THE SLC CONTROL SYSTEM – STATUS AND DEVELOPMENT*

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Abstract

The SLC control system is installed and operational in the full SLC through the Linac, Damping Rings, Positron Source, Arcs and Final Focus. The system now includes a host VAX 11/785, a development VAX 11/780, 4 VAX workstations, a distributed network of 70 microprocessors, and about 270 Camac crates with more than 4000 modules. The micros are used for control and monitoring of the hardware, for pulse-to-pulse feedback, and for consoles (COWs). High level model-driven host software provides a variety of tools for beam setup, optimization, diagnosis, and stabilization. This paper will summarize the current status and projects under development.

Introduction

The Stanford Linear Collider (SLC) will provide high-intensity electron-positron colliding beams at a center of mass energy of 100 GeV[1]. All major components of the machine are completed and commissioning is in progress. The SLC control system is installed throughout the machine and provides monitoring and control for the entire SLC complex. The basic hardware and software architecture has been described in detail in previous publications[2,3] The emphasis here will be on recent additions to hardware and high-level software.

Hardware

The SLC host computer has been upgraded to a VAX 11/785 with 24 Megabytes of memory. The backup and development machine is a VAX 11/780 with 16 Megabytes of memory. Both machines are heavily loaded, especially during prime daytime hours, and additional CPU power and I/O bandwidth is badly needed. Four VAX GPx workstations have been added to the system. They are used primarily as consoles, each running a local copy of the SLC control program. Due to the architectural constraint of a large database and other shared data structures resident on the 11/785, they have not been as successful at providing additional CPU capacity as originally hoped. They are described in detail in Ref. 4. All of the VAXes are connected over Ethernet and run the VMS operating system. There is currently a development project to investigate the possibility of distributing the database to the workstations using DEC local area clustering software[5].

The SLC control system includes almost 70 microprocessors, of which 60 are Multibus Intel 86/30 SBCs with 0.75 - 0.875 Megabytes of RAM. Communication with the host is over SLCNET[6] a 1 Megabaud polled network using an SDLC protocol on a subchannel of the SLC broad-band CATV Communications Line. The local microprocessors are geographically distributed and provide monitoring and control of all hardware through CAMAC. A few special purpose micros are used for the Master Patten Generator, Fiducial Synchronizer, Fast Feedback systems, and Final Focus Machine Protection. There are a total of about 270 crates and more than 4000 CAMAC modules in the full system. A wide variety of hardware controllers and CAMAC interface modules have been developed to meet the tight tolerance and stability requirements of the SLC. These have been described in detail in other publications and in the SLC Hardware Manual[7].

An additional 9 Multibus Intel 86/12 microprocessors are used for the consoles (COWs)[8] which provide the operator interface to the SLC control system. They are currently being enhanced to drive extra general-purpose status displays in the Main Control room. With the addition of the workstations, three versions of the console are now supported: the COW with full graphics and touch panel support, the GPx workstation, and the CALF which runs on a standard terminal, either with or without graphics capability. As many as 24 consoles (9 COWs, 4 Workstations, 11 CALFs) may be in use simultaneously.

System Software

The system communications and device control software in both the Host and microprocessors has been in operation since 1983. As additional parts of the SLC have been commissioned, this has been expanded to support new hardware such as the ARC magnet movers and a wide variety of new beam diagnostics. In the present implementation, most routine checking and database updating is done at the request of a monitor process in the Host. A future project will migrate more of this functionality to autonomously scheduled software in the microprocessors.

Klystron stability is of crucial importance to the successful operation of the SLC. New software has been developed to provide fault monitoring, online analysis of the energy gain of individual stations[9], online analysis and correction of modulator timing, automated measurement of the klystron phase with respect to the beam, and other diagnostics. These have assisted in the energy upgrade of the Linac to the current maximum of 52.9 GeV[10]. A project under development will provide a fast indication of klystron faults to enable rejection of data from single bad pulses. More diagnostics are also needed to rapidly and reliably identify problem stations. Software to replace a faulted station with an available spare and reconfigure the machine to the new energy profile exists in a prototype version and will be enhanced.

Modelling Software

Online software using machine models has been fully integrated into the SLC control program for each console and is described in detail in Ref. 11. The settings of all optical elements are determined according to the desired machine parameters such as energy, phase advance per cell, etc. Once calculated, these settings may be saved as a configuration and restored at a later time. Automated orbit correction is used to stabilize the beam trajectory[12]. Callable utilities provide analysis of energy and orbit errors into the Damping Rings, Linac, Positron target, Arcs and Final Focus. There are also an expanding set of tools for lattice diagnostics and simulation

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studies. Online matching of optics and integration of more sophisticated model-calculation programs (e.g. DIMAT) are in development. Additional high-level applications packages are available to make automated emittance[13] an dispersion measurements. Tailored software will correct the dispersion in the Final Focus, optimize the focussing of the beams at the collision point, and bring the beams into collision by analyzing the beam-beam deflection.

Feedback Systems

A major recent addition to the SLC control system has been the development of closed-loop feedback for stabilization of the machine. A support process running on the Host 11/785 controls all slow (time scale on the order of minutes) feedback loops[14]. Already implemented are loops to stabilize the timing of kicker magnets, to compensate for temperature variations in the Main Drive Line which distributes RF to the klystrons, and to stabilize the energy, energy spread, position and angle of the beams at critical points in the machine[15,16]. A uniform interface was developed to allow the operator to monitor and control these loops from the console.

For some parameters of the SLC, operational stability can be significantly enhanced by making corrections on the time scale of a few pulses or even on a pulse-to-pulse basis. This type of feedback control is provided by dedicated microprocessors. Two such processors are being commissioned to monitor the electron and positron beams at the end of the Linac. One micro will stabilize the energy and energy spread of the beams entering the Arcs[17]. The other will reduce longitudinal wake fields by controlling the injection into the Linac from the Damping Rings[18]. Two more processors will be used near the Interaction Point to read and analyze data from the Beamstrahlung monitors, and to keep the beams in collision. These will be implemented in the next few months. A prototype interface provides operator control of the feedback micros but more work is required to fully integrate these systems.

Conclusions

The SLC control system has successfully supported the commissioning of the SLC. Essentially all of the hardware is installed and operational. Model-driven software is online and used to configure and control the machine. Closed-loop stabilization has been successfully implemented in several areas and more work is in progress. There are remaining response-time problems with the heavily loaded Host CPU and improvements are under study. As the SLC moves from the commissioning phase to providing stable luminosity, a continuing effort will be required to develop better tools to assist operations in quickly identifying malfunctioning hardware.

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