POWER SUPPLY PERFORMANCE MONITORING AND ANALYSIS USING OPERATION DATA *

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Abstract

Magnet power supplies are critical components of a storage ring. The performance of power supplies directly impacts the stability and reliability of the storage ring operation. There are several type of DC power supplies in Duke FEL storage ring. The performance data of power supplies can be collected in a non-interruptive manner by an EPICS archiver or by a MATLAB program. MATLAB based tools have been developed to analyze the power supply data collected during the operation. Careful evaluation of data allows us to identify a power supply with degraded performance and provide a reference to perform preventive maintenance.

INTRODUCTION

The Duke storage ring was designed to accommodate a variety of FELs [1]. There are several type of DC power supplies used to power dipole, quadrupole, sextupole, and corrector magnets. The performance of these power supplies directly impacts the stability and reliability of the storage ring operation. For example, a bad power supply may change the transverse tune, chromaticity, and orbit of the stored beam. So it is important to pay enough attention to these power supplies. The efforts that we have made to improve the performance of power supplies include the following two parts: (1) modifying and tuning power supplies to meet their specifications [2]; (2) maintaining power supplies' performance for operation. In this paper, we will present the method to monitor the performance of the power supplies.

Two kinds of tools are used to log the performance data of the Duke storage ring power supplies. One is the EPICS archiver [3] which has been configured to log the set and readback current of power supplies in a non-interruptive manner. It usually works at a relatively low sampling rate. The sampling rate can be chosen to meet the real operation need. For performance reason, the archiver will be automatically disabled during ramping. Another tool is a MATLAB based tool, "srmonitor", which we have developed to log data at a higher sampling rate. It logs not only the power supply data but also other important parameters of the storage ring. This tool is usually used in machine studies. For example, it can monitor the stability of power supplies and the beam orbit with a fixed lattice, as well as log the ramping data for further analysis.

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POWER SUPPLY PERFORMANCE ANALYSIS

To analyze the performance of power supplies, we have developed a set of MATLAB based tools. These tools are used to read data from the EPICS archiver, convert the data to the MATLAB format, and analyze them. The data are analyzed by computing the difference between readback and set current of each power supply and the peak-to-peak value of this difference (see Eq. 1).

$$\begin{aligned} \Delta I &= I_{\text{set}} - I_{\text{read}} \\ \Delta I_{PP} &= max(\Delta I) - min(\Delta I) \end{aligned} \tag{1}$$

where I_{set} and I_{read} are set and read back currents respectively, ΔI is their difference, and ΔI_{PP} is the difference between maximum and minimum ΔI.

The power supplies of Duke FEL storage ring can be divided into two groups. The first group of power supplies, such as corrector and quadrupole trim supplies, usually work at a relatively low or near zero current level. The ΔI_{PP} is used as the performance merit for this type of supplies. Another group of power supplies, such as dipole and quadrupole supplies, usually work at a relatively high current level. For this type of power supplies, the normalized peak-to-peak value is calculated for performance as follows:

$$\Delta I_{\text{NPP}} = \frac{\Delta I_{PP}}{I_{\text{set}}}.$$

The performance of each group of power supplies is usually plotted in separate bar charts: (1) main magnet supplies, including dipole and quadrupole supplies; (2) quadrupole trim supplies; (3) orbit corrector supplies. The difference between readback and set current of each power supply is also plotted as s function of time for detailed analysis.

The power supply performance has been analyzed weekly. To cover a wide energy range of operation in the entire week, the largest peak-to-peak performance of each power supply is plotted on the bar chart for the worst case scenario analysis.

The measured power supply performance is sometimes distorted by the accuracy of the control and readback system. For example, the Walker supplies powering straight section quadrupoles are read by a 14-bit CAMAC SAM ADC with auto-gain which has a relative accuracy of 300 ppm. The specification of power supply and the measurement accuracy of the control/readback system are listed in Table 1.

Table 1: Power Supply Specification and Measurement System Accuracy at 1 GeV

Magnet Family	**Power Supplies**	**peak-to-peak Spec.**	**Meas. Accuracy**
Dipole	PEI	50 ppm	$<$ 20 ppm
Arc Quad.	Bruker	50 ppm	$<$ 20 ppm
SS Quad.	Walker	100 ppm	300 ppm
Orbit Trim	Corrector	2 mA	$<$ 1 mA
Quad. Trim	Corrector	2 mA	$\sim$ 1 mA

Fig. 1 and Fig. 2 show the logged data of main magnet and horizontal orbit corrector supplies on Dec. 13, 2002 at 700 MeV. With the exception of one Walker supply, all power supplies seem to be operating normally within the limits of the measurement system.

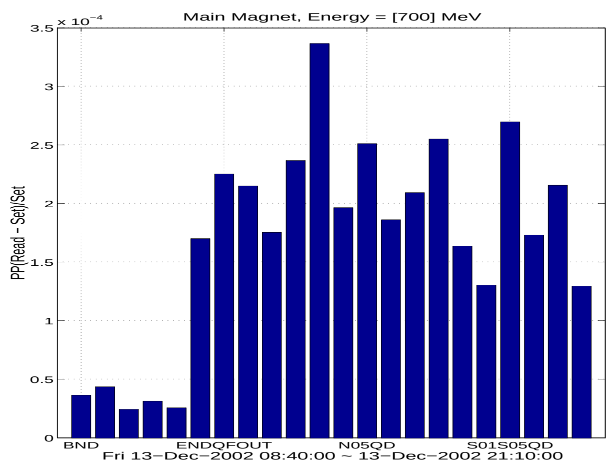

Figure 1: Peak-to-peak values of main magnet supplies. The first supply is PEI, followed by 4 Bruker and 17 Walker supplies.

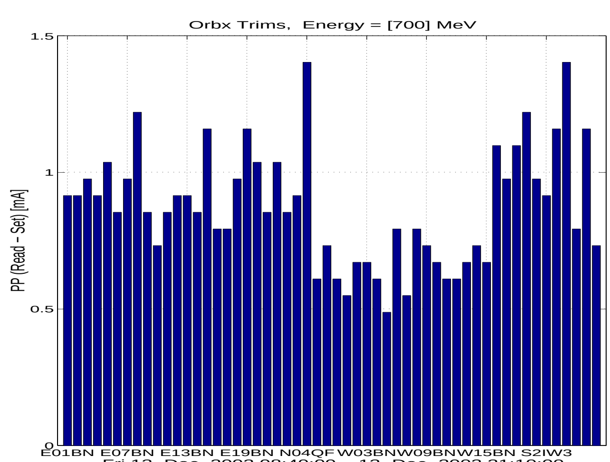

Figure 2: Peak-to-peak values of X orbit correctors.

To reveal the problem of a misbehaving power supply, the detailed performance data is plotted as the function of operation time. As an example, when analyzing the data on Feb 18, 2003, we found the normalized peak-to-peak value of the PEI supply powering the dipole magnets was 90 ppm which was about twice of its specification. Plotting the difference between the readback and set current, we found that it varied by 30 mA (see Fig. 3). This problem was reported and has been investigated.

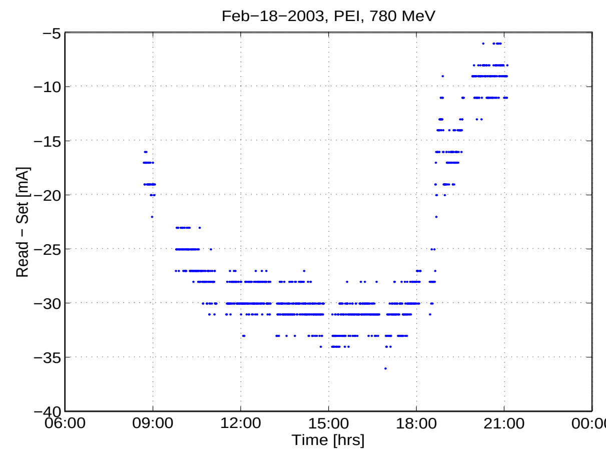

Figure 3: Performance of dipole magnet supply (PEI). The difference between the readback and set current varied by about 30 mA.

OTHER ANALYSIS BASED ON THE ARCHIVED DATA

Besides for power supply performance analysis, the logged data can also be used to characterize the ramping performance and orbit stability.

Ramping Analysis

There are several operation modes for the Duke storage ring, most of which need energy ramping after injection. The control system is developed based on physics quantities. The energy ramping can be carried out by stepping the energy knob [4]. The “srmonitor” has been used to log the ramping data (see Fig. 4). Since the energy ramping is a relatively fast procedure, the sampling rate for “srmonitor” is chosen as 1 Hz. Using the logged data, the following effects can be studied:

- missed current setpoints during energy ramping;
- the accuracy that readback tracks the setpoint;
- the overshoot at the end of ramping;
- lifetime and orbit stability during ramping.

For example, from Fig. 4, we can see there are no missed points during the ramping, and the the readback tracks the setpoint well. The current dependency is more than linear after 800 MeV, indicating that the field begin to saturate.

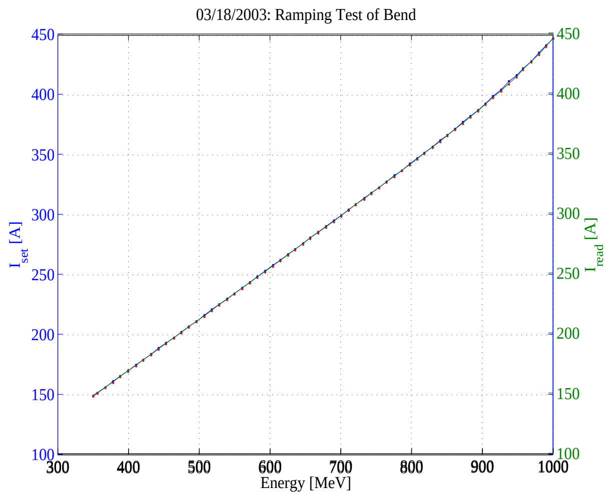

Figure 4: Performance of dipole supply during ramping

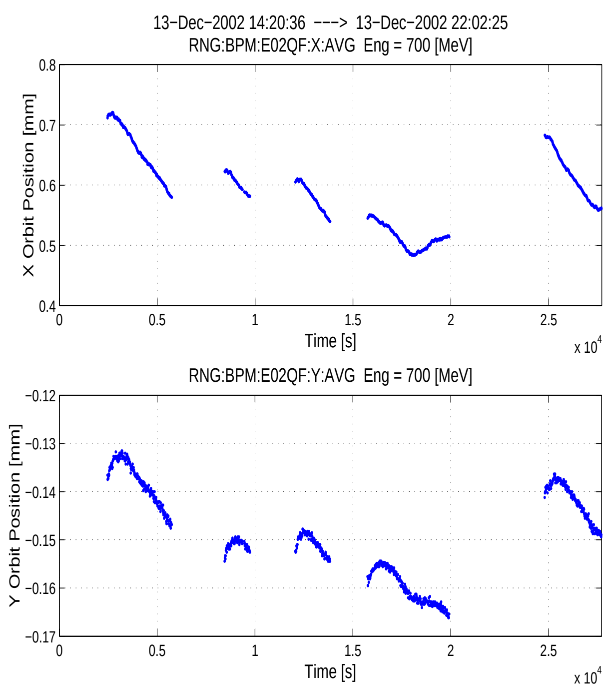

Figure 5: Orbit stability at BPM E02QF without orbit feedback.

Orbit Stability Monitoring

Using the logged data, the orbit reproducibility and stability during operation can be analyzed. The following is an example of such analysis using the orbit data at BPM E02QF (see Fig. 5). The data were logged with a fixed storage ring lattice without orbit feedback. For this BPM, the worst orbit reproducibility among all fills was about 180 μm horizontally and 20 μm vertically. During the run after refill, the max orbit drift was about 140 μm horizontally and 16 μm vertically. It is worth pointing out that part of the orbit drift was due to the current dependency of BPM readings. This problem is been investgated and will be resolving soon [5].

CONCLUSION

Several misbehaving power supplies have been found by analyzing the logged data using these tools. The results have been reported for maintenance reference. Besides for the analysis of power supply performance, the tools can also be used to do a variety of analysis, which are also very useful to improve the performance of the ring.

ACKNOWLEDGMENTS

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