AUTOMATED SYSTEM FOR PRECISION CURRENT SOURCES TESTING

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Abstract

The beam correction system for European XFEL includes about 400 precise current sources. The every current source must tested and verified in concordance with specifications before including in XFEL equipment. For this purpose there was developed the automated system that allowed to test up to 7 current sources simultaneously. The system consists hardware stand and software that written for Linux OS. The stand was equipped emulated real load test loads, with precise DCCT and by precise analog-to-digital converters with CANbus interface. During testing the current in each current source was changed and digitized in concordance with different algorithms. The duration of typical session was 25 hours. The specific software was developed for this stand. It provides testing process, collecting and storing the primary information and displaying the first information. There are addition utilities which allows to make different analyzes in off-line mode using data accumulated during tests. The article provides a detailed description of the stand and main results.

INTRODUCTION

In 2009 at the DESY (Deutsches Elektronen-Synchrotron) research center, construction of the world's largest free-electron laser was started. The project was called XFEL (X-ray free-electron laser).

The realization of this international project will make it possible to observe molecules in dynamics while they are involved in chemical reactions.

The XFEL has a total length of 3.4 km and consists of a linear accelerator and a complicated magnetic focusing system. The XFEL beam correction system consists of almost 400 corrective dipole magnets. To ensure the power supply for these magnets, the BINP has been contracted to design and provide four hundred precision current sources. The sources have to meet a number of requirements, some of which are listed below:

- The RMS noise of output current in the frequency range from 0 Hz to 1 kHz should not exceed 10 ppm.
- The deviation of the absolute value during long-term use should be not more than 100 ppm.
- To control a number of parameters, each precision source must be tested during 25 hours with a gain of statistical data.

Considering the above requirements, it is reasonable to create an automated system that would be able to perform the real time test for several precision current sources simultaneously.

Physically, the automated system consists of a stand, to which seven precision current sources can be connected, and the software that automatically controls the stand.

BLOCK DIAGRAM OF THE STAND

Figure 1 shows a block diagram of the stand. The stand has seven independent channels, which provide a non-contact method of measuring current in a range of ± 10 amps. The channel has a power input for connecting a precision power source and output for connecting an equivalent load. In the figure, the precision sources are indicated as MPS, and the equivalent load is shown as a series connection of resistance and inductance. Furthermore, each channel has two additional analog outputs: **C** (Current) for indicating the measured current equivalent (in volts) and **T** (Temperature) for indicating the temperature equivalent (in volts) from the temperature sensor in the channel. Current and temperature values are measured by six-channel ADC of CPS01 controller. CPS01 controllers and MPS precision sources are controlled via CANbus.

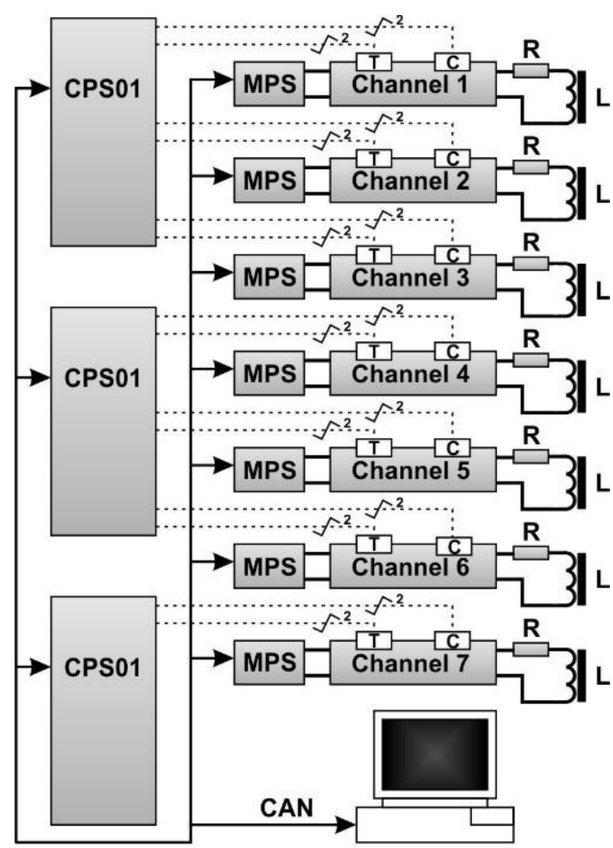

Figure 1: Block diagram of the stand.

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BLOCK DIAGRAM OF THE CHANNEL

Figure 2 shows a block diagram of the channel. Its detailed description is given below.

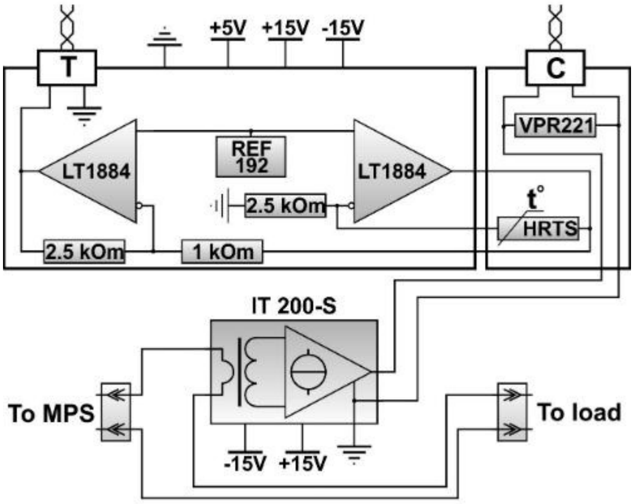

Figure 2: Block diagram of the channel.

A precision non-contact sensor IT200-S (LEM production) is used for the measurement of the source current. The sensor is a DC current transformer with a transformation ratio of 1:1000. The current output of the sensor is loaded on the precision resistance VPR221 (Vishay production), the voltage on which indicates the current value in the channel. VPR221 resistor body is attached to the radiator for temperature stabilization. In addition, the temperature monitoring of the precision resistor is performed. In Fig. 2, the temperature sensor indicated as HRTS. Operational amplifiers shown in the figure, provide a linear dependence between the output voltage and the temperature. The precision resistance and the temperature sensor are attached to the radiator using a copper plate and located tightly to each other. The copper plate ensures a low gradient in temperature distribution over the surface. This allows the temperature of the precision resistor to be measured with a good accuracy.

RESULTS

Defining the Parameters

Before testing precision current sources, some parameters of the stand have been determined, in particular:

- the warm-up time of the stand required to ensure the thermal equilibrium with the environment.
- the temperature drift.

Figure 3 shows the time dependence of the measured current values on all channels of the stand during the warm-up period. The current was passed consistently through all channels of the stand and set by the same MPS source. It should be noted that the current curves show a summarized drift from the precision current source and DCCT precision meter.

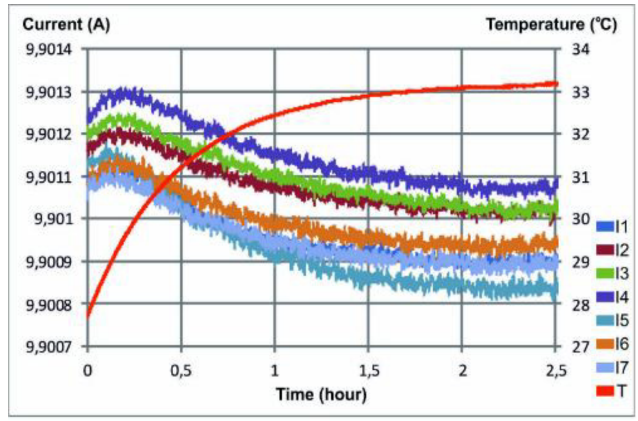

Figure 3: Warm-up.

Warm-up time was determined at a current of 9.9 amperes. The diagram shows that the greatest change in the current occurs between 1 and 1.5 hours after turning on. Based on this result, it was concluded that daily testing of the sources makes sense after at least one hour of the stand warming up.

To determine the temperature drift of the stand a Fluke 5730A current calibrator, which had its own temperature drift of ~5mka/^{0}C, was used. The current was passed through all channels of the stand consistently and set by the calibrator. The measurements were performed for both polarities of the current and for each polarity statistic has been acquired during the day. The data processing showed that when the current is positive, some channels have a positive drift, while others have a negative one. When the current is negative, all channels have a drift of the same sign.

Figure 4 shows the drifts of two channels at positive current that have the greatest temperature dependence. Black lines along the graphs are the trend lines calculated using Microsoft Excel. According to the diagram, the channel with positive drift has a drift value of 17.9 mka/^{0}C, while the channel with negative drift has 7.1 mka/^{0}C.

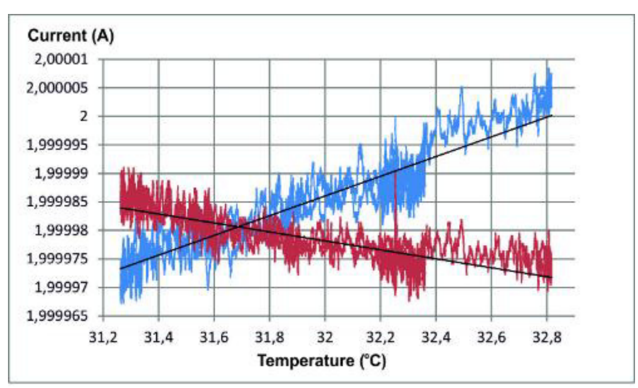

Figure 4: Current temperature drift. Positive current.

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Figure 5 shows a drift of one of the channels with the greatest temperature dependence at the negative current. Simple calculations show that the maximum drift at the negative current is equal to 13.2 mka/ ^0C .

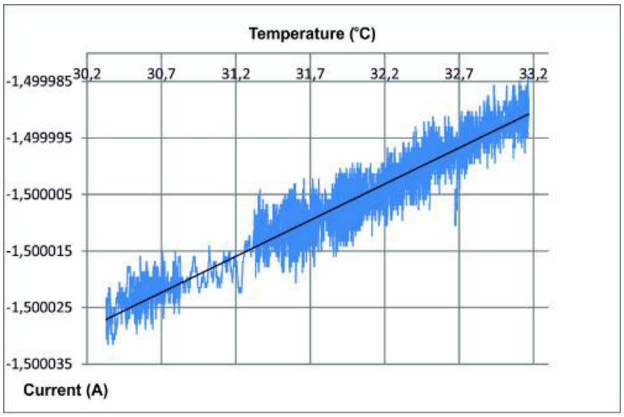

Figure 5: Current temperature drift. Negative current.

Unfortunately, it is difficult to say how the drift of the calibrator affected the results. But even if the calibrator moved down the positive drift at the positive current, then compensating for the drift decrease, we obtain: 17.9 + 5 = 22.9 mka/ ^0C . Therefore, the maximum possible drift of the current due to the temperature changes is almost 23 mka/ ^0C or 2,3ppm/ ^0C .

The Stand Calibration

All channels of the stand have been calibrated before testing the sources. Calibration is needed to compensate inaccuracy of absolute measurement of the real current. To calibrate the stand, an MPS precision current source and an external DCCT precision non-contact current meter were additionally used, The latter has been preliminary configured and calibrated to measure the absolute value of the current with an accuracy of 10^{-5}. The source current was passed through all channels of the stand consistently and controlled additionally using an external high-precision measuring instrument. The measurements were carried out at two current values, 9.5 A and -9.5 A. These currents were displayed by the external current meter. After the data were acquired, the current measured on the channels was compared with that measured by the external DCCT meter. The real current on the channels is calculated by the formula (1):

$$J = a + b * I \tag{1}$$

Where ***J*** is the real current, ***I*** is current measured on the channel, ***a*** is DC offset and ***b*** is correction factor to the measured current. Correction factors ***a*** and ***b*** are selected for each channel of the stand so that the current ***J*** corresponds to the readings of the external DCCT precision current meter. The program that controls the stand takes into account these correction factors and displays current ***J***.

The Process of the Sources Testing

Daily testing of precision sources consists of two stages. The first stage is the Ramp Test, figure 6 shows a small interval of this test during the real test of one of the sources.

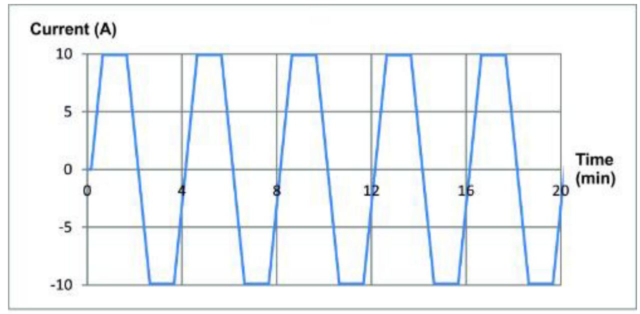

Figure 6: Ramp test.

Within 24 hours, the program performs the switching between the maximum current values of the source as follows:

- the transition from the maximum current value of one sign to a maximum current value of the other sign is performed during one minute.
- the sources are working at the maximum currents during one minute.

The RMS noise calculation is performed by the program at maximum currents, but for the calculations only the last 30 seconds are considered, not the whole one minute interval. This is due to the fact that immediately after reaching the maximum current, during the first few seconds, a transition process takes place.

The second stage of the testing is called the Full Power Test. This test is automatically started immediately after the end of the Ramp Test and lasts for one hour. During this test, the sources work 30 minutes at + Imax and 30 minutes at -Imax. Similarly as in the previous stage, the RMS noise is calculated at the maximum currents, but in this case during 29.5 minutes. The first 30 seconds of the plateau, similarly as in the Ramp Test, are not taken into account due to the transition process.

During the testing, the measured data is written in the text files in the real time mode. Seven text files are created after completing the test for each source: three files with the Ramp Test data, one of which contains all data, and other two files contain the data for selected intervals. The same algorithm is for three files of the Full Power Test. The last file is the log file. The data from this file provide the basis for making a conclusion whether the the source passed the test or not.

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