ONLINE BEAMLINE CENTERING AT PSI

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Abstract
Primary beamlines at the PSI accelerator are equipped with automatic stabilization of the center of gravity of the particle beam. Position pickups, steering magnets and the control system are used for this process. The hardware, the software with the used algorithms and the implemented data structures are explained. The upgraded package includes an Oracle database, the prediction of the steering influences based on actual magnet settings and the closed loop control process. Included are auxiliary programs for development and maintenance. Over 10 years of experience in operation, performance, and encountered problems are explained. Plans for future improvement and enhancement are outlined.

1. PSI Situation of Accelerators and Beamlines

The cyclotron accelerators at PSI produce beams with intensities exceeding 1.5 mA. These beams are split in two places to provide simultaneous service for different facilities

2. Control System

The control system implements a classical distributed architecture. Front end computers are HPrt_743 risk processors in VME with the HPrt operating system. Serial CAMAC loops are used for the process interface. The communication is based on Ethernet and implements a message oriented protocol developed in house. OpenVMS Workstations form the operator interface.

3. Reason for online beam centering

The high intensity beams have a power of up to 1 MW within a few square mm's. This demands a high stability in the beam trajectory so as not to destroy delicate components that need to be near to the beam. The small apertures at collimators and targets and the requirements from experiments demand high stability for beam position. Instabilities are caused for instance by discharges in electrostatic elements or the accelerating cavities. An additional problem is the strong dependency of the beam characteristics on intensity. This causes problems for the recovery of the beam after an interlock. The variation of beam properties is caused by the intensity dependence of the space charge effects and by the variable asymmetric collimation in transverse phase space that is used for intensity control.

4. Beam control

The following applications for beam control exist, in addition to the closed loop centering.

- Open loop beam position compensation for switching on and ramping of beam intensity.
- Open loop beam position centering with the moving wire profile monitors.
- Transport with an interface for acquisition and setting of beam line elements and the measurement of the beam characteristics. The operator may then ”close the loop” by setting recommended new values.
- Online measurement of influence parameters of steering elements to positions for the verification of machine model data.
- Generic two by two parameter PID control task, including methods to measure transfer functions and frequency response of the controlled system.

5. Data structures

The description of the structure of the beam lines and the data for the optical elements is derived from the general accelerator database in ORACLE. For each beam line this data is transformed to a file in ASCII format and exported to all workstations. Additional data used for configuring is also in from of ASCII files. The preparation of the static data structures for the workstations is done offline.

6. Influence prediction

At process initialization the actual settings of quadrupoles and bending magnets are acquired. Together with the beam line structure file, this data is used to calculate the influence matrix of the steering elements on the beam positions. The prediction is based on the transport algorithm. For use by the closed loop correction, a quadratic selection of this matrix is inverted.

7. Control process

The actual control process is implemented as a classical PID loop where the input and output parameters are represented as vectors. The correction vector is calculated by multiplying the error vector with the inverted influence matrix. At present we support only quadratic matrices and stabilization at the location of beam position monitors. Other configurations with additional boundary conditions are being studied. The determination of the influence matrix is part of the control process, on request the operator may repeated this procedure online to correct for changes in quadrupole settings after tuning the beam line. The underlying control system provides the interface for the acquisition of the beam positions and setting of the correction values to the steering elements. Graphical User Interface Like all applications on the control system the beam line centering control process uses Xwindow Motif as graphical user interface. The user surface provides extensive control over the behavior of the control task. Values of references for beam positions, P-, I-, D gain, filter constant for feedback and minimum beam intensity for activation of the closed loop may be adjusted by sliders or by increments. At initialization the screen image is created using the beam line and configuration data files Performance The beam itself has a noise spectrum far exceeding our capabilities in frequency response for measurement and control. The machine is operated in a static way, so the magnets are made from solid iron they are not laminated hence they are slow, having time constants in the order of 0.1-1 second. The position pick ups are similarly slow with time constants of 0.3 sec. We have chosen a repetition rate of 3 Hz for the closed loop position control.

8. Problems

There are no really severe problems but we still question some facts The stability, linearity, beam intensity independence and noise of the beam position measurement could be improved. This is no wonder in all closed loop systems the acquisition of the controlled value is the most critical part of a all other errors are within the loop and therefore they are reduced by the gain of the system. The precision of the predicted influence values is another critical point. These errors produce a temporary violation of the waist to waist transformation in the beam line. In our case the waist at extraction is reproduced at the target station, instabilities inherently occur in the direction of the extracted beam. When the beam intensity is ramped up to its nominal value after a interlock, the position of the beam at the target station is shifted causing an additional beam trip.

9. Future developments

Include the possibility to specify beam positions at locations along the beam line that are not at the position of a position measurement. This will allow to specify the beam position at a target station where it is not possible to place a monitor. To solve this wee need algorithms for the calculation of the effective orbit outside the position sensors, including the compensation for all errors in the system.

Online check of the correctness of the used influence matrix. This will alert the operator in case of a malfunctioning device and then help to localize the fault. The closed loop provides a lot of data online about the characteristics of the system. Correlation methods on a model have shown encouraging results. In the real case however this failed. This leads to the next theme. Compensation of the hysteresis of the magnets. In a closed loop regulation, the individual corrections that are applied in each iteration are small in amplitude and vary in sign, they are similar to a small noise signal. As the local hysteresis loop of the magnet is comparable to the correction amplitude a compensation of this effect may improve the predictability of the system.