

# MACHINE PROTECTION AND INTERLOCK SYSTEMS AT SYNCHROTRON SOLEIL

Y.M. Abiven, F. Dohou, P. Rommeluère,  
Synchrotron SOLEIL<sup>#</sup>, Saint Aubin, France.

## Abstract

SOLEIL is a third generation Synchrotron radiation source located in France near Paris, having the classical accelerator structure consisting of a Linac pre-accelerator, a Booster accelerator and a Storage Ring, which are connected by two transfer lines[1]. At the moment, the Storage Ring delivers photon beam to 18 beamlines. In order to protect the very sensitive and essential equipment during machine operation, (vacuum chambers, vacuum valves, mirrors, etc.) an interlock system has been implemented. This system is based on industrial and autonomous PLC (Programmable Logic Controller). This paper describes each level of the interlock chain from the diagnostics and vacuum sensors and processes, up to the backbone of the interlock system which stops the RF system.

## INTERLOCK SYSTEM DESCRIPTION

### Principle and Organisation

The interlock system collects the critical defaults from diagnostics and vacuum subsystems to switch off the RF system which kills the beam in the storage ring and/or disables injections.

At Soleil, the interlock chain consists of two levels.

The first one is composed of local processes developed by the Vacuum and Diagnostics groups in each of the 16 cells around the storage ring. At this level, signals are picked up from sensors and processed by PLCs. This process actuates locally and supplies the default signals to the interlock system.

The second level is the interlock system itself which is developed and implemented by the ECA group (the Electronic group). This system reads the critical signals from subsystems and stops the RF power or inhibits pulsed elements. The system reacts in less than 1ms.

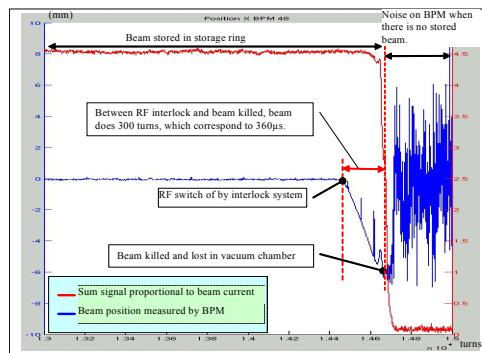


Figure 1: this graph shows the loss of beam when the interlock system switches off the RF power.

### Architecture of the Interlock System

The interlock system is based on PLC technology (Siemens [2] S7-300), with 17 modules distributed around the accelerators. They are linked together to the Master PLC by the Profibus network. Moreover, the Master PLC is connected to supervision via Ethernet. Each distributed module embeds a boolean processor (FM352-5) which ensures a quick reaction (less than 1ms) and is autonomous from the control system. In order to improve system reliability, the signal stopping the RF is cabled with redundancy as shown in figure 2.

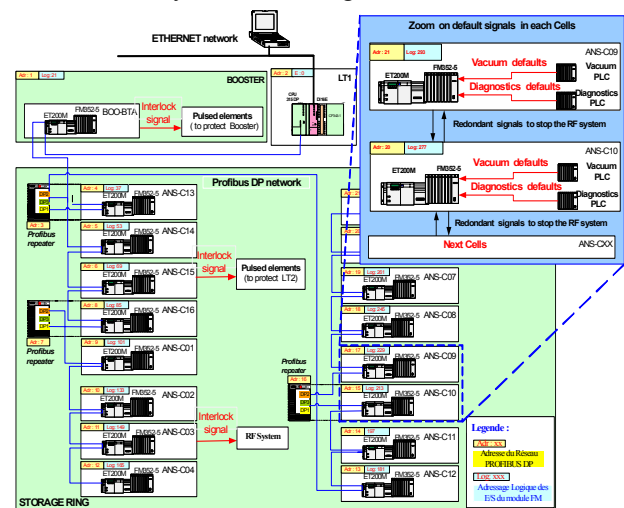


Figure 2 : Interlock system architecture.

On the Booster and the transfer line linked to the storage ring, the interlock system is used to protect vacuum valves. In this case the interlock inhibits the pulsed elements to avoid beam injection when a vacuum default is detected. This action does not have any impact on the stored beam in the storage ring.

### Processed Signals

About 100 critical signals are picked up around the storage ring to protect vacuum chambers and mirrors. These signals are the following:

- Beam position default signal generated when the stored beam current is above a current threshold (20mA).
- MRSV default signal. MRSV is the optical system allowing observing visible synchrotron radiation.
- Instability default signal, detecting beam blow-up.
- Vacuum security signals from front-ends, straight-sections and arcs all around the storage ring

These signals are exchanged between PLCs of the interlock system and PLCs of the diagnostics and vacuum subsystems.

<sup>#</sup><http://www.synchrotron-soleil.fr>

They respect positive logic to ensure security policy. Signals are 24V for high level when there is no default and 0V for low level which signifies default. This logic insures that the system works correctly in case of local power supply shut down or sheared cable by stopping the RF system.

## INTEGRATION IN THE CONTROL SYSTEM

### Hardware Integration

Interlock system and subsystems are based on Siemens PLCs S7-300 family products, which are standard hardware components of SOLEIL Control Systems. Surrounding the booster and the 354 meters of the storage ring, 87 PLCs configurations are installed with 50 for vacuum security, 19 for diagnostics subsystem security and 18 for the interlock system.

### Supervision Applications

Interlock system and subsystems are linked to the TANGO [6] Control System by Ethernet. Communication between PLCs and Software devices has been developed by the ICA group (the Software control group). Above the TANGO devices, a GlobalSCREEN [7] application provides a graphical interface of the system to the end user. As shown in figure 4, the application allows operators to configure alarm values and to acknowledge the system. Moreover, states of the systems, default state, first cells in fault and beam intensity are graphically presented in this interface. This presentation of information quickly gives the state of the system to the machine operator.

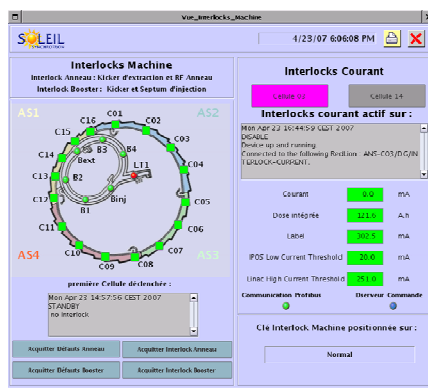


Figure 3 : Interlock Supervision application.

## STORAGE RING VACUUM INTERLOCKS

Stopping the RF system is mandatory to protect some vacuum devices, either to avoid that the electron beam hits the valves when closed or in order to avoid overheating of the vacuum chambers, of the ring absorbers or of the beamline front-ends.

### Signals and Detectors used

Signals which are continuously monitored are:

- Ion pump currents, since they are representative of the pressure. Thanks to the number of ion pumps on the machine (more than 350) and their right repartition, a map of pressure levels can be achieved.
- Pirani gauge pressure (through their controllers) when pressure is too high for ion pump to operate.
- Temperatures from K and J-type thermocouples.
- Cooling water flowing by flow meters.
- Valve states through open position switches
- High vacuum triggers (in front-ends only)
- Temperatures of mirrors for infrared beamlines

Cold- and Hot-cathode gauges are also present at SOLEIL but are not used on the interlock chain.

Security is ensured by one vacuum PLC per arc (16 on the storage ring, 6 on the booster) or per straight section (24) or per front end (12 in 2007). To achieve maximum detection speed, analog or digital signals acquired by dedicated measurement cards in the PLC are preferred to remote measurement modules via the Profibus link. For a few devices (such as the ion pump controllers), digital outputs of the controller are used to detect the alarm state. Profibus information which is slow, is employed as a confirmation of the alarm.

### Security Rules

RF interlock is generated when:

- The signal of at least one security device is incoherent or above the alarm value.
- At least one security device is off or out of service
- At least one arc gate valve is closed

Each device can be excluded from the security chain by an authorized person or an expert.

### Performances

PLC cycle time ensures a signal detection and RF interlock generation between 30 and 50 ms. This time is faster than the movement of a normal cell gate valve which receives the interlock at the same time. This response time allows normal RF shutdown before the gate valve hits the electron beam.

There is one exception for front-end fast closing valves. These valves may hit the beam when closing because of their special driving method (they receive the closing command not only from the PLC but also from a faster dedicated electronic box associated with a special gauge acting as a trigger) and their short closing time (10ms). Closure of these valves is not supposed to happen frequently (only in case of accidental incoming air rush from the beam lines). If this occurs, the damaged fast valve may have to be changed.

## DIAGNOSTICS DEFAULTS ON THE STORAGE RING

Diagnostics defaults are mandatory to avoid overheating any component inside the vacuum chamber.

### *Beam Position Interlock*

The position of the beam is detected by 120 Beam Position Monitor (BPM) and measured by Libera modules which are the acquisition and processing electronic device by I-tech [3]. BPM and Libera modules are distributed around the storage ring within the 16 cells. Position default is generated by each Libera module when the beam position is out of range. In each cell, seven or eight position default signals are multiplexed by a dedicated diagnostics PLC to generate the faulty signal. The response time between the input and the output of this PLC is lower than 75 $\mu$ s. Presently, this position interlock is enabled on only 32 BPM.

### *MRSV Interlock*

The MRSV system uses a mirror located inside the storage ring which allows visible synchrotron radiation to be observed. MRSV default protects the mirror from overheating to prevent surface deformation.

The mirror, fixed on a motorised blade, surfs on the X-Ray part of the photon beam. Close to the mirror thermocouple sensors measure temperature (See description in Figure3). In order to protect the mirror a feedback is implemented to move the mirror as fast as temperature increase. Moreover, if the MRSV is not well extracted and if the temperature exceeds a given threshold, a default signal is sent through the interlock system to kill the beam. Process to read the thermocouple and generate default signal is done by diagnostics PLC.

### *Instability Interlock*

An instability default system is installed to protect from beam blow-up the storage ring equipment which are not cooled. The system is made of a 5mm slit equipped with 6 thermocouples, 3 on each blade of the slit. In operation, the photon beam goes through the slit (See the description in Figure3). The temperature on the blades of the slit is measured by a PLC. Instability default signal is sent out to the interlock system when the temperature goes beyond a given threshold.

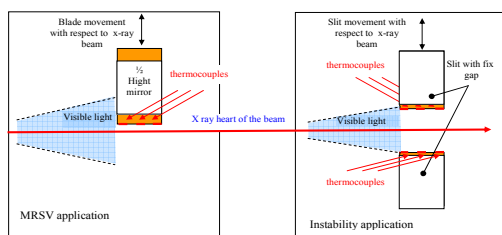


Figure 4 Description of the MRSV and the instability applications.

### *Current Interlock*

The Current Default System measures the stored beam current in the storage ring and generates 4 alarms according to the beam intensity. Among these alarms, Alarm2 is used in the interlock system to enable the position default.

The generated alarms are listed below:

- Alarm1: stops Linac injection when maximum intensity is reached.
- Alarm2: enables position interlock when the current is higher than 20 mA.
- Alarm3: enables top-up when the operational current is reached in the storage ring (not yet implemented).
- Alarm4: enables instability interlock when the current is stored.

The sensor used to read the current is a DCCT (Direct Current Current Transformer) associated with its electronic device by BERGOZ [4] which converts the current into an analog tension (0-10V). Alarm levels are configured in a PAXD0010 module by RedLion [5]. This module reads the current measure by means of the DCCT electronic devices and activates relays according to the programmed level. For redundancy two independent systems are installed on the storage ring.

## CONCLUSION

Nowadays, the interlock system has been fully commissioned and is operational. It reacts as expected and allows accelerators to work safely with 300mA (500mA) beam in the storage ring. Currently, all diagnostics default applications are installed. For vacuum defaults some front-ends have to be installed in the next years and integrated into the interlock system.

## REFERENCES

- [1] J.M. FILHOL, Overview of the status of the SOLEIL project, EPAC 2006.
- [2] Siemens PLC supplier, [www.siemens.com](http://www.siemens.com)
- [3] I-tech Liberas supplier, [www.i-tech.si](http://www.i-tech.si)
- [4] BERGOZ manufacturer, [www.bergoz.com](http://www.bergoz.com)
- [5] RedLion, [www.redlion.net](http://www.redlion.net)
- [6] The TANGO framework, <http://www.tango-controls.org/>
- [7] GlobalSCREEN software is edited by Ordinal Technologies, <http://www.ordinal.fr/>