

HIGH CURRENT UNIPOLAR MAGNET POWER SUPPLY SYSTEM AT THE PLS-II STORAGE RING*

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Abstract

Lattice of the Storage Ring (SR) is changed from TDB to DBA, and beam energy is enhanced from 2.5 GeV to 3.0 GeV at the Pohang Light Source upgrade (PLS-II). At the PLS-II, Magnet Power Supplies (MPS) were newly designed according to magnet specification of the PLS-II. All MPSs are developed as switching type power conversion technology. High current unipolar MPSs for bending (BD), main-quadrupole (MQ), sextupole (ST) and septum (SP) magnet are consists parallel operation type of unit stack buck type power supply [1]. Unit stack of unipolar MPS has capability maximum 250A and operation 10 kHz. BD and MQ MPS are adopted four stack as each stack 90 degree phase shift switching, and have capability maximum 1000 A. ST MPS is adopted two stack as each stack 180 degree phase shift switching, and have capability maximum 500 A. SP MPS is adopted single, and have capability maximum 250 A. All unipolar MPSs are developed as full digital controller, embedded EPICS IOC and operated less than +/-10 ppm current stability. In this paper, we report on the development and characteristics of the high current unipolar MPS for the PLS-II SR.

ONE CELL LINEAR LATTICE OF THE PLS-II SR

Lattice is DBA structure, and one gradient magnet, four quadrupole and four sextupole are arranged at half section of 1-cell. Bending magnet is consisted of main bending winding and trim winding, quadrupole magnet is consisted of main quadrupole winding and auxiliary quadrupole winding, and sextupole magnet is consisted of main sextupole winding, skew and corrector (V/H) winding. Fast corrector magnet is allocated up-stream and down-stream of each cell. The PLS-II SR has twelve cells. Figure 1 shows PLS-II SR one cell linear lattice.

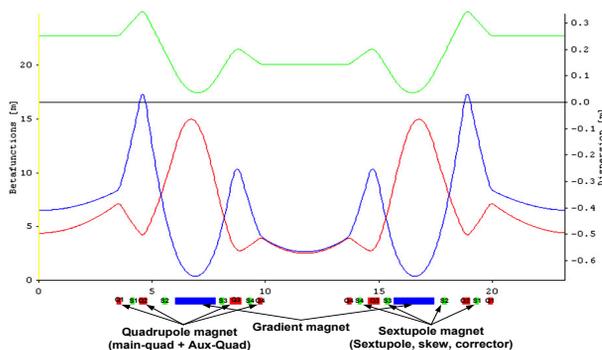


Figure 1: 1-cell linear lattice of the PLS-II SR.

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UNIPOLAR MPS OF THE PLS-II SR

Unipolar MPS is bending, main-quadrupole, sextupole and septum at the PLS-II SR. According to magnet requirement, bending and main-quadrupole MPS are developed as maximum 1000 A output, and sextupole MPSs developed as maximum 500 A output, and septum MPS is developed maximum 250 A output. All magnet and lattice of PLS-II are difference with the PLS SR. Therefore, all unipolar MPSs are newly development as switching type power supply adopted full digital controller.

UNIPOLAR MPS SPECIFICATIONS

Table 1: Main Specifications of Unipolar Magnet

MPS	Mag.[A] max	MPS[V] min	24 mag R[mΩ]	24 Mag. L[mH]
BD	928	508	528.0	696.0
MQ1	898	384	393.6	52.6
MQ2	914	483	496.8	81.1
MQ3	840	588	662.4	127.4
MQ4	898	384	393.6	52.6
ST1	456	404	818.4	52.1
ST2	455	461	945.6	72.0
ST3	455	461	945.6	72.0
ST4	455	461	945.6	72.0
		MPS [V]min	mag R[mΩ]	
SP	230	24	112.9	

Table 2: Main Specifications of Unipolar MPS

MPS	BD	MQ	ST	SP
AC input (Δ/Y)	470/470	400/400(1,2,4) 460/460(3)	440/440	30/30
output[A]	1000	1000	500	250
output[V]	528	394(MQ1, MQ4) 497(MQ2) 662(MQ3)	409(ST1) 473(ST2,3,4)	28.3
Main circuit	12-p diode rectifier, buck converter Stacked buck converter Cooling: water, forced air			
parallel no.	4	2	1	
Stability[ppm]	+/-10(long term) fwhm			
controller	Full Digital ADC: 18bit Embedded EPICS IOC			
protection	Internal: IN/OUT voltage, OC, OT, cooling External: input(2), output(2)			

Table 1 shows main specifications of unipolar magnet. BD, MQ and ST MPSs are series connected with 24 magnets. SP MPS is individual connected with magnet.

Magnet maximum current is at magnet degaussing time, and normal operation current is 90% of maximum current. Table 2 shows main specifications of unipolar MPS.

MAGNET AND POWER SUPPLY CONNECTION

Bending magnet has main bending and trim winding. Twenty-four main bending winding is series connection by one MPS. quadrupole magnet has main quadrupole and trim winding. Four type twenty-four main quadrupole winding is series connection by four MPSs (MQ1, MQ2, MQ3, MQ4). Sextupole magnet has main sextupole and trim(skew and V/H corrector) winding. Four type twenty-four main sextupole winding is series connection by four MPSs (ST1, ST2, ST3, ST4). Septum magnet is individually connected by single MPS.

POWER CONVERSION

At the PLS-II SR, power conversion of all unipolar MPSs is adopted unit stack power supply by buck type topology. Nominal output current and voltage of stack power supply are 250A and 700 V, respectively. Figure 2 shows circuit diagram of unipolar MPS unit stack power supply.

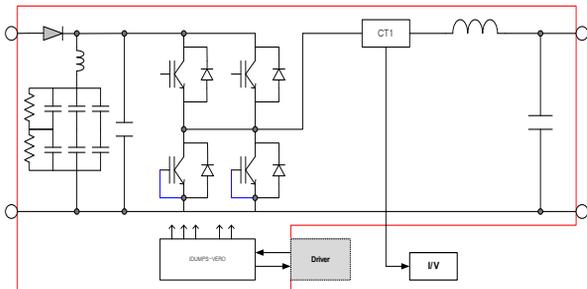


Figure 2: Circuit diagram of unipolar MPS unit stack power supply.

AC input transformer of BD, MQ and ST MPS is allocated at outside of power supply. In order to reduce input voltage ripple, secondary of transformer is adopted delta(Δ) and wye(Y) winding. Power supply is consisted of rectification, stack power supply (input filter, buck converter, output filter) and controller. Controller is adopted full digital controller with built-in embedded epics IOC function.

1000 A Class Unipolar MPS

1000 A class unipolar MPS for bending and main-quadrupole is parallel operating of four stack power supplies. Total output current is sense by precision DCCT(LEM IT-1000S). Figure 3 shows 1000 A class unipolar MPS circuit diagram for bending and four quadrupole magnet.

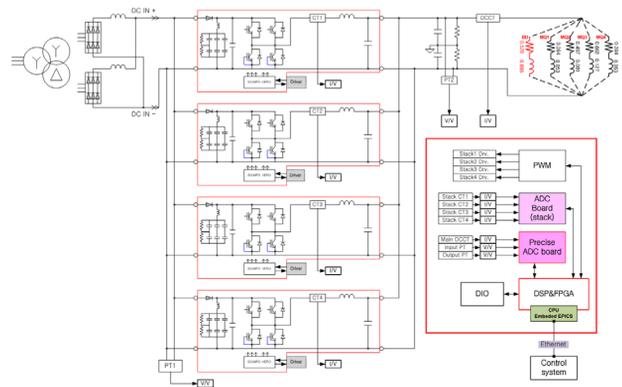


Figure 3: Circuit diagram of 1000[A] class unipolar MPS.

500 A Class Unipolar MPS

500A class unipolar MPS for sextupole is parallel operating of two stack power supplies. Total output current is sense by precision DCCT(LEM IT-600S). Figure 4 shows 500 A class unipolar MPS circuit diagram for four sextupole magnet.

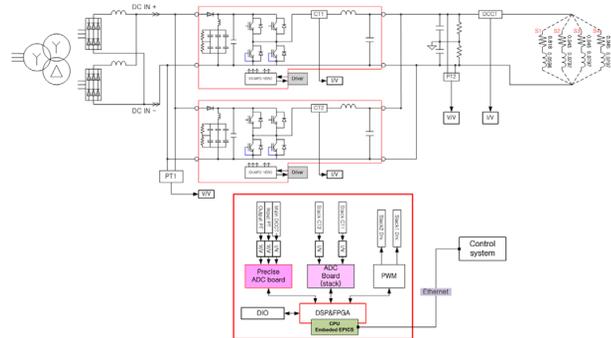


Figure 4: Circuit diagram of 500 A class unipolar MPS.

250 A Class Unipolar MPS

250 A class unipolar MPS for septum is single operating of stack power supply. Total output current is sense by precision DCCT (LEM IT-400S). Figure 5 shows 250 A class unipolar MPS circuit diagram for septum magnet.

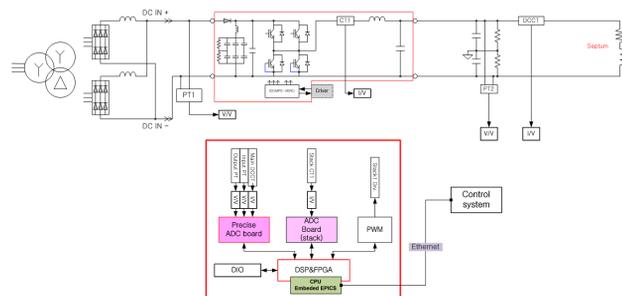


Figure 5: Circuit diagram of 250A class unipolar MPS.

FABRICATED UNIPOLAR MPS

Size of stack power supply is 610mm (W) x 250mm (H) x 604mm (D). Size of BD, MQ and ST MPS is

1300mm (W) x 2000 mm(H) x 1000 mm(D) and SP MPS is 750 mm(W) x 2000 mm(H) x 1000 mm(D). Figure 5 shows stack power supply, and Figure 6 shows fabricated BD and MQ MPS. BD and MQ MPS are operating as each stack 90degree phase shift switching. ST MPS is operating as each stack 180 degree phase shift switching.

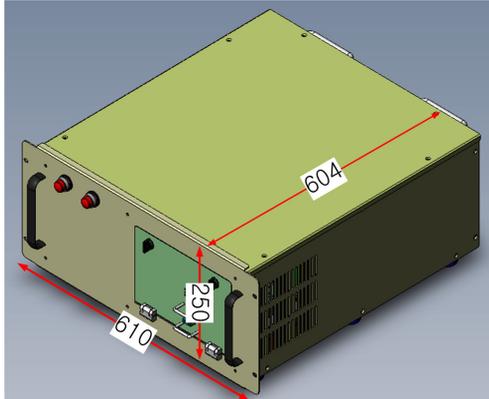


Figure 5: Stack power supply.

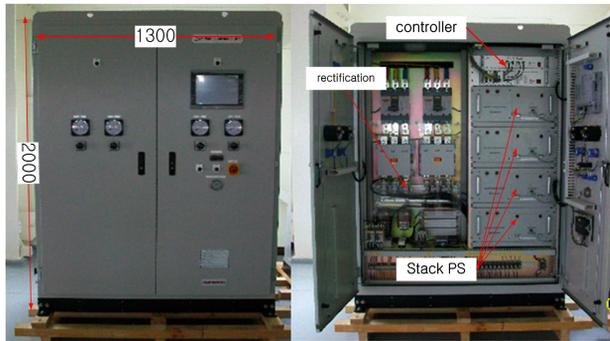


Figure 6: Fabricated BD and MQ MPS.

CONTROLLER

Digital controller of unipolar MPS is consisted of DSP board, ADC board, DIO board, PWM board and control power board. Operating number of stack power supply is able to control at DSP board. Stack power supply of BD and MQ MPS is four, and ST MPS is two, SP MPS is single.

DSP Board

- Control algorithm: Feed forward PI control.
- 150MHz Fixed point TMS320F28335 DSP.
- PWM Frequency: 100 KHz_max.
- CPU: embedded epics IOC.

ADC Board

- Resolution: >18bits.
- Input Range(selectedtable): $\pm 10V$, $\pm 5V$.
- ADC input port: 3 Ch.

PERFORMANCE

Stability

Output current stability is measured during MPS normal beam operation. Stability of BD, MQ and ST MPS is measured below than ± 10 ppm. And SP MPS is slightly high than ± 10 ppm. Table 3 shows unipolar MPS stability. Figure 7 shows BD MPS stability at 2011-11.

Table 3: Stability of Unipolar MPS

MPS	Long term Stability		
	operation[A]	+/-ppm(fwhm)	remark
BD	882.6	4.9	2011. 11
MQ1	574.0	5.4	
MQ2	825.9	7.7	
MQ3	673.5	5.2	
MQ4	636.2	4.7	
ST1	213.0	5.0	2011. 8
ST2	225.0	5.8	
ST3	251.0	8.5	
ST4	241.0	6.6	
SP	193.0	14.7	2011. 8

Resolution and Reproduction

Resolution and reproduction are measured for BD and MQ MPSs. Resolution and reproduction are measured 0.01 A and <10 ppm, respectively.

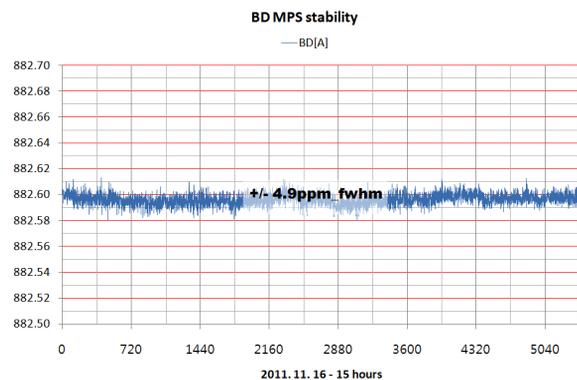


Figure 7: BD MPS stability (2011-11).

SUMMARY

Unipolar MPSs of the PLS-II SR developed as parallel operation scheme of buck type converter power supply. These MPSs are adopted full digital controller, embedded epics IOC PS and compact size. And operation is four-parallel, two-parallel or single buck type. Stability is below than ± 10 ppm except SP MPS, resolution and reproduction of BD and MQ are 0.01 A and <10 ppm, respectively. MPS doing normal operation during PLS-II commissioning and beam operation (2011. 6 - 2012).

REFERENCES

- [1] S.C.Kim. "Storage Ring Power Supply System at the PLS-II", IPAC 2010 proceeding, pp. 3248-3250.