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STATUS OF THE NATIONAL SYNCHROTRON LIGHT SOURCE CONTROL SYSTEM*

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E. Bozoki, B. B. Culwick, and J. D. Smith
National Synchrotron Light Source
Brookhaven National Laboratory
Upton, NY 11973

Abstract

The control system for the National Synchrotron Light Source is implemented using dual central computers and many remote microprocessors.[1] This paper describes developments in four areas: 1) System organization. 2) Hardware status, particularly control desk and operator support facilities. 3) Central computer software system organization to support data base structures and access, and communication between application programs and hardware. 4) High level control programs which allow the operator to examine and control the transport lines and rings in terms of beam and machine parameters using mathematical models of the system. The output of these programs can be viewed on a color graphical display.

System Organization

The general organization of the NSLS control system is described in reference (1). The system as currently implemented is shown in Fig. 1. This configuration is adequate for initial operation of the accelerator complex but offers extremely flexible expansion possibilities to meet future needs. Expansion can be implemented at three levels:

1) Addition of almost any Data General processor to the MCA network. This would be appropriate for the support of additional control desks, independent activities unrelated to operator procedures etc. or to provide additional CPU power for calculational needs.

2) Addition of any processor to the serial, asynchronous network. These could range from microprocessors to mini or larger processors with coupling limited by the 38.4 K baud link rate. Additions would be appropriate for additional accelerator hardware, experimental data acquisition, building services interface, etc.

3) Addition of MULTIBUS (© Intel) interfaced processors to the existing microprocessors. The "multi-master" contention capability of the MULTIBUS allows additional processors to communicate with peripheral devices and memory on the MULTIBUS. This is appropriate where accelerator hardware requirements preclude use of the basic microprocessor or where system modularity considerations suggest a dedicated processor.

Option 3) is the only one actually planned at this time but the expansion capabilities at other levels offer satisfying insurance against future demands.

Hardware Status

The two Eclipse S-250 computers with their conventional peripherals are fully operational linked by the two MCA's used for network communication and utility 250 to 250 communications respectively. The operator's control desk interface has been constructed with keyboard, joystick, and multiple alphanumeric displays coupled to the S-250 via a microprocessor which allows 4 time-shared ports on the S-250 to be operated simultaneously. Output is displayed in parallel while the input facilities can be steered to

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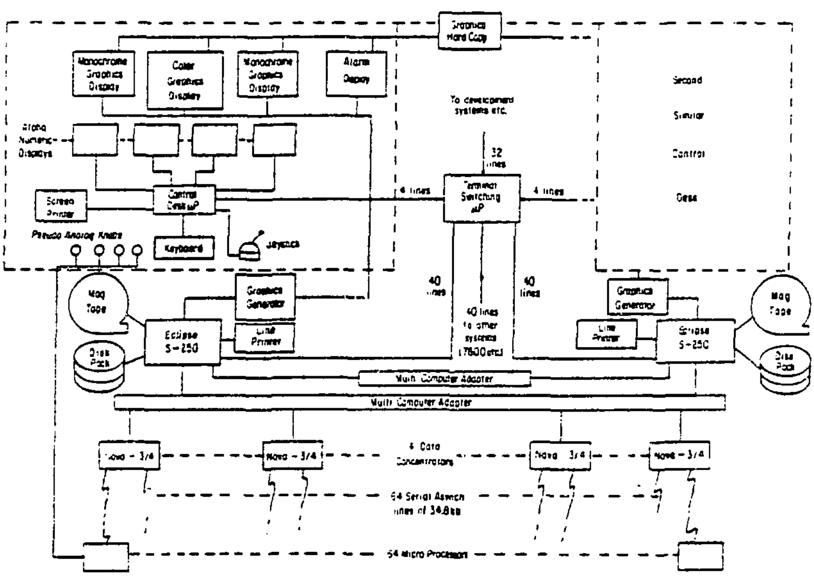

Figure 1. Control System Configuration.

whichever program requires input at any instant. This facility permits generous di:olay capability and very rapid, one-button switches between programs. The additional program switch capability via the S-250 operating system typically takes several seconds and is used for less frequent operator context switching. Eight simulated analog control knobs are supported by another microprocessor connected to the serial network. After initial assignment of a knob to a variable by command issued from the S-250 to the knob microprocessor, only microprocessor to microprocessor network communications are required to control the assigned variable. This permits a few millisecond response time for adjustments. In practice data is updated every 100 ms and only when it has changed. This application illustrates the precise functional capability of the dedicated microprocessor which is exploited throughout the control system. The color and monochrome graphical displays drawn by Genisco GCT-3000 raster generators are fully operational but the S-250 interfaces on not quite stable. The four NOVA data concentrator/buffers which provided the serial network switching capability are operational. Microprocessor implemented include timing system support, power supply control for static and slowly varying supplies, vacuum pump control and pressure monitoring, function generator control for synchronous, time dependent applications, pulsed power supply control and diagnostic equipment interfacing processors. The prototypes for these applications are all operational and, in most cases, replication of functionally identical processors is complete or nearing completion. Major areas still to be implemented include radiofrequency systems and beam line valve control.

Systems Software Status

The S-250's operate under Data General's Advanced Operating System with which up to 64 processes and 32 terminals are supported on each processor. About 6 processes support extended functions of the manufacturer's operating system and 4 more provide shared functions for the NSLS control system. The remaining processes are available for the specific operations of the NSLS project, ranging from conventional data reduction and documentation through data acquisition for magnet measurements to cross assemblers for microprocessors and real-time access to accelerator equipment. The total demand constitutes a heavy load for a single processor. An attempt is made to assign real-time activities to one processor and development activities to the other. The development processor acts as backup to the real-time processor when system activities or, rarely, a hardware failure remove it from operation. This division of responsibility is managerial and not required by any system restrictions. Application program access to the MCA network, the graphic display driver and device data base is implemented via operating system supported shared memory and interprocess communication procedures written by Point Consulting (now Logical Solutions) to NSLS specification. Very extensive file structures are used in both operation and development and are ably supported by the operating system. In particular, a data base describing the fixed properties of the accelerator components is maintained on disk and accessed via temporary copies in a large main memory buffer. This procedure and a library of suitable routines provide application program access to device address paths, device properties and calibration constants, etc.

The NOVA data concentrator/buffers operate under a store-and-forward message switching code developed by Data General personnel to NSLS specification.

The accelerator interfaced microprocessors operate under an NSLS developed monitor which controls and buffers message receipt and generation and provides dispatching and elementary scheduling for dedicated code. The specific code for microprocessor applications is assembly coded and tightly interfaced to physical device properties. This code serves to control and protect equipment, monitor its performance and presents a consistent, rational and efficient interface to the network to simplify control procedures. The essential functions of the microprocessors are translations to provide this interface and device support which could not be provided without these dedicated processors. Microprocessor code is developed by means of a cross assembler operating on the S-250's and loaded down via a terminal access line into read/write memory temporarily installed in the micro. When suitably verified this code is intalled in read-only-memory for final system operation.

High Level Control Programs

Although a set of ON/OFF/SETPOINT ADJUST programs is available for debug and test purposes, it is the object of the control system to operate the accelerators via high level programs which adjust hardware settings in terms of beam and accelerator parameters using mathematical models of the accelerators. Two high level control programs have been developed, TRANCO[2] for the transport lines and RING* for the accelerator and storage rings. These programs are "data-driven" so that TRANCO can be used for any of the transport lines (Linac to Booster, Booster to VUV, Booster to X-ray) and RING for any of the rings (Booster, VUV or X-ray). The characteristics of the different lines and rings are stored in a system data base and they "drive" the program to call on the appropriate models.

In operation, the programs access the appropriate microprocessors via the network to obtain the current settings of magnet power supplies and accept operator input defining desired conditions and options. They then calculate a new group of settings and the corresponding derived variables which will result from these settings. The new settings may be, optionally, transferred to the power supplies.

Each program can perform the following tasks:

1) Control task; controls adjustable power supplies via the network and microprocessors.

2) Evaluation task; on-line evaluation of data from microprocessor controlled diagnostic instruments. The results of these calculations are used in the control task and can be displayed by the information task.

3) Information task; to help quick decision making and to visualize the consequences of a given set of magnet strengths. A status report of the beams and accelerators can be printed or displayed on the color graphical display.

Control Tasks

The following operations can be performed by TRANCO:

1) The phase ellipses can be matched at the end of the transport lines and dispersion can be controlled by adjusting designated quadrupoles.

*This is an adaptation of the SCORE[3] program written at PEP.

2) A horizontal waist can be made at the desired location by adjusting a quadrupole triplet.

3) The phase ellipses at the end of a transport line can be positioned with respect to the acceptance ellipse by using two pairs of horizontal and vertical correction dipoles. (In some cases a septum magnet is used in lieu of one of the correctors.)

4) The beam can be steered through the desired trajectory by adjusting the strengths of dipole correctors.

RING can perform the following functions:

1) The lattice parameters ($\nu_x, \nu_y, \beta_x, \beta_y$, etc.) can be changed by adjusting the ring quadrupoles in a sequence of sufficiently small changes to avoid beam loss.

2) The chromaticity of the ring can be changed by adjusting the ring sextupoles.

3) The closed orbit (around a ring) can be corrected by finding the most effective correction dipoles and adjusting their strengths.†

4) The closed orbit can be distorted locally to achieve a specified displacement or slope at a given point by adjusting the nearest correction dipoles.

Certain options make the programs more flexible.

1) NO FIT option. This option performs calculations with current magnet strengths and reports on the current system status.

2) GO/NOGO option. After calculating new settings, they are presented to the operator who can accept or reject their transfer to the equipment.

3) GUIDE option. The control task can be supplied with operator defined starting values for selected magnet strengths in lieu of the actual current values.

Data Management/Data Base

Conceptually, all data fall into one of four categories and are treated accordingly.

†This is a version of the CERN MIKADO[4] program.

1) Permanent data characteristic of the transport line or ring. These data "drive" the program and are kept in disk data files which are read by the program.

2) Temporary data including operation to be performed and options selected in addition to temporary values of accelerator parameters. These quantities are entered by the operator via the control desk keyboard or other terminal.

3) Variable data. These include magnet strengths and measured data from position monitors, profile measuring devices, etc. These parameters are read from the microprocessors controlling the devices.

4) Calculated data. Data calculated by RING or TRANCO are stored in random access disk data files. The data in these files can be printed or displayed and redundant calculation is avoided by sharing results between the programs. Permanent files can preserve data for later use and record keeping.

Program Organization

Both RING and TRANCO are modular in design; different subtasks (model calculations, iteration, network access, etc.) are executed by modules under control of a driver module. Program size limitations led to the decision to group the display programs (written for a Genisco GCT-3000 by Genisco Corp. using the GRAFPAC II graphic package) as an independent DISPLAY program. TRANCO, RING and DISPLAY can be activated from the control desk or a terminal. DISPLAY can be called from TRANCO or RING, returning to the calling routine on completion. Data are communicated between programs via random access data files. Figure 2 shows the execution and data flow.

References

1) K. Batchelor, et al., Distributed Control System for the National Synchrotron Light Source, IEEE Trans. on Nucl. Sci. 26, 3387 (1979).
2) E. Bozoki, Users Guide of the TRANCO program, Informal Report BNL 28752.
3) PEP I&C Group and Theory Group: PEP Computer Control System, IEEE Trans. on Nucl. Sci. 26, 3268 (1979).
4) B. Autin and Y. Marti, Closed orbit correction of A.G. machines using a small number of magnets, ISR-MA/73-17.

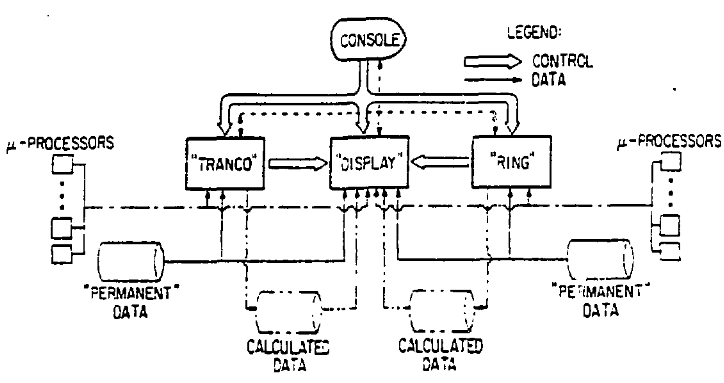

Figure 2. Execution and Data Flow for TRANCO, RING and DISPLAY.