PERFORMANCE OF THE WHITE CIRCUITS OF THE BESSY II BOOSTER SYNCHROTRON *

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Abstract

The power supply system of the BESSY II booster synchrotron drives three independent 10 Hz White Circuits. A new concept for the 10 Hz AC converters, based on four quadrant IGBT current sources is realized. The main features of the performance as stability in amplitude (± 25 ppm) and phase (± 280 ns), higher harmonic content (- 75 db) and reliability are reported.

1 INTRODUCTION

The basic requirements for the design of the BESSY II booster synchrotron power supply system are the following:

- In order to achieve short injection times for the BESSY II storage ring the chosen repetiton rate for the booster synchrotron is 10 Hz.
- To minimize the load to the mains a White Circuit is realized.
- Due to the required flexibility of the booster optics, three independant White Circuits (bending, QF and QD) are installed.
- The demanded narrow margin for the tuneshift ($\delta Q_{x/y} \leq \pm 0.05$) [1] during acceleration resulted in high requirements for the power supply system and especially to all components contributing to the tracking of the three circuits.

2 LAYOUT OF THE WHITE CIRCUITS

To relieve the mains a resonant circuit with energy storing elements is needed, so that only the power losses burden the mains. The loss of flexibility and the additional power losses (compared to the direct energizing) due to the energy storing parts are of less importance (65% of the losses are due to the magnets themselves [5]). Fig. 1 compares the power fluctuations at direct powering of the dipoles to the White Circuits.

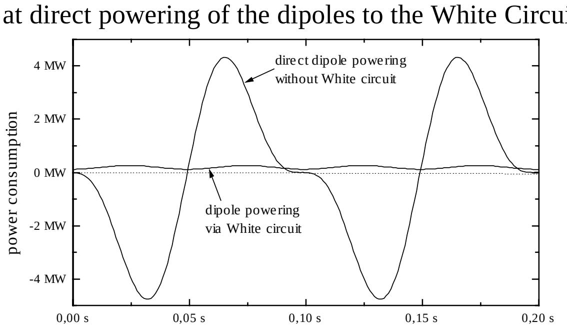

Fig. 1: Power fluctuations

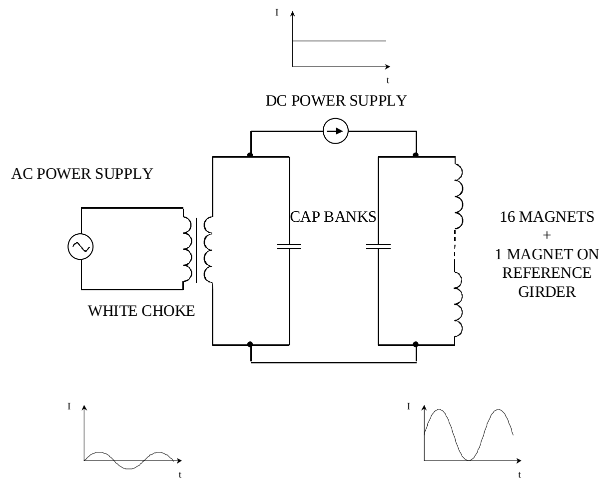

Fig. 2: Schematic of one White Circuit

The three White Circuits have the same basic schematics (see Fig. 2) as a one mesh White Circuit. The AC and DC currents are generated by independent sources. The main parameters of components are collected in Table 1. The function for the current in the magnets follows the equation

$$I_{magnets}(t) = I_{DC} + I_{AC} \cos(2\pi f_{rep} t)$$

Table 1: Main parameters of the BESSY II White Circuits

	DIPOLE CIRCUIT	QF CIRCUIT	QD CIRCUIT
$I_{PEAK\ MAGNETS\ at\ 1,9\ GeV}$	2277 A	492 A	395 A
$V_{PEAK\ MAGNETS\ at\ 1,9\ GeV}$	3112 V	527 V	423 V
L_{CHOKE}	40,8 mH	33,6 mH	33,3 mH
R_{CHOKE}	17,5 mΩ	29,6 mΩ	28,7 mΩ
C_{CHOKE}	6 210 µF	7 540 µF	7 610 µF
$L_{MAGNETS}$	42,7 mH	31,9 mH	31,9 mH
$R_{MAGNETS}$	50,6 mΩ	137 mΩ	136 mΩ
$C_{MAGNETS}$	5 930 µF	7 940 µF	7 940 µF
$I_{DC\ POWER\ SUPPLY}$	1375 A	340 A	340 A
$V_{DC\ POWER\ SUPPLY}$	120 V	70 V	70 V
$I_{PEAK\ AC\ POWER\ SUPPLY}$	778 A	200 A	200 A
$V_{PEAK\ AC\ POWER\ SUPPLY}$	311 V	184 V	184 V

All the resonant circuits are tuned to f_{rep} = 10 Hz (± 20 mHz).

3 THE CONVERTERS

A study [2] of the existing converters feeding the AC component of the White Circuits by thyristors or GTOs showed a lot of disadvantages:

- The couplings of the White Chokes must be extremely high.
- They are extremely sensitiv to detuning of the load.
- Fluctuation of reactive power on the mains is high.
- Additional components or delicate trigger systems to reduce the content of higher harmonics in current are necessary.
- Limited step width for phasing of the three circuits.

The technique for the BESSY II AC Power Supplies is based on IGBTs. In this way a full four quadrant current source for high power applications is achieved. Due to this it is possible to run the White circuits totally detuned.

- A 10 Hz tuned circuit was powered in a test between 5 Hz and 20 Hz. Concerning the reactive power the only limit is the installed power.
- Phase shifts up to 180° in 100 ms on the quadrupole AC-PS are possible.
- The contents of higher harmonics in the output current are negligible (see Fig. 3)

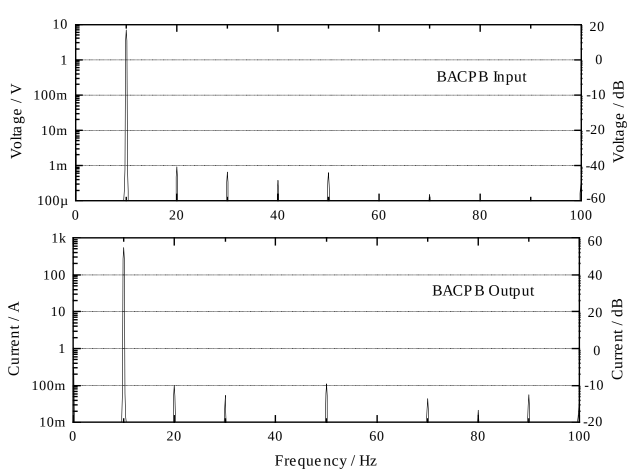

Fig. 3: FFT analysis of 10 Hz output current of dipole AC PS [3]

4 EXTERNAL REGULATION LOOPS

The readbacks for the external regulation loops based on aircoil signals out of the magnets on a reference girder are created in a 10 Hz analyser board.

4.1 FIELD REGULATION

One output of the 10 Hz analyser is a DC voltage proportional to the AC peak field in the magnets. This value is compared to the setpoint value and the result is given to the amplitude modulation input stage of the 10 Hz sine generator.

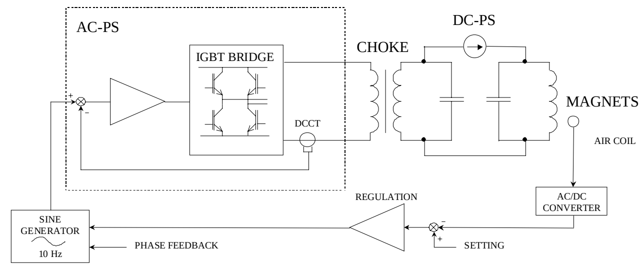

Fig. 4: Field regulation of the AC converters [4]

4.2 PHASE REGULATION

A second output of the 10 Hz analyser is a TTL signal representing the zero crossing time of the air coil signal. The dipole circuit is free running due to its 10 Hz sine generator and is master for all the following systems. The timings of QF and QD circuits are measured with reference to the dipole, compared to the setpoint and regulated in a Dynamic Control Processor System.

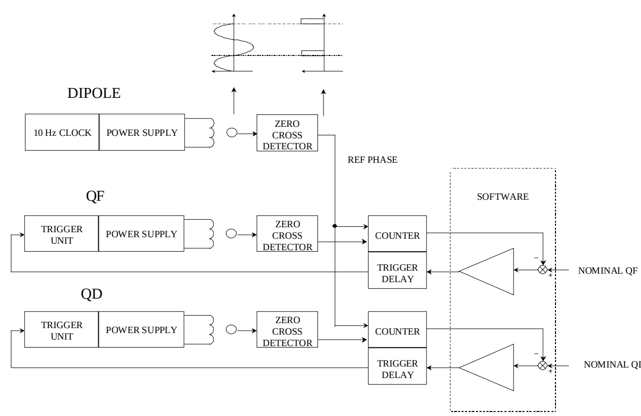

Fig. 5: Phase regulation of the AC converters

5 ACHIEVED MAGNET CURRENT QUALITY

Based on the demanded tuneshift limits during acceleration the overall stability requirements for the White Circuits are calculated to $\delta\alpha \leq \pm 2.6\ 10^{-4} \approx$ (-70 dB) for amplitude tracking and $\delta\varphi \leq \pm 23\mu s$ for the phase tracking between dipole and quadrupole field. These errors are to be divided to the different components, that contribute to the overall stability (see Table 2 and Table 3).

Longtime measurements during several days of a storage ring commissioning period are shown in Fig. 5 and Fig. 6

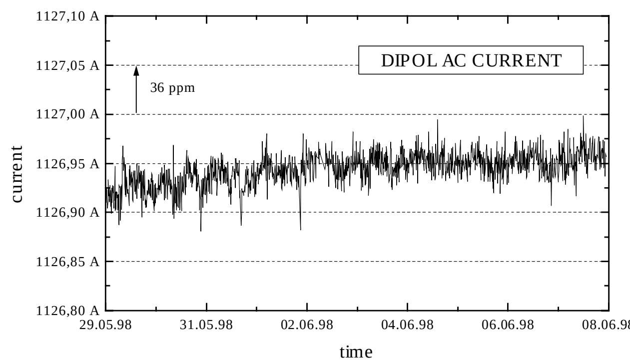

Fig. 5: 10 Hz current amplitude stability measurement

Table 2: amplitude stability requirements for the different components and achieved values

	short time stability (t < 60 s)		long time stability (t < 1 month)	
	specified:	achieved:	specified:	achieved:
AC Power Supply	±100 ppm	± 25 ppm	regulated to zero	-
DC Power Supply	± 50 ppm	± 5 ppm	± 20 ppm	<± 5 ppm
10 Hz Analyser	± 50 ppm	± 20 ppm	± 50 ppm	± 35 ppm
Regulation	± 20 ppm	± 3 ppm	± 20 ppm	<± 5 ppm
Sine generator	± 50 ppm	± 15 ppm	regulated to zero	-

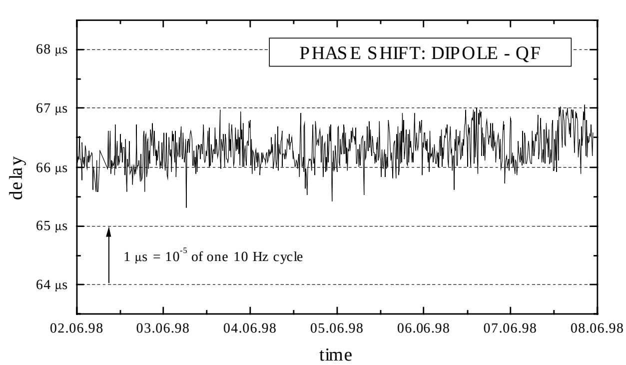

Fig. 6: Phase stability measurement dipole to QF

Table 3: Phase stability requirements for the different components and achieved values

	short time stability (t < 60 s)		long time stability (t < 1 month)	
	specified:	achieved:	specified:	achieved:
10 Hz Clock	± 0.1 •s	± 0.01 •s	± 0.1 •s	± 0.01 •s
Trigger Unit	± 0.5 •s	± 0.35 •s	regulated to zero	-
AC Power Supply	± 12 •s	± 0.28 •s	regulated to zero	-
Zero Cross Detector	± 1.0 •s	± 0.4 •s	± 1.0 •s	± 0.3 •s
Regulation	± 0.1 •s	± 0.01 •s	± 0.1 •s	± 0.01 •s

6 SUMMARY

The new technique of the power supply system for the BESSY II booster synchrotron, based on IGBT driven four quadrant current sources fits all the specifications and basic requirements. One year of operation shows that this system is highly reliable and robust.

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REFERENCES

[1] E. Weihreter et al. This conference.

[2] K.Bürkmann, T.Schneegans, Technical Report Konzeption der Stromversorgung der Synchrotronmagnete für BESSY II BESSY TB Nr. 189/94 (1994)

[3] K.Bürkmann, T.Schneegans, Technical Report Oberwellen in den White-Kreisen von BESSY II BESSY TB Nr. 213/97 (1997)

[4] K.Bürkmann, T.Schneegans, Technical Report Vermessung der White-Kreis Netzgeräte für BESSY II BESSY TB Nr. 204/97 (1997)

[5] K.Bürkmann, T.Schneegans, Technical Report Energieverhältnisse in den White-Kreisen von BESSY II BESSY TB Nr. 215/97 (1997)