# SOME ASPECTS OF DEVELOPMENT OF CONTROL AND DIAGNOSTIC SYSTEMS FOR THE FOURTH-GENERATION RUSSIAN SYNCHROTRON RADIATION SOURSE*

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*Abstract*

A fourth-generation synchrotron radiation source assumed as a powerful instrument of mega science program in Russia. Recently several divisions of Kurchatov institute are involved into this project for detailed study of parameters of the beam diagnostics and the supervision control system. The actual status of this study is presented.

## INTRODUCTION

The fourth-generation Specialized Synchrotron Radiation Source (SSRS-4) is the new radiation facility based on both synchrotron and FEL radiation. The project aims to create a fundamentally new specialized X-ray source - a specialized synchrotron radiation source of the 4th generation (SSRS-4) with extremely high spatial coherence corresponding to that of laser radiation, a record high brightness and temporal structure.

Both synchrotron and XFEL based on top-up injection linac are proposed to construct in SSRS4 complex. Suggested prototype of the injector initially will include 10 MeV RF photo-gun and 50 MeV regular section.

Main preliminary parameters of the SSRS4 synchrotron are [1]:

- Beam energy in synchrotron 6 GeV.
- Beam current up to 300 mA.
- Transverse emittance <100 pm·rad (two schemes are under simulation today: “user machine” with emittance of 70-100 pm·rad and “record machine” with 20-50 pm·rad).
- Top-up injection from linac or booster.
- MBA magnet structure with SR length ~1300 m and 40 superperiods
- Four groups of RF cavities (3 or 4 cavities/group) in fully symmetries periods, solid-state RF power sources, operation frequency 500 or 700 MHz.

## CONTROL AND DIAGNOSTIC SYSTEMS

Main parts of SSRS-4 synchrotron, dependent of selected scheme, are medium or full energy LINAC, compact or full-scale Booster, Main Ring of Synchrotron and Beam Transfer Lines. Main control systems (Fig. 1) are:

- RF systems for LINACs, Booster and Synchrotron.
- LINACs, Booster Synchrotron and Beam Transfer Lines magnet systems, which include slow elements control, ramping elements control, fast correction control, injector and extractor elements control, with servomechanisms control.
- Timing system.
- Vacuum systems.
- Water flow control and temperature control.
- Area access control and dosimetry control.
- Beam diagnostic systems, such as beam position monitors (BPMs), Beam Current monitors, Beam profiles and emittance measurements, Beam Loss monitoring system and so on.

Control system core, TANGO [2] or similar, should include: set of operator’s terminals, configuration database server, History server(s), set of Event servers.

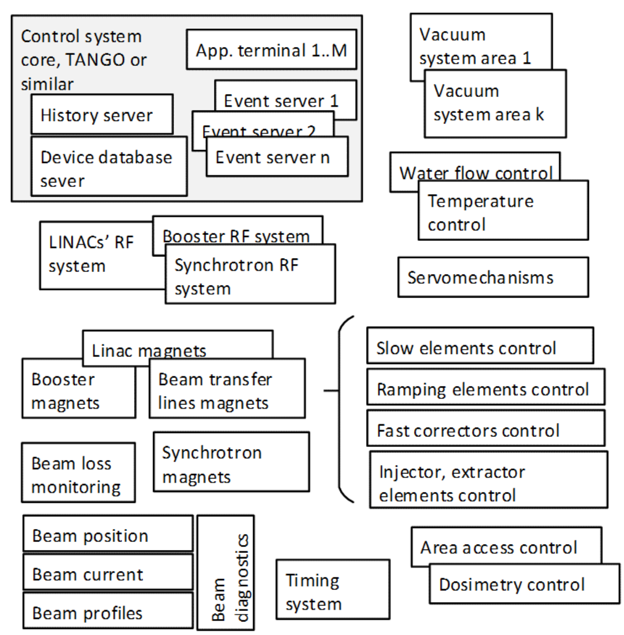


Figure 1: SSRS-4 systems.

## CONTROL SYSTEMS DEVELOPMENT

To develop software for the SSRS-4 CS, a development model was chosen in accordance with the Rapid Application Development (RAD) rules [3]. RAD is the concept of creating software development tools, focusing on the speed and ease of programming, creating a technological process that allows the programmer to create computer programs

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as quickly as possible. In general, RAD approaches to software development put less emphasis on planning and more emphasis on an adaptive process.

It is advisable to use RAD technology when certain priority areas of project development are clearly identified, but the requirements for software before the development is not completely clear. RAD technology assumes that software development is carried out by a small team of developers with active customer involvement already in the early stages, using incremental prototyping with the use of visual modeling and development tools. Graphical user interface builders are often called rapid application development tools. RAD technology allows you to execute the project in a short time and at a relatively low cost. RAD is well suited (although not limited to) for software development with special attention to the user interface, with relatively low computational complexity. The use of RAD technology is due to the possibility of splitting the project into logical parts. The described requirements and conditions are in good agreement with the conditions for the SSRS-4 CS development.

The main stages of development in RAD technology [3] are the following:

- Requirements planning – users, managers, and IT staff members discuss and agree on business needs, project scope, constraints, and system requirements.
- User design – users interact with systems analysts and develop models and prototypes that represent all system processes. This is a continuous interactive process that allows users to understand, modify, and eventually approve a working model of the system that meets their needs.
- Construction – program and application development task, when users continue to participate and can still suggest changes or improvements. The user design and construction stages require the use of the commercial integrated software development frameworks, which includes application development, coding, unit integration and system testing tools with graphical user interface builders, such as: Embarcadero RAD Studio [4] or Microsoft Visual Studio [5].
- Cutover – include data conversion, testing, changeover to the new system, and user training.

## ARCHITECTURE OF CONTROL SYSTEM

The SSRS-4 control system has a multilevel architecture (Fig. 2). The high-level data bus of the control system is an Ethernet type with the selected data transfer protocol. On a high-level Ethernet bus, data must be transferred between the following main control system nodes: a set of operator terminals, such as control system configuration, subsystem controls, and experimenter's control and data acquisition; general configuration and general archive databases with a set of event servers; servers of subsystems.

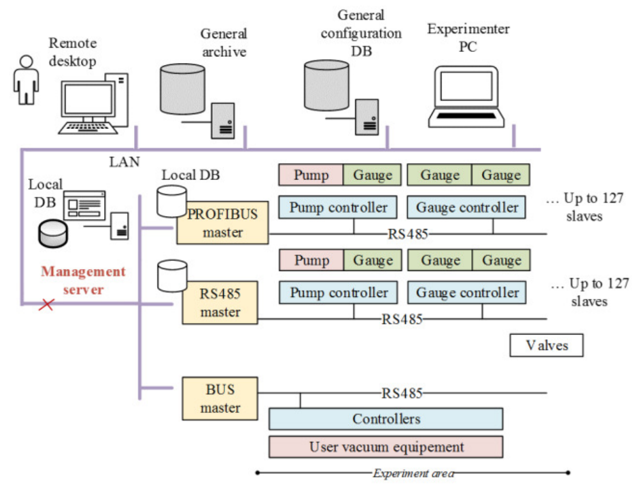


Figure 2: SSRS-4 Control System architecture.

The architecture of the control systems of individual subsystems of the SSRS-4 can be either single- or multi-level. The control systems of individual subsystems of the SSRS-4 are usually physically connected to the high-level Ethernet data bus of the accelerator, but can be logically separated, having in this case local configuration and archive databases. This choice is made by changing the configuration parameters of SSRS-4 CS.

### *Example: vacuum subsystem*

The need to organize sublevels in the control system for the selected subsystem of the accelerator is largely determined by the control interface and the data transfer protocol for individual devices of this subsystem. One example, shown in Figure 2, is the vacuum subsystem.

A typical pump or sensor controller, for example from the Pfeiffer Vacuum [6] manufacturer, has one of the interfaces of a serial type. In this case, for the vacuum subsystem, an additional level of the control databus must be created (see Fig. 2), with an additional server performing the functions of the master data bus controller of this subsystem of the accelerator. In the case where the vacuum subsystem is integrated in the SSRS-4 CS, this server should also act as an intermediate bridge between the high-level CS databus and the subsystem databus.

RS-485 or Profibus-DP [7] are the main types of serial interfaces for Pfeiffer Vacuum controllers. The high-level Profibus-DP communication protocol in the Pfeiffer Vacuum controllers uses the RS-485 serial differential interface as the physical layer protocol in the OSI model. The RS-485 standard corresponds to an electrical network with a bus topology using a shielded twisted pair as the physical interface for data transmission. The bus structure enables non-reactive coupling and decoupling of stations and incremental commissioning of the system. Profibus DP (Decentralized Peripherals) is used to operate sensors and actuators via a centralized controller in production (factory) automation applications. Profibus DP is a protocol made for (deterministic) communication between Profibus masters and their remote I/O slaves, up to 126 devices on single net. Profibus DP communication protocol allows cyclical and aperiodic communication, where a master prompt the

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connected slaves to exchange data, and the polled slave answers the prompting master with a response message. In the main cyclic operation mode, the typical cycle time of the bus is approximately 10 ms. The main Profibus node must be implemented either on the basis of one of the standard ASIC chips, or in one of the real-time microcontrollers, for example, with the ARM core, if additional flexibility is required.

### *Example: Low-level RF Control*

The Low-level RF control (LLRF) system is an example of another type of subsystem controllers that are directly connected to the high-level control system databus. Over the last ten or more years LLRF controllers are based, as a rule, on modern Micro-Controller Unit (MCU) and Field Programmable Gate Array (FPGA) technologies, which, in particular, allow the implementation of control algorithms in devices that support the Ethernet interface.

The SSRS-4 synchrotron will have several accelerating sections belonging to the linac, booster, or to the main ring. All of them require an automatic control and synchronization system. The need for synchronization of radio-frequency fields in accelerating sections and large time constants in superconducting accelerating resonators allows the use of only one main LLRF controller to RF control of the entire SSRS-4 accelerator complex. In this case, the entire RF system will be controlled through one LLRF controller over the SSRS-4 Ethernet structure. Additionally, the LLRF controller must have low-level data bus (serial is preferable) to control slave devices, such as a resonator tune controller. Alternatively, depending on the relative location of the linac and rings, it may be preferably to have an individual LLRF for each resonator or group of resonators to shorten local feedback loop. In this case it would be easy to implement the elements of RF over fiber technology with phase drift correction. In the frame of the Agreement in force a conceptual design is prepared for all mentioned variants.

## LOW EMITTANCE MEASUREMENTS

A real challenge for the fourth-generation SRS is a measurements of the low-emittance beam profiles which could be as small as six micrometers in vertical plane. The same diffraction effect which limits the optical size of the radiation source will affect the resolution of the beam profile measurements based on optical methods. In order to make the optical observation meaningful, we propose a dedicated insertion device with a shorten oscillation period and Gaussian-shaped amplitude modulation (see Fig. 3).

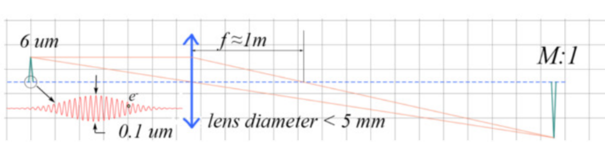


Figure 3: The X-ray optical system layout for the beam profile measurements.

We have developed a 3D computer code DMISRTOOL for MATLAB to simulate such or similar optical systems during the conceptual design stage. For instance, Fig. 4 shows the evolution of a short light wave packet, generated by single electron in undulator with 10-millimeter oscillation period and a box-car amplitude modulation. On this figure it is to be noted that the image has different scales for vertical and horizontal axes as well as between different wave fragments. Following the scheme from Fig. 3 the wave packet is focused by a single compound lens and traced then down to the necking plane shown on the third fragment. No chromatic effects were taken into account.

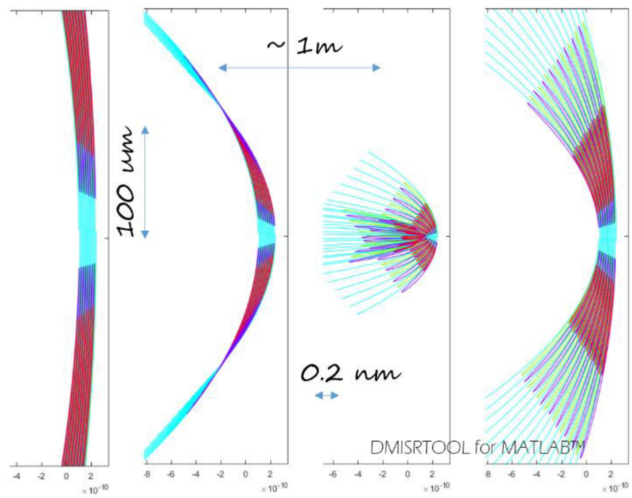


Figure 4: The evolution of the light waves for the system, shown on Fig. 3.

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