High-level control programs at NSLS*

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Overview

The mathematical model of an accelerator can be used to control its operation and also to simulate its behavior. Through the use of such modeling programs it is possible to control a few important machine parameters rather than the many individual magnets. Such programs have been implemented for the current generation of accelerators.

At the NSLS, two control program systems have been developed; TRANCO¹ for the transport lines and RING² for the accelerator/storage rings. These systems are modular, can be used independently or in conjunction with each other, can communicate with each other via sequential and random access data files and has a common data base. There are modules for computation, control, display, measurements, data base manipulation, etc. [Fig. 1 shows the interaction of some of the main modules and the data flow.]

Fig. 1.

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The programs are data-driven, so that they can be used for any transport line or ring. The characteristics of the different lines and rings are in the system's data base and they "drive" the program to call on the appropriate models.

All programs can be used (a) on-line for measurements and control or (b) off-line as a tool for exploration and design. Color graphics are available in either mode.

In the on-line mode, they access the appropriate μ -processors to obtain the current settings of the magnet's power supplies and/or the current digitized monitor readings. They also accept operator input specifying desired conditions and options.

The programs then calculate a new group of settings and the corresponding derived variables which will result from these settings. Upon examination of the results (colored graphic and alphabetic displays are available) the new settings may be transferred to the power supplies.

Calculations & Operations

TRANCO uses first order 6×6 transport matrices (similarly to the TRANSPORT code) to calculate phase ellipses, beam matrices and emittances. The following operations can be performed. (1) phase ellipse matching at the end of the transport line by adjusting designated quadrupoles (2) waist can be made at the desired location by adjusting designated quadrupoles, (3) phase ellipses can be positioned at the end of the transport lines with respect to the acceptance ellipse by using H & V correction dipoles (in some cases the septum magnet is used in lieu of one of the correctors) (4) beam can be steered through the desired trajectory by adjusting the strengths of correction dipoles (5) emittance can be calculated.

RING uses two (H & V) first order 3×3 transport matrices (similarly to SYNCH) to calculate beam and lattice parameters such as tune, Twiss parameters, dispersion, chromaticity, beam sigma, synchrotron integrals and the like. The following operations can be performed (1) tune (or other lattice parameters) can be changed by adjusting certain quadrupoles (2) the chromaticity of the ring can be changed by adjusting sextupoles (3) closed orbit can be measured (4) closed orbit can be globally corrected by finding the most effective correction dipoles and adjusting their strengths (5) closed orbit can be distorted locally to achieve a specified displacement or slope at a given point by adjusting the nearest correction dipoles, (6) orbit changes as a consequence of specified kicks around the lattice can be calculated.

Data Base

Conceptually, all data fall into one of four categories and are treated accordingly.³

- 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 (a) from the microprocessors controlling the devices in the on-line mode or (b) from data files in the off-line mode.
- 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 program modules.

Model Calibration

The control and predictions from the above programs are as good as the models themselves which are used by the programs. All models represent a simplification, thus introducing deviation of the real machine from its mathematical model. The accuracy of the model is limited by the approximations made in describing the structure and components of the accelerator and the behavior of the beam, by the omission of some effects from the model and also by the errors and uncertainties of magnet calibrations which are incorporated into the model.

An alternative or complimentary method to the magnet calibrations, a method which empirically eliminates the effect of all inaccuracies is the calibration of the model⁴ itself through calibration of "physics" quantities (e.g. tune, dispersion, chromaticity, etc.) from measurements on the operating machine (see Fig. 2).

This is possible, since all NSLS rings were designed to have modular control features; that is certain groups of magnets are used to control only specific "physics" quantities. There is one family of quadrupoles in each ring which is adjusted to control dispersion, there are 2 (or 3) families of quadrupoles to control the H&V tunes (and one other measurable machine parameter in the X-ray ring), there are 2 families of sextupoles to control the H&V chromaticities.

Fig. 2.

The advantage of this method is, that it compensates for any inaccuracy in the magnet measurement. Actually, there is no need for magnet measurements at all, which might be of great help for super large accelerators where accurate measurement of all magnets is very time consuming and costly.

There are effects, not directly included into the model, whose significance are different under different operational conditions. This introduces some inaccuracy into the model calibration. For example, as the beam intensity is increased, different beam instabilities will be important and they effect the measured tune.

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