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PULSE-TO PULSE MODULATION OF THE BEAM CHARACTERISTICS AND UTILIZATION IN THE CERN PS ACCELERATOR COMPLEX

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Summary

The CERN PS complex (comprising the 50 MeV Linac, the 800 MeV Booster, the 28 GeV PS and the 3.5 GeV/c Antiproton Accumulator) must deliver beams of various characteristics (e.g. energy, intensity, emittances, ejection mode) to several users, with a repetition time as low as 0.65 s. The SPS accelerator, ISR and LEAR storage rings and the 25 GeV physics experiments receive beams in a repetitive sequence, called a supercycle. The coordination is achieved by the Program Lines Sequencer (PLS) which sends to the equipment concerned (before every machine cycle) a serial message, describing the user and the characteristics of the beam. This message is created by an on-line computer using (i) previously-entered information through a series of application programs and (ii) external conditions coming from the process or the users: these signals in turn can modify the information (i) accordingly.

Introduction

The users of the CERN PS complex of accelerators receive beams of particles according to pre-established sequences. The supercycle is made up of interleaved magnetic cycles of different shapes (Fig. 1), one or several cycles allocated to each user. The main users can also automatically accept or refuse the beam and in case of refusal, a backup user receives a beam with the appropriate characteristics.

The allocation of each cycle and also the composition and the duration of the supercycle change frequently during a machine run (6 or 7 weeks) in order to allow the different physics operations and accelerator study programs to be carried out. Each user can also work with various beam characteristics and can request for several changes during a machine run. Fig. 1 gives an example of PSB and PS supercycles for different users, each with their own beam characteristics. Extraction mode as well as beam properties (energy, intensity, RF structure, longitudinal and transversal emittances, and at present, the particle type) have thus to be modulated from cycle to cycle; this working mode is called pulse-to-pulse modulation or PPM.

The complexity of this PPM has regularly increased from the first years of the PS operation. In the beginning, the cycles were all identical and it was only envisaged to change the extraction mode from one cycle to the next. The supercycle and the modulation of the beam properties came into operation in 1976, when the PS became the injector for the SPS.[1] This year, new operating modes with protons and antiprotons will need more complex and longer supercycles (comprising up to 20 cycles).

Principles and Characteristics of the PLS

The coordination is achieved by a master programmer called "Program Lines Sequencer" (PLS); to describe the user and the beam properties, for every machine cycle this system generates a set of conditions which are sent to all the equipment concerned. One distinguishes two kinds of equipment:

- PPM equipment which is used on all the cycles of the supercycle and the values of which (voltage, currents) change from one cycle to the next. This kind of equipment receives a group of conditions, each group corresponding to a particular beam property (e.g. intensity). The conditions in a group are exclusive and represent different adjustment levels (e.g. intensity levels).
- Specific equipment which is only activated on one cycle and which receives just its appropriate PLS yes/no condition.

Table 1 gives the main groups of the PLS conditions presently used to control the PSB and the PS. All the PLS conditions are sent to the equipment via a simple distribution system. A serial code called PLS telegram (1 telegram per machine of the PS complex), centrally generated, is sent to the equipment. Locally this telegram is decoded by special modules which select the appropriate conditions.

A specific computer is dedicated to control this particular process in real-time.[2] It uses two classes of information: 1) information for scheduled operations

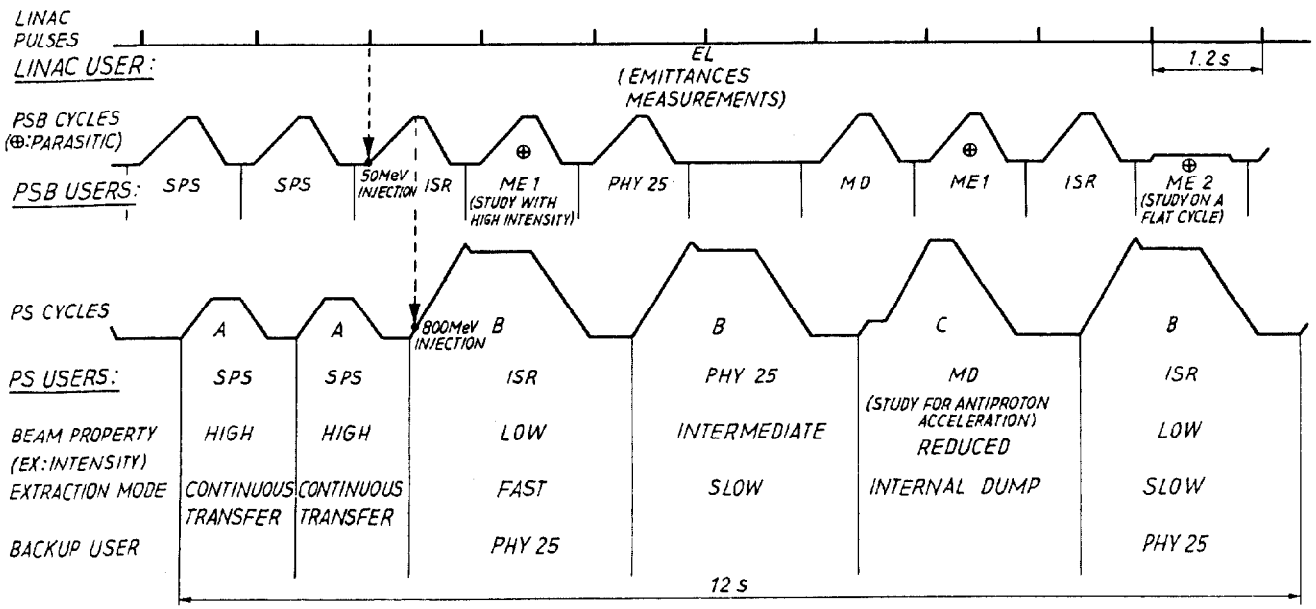

Fig. 1 SUPERCYCLE AND BEAM USERS (example)

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with their planned properties introduced from the operation consoles by the operator; 2) information coming directly from the process e.g. synchronization pulses, hardware status and user beam requests. Taking into account all this information, the computer prepares both the next and the present cycle conditions which are then sent to the interface for serial coding.

	PSB	PS
BEAM USERS	8 possible USERS per supercycle	8 possible USERS per supercycle
BEAM PROPERTIES	5 CYCLE TYPES 5 INTENSITY LEVELS 5 WORKING POINTS 4 EJECTION MODES	5 CYCLE TYPES 5 INTENSITY LEVELS 5 LOW ENERGY SETTINGS 5 HIGH ENERGY SETT. 5 INJECTION MODES
EXTRACTIONS	EJECTION INHIBIT	12 FAST EXTRACTIONS . CONTINUOUS TRANSF. . SLOW EXTRACTION
BEAM DESTINATIONS	PS or MEASUREMENT LINE	8 TRANSFER TUNNELS to OTHER MACHINES

Table 1

Fig. 2 gives the main scheme of the PLS system.

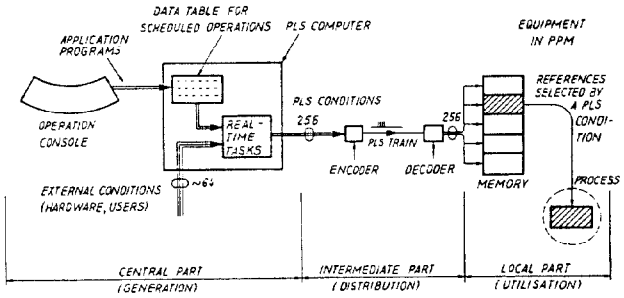

Fig. 2 PRINCIPLE OF THE PLS SYSTEM

This system presents many advantages for the CPS complex operation:

- by centralising computer control of the PLS system, the PPM control is made homogeneous for the whole PS complex.
- The computer working in real-time is the heart of the system and it allows great flexibility for the many changes occuring in the PS operation schedule.
- The new PS operation consoles with their different interactive tools give the operator a very clear presentation of the whole process.
- Good reliability is obtained by using a very simple distribution system and a computer for these complex conditions. In addition, a general computer back-up scheme is available.[3]

PLS System Description

Overall Structure

Since last autumn the PLS is controlled by the new PS control system.[3] Due to its importance for the running of each accelerator and for individual control of the equipment, it was necessary to study and to convert this system in the first package of the overall computer control project.[4]

The PLS computer receives and gives information via standard CAMAC interface, the PLS conditions are sent to all the CAMAC interfaces controlled by the other computers (process and consoles). Figure 3 gives the simplified layout of the PLS in the computer control system. For the following description, we distinguish the software part in the PLS computer and the hardware part (standard and specific interfaces).

PLS Software

The generation of the PLS conditions is achieved by a main task working in real-time (RT) in the computer.[5]

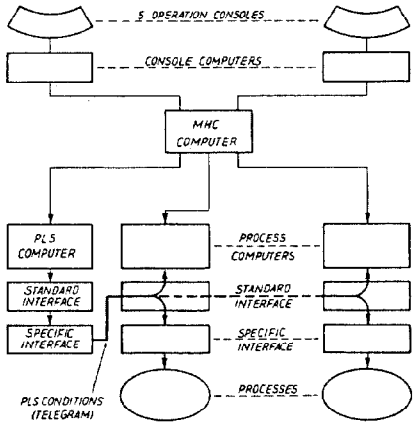

Fig. 3 PLS IN THE NEW CPS CONTROL SYSTEM

It uses a data table filled from the operation consoles through several application programs. This table, organized according to the Linac pulse number (and also to PS and PSB cycle numbers) contains all the information about the operation scheduled, e.g. beam users, beam properties, destinations, extraction mode, backup users (Fig. 4). Synchronization with the general timing of the machines is made by receiving external key pulses which are used as interrupts to start the RT task each cycle or to synchronize with the supercycle. The external conditions are acquired once each cycle after a key pulse. The RT task then makes a logical calculation in several steps: it checks the status of the external conditions corresponding to the scheduled operation in the data table and decides which user (normal or backup) must receive the beam.[6] After this treatment, two sets of PLS conditions are sent to the interface: conditions announcing the next machine cycle (early program lines) and conditions for the present machine cycle (present program lines).

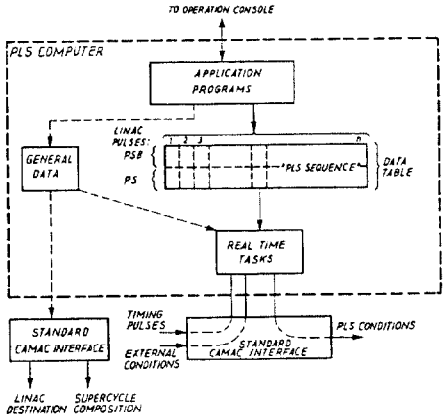

Fig. 4 SOFTWARE ORGANIZATION

Several other tasks in the PLS computer complete the main task, e.g.:

- A real-time task called "ALARM" is activated by random interrupts coming from special external events. In this case, part of the PLS conditions are modified and immediately sent to the CAMAC interface.
- Another real-time task allows the sending of PLS information to character generators for video screens every LINAC pulse. These refreshed video signals can be observed on the operation consoles.

The application programs also control the equipment associated to the PLS process, particularly the PS Main Power Supply (supercycle composition) and the Linac Beam Sequencer (Linac destination). Several acquisition programs have been implemented to display PLS information in real-time (TV colour photo on Fig.5).

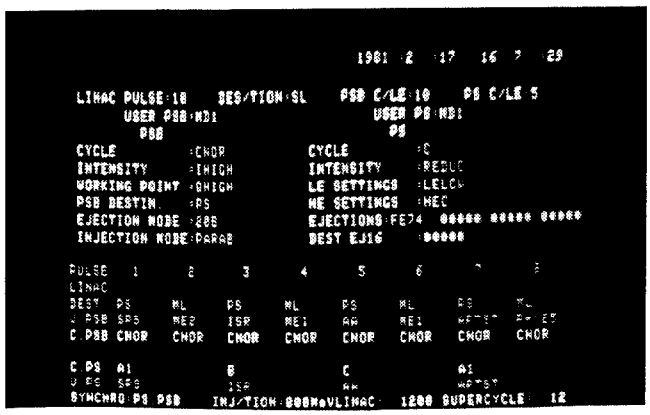

Fig. 5 PLS display on main console

PLS Hardware

- The Central CAMAC Interface allows the exchange of information between the computer and the process. Synchronization pulses (16) and alarm events (22) are received in interrupt registers; external conditions (64) from PS complex hardware or from users are received in an input register. The computer delivers the PLS conditions (or program lines) via CAMAC output registers (16 words of 16 bits per accelerator).
- The PLS conditions are coded in a specific interface called "PLS encoder". The PLS telegram structure is very simple (Fig. 6); it comprises a pulse train of 10 kHz frequency, each pulse indicating the number of a given PLS condition. If this condition is effectively present for a given machine cycle, this pulse is followed by a second pulse.

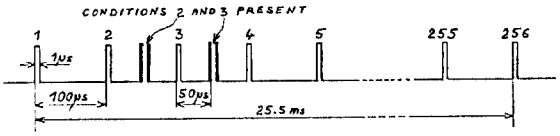

Fig. 6 PLS telegram

- The serialization of the information allows the use of standard timing distribution networks (pulse repeaters and coaxial cables).
- The PLS information is normally distributed between two machine cycles. Fig. 7 shows on the same diagram the distribution times of the telegrams for the PSB and the PS. Real-time events controlled by the "alarm" program and corresponding to the first 16 bits in the telegram can be distributed at any moment within a cycle.

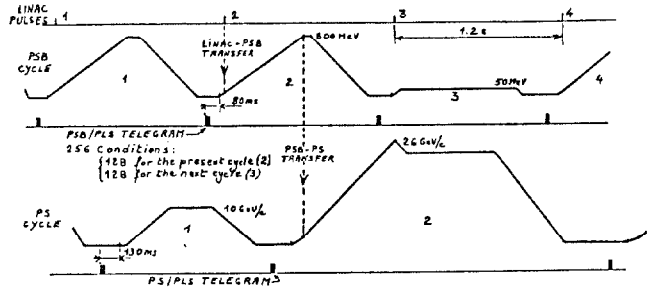

Fig. 7 Distribution of the PLS information

- PLS telegrams are received in CAMAC modules. Two types of utilizations are achieved :
1. "PLS receiver"modules memorize the whole PLS information. The acquisition of the memorized information is used for synchronization of the process and consoles computers and auxiliary crate conrollers (ACC) with the program lines. The ACCs locally control the PPM, by choosing from its memory and sending to the process the appropriate values corresponding to the acquired PLS conditions.[7]
2. "PLS decoder"modules with 8 independent output channels are used to deliver program lines to specific equipment. The information required is selected by software. Two identical PLS decoder channels are included in the dual preset counter CAMAC modules.
- Special equipment, linked to the PLS process, is controlled by standard modules in a serial CAMAC loop especially the "PS supercycle composition" and the "Linac Beam Sequencer".[8]

Conclusion

The PLS system has been working successfully for 3 months with the PS control system. New sophisticated application programs must still be implemented this year and the conversion of the PLS-PS hardware is envisaged during the next 2 years.

This system showed, from its start-up, qualities of clear presentation, flexibility and reliability, qualities indispensable for the present and future operation of the fast growing PS complex.

Acknowledgements

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