp. 169-171 (2011).
[4] http://www.atmel.com/