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PRELIMINARY DESIGN OF CONTROL SYSTEM FOR STORAGE RING RF IN KOREA 4GSR*

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Abstract

The control system for SRRF (Storage Ring RF) in the Korea-4GSR is being designed for machine safety and stable operation. The SRRF is composed of 10 RF stations and each RF station includes LLRF (Low Level RF), HPRF (High Power RF), RF transmission, cavity and instruments. In this paper, the design of control system will be described. It will include control network, operating interface, emergency interlock and so on.

INTRODUCTION

The construction of 4th Generation SR (Korea-4GSR) based on synchrotron light source was decided and started on 2020 shown in Fig. 1. The machine target parameters are 4-GeV beam energy, 400 mA beam current and less than 100-pm-rad emittance with so-called 4GSR characteristics [1, 2]. The evaluated brilliance and coherence are approximately 100 times higher in the hard X-ray region than those of the PLS-II, the third-generation storage ring [1-3].

Figure 1: View-map of the Korea-4GSR[1].

The preliminary arrangement of accelerator sub-systems such as the storage ring, booster ring, LINAC and RF (Radio Frequency) system is shown in Fig. 2, in which 52 beamlines are embedded. The electron beam generated from LINAC passes through LTB (LINAC To Booster). The booster-ring accelerates the electron beam from 200 MeV to 4 GeV. The BTS (Booster To Storage) is placed between the booster-ring and the storage-ring for the injection of electron bunches [1].

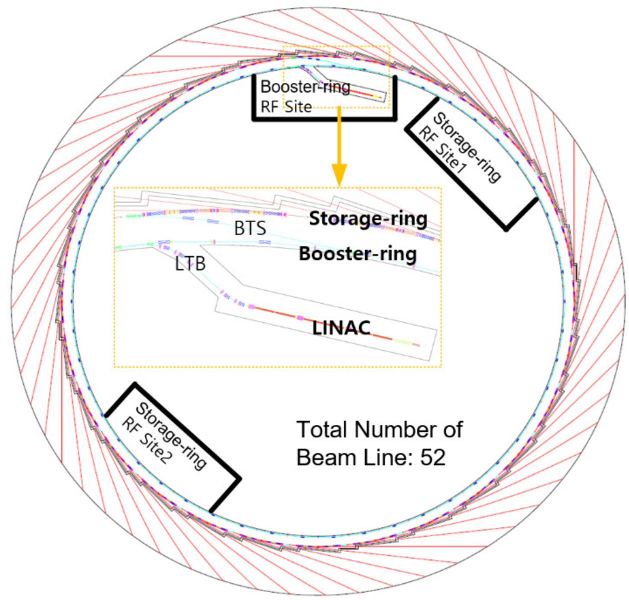

Figure 2: Layout of the Storage-ring in the Korea-4GSR [1].

The capability, availability and reliability of photon beam are immediately affected by the RF system of the storage-ring. The preliminary RF parameters for stable beam operation are shown in Table 1. The frequency of the SRRF (storage-ring RF system) is 499.8773 MHz, which correlates with the frequency of LINAC, booster ring and storage-ring revolution frequency [1]. The total beam loss power is estimated to be 740 kW from bending magnets, insertion devices, and to include the broad band losses in the RF cavities, vacuum chambers, BPMs, gate valves, etc [1].

Table 1: RF parameters of the Korea-4GSR [1].

Parameter	Unit	Values
Energy	GeV	4.0
Current	mA	400
Circumference	M	798.84
Revolution frequency	MHz	3.7528
Harmonic number	-	1332
Electron energy loss/turn by bending magnets and IDs	KeV	1850.1
Total beam loss power	kW	740.01
RF frequency	MHz	499.8773
Accelerating voltage	MV	3.5

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For the beam stability with 400 mA beam current and 100 pm-rad emittance, a HOM damped cavity would be indispensable for the storage ring. The SRRF is composed of 10 RF stations to support accelerating voltage of 3.5 MV for the optimal bucket height and sufficient RF power. Each RF station includes LLRF (Low Level RF), HPRF (High Power RF), RF transmission, cavity and instruments (Fig. 3).

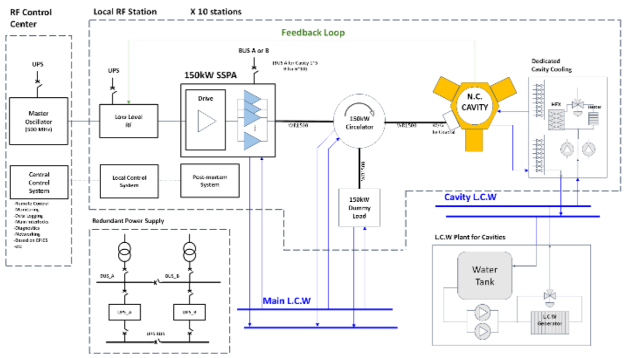

Figure 3: Block diagram of the SRRF.

To supply beam loading power of 74 kW each unit, the rated power of HPRF is estimated as 150 kW with considering transmission efficiency, easiness of amplitude control by LLRF and system life time, which is about 140% of the estimated power through the coupler, 107 kW. The LLRF system maintains amplitude and phase of the accelerating field within 0.1% and 0.1 degree respectively. Each cavity assembly consists of a normal conducting cavity, vacuum devices, temperature measuring devices, cavity-cooling system. A cavity bears HOM damper, power coupler and frequency tuner.

In this paper, we describe the design of the control system for the SRRF. It will include control network, operating interface, emergency interlock and so on.

CONTROL SYSTEM OF SRRF

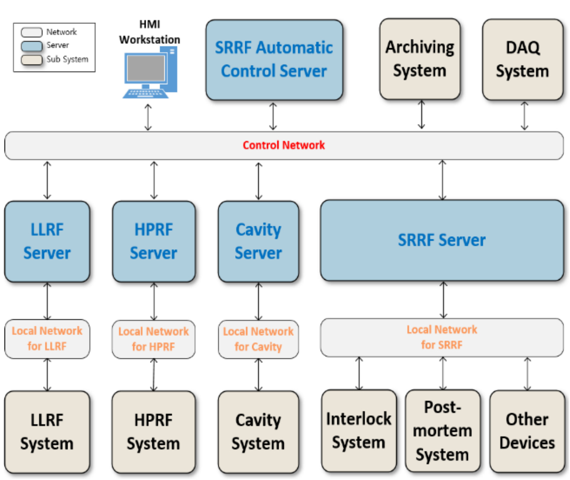

Figure 4: Concept of networks for the SRRF.

The SRRF is composed of RF subsystems (LLRF, HPRF, Cavity) and each RF subsystem has own local network to ensure stability and safety as shown in Fig. 4.

The EPICS protocol is used on the control network for the SRRF operation and the Beam operation. A server to support EPICS IOC service is needed in each RF subsystem to support the protocol and connect a local network and the control network. Each EPICS IOC will support their own RF subsystem. The control system additionally includes the interlock system, the post-mortem which is for the fault diagnosis during beam operation, the DAQ and archiving systems. The RF system should be operated without human interference by mode selection through the SRRF automatic control server. An operator can control RF subsystems using the HMI S/W if necessary as shown in Fig. 5.

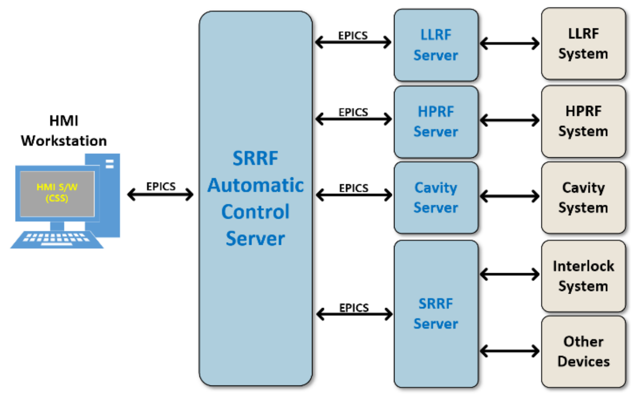

Figure 5: Control diagram of the SRRF.

The interlock system is to protect systems from an abnormal event during power operation and it communicates with every subsystem. But it can't cover every failures. The interlock signal connection among subsystems of the SRRF is shown in Fig. 6. The post-mortem is to get snap shot data of primary RF parameters at fault events for diagnostics. So only the critical signals such as beam current, amplitude, phase, vacuum pressure and arc detection will be handled.

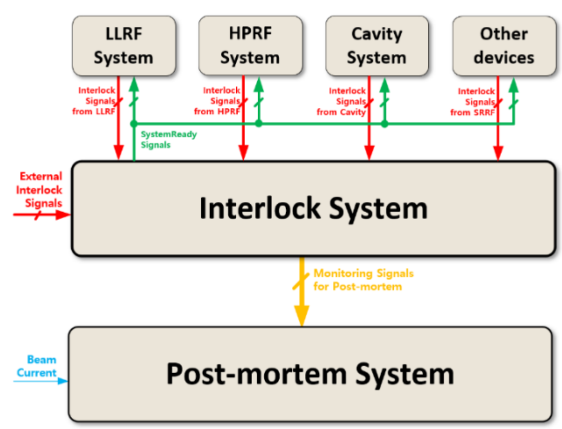

Figure 6: Interlock signal connection among subsystems of the SRRF.

The interlock system is composed of 16 local interlock controllers and master interlock controller as shown in Fig. 7. It will cover the 10 fundamental cavities and 6 harmonic cavities for the storage-ring. The main interlock

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controller will cut forcely RF power providing to cavities, when the external interlock signals (Machine Protection Interlock, Personnel Safety Interlock, Beam Position Interlock) are on. The local interlock controller gathers the status signals from each RF components and produces "ready" or "non-ready" signals. Also they will be passed to the master interlock system as shown in Fig. 7

A RF-dump occurs by external interlocks, local interlocks and force stop command from the operator. RF-dump time (from generation of the interlock signal to RF-dump) is the most important parameter of the interlock system to protect human and machines. The desired RF-dump time for the SRRF is defined as 100 us to include a safety margin.

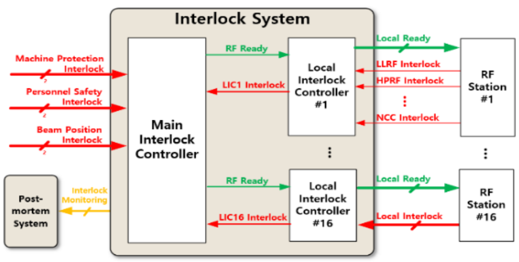

Figure 7: Block diagram of the interlock system for the SRRF. 10 for fundamental cavities and 6 for harmonic cavities.

Monitoring signals from RF stations and the interlock system are recorded by the post-mortem at abnormal beam event. The usual recorded data is stored automatically on the network storage server with the event. Additionally the primary parameters of diagnostics to be monitored should be recorded in the quick recordable media of the post-morterm with a given time frame, +/-1 second for example.

To merge and analysis the data, the system has Post-mortem Data Analysis Device as shown in Fig. 8. To increase finding rate of errors' cause & phenomena, the post-mortem should have more than 1MS/s sampling rate and more than 1Mpoints record length each input channel.

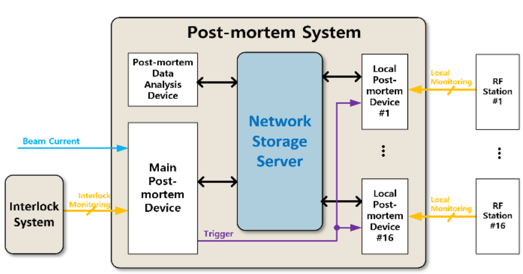

Figure 8: Block diagram of the Post-mortem System for the SRRF. 10 for fundamental cavities and 6 for harmonic cavities.

Additional signals of the SRRF without EPICS PV are measured and digitized as EPICS PV by the DAQ system as shown in Fig. 9. For the fast acquisition, more than 200kS/s sampling rate is required on each input channel of the DAQ system.

The EPICS PV data from the DAQ system are stored in the archiving system. The archiving system will cover 500 fast-PV (0.1 second period)s and 5000 slow-PV (1 second periods). The archiving system consists of two servers (the short-term send long-term servers) (Fig. 9) to ensure data archiving. At every maintenance term, periodically the data will be transmitted from the short-term server to the long-term server to avoid congestion of the control network in case too many clients request data at the same time during operation.

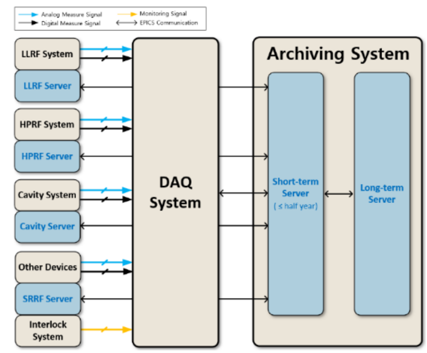

Figure 9: Connection diagram of the DAQ System and the Archiving System for the SRRF.

CONCLUSION

The Korea-4GSR target parameters are 4-GeV beam energy, 400 mA beam current and less than 100 pm-rad emittance. For the beam stability with 400-mA beam current and less than 100 pm-rad emittance, a HOM damped cavity would be indispensable for the storage ring. The SRRF is composed of 10 RF stations to support accelerating voltage of 3.5 MV for the optimal bucket height and sufficient RF power. Each RF station includes LLRF, HPRF, RF transmission, cavity and instruments. The design direction of the control system for the SRRF was described. The servers for each subsystem, the interlock system, the post-mortem, the DAQ and the archiving system are included in the control system.

The RF test facility will be prepared at the PAL site until October 2023 to verify basic performance of LLRF, HPRF, cavity and instruments to be applied to the Korea-4GSR. The prototype of control system will be implemented and tested at the facility. The prototype will be used as reference for development of final product in the Korea-4GSR.

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