ARCHITECTURE AND CONTROL OF THE FAST ORBIT CORRECTION FOR THE ESRF STORAGE RING

F. Epaud, Jean-Marc Koch, Eric Plouviez, ESRF , Grenoble, France

Abstract

Two years ago, the electronics of all the 224 Beam Position Monitors (BPM) of the ESRF Storage Ring were replaced by the commercial Libera Brilliance units to drastically improve the speed and position resolution of the orbit measurement. Also, at the start of this year, all the 96 power supplies that drive the orbit steerers have been replaced by new units that now cover a full DC-AC range up to 200Hz [1, 2].

We are now working on the replacement of the previous Fast Orbit Correction Feedback system. This new architecture will also use the 224 Libera Brilliance units and in particular the 10 KHz optical links handled by the Diamond Communication Controller (DCC) which has now been integrated within the Libera FPGA as a standard option. The 224 Liberas are connected together with the optical links to form a redundant network where the data are broadcast and are received by all nodes within 45 µS. The 4 corrections stations are based on FPGA cards (2 per station) also connected to the FOFB network as additional nodes and using the same DCC firmware on one side and are connected to the steerers power supplies using RS485 electronics standard on the other side. Finally two extra nodes have been added to collect data for diagnostics and to give BPMs positions to the beamlines at high rate. This paper presents the network architecture and the control software to operate this new equipment.

MOTIVATION

The present Fast Orbit Correction installed in 2004 and using only 32 BPMs, 32 correctors in the horizontal plane and 16 correctors in the vertical plane, is rapidly aging and is less and less reliable. Also its' Electronics based on VME-DSP71 cards using C40-DSP and developed at the ESRF, PXI-Sundance C67-DSP cards and Windows 2000 operating systems is now obsolete. Also, we have to rely on very few spares to operate this equipment. It is working at 4.4 KHz sample frequency and corrects the beam positions in a bandwidth from 0.05Hz to 150Hz.

Also since 2 years the 224 Liberas Brilliance devices [3] connected to the 224 BPM heads and also the 48 BILT power supplies connected to the 96 steerers are in operation to perform the slow orbit correction every 30 seconds. The correction loop is performed by software using TANGO control system and several device servers reading positions data from the Liberas, calculating the corrections and writing them to the steerer power supplies over Ethernet and using standard TCP/IP protocol.

These two systems have recently being coupled [4].

Since the beginning of the slow orbit correction refurbishment we have also kept in mind the Fast Orbit Feedback upgrade and decided to use the continuous 10 KHz positions data stream delivered by the Liberas over the four 1Gbits/sec optical Links. We have also designed the BILT steerers power supplies in order to be able to apply fast correction over a RS485 serial line in addition to the slow correction coming from the Ethernet.

NETWORK ARCHITECTURE

Liberas Ring

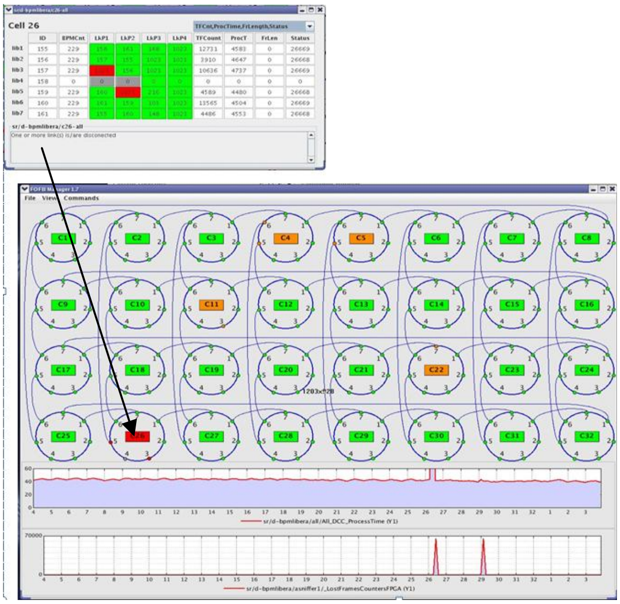
When we bought our 224 Liberas, Instruments Technologies, the Libera manufacturer, proposed to use their standard "Gbits Ethernet protocol", but for several reasons we do prefer to use the Communication Controller protocol (DCC) developed by Diamond Light Source and already in use at Diamond and Soleil. Therefore for warranties, support and to not have to modify the Libera's embedded FPGA program, we asked to Instruments Technologies to integrate this protocol as an option of the Libera.

This add-on allowed us to connect our 224 Liberas (32 cells * 7 BPMs) all together using our standard Ethernet infrastructure. At the ESRF, the 32 cells are wired with a 12 pairs optical fibbers going to a central point behind the control room. Only one or two pairs are used for the Ethernet network and the rest is available for other purpose. Therefore we used 4 pairs to build our Liberas Fast network (4 pairs are necessary for redundancy).

The 7 Liberas of each cell are connected together with copper cables to form a primary ring then two of these Liberas are connected to the cell N-1 and cell N+1 via the optical fibber. Also two other Liberas are connected to cell N-8 and cell N+8 to make redundancy.

We had also to develop a synchronisation card which allows sending the required pulses to synchronise all the Liberas and to start the DCC, following a strict timing protocol. When the Liberas have been synchronised, the time to refresh all the X and Z positions is around 45 µs.

We have also developed tools to ease the commissioning of the Fast network, which will also be used latter during the USM (Users Service Mode) to survey this equipment. This software uses a TANGO device server which collects connections status on all the Liberas and displays them on a Java application. The Figure 1 below shows the status of the network with some faults on cell 26 which are highlighted in the window on the top to better determine the origin of the problem.



Cell 26

	ID	BPMCnt	LkP1	LkP2	LkP3	LkP4	TFCount	ProcT	FrLen	Status
lib1	155	229	158	161	168	1023	12731	4583	0	26669
lib2	156	229	157	155	1023	1023	3910	4647	0	26668
lib3	157	229	[illegible]	156	1023	1023	10636	4737	0	26669
lib4	158	0	0	0	0	0	0	0	0	0
lib5	159	229	160	[illegible]	216	1023	4589	4480	0	26668
lib6	160	229	161	159	103	1023	13565	4504	0	26669
lib7	161	229	155	160	148	1023	4486	4553	0	26668

sr/d-bpmlibera/c26-all

One or more link(s) is/are disconected

Figure 1: Java application which controls and surveys the Liberas Fast network status. Here is shown a problem with the Libera 4 of cell 26, which is not running and has lost the connection with its neighbours.

Sniffer

Even if the Liberas Fast network is running well, we need also to be able to collect the positions data. Therefore we use a PMC-FPGA-03 mezzanine module from Curtiss Wright which is connected on a PCI carrier. This module has the same optical coupler than the Liberas and allowed us to integrate the Communication Controller FPGA program to sample the data in real-time (@ 10 KHz) and sends them to a CPU with DMA cycle over PCI every 4096 frames (every 400 milli-seconds).

This card is plugged in a rackable PC running Windows XP. We finally have installed two sniffer systems: 1) To collect positions data used by a server which calculates the positions, angles, FFT and RMS in the middle of the straight sections and make them available to the beamlines, 2) To carry-on the commissioning of the whole FOFB system.

These two systems are two extra nodes of the Fast network.

Corrections Stations

At the ESRF, the steerers magnets of 8 cells are controlled by power supplies located at 4 areas around the storage ring, therefore we had to fit with this architecture already in place and had to install the corrections stations in these areas. We decided to use a card similar to the one already used by the sniffers, but more powerful and more up-to-date, the XMC-FPGA05F mezzanine module from Curtiss Wright [5]. We also used 4 Windows XP rackable PCI crates, but the FPGA simulation demonstrated that one card to handle 24 steerers was not enough and we had to use two cards per crates. This was also justified by the lack of place to connect the steerers power supplies interfaces.

Finally, each card can handle up to 14 steerers on both planes. Once again, these cards are connected to the Libera Fast network as 8 extra nodes. They collect positions data within 45 µs out of the 100 µs available, leaving 65 µs to calculate the corrections according to the correction matrix and the PID coefficients. It send also the corrections both to the steerer power supplies via RS485 and to the Fast network for debugging purpose (correction data are multiplexed at this point).

Synchronisation Mechanism

There is actually no hardware synchronisation mechanism to synchronise the start of the 8 cards of the 4 stations. They are started using TANGO group calls meaning that the jitter can be up to a few milli-seconds and more in case of network overload. This is acceptable but nevertheless we envisage to add such a mechanism.

SOFTWARE ARCHITECTURE

In fact, as far as the positions acquisition , the corrections calculation and the communication with steerer power supplies are made within the FPGA program, the control software using TANGO device servers is quite simple and is limited to provide the parameters to the FPGA cards and to survey the state of the 8 cards (See Figure 2).

FOFBCorrectionStation

This device server runs locally on each of the 4 Windows XP stations and manages two devices (one per card). One device/card can handle up to 14 steerers in both planes. Thanks to the 'fusionXP' driver, it communicates using a memory area on the PCI bus seen also from the FPGA. This area allows giving the PID, corrections and stimulus coefficients to the correction firmware. It also allows starting and stopping the correction and/or the stimulus and finally handles the errors coming from the FPGA.

FOFBCorrectionGlobal

On top of the 4 FOFBCorrectionStation device servers is the FOFBCorrectionGlobal device server allowing to manage the whole system as is there was only one correction station. This server manages two devices, one in both plane and has the knowledge of the architecture behind it. In particular it knows which steerers are managed by which stations and therefore can dispatch the corrections vectors for each steerer according to the correction Matrix provided by higher level application (matlab at the moment). Also it manages the errors of the 4 stations and can decide to stop the correction in case of problem.

FOFBSniffer

This device server handles continuously the DMA cycles coming from the FPGA via a FIFO. It collects the data and insert them into a circular buffer having a depth of 10 seconds. The clients can pick-up data on this buffer and can read BPM history. The recording can also be frozen in order to not lose the synchronisation when several BPMs need to be read. Also the whole BPMs positions and the whole corrections values can also be read on a defined depth by one command to keep the synchronisation between data.

Applications, Commissioning

We are currently commissioning the whole system and had to develop some tools (as the LABView application below) in order to treat the huge flow of data. We also use a lot 'jive', the TANGO generic tool, to verify that the parameters coming from the higher application are dispatched on the right station and at the right place, for the right steerer. For example, this helped to discover that our steerers numbering was not the same everywhere and that the number one was the first steerer of the cell 1 for wiring aspects but was steerer 1 of the cell 4 for physics and computing aspects. One should know that at the ESRF, the first cell after the extraction to the Storage Ring is the cell number 4.

Also, Matlab is widely used by the diagnostics experts, especially this software is perfectly adapted to calculate and invert the correction matrix. Latter, an application for the Control room will be developed, may be in matlab like the previous system or in Java.

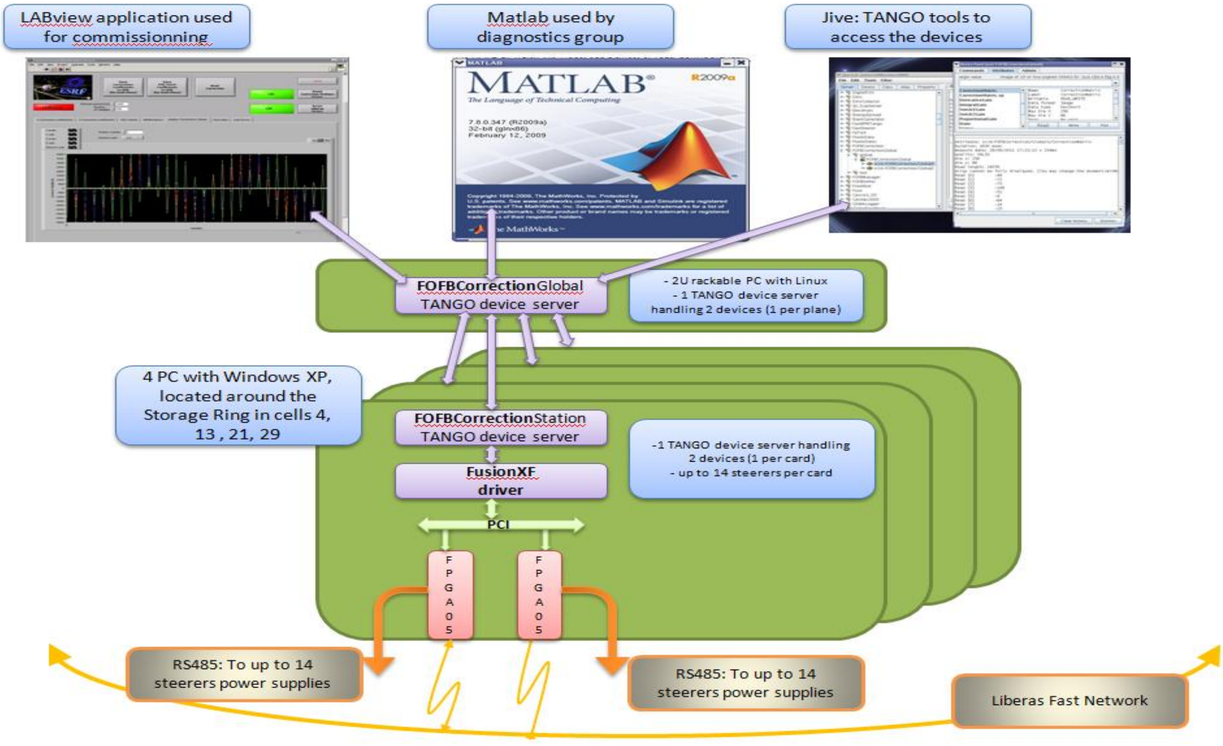


Figure 2: Software architecture of the Fast Orbit Feedback based on Liberas.

RESULTS

Very few MDT time has been allocated to the commissioning of this new equipment, therefore we are trying to make as much as possible during the USM and had to prepare carefully our MDT programs. We have also suffered from some bugs and human mistakes which provoke some beam loss or unexplained beam motion during the USM. Recently, we succeed to close the loop and to correct the beam positions in both planes [7].

REFERENCES

[1] K.B.Scheidt, F.Epaud, ESRF, Grenoble, Installation and Commissioning of a complete upgrade of the BPM system for the ESRF Storage Ring, MOPD05, DIPAC-09, Basel,

[2] F.Epaud, ESRF, Grenoble, ESRF's new beam position system for the storage ring using Libera Brilliance devices, THP004, ICALECS-09, Kobe

[3] Instrumentation Technologies. http://www.i-tech.si

[4] E.Plouviez, L.Farvacque, JM.Koch, JL.Pons, F.Uberto, ESRF, Grenoble, Improvement of the fast orbit correction on the ESRF storage ring, TUPD05, DIPAC-09, Basel.

[5] Curtiss Wright Controls http://www.cwcembedded.com/

[6] E.Plouviez, F.Epaud, JM.Koch, KB.Scheidt, ESRF, Grenoble, The New Fast Orbit Correction System of the ESRF Storage Ring, MOPD74, DIPAC-2011, Hamburg.

[7] J.M. Koch, F. Epaud, E. Plouviez, K.B. Scheidt, ESRF, Grenoble, Fast Orbit Correction for the ESRF Storage Ring, ICALEPCS-2011, Grenoble.