RIPPLE DIAGNOSTIC ON BESSY II POWER SUPPLIES

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Abstract

Keeping the ripple of power-supply currents within the specification limits is crucial for the beam stability of the BESSY storage ring. Malfunctioning or aged electronic devices cause an increase of output ripple over the years. This increase is hardly noticed by the operator or operation analysis because the slow integrating AD converters for the current readbacks filter out the ripple. Furthermore, it is almost impossible to find the connection between certain beam movements or beam noise and the faulty power supply causing it. To improve this situation, ripple information for every power supply is required within the control system. The latest series of the CAN bus-connected power-supply interface cards used at BESSY provide an additional fast AD converter. With a sampling frequency of 83.5kHz, this ADC samples ripple information over one period of the mains voltage. The results are transferred over the CAN bus to the EPICS-based control system and can be processed in the usual ways. Using this setup, even temporarily increased ripple can be detected without complex measurement methods.

INTRODUCTION

The electron beam in the BESSY-II storage ring is guided with several magnets driven by power supplies with specified maximum ripple values. Beam stability essentially depends on the power supplies driving the magnets. The guarantee for the specified ripple of the power supply current is essential for beam stability at BESSY.

POWER SUPPLY FAULTS

Malfunctioning or aging electronic devices cause an increase of output ripple over the years. Even a temporarily increased ripple causes instabilities and declined measurement conditions for the experiments. These power supplies at least temporarily do not meet their specifications.

PROBLEMS IN DETECTION

Detecting these problem-causing power supplies generally requires time-consuming observations and measurement with a lot of equipment – and hence performing these tests on hundreds of power supplies is an unreasonable amount of effort.

It is almost impossible to detect interference between the affected power supply and beam movement or beam noise. An increased ripple is not noticed by the operator, because of the slow integrating filtering AD converters for the current readbacks.

This situation requires ripple information inside the control system for each power supply.

SOLUTION WITH EXISTING HARDWARE

A new and in many power supplies existing interface card type includes an additional fast AD converter. The new ripple measurement method is a procedure for permanent or cyclic supervision of power supply ripple values using this fast AD converter. A CAN object triggers the start of the ripple measurement for all power supplies in the ripple measurement system. At any time a single power supply can as well be tested. The power supplies transmit their measured and calculated ripple value to the control system. Due to the combination of cyclic measurement and archiving of the ripple data a supervision of continuous and temporary ripple behaviour is possible.

METHOD

The primary side of any power supply is connected to the 50Hz mains voltage. Often the ripple behaviour depends on the mains frequency. With this background the measurement time is set to one 50Hz period of 20ms (Figure 1). During these 20ms the AD converter takes 1670 samples of the current readback. This is equal to a sample rate of 83.5KHz

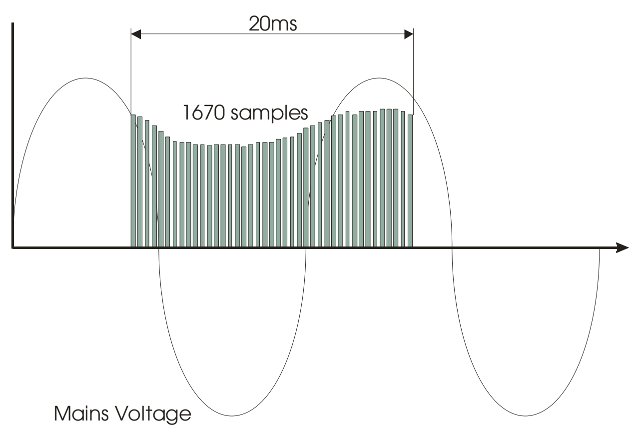

Figure 1: Sampling period.

All measured values are stored in the embedded controller memory. In order to suppress noise added by the AD converter, it is possible to average the measured values over a maximum of 255 samples. This smooth factor is useful for cutting higher frequencies of ripples. The difference between highest lowest smoothed sample is calculated and transmitted over the CAN bus to the control system.

During ripple measuring period, the normal cyclic readback of current and voltage is disabled in order to perform accurate equidistant AD conversions.

MEASUREMENT EXPERIENCES

Signal Processing

There are two reasons that enforce signal processing:

- With an ideal direct voltage on the AD converter card input the AD converter noise is at least 150ppm (related to 10V). However much lower ripple values cause beam problems, it is necessary to reduce the noise by mathematic functions. This is done by the configurable average determination.
- The frequent transmission of arrays with at least 1670 values of 16bit over the CAN bus is not practicable.

After the testing of different methods, the following solution was chosen:

Smoothing with average determination over all values and transmission of the difference between the highest and lowest value. Figure 2 demonstrates this method:

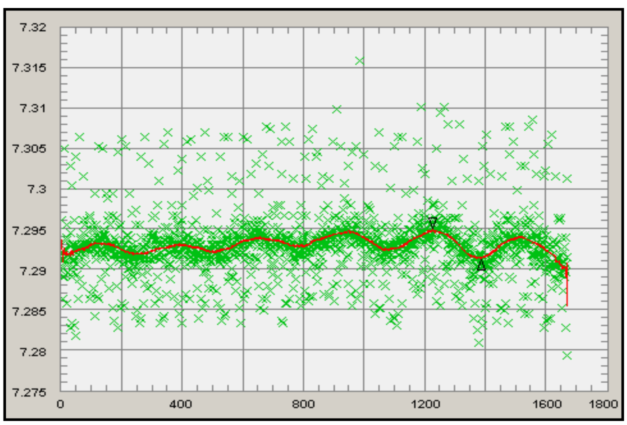

Figure 2: Ripple measurement on dipole power supply.
X-axis: current AD conversion number.
Y-axis: current readback in 7.275...7.32V

The green crosses represent the 1670 individual measurements. The red line shows the values smoothed over 81 samples. Black markers are showing the maximum and minimum value. The marker difference is the transmitted ripple value. Smooth 81 means that averaging of every smoothed value uses a count of 40 values before and 40 values after this value for calculation. In order to get useful values for the first 40 and the last 40 measurements, the software in the embedded controller increases the total count of measurements according to the smooth factor. The smooth factor is transmitted to the embedded controller over the CAN bus together with the ripple measurement start command. Smooth factor zero means no averaging at all (raw values), a smooth value of 255 means maximum smoothing. A comparison with an oscillogram of the BPM readback in figure 3 shows a comparable waveform.

Laboratory Measurements

The average computation has an effect on the noise and the bandwidth of the ripple measurement. To quantify

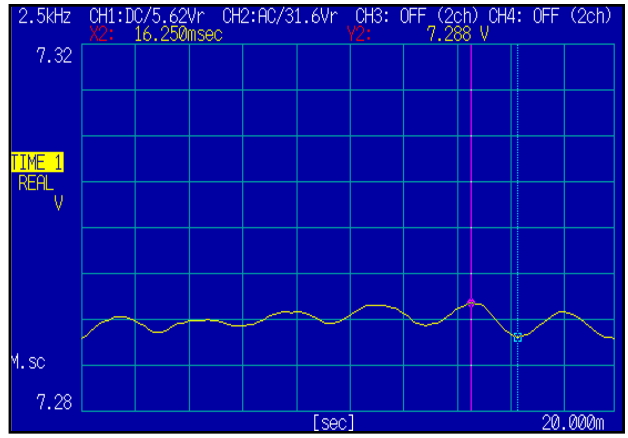

Figure 3: BPM readback with ONO SOKKI CF-6400.

these two effects two laboratory measurements were performed:

- To detect the reduction of the AD converter noise by the average computation, a sine wave generator was connected to the AD converter card inputs with a frequency of 100 Hz. The amplitude was varied from 50 uV to 500 mV and in every case measured with the AD converter card. In an ideal case, the measured signal should have the same amplitude as the generator source signal. In the diagram (Figure 4) this should produce a diagonal. With higher smooth factors the limit of detection shifts to smaller amplitudes. The reliable detection of a 20ppm signal is a respectable result with a 31ppm resolution AD converter.

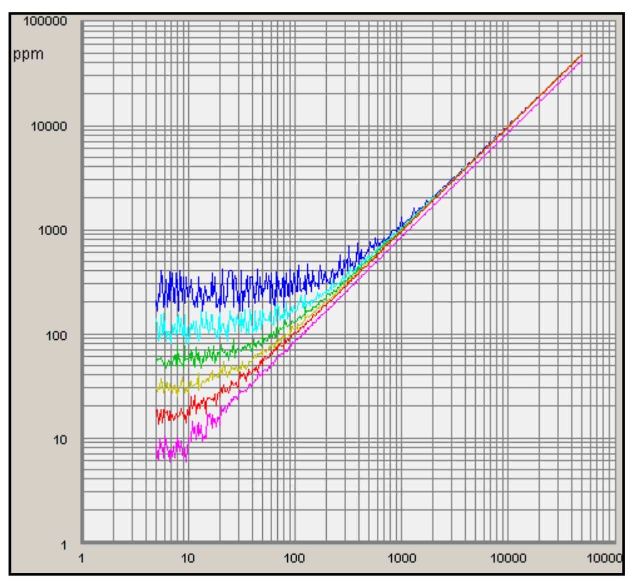

Figure 4: resolution limit with different smooth factors.
X-axis: Amplitude of sine wave generator at 100 Hz.
Y-axis: Amplitude measured by AD converter
(1..100000 ppm related to 10V).

- To detect the measurement bandwidth the amplitude of the sine wave generator was kept constant and the frequency was varied from 10Hz to 100kHz (Figure5). As expected, an increased smooth factor decreases the bandwidth. With additional mathematic functions a stronger reduction of higher frequencies would be possible, but the 386EX processor without FPU would need a lot of time for these calculations. The smoothing of a 20ms array over 81 measuring points currently needs more than 3 seconds.

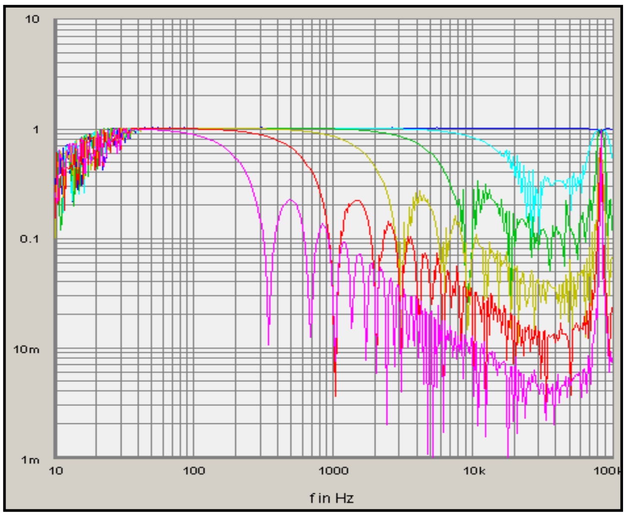

Figure 5: Bandwidth at different smooth factors. X-axis: Frequency of sine wave generator (10Hz..100kHz; amplitude 1V). Y-axis: Amplitude measured by AD converter.

The results of the measurement shown in figure 4 and 5 are summarized in the following table:

Table 1

Smooth factor	**Detection limit**	**Bandwidth**
0	500 ppm	30 Hz – 45 kHz
3	200 ppm	30 Hz – 15 kHz
9	100 ppm	30 Hz – 4,5 kHz
27	50 ppm	30 Hz – 1,5 kHz
81	20 ppm	30 Hz – 450 Hz
243	10 ppm	30 Hz – 150 Hz

MEASUREMENTS ON REAL STRORAGE RING POWER SUPPLIES

After these tests under laboratory condition a range of random tests on storage ring power supplies was performed. With the power supply type DF883 it was necessary to use a parallel capacitor of 220nF in order to block noise peaks. Figure 6 shows a composition of 2 different measurements for each of the 13 power supplies.

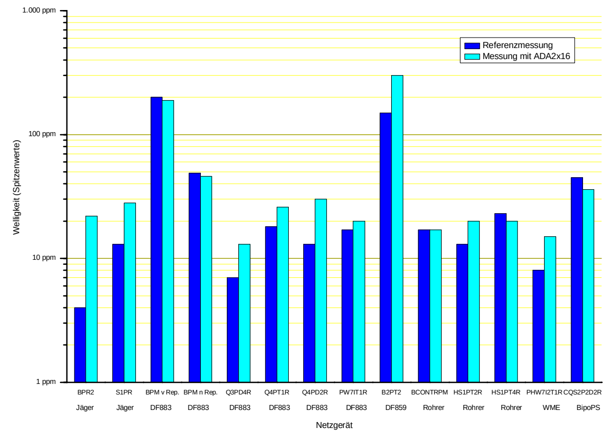

Figure 6: Ripple measurements on different power supplies.

The dark blue bar shows the ripple value measured with the CF-6400 and a 2 kHz low pass filter as a reference. The light blue bar is the ripple measured with the AD converter interface card. Smooth 81 is equivalent to a bandwidth < 450 Hz with low reduction of higher frequencies. This choice suppresses the relevant harmonics of the mains frequency. In principle both measurements show the same dimension. An obvious difference is just at the dipole power supply BPR2 visible. This device has a ripple of 4ppm what is not measurable with the AD converter card (limit of detection approx. 20ppm).

CONCLUSION

The performed measurements demonstrate the usefulness of the ripple measurement system at BESSY using of the existing hardware. The detection of defective hardware is considerable faster and easier. Now a sometimes just temporary increased ripple is detected without complex measurement methods.

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