Controls Upgrade of the RF Systems of the CERN PS

R. Garoby, M. Gourber-Pace, S. Hancock, F. di Maio, N. de Metz-Noblat
PS Division, CERN, CH-1211, Geneva 23, Switzerland

Abstract

The latest upgrade of the control systems of the CERN PS Complex has seen the replacement of all components of the controls interface to the RF systems of the PS machine. New hardware offers features which have been exploited not only by concomitant software developments but also by changes in the philosophy underlying the operation of those RF systems. In addition, a novel measurement scheme has been installed which provides a display of RF parameters by processing a wide variety of signals continuously sampled at 1 kHz. New timing diagnostics have also been implemented.

This paper reviews the main advantages of the new equipment and the evolution in operational principles which it has afforded.

1. INTRODUCTION

The PS (Proton Synchrotron) Complex comprises three linear accelerators and six circular ones, all interlinked. At its heart lies the thirty-six year old PS machine which handles a variety of particle beams on a cycle-to-cycle (so-called "PPM") basis. A rejuvenation of the control system of the PS is foreseen in two stages, the first of which has been completed and has affected all components of the interface to the three RF systems of the machine.

Figure 1 is a greatly simplified schematic diagram showing the main features of a PS RF system. Three types of control variable are employed: analogue functions (RF voltage, servo loop gains, etc.); timing pulses; and bit patterns for quasi-static parameters which are only refreshed once per machine cycle. The corresponding hardware comprises a total of 6 VME, 2 CAMAC and 21 G64 crates.

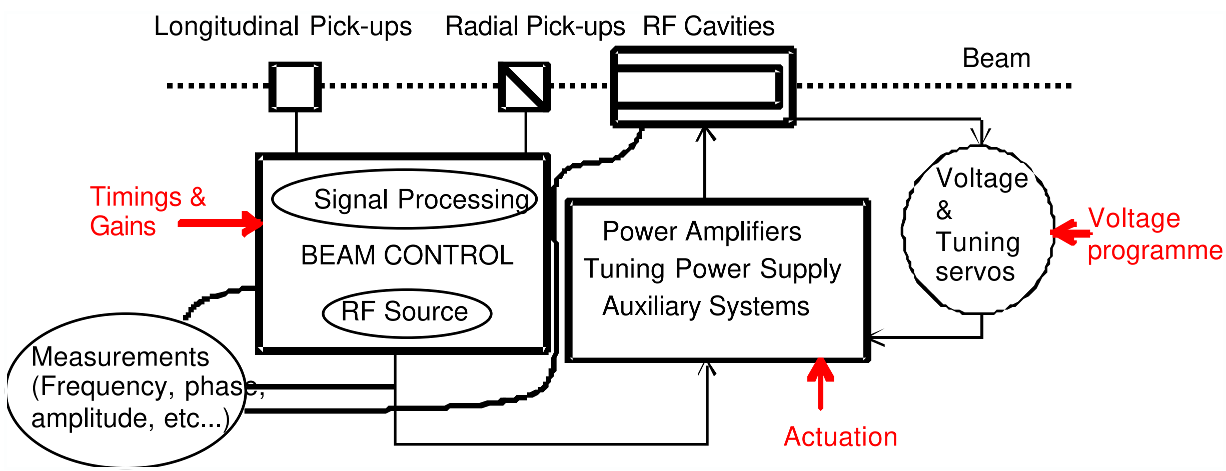

Figure 1. Basic RF layout.

2. HARDWARE

2.1 Function Generators

New VME-based function generators [Ref. 1] have increased by an order of magnitude the number of vectors available for the production of analogue signals. The need for extensive combinations of generators and summing amplifiers to provide detailed functions has thus been removed. However, the tremendous flexibility of the principal RF system of the PS derives from a combinatorial philosophy which has, therefore, been extended in this particular case. In order to avoid the transmission of analogue signals over long distances, a galvanically-isolated serial link carries the instantaneous digital values of the generated function either to a simple DAC for normal applications or to a multiplier plus DAC which converts the product of two such digital inputs. The latter permits different cavity voltage programmes to be generated within the same machine cycle as variants of a common fundamental programme.

In addition to more vectors, a function may contain multiple internal stops to hold the output at a certain value until a restart pulse is received and processing of the vector table is resumed. This facility is used extensively to synchronise transitions in the individual cavity voltage programmes with each other and with specific events (e.g., the opening or closing of the corresponding cavity short-circuits). The overall number of RF timings has been reduced since the wealth of vectors allows the duration of a flat first vector to determine the effective start of many functions. This trades off a dedicated start pulse against just one extra vector. Further economies have been possible because PPM means that restart pulses may be "re-used" at different times on different machine cycles.

A function may also be regenerated *ad infinitum* by processing the vector table in a loop. This permits the generation of a low frequency (< 20 kHz as the minimum vector duration is 5 µs) periodic function burst for modulation purposes from a description of one or more periods in the vector table.

2.2 Timing Generators

New VME-based hardware has permitted a change in the philosophy of timing generation. The majority of RF timing pulses are now generated in absolute time (with respect to the start of a machine cycle) rather than as delays from other timings. This is an advantage in large timing systems since there are no cabled links. Indeed, the very notion of timing structure has merely been emulated by establishing logical links between timing channels. A hierarchical timing cascade, which can be structurally different from cycle to cycle, may be maintained at application program level even though the hardware generates pulses entirely independent of each other. A further advantage is that a negative interval may be programmed between a linked timing and its logical predecessor without the need for an advanced prepulse (see Figure 2).

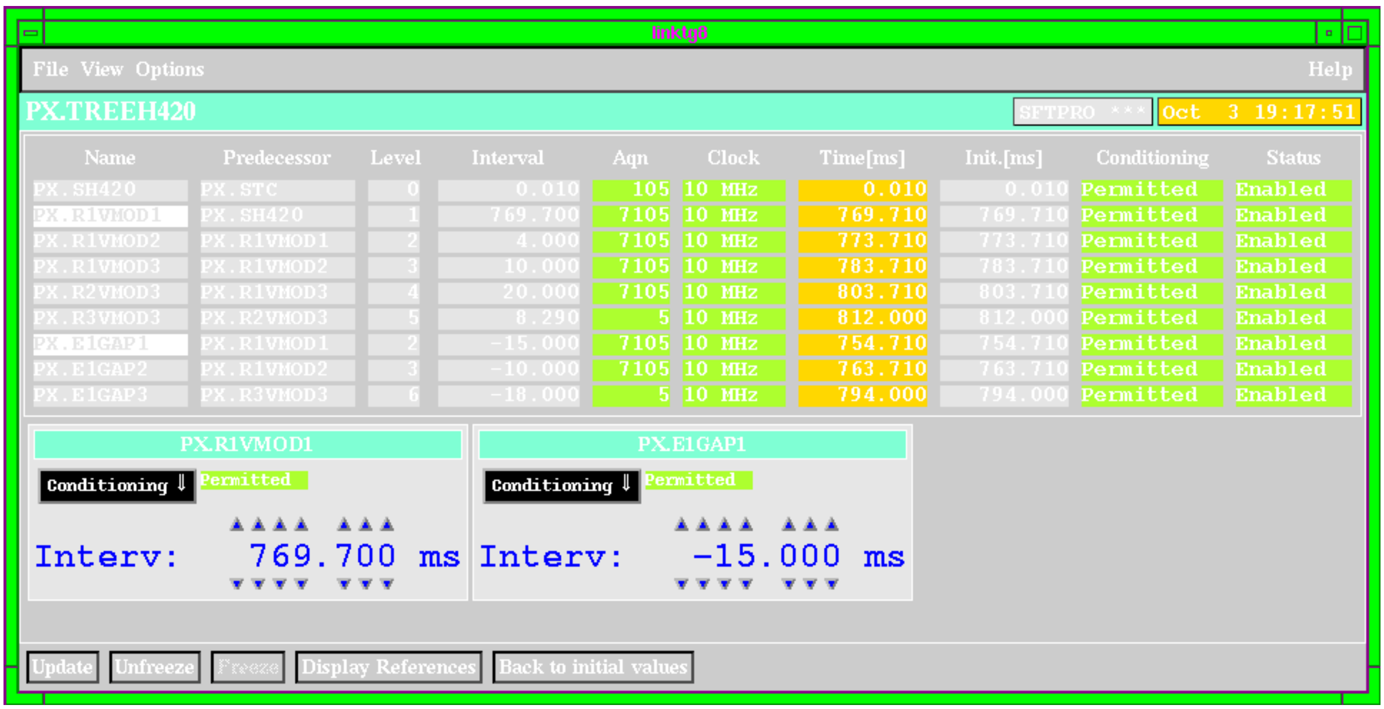

Figure 2. Linked timing application program.

Underlying the new system [Ref. 2] is a master timing generator (MTG) which distrubutes timing information on a single cable to all timing receiver (Tg8) modules [Ref. 3]. Each Tg8 receives the information in the form of timing frames which may subsequently initiate locally programmed actions. An action may add a delay (specified as a count of either an internal [10 MHz] or external clock train) before producing an output pulse, a VME interrupt, or both. Different actions may pertain to the same output channel and this feature is exploited to produce multiple restart pulses for function generators. Up to eight timing frames are transmitted during a 1 ms time slot and are validated by a "1 kHz event" at the end of this time. Thus, absolute time is readily described in terms of a number of Tg8 internal clock pulses after a particular millisecond from the start of a machine cycle. Time delays may be expressed with respect either to some other MTG event or to an external start.

The 1 kHz frequency of the MTG is derived from a 10 MHz rubidium gas oscillator which is, in turn, updated by a radio link from an atomic clock. However, the encoding of frames by the MTG and their decoding by a Tg8 are performed using free-running 4 MHz oscillators with the result that the 1 kHz events are subject to a jitter of ±250 ns. This is entirely sufficient for all except a small number of beam-related timings which require external starts and external clock trains.

2.3 High-power Equipment Interface

The high-power drive electronics of the twenty-one cavities in the PS are extensively protected by interlocks. The actuation of these systems is controlled and their status monitored via a completely new, G64-based interface [Ref. 4].

3. DIAGNOSTICS

3.1 Sampled RF Measurements

A powerful digital system has been assembled which provides a measurement of the essential RF parameters each millisecond during the active part of every machine cycle. The 1 kHz sampling frequency is derived from the same oscillator on which the MTG is synchronized. Various real-time tasks control the acquisition of: the beam revolution frequency and selected RF frequencies; the phase with respect to a revolution frequency reference of each of the principal RF cavities; the harmonic number of each of those cavities and all programmed and detected cavity voltages. These data are made available during the dead time at the end of a cycle for processing by an additional real-time task [Ref. 5] which computes the resultant voltage and phase components of the principal RF system by summing vectorially over all the cavities which are on the same harmonic (see Figure 3). It also computes the phase error, with respect to the phase sum for the appropriate harmonic, of each principal cavity. Both the raw and processed data can be accessed for display or further treatment.

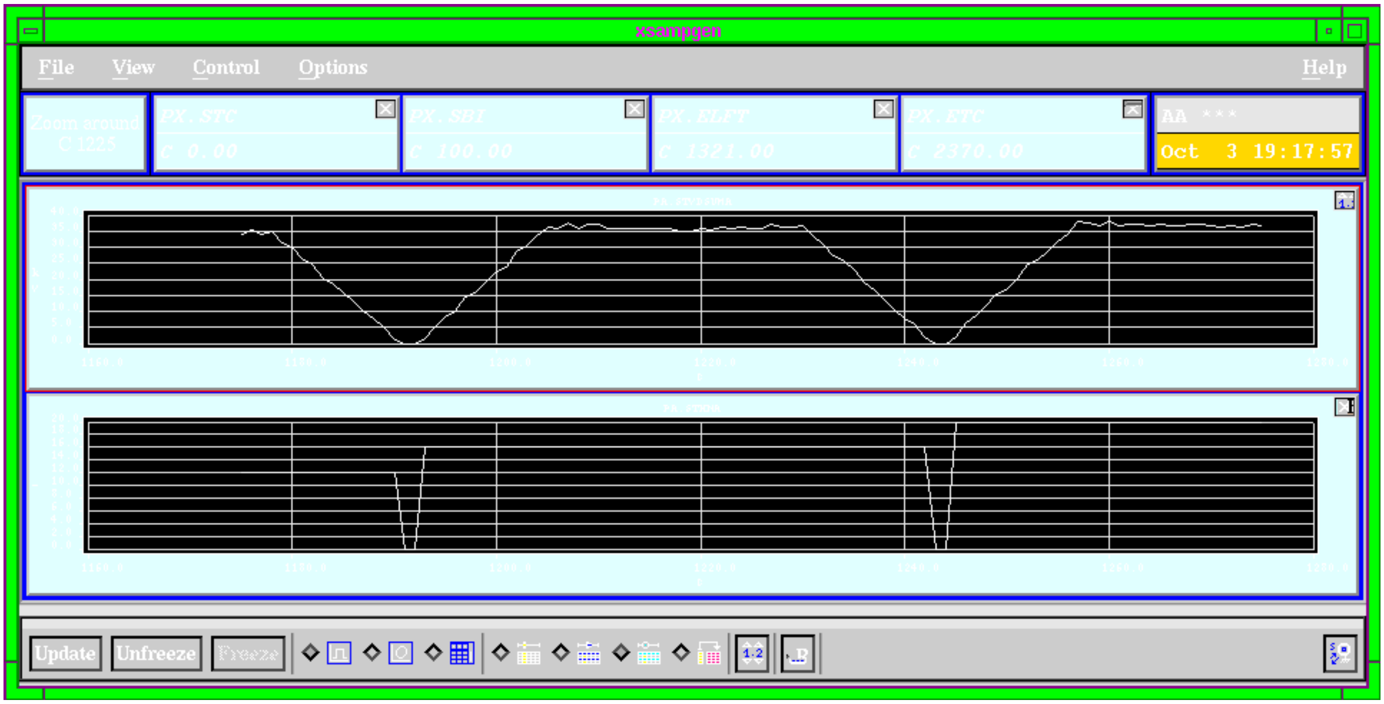

Figure 3. Total detected voltage and corresponding harmonic number measurements.

3.2 Timing Surveillance

Among the most difficult tasks in the operation of an accelerator is the diagnosis of timing problems. A timing surveillance (TSM) system [Ref. 6] has been developed to monitor simultaneously some 150 timing channels. All pulses, including multiple ones, are recorded with a resolution of 100 ns and an exhaustive list may be produced for an entire supercycle of the machine.

The precision of the TSM measurement is a consequence of its reliance on the widely-distributed 10 MHz clock described above. However, it is insufficient to monitor the beam-related timings that are required to synchronize the PS with its neighbours and client machines for injection and extraction purposes. To this end, a transfer timing surveillance (TTSM) system [Ref. 7] has been developed to measure time differences between key signals with a resolution of 1 ns. Eight different types of beam transfer may be monitored and warnings are issued for tiings that are out of tolerance.

3.3 Fault History

Any problems with the high-power RF systems of the machine are automatically logged so that a complete record of faults [Ref. 8] is available to specialists.

4. ACKNOWLEDGEMENTS

The success of the controls upgrade of the RF systems of the PS machine is due in large part to the dedicated technical support of P. Maesen, J.-P. Terrier and J.-L. Vallet. Important software contributions were made by A. Campbell, J.-M. Nonglaton and A. Gagnaire.

5. REFERENCES

[1] W. Heinze, R. Maccaferri, "GFAS: a new simple VME function generator", CERN/PS/CO Internal Note 93-09 (Tech.) (1993).

[2] J. Lewis, V. Sikolenko, “The new CERN PS timing system”, ICALEPCS, Berlin, Germany, Oct. 18-23, 1993, Nucl. Instr. and Meth. A352 (1994), p. 91.

[3] G. Beetham, G. Daems, J. Lewis, B. Puccio, “A new VME timing module: Tg8”, in Proc. ICALEPCS '91, KEK Proc. 92-15, KEK, Tsukuba (1992), p. 360.

[4] P. Maesen, "The G64 interface used to control the radio-frequency equipment in the PS", CERN/PS/RF/Note 95-12 (1995).

[5] A. Campbell, "Real-time formulae processing task for the PS 10 MHz cavity measurement system", CERN/PS/RF/Note 95-28 (1995).

[6] P. Bobbio, "Timing surveillance module", CERN/PS/CO/Note 91-07 (1991).

[7] S. Payaud, "Transfer timing survey module", CERN/PS/RF/Note 93-20 (1993).

[8] M. Beharrell, G. Benincasa, J.-M. Bouché, J. Cuperus, M. Lelaizant, L. Mérard, "Model-based, detailed fault analysis in the CERN PS Complex equipment", ICALEPCS’95 in these Proceedings.