

# SAFETY INTERLOCK IMPLEMENTATION OF TOP-UP OPERATION IN THE SSRF CONTROL SYSTEM \*

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## Abstract

The SSRF[1] has performed two years stable operation on decay mode. In order to realize the top-up operation, the upgrade of control system has been carried out for top-up trial run. Control system sets up the operation mode control center and accomplishes the upgrading of the MPS system. According to the requirements of the physical design, control system accomplished the design and implementation of the interface for interoperate with PPS system, beam diagnosis system and power supply system and set up the interlocks of the radiation dose, energy, injection efficiency, beam current and beam life in top-up mode. The kernel of top-up operation safety interlock system is based on hardware interlock system and also provides software interlocking as auxiliary. In the meantime, the reliability of software interlock has been improved.

## INTRODUCTION

Shanghai Synchrotron Radiation Facility is a third-generation of synchrotron radiation light source that was built in 2009, referred to as the SSRF. It includes a 150MeV Electron Linac, a 3.5GeV Booster, a 432-meter perimeter Storage Ring and seven beam lines and experimental stations at first phase. To the end of 2011, SSRF is opened to user for more than 3,000 users that come from 217 different units and carried out the experiments and researches more than 10 subject areas. From the beginning, SSRF ran in Decay mode and the design of top-up mode was started after one year of stable operation.

Since the shutters of beam lines is open during the beam injecting process. In top-up mode, the energy deviation of injecting beam and the orbit disturbance of stored beam may cause beam enter into the beam lines, so how to ensure the safety injection and the safety interlock system related has become the most important issue. SSRF safety interlock system consists of MPS (machine protection system) and PPS (personal protection system) and the safety of the top-up mode mainly carry out by these two system. In the design and implementation of Top-up mode, the operation mode control and top-up safety interlock for the each subsystem of accelerator are realized in MPS system centralized and the dose interlock and injection interlock control are realized in PPS system.

SSRF control system is based on the EPICS[2] distributed control system. The MPS controller is used PLC system. MPS design architecture is based on the hardware interlock and software interlock is implemented by the IOC interlock signals as the address mapping of PLC system, all of the interlocking logics are executed in the PLC system[3]. The upgrade of top-up mode control

system is based on this MPS architecture. Figure 1 show the structure of the MPS in top-up mode.

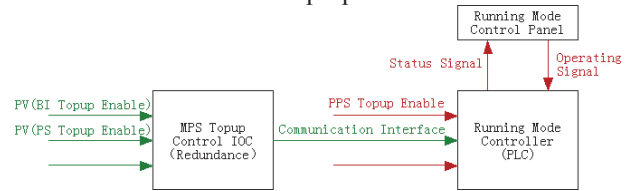


Figure 1 MPS structure in top-up mode.

## THE REQUIREMENTS OF TOP-UP SAFETY INTERLOCK

When SSRF is completed construct, decay operation mode has been fully equipped with the safety interlock system. Therefore, the overall interlocking logic of top-up operation mode is defined as the device is limited to run in decay mode and cannot start or stay in top-up mode when the conditions of top-up operation are not satisfied. In accordance with the physical design, the accelerator running in top-up mode should be automatically transferred to decay mode when any of the following interlocking signals is generated[4]:

- The low limit of the storage ring beam current: when the beam current is below this limitation, the accelerator is prohibited to start top-up mode, or switch to decay mode if in top-up mode.
- The low limit of the storage ring injection efficiency: when the cumulative injection efficiency of the continuous period of time (10~15 minutes) is below this limitation, the accelerator will be transferred to decay mode.
- The interlock signal of injection energy range match limitation: when the difference between current of bending magnet at high-energy transport line and storage ring is beyond a certain value, the accelerator will be transferred to decay mode.
- The dose interlock signal of experimental stations: when the cumulative dose of the beam lines exceed the safety threshold in a certain period of time (four hours), the accelerator will be transferred to decay mode.

In addition, the beam life time, current of the quadrupole and sextupole at storage ring are used be auxiliary safety interlock conditions of top-up mode, related requirements were added in the implementation.

## CONTROL DESIGN OF OPERATION MODE

Before the upgrade to Top-up operation mode, the injection time interval of decay mode is 12 hours. No matter what the Linac and Booster enter standby or offline status with a completion of injection, it will not affect the storage ring to provide light until the next

injection. But in Top-up mode, the storage ring need injection at any time and the Linac and Booster need to maintain normal operation continually. Figure 2 show the state transition diagram of the operation mode control.

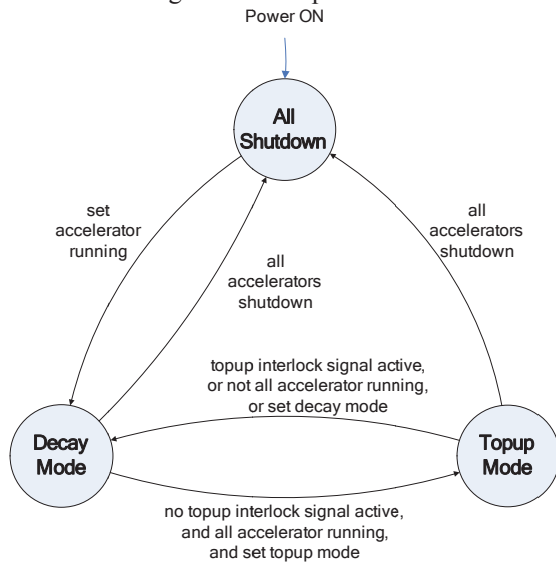


Figure 2: The state transition diagram of the operation mode control.

### THE UPGRADE OF CONTROL SYSTEM

The upgrade of the control system is based on the structure of original MPS. In order to achieve the operation mode control and safety interlock in top-up mode, the control system upgrade includes two aspects. One is the new operation mode controller, which is a hardware equipment including PLC and an operator panel. The controller has special key to authorize access control of the mode operation to prevent the illegal operation. The new PLC is tightly integrated with the other PLC system of MPS and in charge of the new hardware interlock signal connectivity between MPS and other systems and IOC software interlock signal connection. Because all the accelerator system except PPS are used EPICS software so that the collaborative work with software interlock signals are very conveniently. For the hardware interlock signal connection, the signal must be connected with cable from the local controller to the MPS cabinet in the center control room.

The MPS system receives the top-up safety interlock signals from the power supply system, beam measurement system and PPS. It realizes interlock logic control and the operation mode setting. MPS outputs operation mode control signals to the PPS, which is the final system to execute the interlock control of top-up injection. In the Top-up operation design, each part is divided clearly as below: the setting of the operation mode is operated in the operation mode controller, the safety interlock system is responsible for monitoring the interlock signals inputted from each system and provides the injection enable signals and the actual operation of top-up injection is handled by the physical application

software. Division of each system and interfaces in top-up mode are shown in Figure 3.

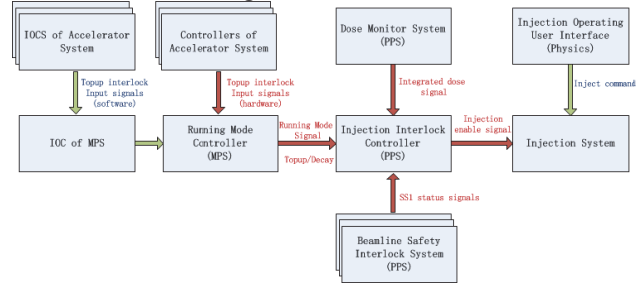


Figure 3: The Top-up mode control and safety interlock implementation chart.

In the interlock signals which inputted from various system to MPS in Top-up mode, the interlock signals of DCCT beam current, bending magnet current and the cumulative dose are hardware signals, and the others are software signals. The interlock signals of various system inputted to the MPS are given in the form of switch values and the safety threshold setting and the real-time comparison calculation for each signal are handled within those systems.

### THE PHYSICAL APPLICATION INTERFACES

The operation mode control and safety interlock are handled in the control system and the actual operation for injection in Top-up mode is handled by the physical system which is implemented in the new top-up software. Figure 4 is OPI panel of the top-up control. Signal interfaces for physical application needed are provided by MPS, which include the following software signals:

First of all, the operation mode signal of the MPS is referenced by the physical application software, as a prerequisite of Top-up injection with physical application.

Second, the physical application is completed by the MPS IOC. It exchanges the operation status signals with other systems in Top-up mode, including the Top-up operation starting signal of the PPS cumulative dose calculation, and the Top-up injecting real-time operation signal, which are required in the disturbance-sensitive experiment at the experimental stations.

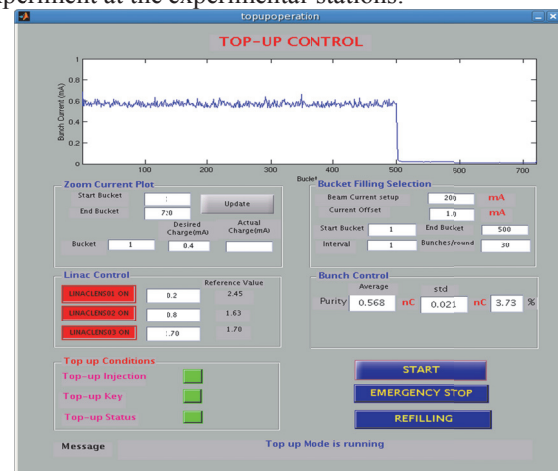


Figure 4: The Top-up control panel.

Table 1: Interlock Logical Summary of MPS Running Mode Control

Topup/Decay Mode	Topup			Decay			
	All Running	LA Running	LA Maintenance	BS Running	BS Maintenance	SR Running	SR Maintenance
Running/Maintenance Mode							
SR-LA Egun Trigger Interlock	●	●	×	N.C.	N.C.	●	×
BS-LA Egun Trigger Interlock	●	●	×	●	×	N.C.	N.C.
SR-BS Extraction Interlock	●	N.C.	N.C.	●	×	●	×
LA Inter-system Interlock	●	●	×	N.C.	N.C.	N.C.	N.C.
BS Inter-system Interlock	●	N.C.	N.C.	●	×	N.C.	N.C.
SR Inter-system Interlock	●	N.C.	N.C.	N.C.	N.C.	●	×

Definition: ● = interlock active      × = interlock inactive      N.C. = not care

### INTERLOCK LOGICAL FOR MODE CONTROL

The Linac, Booster and Ring can set to the status of running and down for maintenance separate. When an accelerator under the down for maintenance mode, the upstream accelerator cannot export the beam to it and this is ensured by the PPS system. The personnel safety interlock under the maintenance mode is implemented by the PPS system already so the MPS system just need to remove the invalid logic according to the ready signal of safety interlock given by the PPS and the setting of the maintenance. The interlock process for the maintenance mode by MPS system is below:

- The interlock signal of an accelerator under maintenance mode is no effect to other accelerator.
- Under maintenance mode, all the interlocks charge by MPS system between subsystems inside an accelerator is released.

Table 1 shows the interlock logical will realize by the MPS system between the different accelerator and subsystem inside each accelerator before add the for maintenance mode.

### CURRENT STATUS AND SUMMARY

The upgrade implementation of control system for the Top-up mode has been completed and finished the online

test. The necessary hardware and software for operation mode control system and the safety interlock had been realized for the basic foundation of running in Top-up mode. Furthermore, though the high-reliability hardware interlock solution was adopted and the principle of failure meaning security was also followed in the design of control system, but there are still some interlock signals which were not suitable to implement through the hardware solution that only implemented through the software solution. So the reliability of the software solution is not as good as the hardware solution clearly and to improve the reliability of software interlock is the problem we faced. We have tested the redundancy IOC for software interlock system which based on pooling technique [5]. It will apply in the running stage of top-up mode.

### REFERENCES

- [1] <http://www.ssrp.ac.cn>.
- [2] <http://www.aps.anl.gov/epics/>.
- [3] SSRF Design Report, SINAP-Report/2004.
- [4] SSRF TOP-UP mode concept design report/2010.
- [5] [http://en.wikipedia.org/wiki/Reliable\\_server\\_pooling](http://en.wikipedia.org/wiki/Reliable_server_pooling).