CONTROLS FOR THE ELECTROMAGNETIC ELLIPTICAL WIGGLER AT ELETTRA

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Abstract

The main aspects of the design and realization of the controls for the Electromagnetic Elliptical Wiggler of ELETTRA are summarized.

1 INTRODUCTION

On January 1997, an Electromagnetic Elliptical Wiggler (EEW) has been installed in the 2.4 GeV third generation synchrotron light source ELETTRA [1]. The device provides a source of circularly polarized light in the VUV/Soft X-ray region with a variable helicity [2].

The EEW is a double electromagnet which combines periodic horizontal and vertical field in the same structure. The vertical electromagnet is powered with d.c., producing a wiggler field. The horizontal field component is operated either in d.c. or a.c. mode. Fast switching, in the order of 10 ms, trapezoidal waveforms ranging from 0.1 to 10 Hz and sinusoidal waveforms ranging from 10 to 100 Hz can be used in a.c. mode. This enables different types of data acquisition methods to be used to maximize the dichroism signal detection.

2 POWER SUPPLIES

Two Pulse Width Modulation (PWM) power supplies are employed, a mono-polar for the vertical field (PSEEWV) and a bipolar for the horizontal one (PSEEWH).

Performance data are shortly summarized in table 1.

Table 1: EEW Power Supplies performance data

	PSEEWV	PSEEWH
Max. Current	200 A	±300 A
Max. Voltage	75 V	580 V

Special attention has been given to the stability of the power supplies since it strongly affects the elicity of the radiation. Ripple and short term stability have thus been specified to be $\pm 5 \cdot 10^{-5}$.

The symmetry of the positive and negative current values in a.c. mode is also critical. A precision in the order of 10^{-5} must be achieved.

3 CONTROL SYSTEM HARDWARE

The controls of the EEW are based on the existing ELETTRA control system standard [3]. One Equipment Interface Unit (EIU) is in charge of the basic controls of the power supplies and provides also signal generation capabilities for the operation of the EEW in a.c. mode. The EIU is a VME-bus system with a MC68030 CPU board and is connected to the control system middle layer computers via the MIL-1553B field bus. The layout of the EIU is shown in figure 1.

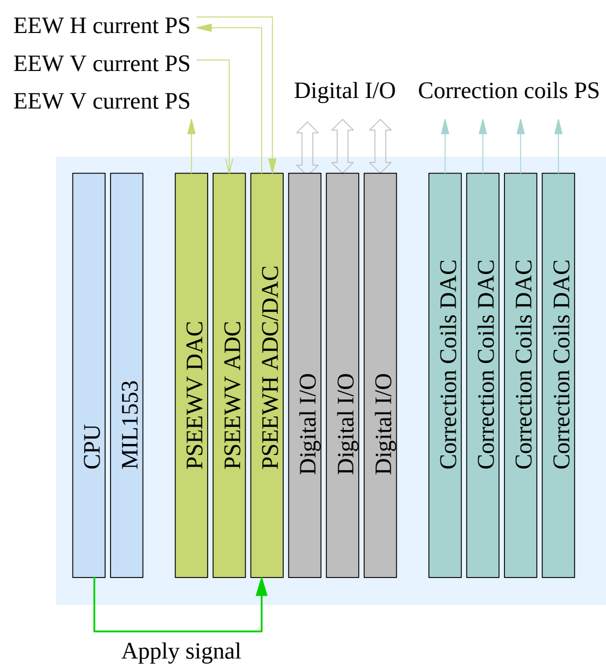

Figure 1: layout of the Equipment Interface Unit (EIU) for the controls of the EEW.

Two 16-bit DAC and ADC boards provide the reference and the current reading for the vertical field current. For the generation of the horizontal field reference, another board has been adopted: it provides a good amplitude stability (±10 ppm-full-scale/°C) and enough bandwidth to generate the required waveforms. Digital commands and readings (ON, OFF, status reading, etc.) are treated using 16-channel digital Input/Output (I/O) boards.

4 CONTROL SYSTEM SOFTWARE

A *device server*, which is a process running in the EIU, manages the operation of each power supply. Another process, the *RPC server*, receives the requests coming from the control room clients and passes them to the *device server* for execution.

While the generation of the slow ramps and slow trapezoidal waveforms is performed directly by the device server, for the fast switching modes of the horizontal field a dedicated device driver has been developed. The required timing is provided by a counter/timer chip (CIO) on the CPU board, which is programmed to generate interrupts to the CPU. The interrupt routine writes the desired output values in the DAC boards via the VME bus. In order to convert each sample to analog with the desired synchronization, the counter/timer generates also an "apply" signal, which is externally connected to the DAC board through an additional cable.

The fast trapezoidal waveform is made of 10-ms ramps and flat tops. The sinusoidal waveform is generated by means of a number of digital samples that are converted to analog in a repetitive way. The samples of one sinusoid period are calculated and stored in a memory buffer. When the generation of a waveform is activated, the interrupt routine cyclically applies the samples to the DAC board. In order to guarantee a good spectral purity of the sinusoidal signal, the D/A conversion is performed at up to 4 ksample/s.

5 CORRECTION SYSTEM

Operating the EEW in a.c. mode disturbs the closed orbit and can affect users of the other beam-lines. In order to guarantee a smooth operation a feed-forward correction system has been developed that dynamically compensates for the magnetic field integral errors.

The system is made of four power supplies connected to two horizontal and two vertical correction coils, which are placed at the beginning and at the end of the magnet. Each end is equipped with a horizontal and a vertical coil (figure 2).

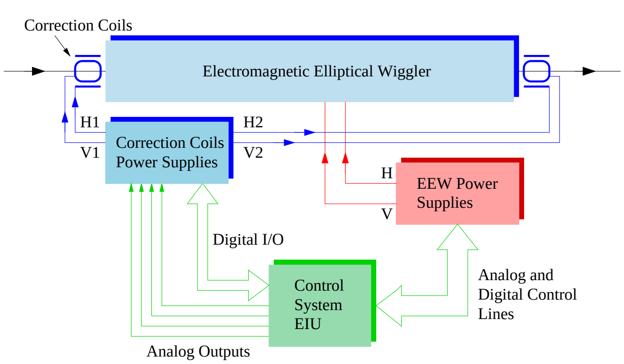

Figure 2: block diagram of the feed-forward correction system

The air-cooled coils can provide a magnetic field of 7.2 Gm in both planes at a 4 A driving current, with an inductance of 2.3 mH per coil pair. The power supplies allow the above current to be produced at a frequency of at least 1 kHz. The present configuration uses four DAC VME boards for driving the power supplies.

The correction coil current values for each pair of horizontal/vertical EEW settings are empirically determined by performing an off-line calibration based on the minimization of the closed orbit distortion [4]. These values are then stored in a lookup table. The actual correction is performed by a dedicated process running on the CPU, which implements a feed-forward scheme. It reads the EEW current settings and calculates the corresponding correction coil currents by interpolating the values contained in the lookup tables. The four values are then applied to the correction coils.

The minimum achieved period of the correction loop is 80 ms, which is sufficient for the present operation of the horizontal field with setting ramps of about 30 s.

In view of the operation in fast a.c. modes, a novel approach has been adopted which is based on a dedicated Digital Signal Processing (DSP) system.

6 DYNAMIC CORRECTION

Figure 3 shows the block diagram of the new system. It is based on A/D and D/A converters and a DSP board.

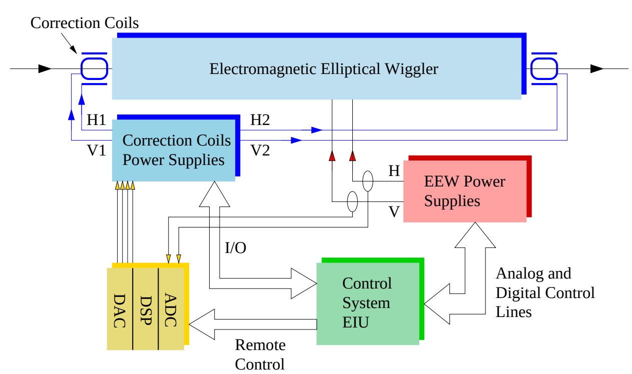

Figure 3: block diagram of the DSP-based correction system.

The horizontal and vertical EEW currents are measured by two DCCTs and sampled by two A/D converters. The DSP acquires the digital samples and calculates the correction coils values that are converted to analog by four D/A converters.

The DSP board is a Pentek model 4284 VME board equipped with one TMS320C40 DSP. Two Pentek model 4243 boards perform the analog I/O: each of them features two 18 bit A/D and D/A conversion channels with a maximum sampling rate of 192 ksample/s. A mezzanine bus (Modular Interface eXtension, MIX) connects the I/O and the DSP boards. An additional

VME CPU board acts as a bridge between the DSP and the control system Ethernet.

The maximum frequency of the correction loop achieved with the DSP system is 20 kHz. We usually operate at 8 kHz.

The program running in the DSP is written in "C" language. A complete development environment and a special Ethernet communication protocol allow to compile, download and debug the programs in the DSP from UNIX workstations.

An interactive computer workbench based on Matlab has been developed to operate the DSP system directly from the Matlab workspace [5]. A set of MEX-file commands allows to download the correction lookup table, close/open the loop, acquire input signals, generate output waveforms, etc.

7 PERFORMANCE

A prototype of the DSP system has been installed to check the correction efficiency. The Photon Beam Position Monitor (PhBPM) in Section 2 has been used to measure the angle of the closed orbit in the center of the corresponding Insertion Device (ID_S2). The EEW is located in Section 4. In this test, the horizontal field current has been driven with a trapezoidal waveform of 5-second flat top and 1-second ramp. The EEW currents are ±150 A for the horizontal field and 100 A for the vertical one.

Figure 4 shows the results. With the loop disabled the closed orbit angle perturbation in the ID_S2 center due to the EEW switching is ±12 μrad. After 50 seconds the feed-forward system is activated, reducing the perturbation to about ±1 μrad.

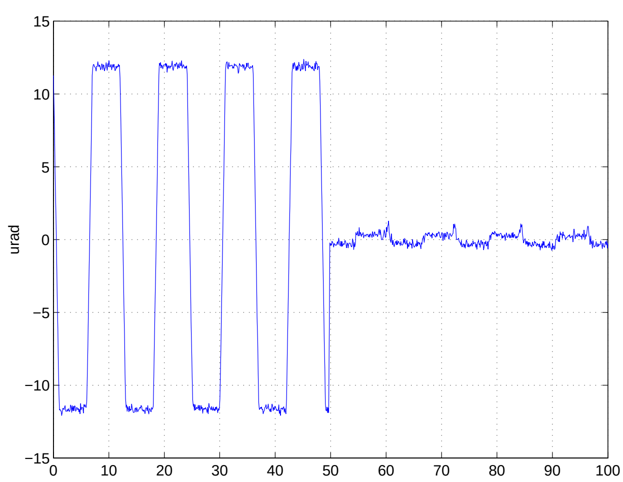

Figure 4: Horizontal plane close orbit angle in the ID_S2 center with loop off/on.

In principle, the residual orbit distortion could be cancelled with an accurate finding of the settings of the correction coils. In practice, orbit drifts, BPM precision and hysteresis effects of the EEW coils affect the calibration process and limit the performance.

Further tests with faster waveforms are being done. Preliminary results show a degradation of the correction performance at higher frequencies. This is likely due to Eddy currents effects of the EEW coils which produce a waveform distortion of the horizontal field.

The computing power and the programmability of the DSP system allow the implementation of different correction algorithms to solve the above problems. Moreover, the use of PhBPMs and of new faster BPMs will provide data for more sophisticated calibration and correction methods.

8 CONCLUSIONS

The low-level controls for the EEW have been presented. The present correction system for the compensation of the field integral errors is effective only when the EEW is operated with slow setting ramps. In view of the operation in fast a.c. modes, a DSP-based system has been developed and is currently under test.

9 ACKNOWLEDGEMENTS

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