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Correlation Plot Facility in the SLC Control System*

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Abstract

The Correlation Plot facility is a powerful interactive tool for data acquisition and analysis throughout the SLC. A generalized interface allows the user to perform a wide variety of machine physics experiments without the need for specialized software. It has been used extensively during SLC commissioning and operation.

The user may step one or two independent parameters such as magnet or feedback setpoints while measuring or calculating up to 160 others. Measured variables include all analog signals available to the control system as well as a variety of derived parameters such as beam size or emittance. Various fitting algorithms and display options are provided for data analysis.

A software-callable interface is also provided. Applications based on this facility are used to phase klystrons, measure emittance and dispersion, minimize beam size at the interaction point and maintain beam collisions.

Introduction

During the development of the SLC, the wide variety of machine experiments to be performed required software to allow the online acquisition, analysis, and display of a large number of different types of information. Rather than design and develop a different piece of code for each combination that might be of interest, the Correlation Plot facility was planned as a generic utility where many different types of information could be obtained from a large number of different devices. It was also designed to be easily extensible as new types of data were required. Due to the initial success in the implementation, a callable interface was provided so that other packages could take advantage of the plotting and fitting functions provided. This also provides a more consistent interface for other parts of the control system.

Organization

The main components of the Correlation Plot facility are:

- A general control package that can step the setpoints of magnets, klystrons, feedback loops, timing parameters and other devices.
- A general data acquisition package that can acquire information from a variety of sources, including high-level parameters derived from analysis of klystron fast time plots or wire scans.
- A variety of curve fitting algorithms, including average, linear, polynomial, gaussian, sinusoidal, and the specialized beam deflection curve.
- A general plotting package to display the acquired and fitted data. The sampled data may be plotted against the step variable, any of the sampled quantities or the step number.

For data acquisition, the user may select either manual or automatic mode. In automatic mode, the software runs the step variables through a range determined by the operator. In manual mode the operator requests a data point by pressing a button on the touch panel. At each of the steps, the acquisition may wait a specified settling time before all of the sampled data is acquired.

Interfaces

Touch panels

The Correlation Plot facility is an integral part of the SLC Control Program (SCP)[4]. The main user interface is by means of touch panels although the same functionality may be provided by a mouse, track ball or cursor keys, depending on the hardware. The main panel provides buttons for specifying the step and sample variables, selecting the range of the step variable, and setting other acquisition parameters. A generalized input parser interprets the input in a context sensitive manner where the meaning of each token depends on the valid tokens already accumulated. At any point a list of the valid responses may be requested to guide the user.

From the touch panel and keyboard, the user may initiate data acquisition, terminate acquisition or temporarily pause during an acquisition sequence. After data is acquired, display panels allow selection of fit and plotting options. The user may request displayed or printed plots as well as tabular displays. Capability is provided for users to manually exclude or include selected data points and recalculate fit parameters. An auxiliary output panel allows the user to save data to disk files in various formats for subsequent offline analysis. An option is also provided to reload previously stored data files for further analysis and

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display. In the same manner, the set of control and sampled variables may be saved and reloaded.

A generic optimization feature is also available; users may set up a correlation plot to vary a step variable, obtain sampled data for each point, fit a parabola to the data and implement the value of the step variable which results in the fitted minimum.

Callable routines

All of the actions that are accessible via the operator interface are also available to software control. This makes it very easy to develop a layered application using well known building blocks. Callable functions support setting up variables and other data acquisition options and acquiring data. Applications may retrieve the data after it is acquired, or request data fitting and retrieve the fit parameters. Routines are also provided to select plots for display. Some applications acquire data through specialized protocols and then use the correlation plots for fitting and display functions.

Capabilities

Monitoring

Correlation plot support is provided to measure or calculate a wide variety of data. Up to 160 variables may be sampled within a single acquisition sequence and up to 100 data points are saved for each. Measured parameters include beam related data from position monitors or toroids, analog values from devices such as klystrons, magnets, thermocouples, vacuum pumps, etc. and the current time. For klystrons, in addition to simple analog values the user may sample values derived from an analysis of a 64 pulse Fast Time Plot such as phase and amplitude jitter, energy gain of the station or perveance. This makes it possible to quickly scan the energy gain as a function of klystron phase to find the optimum setting, or to map out buncher jitter as a function of phase shifter setting in the SLC injector.

Other calculated quantities available include energy, energy spread, particle yield and beam position or deflection angle at the IP. Residual dispersion at the collision point may be measured non-invasively by correlating position and angle at the IP with energy fluctuations. In addition, interfaces to other applications allow sampling of various derived quantities such as beam states calculated by feedback and beam sizes, emittance and skew parameters determined from wire scans, beam scans, or profile monitor digitizations. These quantities are used in a wide variety of beam optimization procedures. Finally, a generic data acquisition capability allows user-provided ASCII command procedures to be used in data acquisition; this allows easy expansion to accommodate devices which are not standard for the SLC control system.

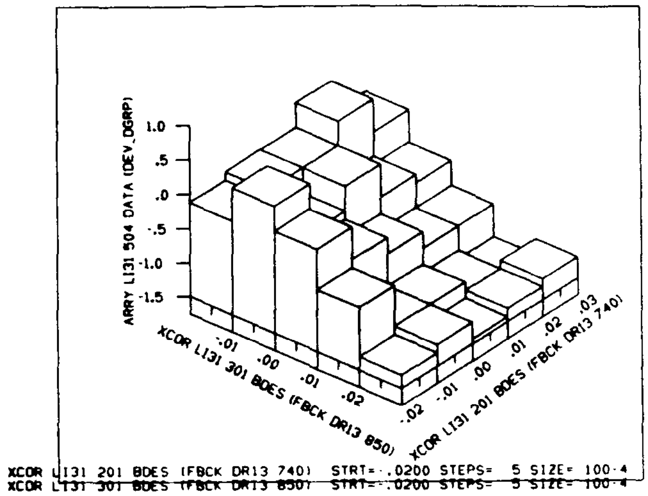

Figure 1: Results of 2 Variable Plot

Control

The user may select to use either one or two step variables. Most of the variables available to software control have been implemented. These include:

- Setpoints of magnets or other analog control devices
- Klystron setpoints, including amplitude, phase, and timing
- Timing delays for any triggered devices
- Combinations of devices through the Multiknob facility
- Setpoints of feedback loops stabilizing the beam [3][1]
- Time

For many experiments, the Time step variable provides a simple delay between samples in order to study the time structure of variations in normal running. Users can study correlations between sampled variables without modifying any control parameters. Most of the time only one step variable is used, so a third has not been considered necessary. When two step variables are used, they define a grid of values and the second is stepped through the whole range for each setting of the first. A display for two step variables is shown in Figure 1.

Data reduction

To aid in the analysis of the data, a variety of fitting routines may be used. These include average, linear, polynomial, sinusoidal, gaussian and beam deflection fits. The selection of fitting algorithms may be accomplished by user selection from the touch panel or by application software. Figure 2 shows the special beam-beam deflection fit which is used for optimizing collisions and estimating beam size.

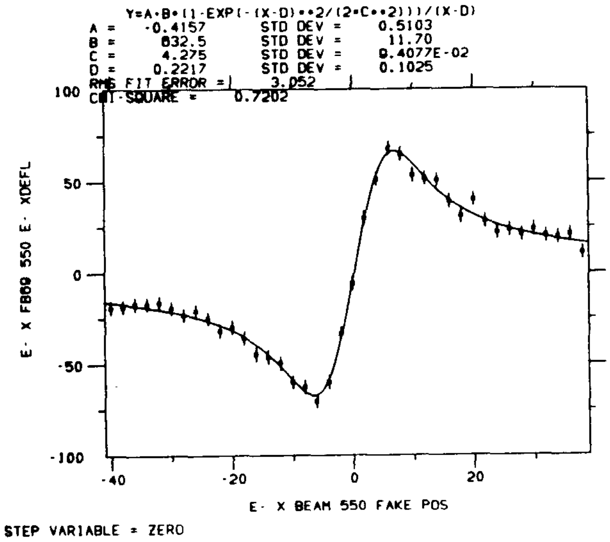

Figure 2: Fitting of Beam-Beam Deflection

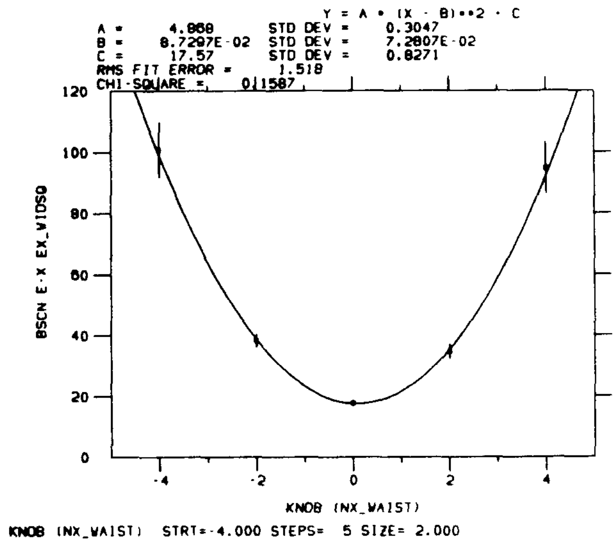

Figure 3: Beam Waist Optimization using Beam Scans

Applications

Various software applications used in the SLC have been built upon capabilities of the Correlation Plot facility. Automated wire and beam scan applications are used to optimize beam properties at the interaction point and minimize spot size. Auto beam collision software brings the beams into collision at the interaction point and provides calculations of beam sizes and luminosity. In several locations throughout the SLC, wire scan applications[2] provide measurements of emittance parameters and beam skewness. Another emittance package determines beam parameters by varying quadrupoles and measuring wire scan or digitized profile monitor data. A general package supports dispersion measurements throughout the machine. In the Linac, an automated application is used to determine optimal phases for the 240 klystrons.

Figure 3 is produced by an application which optimizes the interaction point waist position. For this plot, each point of the Y axis represents a beam width-squared as determined by a beam scan deflection fit. Each X axis point is a setting for a multiknob which adjusts the final quadrupoles to move the focal point along the beam line. The center of the parabola is the optimal waist position for the beam.

Conclusions

The Correlation Plot facility has proven to be an extremely powerful tool for the analysis of the new problems associated with the commissioning of the SLC and for building software applications. The flexibility provided by the different types of variables that may be controlled and monitored has allowed operators and machine physicists to rapidly design and execute a vast assortment of experiments without new software. In fact the Correlation Plots are used so extensively that most experimental data presented comes directly from the Correlation Plots and it is extremely rare that data needs to be plotted offline. Even for complicated experiments where further analysis is required, the Correlation Plots provide the data acquisition and online validation. The Correlation Plots facility has made an essential and invaluable contribution to SLC development.

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