AN OBJECT ORIENTED CONTROL SYSTEM FOR THE THIRD STORAGE RING RF UNIT AT THE ESRF

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Abstract

The ESRF was initially equipped with turnkey radio-frequency transmitters including the control systems of the RF plants. They still perform according to the original specifications. However, since they did not follow the update of the ESRF control system, their maintenance and upgrade are increasingly difficult. At the occasion of the construction of a third RF unit for the storage ring, it was therefore decided to build a new control system. It contributed to a large extent to the successful commissioning of the new RF unit which is now in continuous operation. The object oriented design provides the flexibility required for easy technical evolution and maintenance. The interlock system for the slow and fast protections of the transmitter and cavities was fully redesigned. Standard tools provided by the ESRF Computing Service are used to control the various devices. The upper level consists of a sequencer for the RF state machine, a graphical user interface based on synopsys and fast signal monitoring. Improved data logging developed for the new RF unit has proved to be an efficient tool in analysing the history of trips. In the coming years, it is foreseen to upgrade the hard and software of the old RF stations

1 INTRODUCTION

Four 352.2 MHz cavities and two 1.3 MW transmitters were initially installed on the ESRF storage ring to support an operation with a current of 200 mA at 6 GeV [1,2]. In order to guarantee high intensity operation and to improve the reliability by limiting the nominal power load on the various RF subsystems, the ESRF has constructed a third 1.3 RF transmitter feeding a third pair of cavities which is in operation since summer 1997 [3,4].

When the ESRF was built, the two radio-frequency transmitters of the storage ring and the booster one were bought as turnkey systems including the control system of each RF unit [5]. The hardware and software provided at that time still operate according to specifications. It was designed as a very complex and powerful system for the 1990s. The choice to subcontract the control system to an external company at the early stage of construction of the ESRF proved to be efficient, leading to a fast start-up of the machine and reliable operation. However, maintenance and upgrade has become more and more difficult on such systems which did not follow the updating of the ESRF control system. The construction of the third RF unit for the SR gave the opportunity to design and build in house a new control system fully integrated into the existing ESRF accelerator control system [6].

2 OBJECTIVES OF THE NEW DESIGN

The new design of the SRRF3 control system was based on the expertise gained during the commissioning and the operation of the existing RF systems in a photon factory context. The reconstruction of the ESRF Linac control system in 1993 was also an important input for this project[7].

The requirements which are to improve the reliability, the flexibility and to ease maintenance lead to:

- Object oriented structure of the control system,
- The separation between transmitter and cavities,
- The separation of the hardware protection from the software control,
- The implementation of software regulation loops when possible,
- The possibility of restarting the control system without stopping the RF production,
- Improved diagnostics for follow-up and trip analysis,

and required

- Close collaboration between the RF group, the Computing Service and the Operation Group.
- Using in-house standards of hardware and software as much as possible
- No software out-sourcing, extra manpower was hired for the in-house development in order to benefit from full expertise.

3 ARCHITECTURE

The object oriented structure is organised around a transmitter which can feed either a pair of cavities or a dummy load for tests.

The transmitter and the pair of cavities are considered as high level class objects which group basic devices for which we have defined [6]:

- The functionality
- The data fields (analog I/O..)
- The action (Switch ON/OFF, Set a current, Read the state, Read a status, Reset ...
- The logic chain which corresponds to the action of a set of interlocks on this device.

- The state transition diagram
- The interface.

The use of object oriented TACO (the ESRF control system [8]) straight from the beginning of the specifications of the third RF transmitter lead to a system which is now fully integrated and which can benefit from future developments. An overview of the design based on the device server concept is given in the figure 1. Device servers are based on the client/server model and run on a VME/OS9 local controller and/or UNIX workstation.

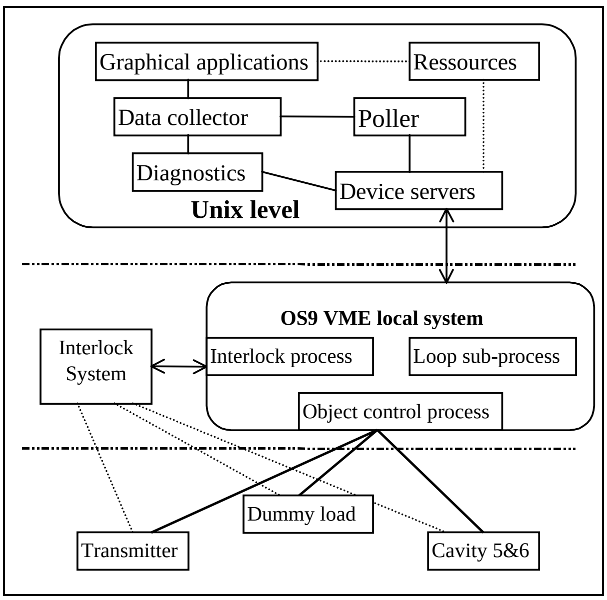


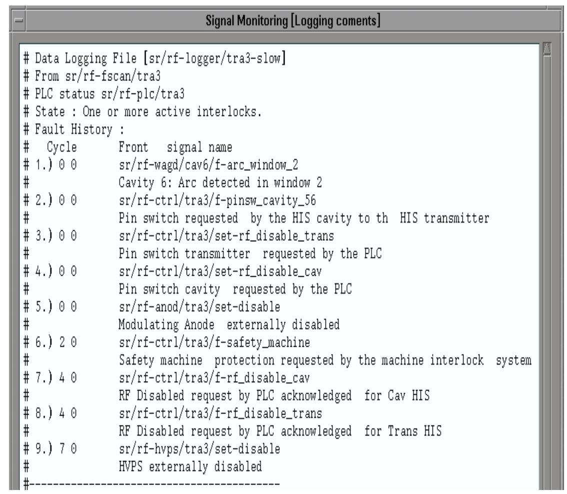
Figure 1: architecture

4 THE INTERLOCK SYSTEM

The full RF safety is under the control of an independent interlock system split into three parts:

- For **personal safety** protection against electrical or radiation hazards, an emergency interlock chain, based on redundant relays, acts on all power sources.
- The **transmitter** is protected against RF and electrical damage. For RF protection, the fast and slow interlocks act on a pin-switch in order to switch OFF the RF at the input of the klystron in a few microseconds. For electrical protection the fast interlocks trigger the high voltage power supply crowbar while the slow interlocks act on the disable input of the power supplies.
- The **cavities** are protected against RF damages which could come from the transmitter or the beam sources. The fast and slow interlocks are acting on the pin-switch of the local transmitter and also on the machine interlock system which kills the beam by switching OFF all storage ring RF transmitters. The possibility of using the cavity in passive mode during this test configuration and the fact that the beam could be maintained in the SR by only two powered pair of cavities lead us to consider each cavity as a piece of vacuum chamber included in the general machine protection system.

The fast interlocks (arcs, over-power, over-voltage ....) are managed by a hardwired latch system while slow interlocks (temperature too high, cooling flow too low...) are under the control of a PLC. The original interlock and the history of following faults and actions are always stored after a trip for analysis (figure 2). The whole interlock system is connected with a single serial line link to the main control system in order to obtain the status and the history of faults. The whole interlock system was fully developed by the RF group.




```
# Data Logging File [sr/rf-logger/tra3-slow]
# From sr/rf-fscan/tra3
# PLC status sr/rf-plc/tra3
# State : One or more active interlocks.
# Fault History :
#   Cycle      Front   signal name
# 1.) 0 0      sr/rf-wagd/cav6/f-arc_window_2
#              Cavity 6: Arc detected in window 2
# 2.) 0 0      sr/rf-ctrl/tra3/f-pinsw_cavity_56
#              Pin switch requested  by the HIS cavity to th  HIS transmitter
# 3.) 0 0      sr/rf-ctrl/tra3/set-rf_disable_trans
#              Pin switch transmitter  requested by the PLC
# 4.) 0 0      sr/rf-ctrl/tra3/set-rf_disable_cav
#              Pin switch cavity  requested by the PLC
# 5.) 0 0      sr/rf-anod/tra3/set-disable
#              Modulating Anode  externally disabled
# 6.) 2 0      sr/rf-ctrl/tra3/f-safety_machine
#              Safety machine  protection requested by the machine interlock  system
# 7.) 4 0      sr/rf-ctrl/tra3/f-rf_disable_cav
#              RF Disabled request by PLC acknowledged  for Cav HIS
# 8.) 4 0      sr/rf-ctrl/tra3/f-rf_disable_trans
#              RF Disabled request by PLC acknowledged  for Trans HIS
# 9.) 7 0      sr/rf-hvps/tra3/set-disable
#              HVPS externally disabled
#-----------------------------------------
```

Figure 2: History of a trip.

An arc detected in cavity 6 window 2 produced a safety machine interlock in order to kill the beam and to stop the RF of the SRRF3 transmitter.

5 STATE MACHINE AND SEQUENCER

Four main states are used for testing and operating the RF unit:

- **OFF** --> All devices are switched OFF
- **Low-Heating** --> The klystron filament is heated at a low temperature for a long waiting time without beam in the tube. The cavity water and air cooling is switched ON in order to validate the safety machine protection chain.
- **Standby** --> The transmitter, with a reduced current in the klystron, is now ready to provide RF.
- **ON** --> The transmitter provides RF at nominal power with all loops closed, in particular, the cavity tuning loop is operational. If one of the measurements, one of the settings or one of the loops is out of the operating range the high level object turns in an **Alarm** state.

A lot of sequencing is necessary to change from one state to the other. A sequencer device server was designed to run interpreted TCL scripts which are very flexible for modification. All sequences were written by the RF group so as to adapt them to the hardware or operation requirements. In case of a fault, the operator must analyse and reset the devices affected prior starting the sequencer.

6 APPLICATIONS

A set of graphical applications was developed with the Loox Maker editor for human interfaces:

- A general synopis application to display synthetic information and to control the state of all transmitters (figure 3).
- Cavity and transmitter synopsis for independent and individual object control.
- A viewer to read the state of the interlock chains.
- A configurable tuning application to display and set all parameters.
- A configurable signal monitor was developed to plot analog signals. Among them, a set of signals can be displayed in real time at a sampling rate of 10 Hz accessed via the ethernet network .

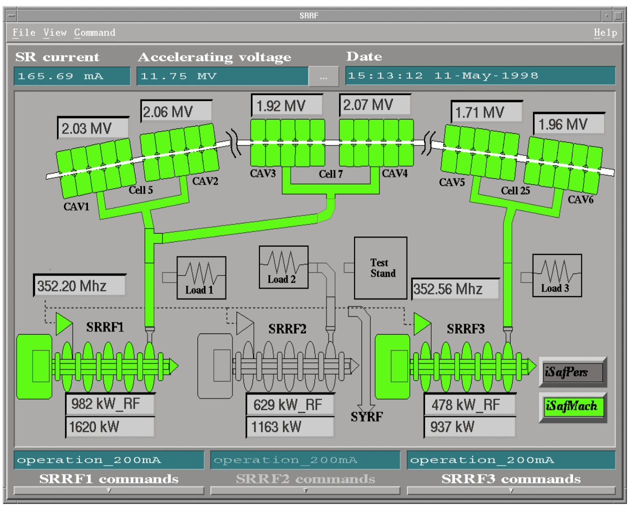


Figure 3: storage ring RF synopsis

All the applications obtain their information from a data collector process which is filled every 2 seconds by a set of pollers connected to the device servers. Data can be used by many applications without slowing down the network.

7 DIAGNOSTICS

For each device, the status (including state, warning and error messages) and the analog signals are stored every minute in the ESRF general **history data base**. This information can be used to follow-up critical parameters or for fault analysis.

In case of RF trips, the **interlock history** gives information on the sequence of events. To trace back the origin of the fault, the operator can access a set of analog data records:

- The **Slow analog data** logging contains a copy of the buffer used for the 10 Hz signal monitoring. It also includes the source of the logging trigger (beam loss, crowbar fired, pin-switch requested or configurable analog signal threshold).
- The **Fast RF analog** logger triggered at the same time records the evolution of 16 channels sampled at 1 Mhz during 1 ms.
- The **fast Beam Loss** data logger records the beam current and phase, in addition to the RF voltage power and phase of the three transmitters.

The cross interpretation of the data loggers is a very powerful tool for the identification of the cause of the problem. All data could be displayed using the signal monitoring application. As an example, we could attribute the high reflected power detected at the circulator output to high reflected power coming from one cavity. This was the result of a transient short circuit in one cell during the conditioning period.

8 CONCLUSION

The control system of the new RF unit is now fully operational. The interlock system and all servers were ready at the start-up of the commissioning. The sequences, the graphical application and the diagnostics were finalised in parallel to the operation. After six months of operation, the new design was proved to be efficient, reliable and easily maintained.

The upgrade of the hardware and the software of the old RF stations has started and will be done in parallel to the operation.

9 ACKNOLEDGEMENTS

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