ELECTROMAGNETIC COMPATIBILITY OF THE POWER SUPPLY SYSTEM FOR CORRECTOR MAGNETS OF THE EUROPEAN XFEL

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Abstract

The power supply system for the corrector electromagnets of the European XFEL includes over 300 precision current sources with an output power of up to 600 W. BINP developed, manufactured and supplied the power sources for the corrector magnets. For reliable operation of the physical installation, at the design stage it was necessary to ensure electromagnetic compatibility of the power supplies with other electronic equipment of the European XFEL.

INTRODUCTION

During the development of high-precision power supplies for electromagnets, it is necessary to ensure compliance of the precision and stability of the power supply parameters. This is a challenge on large physical installations because the power supplies shall work in contact with a variety of other electronic devices. It is therefore necessary to make the power supplies capable to work in a specific electromagnetic environment, while maintaining the stability of their parameters and without creating intolerable electromagnetic disturbances to other electronic devices.

BINP members developed MPS-10-60, a prototype of the power supplies for the corrector magnets [1]. This prototype was verified in relation to compliance with certain directives of the EMC international standard: EN 61000-4, EN 61000-6, EN 55011, and EN 61326-1. The tests were conducted at the EMC Laboratory "TÜV NORD" (Hamburg). Upon successful completion of all the tests, the production of 400 power supplies for the corrector electromagnets of the European XFEL started.

GENERIC EMISSION OF THE POWER SUPPLIES

For the sake of convenience of arrangement and maintenance of the power supply system, all the sources were made with natural air cooling. The cases of the power supplies are heated during operation, which results in output current instability caused by temperature drift. Therefore, high-precision power supplies should have high efficiency. Reducing the dynamic losses in switching elements often leads to an increase in the radiated power of electromagnetic interference. Electromagnetic shielding of the units of the power supply inverter would not be effective in this case since the screens hinder cooling. The largest emission amplitudes were in the frequency ranges of 30 ÷ 60 MHz (interference from the rise/fall of the fast switches mosfet of the inverter) and 100 ÷ 200 MHz (interference from the CAN line). Additional low-pass filters turned out to be helpful in both cases. A graph of the radiated emission of power supply for the corrector magnets in the frequency range from 30 MHz to 1 GHz is shown in Fig. 1.

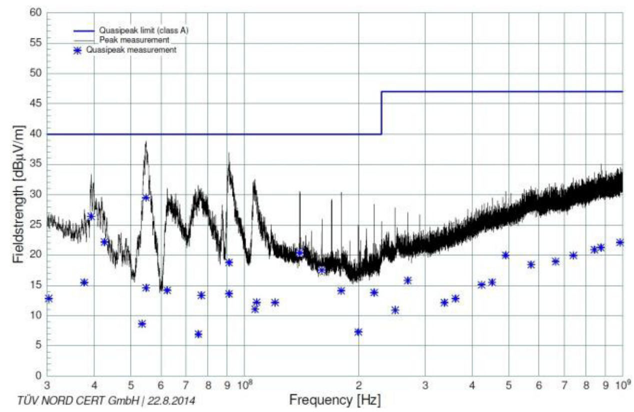

Figure 1: Radiated emission. Vertical antenna polarization.

In addition to the radiated emission, we measured the amplitude of the conducted emission of power supply to a 230 VAC mains in the frequency range from 150 kHz to 30 MHz. The maximum amplitudes of the emission were observed at the switching frequencies of the power switches. The emission decreased after addition of a CM/DM power line filter. A graph of the conducted emission is shown in Fig. 2.

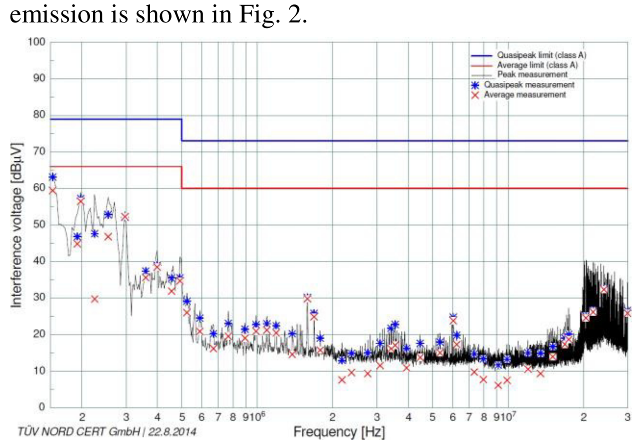

Figure 2: Conducted emission. Disturbing voltage on conductor L.

IMMUNITY TO INDUCED DISTURBANCE

Below are described tests that were carried out for verification of the immunity of the power supply output parameters to the effects of conducted and inducted interference. During the tests, external devices were controlling the stability of the power supply parameters.

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The first test was to check immunity to electrostatic discharges. Selected points (marked with arrows in Fig. 3) were subjected to an electrostatic discharge via pulses of different polarity and an amplitude of 2, 4, and 8 kV (air discharge), as well as an amplitude of 4 kV (contact discharge). The stability of the output current and of the operation of the CANbus and the external indication was controlled.

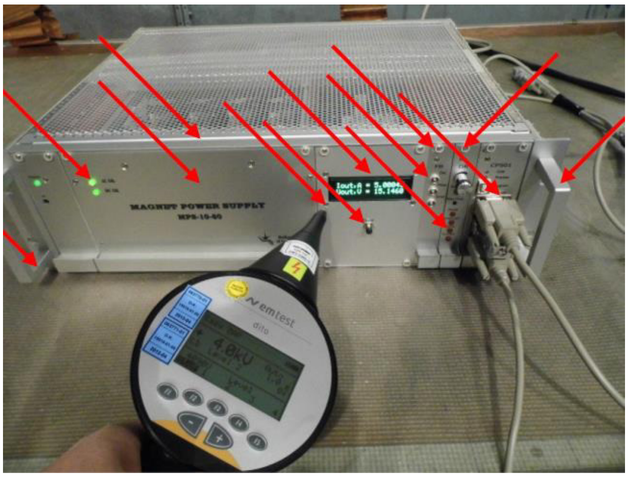

Figure 3: Test set-up for ESD testing.

In the next test, we were checking the immunity of power supply to impact noise. The amplitude of the noise was ± 2 kV on the AC power lines and ± 1 kV on the DC output, Interlocks connector and CANbus cable. The duration of the pulses was 50 ns; the pulse rise time was 5 ns; the repetition frequency was 5 kHz. Like in the previous tests, we controlled the output current stability.

In addition to the previous test, we were checking the power supply immunity to impact noise in the 230 VAC mains. During operation of the power supply, single pulses with an amplitude of 0.5 kV and 1 kV (line to neutral) and 0.5 kV, 1 kV and 2 kV (line to earth) were applied to the mains input. The pulse duration was 50 µs and the period was 1 min. The pulses were applied synchronously with the mains frequency and with phase shifts of 0^0, 90^0, 180^0, and 270^0. The entire test lasted for 2 h 40 min. An external device was monitoring the stability of the output current of the power supply.

In the fourth test, we were checking immunity to conducted disturbance induced by radio frequency fields. The coupling was performed with a coupling network into the power leads and a coupling clamp into the data lines. An electromagnetic field was induced on the AC power lines, DC output and CANbus cable. The amplitude of the induced field was 3 V; the frequency was 150 kHz to 80 MHz. During the experiment, we controlled the stability of the output current of the power supply.

In the fifth test, we were checking immunity to power frequency magnetic field. An operating power supply was placed in a frame with a variable magnetic field with an amplitude of 30 A/m and a frequency of 50 Hz (Fig. 4). As in the previous test, the stability of the output current of the power supply was monitored.

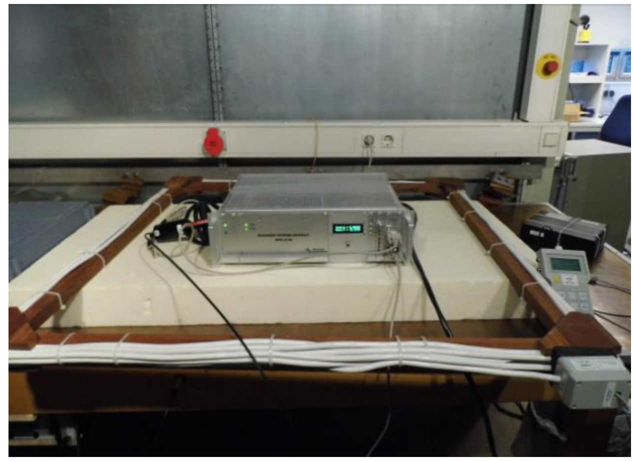

Figure 4: Test was performed with frame-coil.

In the sixth test, we were checking the immunity of power supply to electromagnetic field effects. The tests were carried out in an anechoic chamber (Fig. 5). In the frequency range of 80 MHz to 1 GHz we used a horizontally- and vertically-polarized log-periodic antenna with an amplitude of 10 V/m. In the frequency range of 1.4 GHz to 2.7 GHz we used a horizontally- and vertically-polarized horn antenna with an amplitude of 3 V/m. The immunity of the output current of the power supply to electromagnetic field effects was monitored.

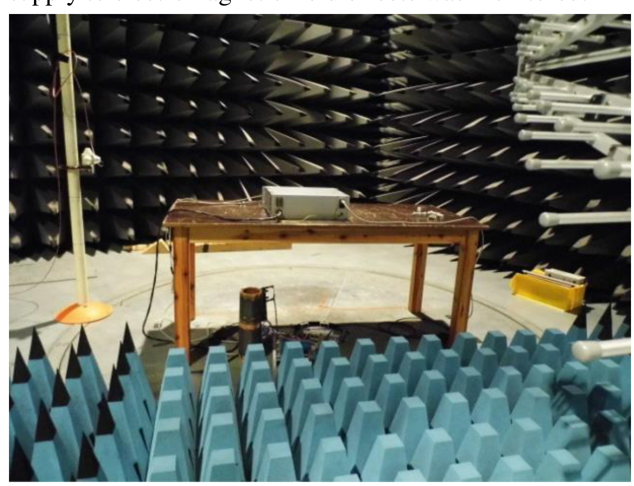

Figure 5: Test set-up for radiated susceptibility.

In addition to the above tests, we carried out additional tests with the 230 VAC mains and checked immunity to voltage dips, short interruptions, voltage variations, etc. All the tests were successfully completed in September 2014.

CONCLUSION

Developing power sources in accordance with the above-mentioned European directives makes it possible to avoid mutual interference of electronic devices and prevent a lot of start-up problems. Successful completion of tests at specialized laboratories enables supply of the power sources to any European research center. By the moment of this writing, most power supplies for the

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corrector magnets were delivered to the European XFEL and commissioned.

ACKNOWLEDGMENT

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REFERENCES

[1] O. Belikov, et al., “Corrector magnet power supplies of the European XFEL”, THPSC021, these proceedings.

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