LOW CURRENT BIPOLAR 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. Bipolar MPS are adopted H-bridge type switching power conversion technology. Low current bipolar MPSs are vertical corrector (VC), horizontal corrector (HC), fast corrector (FC), aux.-quadrupole (AQ), skew (SK) and dipole trim coil (TR). All MPSs are performed less than +/- 10 ppm output current stability and adopted full digital controller. Except vertical corrector MPSs, New bipolar MPSs for HC, AQ, SK, and TR magnet are developed as embedded EPICS IOC. Vertical corrector (VC) MPS is built-in PSI digital controller and VME IOC. In this paper, we report on the development and characteristics of the bipolar MPS for the PLS-II Storage Ring.

ONE CELL LINEAR LATTICE OF THE PLS-II SR

Lattice is DBA structure, and one gradient dipole, four quadrupole and four sextupole magnet are arranged at half section of 1-cell. Dipole magnet is consisted of main bending winding and trim winding (TR), quadrupole magnet is consisted of main quadrupole winding and auxiliary quadrupole (AQ) winding, and sextupole magnet is consisted of main sextupole winding and corrector winding(skew(SK), corrector (VC/HC)). Fast corrector (FC) magnet is allocated up and down-stream of each cell. The PLS-II SR has twelve cells [1]. Fig. 1 shows one cell linear lattice of the PLS-II storage ring.

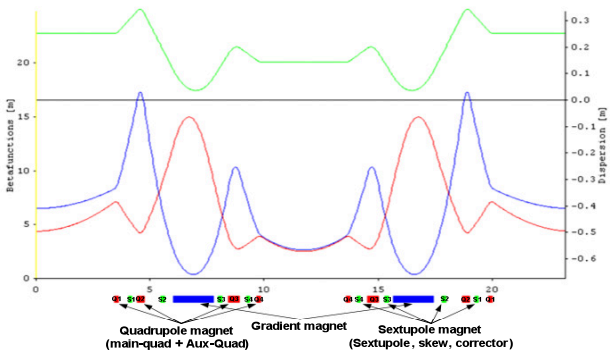

Figure 1: 1-cell linear lattice of the PLS-II SR.

BIPOLAR MPS OF THE PLS-II SR

At corrector magnet of the PLS-II, requirement maximum current of VC, HC, AQ, SK, TR and FC magnet is 12.5 A, 14.9 A, 13.2 A, 16.4 A, 9.6 A and 10.2[A], respectively. Therefore, bipolar MPS have to be capability minimum 20[A].

BIPOLAR MPS SPECIFICATIONS

Table 1: Main Specifications of Bipolar Magnet

MPS	Mag. (A)	MPS (V)	Mag. (V)	Magnet R(mΩ)	Magnet L(mH)
AQ1	13.23	13.2	10.2	768	23.2
AQ2	13.23	15.8	12.8	971	35.7
AQ3	13.23	20.3	17.3	1304	56.1
AQ4	13.23	13.2	10.2	768	23.2
Skew (SK)	16.41	9.5	6.5	398	14.7
HC1(slow)	14.91	26.7	23.7	1589.3	41.3
HC2(slow)	14.91	31.3	28.3	1898.5	57.1
HC3(slow)	14.91	31.3	28.3	1898.5	57.1
HC4(slow)	14.91	31.3	28.3	1898.5	57.1
VC1(slow)	12.44	22.8	19.8	1589.3	75.8
VC2(slow)	12.44	26.6	23.6	1898.5	104.9
VC3(slow)	12.44	26.6	23.6	1898.5	104.9
VC4(slow)	12.44	26.6	23.6	1898.5	104.9
Fast HC(fast)	10.2	4.5	1.5	150	1.61
Fast VC(fast)	10.2	4.5	1.5	150	1.61
Dipole Trim(TR)	9.6	18.0	15.0	1562	82

Table 2: Main Specifications of Bipolar MPS

	AQ	SK	VC/HC	FC	TR
No.	96	24	VC: 96 HC: 96	FVC: 48 FHC: 48	24
INPUT(V)	23	15	23	15	15
OUTPUT(A)	**20**	**20**	**20**	**15**	**15**
circuit	H-bridge type				
Stability	+/- 10 ppm, Long term				
Controller	Full Digital ADC: 18bit Slow corrector(VC): VME IOC Slow corrector(HC, AQ, SK, TR): embedded EPICS Fast corrector: high speed RS422 comm.				
protection	Internal: IN/OUT voltage, OC, OT, cooling External: input(2), output(2)				

Tables 1 and 2 show main specifications of bipolar magnets and MPSs. Maximum output current of all bipolar MPSs is 20 A.

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MAGNET AND POWER SUPPLY CONNECTION

Bipolar magnets of each cell are same allocation. Therefore, bipolar MPSs are connected individual with bipolar magnet. V- and H-corrector MPS are connected all corrector winding of sextupole magnet, And skew MPSs are connected at skew winding of first and last sextupole magnet at each cell. Dipole trim coil MPSs are connected at trim winding of dipole magnet. Fig. 2 shows connection diagram between bipolar MPSs and magnet for one cell.

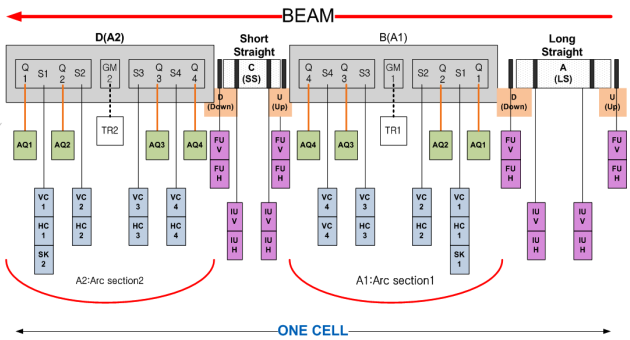

Figure 2: Connection diagram between bipolar MPSs and magnet for one cell.

BIPOLAR MAGNET POWER SUPPLY

At the PLS-II SR, Power conversion of bipolar MPS is adopted H-bridge switching type topology. Switching device is IGBT, and frequency is 25 kHz MPS is consists of AC rectification, input filter, H-bridge switch, output filter, DCCT and controller. Cut-off frequency of input and output filter are 17 Hz and 3.75 kHz, respectively. Controller is full digital controller and function embedded EPICS IOC. Precision monitor of output current is measured by precision DCCT. (LEM IT-200S or HITEC MACC-150) Size of bipolar MPS is 450mm (W) x 134 mm(3U, H) x 450 mm(D). Fig. 3 shows basic circuit diagram of bipolar MPS. Fig. 4 shows fabricated bipolar MPS.

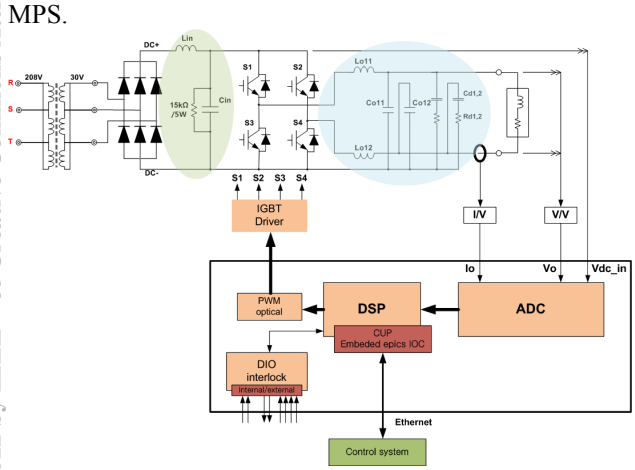

Figure 3: Circuit diagram of bipolar MPS.

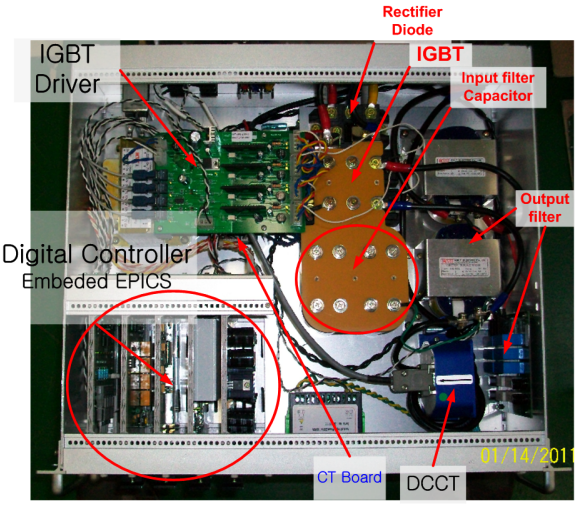

Figure 4: Fabricated bipolar MPS.

CONTROLLER

Bipolar MPS digital controller is consisted of DSP board, ADC board, DIO board, PWM board and control power board. Fig. 5 shows DSP and ADC board of controller.

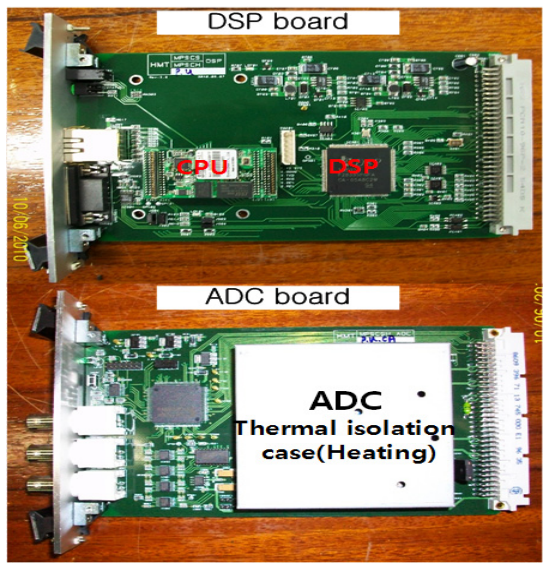

Figure 5: DSP and ADC board of controller.

DSP board

- Control algorithm: Feed forward PI control
- 150MHz Fixed point TMS320F28335 DSP
- PWM Frequency: 100 KHz_max
- Remote interface
  - Slow corrector: embedded epics IOC
  - Fast corrector: fast RS422(max. 5.2Mbps)

ADC board

- Resolution: >18bits.
- Input Range(selectable): ±10V, ±5V
- ADC input port: 3 Ch.

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PERFORMANCE OF BIPOLAR MPS

Slow Corrector Performance

Stability, resolution and reproduction of slow corrector (VC, HC, AQ, SK, TR) MPS are +/-3 ppm, 50 μA and +/- 50 μA, respectively. Fig. 6, Fig. 7 and Fig. 8 show long term stability, resolution and reproduction performance, respectively.

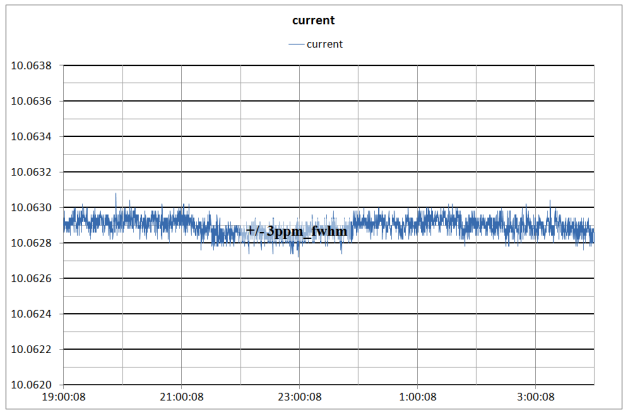

Figure 6: Long term stability of slow corrector MPS.

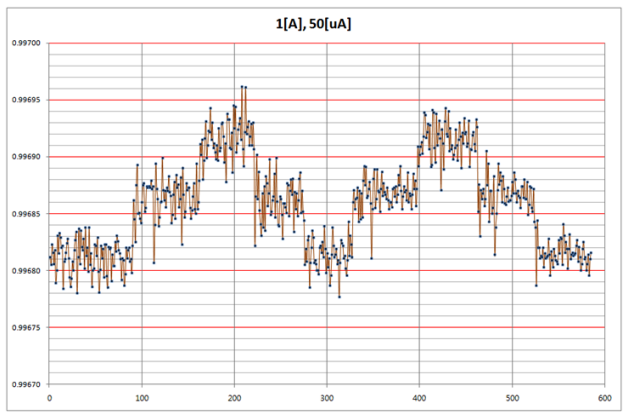

Figure 7: Resolution of slow corrector MPS.

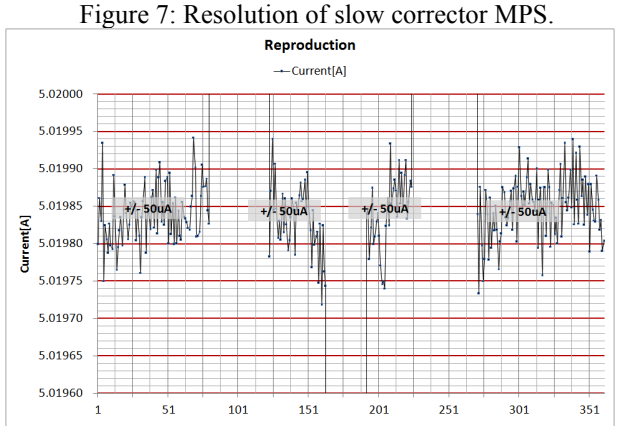

Figure 8: Reproduction of slow corrector MPS.

Fast Corrector Performance

Stability of FC MPS is +/-10ppm, and resolution and reproduction are same with slow corrector MPS. Rising and falling time for step current are 320 μs for 3 A. FC MPS latency time is measured 380 μs at 926kbps communication speed. FC MPS communication speed for fast feedback is 5.2Mbps at the PLS-II. In this case, MPS latency time is forward to 315 μs. Fig. 9 shows long term stability. Table 3 shows summarized table of bipolar MPS.

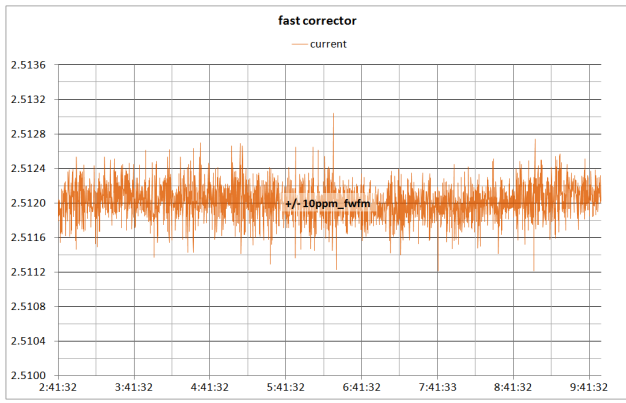

Figure 9: Long term stability of FC MPS.

Table 3: Bipolar MPS Performance

	Slow corrector	Fast corrector	Remark
stability	+/- 3	+/- 10	ppm_fwhm
Resolution	0.05	0.05	mA
reproducibility	+/-0.05	+/-0.05	mA
Remote interface	Ethernet	Fast RS422	
Latency time		380	μs@926kbps
Remote interface	Ethernet 100Mbps	RS422 5.2Mbps	

SUMMARY

Bipolar MPSs of the PLS-II SR developed as H-bridge converter type power supply. These MPSs are adopted full digital controller. Slow correctors are developed as embeded epics IOC PS, and fast corrector is developed as high speed RS422 communication. Stability is below than +/-10 ppm. Resolution and reproduction are 50 μA and +/- 50 μA, respectively. Bipolar MPSs are well working during normal operation during PLS-II commissioning and beam operation.(2011. 6 ~ 2012. 5)

REFERENCES

[1] S.C. Kim. “Storage Ring Power Supply system at the PLS-II”, IPAC2010 proceeding, p. 3248-3250.

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