THE 3HZ POWER SUPPLIES OF THE SOLEIL BOOSTER

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Abstract

SOLEIL is a 2.75 GeV new third generation synchrotron radiation facility under construction near Paris [1]. The injector system is composed of a 110 MeV electron Linac pre-accelerator followed by a full energy (2.75 GeV) booster synchrotron. A repetition rate of 3Hz has been chosen for the filling of the Storage Ring together with the possible need for discontinuous operation with top-up filling mode. Based on digital regulation loop, the four power supplies (2 for the dipoles 600 A x 1000 V and 2 for the quadrupoles 250 A x 450V) reach the current tracking tolerance specification of 10^{-3}. The aim of this paper is to describe the main issues from the loads to the mains network through the power converters that are essential to reach the required performances.

INTRODUCTION

The energy ramping from 100MeV up to 2.75GeV of the SOLEIL booster synchrotron is completed within 150ms at a mains network triggered frequency of 50/17Hz (2.9412 Hz).

The nominal horizontal and vertical transverse tunes of the booster are Q_x=6.6 and Q_z=4.6 with the restrictive tolerance ΔQx,z less than 0.01, providing a good beam stability.

Thus the currents in the 2 quadrupoles circuits have to track the dipoles current within tight tolerances in the 10^{-3} region (see Eq. 1).

$$\Delta Q_{xz} < 0.01 \approx 10 \cdot \frac{.\Delta I}{I} \Rightarrow \frac{.\Delta I}{I} \leq 10^{-3} \quad (1)$$

In the past the classical way to power booster magnets was based on the “White Choke” circuit principle, like at the ESRF plant in Grenoble FRANCE [2].

For a few years, IGBTs switched converters controlled by digital loop with DSP-FPGA have been adopted for such applications. The benefits are multiple: firstly the cost is lower and the exploitation becomes much easier. The only drawback is the max. output voltage to stay with simple circuits. For SOLEIL booster PS we have adopted the SLS digital control under license [3].

THE BOOSTER AND ITS MAGNETS

The booster has a 156.62m circumference and is based on the classical FODO lattice with missing magnets.

Utility parameters:

The impedance from the mains network is equal to 1.33Ω under 20kV. We can derive an 2.66mΩ input impedance viewed from the first stage buck power converters.

The inlet cooling temperature is 30°C+/-1°with a 10° IN-OUT temperature drop.

The operating pressure is 8 bars with a 6 to 7 bars drop. We can deduct 21 l/min for each dipole PS and 6.5 l/min for the Qpoles ones considering that half of the losses are evacuated by cooling water.

Load and magnets parameters:

Each of the 36 dipoles has separate upper-lower coils connections; the dipole load has been split in two 36 alternate lower-upper coils in series making up 400mΩ & 156mH each (see Table 1).

Table 1: Major booster parameters

Injection energy	110	MeV
Extraction energy	2.75	GeV
Number of dipoles	36	
Dipole magnetic length	2.16	m
Dipole gap	22	mm
Dipole field @2.75GeV	0.74	T
Dipoles inj. current	19.7	A
Dipoles ext.current	541	A
Dipoles load resistance	400	mΩ
Dipoles load inductance	156	mH
Number of quadrupoles	22Foc + 22Defoc	
Qpole magnetic length	400	mm
Qpole bore diameter	57	mm
Max. Qpoles gradient:	12	T/m
Qpoles inj. current	5.8_{defoc} - 7.2_{foc}	A
Qpoles ext.current	160_{defoc} - 200_{foc}	A
Qpoles load resistance	600	mΩ
Qpoles load inductance	143	mH
Number of sextupoles	12Foc+16Defoc	
Sextu. Magnetic length	150	mm
Sextu bore diameter	60	mm
Max. Sextu gradient	10	T/m²
Max. Sextu current	10	Arms
Sextu load resistance	930_{foc}-1140_{defoc}	mΩ
Sextu load inductance	9_{foc}-12_{defoc}	mH

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Figure 1: the 3Hz PS hall at SOLEIL

PS ARCHITECTURE CHOICE

In the aim to stay inside the Low Voltage B standards thus allowing the use of low cost cables the PS output is 1000v max symmetrical versus ground (<600V versus PE), we spitted the 36 high and low dipoles coils in 2 sections composed of 2 times 18 of each type (see Fig. 2).

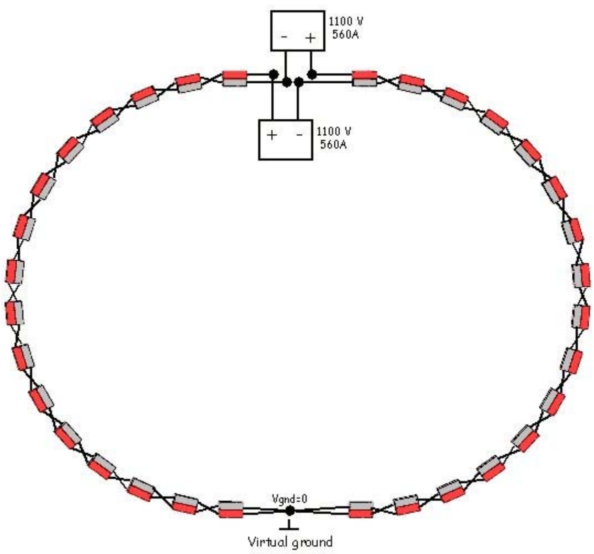

Figure 2: split dipoles cabling with 2 PS

The structure is modular; one PS module is composed by a buck stage with capacitor bank and a 4Q output designed for a quads family (see Fig. 3).

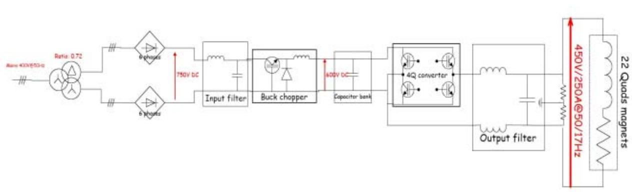

Figure 3: Qpoles PS main schematics

A dipole power supply is composed of 2 Qpoles ones Master/Slave in series no more no less (see Fig. 4).

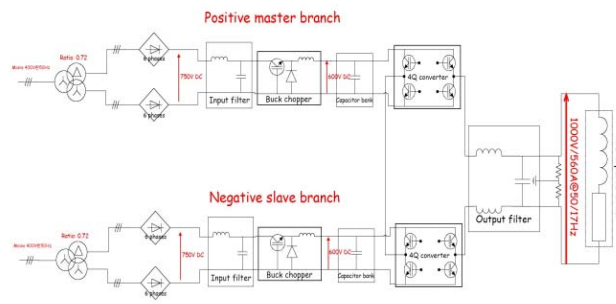

Figure 4: dipoles PS main schematics

PS DESIGN AND RESULTS

Buck DC-DC link (chopper) converter stage

This stage is placed between the mains rectifier and the capacitor bank avoiding too high 3Hz mains current pulsation and keeping as constant as possible the capacitor voltage.

4 Quadrants DC-AC converter stage

This stage drives the load current with the best curve fitting. Comparatively to a 2Q circuit, the 4Q configuration offers a better accuracy at low current thus at injection point.

Output filter

This second order filter gives a good adaptation to the load and its cutoff frequency is a best compromise between efficiency and accuracy.

Tracking acquisition and measurement device

The tracking is measured by a specific DCCT probe in each PS via a PXI crate under LabVIEW [4] software with an 8 channels 18bits@500kHz sampling board referenced NI M6281 [4] (see Fig.5 & 6).

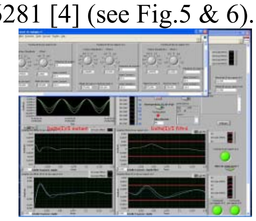

Figure 5: tracking measurement under LabVIEW

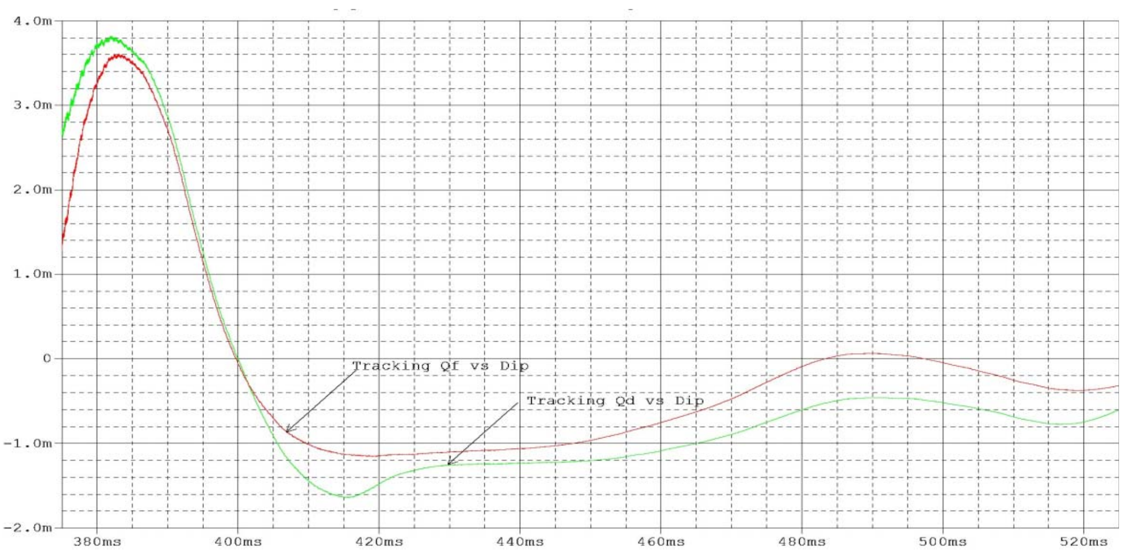

Figure 6: Qpoles tracking versus dipoles

The error is quite in phase with the output voltage (see Fig.7) as the hollow in the capacitor voltage with the output peak current.

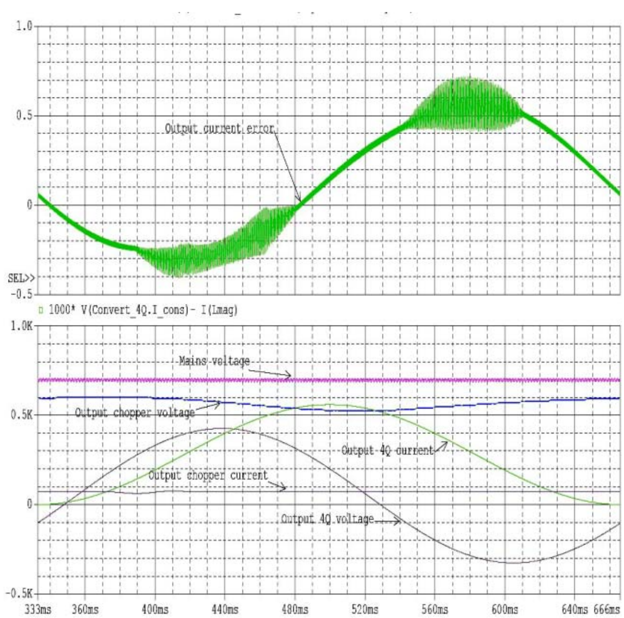

Figure 7: simulated error and main PS signals

The buck chopper stage avoids too high a mains current flickering which could happen if the 4Q stage was directly connected to the input filtered rectifier (see Fig. 8).

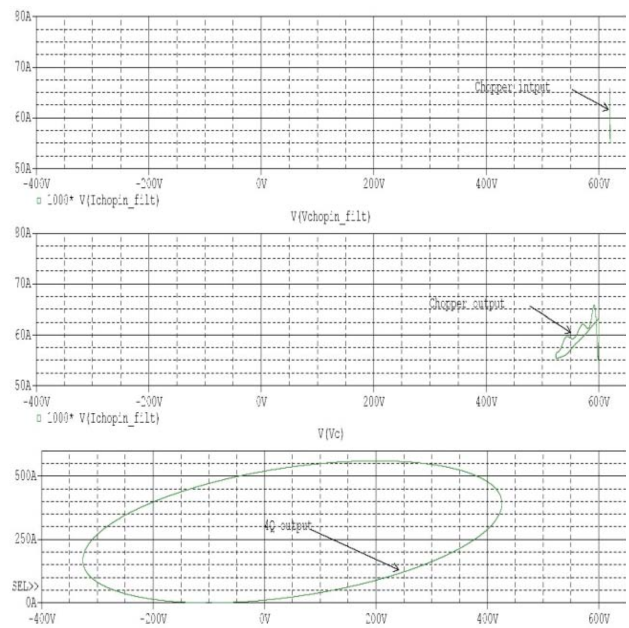

Figure 8: Buck in -out and 4Q output I vs U cycles

CONCLUSION

With such a 3Hz PS equipment we have been able to push the electron energy from 100MeV to 2.75GeV during an outstandingly short booster commissioning.

REFERENCES

[1] SOLEIL “Rapport d’avant projet détaillé” Juin 1999
[2] ESRF Foundation Phase Report February 1987
[3] SLS (Paul Scherrer Institut) “A 3Hz 1MVA peak Bending Magnet Power Supply for the Swiss Light Source”, G. IRMINGER, M. HORVAT, F. JENNI, H-U BOKSBERGER Nov. 1998.
[4] LabVIEW and PXI are trademarks of National Instruments Corp.