INSTALLATION AND COMMISSIONING OF A COMPLETE UPGRADE OF THE BPM SYSTEM FOR THE ESRF STORAGE RING

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Abstract

The ESRF Storage Ring has, over the last 3 winter months, been fully equipped with new electronics for its BPM system while causing a minimum disturbance to its large community of X-ray beam-line users. The Libera-Brillance is now doing the treatment of the weak RF signals on all 224 BPM stations, and has replaced the old RF-Multiplexing system that had served reliably for 17 years. This paper describes the precautions that had been taken to make the whole transition as smooth as possible, with regards to the reliability for the SR operation and the positional stability of more than 40 X-ray beams. Information is given on the network & computer control, based on the Tango distributed control system and its device-servers and tools. Results will be presented to demonstrate the strongly improved performance and functionality in every field of application, and that will make this new BPM system the key component in the near future's upgraded orbit stabilization system.

HISTORY, MOTIVATION , CHOICE OF TECHNICAL SOLUTIONS

The agreed upgrade program of the ESRF light source, including that of the accelerator complex [1], has created an opportunity to modernize drastically the old BPM system of the SR. For its orbit control and beam stabilization (incl. feedbacks) the ESRF SR depended on 2 separate and independent systems, both of in-house design & conception : 1) The slow BPM system of 224 stations that had been conceived 20 years ago, and 2) the fast-BPMs with only 32 stations and 16 (vert.) & 32 (hor.) correctors for fast-feedback.

Both BPM types use blocks with 4 buttons for vacuum wall-current pick-up of the RF signal. At the time of conception (i.e. before 1990) of the slow system it was believed that fast & high-resolution beam position measurements would not be possible with the button-type of BPMs (and its RF electronics for signal treatment) and that instead X-BPMs, installed on numerous X-ray beam-lines would satisfy those fast needs. However, such X-BPMs suffered from intrinsic limitations and have never satisfied these requirements.

To overcome this, additional, independent BPM blocks were installed with electronics for fast measurements. Their purpose and usage has evolved progressively over the years, from first pure local fast feedbacks to finally a pure global SR ring feedback system to which very recent improvements were made to cover the full frequency band of the needed orbit stabilization [2].

The slow BPM system had an addition to its basic functionality with a high-resolution 'quasi' Turn-by-Turn measurement mode [3] that, with a stable & reproducible synchronization to an orbit kicker, allows the precise measurement of the SR lattice parameters. But it does not have a genuine single turn capacity, and for injection studies or for coping with severe injection problems, this old system requires certain conditions (4 strong injection currents for a single measurement) that are today no longer compatible with operation needs, nor with restrictions imposed by radiation safety regulations.

The satisfaction of today's requirements on the performance and functionality of a BPM system is no longer realistic through an 'in-house' design because of the technical complexity of different fields inside such system like RF signal treatment, digital signal conditioning through FPGAs, and interfacing with computer networks. This argument applies also to the ability to exercise the rigorous quality-control that is needed for production of a large series of units.

A few years ago the BPM needs of the new synchrotron light sources DLS and Soleil [4,5] had been satisfied successfully, in collaboration with them, by a commercial product called 'Libera-Electron' of the Instrumentation Technologies company [6]. Subsequently this product has provided more light sources for their BPM needs. [7,8,9]

This original product, after being fully employed & analysed by the DLS and Soleil [10,11], was improved in 2007 by a successor called 'Libera-Brilliance'. A total of 8 units of this product were procured at the end of 2007 and tested at the ESRF, during the first half of 2008, for full compatibility with the ESRF needs and the ESRF particularity of (multiple-) single bunch fillings.

VERIFICATIONS ON PROTOTYPES

These single bunch fillings yield an electric signal from the pick-up buttons that reaches a high peak voltage (upto 100V), and is very rich in harmonics (at 355KHz revolution frequency) in the frequency spectral domain. Both aspects can pose a problem to the Libera in terms of degradation of its performance, notably its low noise characteristic and its reproducibility for different SR currents & filling patterns : a) the input electronics may not have fully linear transmission characteristics for such high peak voltage, and b) certain spectral lines of the input signal may mix in an un-expected way with some of the Liberas 'internal' frequencies (the rates of the ADC convertors and the RF 'cross-bar' switches for internal calibration purposes) or some of its harmonics.

The old ESRF system had employed, directly after the pick-up buttons , RF bandpass filters (352 MHz, 40MHz bandwidth) and our long experience of their robustness, reliability and stability is such that we rely on these same components, now employed just in front of the Libera RF inputs, i.e. after ~20m of RG223 RF cable.

This solves the peak-voltages' question, but is of no remedy to excess noise in the output results due to a combination of small intrinsic ADC dislinearities and the internal mixing of the many frequency components that un-avoidably enter the system and that randomly fall in or out the bandwidth of the output signal, and that is generally made worse under the following conditions : 1) rich RF input spectrum (i.e. single bunch filling), 2) non-identical phase of the 4 RF inputs (i.e. due to un-equal RF cable lengths), 3) operating the ADC in the upper half of its dynamic range. 4) operating with the 4 RF inputs of strongly different amplitudes.

These problems had already been experienced with the original Libera-Electron and found a satisfactory solution in applying so-called 'offset-tuning' [4,10], a technique that allows to put the exact ADC' sampling rate at a slightly different value from an exact harmonic (304 for ESRF) of the orbit revolution frequency.

We did extensive verifications on the spectral contents of the so-called FA output (10KHz) that ultimately serves for fast orbit feedback and therefore the most sensitive to such spurious noise. Such noise lines clearly appear in the FA spectrum if the bad conditions are sufficiently fulfilled, but can then be 'moved', by adjusting the offset tune value, out of the bandwidth of interest.

Moreover, attention was paid to getting the new RF cables of reasonable good equal length (the average (over 224 BPMs) is 21mm maximum difference in a set of four), and we run the ADCs (by using the standard Libera AGC) in the lower half of their full dynamic range.

INSTALLATION & COMMISSIONING

The SR is divided in 32 cells of 7 BPMs each, and a first full cell was equipped in sept 2008 with exclusively Liberas, and 2 more full cells in dec. just 2 weeks before the 4 weeks winter shutdown. This allowed to gain confidence with the both the system and with the work & tools for this transition. This was important since the re-cabling and re-organisation of electronics in the receiving cabinets was irreversible. The 4 weeks shut-down therefore could be used to do a maximum of 13 more cells meaning that (a possibly) delicate re-start was now faced with 2 equal halves of the SR under a different BPM system. The remaining half was done at a rhythm of 3 cells per week, on its MDT day with about 4 hours of beam cut and subsequently ~8 hours more of new beam-based BPM offset measurements. The latter was needed to compensate for a change of positional offset between the old and the new electronics, and so the ensure that, after each stage of installation, the beam-lines would endure a minimum of X-ray beam displacement.

COMPUTER CONTROL & READ-OUT

The interfacing software that controls the 224 Liberas and acquires their data is based on the Tango control system [12] that is now widely used at both the ESRF and a few other European light sources. So far we have been using the original Tango device server of the Soleil Liberas that was developped more than 2 years ago.

We have at present one device server per Libera. Embedding this server, in principle possible since the Libera is a Linux based computer, has so far not been achieved mainly due to the modest floating point performances of the ARM processor. This may be reconsidered now with the new release firmware 2.0 but is not of high priority. Instead we have 224 device servers running on 4 dedicated Linux computers that each are equipped with powerful configurations (Dual core Pentium 4 running at 2.5 GHz with 3 GBytes RAM) and connected to a dedicated Ethernet VLAN with 1 GBits links. The 32 cells hosting each 7 Liberas are connected with 100 Mbits links.

On top of these 224 device servers is another Tango device server which collects the X and Z positions data using Tango Group calls : each read command is sent in parallel to all of the 224 lower level devices within 15 milli-seconds. This higher level device server also performs many other tasks like the positions corrections according to the SR current, the periodic storage into the ESRF History Database of the X & Z positions, the RMS values of scalable fast and slow buffers, and a number of maintenance & survey parameters.

The reliability of this dense and complex software structure was a serious challenge, also because it was based on the Soleil Tango server that we had limited familiarity with ourselves and to which we had to make a number of modifications in order to include both particular requirements for the ESRF and new functionalities that became available in new Libera firmware releases. This challenge was meet despite the little time available for testing purposes as the SR continuously depends on this BPM system to satisfy the light source users without interruption.

As to Liberas' firmware : All units were delivered (Nov. 2008) with the 1.82 release, and in Jan. 2009 we started to test the 2.00 release. At the time of editing this paper we have nearly half of the units upgraded to a subsequent 2.02 release that patches a discovered bug (the PM crashing the DSC daemon), includes some improvements and now also has the Communication Controller [15] (for FA data distribution, original design DLS) integrated & supported by the company.

Another major task was the development of the tools to, from a central point, properly install new firmware releases to all units and to subsequently upgrade the associated device-servers with it. Despite the optimization of these tools, the whole procedure of upgrading the full Libera system to a new firmware (in particular for the 1.8 to 2.0 releases) is very time consuming, also since the system is in quasi-continuous use for SR orbit control.

In addition to this, a restructured Tango device server, that is planned to replace the old Soleil Tango server next month, is being prepared and tested. Next to that higher level applications are being developed to allow the operation crew to more fully benefit from the new & high performance features of this new BPM system, and to allow an adapted control & read-out for beam dynamics studies like injection and lattice measurements.

RESULTS & PROSPECTS

A total of 15 Liberas units (out of 230 procured) needed repair action on the site of the manufacturer. Only a few of these problems arrived while in active use for orbit measurement & control, the majority had been trouble-shooted by simple & quick verifications with RF test signals strait after installation in their cabinets.

Presently only the SA (10Hz) output is used for continuous and routine beam orbit monitoring and control in the SR. The performance of the Libera system has been verified in terms of precision, resolution and reproducibility to satisfaction. On average a few out of the 224 stations are out-of-use, mainly because of recurrent problems with the quality of an SMA connector or an RF-cable, or some un-explained variation of the signal obtained from a button. The Tango device server scrutinizes the quality of a position result by verifying the 'coherency' between the 4 signals of each BPM, and an automatic rejection is carried-out in case a single signal drifts or fluctuates in excess of a small threshold.

The DD output for Turn-by-Turn measurement needs precise adjustments of the timing signals & internal delay values so to ensure that in an acquisition each station is strictly synchronised on the same turn, and with a minimum of leakage or smearing with neighbouring turns. [13] This adjustment was easy to achieve with single shot injections and measuring the Sum signal. However, for even more stringent T-b-T measurements a so-called MAF filter can be installed that is free of such smearing [14]. The use of this special filter, and its preceding timing adjustments was so far done (i.e. tested) to satisfaction on 3 cells only.

The timing signals for the PM buffer, for analysis after a beam-loss or some other triggerable event, have been installed and tested. This revealed a software problem in the 2.00 release that has been corrected since.

The Interlock function is activated on only 8 stations and only in the vertical plane with a +/- 0.7mm threshold. A new software release soon will allow to avoid the systematic triggering on a beam-loss which causes unnecessary confusion to our existing accelerator interlock & protection system.

The Sum signal (of the 4 button signals) shows a very good stability that allows its exploitation at different data-rate outputs. On the SA data a beam lifetime measurement averaged over the large number of Libera units shows a better resolution than that obtained with the PCT current monitors. On the DD data the same Sum signals allow a precise measurement & study of accumulation & injection efficiency.

The rudimentary air-conditiong & temperature control of the technical galleries where the cabinets, housing the 7 Libera units, are situated have made necessary the installation of new doors, plates and ventilators to avoid the ventilators inside the Libera itself reaching the maximum rates. This work has been done sofar on 5 cells with the remainder to be finished before this summer.

A large network of fibre-optics is already installed and ready to be connected-up for the distribution of the 10KHz FA data between all Liberas and a small number of feedback processors. This distribution is handled by a so-called Communication Controller [15] that runs in parallel on the FPGA in each Libera, and facilitates its exploitation in the near future's complete upgrade of the SR orbit stabilization system.

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