Performance of the ELETTRA Storage Ring Main Power Supplies

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Abstract

The 42 "families" of the main magnets (dipoles, quadruples, sextupoles) of the ELETTRA storage ring are powered by thyristor controlled, highly stabilised, DC power supplies. Due to the high precision required, components and subsystems (DAC's, ADC's, DCCT's, etc.) with high performance and stability have been chosen. The performances achieved and the calibration scheme adopted will be reported.

1. INTRODUCTION

The ELETTRA Storage Ring optics has a Double Bend Achromat structure, with period 12. The magnet system is organised in 42 "families" (i.e. groups of magnets connected in series), as described in the following table 1 and figure 1:

Table 1
Magnet types and their grouping

Magnet type	Number of magnets	Num. of families	Magnets per family
Dipoles	24	1	24
Quadrupoles:			
Q1, Q2, Q3	72	36	2
QF	24	1	24
QD	12	1	12
Sextupoles	72	3	24
TOTAL	226	42	

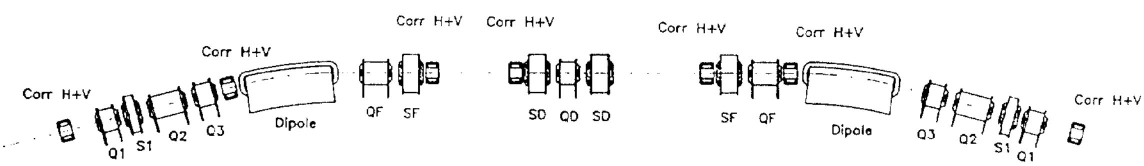

Figure 1. ELETTRA's achromat structure

Each family is powered by a DC highly stabilised thyristor controlled power supply. Due to the structure of the Storage Ring it was possible to group the power supplies in cabinets as described in the table 2.

Table 2
Power Supplies arrangement

Power Supply for	Number of Power Sup.	Number of cabinets	Number of PS / cabinet
Dipoles	1	1	1
Q1, Q2, Q3	36	12	3
QF	1	1	1
QD & S1	2	1	2
SF & SD	2	1	2
TOTAL	42	16	

The main specifications for the power supplies are summarised in the following table 3.

2. THE POWER SUPPLIES' STRUCTURE

In order to guarantee a high level of reliability, using standard industrial components, a traditional structure has been chosen for the power part of the supplies. The design consists of a fully controlled full wave bridge with an freewheeling diode followed by a passive and an active filter and a freewheeling diode for the protection of the magnets. The transformer matches the bridge to the grid and is connected via a circuit breaker and a main switch to it, see figure 2.

The power supplies for the quadrupole families Q1, Q2, Q3, QD and the sextupole family S1 have one full wave, controlled bridge. The power supplies for the dipoles, for the quadrupole family QF and the sextupole families SF and SD have two full wave controlled bridges connected in series and the ground point is at the common point of the two bridges in order to half the voltage versus ground.Due to the power involved, the dipole power supply is fed by the internal 20 kV grid and the circuit

Table 3
Main Power Supplies specifications

PS Name	# of PS	# of mag.	Inom [A]	Vnom [V]	Ripple [10^{-5}]	Stability 24h [10^{-4}]	Load induct. [mH]	Load resist. [mOhm]
Dipole	1	24	1950	530	±4	±2	213	254
Q1 & Q3	24	2	300	40	±2	±2	27	105
Q2	12	2	300	65	±2	±2	36	166
QF	1	24	300	240	±2	±2	388	1748
QD	1	12	300	660	±2	±2	162	639
S1	1	24	300	350	±5	±5	192	944
SF & SD	2	24	300	480	±5	±5	240	1285

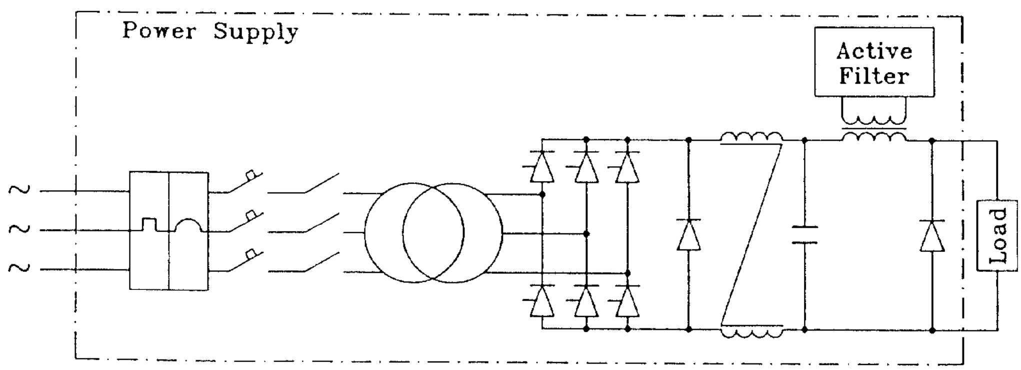

Figure 2. Sample structure of a power supply

breaker, the main switch and the transformer are separated from the cabinet and placed in a nearby building.

The regulation is build up by a slow current loop guaranteeing the overall stability and a fast voltage loop, which is underneath the first one.

For redundancy, the current reading is done with two high precision DC current transformers (DCCT) with a stability vs. temperature and time better than 1 ppm/^{0}C and 1 ppm/month are used.The precision and the stability of the reference of the current set is given by a 16 bit digital to analog converter (DAC) with a stability vs. temperature better than ±10 ppm FSR/^{0}C, while the output of the DCCT is converted by a 16 bit analog to digital converter (ADC) with a stability vs. temperature better than ±10 ppm FSR/^{0}C.

The whole system is connected to the control system [1] via the equipment interface unit (EIU) containing communication boards, CPU, DAC, ADC and digital I/O boards for the commands and the status of the power supply.

The schematic structure of the whole power supply system is shown in figure 3.

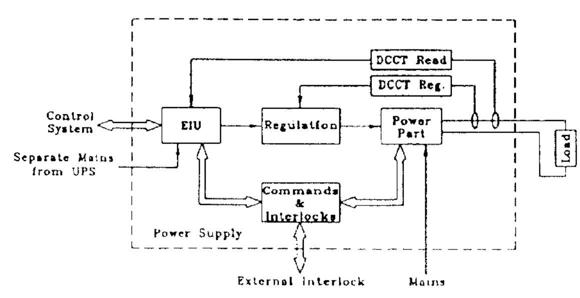

Figure 3. Block diagram of a power supply

3. POWER SUPPLY CALIBRATION [2]

The goal of the calibration is to define precisely the output current of a power supply; i.e. the correlation between the bit pattern defining the requested current and the actual output current, as well as the correlation between the actual output current and the bit pattern representing the reading of the output current. The functions indicated in Fig. 4 describes the overall functioning of a power supply as follows:

f: the transfer function between the I_{set} [digit] and the I_{out} [A], i.e. the power supply output current corresponding to the digital setting, describing the whole system: the digital to analog conversion, all regulation and the power part.

f*: the conversion function between the I_{set} [A] (imposed by the operator) and the I_{set} [digit], being the inverse function of f.

g: the transfer function between the I_{out} [A] and the I_{read} [digit], describing the whole current reading system: the DCCT, the electronics and the analog to digital conversion.

g*: the conversion function between the I_{read} [digit] and the I_{read} [A] seen by the operator, being the inverse function of g.

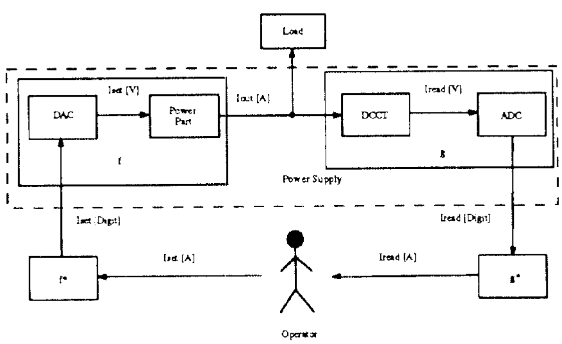

Figure 4. System from calibration point of view

Functions f and g have been measured and are determined by a polynomial fit to the measured data. Even if the specification for the linearity is very tight, a linear function fits the measured data sufficiently well. A second order fit has been considered in order to improve the reproducibility in the range of a few ppm.

4. ACHIEVED PERFORMANCE

Factory tests on ripple, stability and linearity of the power supplies have been performed on each machine. Some of these tests have been randomly repeated after the installation, the connection to their final loads and the start up of the power supplies. A 24 hours test at full power was also performed on all power supplies.

The results of these tests are reported in the following table 4. The data associated to similar power supplies are grouped together.

Table 4
Summary of the tests on the Power Supplies

PS Type	Ripple $[10^{-5}]$	Stability on 1 h $[10^{-5}]$	Linearity $[10^{-5}]$
Dipole	<1	±5	7
Q1 & Q3	<1	±5	1+3
Q2	<1	±5	1+3
QF	<1	±3	7
QD	<1	±3	7
S1	<2	±2	5
SF & SD	<2	±4	1+7

A sample of a stability measurement is shown in figure 5 (PSQD at 130 A, about 1 hour).

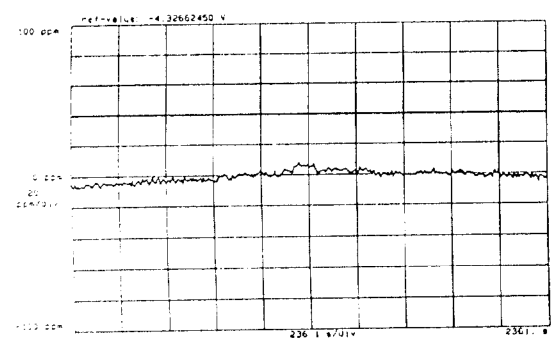

Figure 5. Sample of stability measurement

5. REFERENCES

[1] The ELETTRA Power Supply Control System - D. Bulfone, P. Michelini - 3rd European Particle Accelerators Conference, Berlin 24-28 March, 1992.

[2] Basic Considerations on Power Supply Calibration - R. Richter, R. Visintini - Sincrotrone Trieste internal note ST/M-TN-93/4 Feb. 1993