THE SOFTWARE TOOLS AND CAPABILITIES OF DIAGNOSTIC SYSTEM FOR STABILITY OF MAGNET POWER SUPPLIES AT NOVOSIBIRSK FREE ELECTRON LASER

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Abstract

The magnetic system of Novosibirsk free electron laser (FEL), which contains a lot of magnetic elements, is fed by power supplies of different types. The time stability of the output current of these power supplies directly influences the coherent radiation parameters and operation of the entire FEL facility. In this connection, we developed a system for diagnostics of the power supplies state, integrated into the common FEL control system. The main task of this system is to analyze the output current of the power supplies and calculate their time stability characteristics. Besides, this system is capable to determine the amplitude and frequency of output current ripples, if any, for a particular power supply and display obtained results. This paper describes the main architecture and some other capabilities of this system, and presents examples of its usage.

INTRODUCTION

A high-power FEL based on a multiturn energy recovery linac (ERL) [1] is under construction now at Budker Institute of Nuclear Physics. The first and second phases of the project have already been commissioned and are in operation.

The magnetic system, one of most important systems of the ERL, consists of numerous magnetic elements of different types. All these elements are fed by DC power supplies of different output powers and currents. The stability of operation of the FEL and its main parameters depends on the time stability characteristics of these power supplies. In this connection, there was developed a set of particularized software tools for monitoring of the output currents of all the power supplies. The architecture of the current system is influenced by the factors below.

1. The architecture of the software of the control system for the magnetic system and the installation as a whole.
2. The type and operation characteristics of the communication bus between the control PC and the power supply control devices.
3. The capabilities and main operation modes of these power supply control devices.

HARDWARE AND ARCHITECTURE OF CONTROL SYSTEM OF MAGNETIC ELEMENTS

The magnetic system and its control system of Novisibirsk FEL are described in detail in [2]. All power supplies are controlled by modules embedded into power supply racks and communicating with the central IBM-PC via a CAN bus interface. Power supplies of different types are governed by different controllers. For low-power current sources with an output current of up to 17 amperes, pairs of multi-channel controllers are used, controlling up to 16 power supplies – 16-channel DAC and 40-channel ADC devices. For high-power current sources, each power supply is commanded by a separate controller with 1-channel DACs and 5-channel ADCs. All controllers are connected to one CAN bus line [Fig. 1].

Table 1: Parameters of the Power Supply Controllers

Device	*CANDAC16*	*CANADC40*	*CDAC20*
Qty	24	24	13
PS Number	16	16	1
PS Imax	17	17	2500
ADC channels	---	40	5
DAC channels	16	---	1

Above is presented a comparative table of main controller parameters (Table 1.). As seen, all controllers containing an ADC module have multiple input channels. In the regular operation mode, these modules are working in the multi-channel mode, i.e. serial measurement of voltage in all input channels and sending of the values measured to the control PC via the CAN bus interface. In this case, the ADC works in the cyclic mode: once the measurement of the last channel is completed, a new measurement cycle begins from the first channel. The architecture of the set of commands for all these controllers and the CAN bus protocol allow operation of numerous controllers in such mode.

For diagnostics purposes, another measurement mode – “single-channel mode” – was realized. When switched to this mode, the controller starts serial measurements of a single selected channel, until it receives from the central PC a command “STOP” or a command “start new measurement cycle”. As mentioned above, switching

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from one mode to another does not influence the operation of the rest modules and their data transfer to the central PC.

METHODS OF POWER SUPPLY DIAGNOSTICS

The main methods of diagnostics of the power supply output current are described below.

1. "Adjustment accuracy": comparison of the current value specified by the user with a real pre-set value.
2. "Long time stability": comparison of the current value measured after the user specified the latest new value with the value measured at the actual moment of time.
3. "Ripples diagnostics": Oscillographic measurements of the output current and processing of the waveform obtained for detection of possible current ripples.

The first two methods of diagnostics are used in the background mode during all the time of control software operation. In the main window of the application, a string with the names of power supplies whose current value difference exceeds the allowed warning or alarm value is marked yellow or red. These types of diagnostics are applied only to data obtained in the usual operation mode and do not require switching the ADC to another measurement modes. No need in any complicated mathematical processing of data.

The third method of diagnostics shall be switched on by the user and requires some manipulation with the modes of ADC operation and some mathematical processing of the data.

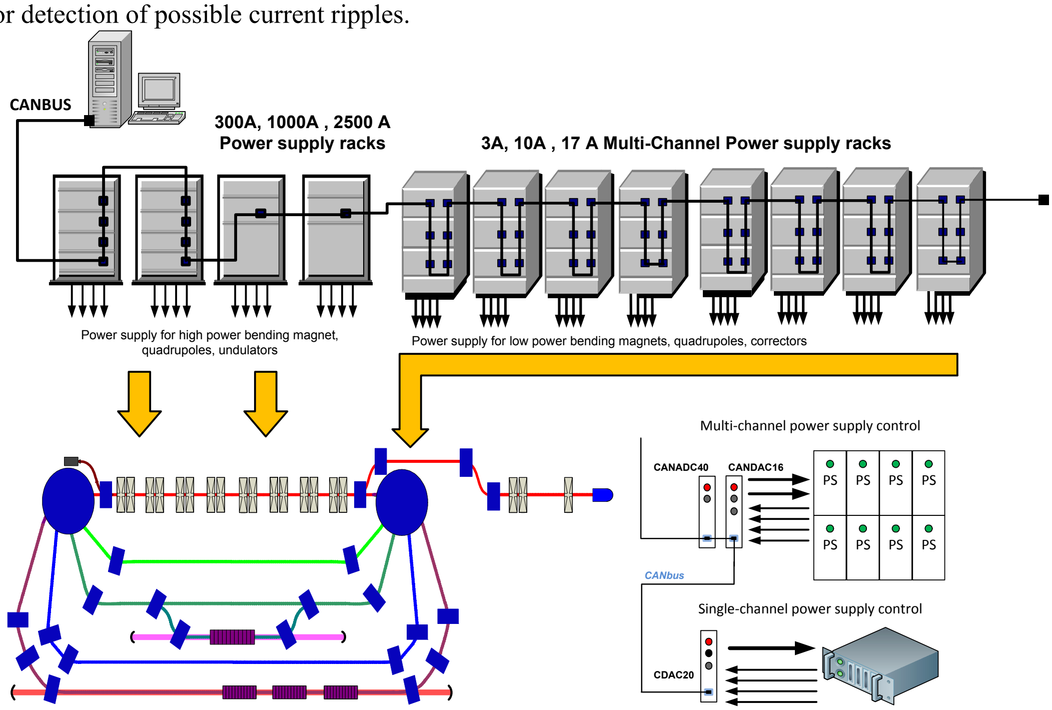

Figure 1: Main scheme of the system.

When this diagnostics procedure is started, the control application initiates the cyclic processing of the power supplies in the order of their placement in the power supply racks. Below is given the sequence of the cycle of the current ripples diagnostics method.

1. The ADC shall be switched to the single-channel mode. In so doing, the input channel is selected to which the current output of the power supply of interest is connected.
2. Collecting of data. Waiting for the ADC to accomplish a set number of measurements. The measured values are collected in one waveform. The number of measurements shall be specified by the user.
3. Processing of the obtained waveform of the measured current.
4. Stop of the current measurement mode of the ADC. If there are other power supplies, next to the just-scanned one, with current outputs connected to the running ADC channel, then the procedure is repeated from step 1 with next power supply and corresponding ADC input channel. Otherwise, the current ADC is switched to the usual (multi-channel) mode, and the application starts working with next power supply, i.e. it defines the required ADC and the input channel number and then starts from step 1.

Besides, it is possible to start this diagnostic procedure for a single power supply specified by the user.

As mentioned above, the user can specify the number of measurements, as well as the time for one measurement with the ADC, from 1 to 160 milliseconds. These two parameters allow one to specify the duration of the

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measured oscillogram and its sampling frequency. Different values of these parameters could be useful for different types of output current diagnostics.

PROCESSING AND OUTPUT OF DATA MEASURED

When the measured current waveform for the power supply in question has been obtained, the following mathematical processing is executed:

1. The average current value for the entire waveform is calculated.
2. The mean square deviation and maximum deviation values for the entire waveform are calculated.
3. The spectrum of current ripples is calculated using the fast Fourier transform.

After execution of these operations, all the obtained values can be presented in the following graphs:

1. A dialog window with the graphs of the measured current waveform and its spectrum (Fig.2). This latter graph can be used for a direct view of the measured current waveform and its frequency characteristics.

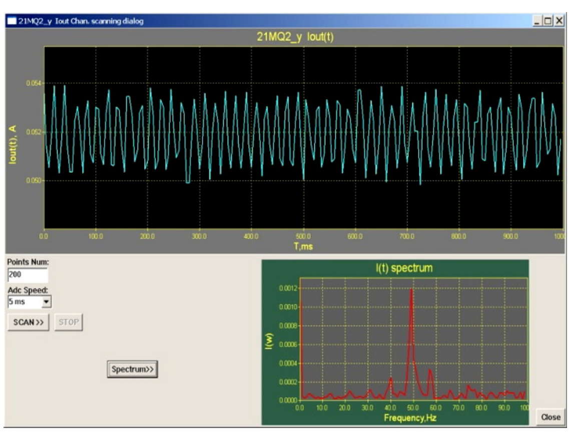

Figure 2: Graphs of the waveform of the measured current and its spectrum.

2. A dialog window with a total comparative graph of the calculated mean square deviation and maximum deviation values for all the power supplies (Fig.3). The comparative plot in this window is very useful for finding power supplies with the highest ripple values. Every power supply in the upper plot is presented with a red bar, showing the maximum deviation, and a blue bar, showing the mean square deviation. Besides, the user can launch repeatedly a scanning of each power supply and view the obtained waveform on the graph below.

3. A dialog window with a graph of all the calculated values (the mean square deviation and maximum deviation values) for a selected power supply for the time when these values were obtained (Fig.4). Since in this method the scanning of the power supplies is executed in the cyclic mode, the control application stores every calculated ripple value (after completion of the scanning) with its timestamp. As result, the user is able to view the history of these values for each power supply during all the time of operation of the control application.

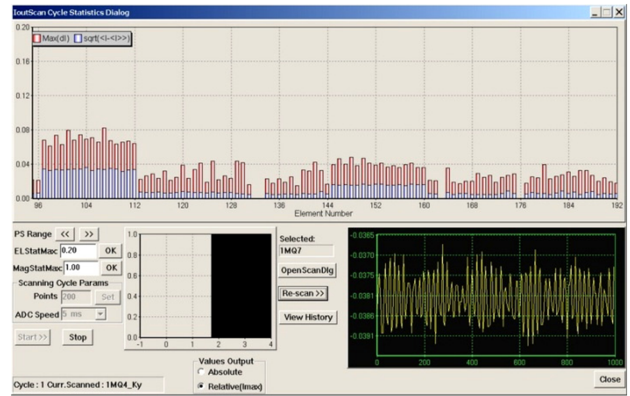

Figure 3: Comparative graph of calculated values for all power supplies.

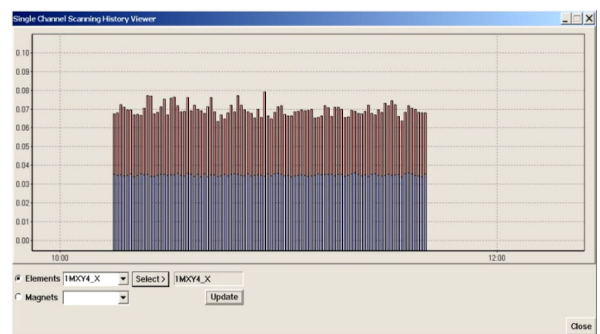

Figure 4: History of ripple values during all the operation time of the control application.

CONCLUSION

The above-described software modules give an advanced tool for diagnostics of the timewise behavior of the output current of any power supply. With this tool, the user can both investigate the output current of a single selected power supply, as well as its frequency characteristics, and start a scanning cycle for all power supplies to find those with maximum output current ripples. Storing and displaying of the calculated ripple-value history allow the user to control the quality of operation of a power supply during all the period of the facility operation.

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