STRUCTURE AND HARDWARE OF LIA-20 CONTROL SYSTEM

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Abstract

The control system of a linear induction accelerator LIA-20 for radiography is presented in this paper. The accelerator is designed to provide a series of three consecutive electron pulses with energy up to 20 MeV, current 2 kA and lateral size less than 1 mm. To allow reliable operation of the whole complex, coordinated functioning of more than 700 devices must be guaranteed in time frames from milliseconds to several nanoseconds. Total number of control channels exceeds 6000. The control system structure is described and the hardware in VME and CAN standards is presented.

INTRODUCTION

Linear Induction Accelerator LIA-20 (see Fig. 1) is designed to pro-vide 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. It is planned to pro-vide three consecutive pulses, with one of them divided into 9 angles. The accelerator will be used for the flash X-Ray radiography. Successsfully commissioned LIA-2 accelera-tor (2 MeV, 2 kA) could be considered a prototype for the injector of the 20 MeV installation [1]. The control system of the LIA-2 is described in [2]. Both accelerators consist of a large number of complex electrophysical devices that require extensive control.

To attain the minimum possible beam size the structure with low acceleration rate was chosen. The upside of this approach is that common and cheap HV technology could be used (thyratrons, cabling). The downside is a large quantity of required devices. In case of LIA-20 we have more than 6000 control and measurement channels, this is approximately ten times more than LIA-2 and all known LIA flash radiography installations (DARHT, FXR, AIRIX, DRAGON)[3]. Therefore we had to introduce a lot of new approaches for design of our control system. Structure and hardware of the control system are the scope of this paper, while the software and the computational infrastructure are described in [4].

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STRUCTURE OF THE ACCELERATOR

LIA-20 consists of the injector and a number of accelerating modules. 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, therefore controlling the positioning of optical system is critical. The injector has individual support, two SAM’s are placed on one support and each LAM is placed on a separate one. Two position control systems are provided to control the horisontal, vertical and angular offsets of the axis of supports.

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

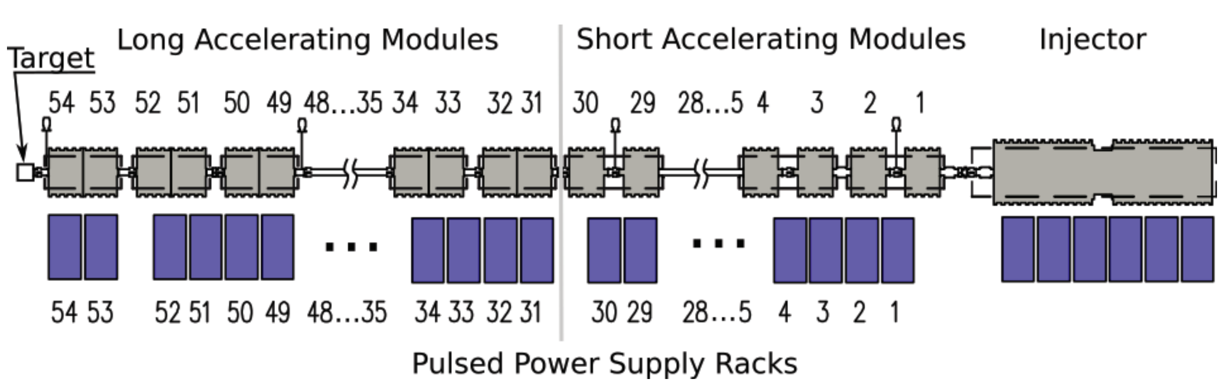

Figure 1: Scheme of LIA-20 Accelerator

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modulators. Each modulator is a high-voltage device based on thyratron that provides 40 kV 60-300 ns pulse with fronts better than 5 ns for two inductors. To provide several consecutive pulses, several modulators are used. Each thyratron has it's own delay, therefore to get required accelerating voltage pulse form, starting moments must be arranged in time 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, two SAM's are supplied by one PPSR, and each LAM is supplied by one PPSR's. PPSR's 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.

It should be noted that to facilitate the launching process a 5 MeV version of the installation would first be assembled at BINP. Then after necessary beam parameters would be obtained, 20 MeV single-pulsed installation would be assembled. After that, several pulses and several angles are planned.

CONTROL OBJECTIVES

Let us formulate the objectives of the control system. It should be noted, that flash radiography experiments that would 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 as much information as possible about the installation should be collected. Also to prohibit the experiment in case some of the subsystems are working incorrectly the fast interlock system is necessary.

Another objective of the control system is to allow the operator control such an installation. This is not an easy task. With big amount 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 channels for one-pulsed version of the 20-MeV machine. "D." means a digital channel.

STRUCTURE OF THE CONTROL SYSTEM

It is reasonable to divide the control elements into the 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. Three control units would be necessary for the injector. The control units are connected using Ehternet.

The control system in whole could be divided into following subsystems:

- Synchronization
- Measurement
- Fast interlock
- Slow controls

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 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.

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 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 [5]

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.

The slow controls subsystem incorporates: vacuum and pumps controls; optical system alignment control (described in detail in [6]); control of the parameters of charging device, degauss and lense power supplies, and modulators; cathode filament power source.

HARDWARE

The slow controls is realized using CAN-BUS. Several previously developed devices: CANDAC, CANADC,[7] are used. Specialized controllers were developed for: the demagnetizing source, the cathode filament power source, modulators and optical system alignment control.

Specialized VME crate was designed for the control unit of the control system. It has the following features:

1. 21-position 2-U VME crate
2. VME-64x standard compatible
3. ± 12 V 6 A power lines
4. integrated remote power control by CAN-BUS

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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

5. synchronization and clock lines on U/D pins
6. inter-module communication daisy-chain on U/D pins

A number of modules were developed specially for the control system and the VME-BINP crate. First are the two oscilloscope modules developed for the measurement subsystem.

ADC4x250VME

- 4 ADC channels
- 250 MSps
- 80 MHz bandwidth
- 0.75 MWords/Channel

ADC-32VME

- 4 8-channel ADC's (32 channels)
- 125 kSps (switchable)
- 300 kHz bandwidth
- 0.75 MWords/Channel

Next, we present two modules for the synhcronization subsystem: the delay line DL-250VME and the Timer-VME.

DL-250VME

- 16 channels (RIO) + 8 channels (Front)
- Discrete 4 ns
- Range 17 s

Timer-VME

- optical connection
- propagation delays accounting
- clock accuracy 2 ns
- low-jitter < 100 ps
- VME-Binp synchronization

CAN-Bus is used for all slow and technological control needs. **VME-CAN** board provides the interface for 2 CAN-Bus networks to the VME.

CONCLUSION

Using the experience of LIA-2 the control system structure for LIA-20 was devised with focus on modularity, extensibility. The developed VME-BINP crate is a extension of VME-64x standard. A number of modules are developed and Currently an inductor test stand with 2 PPSR's and 4 SAM's is comissioned and control system elements are being tested on it. Next step is the assembly of LIA-5 – the 5 MeV linear accelerator with all control system elements. Then the 20 MeV one-pulsed version is planned.

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