ISBN: 978-3-95450-193-9 doi:10.18429/JACoW-ICALEPCS2017-THPHA052

LIA-20 CONTROL SYSTEM PROJECT

G. Fatkin*, A. Baluev, E. Bekhtenev, E. Kotov, A. Ottmar, A. Pavlenko,
A. Panov, A. Senchenko, S. Serednyakov BINP and NSU, Novosibirsk, Russia
A. Batrakov, Ya. Macheret, V. Mamkin, K. Shtro, A. Selivanov,
P. Selivanov, S. Singatulin BINP, Novosibirsk, Russia

Abstract

The project of the control system of linear induction accelerator LIA-20 for radiography is presented in this paper. The accelerator is a complex pulsed machine designed to provide a series of three consecutive electron pulses with an energy up to 20 MeV, current 2 kA and lateral beam size less then 1 mm. To allow reliable operation of the whole complex, coordinated functioning of more then 700 devices must be guaranteed in time frames from milliseconds to several nanoseconds. Total number of control channels exceeds 6000. The control system is based on a variety of specially developed VME and CAN modules and crates. Tango program infrastructure is used. The first stage of commissioning will take place in the end of 2017 and will include launching 5 MeV version of the accelerator.

INTRODUCTION

Linear Induction Accelerator LIA-20 is designed in BINP to be used for the flash X-Ray radiography. It will provide three consecutive electron beams with an energy up to 20 MeV, current up to 2 kA and the beam lateral size after focusing on the target less than 1 mm. Successsfully commissioned LIA-2 accelerator (2 MeV, 2 kA) could be considered a prototype for the injector of the 20 MeV installation [1].

To facilitate the launching process and test all equipment first a 5 MeV version of the installation would be assembled at BINP. Then after necessary beam parameters would be obtained, 20 MeV single-pulsed installation would be built. After that, several-pulsed version is planned.

It is necessary to design an adequate control system for such an installation taking into account different requirements and a scope of the project. Such a project, however not final is presented in this paper.

* G.A.Fatkin@inp.nsk.su

STRUCTURE OF THE ACCELERATOR

LIA-20 consists of the injector, a number of accelerating modules (AM) and transport channel. The injector has 92 inductors and generates an electon beam with the current up to 2 kA and the energy 2 MeV. 30 “short” accelerating modules (SAM) are placed after the injector. Each of them consists of 16 inductors and adds an energy of 0.33 MeV to the beam. Then 12 “long” accelerating modules (LAM) are placed each of them consists of 32 inductors. Each LAM adds an energy of 0.66 MeV to the beam.

The total length of the accelerator is about 75 meters without the transport channel and about 120 meters with it. Therefore controlling the positioning of optical system is critical. Two position control systems are provided to control the horisontal, vertical and angular offsets of the beam axis.

Focusing solenoidal lenses and correctors are placed between accelerating modules. The lenses are powered by pulsed power supply that provides 0.5 kA, 2.05 ms sinusoidal pulse. Beam position monitors (BPM’s) are present between accelerating modules. Several other technological sub-systems including vacuum and insulating gas pressure require control.

Accelerating pulses on the inductors are formed by the modulators, each of them provides 40 kV 60-300 ns pulse with fronts better than 50 ns for two inductors. To provide several consecutive pulses, several modulators will be used. Each thyratron in modulator has it’s own delay, therefore to attain required accelerating voltage pulse form, starting moments must be tuned with accuracy better than 4 ns.

The modulators are grouped in racks called pulsed power supply racks (PPSR). Eight modulators provide one pulse, 16 are used for two-pulsed regime and 24 are required for three consecutive pulses. The injector is supplied by 3 PPSR’s,

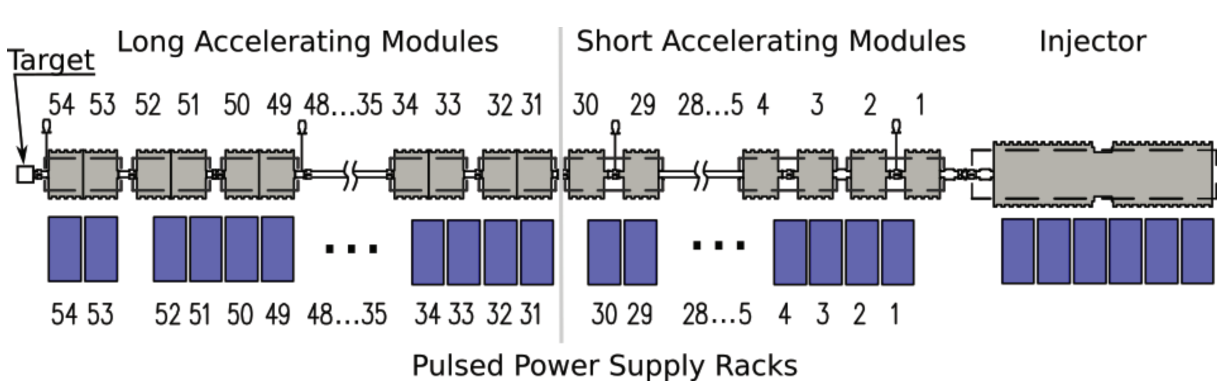

Figure 1: Scheme of LIA-20 Accelerator.

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Table 1: Controlled Devices and Number of Channels

Name	Control	Measurement	Synchronization
Inductors	0	480	0
Modulator	0	480	0
Pulsed Power Supply	480 D.	480 + 480 D.	540
Demagnetizing	60 D.	60 + 60 D.	60
Lense power supply	60 D.	60 + 60 D.	60
Charging device	6 D.	6 + 6 D	6
BPM	0	120	0
Positioning (wire)	0	28 D.	0
Positioning (water)	0	84 D.	0
Technological and Vacuum	≈ 100	≈ 100	0
Total	706 D.	1686 + 818 D.	666

two SAM's are supplied by one PPSR, and each LAM is supplied by one PPSR's.

Modulator forming lines are charged by charging devices that are placed along the installation. The sinusoidal demagnetization pulse (100 A, 1 ms) is required for inductors and is provided by high-voltage demagnitizer that supplies 16 inductors.

CONTROL OBJECTIVES

Let us formulate the objectives of the control system. It should be noted, that experiments that will be held using LIA-20 are very time and resource consuming. Therefore one of the main tasks is to provide reliable and coordinated functioning of all the elements of the installation. To ensure the reliability we should collect as much parameters of the pulse as possible and also all necessary long-term machine statistics. To furhter increase the reliability, a fast interlock system that prohibits the experiment in case some of the subsystems are working incorrectly is absolutely necessary.

Another objective of the control system is to allow the operator to control such an installation. With big amounts of information, human couldn't effectively control all of it, therefore automation of information processing should be introduced, providing the integral indicators. But every individual channel must be tracked and controlled and the operator should be able to change single parameters manually.

Table 1 presents the summary of main channels for one-pulsed version of the 20-MeV machine. "D." means a digital channel.

STRUCTURE OF THE CONTROL SYSTEM

LIA-20 will have a linear organization, therefore it is reasonable to divide the control elements into structural units and place these units along the installation. It was decided that we can have one control unit providing all necessary functions for one LAM, or for two SAM's, thus each conrol unit controls 16 modulators and 2 PPSR's. Three control units would be enough for the injector.

These control units are built using VME-BINP Crates [2]. Modular composition allows to easily increase the number of pulses through the comissioning. Each crate has a similar set of modules shown on fig.2 that provide all the necessary functions. Ethernet is used to interconnect controllers and provide a link to control room. The total planned number of control crates is 33 for 20 MeV accelerator.

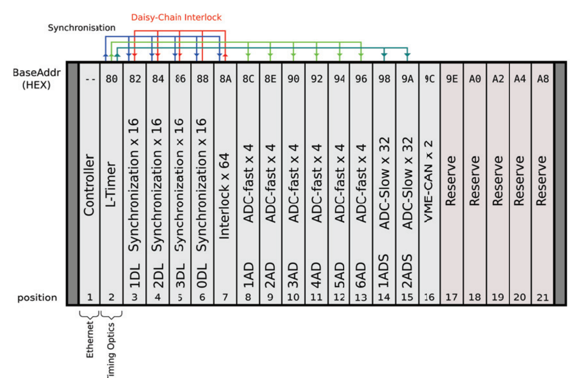

Figure 2: VME Crate Composition

The control system in whole could be divided into the following subsystems: Synchronization, Measurement, Fast interlock, Slow control and Transport Channel and Target control. The last one will not be presented in this paper. Human safety and access control is also not discussed here.

First three of them are used to control the processes during the "pulse" of the accelerator, including: charging the pulsed power supplies, forming the inductor demagnetizing and magnetic lenses current pulses, initiating the experiment, launching thyratrons and measuring all the resulting signals and pulses. The last one takes care of all the processes deemed "slow". This processes take place between the pulses and include: controlling the position of the accelerating structure, controlling vacuum pumps and vacuum quality, controlling the incandescence of the cathode, etc.

The measurement subsystem digitizes two groups of signals: the "fast" (up to several us) signals and the "slow" (up to several ms) signals. "Fast" signals include: form of the voltage on inductors, form of the current on lenses and beam

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positioning monitor signals. "Slow" signals are: charging device and modulator voltages and demagnetizing currents. More detailed description of the measurment subsystem could be found in [3].

The main goal of the fast interlock subsystem is to prohibit the start of the experiment if some critical component doesn't work correctly at the moment. It has to collect the interlock signals from all devices and make a fast decision. More detailed description of the interlock subsystem could be found in [4].

Slow Controls Subsystem

The slow controls subsystem incorporates: vacuum and pumps controls; optical system alignment control (described in detail in [5]); control of the parameters of charging device, degauss and lense power supplies, and modulators; cathode filament power source.

1. Geodetic Angle positioning (water-based)
2. Geodetic X-Y positioning (wire-based)
3. Modulators control
4. Degaussing control
5. Lense power supplise control
6. Cathode heater control
7. Vacuum control
8. Crate power control

The slow control is mostly realized using CAN-BUS. Several previously developed devices: CANDAC, CANADC, CEAC124 [6] are used. Specialized controllers were developed for: the demagnetizing source, the cathode filament power source, crate power control, modulators and optical system alignment control.

Vacuum control also requires to connect turbomolecular pump and spectrum analyzer with specific Windows-based software. Therefore a separate industrial PC is used for this task with remote desktop software for operator access.

Synchronization Subsystem

The synchronization subsystem provides all controlled and controlling devices with start pulses. The overall accuracy must be better than 4 ns across 70 m of length. This means that the propagation delays between control units must be taken into consideration and negated.

Three kinds of modules described in [2] are used in this subsystem. S-Timer provides a common 125 MHz clock with encoded events stream to L-Timer's placed in control crates along the installation. All modules in the crate are synchronized to this clocks and events. DL250-VME and DL250-RIO modules are used to form starting pulses for the PPSR's and other electronics.

The total number of synchronization channels at the installation for 3-pulse version will be around 2000. Another

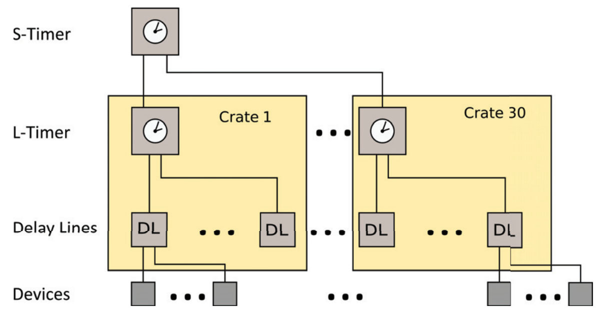

Figure 3: VME

complication is that a beam should be formed after the experiment start and this moment is unpredictable. Thus we have two sections of the time diagram: before the experiment and after the experiment. The first one is started by an operator, and the second uses an external start pulse. To alleviate operator's work we devised a method and software for timing diagram composition for this subsystem. It is described in [7].

SYSTEM INFRASTRUCTURE

Main part of the control system is based upon custom built VME and CAN electronics. The infrastructure, servers and operator's computers are COTS. HP Proliant DL80 server with Intel E5-2609 processor is used to host virual machines with servers. Its storage is configured as RAID5 with 4 1Tb SAS disks. Operator's computers are based on Interl Core i3 with Sapphire FirePRO W4100 as a very cost-saving 4-monitor configuration.

Custom-built Debian OS is used on VME crate controllers, Ubuntu LTS Server with KVM is used on server and Ubuntu LTS Client with xfce is used on operator's stations. The control system software is Tango-based and is described in [8].

1 Gb ethernet is used throughout the installation based on HP 1910-24G. On 5 MeV installation copper-based channel is used, optics will be used on 20 Mev as the total length will be about 200 m.

CONCLUSION

Using the experience of LIA-2, the control system project for LIA-20 was devised with focus on modularity, extensibility and reliability. It is based on custom-built VME-BINP crates and modules and CAN-BUS devices. Currently an inductor test stand with 2 PPSR's and 4 SAM's is commissioned and control system elements are tested on it. Main problems we are experiencing are caused by EMI because control system crates are situated near the pulsed power elements.

LIA-5 – the 5 MeV linear accelerator is assembled with all control system elements and the tests will commence shortly. The 20 MeV one-pulsed version will be constructed after the beam is obtained on 5 MeV machine.

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