PREPARING SLOW CONTROLS AT BESSY FOR FAST ORBIT FEEDBACK*

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Abstract

The CAN field bus based control system interface to the BESSY power supplies was designed with emphasis on robustness, long-term stability, reproducibility and precision, relying on the basic idea that intrinsic beam stability is achievable at any required level. In preparation for the first phase of a fast orbit feedback system installation, a number of steps at different levels have been taken to enable the existing interface for fast, parallel, synchronized distribution of set point values to corrector power supplies. The design goal was achieving the maximum update rate and a minimum jitter, without major and/or expensive changes to the control system design or hardware. The paper discusses the shortcomings found, the measures taken, and the achievements made.

MOTIVATION

When the BESSY II storage ring was designed in the early 1990s, orbit stability considerations were based on the idea that intrinsic beam stability could be achieved at any level required. The specifications of the power supplies and the design of their control system interface was focusing on robustness, precision, long-term stability and reproducibility [1,2]. This system was delivering the required performance, leading to excellent orbit stability during the first years of operation [3,4,5,6].

Increased processing bandwidth at the experiments and the demand for rapid compensation of noise spikes initiated plans for a fast orbit feedback system (FOFB), necessary to meet the new requirements [7].

For fast feedback using correction rates up to 100 Hz, major investments will have to be made, as such an upgrade will not only require the replacement of today's stability optimized corrector power supplies, including their control system interfaces. To secure such an investment and prepare for a global FOFB system with competitive speed and precision, it was decided that an attempt should be made to further develop the currently installed system to reach its set point transmission limits. The resulting medium fast system would allow for additional studies to be performed and identify the requirements for a final FOFB set-up [9].

CURRENT INSTALLATION

The existing system is based on the EPICS (Experimental Physics and Industrial Control System) toolkit and has been described in more detail in former publications [1,2,5].

System Design

Beam Position Monitor (BPM) data is collected in 16 VME front-end Input/Output Controllers (IOCs) running VxWorks on Motorola 68020 CPUs, connected by 10 MBit Ethernet on optical fiber feeding a 17th VME data collection master. In this system position, precision, and status information are packed into a waveform record and distributed. The orbit correction client program executes as a single workstation application written in C++, connecting through EPICS' Channel Access protocol to the 8 IOCs controlling the corrector power supplies plus the IOC controlling the GP-IB attached RF frequency generator. The 8 corrector power supply IOCs, VME based systems running VxWorks on MPC8240 embedded PPC CPUs connected by 100 MBit Ethernet, use a 1 MBit CAN field bus link to write the set point data to the power supply controllers, 386EX based embedded CPUs on the converter cards hosted in the power supplies [2].

Feedback Rate

In regular mode, the orbit correction application is collecting slow BPM data every 2 seconds, writes new set points to the corrector power supplies during the next measurement cycle, and allows for one cycle settling time, resulting in a 6 second correction cycle.

LIMITATIONS

Despite the fact that orbit data are already available on a second fast data branch (see below), several areas have been identified that effectively limit the correction rate of a possible orbit feedback system.

Ethernet Communication

While the bandwidth (throughput rate) of EPICS' Channel Access (CA) network protocol is high, buffering in the IP stack and the in-deterministic behavior of Ethernet itself cause a variable propagation delay on each of the TCP circuits used for distribution to multiple IOCs, creating a large jitter between receiving set points in the power supply IOCs of up to 100 ms.

CAN Field Bus Communication

The CAN (Controller-Area Network) field bus provides very reliable, deterministic communication over a serial link. At the 1 MBit speed utilized at BESSY, a single message containing set point data for one power supply needs about 150 µs on the wire. Set point communication uses an acknowledged service of the CANopen standard [8], with round trip times of about 500 µs. The time needed to send new set points to 10 CAN bus nodes on a field bus segment adds up to about 3.5 ms. The achievable

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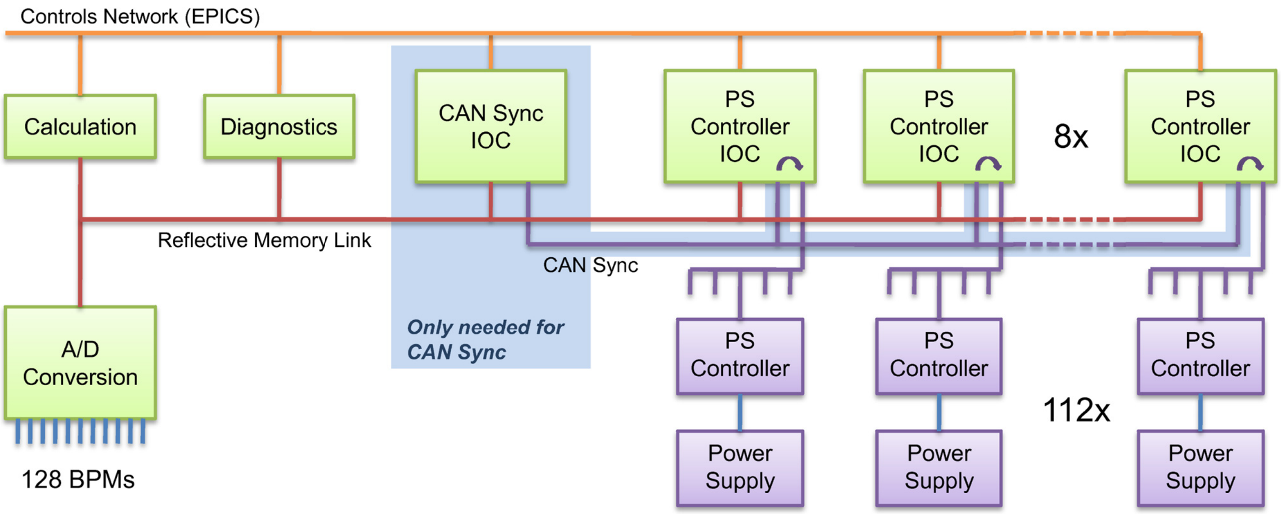

Figure 1: Sketch of the FOFB set point data distribution.

minimum jitter between the set point changes on one CAN segment is about 1.5 ms.

NEW DESIGN

The new design for a medium fast orbit feedback using the existing technology introduces changes in several places.

Collecting BPM Data

All 128 storage ring BPMs at BESSY II have a secondary set of cabling connecting pre-processed analog signals (500 MHz signal, filtered, AGC amplified, through an 300 Hz low-pass filter) to one location on the storage ring tunnel. By using that cabling, x and y position data from all 128 BPMs is fed into one VME crate for A/D conversion, eliminating the need for a fast communication mechanism between BPM processors distributed around the ring. Conversion is done by 16 VME A/D converter cards with 16 channels each using 16 bit resolution. The main processor in that acquisition VME crate, a Motorola MVME5500 running VxWorks, uses a reflective memory PMC adapter to send the BPM data to the calculation processor, providing a maximum achievable scan rate of 2.4 kHz.

The conversion and all followings steps of the feedback system are hardware triggered, using a derivative of the revolution clock.

Feedback Algorithm

Calculation is moved from the workstation application to a rack based PC (HP DL380G5), running the feedback algorithm within Matlab 2007b environment under embedded RTLinux. This allows to conveniently utilize the storage ring configurations of Matlab Middle Layer (MML), operational and well tested at console level. To facilitate feedback diagnostics without influence on the running system, a second similar rack based PC will be used, connected to the live system through a similar reflective memory interface.

Measurements using a slower calculation PC (HP D530 using a Pentium4 CPU at 2.8 GHz) show a latency below 5 ms (from A/D conversion to providing new corrector values) for a SVD (Single Value Decomposition) algorithm covering all 128 BPMs and 112 correctors and using half of the eigenvalues.

Distribution to Power Supply IOCs

As the large jitter introduced by TCP connections make it impossible to use Channel Access to distribute set point data, and the connection speed vs. allowed length tradeoff of the CAN field bus doesn't allow to use that, either, a fast Ethernet based distribution mechanism based on UDP multicasts was implemented.

While testing this service, it was found that VxWorks runs all network IO within one thread and – from the same thread – queries the Ethernet chip for link status every 5 s, blocking all IO for about 10 ms. This behavior effectively limits the correction rate to under 100 Hz, which is not acceptable for this application.

To work around this limitation, it was decided that all power supply controller IOCs will be equipped with reflective memory PMC modules, and distribution of power supply set point data is done through reflective memory.

CAN Bus Communication

To speed up distributing the set point data to the power supply controllers, an unacknowledged CAN service was implemented on both the distributing IOC and the receiving embedded controller side. This shortens the time needed to distribute set points to 10 power supplies on one CAN segment to about 1.8 ms, scaling with the number of correctors per CAN segment.

As CAN supports broadcast messages, a new set point mode was implemented on the embedded controller, which just receives the new data and loads a register on the converter card, without actually activating the new setting. This allows for a broadcast “sync” message that results in writing the set point register to the converter, thereby activating all set points in the power supplies on a bus segment at the same time, minimizing the jitter between them.

Corrector PS D/A Conversion Trigger

Two possible trigger distribution schemes have been implemented.

One uses a “slow” CAN field bus segment to distribute a sync message to all participating VME-CAN interface boards. These boards support a “mapping” feature, that forwards an incoming message on one of their ports to an outgoing message on a different port. This feature is used to map the sync message from the “slow” global segment to the “fast” local power supply segments, without interaction of the VME system CPU.

The other scheme uses an event of the reflective memory system to notify the VME CPUs, which then in turn send the sync messages to the “fast” power supply segments.

In addition to the “soft” trigger event from the CAN bus, all converter cards support a hardware trigger input. To achieve the highest level of synchronization with the lowest possible jitter, one hardware trigger signal could be used, with additional wiring, to force synchronized D/A conversion in all corrector magnet power supplies.

STATUS

All components of the new set-point distribution set-up have been implemented and separately tested in the laboratory. Integration and testing in the production system is under way, as fast as limitations in man power and testing time allow.

CONCLUSION

To overcome limitations found in the existing design, and to prepare for the first introductory phase of a fast orbit feedback system at BESSY [9], several changes have been implemented in the different layers of the existing orbit correction and power supply interface schemes.

Results of component tests in the laboratory show that the new design should provide the correction rates needed for a medium fast correction, aimed at reduction of noise in the 0.2 Hz - 50 Hz range.

REFERENCES

[1] J. Bergl, B. Kuner, R. Lange, I. Müller, R. Müller, G. Pfeiffer, J. Rahn, H. Rüdiger, “Controller Area Network (CAN) – a Field Bus Gives Access to the Bulk of BESSY II Devices”, Proceedings of ICALEPCS1995, Chicago, 1995, p. 1017.

[2] J. Bergl, B. Kuner, R. Lange, I. Müller, R. Müller, G. Pfeiffer, J. Rahn, H. Rüdiger, “Embedded Controllers, Field Bus and a Modular IO Concept: Central Elements of BESSY II Controls”, Proceedings of the 1997 PAC, Vancouver, 1997, p. 2493.

[3] R. Bakker et al., “Status and Commissioning-Results of BESSY II”, Proceedings of the 1999 PAC, New York, 1999, p. 197.

[4] D. Krämer et al., “BESSY II: Exceeding Design Parameters – The First Year of User Service”, Proceedings of EPAC 2000, Vienna, 2000, p. 640.

[5] R. Müller, R. Bakker, K Holldack, P. Kuske, “Orbit Control at BESSY II: Present Performance and Plans”, Proceedings of EPAC 2000, Vienna, 2000, p. 666.

[6] J. Feikes, K. Holldack, P. Kuske, R. Müller, “Beam Stabilization at BESSY: Set-up, Performance, Plans”, Proceedings of ICALEPCS2003, Gyeongju, 2003, p. 551.

[7] R. Müller, J. Feikes, K Holldack, P. Kuske, “Orbit Stability at BESSY”, Proceedings of the 2005 PAC, Knoxville, 2005, p. 2366.

[8] “CANopen Application Layer and Communication Profile”, CAN in Automation (CiA) Draft Standard 301, CiA e.V., Nürnberg.

[9] R. Müller, R. Görgen, R. Lange, I. Müller, J. Rahn, “Introducing Fast Orbit Feedback at BESSY”, THP059, this conference.