

# The New RF Control System for the CERN SPS Accelerator

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## Abstract

The old SPS RF control system designed in 1972 has been replaced completely, hardware and software. The new system has to control both RF equipment conceived during the last 23 years, and future (modern) equipment. Using information analysis method, we derived a model of an RF command and designed a database accordingly (*ORACLE*<sup>®</sup>). Information from this database is used for command generation, processing, and also for archiving settings. The advantage is purely generic software, that is the same computer code is used for switching on an RF amplifier, or for setting a frequency synthesizer. New equipment is added very simply by entering new records in the database. Additional features include a reservation scheme whereby a user can take private control of an equipment, a reporting facility notifying the user of the simultaneous control activity by other users on RF equipment, and a capability scheme assigning a level of expertise to each user restricting action on the equipment.

## 1 THE SPS RF EQUIPMENT

The SPS is a 7 km long machine accelerating protons, electrons, positrons and heavy ions. The RF equipment consists of the following systems:

- 200 MHz TWC. 4 cavities at 200 MHz, of the travelling wave type, used for protons and ions acceleration.
- 200 MHz SWC. 21 cavities at 200 MHz, of the standing wave type, used for leptons acceleration.
- 100 MHz SWC. 6 cavities at 100 MHz, of the standing wave type, used for leptons acceleration.
- 352 MHz SUPRA. 4 supraconducting cavities at 352 MHz, used for leptons acceleration.
- 400 MHz SUPRA. 1 supraconducting cavity at 400 MHz, prototype of the cavity for the future LHC.
- Beam Control. Settings and acquisitions: Radial loop, phase loop, frequency program ...
- RF Synchronization. Settings and acquisitions for synchronizing the bunch into bucket transfers from CPS into SPS, and from SPS into LEP.
- 352 MHz SUPRA beam dump and veto field. Monitoring of the faults in the cavity.
- Measurements. Acquisition of data for diagnostics.

## 2 ARCHITECTURE

Our control system follows the architecture proposed by the CERN Controls Groups [1]. It consists of three layers (see figure 1).

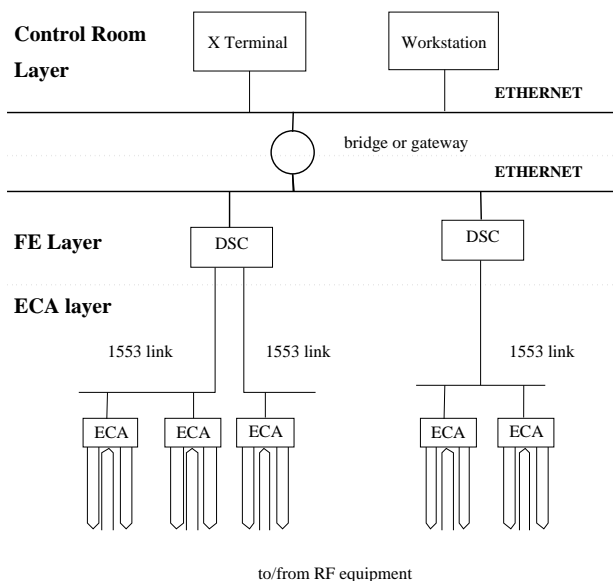


Figure 1: Three layers architecture.

The *Control Room Layer* with its UNIX workstations and X-Terminals, is connected via a network (local Ethernet segments bridged to large Token-Rings) to the *Front End Computing Layer*. The Front End process computers are IBM type PCs with LynxOS operating system. They are called *Device Stub Controllers* (DSC) [1]. Each DSC can drive a set of MIL-1553 fieldbuses connecting it to the *Equipment Control Assembly* (ECA) layer. The ECAs are G64 crates with 8 bit microprocessors and AMX based real time operating system [2]. The G64 crates are equipped with Input/Output cards connected to the RF equipment.

### 2.1 Control Room layer

We have developed a Man Machine Interface (MMI) program meant to run on any workstation on the network. The program deals with command generation and display of replies: It guides the user through the generation of a valid command via graphics, menus and selections by the mouse. It displays the replies resulting from that command while it executes, and reports on possible modifications to the equipment triggered by other simultaneous users.

## 2.2 Front End Computing layer

The following tasks are implemented at this level.

- **Filtering:** Each user is assigned a *capability* thereby restricting action on the equipment. Upon reception of a command, the DSC checks that the user is allowed to request such an action.

Some equipment (an amplifier for example), can be controlled by only one user at the time. It must then be *reserved* before sending a command to it. In such a case, the DSC checks that the user is the current owner.

- **Sequencing:** An action on a piece of RF equipment typically implies the execution of a *sequence* of steps, with the result of one step conditioning the execution of the next one. This sequencing is done in the DSC, each step may involve one or several calls to the ECA(s).
- **Transmitting replies:** Replies can be either data requested by the user (read command) or messages notifying the user of the execution of the steps in a sequence.
- **Transmitting reports:** *Reports* are messages notifying a user of the execution of a sequence called by another user. Using these reports, one can be notified of the simultaneous control activity of a portion of the RF equipment.
- **Notifying the Actif server:** If a write command is successful, i.e. it did modify the value of a setting, the DSC sends a notification to a server responsible for maintaining archives.

## 2.3 Equipment Control Assembly layer

The ECA's treat the command received from the DSC. During switching operations possible time-out situations are surveyed. In such a case the ECA returns the equipment to a safe state. They have dedicated hardware, responding to the SPS MTG (Master Timing Generator), that sends settings, synchronous with the machine supercycle, to the RF equipment. They are responsible for initializing the equipment at start-up and for maintaining fault logs.

## 3 COMMAND REPRESENTATION

The control system is mainly concerned with the manipulation of commands: Command generation, filtering, routing to the server concerned ... Choosing an adequate model for a command is thus very important.

### 3.1 The Graph

The *RF Graph* consists of two types of objects: *nodes* and *leaves*, related by filiations (arrows). See figure 2. We impose the following restrictions on the graph:

- There is a single root node.

- There is no recursive path.
- Leaves have no child.
- Each node has, at the most one child leaf.

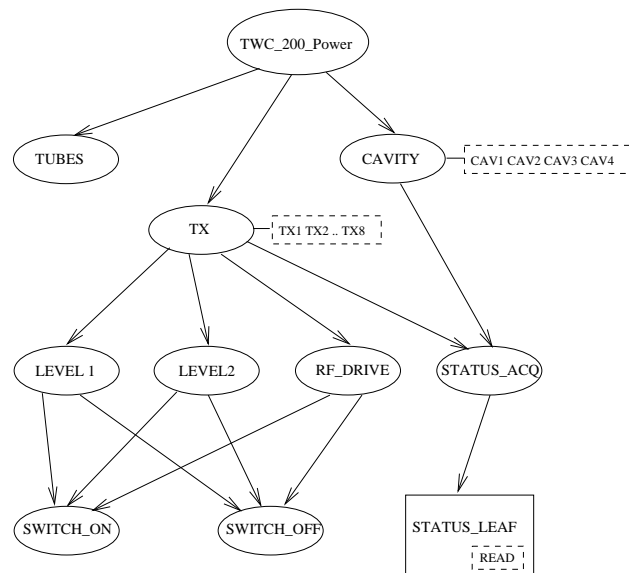


Figure 2: A portion of the TWC 200 MHz Power graph

We have one such graph per RF system (as defined in section 1). The root is the system's name. Nodes are meant to represent functionalities, with children nodes as sub-functionalities. Figure 2 shows a portion of the graph representing the four Travelling Wave Cavities at 200 MHz. Each cavity is driven by two amplifiers traditionally called transmitters (TX). Nodes are represented by small ellipses. The dashed rectangles represent a list of *targets* to which the functionality of the corresponding node can be applied: CAVITY can be applied to the four cavities (CAV1 to CAV4); TX can be applied to the eight transmitters (TX1 to TX8). Wherever a node has only one target, it is not drawn on the figure.

Leaves are meant to represent data. They are drawn as square boxes on the figure. The STATUS\_LEAF describes the data returned by a status acquisition on either a cavity or a transmitter. The leaf can eventually be applied to a set of *transfer modes* drawn in a dashed rectangle inside the leaf box. The STATUS\_LEAF has only one transfer mode: read.

### 3.2 A Command

A command is a *path* through the graph, starting at the root, with a list of selected targets at each node, and, if the path ends in a leaf, a single selected transfer mode plus possible parameters and data (write).

Referring to figure 2, we derive the command: **switching on the RF drive for transmitters 1,2 and 3.**

- Node TWC\_200\_Power (root) and selected target DEFAULT.

- Node TX, selected targets TX1, TX2, TX3.
- Node RF\_DRIVE, selected target DEFAULT.
- Node SWITCH\_ON, selected target DEFAULT.

## 4 CONTENT OF THE DATA BASE

The graph data base describes all RF commands. Figure 3 shows the portion of the graph relevant to the above command.

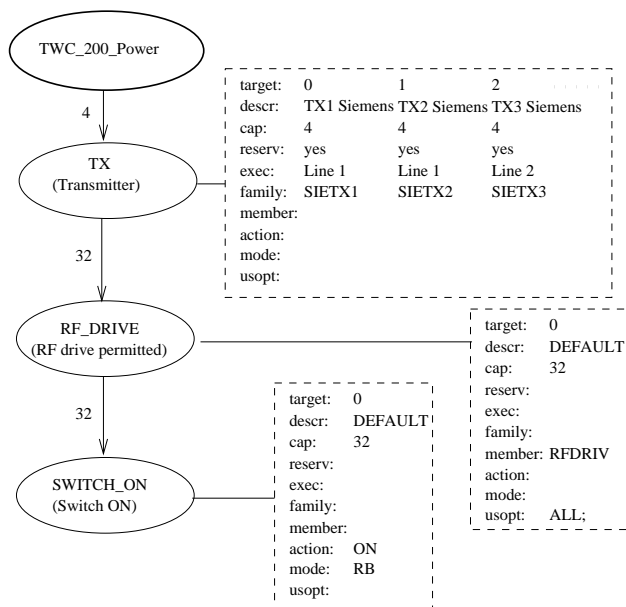


Figure 3: Content of the graph data base

In each node, we find the node description (between brackets) used by the MMI program. The numbers on the node filiation arrows are the required capability levels: 32 corresponds to the user Machine-Operation, and is the minimum required to use sub-functionality RF\_DRIVE underneath TX. A user with a lower capability could only move to sub-functionality STATUS\_ACQ shown on figure 2.

Each node has at least one target. (Only the first three targets of TX are listed). One possible attribute of the target is the specification of the *executer*, i.e. the process in the DSC responsible for the control of the corresponding equipment (section 2.2): The first two targets of node TX are controlled by the executer Line 1, while the third is controlled by Line 2. The *reserv* attribute specifies whether the user must be the current owner of the equipment (section 2.2).

The MIL-1553 fields [2] family, member, action ...used for communicating with the ECA's are easily derived from the attributes of the targets in each node of the command path. (Wherever an attribute of a target is not defined, the corresponding field is left empty in figure 3).

Not represented on the figure are the specifications of the DSC (actually dependent on the system only, i.e. defined at the root).

If a command involves data, its path terminates in a leaf. The graph gives the possible transfer modes. For each transfer mode (read or write), the data base indicates the types of data (longinteger, float or string), whether the number of data is fixed or variable, possible maximal number of data, bounds, the *conversion algorithm* to be applied to the data, possible parameters, the *synoptic* to be used by the MMI program for display ...

## 5 IMPLEMENTATION OF THE DATA BASE

Following the experience of LEP [3], the information analysis was first done using the NIAM method (Natural Information Analysis Method) [4]. This method consists in the representation of knowledge as *facts* between *objects*. Derivation of the proper facts and objects from the graph is straightforward: Most important objects will be nodes, targets, leaves ...

We have used the CASE (Computer Aided Software Engineering) tool RIDL\* [5] from IntelliBase for mapping our NIAM diagram, into a DBMS (Data Base Management System). RIDL\* integrates a graphic interface for entering the NIAM diagram, an analysis package, and a mapping package generating a SQL text file with statements creating the tables and defining the constraints for the chosen DBMS (Oracle version 7). The graph data base was thereby mapped into 52 tables (a total of 235 columns) and 366 constraints.

Data are extracted from the data base and loaded into dedicated data structures for the processes running on the DSC's and workstations.

## 6 CONCLUSIONS

We started commissioning the new control system in March 94 with only three of the RF systems of section 1. In the last two years, it was extended to cover all RF equipment. The data base approach makes addition of new equipment very easy. The generic software is also much appreciated by the user. The interface is uniform across all equipment.

## 7 REFERENCES

- [1] PS and SL Controls Groups, PS/SL Controls Consolidation Project, CERN/SL/91-12(CO), April 91.
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- [5] RIDL\* (V1.2) manual set, IntelliBase nv/sa, Plantin en Moretuslei 220 bus 3, 2018 Antwerpen, Belgium, 1991.