# DESIGN OF THE MAGNET CONTROL SYSTEM FOR THE 1.8-GEV SYNCHROTRON RADIATION SOURCE AT TSRF

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*Abstract*

The magnet control system has been designed for the 1.8-GeV positron storage ring at Tohoku-Synchrotron Radiation Facility (TSRF). TSRF is a third-generation synchrotron radiation facility planned to be constructed at Tohoku University. The control system is comprised of Linux clients/servers and FDDI (Fiber Distributed Data Interface) high speed network. Linux PCs are employed to provide process control and user interface implemented in Java. The FDDI provides a token-passing, dual-ring LAN using a fiber-optic link suitable for exchanging control data reliably. The design of the control system for the magnet at TSRF is discussed.

## INTRODUCTION

Each author should submit all of the source files (text and figures), the postscript file and a hard copy version of the paper. This will allow the editors to reconstruct the paper in case of processing difficulties and compare the version produced for publication with the hard copy. TSRF (Tohoku Synchrotron Radiation Source Facility) is a new third generation synchrotron radiation source that is currently proposed at Tohoku University, Sendai, approximately 350km north of Tokyo, Japan. TSRF is planned to be constructed at the site of Laboratory of Nuclear Science, Tohoku University, where a 300MeV-Linac and 1.2GeV Stretcher Booster Ring are currently in operation for nuclear physics experiments [1]. By taking advantage of the existing facility, TSRF employs the Stretcher Booster Ring as the injector for the TSRF storage ring. This can greatly reduce construction cost for the TSRF generation synchrotron radiation source.

TSRF is designed to provide VUV-SX synchrotron radiation to the experimental hall where experiments such as VUV experiments, surface physics, soft x-ray lithography, microscopy and crystal structure analysis, will be simultaneously carried out. The high-power wiggler/ undulator beam lines are simultaneously in operation, producing very intense synchrotron radiation beams [2],[3]. TSRF has a 1.8GeV storage ring with a DBA(double-bend-achromat) type, third-generation storage ring with emittance of 4.9nm-rad, and a circumference of 244.8m as shown in Table 1.

The control system has been designed for the magnets for the 1.8GeV TSRF synchrotron radiation source in order to operate the storage ring, providing stable synchrotron radiation to users at the experimental hall, and to improve the performance of the storage ring. Since the man-power available for development of control systems at TSRF is severely limited, and to reduce software costs we employ Java which provides almost uniform environment across various platforms. In this study, the design of the magnet control system for the TSRF is described.

Table 1 Principal parameters of the synchrotron radiation source at TSRF

| | |
|---|---|
| Beam Energy | 1.8 GeV (Max. 2 GeV) |
| Circumference | 244.8 m |
| Lattice | DBA×16 |
| Straight Sections | 5m x 14, 15m x 2 |
| Emittance | 4.9 nm-rad |
| RF Frequency | 500 MHz |
| Harmonic Number | 408 |
| RF Voltage | 1.0 MV |
| Beam Current | 400 mA |
| Beam Lifetime | > 12 hr |

## SYSTEM CONFIGURATION

The storage ring has 228 magnets distributed along with the storage ring. Table 2 shows typical parameters of the magnets [4]. A typical power supply for the magnet has an embedded 16-bit DAC and DAC to obtain resolution of less than $10^{-4}$ of their maximum current. The power supply for a magnet has digital parallel I/O ports including a set of input ports for current-setup (16 bits), an additional 32 bits for strobe/control, two output ports: 16 bits for the DC current transformer (DCCT) to provide an actual current in the magnet in digital format, and additional 32 bits for safety interlocks; including interlocks for over-trip points, absolute-maximum points, temperature monitors at the yokes, cooling-water flow-switches, and radiation-safety monitor. Each parallel port is electrically isolated using photo-couplers in order to obtain better noise immunity caused by switching noise, surge noise, and induction noise.

Table 2 List of magnets for the TSRF storage ring

| magnets for the storage ring | Quantity |
|---|---|
| Bending magnet | 24 |
| Quadrupole Magnet | 108 |
| Sextupole Magnet | 84 |
| Octupole Magnet | 4 |
| Hor./Ver. Steering Magnet | 8 |
| Total | 228 |

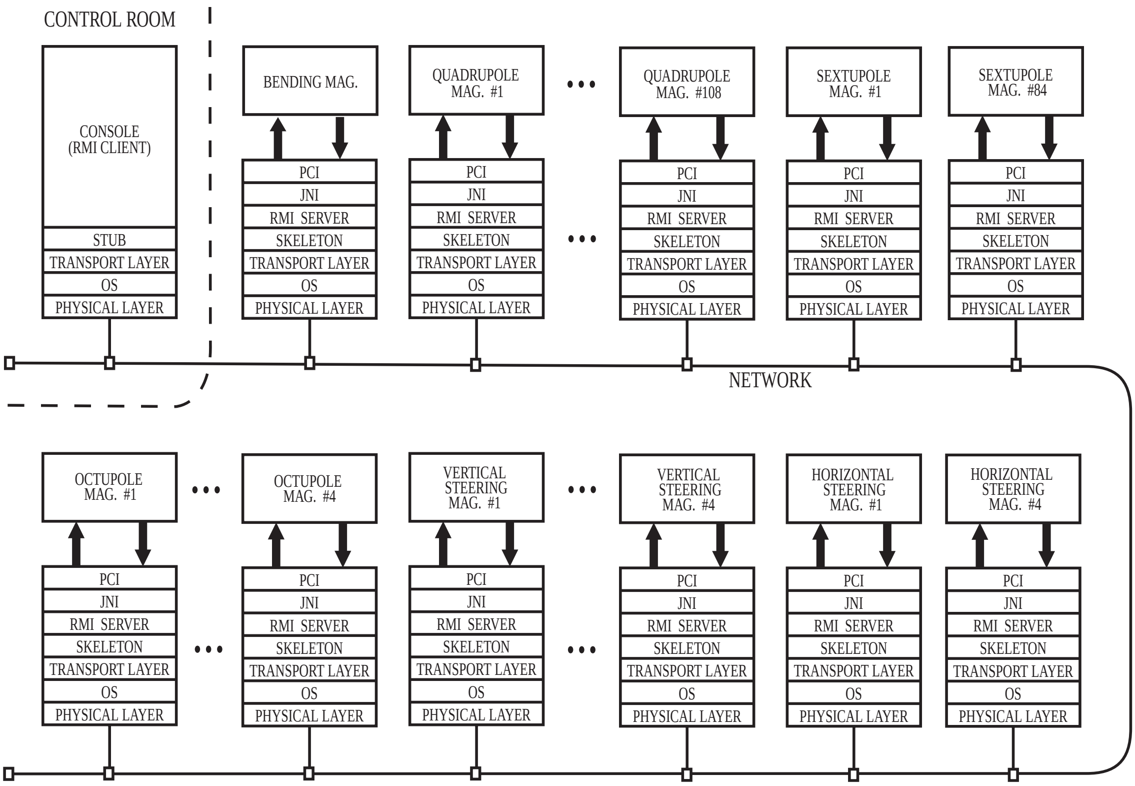


Figure 1: Schematic diagram of the magnet control system for the 1.8GeV storage ring at TSRF

Figure 1 shows the block diagram of the control system. In order to reduce the construction cost for the control system, a combination of Linux/PC is employed. The control system comprises twenty-eight Linux PCs and a high speed network. Each PC has PCI extension units to control up to eight magnets. Linux PCs provide process control and user interface implemented in Java, and they are connected to the FDDI (Fiber Distributed Data Interface) high speed network. The FDDI provides a 500-Mbps, token-passing, dual-ring LAN using a fiber-optic link suitable for exchanging control data reliably.

The software system is based on a client-server model. In particular, software interfaces for the hardware have been implemented with Java Remote Method Invocation (RMI) running under the distributed computers on the network. By taking advantage of Java RMI's capability, many remote accesses are carried out easily for remote communication as if the remote equipment was residing on the local machine. Java programs run on the Virtual Machine (VM) providing homogeneous environment on different platforms independent of operating systems as well as hardware architecture. Although the VM runs in principle under many operating systems it has no direct interface to physical devices tightly implemented upon specific operating systems. Thus those physical devices are not accessible to control applications. The interfaces to physical magnets are platform-dependent upon each specific operating system. New interfaces for PCI modules have been developed for the Java Native Interface (JNI) through which allows Java classes to access the magnets.

The console implemented is an RMI client running under Linux (kernel 2.2) on a PC and it also provides the graphics interface for the operator. The RMI servers are also implemented under Linux on a PC (clock=1.2GHz). Average access time measured between a client and different remote servers for power supplies is attained at approximately 0.31 ms when the client sets a current value to all power supplies through the PCI output modules under various operational conditions and network-loads [5]. This remote access time attained is reproducible, and sufficient to control the magnets of the storage ring.

For remote access to the safety-interlocks of a magnet, a remote notifier is implemented in RMI to reduce the CPU load of the client without using the polling mechanism. A safety interlock, such as over-trip point, is usually in ‘normal condition’, and it is triggered if and only if the current in the magnet exceeds a preset-trip-point in order to protect the power supply and the magnet. Thus, for a client, frequent access to such safety interlock through the server can cause heavy CPU load making the performance of the control system very low. Using the remote notifier, the server automatically notifies the client of a failure at one of the safety-interlocks. Upon detecting a change in the status of the safety interlock, i.e., when there is an emergency failure in the magnet, the console is notified of it from the server and receives the result. It allows the operator to take an immediate action necessary for safe operation.

Each server is interconnected to the power supply of the magnets and related components of the storage ring for local process control carrying out time-critical control for the magnets: during beam acceleration at the storage ring, a power supply for bending magnets of the storage ring, and power supplies for families of quadruple magnets, and sextupole magnets are automatically synchronized in order to keep the betatron values constant.

Automatic operation at the console (RMI client) is to setup, in principle, the parameters to the bending magnets and families of quadrupole/sextupole magnets, and then to initiate them. This can be carried out by invoking commands defined in a command file, whose file name is specified by an automatic instruction message solicited by an operator. The servers automatically set up parameters for injection of the beam after initializing magnets.

Man-machine interfaces at the console, including graphic status displays providing menu driven interface are also coded in Java Swing graphics class libraries. There are other clients running on different operating systems (not shown in Fig.1). These clients are used for monitoring operational behavior of the magnets. They are implemented on exactly the same classes as those implemented on the console. There is no need to recompile the client source code developed for the console since poring codes is done by duplicating the original classes developed one operating system to another. It means that the exactly the same client code can reside without any modification reducing the development cost greatly.

Each server has a shared memory table on which all of operational parameters of the magnets are mapped in the relevant data entries [6]. The table is also mapped to the physical memory capable of being referenced by any application process. The purpose of the table is to allow all application processes to utilize the operational parameters as well as the present status of the accelerator complex necessary for their specific operation without directly accessing actual magnets.

## CONCLUSION

The design of the control system for magnets is described for the 1.8GeV synchrotron radiation facility TSRF, Sendai-city, where a 300MeV Linac and 1.2GeV Stretcher Booster Ring are ready as the injector for the 1.8GeV storage ring. The control system is comprised of Linux clients/servers connected to the high speed FDDI network. The control system allows automatic operation for synchrotron radiation experiments as well as machine-study operation to improve the accelerator performance and to study accelerator physics.

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