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Control and diagnostic systems for specialized synchrotron radiation source of 4th generation SSRS-4

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Abstract. The general layout for Specialized Synchrotron Radiation Source 4th generation SSRS 4 is under development by leading of National Research Center “Kurchatov institute”. In the framework of a collaborative project with European Synchrotron Radiation Facility (ESRF) supported by the Ministry of Education and Science of the Russian Federation, the applied research on determination of the configuration and key technical parameters for the control and beam diagnostic systems for 4th generation Specialized Synchrotron Radiation Source – SSRS-4 is going on. The preliminary view of the proposed control and diagnostic system is presented and discussed. SSRS-4 inherits the experience of the scientific community including a great ESRF expertise in control system development (as founder of TANGO), robust diagnostics and long operational experience on ESRF’s accelerator.

1. Introduction

Synchrotron radiation (SR) is a multipurpose science instrument, that is under permanent improvement since 1990th [1]. Now many researchers use SR at different fields of science. In the world tens of modern synchrotron complexes were built to meet researchers’ needs [2]-[12]. Total number of synchrotron facilities is more than 75, where more than 20 thousand scientists are working every year. Furthermore, these numbers continue increasing each day. The synchrotron sources are used and are improved continuously at all technologically advanced countries. Moreover the international facilities with ultra-high parameters were built in international collaboration as European Synchrotron Radiation Facility in Grenoble, France, for example

Main synchrotron radiation consumers are material science and life science. These large branches of science have the greatest impact on industry based on the development of high tech devices and drugs - or “economy of knowledge”. Taking into account the industrial development of various world regions and the growing role of the knowledge economy it is necessary to have the national strategies for such development, as well as the corresponding infrastructure and competence centers.

Historically sources of SR are divided into four generations.

The first generation synchrotrons were built initially for experiments with high-energy physics. That time SR was considered only as an inevitable accessory effect. The first experiments used SR started at these synchrotrons.

The second generation synchrotrons were built specially for produced SR. Only bending magnets were used for generation SR at these facilities.

The third generation synchrotrons are modern facilities operated now in more than 20 countries. Their design includes number of long (five or more meters) straight sections where wigglers or undulators are installed. Such inserted devices significantly improve the energy efficiency of the device, since most of the energy radiated by the electrons is output directly to the experimental stations, so power consumption was reduced significantly.

The fourth-generation SR sources are based originally on free electron (FEL) lasers and linear accelerators with energy recuperation. It was believed that a significant emittance reduction (less than 0.1 nm) and increase in brightness can be achieved only by switching synchrotrons to FEL. However, P. Raimondi and his collaborators showed that it is possible to create a storage ring structure where electron beam emittance can reach values much less than 100 pm [13]. Such small emittance enables X-ray sources with a characteristic transverse size of about 10 microns or less and high degree of coherence beam. For radiation with a wavelength of more than 1A, such a source can be designed even as diffraction limited and completely coherent. Now NRC "Kurchatov institute", NRNU MEPhI, Budker Institute of Nuclear Physics of SB RAS and other are developing complex of specialized synchrotron radiation source of the fourth generation - SSRS-4. It was shown that a storage ring with 6 GeV beam energy can provide the proper instruments for the key experiments. Two variants of the top-up injector in the storage ring are discussed: one use the top-up linac injection, the second one use a booster. The first approach (top-up linac) enables realization of a free-electron laser (FEL) which can work between the cycles for fulfilling the storage ring. However, it will be necessary to use two sources of the electron beam - one with a thermo cathode to fill the ring accelerator and the other one based on the photo gun to operate for the FEL. Such the accelerator complex requires the production of a reliable control system based on a powerful beam diagnostic system.

2. Beam diagnostics and control systems

The modern diagnostic and control systems have to provide the increasing quality requirements for such parameters as:

- efficiency of access to data
- velocity of experimental data processing
- uniformity in the data provided and processing quality
- fault tolerance of both hardware and software

The list of diagnostic devices for the designing complex is shown in Table 1.

It is expected that a basic configuration of the accelerator complex based on beam dynamics simulation, carried out in cooperation with ESRF experts, will be developed by the end of 2018. The simulation is under process in two directions: the development of a magnetic channel for emittance of 70-100 ppm providing the needs of all experimental works now, and for a record emittance of ~ 20 pm, in order to determine the feasibility of this solution. Speaking about beam diagnostics system, beam position sensors are under experimental development [14], [15]. Particular attention is devoted to the development of small beam emittances measurements in - SSRS-4 [16]-[21]. The work is under process in collaboration with specialists from the BNU of Kaliningrad [22], pp. **33-42**

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[23]. Simultaneously the development of electronics is underway for these sensors. A scaled stand for control system synchronization system and electronic components testing is under development [24]-[32].

Table 1. List of diagnostic devices for SSRS-4.

Name	Placement location	Beam parameter
Current monitor	On all structural components of the facility	Beam charge measurement
DC current transformer	On all structural components of the facility	Beam charge measurement
screen	On injector after the buncher, The second on FEL diagnostic line	Emittance, energy, energy spread
screen	On linac, Transport line to ring Transport line to FEL	Transverse beam size (mean and end) Emittance
BPM – beam position monitor	On all structural components of the facility	Beam trajectory dispersion: horizontal and vertical betatron oscillation frequency
Faraday cup	Injector Special Faraday cup after FEL's undulator before damp	Injection phase, Microbunch charge and beam structure (approximate) after FEL's undulator (Special Faraday cup)
Streak camera	Injector Transport line to FEL Storage ring Buster ring	Bunch length
Beam loss monitor	Transport line to ring Storage ring	Beam losses
interferometer	Storage ring	Transverse beam size Emittance

The basic principles of control and diagnostics systems have been formulated and developed since the 90th of the last century. During that time the efficiency of commercial and specialized equipment has been increased continuously reducing the operation cost and simplifying communication processes between the system elements. In practice, the software and hardware components themselves are becoming increasingly complicated. Anyway the apparent simplification is reached by the development, optimization and standardization of the user interface between the application programs and the object and transport layers of the diagnostic and control systems. Modern computers allow implementing remote file systems, server name functions, and event server functions on ordinary PCs. This approach makes the system more decentralized, while reducing the load on the network segments. Effective development tools - RAD (rapid application development) compete with the tools of automatic code generation and IDL, which are add-ons over platforms of the TANGO / CORBA or EPICS classes.

The management system is based on the standard architecture of distributed systems. Figure 1 shows the main elements of the network structure of the complex. The structure shown includes workstations – 1, management terminals – 2, database server – 3, encapsulated local control systems requiring high performance – 4, modular subsystem controllers – 5, wired network routers – 6, peripheral electronics (interfaces for analogue input/output) – 7. Thus, the system is functionally a set of peripheral controllers and operating terminals connected to each other by TCP / IP and UDP network protocols. Exit to the external Internet network and use of wireless components may require additional costs to develop secure protocols with data encryption. The development of the system is due to the addition of new computers and controllers. The physical hierarchy is provided by the components of the network support: routers, network bridges, etc. Parts of the system may include isolated network sections dedicated to local communications. These sites can be protected from access from the global network of the complex. The system performance is determined by the performance of the network and its components.

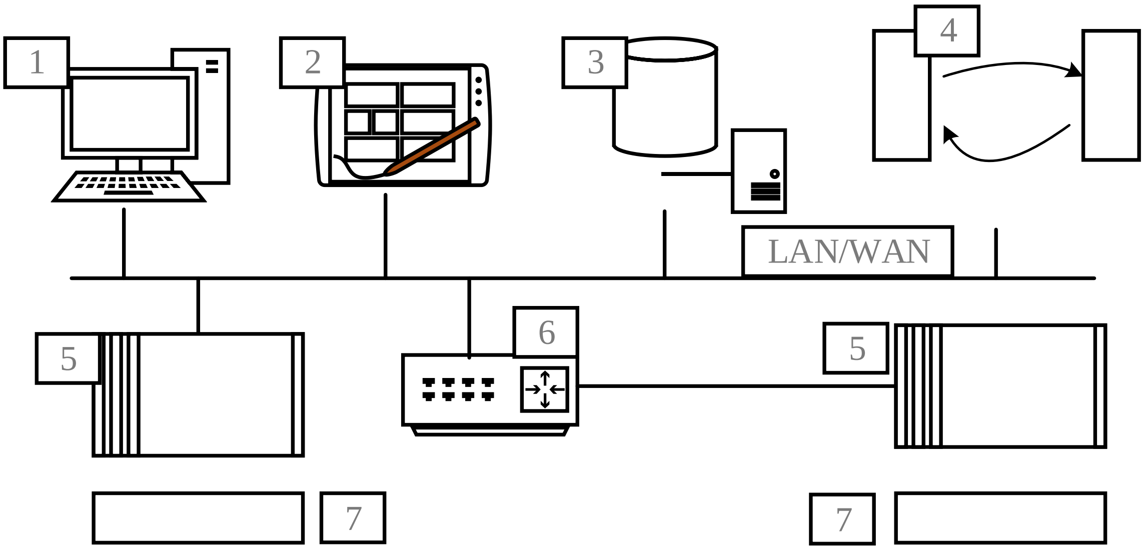

Figure 1. Distributed systems architecture of the complex.

Workstations for control system are a desktop or embedded industrial configuration PC using Windows OS (predominantly) for SCADA systems and Linux for systems using EPICS or TANGO (Windows versions also exist).

Interaction of the elements of the control system with each other is underway via a protocol called the protocol of access to the data transmission channel. As seen in Figure 1, the client and the data transfer server are provided with a network structure and a protocol procedure. As result the client can detect the servers and initiate the data transfer between themselves and the selected remote server. The server part provides access to data that describes in general a certain device – an abstract input-output controller.

Historically, the timer systems have begun with devices that distribute simple voltage pulses through the cables and each pulse corresponds to a specific event and destined for one particular device. Then, the timer events became encoding by a set of consecutive bits, which enables to transmit a set of sync pulses to different devices over a single cable. Over time, copper cables have been replaced by optical cables, which provide better stability and signal transmission for longer distances. Such synchronization systems are implemented in several laboratories that focus on the use of a relatively inexpensive, high-quality synchronization system. For the SSRS-4 the MRF standard (Micro-Research Finland) is the most practical, as the least complex providing required parameters. MRF offers a complete set of components for building a scalable synchronization system based on the encoding of a timer signal transmitted over optical cables. A typical configuration of the system used the extended MRF standard is shown on Figure 2.

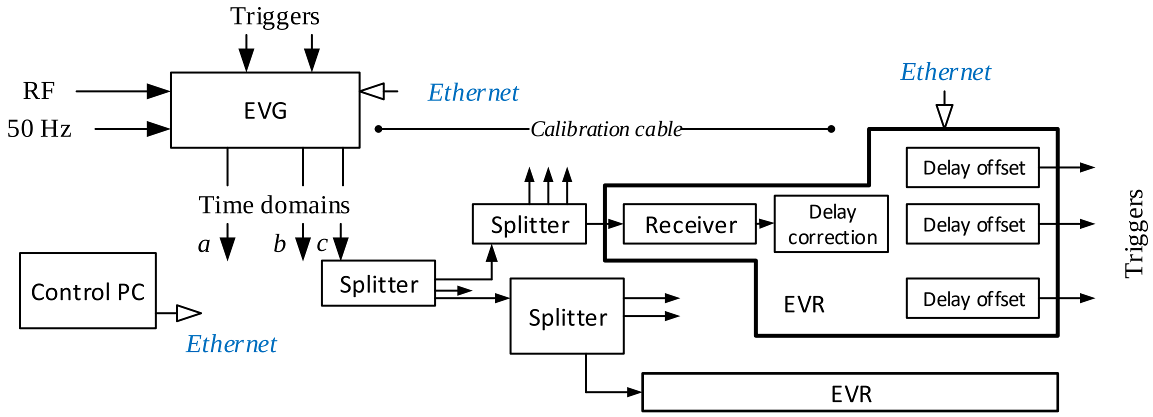

Figure 2. Layout of timer signal transmitted with MRF.

The system includes an event generator (EVG) and a set of event receivers (EVR). EVG synchronized with the phase of the high-frequency accelerating field. The signal branch can be extended by using the signal splitters. Synchronization signals can be converted directly to the form of standard TTL, LVDC, NIM, etc. pulses by the EVR at the application site.

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REFERENCE

[1] Eberhardt W 2015 Synchrotron radiation: A continuing revolution in X-ray science—Diffraction limited storage rings and beyond *Journal of Electron Spectroscopy and Related Phenomena* Volume 200 pp 31-39.
[2] Tavares P F, Leemann S C, Sjostrom M, Andersson A 2014 The MAX IV storage ring project *J. Synchrotron Rad.* 21 862–877.
[3] Rodrigues A R D et al. 2016 Sirius status report *Proceedings of IPAC2016 (Busan, Korea)* pp. 2811-2814.
[4] http://www.esrf.eu/Apache_files/Upgrade/ESRF-orange-book.pdf
[5] Henderson S 2015 Status of the APS upgrade project *Proceedings of IPAC2015 (Richmond, USA)* pp 1791-1793.
[6] Tanaka H, Ishikawa T 2016 Spring-8 upgrade project *Proceedings of IPAC2016* (*Busan Korea)* pp.2867-2870.
[7] https://www.maxiv.lu.se/accelerators-beamlines/accelerators/
[8] http://lnls.cnpem.br/sirius/
[9] https://www.kek.jp/en/Facility/IMSS/PF/
[10] http://www.kek.jp/en/Facility/ACCL/LightSource/
[11] http://www-ssrl.slac.stanford.edu/content/spear3/spear3-accelerator
[12] http://www.diamond.ac.uk/Home/About.html
[13] Raimondi P, Zobov M, Shatilov D 2007 Beam-beam simulations for particle factories with crabbed waist *Proceedings of PAC07 (Albuquerque New Mexico USA)* pp 1469-1471
[14] Slater M et al 2008 Cavity BPM system tests for the ILC energy spectrometer *Nuclear instruments and Methods* V.592, Issue 3 pp.201-217

[15] Tobiyama M et al 2010 Development of button electrodes for SuperKEKB rings *Proceedings of BIW 2010 (Santa Fe New Mexico US)* pp.223-227.

[16] Behrens C, Gerth C, Kube G, Schmidt B, Wesch S and Yan M 2012 Electron beam profile imaging in the presence of coherent optical radiation effects *Physical Review Special Topics - Accelerators and Beams* т. 15 № 6 p 062801,

[17] Couillaud C et al. 1996 Electron Beam Transverse Emittance Measurement using Optical Transition Radiation Interferometry *Proceedings of EPAC1996 (Barselona, Spain)* pp.e-proc. 1594

[18] Ewald F et al 2013 Emittance measurement using X-ray lenses at the ESRF *Proceedings of IBIC 2013 (Oxford UK)* pp.833-836

[19] Elleaume P et al 1995 Measuring Beam Sizes and Ultra-Small Electron Emittances Using an X-ray Pinhole Camera *J. Synchrotron Rad.* 2 p.209.

[20] Ewald F et al 2011Vertical Emittance Measurement at the ESRF *Proceedings of DIPAC2011 (Hamburg Germany)* pp.188-190

[21] Ewald F 2009 Emittance Measurement Using Undulator Radiation *Proceedings of DIPAC 2009 (Basel Switzerland)* pp.182-184

[22] Snigireva I and Snigirev 2006A X-ray microanalytical techniques based on synchrotron radiation *Journal of Environmental Monitoring* т. 8 № 1 pp. 33-42

[23] Schroer C G, Kuhlmann M, Lengeler B, Gunzler T F, Kurapova O, Benner B, Rau C, Simionovici A S, Snigirev A A and Snigireva I 2002 Beryllium parabolic refractive x-ray lenses*Proceedings of SPIE - The International Society for Optical* Engineering AIP Conference Proceedings Volume 705 Issue 1 10.1063/1.1757904 .

[24] http://www.tango-controls.org/

[25] http://www.corba.org/

[26] Antonioni F et al. 2013Developments on the SCADA of CERN accelerators vacuum *Proceedings of ICALEPCS2013 (San Francisco CA USA)* pp.135-138

[27] Pieck M et al 2015LANSCE control system upgrade status and challenges *Proceedings of ICALEPCS2015 (Melbourne, Australia)* pp.464-467

[28] Stefanic R, and Geoffroy L 2007 EPICS to TANGO translator *Proceedings of ICALEPCS07 (Knoxville Tennessee USA)* pp.739-741

[29] Fleck T et al 2007 Status of the control system for HICAT at an advanced stage of commissioning: functions, restrictions and experiences *Proceedings of ICALEPCS07 (Knoxville Tennessee USA)* pp. 47-49

[30] Пономарев О П SCADA-системы, промышленные шины и интерфейсы, общие сведения о программируемых логических контроллерах и одноплатных компьютерах. Калининград 2006.

[31] Matthies S et al FESA3 integration in GSI for FAIR 2014 *Proceedings of PCaPAC2014 (Karlsruhe Germany)* pp.43-45

[32] Urakawa J and Kawamoto T 1991Improvement of TRISTAN timing system *Proceedings of PAC91* pp.1555-1557