The Design of the Energy Ramping System for ELETTRA

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Abstract

A general purpose distributed synchronisation system, completely integrated in the ELETTRA control system, has been designed and installed. The MIL-1553B field bus, which is already adopted for the lower level network, provides a reliable basis for the development of a process synchronisation scheme. The possibility of broadcasting data together with the synchronisation signals enhances the system flexibility. The energy ramping of the ELETTRA storage ring is described, where a complete synchronisation system with effective operation tools has been implemented.

1. INTRODUCTION

The ELETTRA third generation synchrotron light source facility consists of a 1.5 GeV Linac injector, a transfer-line and a storage ring where a large number of insertion devices produces extremely high brilliance photon beams in the UV and soft X-ray range.

An energy ramping system has been installed to provide electron beams at higher energies which are requested by some of the experiments.

During a ramping process, the amplitude of the magnetic fields and of the radio frequency accelerating voltages must be synchronised in order to arrive to a higher energy state while keeping the same optics. This results in the synchronisation of the setting of the 46 bending, quadrupole, sextupole and 164 corrector power supplies, and of the 4 radio frequency plants.

The synchronisation system takes advantage of the distributed architecture of the ELETTRA control system and relies on the equipment controllers already installed. Nevertheless, the ramping procedure does not affect the control system normal operation and allows to continuously monitor, record and control the machine parameters. A user friendly interface gives the operator easy control of the ramping procedure.

2. RAMPING PATH DEFINITION

The ramping path definition has been kept independent from the specification of the values to be synchronously set by the control system DACs, called "steps". This choice allows to use modelling programs [1] for the first and to take into account machine equipment hardware constraints for the latter.

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The ramping path between the injection and the final energy is described by a set of states which uniquely define the machine at intermediate energies. For each magnet, this results in a series of field strength values which are converted into the corresponding power supply currents (called "samples") by means of the calibration curves.

The number of steps is determined by the bending magnet power supply setting limit, which has been fixed to 1 DAC bit/step. For a given step number, the calculation of the step array for each ramping element is done by linear interpolation of the samples (fig. 1).

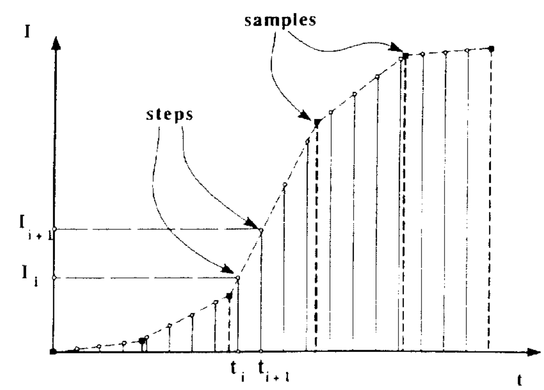

Figure 1. Example of samples and steps.

3. THE ELETTRA CONTROL SYSTEM

The ELETTRA control system, which successfully operates since the beginning of the facility commissioning [2, 3], is based on three computer layers (presentation, process and equipment interface) exchanging information by two types of networks [4, 5]. The computers are geographically distributed over the 260 m storage ring and 170 m linac plus transfer-line.

VME based modular microprocessor systems called Local Process Computer (LPC) and Equipment Interface Units (EIU) both running the OS-9 operating system, are respectively installed at the process and equipment interface level. MIL-1553B highway branches connect each LPC to a group of EIUs. The performances of the MIL-1553B highway allow to assign a single LPC together with the associated EIUs to a major group of controlled equipment such as power supplies, vacuum, injection system, etc. Namely, 1 LPC and 17 EIUs are dedicated to the control of the bending, quadrupole and sextupole (called "big") power supplies, 1

LPC and 24 EIUs to the corrector magnets power supplies, 1 LPC and 4 EIUs to the radio frequency plants.

4. THE SYNCHRONISATION SYSTEM

The design of the synchronisation system started from the scenario above. Relying on the good operational experience and know-how we already had on our field highway, we decided to use MIL-1553B broadcast packets to distribute the synchronisation signals to the EIUs involved in the ramping process. Taking advantage of the broadcast protocol, a MIL-1553B Bus Controller (BC) can simultaneously address and transmit data within a single transaction to all the connected Remote Terminals (RT).

A dedicated LPC and a number of additional MIL-1553B branches, BCs and RTs have been installed for the synchronisation system (fig. 2). Three BCs are placed in the synchronisation LPC and each of them is respectively connected to the supplementary RTs which have been installed in the EIUs of the "big" power supplies, of the corrector power supplies and of the radio frequency plants.

The simultaneous setting of each step is triggered by the synchronisation LPC, which sends a broadcast packet with a special "mode code" [6] by means of the BCs to all the EIUs. Here the RT board generates a hardware interrupt through the VME bus to the CPU of the EIU, which fetches the corresponding pre-loaded step values and writes them into the DAC boards.

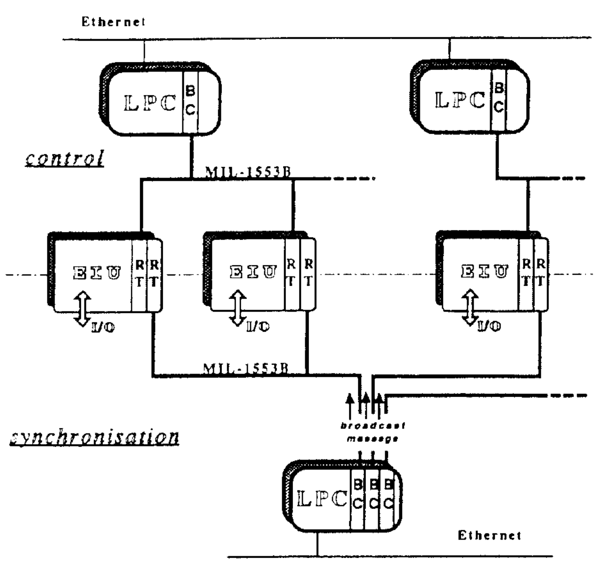

Figure 2. The control and synchronisation systems.

4.1. Jitter minimisation

A special effort has been made to minimise the jitter between the different setting times of the equipment involved in the ramping. As the main CPU board of the synchronisation LPC triggers the transmission of the broadcast packets from the BCs by three successive VME bus write cycles, and the maximum length of the MIL-1553B branches is about 500 m, the jitter of the broadcast reception instant is of the order of few µs.

The main source of jitter is the variable response time of the OS-9 operating system handler to the interrupt generated by the RT, and a series of software enhancements has been developed to reduce this effect. Figure 3 shows the achieved distributions of the delay time between the broadcast generation and the DAC setting.

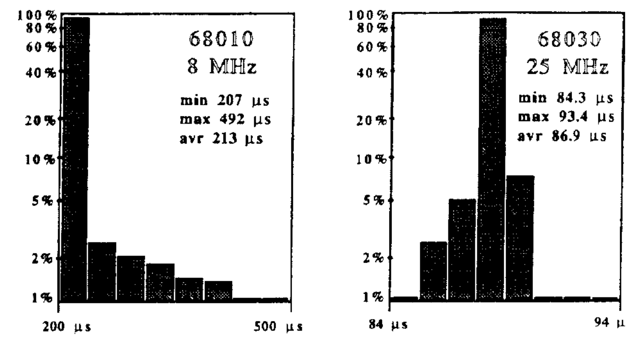

Figure 3. Measured statistical distribution of the delay time between the broadcast generation and the DAC setting.

5. SYSTEM OPERATION AND PERFORMANCES

Three different phases can be distinguished in the ramping procedure:

- the sample values are first loaded from the machine modelling programs into the EIUs. In order to keep a good accuracy for the current-to-field calibration curves of the magnets, up to 1000 samples per ramping element can be given. A few hundreds are necessary for normal operation;
- the EIUs calculate the step arrays for the associated ramping equipment. This process takes advantage of the distributed architecture of the control system as the calculations are carried out in parallel by the EIUs. The maximum number of steps per ramping element is 30000;
- the synchronisation LPC starts sending the broadcast packets and triggers the setting of the successive steps. The maximum allowed frequency of transmission of the broadcast packets is 1 kHz.

5.1. User interface

A complete set of Remote Procedure Calls and a Motif based panel (fig. 4) [7] have been developed to control the ramping procedure from the control room workstations.

The operator first sets up the system by choosing the number of samples, loading the EIUs and starting the calculation of the step arrays. Then, he can select the step setting frequency, start and stop the ramping process, eventually change the step setting frequency, start again, etc.

An additional operational mode, called "file ramping", has been implemented. It allows any synchronised step-by-step variation of the machine settings from the present to the configuration stored in a file. A link to the ORACLE

Relational Data Base allows in fact to choose any machine configuration previously stored as a Machine File [8].

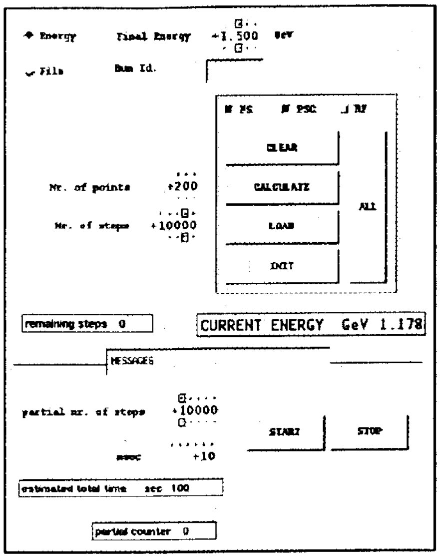

Figure 4. The Motif based ramping control panel.

6. CONCLUSIONS

On January 24th, after one hour of system operation, the electron beam energy was successfully ramped from 1.1 to 2 GeV and higher energies up to 2.3 GeV have been achieved in a few days. A ramp from 1.1 to 2 GeV takes normally 3.5 minutes.

At present, thanks to the system reliability, the energy ramping has become a routine operation.

Considering the variation of the beam parameters, the ramping of the radio frequency voltages is not necessary with the use of the amplitude loop of the cavity voltage. Moreover, during the machine energy ramping, a tune feedback system keeps the transverse tunes constant [1].

The designed system keeps the control system performances unaffected during the ramping process, which results completely transparent to the control room operator.

The implemented general purpose system can satisfy a wide range of needs requesting synchronised actions. The data contained in the MIL-1553B broadcast packets enhance flexibility and allow different possibilities in the field of real-time applications.

The choice of the already known MIL-1553B has avoided the development of new hardware and has minimised the project time and costs.

7. REFERENCES

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