BUNCH PATTERN CONTROL IN TOP-UP MODE AT THE SWISS LIGHT SOURCE

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Abstract

One of the features of advanced third generation light sources is the bunch pattern control in the storage ring, where various filling patterns are of interest for different experiments. The most important step is to keep a uniform charge distribution over all (electron) bunches during the top-up operation. Such a bunch pattern control has been implemented at the Swiss Light Source (SLS). It provides a filling pattern with bunch-to-bunch fluctuation of only a few percent. Since a dependency of the medium term orbit stability on the actual filling pattern was observed in the past, the stability could significantly be improved. Three major ingredients have made the implementation possible: precise timing system, flexible control system and sophisticated diagnostics. The method is applied in the user operation recently and proved to be reliable. This paper describes the hardware and software involved in the filling pattern feedback.

1 BACKGROUND

The SLS has been running in top-up mode for user operation since its commissioning. Until April 2004 only basic controls over the filling pattern of the storage ring has been achieved which have been adequate so far. The procedure was simply to set the first and the last bucket to fill (e.g. from 0 to 389) and then a bucket counter was incremented after each single bucket injection and stopped whenever there is no injection. For the next injection cycle it continues to fill again until it reaches the last bucket and it roles over to first bucket. Because of the different life time of individual bunches this method results with an uneven filling pattern of the bunch train in the storage ring after a while of running in Top-up mode. The uneven filling in turn causes undesired beam oscillations which have been observed at X-BPM (X-ray beam position monitors) in the beamlines. The observed orbit oscillations are caused by non-linearity in the RF front-ends of the DBPM (digital BPM) system induced by sidebands generated by individual bunches with un-even charge densities. The main reason of the non-homogeneity of the filling pattern of course comes from the fact that the storage ring has to be topped-up continuously.

We have been working on this issue since quite a while [1] using BPM pick-up readout but the previous hardware setup was not precise enough to resolve the filling pattern at the bucket level. In this case the readout of the signal was also convolved by the transfer function of the system hardware starting from the BPM pick-up buttons to the acquisition equipment.

Meanwhile the development of the diagnostics beamline has been under way and very recently the filling pattern readout was made available after using an avalanche photo diode (APD).

2 DIAGNOSTICS SETUP

The diagnostics beamline of the SLS is used in the time being for reading of the storage ring charge distribution. The visible part of the synchrotron radiation is coupled out into the experimental hutch of the X05DB beamline [2] and is focused on an APD. The rise time of the APD is 180 ps with a high gain and a bias of typically 165 V.

A permanent setup for the installation of an APD in the storage ring tunnel has been foreseen and its preparation has already started.

3 CONTROLS HARDWARE

As figure 1 shows the feedback loop architecture involves some optic components, the photodiode, data acquisition and controls components, timing system, and injection (extraction) components as well as subsystems.

The APD needs a bias voltage to bring it in the avalanche region which is provided by a simple DC power supply.

The output signal from APD is connected to a fast digitizer without any filtering or even amplification in between. The digitizer is a Lecroy type rack-mountable scope which has just an Ethernet interface for remote control and no local controls are provided. It is triggered externally in the rate of storage ring revolution frequency to be in sync with the electron beam. The sampling clock is also provided externally. The sampling rate is 2 GS/s and the analogue bandwidth is 1 GHz. Both these signals are provided by the SLS timing system [4] which synchronizes all the required components and subsystems together. The timing hardware used here is an EVR (event receiver) and is capable to receive all the global timing events of the SLS.

The only way to communicate to the digitizer is the Ethernet port where all the parameters are set and the calibrations are done to fit a desired acquisition of the filling pattern.

The VME crate houses the required controls cards and run the software which implements the algorithms and the related low level software applications.

The pulsed magnets and gun trigger are also provided by the timing system and at the right time and delays are fired to inject the required current into the desired buckets of the storage ring.

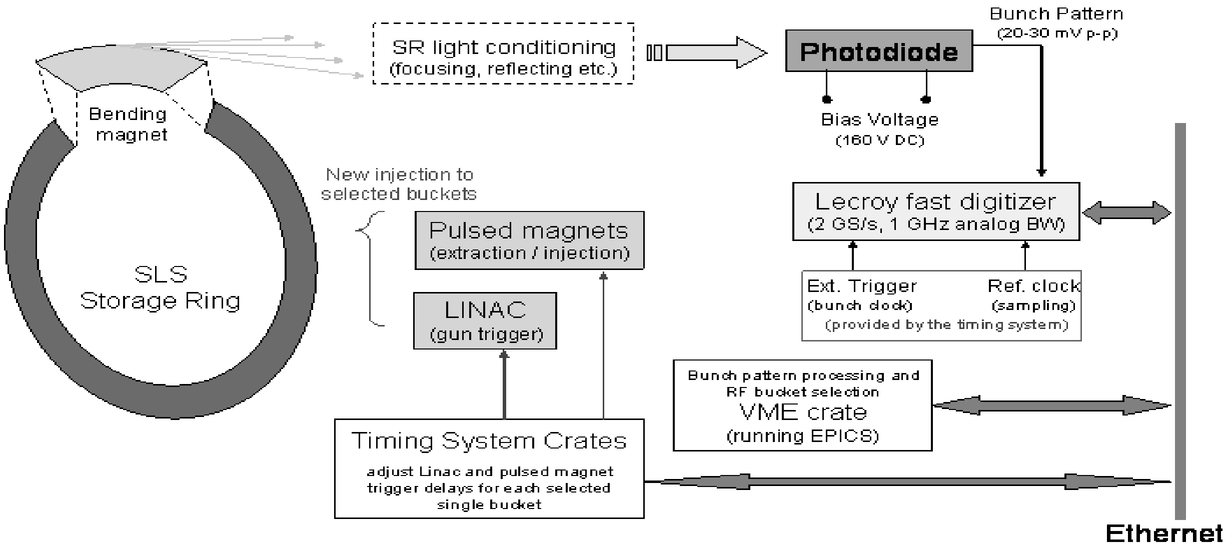

Figure 1: filing pattern feedback loop architecture.

4 CONTROLS SOFTWARE

Software layers

In figure 2 the different software layers used for the filling pattern controls are shown. Starting from the top a TCP/IP server is running on the Lecroy digitizer which talks via stream sockets using a special protocol called VICP (Versatile Instrument Control Protocol).

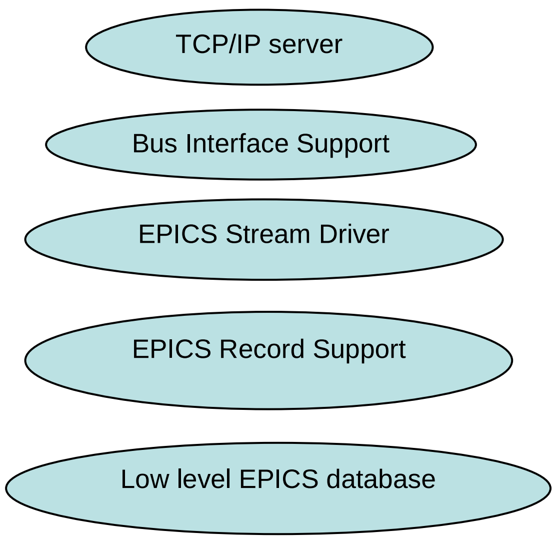

Figure 2: software layers

As the SLS control system uses EPICS, a bus interface support module (a C code) was developed which implements the communication protocol of the device (digitizer) and is able to talk to the next layer which is the EPICS stream driver. The stream driver in turn implements the device support for the standard EPICS record types. So at the end the meaningful data are available at the EPICS databases (or channels) which is the level to implement filling pattern controls algorithms.

Software algorithms

In figure 3 the flow chart of the filling algorithm has been shown. One of the differences here with respect to the normal top-up (without feedback) is that in case of the filling pattern feedback the bucket numbers are not sequentially counted up but rather calculated by processing the actual charge distribution in the storage ring at each top-up cycle. Whenever each top-up cycle finishes and the injection stops, the time duration to the next top-up cycle is calculated according to the beam lifetime, current dead band and integrated current of the storage ring. During this interval the acquired filling pattern is averaged over many turns. Afterwards the values representing the relative charge for each bucket are extracted from the processed pattern. At this stage the bucket numbers are sorted starting from the bucket with lowest charge and ending with the highest. The bucket numbers from this list are used one after the other to be injected to when the next top-up cycle starts. The whole procedure is repeated again as soon as the ring current is topped-up.

This will result in an even (flat) filling pattern which has charge fluctuations of only a few percent from one bucket to another.

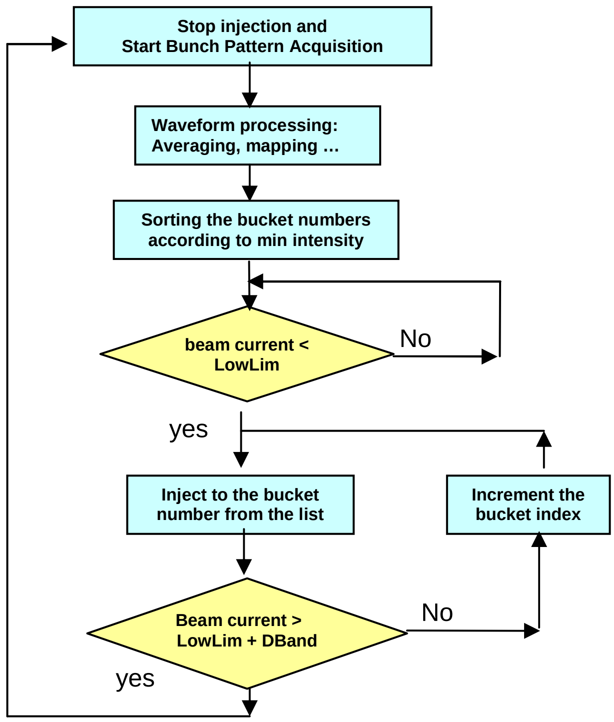

Figure 3: algorithm flow chart

5 EFFECTS OF THE FEEADBACK

5.1 Comparison of the patterns

In figure 4 a comparison of the filling patterns with and without feedback is shown. The lower curve shows the filling pattern without feedback in top-up mode and the upper shows it with filling pattern feedback.

The fluctuation in the charge density over the bunch train has significantly decreased. The fineness of the pattern of course depends on the amount of charge generated by Linac and later injected to the ring. We have reduced the fluctuations by 50% in this case. The unevenness can still be reduced by regulating the gun bias voltage at each top-up injection cycle.

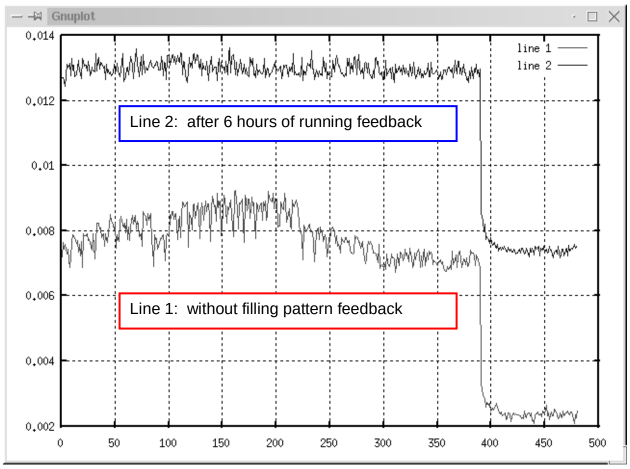

Figure 4: filling pattern comparison

5.2 Effect on the orbit stability

Since the operation of the feedback on the filling pattern, a bucket intensity correlated orbit oscillation has been eliminated (see figure 5). When the filling pattern feedback starts the targeted bucket numbers are not periodic (sequential) anymore and have a rather random distribution. The even filling pattern with equal charge intensities over all the filled buckets has improved the orbit stability in the range of 1 to 2 micron peak-to-peak at the location of the X-BPMs.

The reason is that the RF front-ends of the DBPM system do not suffer any more from its non-linearity when the individual bucket charges are equal. Therefore the (fast/slow) orbit feedback does not make an effort to compensate for it [4]. The readers are referred to [5] for other observations of the reference orbit positions at the beamline locations.

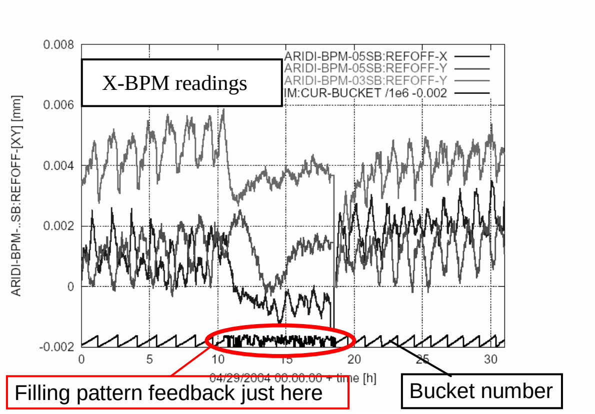

Figure 5: X-BPM readouts with and without feedback

7 FUTURE PLANS

The new features of the filling pattern controls are under development and will be operational in very near future. The idea is to provide the ability to generate simply an arbitrary pattern on the storage ring. To involve the e-gun bias voltage regulation is also one the future steps in this context.

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