FAST ORBIT FEEBACK SYSTEM UPGRADE WITH NEW DIGITAL BPM AND POWER SUPPLY IN THE TLS

C. H. Kuo[#], P. C. Chiu, K. H. Hu, Jenny Chen, K. B. Liu, K.T. Hsu
NSRRC, Hsinchu 30076, Taiwan
A. Bardorfer, Instrumentation Technologies d.o.o., Solkan 5250, Slovenia

Abstract

Orbit feedback system of the Taiwan Light Source (TLS) has been deployed for a decade. The loop bandwidth was limited by existing hardware. The system cannot remove perturbation caused by fast source. Therefore, speed of gap and phase change of the conventional insertion devices is restricted to a relatively slow motion. To improve orbit feedback performance, BPM system and corrector power supply are planned to upgrade within a couple of years. The upgrade plan which replaces half of existing analogue type BPM by new digital BPM will be carried out stage by stage but due to limited resource, the BPM system will be a mixed type at this moment. The digital BPM electronics are commercial available by using direct RF sampling technology, FPGA, and embedded control environment running GNU/Linux. The programmable nature of new system is beneficial for multi-mode high precision beam diagnostics purposes. Sub-micron resolution is achieved for averaged beam position measurement with high update rate. The corrector power-supply is also replaced by high performance switching type power supply with wide bandwidth in the same time. The integration of old and new BPM, power supply control for fast orbit feedback will be summarized in this report.

STATUS OF THE EXISTING ORBIT FEEDBACK SYSTEM

Global orbit feedback system was deployed in ten years ago. The early system was composed of two VME crates. One was for BPM data acquisition; the other was corrector feedback control. A DSP module was installed at the corrector control VME crate to execute control rule. To achieve better functionality and ease the maintenance, the system had been modified slightly in 2002. The modified system was composed of three VME crates. The functions of DSP board were moved into a PowerPC CPU module located at the third VME crate which replaced original DSP module to simplify the programming environment.

The orbit feedback system will use measurement of the beam position to compare against a reference orbit and calculate the desired corrections by the error to be applied to the corrector magnets in the storage ring. This procedure must provide global communication that required higher bandwidth than is available in a commercial network. TLS has a control network for slow data acquisition in 10 Hz and a dedicated network for fast data acquisition in 1 kHz. Reflective memory is a solution to access distributed data without required extra processor time for the latter. Coefficients of PID controller which determines feedback loop performance will be assigned properly. SVD is used to obtain inversion of response matrix.

CORRECTOR POWER SUPPLY AND BPM UPGRADE

To satisfy the users' demand in orbit stability, upgrade the orbit feedback system is planned. Corrector power supplies and partial BPM electronics upgrade will be done before spring of 2008. Orbit feedback system will be improved during the course of upgrade.

Corrector Power Supply Upgrade

Corrector power supply of TLS was composed of linear type power supply oringinally. Despite its low efficiency, suffered from high frequency noise for infrared beamline, the power supply had been modified to reduce its loop bandwidth to less than 10 Hz. Nevertheless, loop bandwidth of the orbit feedback system was limited by the power supply bandwidth and the eddy current effect of vacuum chamber. This kind of power supply was also a burden from maintenance point of view due to its dimension and weight. To provide better performance, switching power supply with good performance was adopted. All power supplies for vertical correctors have been replaced by new power supply during shutdown period of early 2007. Figure 1 shows the better performance of switching power supply compared with that of the old type power supply in standard deviation of read back value. As a result, power supply for horizontal corrector will also be replaced in early 2008.

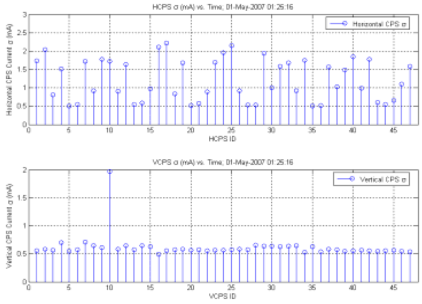

Figure 1: Comparison of steering magnet current read back for old and new corrector power supply.

[#] chkuo@nsrrc.org.tw

BPM Upgrade

To achieve stringent requirements of orbit stability, TLS has developed and improved orbit feedback system ceaselessly. Our recent efforts are primarily put on electronics upgrade for half of BPM of the storage ring, of which we expect better functionality and performance, to suppress vibration down to sub-micro level and up to 50 Hz. Libera Electron is chosen for this upgrade. Each Libera Electron will be connected to slow orbit acquisition server by means of a private Ethernet link. Another gigabit network switcher is used to access fast orbit and connect to VME CPU board. Fast orbit data is stored in the reflective memory and shared to orbit feedback related VME crates via dedicated fibre link. Testing of Libera Electron was performing during this year and it was planned to be integrated seamless into the existing Bergoz's BPM system [1]. The upgrade is scheduled to be completed no later than early 2008.

NEW ORBIT FEEDBACK INFRASTRUCTURE

The new infrastructure of orbit feedback system consists of several VME crates. Their functions include Bergoz's orbit server VME crate, corrector power supply analog setting and read back VME crate, one feedback computation VME crate. There is another node running PC/Linux served as Libera BPM server for slow data access and management independently of orbit feedback. The precision fast orbit data will be acquired by gigabit Ethernet to three CPU modules equipped with gigabit Ethernet ports. The parallel processing is employed to reduce accumulating latency caused by Libera and data transmission. The number of the CPU modules is therefore adjustable according to the results of latency testing. A group of eight to ten Liberas (one super-period) will send Ethernet packets at 10 kHz rate to a gigabit network switch [2] which serializes these packets and sends them to each CPU module. Fast orbit data is shared by all nodes by reflective memory. Figure 2 shows the hardware configuration of the new orbit feedback infrastructure.

Since precision orbit data from Libera Elecein is in 32 bit format with unit of nano-meter, it is not compatible with the existing system which uses 16 bits ADC to convert measured analog output of Bergoz's BPM. Truncation of 32 bit data into 16 bit format is a provisional solution to compatible with the existing system. It is possible to use the 32 bit data after all of BPMs replaced by Libera Electron in the future.

Fast orbit data from Libera Electron is updated into reflective memory in 10 kHz rate. To accompany with existing 1 kHz orbit feedback loop, the data will be re-sampling at a feedback computation engine. The corrector is updated at 1 kHz rate.

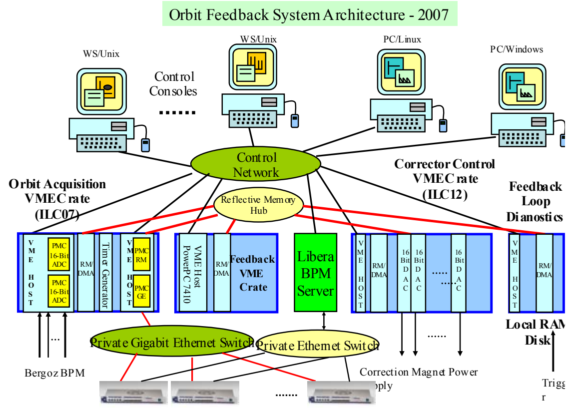

Figure 2. Infrastructure for the orbit feedback system.

PRELIMINARY TEST

To evaluate the performance of the new orbit feedback system, various tests are on-going. Several current efforts are summary in the following paragraphs. Figure 3 shows the set-up for this test.

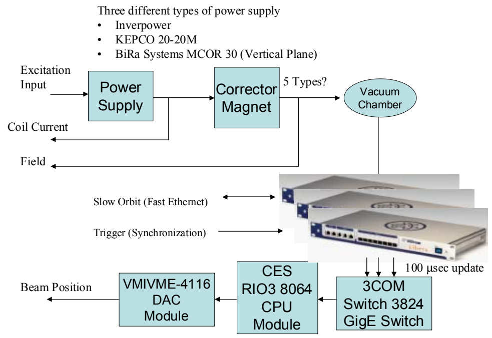

Figure 3. Setup for jitter and response measurement.

Jitter and Performance of GigE Interface

In the real-time system, timing problem is becoming critical in control design and its computer-based implementation as more complicated communication network and stringent speed requirement. It can be categorized three parts: latency delay, sampling jitter and transient errors. Latency delay is primary related to computation and communication delay; sampling jitter is due to assumed constant sampling period but actually time-variant sampling interval; transient errors can result data loss from disturbance in the communication medium.

Our observation implies that the sampling jitter is obvious and never vanishes as process goes on. Research shows that the jitter may degrade the system performance and even lead to instability in the system [3]. In Figure 4, we analyzed the jitter pattern and its distribution. Further research is expected to compensate its possible negative effect.

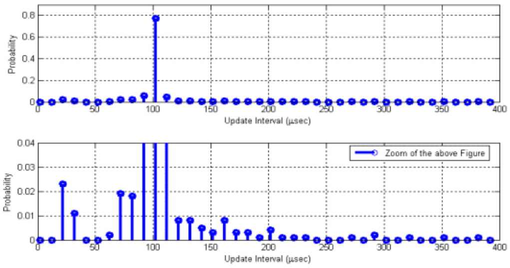

Figure 4. History of the sampling interval for one Libera Electron communicate with VME host.

Since there is one dedicated CPU module for one super-period BPM data acquisition, the GigE interface performance and jitter will vary and depend on how many Libera connected. Test for 10 sets of Libera can guaranteed updated abound 1 msec/update. To improve system efficiency in communication, group of several Libera Electron together and provide better timing of sampling is under way.

System Latency

Latency time of Libera Electron is about 350 µsec. Delay due to communication and computation is estimated around 150 µsec. These delays will not lead any stability problem of the feedback loop. Further simulation will be done soon.

Response Include Beam

To model the system for orbit feedback, except for laboratory measurement of various system components response, response including beam was performed recently. Adopting the similar configuration for jitter measurements, dynamic signal analyzer is employed to measure this response including the beam. Vacuum chamber of the TLS is an 80 mm x 38 mm in major and minor axis respectively. Chamber thickness is 4 mm. There are cooling channels on the major axis direction. Standard TLS vacuum chamber measured response is near to 80 Hz in vertical plane and 20 Hz in horizontal direction. Response including beam in vertical direction with new switching power supply is shown as Figure 5. The notch in magnitude and phase response nearby 1.7 kHz is due to the notch filter designed to remove the glitch of quasi-crossbar switch inside Libera Electron. The -3 dB bandwidth is about 100 Hz in vertical plane while the bandwidth is reduced to less than 20 Hz in horizontal plane with old power supply as shown in Figure 6.

System identification and modelling is still ongoing by means of applying pseudo-random binary sequence (PRBS) or another kind of excitation signals to excite the beam. The system model can be extracted by analysis of the data captured by the Libera Electron.

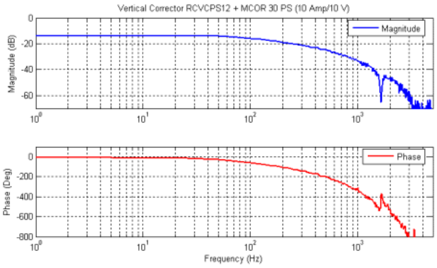

Figure 5. Measured response of the vertical plane with beam.

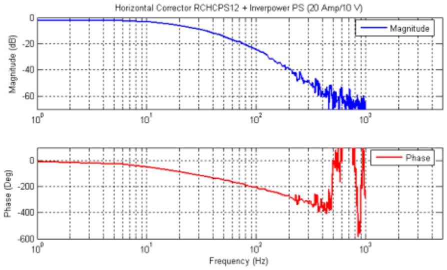

Figure 6: Measured horizontal plane transfer function include beam.

SUMMARY

To achieve a better orbit control and take advantage of latest development, upgrade of orbit feedback system for the TLS is on-going. All of vertical corrector power supplies have been replaced by switching power supplies in February 2007 and the horizontal ones are also planned to upgrade in early 2008. Libera Electron will be integrated into the existing system to enhance functionality and provide precision fast orbit information for orbit feedback purpose. Infrastructure of the orbit feedback system is scheduled and will be finished within 6 months. It is expected that feedback loop can be completed no later than December 2007. It is also expected that this upgrade will provide better orbit control and satisfy users' requirement.

REFERENCES

[1] C. H. Kuo, et al., "Design of a Fast Global Orbit Feedback System for the TLS Storage Ring", 10th ICALEPCS Int. Conf. on Accelerator & Large Expt. Physics Control Systems. Geneva, 10 - 14 Oct 2005.

[2] D. Bulfone, R. De Monte, V. Forchi', G. Gaio, M. Lonza, "Design of a Fast Global Orbit Feedback System for the ELETTRA Storage Ring", 10th ICALEPCS Int. Conf. on Accelerator & Large Expt. Physics Control Systems. Geneva, 10 - 14 Oct 2005.

[3] B. Wittenmark, et al., "Timing Problems in real-time Control System", Proceedings of the American Control Conference, Seattle, Washington, June 1995. p. 2000.