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FIRST IDEAS ON THE CONTROL SYSTEM FOR EHF (EUROPEAN HADRON FACILITY)

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Abstract

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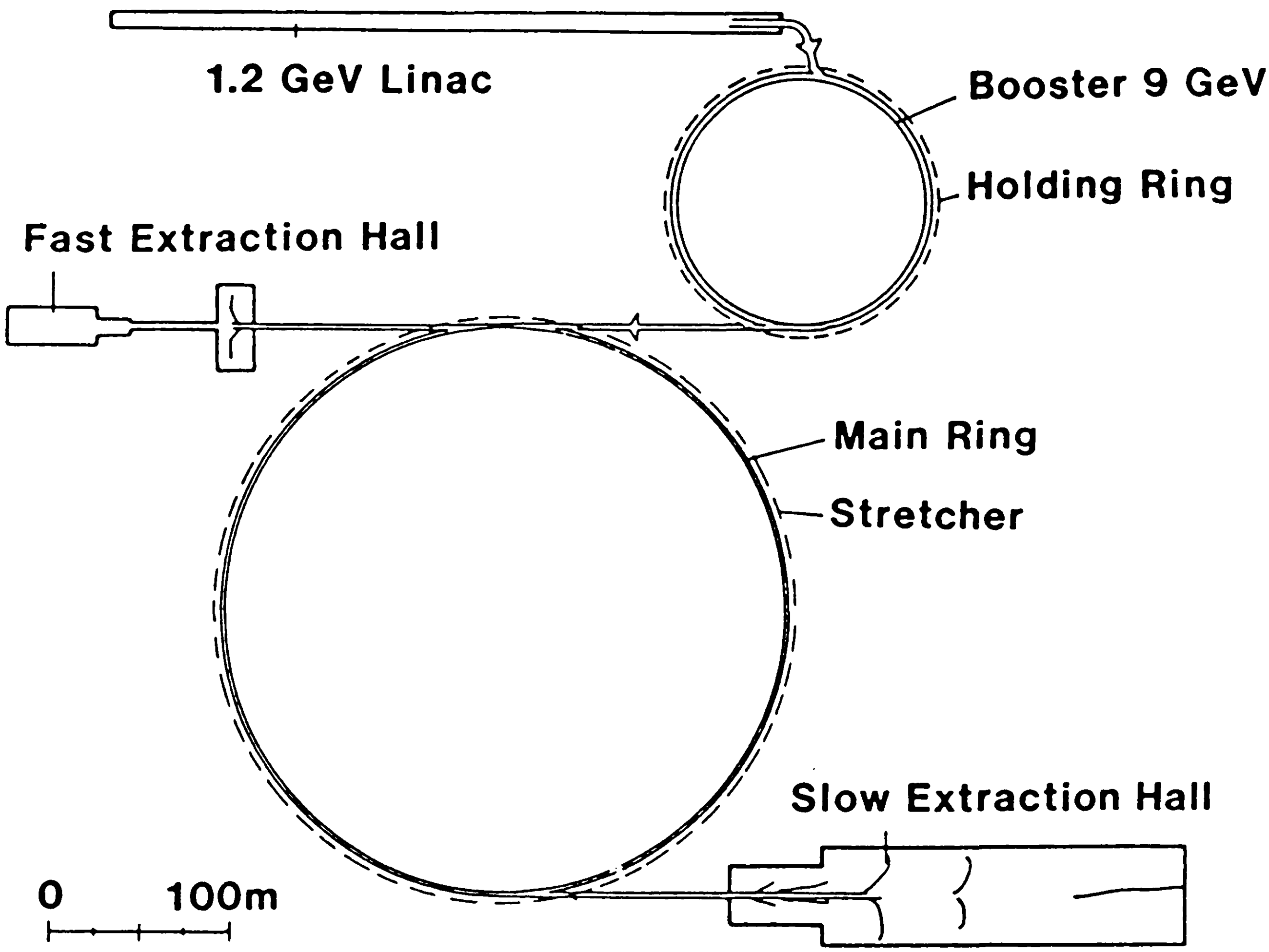

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I) INTRODUCTION

The design of new Control Systems is a challenging task. On the one side, one can refer to existing systems and take advantage of the experience in others laboratories. On the other side, the development and the subsequent implementation times of a control systems are long compared to the evolution of new technologies and very often a system that is completely developed and satisfactorily running is already obsolete.

For this reason the detailed options of a control system must be frozen as close in time as possible to the commissionning of the accelerator complex.

The number and the size of the concerned accelerators, the process requirement, and the real time constraints are in close relationship with the size and complexity of the control system.
Identically, the requirements for a user-friendly operation will probably not change drastically during the next years. It is already possible today to build a broad but realistic scenario of the EHF control system: the technical specifications and the selected options will be, for the time being, necessarily imprecise.

This exercice will neverthless permit to obtain a very first estimate on the complexity and on the costs.

II) THE PROCESS: CONTROL CHANNELS

We have to control five separate machines [1]:

- a 1.2 Gev LINAC

- a 9 Gev BOOSTER

- a 9 Gev HOLDING RING

- a 30 Gev MAIN RING

- a 30 Gev STRETCHER RING

To this "menu" should be added the controls of the beam transport for the two extraction Halls: the FAST and the SLOW ejections.

The secondary particle beams are usually controlled by separate and local systems.

The LINAC, the BOOSTER and the MAIN RING are pulsed processes with different repetition rates: respectively 25 Hz, 25 Hz and 12.5 Hz.

The HOLDING RING and the STRETCHER RING are DC machines.

An important parameter for the definition of the size and then of the costs is the total number of control channels.

A channel is an independent way to execute a simple action on a physical element. For example, a power supply using a status command (ON, OFF etc..)

and a setting value in control and in acquisition, requires four control channels.

With the existing information on the EHF systems, it is not possible to determine the total number of required channels. We can only try to guess some figures by comparison (where possible) with machines of similar size and complexity.

a) Extrapolation with existing similar machines give a figure of 12000 channels for the MAIN RING.

b) The LINAC complex consists of an Ion source, two RFQ's and two LINACs: we allocate 10000 channels.

c) Another 7000 channels for the BOOSTER are obtained by size and complexity comparison with the Main Ring.

d) The STRETCHER RING and the HOLDING RING are DC machines: their controls should then require less parameters than an accelerator of comparable size. We foresee 6000 channels for the STRETCHER and 4000 channels for the HOLDING RING.

The resulting total number of channels (40000) is of about 30% higher compared with reports and predictions of recent projects as SLAC SLC, PS COMPLEX, TEVATRON and LAMPF II: this seems reasonable if the number of controlled machines is considered.
The controls for the different beam transfer lines between the machines is included in the previous estimation.

III) OPERATIONAL ASPECTS OF CONTROLS

III-1) CONTROL ROOMS

The heart of an accelerator complex is the Main Control Room (MCR).

In the past, for historical reasons, several complex had a separate control room per accelerator.

Rationalisation, standardisation and staff restriction have brought as a consequence the centralisation of all relevant control activities in one single point, leaving usually only limited control access near each accelerator.

The number and the characteristics of the access devices (*consoles*) are mainly determined by the operational needs. In general, in operating an accelerator complex, two separate periods of time can be considered: the normal running periods and the setting-up periods. These two situations have very different requirements:

- During the normal operation only a few people are present in the Control Room: their tasks are essentially limited to some adjustements, some verifications and eventually to the execution of measurements. In this case few access points to the process are sufficient.

- The scenario is totally different during the setting-up periods: many specialists are involved in the different phases of preparation and tests of a multitude of systems and subsystems. Although accelerators are usually started sequentially (Linac, Booster and Main Ring in the order), specialists often want to access their systems at the same time. One can easily say that during setting-up periods, the access needs to the controls is at least one order of magnitude higher than during normal operation.

Incidentally, we remember that in a modern computer control systems, there are no manual local access to the elements: the cost of such duplication could be prohibitive.

Other parameters that play an important rôle in the size and complexity of the controls in general, and in the definition of the number of access points in particular, are the number and the kind of different operation modes and the Pulse to Pulse Modulation (PPM see VII).

To cope with these different and, often, conflictual requirements, two implementations have proved their utility:

- the use of general purpose consoles in MCR,
- the installation of a local console near each important machine or system.

Each General Purpose Console (a non-dedicated console) can access any part of the total accelerator complex; this means that, following the necessity of the moment, all consoles can access the same process or each console can be connected to a different system. The flexibility is total !

Local consoles are very useful at least for four separate goals:

- for maintenance purposes,
- to execute machine experiments where it is essential to observe local equipement,
- to alleviate the MCR during setting-up periods,
- during the running-in periods.

A reasonable figure for the EHF control system seems to provide 4 General Purpose Consoles in the MCR and one (may be less powerful) Local Console for each of the accelerators and accumulation rings.

A sufficient number of interactive terminals are also to be provided, mainly for maintenance purposes.

III-2) <u>OPERATIONAL REQUIREMENTS</u>

Independentely of the selected control options, a certain number of requirements are common to most of the existing systems:

- Clear and easy access to the controlled parameters.
  This is a general and obvious requirement that covers a multitude of aspects such as ergonomy studies, standardisation of displays, rationalisation of interactions etc..

- Acceptable response Time.
  This is the time interval elapsed between a command given by the operator (say, to put a power supply ON) and the answer of the system. 0.5 second seems a reasonable figure.

- Comprehensive error report.
  Messages such as "ERROR 185 in PRCK" should be avoided.

- No conflicts between different users.
  Concurrent control of the same parameters by two different persons on two consoles should be avoided or, at least, clearly indicated.

- A detailed and interactive ALARM system.

- GLOBAL operations and archiving facilities.
  One of the main goals for a control system.
  Ideally it should be possible to set an accelerator to a predefined operation by depressing a button.

  Etc...

IV) CONSOLES

In modern accelerator control systems [2], consoles are in most cases based on different versions of the same basic interactive and display tools:

- an high resolution graphical screen.
  The use of colours improves the performances.

- one or more color T.V. screen, used as main display for application programs.

- a certain number (2 to 4) of KNOBS.

- a track-ball or a mouse to select options in a "menu".

- touch-screen to access the hierarchical structure (Trees structure) of the application programs. In certain cases (PSR, Los Alamos) touch-screen and main display are the same device.

The use of keyboard, ancillary B & W screens, separate ALARM screen etc, depends on the particular taste.

If a centralized, analog signal observation is required, a part of the console must be devoted to this purpose and adequately equiped.

IV-1) ALTERNATIVE SOLUTIONS

The console paragraph is not complete without a glance to what is happening today and, more important, what it is foreseen on the market of the ready-to-use consoles.

A certain number of medium sized consoles (APOLLO, SUN) exists and their very competitive price must be carefully weighed against our control requirements. More recently, terminals have been developped that using as basic device a personal computer, can easily control several hundreds of parameters. They are called work station. One of such systems [3], based on a MACINTOSH Computer will permit soon to control several CAMAC crates in the LPI system, for test and measurements purposes (at the moment). All the previously described functions, as KNOBS, TRACK-Ball, Keyboard, Trees stucture etc.. are emulated by the use of the mouse, and the results are encouraging. If colours and bigger display are available in the future on such systems, they can seriously be considered also as alternative solutions to the huge and expensive consoles.

One can imagine to have in the MCR an adequate number of improved work stations, say 10 for example, instead of the 4 big consoles.

These devices must be, at least, considered as an alternative solution for the local consoles.

V) THE CONTROL SYSTEM LAYOUT

A quick survey on the characteristics of the existing accelerator control systems [2], gives this simple result: most of these systems use DEC computers and transmit data to the process using CAMAC.

The rest of the laboratories use different kinds of computers for specific or national reasons (e.g. CERN had to follow the rule "buy European !").

The fundamental options for most of the recent systems have been frozen in the late seventies or, in the best case, in the early eighties: that means about ten years before the presumable date for the implementation of the EHF controls.

The last years have been very rich in developement of new technologies and new ideas arose that are rapidly changing the general controls philosophy.

Unfortunately, we are in an important transition period: there are several tendencies and technical solutions that are being implemented with partial success; the lack of a sufficient operational experience does not permit to affirm that such computers or such transmission systems will be in the early nineties the universally accepted successors of DEC and CAMAC.

V-1) COMPUTERS

The trend in this field is the adaptation of the Latin sentence "divide et impera", that, in our environment could be translated as "distribute intelligence and you will better control the process".

Instead of having a few big computers, each one in charge of an important process, specific tasks are delegated to a large number of microprocessors that are housed in local crates or directly imbedded in the controlled equipment.

Microprocessors are today very cheap and this solution has evident advantages in flexibility and expandibility.

If the distributed intelligence seems today a concept universally accepted, what is not yet clear is the extension of such distribution: will the minicomputers totally disappear in process controls ?

Our personal opinion is that a few numbers (maybe only one or two) of relatively powerful computers should survive in the network.

In an army of clever, but independent people, it is still necessary to have somebody that at any moment knows what is going on all around. This (or these) computers should then act as concentrators: they could also be used as number crunchers.

V-2) NETWORK

This is probably the most crucial point.

Most of the control system's performances depend on the network's capabilities and speed.

One can have more than one network in the same control system: e.g. one network linking computers (if they exist) and another network to control equipments.

The adopted solution will depend on the detailed study of requirements and constraints.

Two kinds of network are mostly used or experimented with in these days:

- Networks asynchronous with collision detection, e.g. the ETHERNET.
  All the users access the bus at the same level of priority: collisions are adequately treated.
  Several examples exist in accelerators controls (FERMILAB, FMIT, LEAR etc..) with good results.

- Networks with sequential access, e.g. TOKEN RING, TOKEN BUS...
  Each user is given a TOKEN for all the time he is using the bus: priorities can be allocated in the use of the TOKEN. A TOKEN RING system is being implemented in the LEP controls.

  As general remark it seems that collision systems (ETHERNET) show better performances if the transfer rate is not very high.
  For very important data transfer rates, TOKEN systems seem more suitable.

  We will follow the evolution of these systems in next years.

V-3) CONTROL CRATES

CAMAC has been very successful mainly for its generalisation and consequently for the possibility to easily obtain modules off the shelf. Unfortunately, CAMAC has not been designed for an easy inter-crates communication: data have to be sent and received using a master computer.

With the actual strong orientation toward the local networks, the use of CAMAC should irreversibly decrease in the next years.

The most promising successor seems to be the VME bus; this bus, designed around the 68000 microprocessors, has already several applications in the accelerator control field [2].

For certain applications, e.g. power supplies controls, a cheaper low level bus, as the G64 could also be used.

V-4) SYNCHRONISATION

In pulsed accelerators controls it is necessary to implement some device that permits to send to all concerned systems information (trigger pulses) on the operations starts and eventually on the characteristics of the coming cycles (see PPM, VII).

Such a device should be imbedded into the control system from the beginning.

The actual implementation could be partially based on the use of a dedicated computer (ex. as at the PS COMPLEX) [6] or a programmed synchronisation box could be used.

As conclusion, investigations for the EHF controls layout must continue taking into consideration, for the next converging proposals, three simple recommandations:

1) make the proposals implementation independent,
2) try to include in the system capabilities for an easy up-grade,
3) when the project is frozen and money is ready, look to the market and decide !

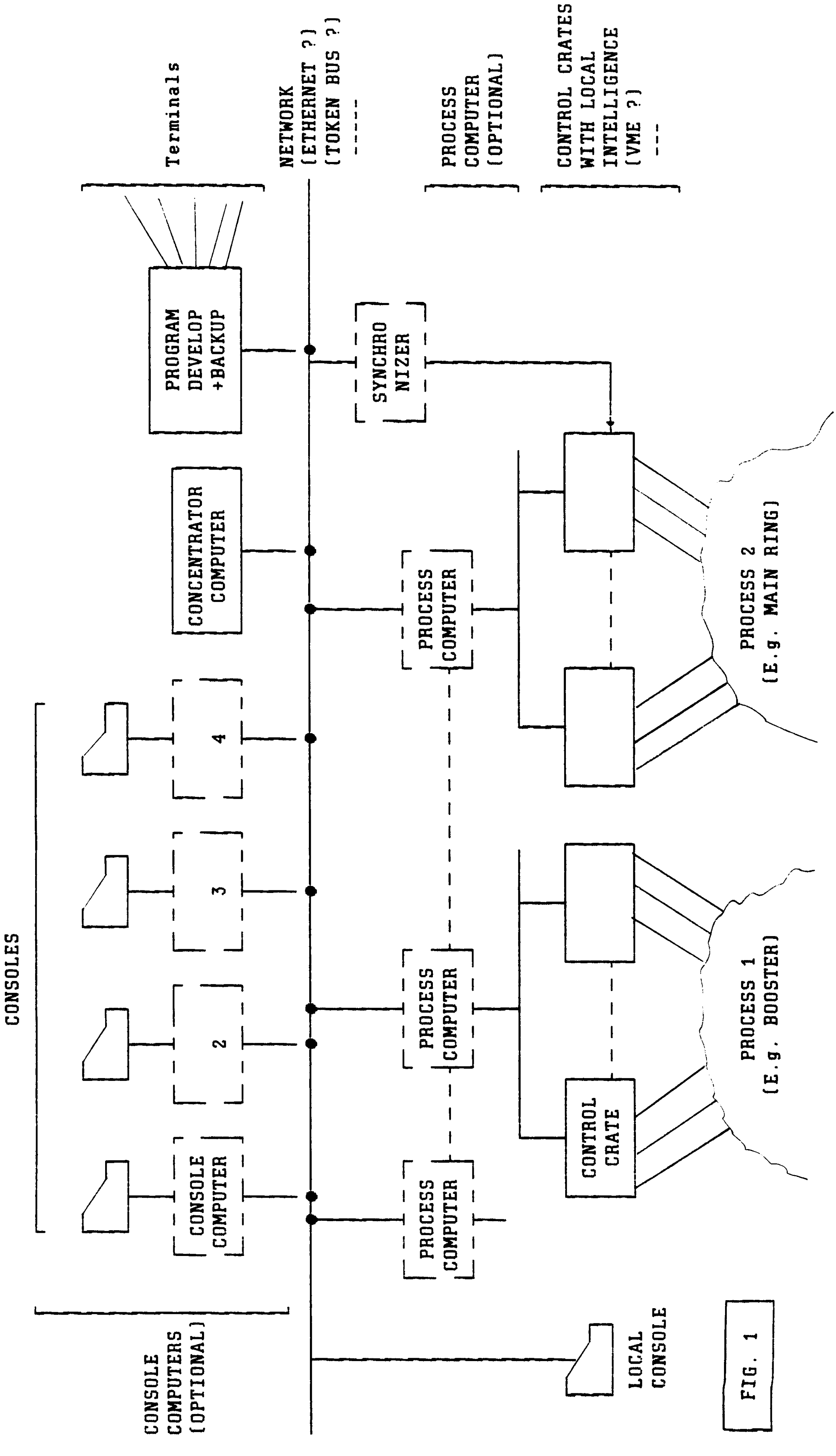
With these premises, Fig.1 should be considered not as a layout proposal, but as a representation of the essential components of a control system based on the present experience. The figure is self-explaining: we have represented in bold lines these essential components that will probably not change in a next future; the parts which present trends tend to eliminate are represented in dotted lines.

VI) LANGUAGES

The selection of appropriate languages in control systems is a controversial question.

Neither unification nor standardisation have been accomplished, and almost each laboratory has followed its own philosophy. In most of the American laboratories FORTRAN is mainly used: claimed advantages are its universality and its continuous up-grading in universities and in industries. In Japan (KEK) two versions of NODAL (the SPS invented interpreter) are used: one is interpreted and the other compiled.

In European laboratories different solutions have been implemented: NODAL is used at the SPS, P+ (an higly structured, home-made, Pascal derived language)


Terminals
NETWORK
(ETHERNET ?)
(TOKEN BUS ?)

PROCESS
COMPUTER
(OPTIONAL)
CONTROL CRATES
WITH LOCAL
INTELLIGENCE
(VME ?)

PROGRAM
DEVELOP
+BACKUP
SYNCHRO
NIZER
CONCENTRATOR
COMPUTER
PROCESS
COMPUTER
PROCESS 2
(E.g. MAIN RING)
CONSOLES
4
3
2
CONSOLE
COMPUTER
PROCESS
COMPUTER
PROCESS
COMPUTER
PROCESS 1
(E.g. BOOSTER)
CONTROL
CRATE
CONSOLE
COMPUTERS
(OPTIONAL)
LOCAL
CONSOLE

FIG. 1

is used in the PS Complex; other laboratories use the languages offered by the computers suppliers.

The ideal situation should be to use only a language for all kinds of applications (this is, e.g., the goal of P+ in the PS).

This goal is not easy to achieve:

- it is difficult to find on the market compilers of the same language for a large range of CPU.

- the requirements are different for different kinds of applications: in certain cases speed is essential, in other cases interactivity and flexibility are necessary.
  A third characteristic, the expansion factor (room occupied in memory), is less important today with the memory price rapidly decreasing.

With the present experience, we suggest to use three languages for the EHF control system:

1) a high level language for most of the applications. The choice could be between FORTRAN and PASCAL - like languages, depending on the importance given to the universatility or to the structuration.
   The ADA language (a product of the Department of Defence) could be a good candidate if more experience will be available in the next years.

2) a low level (or intermediate level) language. This is useful for time critical applications, mainly in the micropocessor field.
   A good candidate seems the C language.
   In case of applications very tight in time (e.g. the PPM or instrumentation treatment in microprocessor) also the use of assemblers could be required.

3) an interpretive language. The use of such languages is of invaluable advantage mainly for maintenance and test purposes.
   NODAL is a suitable candidate.

VII) THE PULSE TO PULSE MODULATION (PPM)

An accelerator controls design is not complete today if it does not include a paragraph on this subject. The PPM is the capability, for a pulsed accelerator, to produce particle beams of different characteristics in separate cycles.

It is not totally clear today if some or all of the EHF machines will run in PPM mode (e.g. protons, polarized protons, antiprotons, different operations etc..), but the implications of such requirements in the controls are so important that excluding this facility at the design stage could be very dangerous and expensive in the future.

Experience at CERN and elsewhere shows that during accelerator life operations became more and more complicated to follow new experiments and to test new ideas.

As an example, at the start of the up-grading project for the PS control system only a few tens of parameters where candidates for PPM: today the total number of PPM parameters amount to some tens of thousands, in practice the most of the controlled parameters.

The same is happening with the SPS controls.
It is highly advisable to be prepared from the beginning !

Independently of the specific adopted solution, the PPM implementation requires in general three [4] separate mechanisms: two of them are synchronized with the accelerator cycles, the third one is asynchronous.

a) the first (synchronous) mechanism permits to send to each physical element (power supplies, RF systems, trigger presets etc..) the appropriate setting value for the coming cycle.
Usually, it is implemented in local microprocessors (or in the intelligence attached to each device, if this solution has been selected): a data table contains the setting values for each element and for all existing machine cycles.
Hard real-time routines select the appropriate setting values and send them to the concerned elements. The use of low level languages and the proximity with the local hardware permit execution times of a few ms.

b) the second (synchronous) mecanism provides to the local intelligences information with the characteristics of the incoming machine cycle (see the "synchronizer" in V).
Using this information, the first mentioned mechanism can select the appropriate setting values.

c) the third (asynchronous) mechanism permits the operator to change setting values in the local intelligence tables.
This mechanism is realized by application programs.

The three mechanisms together realize a complete decoupling between the process needs that are synchronous with the machine cycles and the operator actions that can be completely asynchronous.

The first two activities must be carefully studied for the EHF having repetition rates of 40 - to 80 ms ! (15 - 30 times shorter than, for example, the PS cycles).

In fig.1, the presence of local microprocessors and of the synchronizer provide a basic support for an implementation of the PPM in the EHF.

VIII) <u>COSTS</u>

It is not easy to find in the literature indications of the costs of the accelerators control systems. Where this information exists, it does often not include the developments (hardware and software) done inside the laboratories (an exeption is, for example, the PS Complex) [5].

This is an important point. One must chose between two opposite situations: to buy the maximum on the market or to develop a lot inside the control group.

The implications of this choice are very important on the immediate costs, on the number of staff involved, on the subsequent maintenance etc...

It is too early to decide for one politic or the other; as a general statement our feeling is that we should try to buy as much as possible hardware and software on the market and do internal development only where really needed.

The total costs of a control system can be obtained, at a first approximation, by using a "rule of thumb" derived by the (scarce) experience on the existing systems: the cost varies between 7 and 20 percent of the total complex cost, and this percent is proportional to the inverse of the project size.

The reasons for this are that, also for small projects, a certain number of basic facilities are necessary.

The EHF falls into the category of the big project: a figure of 7 to 10% seems realistic.

IX) CONCLUSIONS

Without question, a computer control system that is responsive, reliable and expandable, can be fabricated for the EHF. It will incorporate the best features of previous systems along with the latest developments in control technology and modern hardware.

The final implementation will be designed in a way that allows to evolve readily to keep the EHF operating on the forefront of accelerator technology.

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