Realtime Aspects of Pulse-to-Pulse Modulation

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Abstract

The pulse-to-pulse modulation of the SIS-ESR control system is described. Fast response to operator interaction and to changes in process conditions is emphasized as well as the essential part played by the timing system in pulse-to-pulse modulation.

I INTRODUCTION

The benefits of pulse-to-pulse modulation in acceleration operating have been described as early as '77 [1]. It is an effective way to increase the overall output of valuable beamtime of one or more accelerators. With beamsharing, rarely all users of the beam will be unable to accept the beam at the same time. If the PPM-handling quickly responds to changing conditions, there will be virtually no dead-time in the machine operating due to inevitable dead-times of experiments, e.g. during new experimental setups.

In a multi-accelerator facility, PPM is almost imperative. Asynchronously running machines, every one of them operating as an injector for the next one, normally have time left between subsequent injections that can be used for experiments.

II CONTROL AND TIMING SYSTEMS

Much has been said and will be said at this conference about the major trends in control systems in the last decade. Most systems recently designed or upgraded are looking more and more similar: Graphic workstations are the operators' I/O tools and software development platforms. The workstations are linked to a communication backbone. Ethernet, Token Rings, or fiber optic links are candidates. The choice rather depends on the distances to be mastered than on technical advantages or disadvantages.

To the same backbone, eventually as subnetworks with bridges in big systems, the equipment control computers are connected, which are mainly VME-, Multibus-, or CAMAC-based.

Extensive use of graphics and CASE tools has made an essential improvement in the operator's and software designers' access to control systems.

The overall trend is from very special systems tailored to the very special task of accelerator control towards more uniform, general purpose systems and the use of standards of the marketplace.

On the process level, however, the special needs of accelerator control, mainly realtime and synchronisation, do still exist or are becoming even more complex. Therefore the functionality of a control system must be biased by a timing system. The diversity of control systems of old has it's evolutionary relic in the diversity of timing systems, which will resist standardisation trends for another while. The more the higher levels in a control system become general purpose (and less realtime), the more process-specific problems must be solved on the lower levels. This is the domain of the timing system, the equipment controllers, and, of course, the equipment hardware. In the trend to general purpose systems the design of the timing system determines the overall performance significantly. The functionality of the timing system may range from simply providing clock signals for subsystem synchronisation to sophisticated timing control of the equipment control computers. However: A control system is only complete with a timing system (Fig.1).

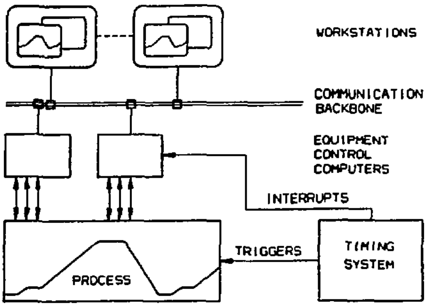

Figure 1: A complete control system

III PPM-MANAGEMENT IN REALTIME

III.1 Realtime Demands of PPM

The control system of Fig.1 already contains all realtime and synchronisation mechanisms to manage the process, e.g. to execute a synchrotron cycle. A system that can execute one cycle can as well execute another one. Nothing principially new needs to be introduced to perform PPM.

What then could be the realtime aspect of PPM? Let me call it the *'online supercycle management'*.

There are three levels of access to supercycle management, with increasing realtime demands:

III.1.1 Offline Management

The supercycle is built up offline to fit the experimental program. The internal timing of the individual cycles is programmed at the same time. There is no realtime demand.

III.1.2 Online Management

The operator may have a need to change either the supercycle or the timing of an individual cycle. The presently running cycle continues unchanged, but the next one will have the modifications.

III.1.3 Process Driven Management

Process conditions may change and need fast response (suspend immediately one type of cycle of the supersycle) or even very fast response (emergency, dump the presently running cycle). Evidently this is beyond the operators' abilities and must be handled on the process level.

For fast response, a request mechanism is very useful: Cycles are only executed upon request. This is the appropriate level to feed in additional conditions, as shown in Fig.2. Effective exploitation of beamtime is not the only aspect of PPM. Security, radiation protection etc. are other ones: *A high energy beam must not be generated if it* cannot reach it's destination point properly.

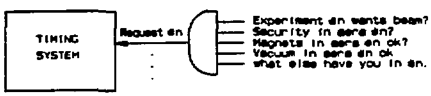

Figure 2: Request Level

Emergency handling is too special in every accelerator environment to be discussed here.

III.2 An Example: PPM Management at SIS-ESR

Fig.3 shows the control and timing system of SIS-ESR. The timing system drives a timing network in parallel to the communication network. Timing interfaces receive the serial timing information and pass it as a 16-bit parallel code, the event-code, to the equipment control computers.

A selectable set of events is transformed to hardware triggers for equipment by the timing interfaces. The time jitter for triggers is smaller than ±.5 microseconds in the system. Nanosecond timing has been left to special solutions to keep the timing system hardware simple.

In contrast to Fig.1 the timing system in Fig.3 is not a special part in the control system. To the operator it looks as, and in fact is, just another equipment control computer.

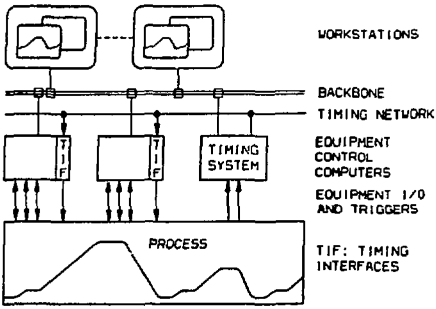

Figure 3: The SIS-ESR Control Architecture

The SIS-ESR timing system has direct timing control over all equipment control computers [2]. Each equipment control computer has available complete settings to execute sixteen different cycles, the 'virtual machines'.

The timing system activates machines by providing the event-code (Fig.4). The equipment controllers do nothing unless they receive events, command events, if nothing else, when no cycle is active and the timing system is idle. In fact, the timing system of the SIS-ESR is a hardware dispatcher to compensate for the loss of realtime abilities on higher control levels: It is the timing system that makes a 'real machine' out of a 'virtual machine'. This given, it is the natural candidate to be the 'supercycle manager'.

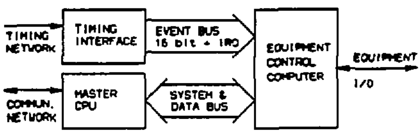

Figure 4: Event-Driven Equipment Control Computer

In comparison to other PPM-solutions, e.g. [3], no special PPM-management components like PPM message decoders are needed at the process conrol level.

Fig.5 gives the operator's view of a simple supercycle.

Figure 5: A SIS Supercycle

The properties assigned to each cycle are
active/inactive
execution count
decement/nondecrement
contiguous/noncontiguous

all of which can be changed online by the operator. Active/inactive provides a simple means to suspend a cycle. An inactive cycle does not leave a gap in the supercycle. It continues with the next active cycle.

The execution count works together with (non)decrement and (non)contiguous.

In non-decrement condition, (non)contiguous is meaningless. The subsequent supercycles are identical containing as many individual cycles in sequence as set by the count number.

With decrement and non-contiguous, the cycle will show up once in as many supercycles as set by the count, and suspended in the following supercycles.

With decrement and contiguous, the cycle is executed as many times as set by the count in only one supercycle.

One type of cycle may show up at different places in the supercycle, giving a high flexibility for supercycle programming.

Fig.6 gives an overview of the supercycles resulting from different settings provided the *status* from the request level is 'true'. If 'false', the cycle in question either will not be executed as in 'non-active' state, or an appropriate gap is inserted into the supercycle, if it is essential to maintain the overall timing structure. The choice is made by a software switch in the timing system.

R/NR is no input channel for the operator. It indicates the request status.

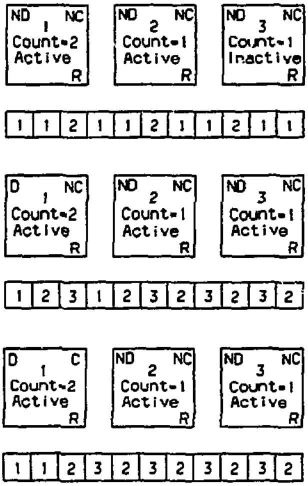

Figure 6: Supercycle settings

The properties given to the cycles, together with the request mechanism, easily allow a preprogrammed dynamic behavior of the supercycle. This is extremely useful when conditions change inpredictibly, e.g. when the storage ring ESR requests a bunch of cycles every few hours.

IV SUMMARY

The benefits of online PPM-management have been described. As an example the PPM-control of the SIS-ESR has been shown. the PPM-management in the SIS-ESR control is very simple and straightforward due to two facts: The central role that has been given to the timing system within the controls, and the proper design of this system. With direct control of the equipment controllers' timing it is the beating heart in SIS-ESR controls, rather than anything else.

After four years of operation, we found no demand for timing that could not easily be granted.

V DEFINITION

A 'virtual machine' in this context means a complete and consistent set of data stored in the Equipment Control Computers to perform an accelerator cycle if activated by the timing system.

VI ACKNOWLEDGEMENTS

[1] The PS Staff, reported by J.P.Potier, Pulse-to-pulse modulation of the CERN PS complex, Particle Accelerator Conference, Chicago, 1977

[2] W.Rösch, R.Steiner, SIS-Timing, GSI Scientific Report 88

[3] Bolliot J. et al., IEEE Trans.Nucl.Sci. NS-28 (1981) 2195