STATUS OF THE DELTA CONTROL SYSTEM

D. Schirmer, P. Hartmann, O. Kopitetzki, G. Schünemann, P. Towalski
DELTA, Center for Synchrotron Radiation, University of Dortmund, Germany

Abstract

Since the change-over to EPICS [9] in 2001 [2],[3] further developments in soft- and hardware and continuous improvements concerning the control system infrastructure as well as the accelerator modelling have been performed. A set of new applications like a bunch filling pattern control and a revised tune measurement software have been established. Furthermore, a new web-server including a content management system has been installed. The complete EPICS data logging and the electronic shift book entries are now managed by a MySQL database. Necessary preparations for automatic machine operation (unmanned control room) are in progress. This article summarizes the activities during the last years and plans for the future.

INTRODUCTION

DELTA [1], the 1.5 GeV electron storage ring facility of the University of Dortmund utilized a standard EPICS based control system architecture since the migration to EPICS in 2001 [2],[3]. This system proves to be stable and efficient. Subsequent improvements were carried out basically regarding the infrastructure of the control system aiming an enhanced failure safety, maintainability and an increase of the network performance. Within the scope of PhD and diploma theses new applications have been integrated in order to enhance handling and control of the accelerator components and to extend electron beam diagnostics.

IT INFRASTRUCTURE: LEGACY ISSUES, EXTENSIONS AND MAINTENANCE

A considerable part of the control system network was based on coaxial cabling (e.g. BNC/AUI). This wiring was fault-prone and limited in bandwidth (10MBit/s). Therefor all obsolescent cabling and all timeworn hubs and switches have been exchanged to standard twisted pair and fiber optics cables as well as modern network components with transfer rates now up to 1GBit/s.

An important issue was the separation of the user-, machine- and office/university-network using a highly configurable firewall (gateway Linux-PC). This was necessary to avoid unauthorized interactive access to devices and critical data as well as for network traffic efficiency. On the other hand records of interest (e.g. beam current, beam lifetime, undulator gap etc.) for diverse user groups in various network domains (user, machine, office, www) are allocated on a so called 'shared IOC' with dedicated read/write access control from each network domain. The new network topology is illustrated in Figure 1.

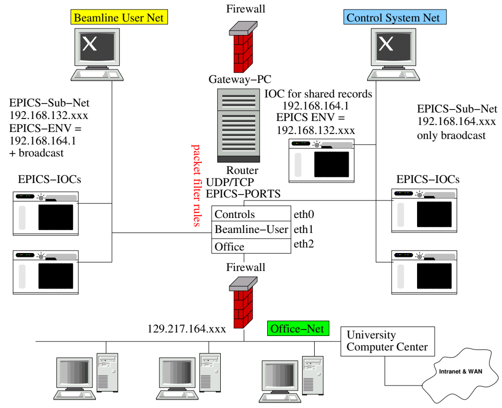

Figure 1: Network separation with shared EPICS record IOC.

The vacuum interlock system has been extended. All valves (snapshot and slow valves) are now under control via an autarkic PLC. This includes also the first valve to the beamlines so called V0 and the synchrotron radiation absorber.

The same apply for the water cooling system. The cooling water temperature is a rather sensitive parameter for the stability of the whole facility, especially for the RF-systems and all injection components. Therefor the water cooling towers are also controlled by an self-sufficient PLC. This PLC and therefor all relevant parameters as temperature, fan revolution speed, fill level etc. are now monitored by the DELTA control system.

In preparation for a unmanned control room, it was required to extend the data display and machine status information system. For this purpose the number of monitor screens in the corridors, machine hall and control room have been enlarged substantially. The video observation, obligatory for the radiation protection system, was completely rearranged. In addition, all important video signals, as the synchrotron light monitors, are stored digitally on a hard disk recorder for subsequent beam investigations. After these upgrades the machine status is visible inside the whole Delta building.

Because of maintenance reasons the Oracle database (DB) [12] (installed in 1999) has been exchanged by the open source DB MySQL [13]. In the framework of this DB-migration the complete EPICS data logging was converted from ASCII data format to DB entries/tables. Additionally, all entries of the electronic journal have been transferred and all Tcl/Tk-programs have been adapted now by use of the MySQL-interface. Hence, the entire EPICS logging is managed by the MySQL database - 500 GB of data up to now.

At present the DELTA web-page and the corresponding intranet will be redesigned. Therefor it was reasonable to install a new web-server including a powerful and flexible content management system (CMS/TYPO3 [14]). The new internet homepage ought to serve not only as an universal information system for synchrotron radiation users (status of the electron beam, insertion devices, beam shutters, scheduled beam time etc.) but also as a platform for technical machine documentation ('Wiktionary').

NEW APPLICATIONS

Libera beam position monitors [5]

Libera[1] beam position monitor electronics have been installed in order to extend the capabilities of the BPM system to turn-by-turn orbit measurements. The already installed analog MX-BPM electronics[2] have proven to be excellent tools for beam orbit measurements up to a maximum bandwidth of 10 KHz. Now, turn-by-turn data offer additional diagnostics at DELTA. Optics parameters as tune and coupling can be monitored with high temporal resolution and high precision. Additionally, detailed phase space measurements and post mortem beam loss studies are currently possible.

Filling pattern control [4]

A precise control of the filling pattern is essential for beam stability and lifetime. Therefor a diagnostic tool to determine and control the longitudinal electron filling structure has been installed at the storage ring as well as at the booster synchrotron. The set up is based on a Linux-PC using an ADC conversion at a sampling rate of 2 GS/s and an analog bandwidth of 1 GHz which is applied to the sum signal of a single beam position monitor. By sampling over successive turns the accuracy can considerably be enhanced, providing full knowledge of the time domain structure of the beam, bunch-by-bunch with a sub-nanosecond time resolution and a threshold of approx. 40 pC bunch charge. The data obtained turn-by-turn over hundreds of revolutions can be further analysed by FFT-techniques allowing a fast detection of longitudinal coupled bunch mode (CBM) instabilities from the phase modulated spectrum. Moreover, the application of the FFT to the amplitude modulated particle distribution allows a post-mortem-investigation of CBM induced beam losses.

Kicker based tune and chromaticity measurement

A tune measurement for the main storage ring Delta based on broadband beam excitation with a kicker magnet and measurement of the relaxation betatron oscillation turn-by-turn has replaced the slow and less precise frequency scan method [6]. By averaging over several kicks the kick amplitude may be as low as 1 μrad in standard user runs, leading to negligible beam distortion. Signal to noise ratios in excess of 10 are reliably achieved down to 200 μA beam current using a maximum kicker amplitude of 30 μrad. The maximum measurement repetition rate is limited to about 12 to 15 s^{-1} by the processor load of the Libera device [6]. Based on this set up a PID based tune feedback algorithm is implemented to compensate tune shifts due to vacuum chamber movements and insufficient compensated orbit deviations in the magnets. The high precision achieved by fitting the turn-by-turn data will allow to set up an online-chromaticity measurement based on a frequency modulation of the main oscillator with very low amplitude.

ACCELERATOR MODELLING

The Accelerator Toolbox (AT) [10] is a collection of tools to model particle accelerators and beam transport lines in the MatLab [11] workbench environment. The 'labCA' [16] and 'mca' [15] packages provide an interface to the EPICS channel access (CA) client library which can be integrated with MatLab applications and toolboxes. Additionally, MatLab provides a large set of optimizing- and fitting-algorithms. Thus, MatLab unifies all essential ingredients in one workbench: read/write control of all Delta devices; accelerator modelling; optimization algorithm test bed; visualization; file handling and programming. This potential is intensely used for machine modelling and beam diagnostics.

Transfer line modelling and optimization

Methods of computational intelligence (CI) were investigated to support the optimization of the electron transfer efficiency from the booster synchrotron BoDo to the electron storage ring DELTA. Neural networks (NNs) and genetic algorithms (GAs) were analyzed alternatively. At first both types of methods were tested on the basis of a theoretical MatLab model of the transport line. After the training, various algorithms were used to improve the magnet settings of the real transport line elements with respect to the electron transfer efficiency. The results of different strategies are compared and prospects as well as limitations of CI-methods to the application of typical optimization problems in accelerator operation are summarized in the references [7],[8].

Storage ring modelling

A complete and detailed machine model of the main storage ring Delta is now implemented with the Accelerator Toolbox in MatLab. For the first time the model fully incorporates the combined function magnets of the storage ring without any thin-lens approximation. The superimposed fields of the quadrupoles with their internal and ex-

[1] I-Tech Libera electron
[2] Bergoz MX-BPM

ternal sextupoles and corrector coils and particularly the sextupole components of the steerers are integrated over their respective effective lengths. The real magnet currents can be loaded into MatLab with the EPICS interface 'labCA' or from saved setup files. The magnet field strengths are calculated using the actual currents values (read back data) considering the saturation effects based on former field measurements [17]. Now the differences between machine and model can be determined to improve the model. Figure 2 shows an example of simulated beam orbit and twiss functions calculated by applying real magnet settings.

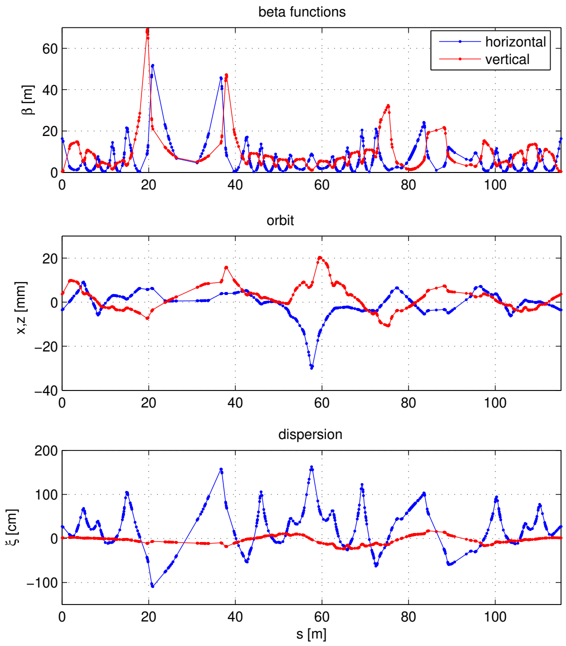

Figure 2: Twiss functions and orbit simulation (based on magnet read back data).

PLANS FOR THE FUTURE

Alarm handler

In the near future we plan to realize an 'unmanned' control room for standard user operation. This would free up manpower which is more beneficial for technical support and service. To achieve this operational mode, many requirements have to be fulfilled (see also IT infrastructure). One important precondition is a stable and well definite state of all accelerator components. For this purpose a first prototype of a simple to configure and easy to use alarm handler has been developed. This Tcl/Tk program is not based on the EPICS severity fields. Thus the warning limits are at all times configurable (no IOC reboot is necessary) and the entire set up is stored in the MySQL database. The application is experimentally in use for the supervision of the vacuum chamber temperature, magnet currents, control area network (CAN) modules and CPU-monitoring.

Fast orbit feedback system

For a fast orbit feedback at Delta first studies based on developments at DIAMOND and SOLEIL are in preparation. Parts of their systems will be adopted to DELTA. In a first step a local orbit feedback for the FEL undulator using two Libera BPMs and four corrector coils will be installed. In a second step we will develop an FPGA board adapter to include Bergoz MX-BPMs into the system.

REFERENCES

[1] D. Schirmer et al, Status of the Synchrotron Light Source DELTA, EPAC 2004, Lucerne, Switzerland.

[2] D. Schirmer et al, Standardization of the DELTA Control System, Proceedings of the 7th ICALEPCS'99, Trieste, Italy.

[3] E. Kasel et al, The Evolution of the DELTA Control System, Proceedings of the 8th ICALEPCS'01, San Jose, USA.

[4] J. Kettler et al, Fast beam dynamics investigation based on an ADC filling pattern measurement, EPAC 2006, Edinburgh, Scotland

[5] P. Hartmann et al, Experience with Libera Beam Position Monitors at DELTA, DIPAC 2007, Venice, Italy

[6] P. Hartmann et al, Kicker based tune measurement for DELTA, DIPAC 2007, Venice, Italy

[7] D. Schirmer et al, Electron Transport Line Optimization using Neuronal Networks and Genetic Algorithms, EPAC 2006, Edinburgh, Scotland

[8] T. Büning, D. Müller, Diploma Thesis, University of Dortmund, Germany, 2005

[9] *EPICS Home Page*, `http://www.aps.anl.gov/epics`

[10] A. Terebilo, *Accelerator Toolbox for MATLAB*, SLAC-PUB-8732

[11] The MathWorks, *MATLAB*, `www.mathworks.com`

[12] Oracle, `www.oracle.com`

[13] MySQL, `www.mysql.com`

[14] Typo3, `http://typo3.org`

[15] A. Terebilo, *Channel Access Client Toolbox for MATLAB*, 8th ICALEPCS, San Jose, 2001

[16] `http://als.lbl.gov/als-physics/portmann /MiddleLayer/release`

[17] M. Grewe, SVD-basierte Orbitkorrektur am Speicherring DELTA, PhD, University of Dortmund, Germany, 2005