HARDWARE FOR INCREASING RELIABILITY OF THE POWER SUPPLY SYSTEM FOR CORRECTOR MAGNETS OF THE EUROPEAN XFEL

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Abstract

The modern linear accelerators, which are quite long, need a lot of electromagnets to correct the position of beam of charged particles. Typically, each corrector electromagnet shall be powered by a separate high-precision current source. Using a large number of high-precision power supplies reduces the reliability of the power supply system. To avoid this we have developed a system of "hot" replacement of power supply, which enables remote replacement of a faulty power supply with a backup one.

INTRODUCTION

The total length of the European XFEL is 3.4 km. 296 corrector electromagnets correct the electron beam position, each magnet powered by an individual high-precision current source [1]. Main parameters of the sources are listed in Table 1.

Table 1: Parameters of power supplies for corrector magnets.

Parameter	Specified Value	Units
Output current, max.	± 5 / 10	A
Output voltage, max.	± 70 / 60	V
Short-term current deviations (up to 1 sec)	< 10	ppm
Long-term current deviation (1 sec to several years)	< 100	ppm
Mean time between failures (MTBF)	≥ 100 000	hrs

A failure even in a single power supply for the corrector magnets significantly affects the electron beam quality. In continuous operation of the XFEL, the estimated amount of faults will be 1 failure per 14 days. The power supplies are distributed along the length of the complex, and it takes quite a time to replace a faulty crate. Given the estimated time for troubleshooting, these time losses are considered as inadmissible.

STRUCTURE OF POWER SUPPLY MODULE

To minimize the downtime at the European XFEL, it was decided to use a redundancy system, i.e. to complement the power supply group with a backup source module, which may be switched on instead of any other. The structure of such a module is shown in Fig. 1. In normal operation, seven power supplies feed the corrector magnets. The eighth power supply (the backup one) is switched to an equivalent load, which enables monitoring of its operability. If one of the normal sources fails, the control system can switch the respective correction magnet to the backup power supply, and the power supply system will continue normal operation.

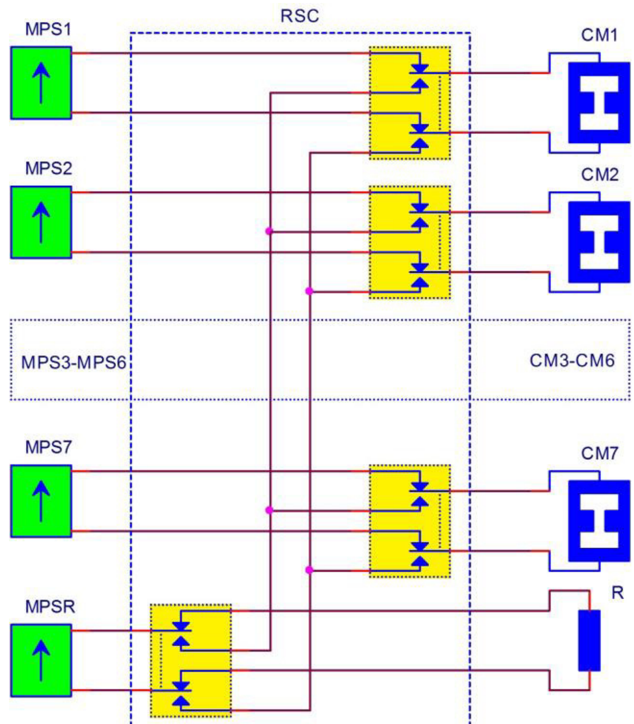

Figure 1: Function chart of power supply module. MPS – Magnet power supply; RSC – Redundancy system crate; CM – Corrector magnet; R – Dummy load.

INCREASING POWER SUPPLY SYSTEM RELIABILITY

48 power modules feed the corrector magnets of the European XFEL, each module having a backup power source. Increase in the number of the power supplies will result in a bigger estimated number of failures. With the redundancy system, a power supply failure that requires operating personnel intervention may occur only in the case of breakage of two or more sources from one module. If maintenance works to replace faulty power supplies are carried out once a month, one can calculate the probability of failure of the power supply system per year by the following formula:

$$P = \frac{N \cdot (n-1) \cdot P_i^2}{12},$$

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where $N = 344$ is the total number of the power supplies; $n = 7$ is the number of power sources in a single module (without backup ones); $P_i \approx 0.088$ is the probability of failure of a single power supply per year. So, $P \approx 1.32$.

With the redundancy system and maintenance performed once a month, the probability of failure of the power system will be 1 time per 9 months, and the estimated time between failures of the power system will increase twenty-fold.

It should be noted that the fundamental simplicity of the solution is complicated by a variety of technological features. For example, a faulty power supply may turn out to be uncontrollable and operate with the maximum output current in the load. The energy stored in the magnet (inductance of 15 H) is quite high and has to be released from the load, otherwise an arc will occur. To this end, a semiconductor switch is provided, as well as a number of other protective circuits.

The semiconductor switch shortened main power supply up to reconnection of load. The output voltage of power supply is shown on Fig.2 (Channel 1). Then programmable delay (6 second, typical) followed. During this time the current in load (Channel 2 on Fig.2) is decreased up to safe value allowing reconnect the load. At the moment of reconnection the voltage on load was 7 V. It is quite acceptable.

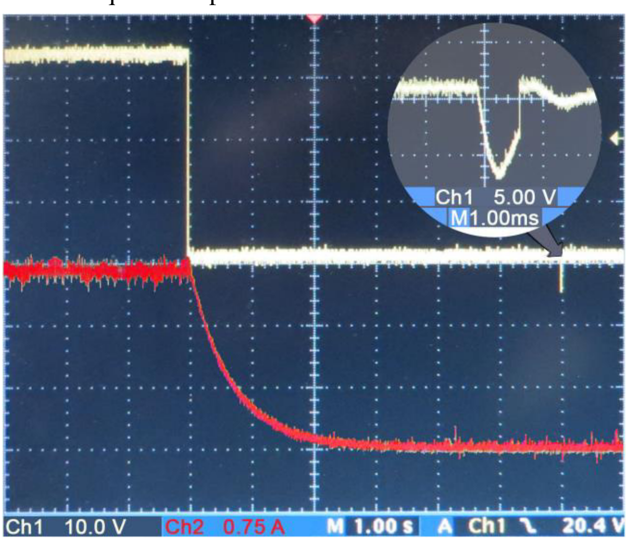

Figure 2: Transient waveform.

ASSEMBLING POWE SUPPLY MODULE

The redundancy system is implemented in a 432×355×133 mm^3 Euromechanics crate (Fig. 3).

Figure 3: Redundancy system crate.

The Power Supply System Module is located in 2000×800×600 mm^3 Euromechanics cabinet (Fig. 4). The module includes up to 7 power supplies for the corrector magnets, a backup power supply and the redundancy system crate. Control and monitoring of the power supply module are performed in accordance with the CANbus standard [2].

Figure 4: Magnet power supply cabinet.

CONCLUSION

Fifty power modules have been delivered to the European XFEL. About 40 power modules have been connected to the control system of the installation and are

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in the trial operation mode. The first year of operation of the system has not revealed any serious problems, which confirms the calculations.

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