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UPGRADE AND FIRST COMMISSIONING OF TRANSVERSE FEEDBACK SYSTEM FOR SSRF*

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Abstract

To be a part of the transverse feedback system upgrade plan in SSRF PHASE II project, a set of Dimtel feedback processors [1] was installed to replace the previous set. In the commissioning, the ability of supressing the transverse oscillation was tested and evaluated, also, beam diagnostics and control tools of the processors was used for injection transient analysis, tune tracking and bunch cleaning. The results of the commissioning and data analysis will be presented in this paper.

INTRODUCTION

SSRF is a third generation 3.5 GeV synchrotron light source with 720 bucket in the storage ring and a RF frequency of 499.654 MHz. The transverse feedback (TFB) system was started in 2010, and the feedback kicker consists of one vertical electrode and one horizontal electrode, one feedback processor designed by Spring-8 to produce 2 independent channel of feedback signal for both planes. In SSRF PHASE II project, 16 more beam line will be built before 2022, and more IUVs are planned to be installed in the storage ring, which would lead impedance of the whole ring increase from 4M Ohm to 8M Ohm. Another challenge for beam transverse motion control is a newly introduced hybrid operation mode, which consists of about 500 filled buckets of 0.5mA and one high current bucket of 20mA. It is evaluated that the feedback system could suppress the transverse instability even when the product of impedance and beam current increases to 3 times, but the limitation of individual bunch current is 10mA. If only one electrode is used for each plane, the dynamic range for each channel is required to reach 32dB, it would be very difficult for TFB processors and power amplifier configuration. So a 3-electrodes kicker scheme was designed, compared with the 2-electrodes kicker, one more vertical electrode was specialized for controlling the hybrid bunch. 2 TFB processors were also to be added to fit the new kicker plan, one for normal buckets in both planes, the other for the big bunch in vertical plane. Since the 3-electrodes kicker is planned to install one year later, the commissioning only refers to the normal operation mode processor.

FEEDBACK SETUP

A stripline kicker with 3 electrodes talked above is going to operate as a transverse feedback actuator in all modes. Normal operation mode is driving when driving a horizontal electrode and a vertical one, Hybrid mode is driving when driving all the 3 electrodes. The designed kicker is shown in Figure 1.

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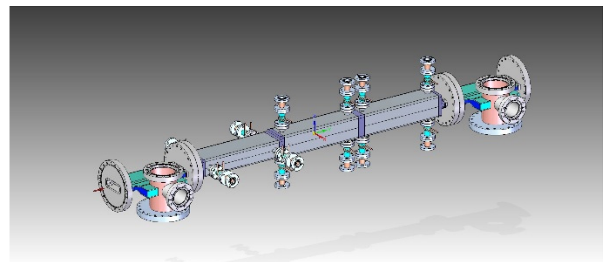

Figure 1: Transverse feedback kicker with 3 electrodes, the first electrode is horizontal electrode, and the 2 and 3 are vertical electrodes.

The feedback electronics includes one hybrid network, one FBE-500LT front-end, and 2 iGp-12 processors. The hybrid signal of differential horizontal and differential vertical (Δx + Δy), and the differential vertical (Δy) of the beam motion are created from BPM signals in the hybrid network (Fig. 2). The 2 channel signals would be processed by FBE-500LT and then fed to iGp-12 separately.

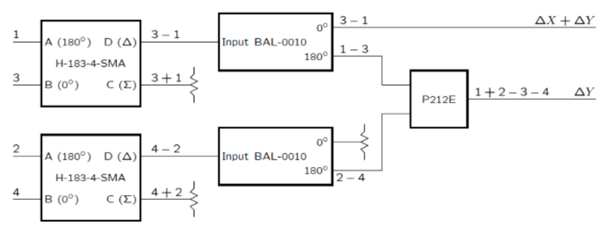

Figure 2: Layout of hybrid network.

Since one iGp-12 only have only one pair of differential input channels, the 16-step FIR filter was specially designed to provide feedback signals in both X and Y plane simultaneously, which is shown in Figure 3. And the differential output is divided into 2 way to fed X and Y kickers.

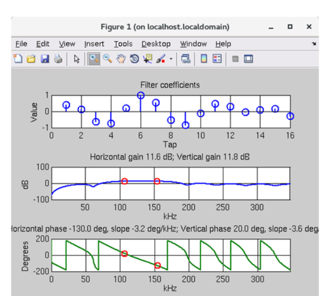

Figure 3: 16 step FIR design of feedback for both X and Y plane.

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COMMISSIONING AND TEST

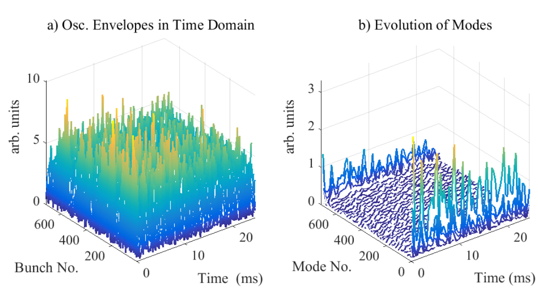
The commissioning of Dimtel feedback system was arranged in a Machine Study after all the hardware had been installed in the rack above power amplifiers, and the old system was left unperturbed. The feedback loop was first closed in single bunch mode, after the parameters of timing, phase and FIR filter were optimized in the mode, the beam current was injected up to 3mA gradually when the instability could be observed and suppressed by the system. In order to check the feedback performance at full current, the multi-bunch mode was switched, and the beam current was increased step by step. Subsequently, the different experiments were also performed:

- Grow-damp measurement at 245mA;
- Injection transients with and without feedback;
- Single bunch tune tracking;
- Bunch cleaning test.

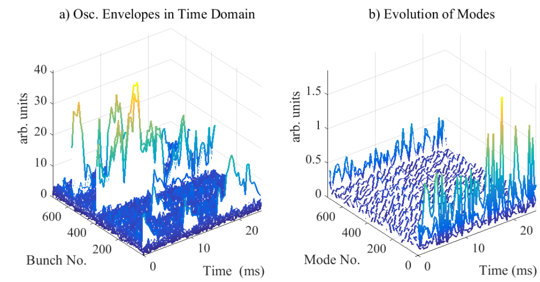
Feedback Performance Evaluation

The previous transverse feedback electronics in SSRF had been running stable and achieving good feedback effect for about 10 years. But recently, it may not worked in the optimal state, as some cables were replaced and reconnected for device maintenance requirement [2].

The Dimtel feedback system provided a set of diagnostics tools, which would help to evaluate the feedback effect. In the experiment, when beam current reached to 120mA, we switched feedback setup to the previous one and then ran it into feedback loop firstly, after capturing some steady-state data and some sets during injection, the Dimtel setup was switched back, and capturing the same data. The distributions of oscillation envelopes and mode evolution in Fig. 4 showed the different feedback effect between 2 setups, and mean mode amplitude in Fig. 5 indicated the main instability mode. The bunch oscillation were well suppressed by Dimtel setup, while there are greater bunch oscillation not fully suppressed by feedback and mode amplitude by old system.



(a)



(b)

Figure 4: 3-D Bunch Beatron oscilloation and mode distribution, (a) for iGp setup and (b) for previous setup.

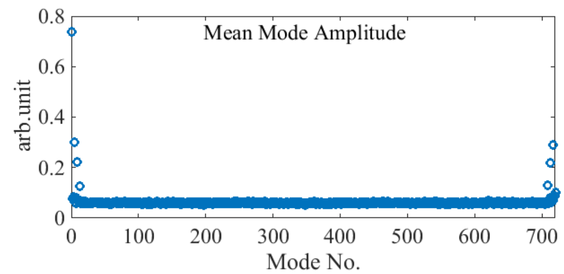


Figure 5: Mean mode amplitude for Dimtel setup, which is the same for previous setup.

By analysis the injection data sets, injection transients also gave the conclusion about the feedback effects between 2 setups. Figure 6 showed the injection transients when Dimtel setup ON / OFF. It is clear that the setup caused faster transient damping and lower peak amplitude with feedback ON. And some individual bunch transient characteristics were demonstrated in Fig. 7, which showed worse feedback effect or even out of control with previous setup.

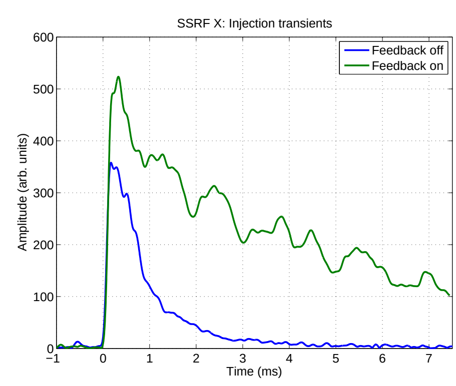


Figure 6: Injection transients comparison with Dimtel setup ON / OFF.

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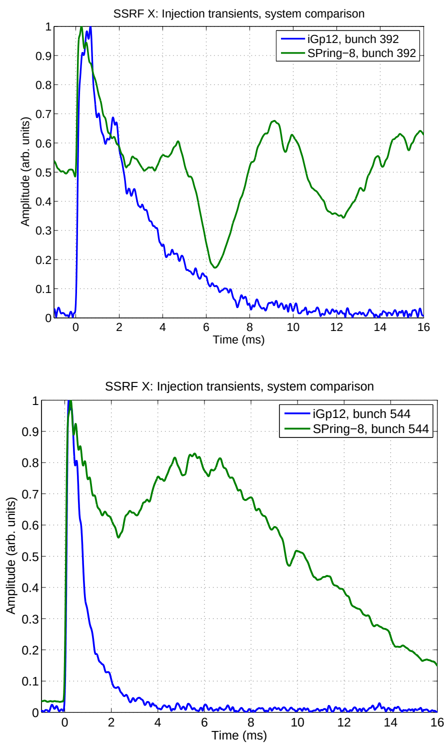

Figure 7: System comparison for bunch #392 and #544 injection transients.

Grow / Damp Measurement

Grow/damp measurement is important to determine the source and strength of coupling impedances. The Dimtel feedback electronics could be turned OFF for a short period of time to allow the instabilities to grow and then turned back ON to damp the motion. This kind of grow/damp measurement is useful to characterize the unstable modes in the storage ring. A grow-damp measurement at 245 mA with mode 719 (-1) being dominant is shown in Figure 8. The mode is considered as resistive wall instability [3].

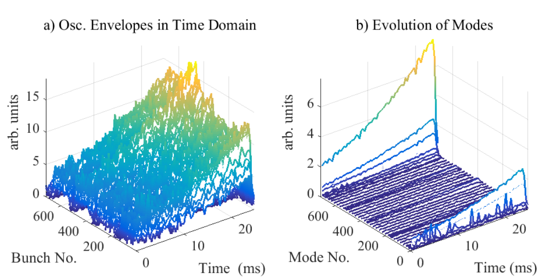

Figure 8: 3-D bunch oscillation envelope and mode evolution in grow-damp measurement.

Grow /damp rate was calculated by fitting grow /damp curve in exponential transients formula of mode 719, which is showed in Figure 9.

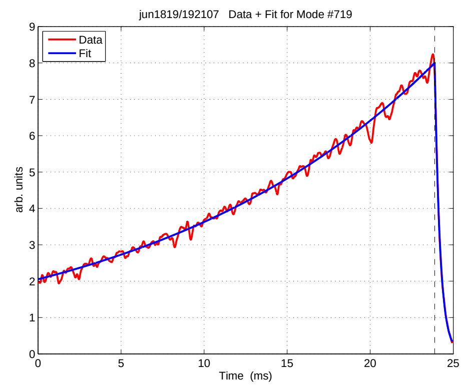

Figure 9: exponential fit of mode 719, Growth rate of 0.057 ms^{-1}, damping rate of -3.0 ms^{-1}.

The current dependency of growth / damping rate study is showed in Figure 10. When current is changed in a very small span (about 0.6mA), it showed clear linear behaviour of growth /damping rate, and very fast damping, scales linearly with gain.

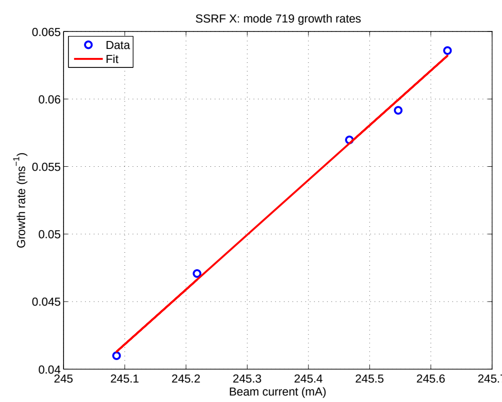

Figure 10: Beam current dependency of growth rates and linear fitting.

Tune Tracking

IGp-12 processor offered a sinusoidal drive generator, which could be employed to sweep sinusoidal excitation for a selected bunch at lower amplitude (20-40 μm). Betatron tune could be measured by the normalized excitation frequency. Response is detected relative to the excitation to determine the phase shift. In closed loop, phase tracker adjusts the excitation frequency to maintain the correct phase shift value; Decimation factor in phase tracker controls tracking bandwidth. Figure 11 showed the fast tune tracking for over 140ms in horizontal plane.

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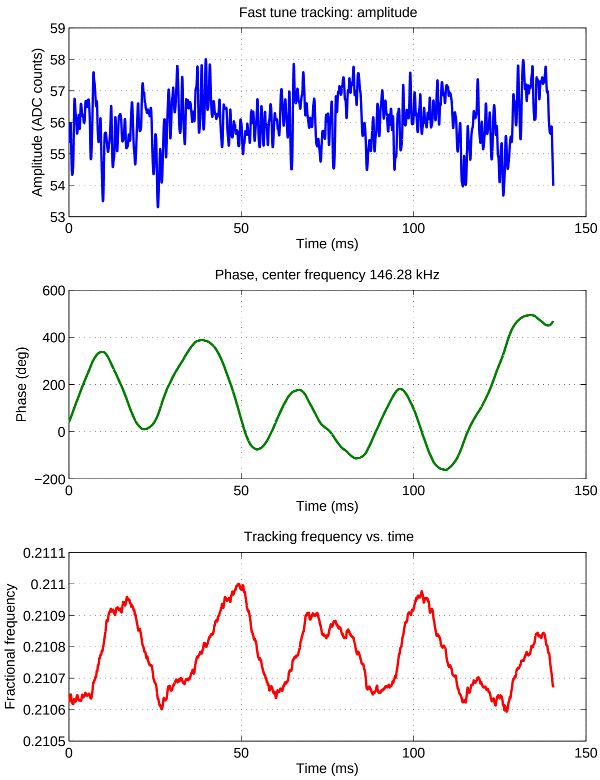

Figure 11: Excition betaron oscillation amplitude (top), phase (middle) and Fast tune tracking (bottom) over 140ms.

Bunch Cleaning

Individual bunches could be kicked out using the integrated bunch driving function. By this mean, highly purified filling-pattern could be demonstrated. The function was tested by driving a selected bunch at the frequency across the vertical betatron tune, the sweeping range and sweeping frequency could be adjusted to knock out the bunch effectively. Figure 12 shows the #600 bunch was successfully kicked out.

Figure 12: Bunch #600 was kicked out using vertical plane excitation with little effect on nearby bunches.

CONCLUSION

We have constructed and tested a transverse bunch-by-bunch feedback system using the Dimtel electronics in SSRF. The feedback system has shown sufficient performance to suppress the transverse instabilities up to a beam current of 245 mA. We have also performed the grow-damp transient analysis of instabilities, and determined that the mode #719(-1) of the horizontal plane grows most rapidly among all instability modes which is considered as resistive wall instability. It is proved that one set iGp-12 processor could be used for the feedback for both vertical and horizontal planes, only by reasonable FIR design. The setup will be continued to optimized and installed month later.

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