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PLANS FOR THE LEP CONTROL SYSTEM

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Summary

As part of the study of the LEP electron-positron storage ring, the influence of technological trends on control system design is being assessed. These include availability of cheap processing power and data storage at all levels, wide-band communication by optical fibres, new modular interfacing systems and software concepts. It is suggested that the LEP control system will be based on two principles : - location of real-time and signal-processing functions within the controlled equipment. Micro-processors will deal with sequencing, monitoring, program generation and the equipment will have to be designed appropriately from the outset to achieve the potential cost savings and improved flexibility. The equipment will be connected by serial lines to a global communications system, structured hierarchically, and performing no significant processing outside the system control computers. Control actions will be caused by messages rather than loading of individual words into registers. The paper describes how the above principles could be applied to LEP and mentions some of the practical difficulties.

1. LEP Control Requirements

The LEP electron-positron storage ring, as currently proposed, will have a circumference of 30 km, with eight equipment centres at regular intervals for the major electronic installations (klystrons, power supplies, controls and instrumentation) close to the intersection points[1].

In order to achieve acceptable average machine luminosity the time taken to fill the machine and accelerate to operating energy must be much less than the beam life time, which is about two hours. The target for the entire filling operation is 15 minutes, the acceleration from say 20 GeV injection to 80 GeV operation being performed in two minutes. It is envisaged that the acceleration process, which is the operation demanding the highest data transfer rates from the control system, will be pre-programmed in the local equipment. At the same time, beam observation data will be sent to the control consoles - for instance a complete orbit plot every 1 GeV - and that sufficient computing power and sufficient communications bandwidth will be provided to permit minor corrections to be made on-line, to the orbit and the tune.

The number of control and monitoring parameters in LEP is approximately 12'000. Many of these, such as vacuum pressure and chamber temperature indications, will require monitoring at all times to avoid damage to the machine or loss of the beams, and this task should be performed every few seconds.

It is clear that the operation of the machine, basically composed of ten or more filling cycles every 24 hours, must be highly automated and that very complete diagnostics must be provided so that any imperfection may be corrected. In view of the large physical size of the site, and the impossibility of manning all remote equipment centres at all times, there must be a sophisticated and totally reliable communications system around the ring.

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Furthermore, it is necessary to construct LEP to a very tight budget, so the cost of interfacing each element of the machine to the control system must be minimised.

2. Local Processing

Major items of LEP equipment, such as klystrons, power supplies and beam instrumentation will be provided with their own micro-processors. Advantage must be taken of the large scale of the LEP project to design these items for integrated micro-processor control. The sequencing, interlocks, monitoring and program generation will be performed by software: standard functions being implemented as 'firmware' i.e. in read-only memory, while maintaining the possibility of down-line loading special tasks into RAM. All instruments will be equipped with a standard communications interface handling two-way message flow, timing signals and requests for attention. In the vast majority of cases this interface will be incorporated as an integral part of the equipment, while in a few special cases, such as for instruments already equipped with a standard bus such as the IEEE-488, external adaptors will be required.

Local processing will reduce the data transmission load on the control system by implementing supervision, programming of operations and self-testing at the local level. Messages will be exchanged with the control centre only when necessary.

Classical interfacing techniques such as CAMAC generate a high unit cost for connecting apparatus to the control computers, this being largely due to the many transformations performed on the form of the data at the several levels of the interface system, and not least to cost of cabling and connectors. By adopting a standard serial interface, and by concentrating the signal processing in the top and bottom levels of the control system hierarchy, very considerable economies in production costs may be made. Furthermore, the conventional local control facilities may be removed, or drastically simplified. It is intended to provide many simple test sets for use in factory and on-site commissioning: these will be essentially intelligent terminals incorporating floppy discs for the test programs. A useful by-product of this approach will be to ensure that technicians in all equipment groups will become familiar with the computer control techniques, and will be able to maintain their equipment effectively.

In operation, control and monitoring commands will be sent to each unit of equipment in the form of messages, requiring interpretation. In this way, the concept of the 'data module'[2] is given its fullest possible decentralisation. A control computer need not take account of minor differences between units, and the individual components of LEP may evolve over the years without requiring changes to the interface systems, or even to the application software in the control centre.

3. Communications

The overall LEP communications facilities must deal with control system data links, timing signals, transmission of waveforms, television and voice communications, and the data links used for experiments. The facilities must be provided in a highly reliable, yet flexible, manner and may be expected to follow PTT

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practice in terms of supervision of data flow, error detection and correction, automatic switching to spare channels, etc.

As the major equipment centres are located around the LEP ring at intervals of almost 4 km, cable transmission is not able to offer adequate bandwidth at a reasonable cost, particularly if one wishes to avoid installation of repeaters in the tunnel. Alternative possibilities are being investigated, such as waveguides or optical fibres. The heavy shielding around the LEP vacuum chamber, coupled with suitable local shielding around optical fibre cables, may make it possible to use optical fibres in the tunnel.

The data communications network used by the control system will be a single, monolithic system as seen by the external users. It will be charged with the delivery of messages between any two ports with defined constraints for throughput and for maximum tolerable delay. The same network will be used for computer-to-computer communications within the control centre and for local communications in the equipment centres. It is clear that the internal structure of the network will have to reflect the traffic pattern for which it is specified, as the number of access points used will exceed 4'000 and the number of points eventually provided for must be even greater. Such a large number of physical access points implies a hierarchical structure of links with intermediate nodes, and yet the requirements for message transmission along certain paths will be similar to those of the much simpler networks used to line 20 to 30 control computers via a single message-switching node. It must be stressed that the data communications network will be tightly defined in respect of the service offered at each 'socket on the wall' and that the responsibility of the group providing this service will end at the socket. In consequence, the standard communication interface will need to be specified at the start of the LEP construction period, and will have to be of appropriate technical characteristics and performance to meet the operational needs 10 to 15 years later.

4. The Control Centre

The LEP control centre has to provide for the operation of a complex of several machines: linacs, synchrotrons, positron accumulator, and the main ring. It would be foolhardy to specify the layout and the computer configuration at the present time, but a few remarks can be made. Firstly, the performance of the time-critical tasks by local 'intelligent hardware' means that the control centre plays a mainly supervisory role, guided by the operators. Secondly, there are no major systems in the main ring which are localised to a particular octant, so that overall control of each system such as the r.f. must be coordinated from the control centre. Only the injectors should be provided with major quasi-independent system-control computers, and these are in any case quite close to the control centre.

Consequently, a modern multi-computer control system such as that of the SPS could be virtually transplanted to the LEP control centre with satisfactory results, from the points of view of hardware and of software[2]. Evolution in computer system technology between now and 1986 (earliest possible date for using part of the control centre) will cause some changes to be made to this concept. For example, many more processors will be employed for dedicated tasks such as generation of displays, as well as the variable tasks requested by the operators. It is probable that LEP operational optimisation will require a significant degree of parallel processing in view of the severe constraints on LEP filling and set-up time.

Flexibility in handling the varying requirements of the control system will be attained by use of an interpreter. Software modules which are complex and which are handled by the interpreter will be written in a good high-level block structured language. If this language can be the same as for the interpreter, so much the better.

As LEP may well be the last major machine built in Europe this century, its control system must be designed around computer-independent concepts and not around the characteristics of a particular series of computers from a single manufacturer.

5. Timing

High-precision timing signals will need to be sent over dedicated channels in the communications system. Other timing should be handled by means of 'event' codes transmitted to all parts of the LEP complex. These event codes will be used to synchronise all local processing tasks, such as beam monitoring and magnet power supply adjustment. Regular event codes can be transmitted at 1 ms intervals for local timing, together with time-of-day sequences every second. Other codes would signal major actions such as injection, or 1 GeV intervals reached in acceleration. In this way, all equipment could find out what was happening and take appropriate, pre-programmed action. It could even add the time of day to alarm messages, to facilitate later analysis. Recently developed l.s.i. circuits will permit the required event codes to be picked out of the incoming stream without imposing an unnecessary overhead on the local micro-processors. Event codes may be used to prime high-resolution timing systems so as to permit the expensive wide-band timing channels to be shared.

6. Problems

The vast size of the site implies that automatic operation and fault diagnosis must be given even greater emphasis than usual. The large size of the machine also implies that a very tight control must be maintained on the working conditions. The very long cycle time (2 hours) compared with synchrotrons implies an avoidance of trial and error techniques in optimising performance. In consequence, the control algorithms must be prepared and tested meticulously in advance of the commissioning of the machine rather than concurrently, and powerful simulation techniques will be required.

The long construction period, estimated at 6 or more years, will see many technological improvements, and yet the standards for parts of the hardware and software will need to be established by the start of this period and remain valid at its end.

Integration of the control hardware and some software into the controlled equipment will require closer collaboration between the controls specialists and the equipment specialists than ever before. (This is inevitable in any case, and does not need the stimulus of the LEP project).

7. Development Work

In the framework of the LEP study, the main activities over the next two years will be the following :

- evaluation of the controls requirements of the various LEP systems, main ring and injectors,

- evaluation of wide-band communications facilities such as optical fibres, coaxial cables and waveguides in relation to the LEP performance and installation criteria.

- communications system studies and modelling.
- investigation of hardware and software techniques for local microprocessing in LEP equipment.
- investigation of the possibility of reconciling use of interpreters such as NODAL with use of highly structured programming languages such as Pascal.
- assessment of hardware and software standards for micro-processor based equipment.

8. References

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[2]M.C. Crowley-Milling, 'Experience with the Control System for the SPS', CERN 78-09, 21st December 1978.