NEW MAGNET POWER SUPPLY FOR PAL LINAC*

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Abstract

Since the completion of PLS in 1994, PLS Linac magnet power supply (MPS) has been operated for 12 years with 12-bit resolution and 0.1% stability. Improvement in the resolution and the reliability of the Linac MPS is highly required now for the stable beam injection and 4th generation light source research. To improve performance of MPS, we developed a new compact MPS with 16-bit resolution and 20ppm stability using four-quadrant switching schemes with 50kHz MOSFET device. Bipolar MPS for a corrector magnet consists of one main power board, control power board, regulator board and CPU board. Size of each board is only 135mm width and 250mm depth. A unipolar MPS for quadrupoles and solenoid magnets is composed of 4-parallel operation of two main power boards, doubling the current output. Output of the MPS is 10V, ±10A for the bipolar and 50V, 50A for the unipolar magnet.

INTRODUCTION

Beam transport line (BTL) of PAL Linac has 22 solenoid magnets, 48 quadrupole magnets, and 28 corrector magnets. MPS have been operated twelve years since the completion of PLS in 1994. Power conversion scheme of these magnet power supplies is linear regulator of SCR phase rectifier. The resolution of output current is less than 12 bit. Stability is over ±1000 ppm(± 0.1 %). This type MPS has simple structure but heavy and large volume because of an input transformer, an inductor and a capacitor. A remote controller using RS422 serial communication is separated with MPS. One controller is connected with four MPS. Therefore, MPS system of PAL Linac has lower quality, and it was difficult for maintenance. The new type MPS for the Linac has been developed. Topology of the MPS using full-bridge four-quadrant DC/DC converter is adopted. This scheme is able to operate bipolar or unipolar mode by PWM switching method. Identical main power conversion PCB is commonly used at bipolar and unipolar MPS. This paper presents the development and characteristics of the new MPS for PAL linac.

BASIC CONCEPT OF NEW MPS FOR PAL LINAC

A full-bridge four-quadrant DC/DC converter topology of MPS was selected for PAL Linac. This type converter is able to operate bipolar or unipolar output current according to PWM switching method. Figure 1 and Figure 2 show the circuit diagram of bipolar and unipolar MPS operations of a full-bridge four-quadrant DC/DC converter.

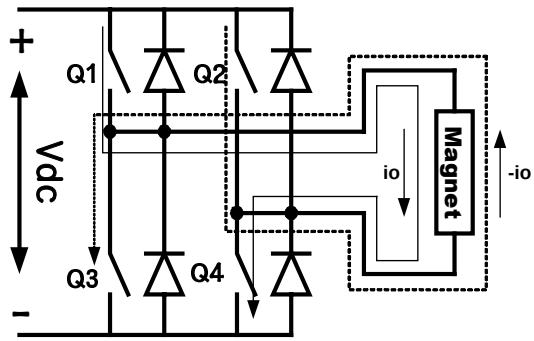

Figure 1: Bipolar MPS operation of full-bridge four-quadrant DC/DC converter.

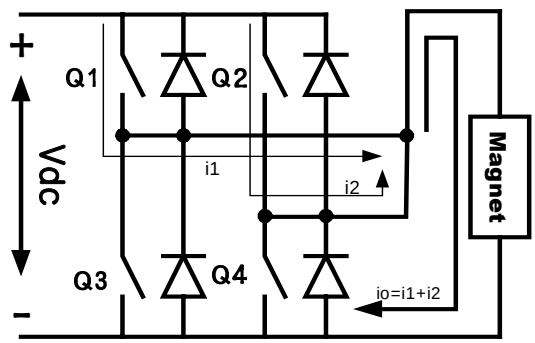

Figure 2: Unipolar MPS operation of full-bridge four-quadrant DC/DC converter.

In figure 1, output current flows to a load as positive or negative direction (i_o or $-i_o$) by on or off its contact point of two-switch pair (Q1-Q4 or Q2-Q3). In figure 2, output current flows to the load as only positive direction (i_1 or i_2) by on or off its contact point of two-switch leg (Q1-Q3 or Q2-Q4). In this case, if two-switch legs are parallel simultaneously, twice amount current ($i_1 + i_2$) flows to the load. It is possible that their parallel operations can give unipolar quadruple current to the load.

NEW MPS FOR PAL LINAC

Specifications

Required maximum output current is ±10A and 50A, and stability is ±100ppm and ±15 at the bipolar and unipolar

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MPS, respectively. Table 1 shows development specifications of the PAL Linac MPS.

Table 1: Development specifications of MPS

	Bipolar	Unipolar	
Size (W x H x D)	435x135×450	435×178×450	mm
Input	1ϕ 220V	3ϕ 30V	V
Output	±10/20	50/50	A/V
Output stability	±50ppm	±20ppm	< 1 hour
	±100ppm	±50ppm	> 10 hours
Output resolution	16		bit
Topology	Full-Bridge 4-Q DC/DC converter		
Switch freq.	50		kHz
Output Filter Cut-off freq.	< 5		kHz

Configurations

New MPS of the PAL Linac consists of eight parts, DC bus, back-plan board, control power board, CPU board, regulator board, main power module, filter board and DCCT. Size of control power board including CPU board, regulator board, main power module, back-plane board and output filter board is standardized for the common applications for bipolar and unipolar MPS. Size of control power system including CPU, regulator and main power module board is 135mm width and 250mm depth. Main power module used one- and two-modules for bipolar and unipolar MPS, respectively. Figure 3 shows configuration diagram of the MPS of PAL Linac.

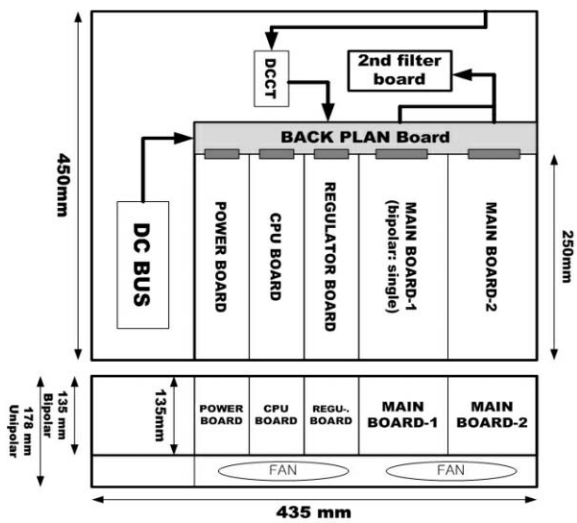

Figure 3: Configuration diagram of PAL Linac new MPS.

Figure 4 and 5 are circuit diagram of the bipolar and unipolar MPS. Output current of bipolar MPS flows to a positive or negative directions during operating its switch. In a unipolar MPS, each leg of main board is operating in parallel, simultaneously. In that case, output current is sum (I_{1A}+I_{1B}) of each leg current. If two main boards are parallel operating then output current is four times (I_{1A}+I_{1B}+ I_{2A}+I_{2B}) of single-leg current. In case of parallel operation, control of each leg must be exactly same as PWM. LA-55P of LEM and ULTRASTAB-867 of Danfysik are used as DCCT in the bipolar and unipolar MPS, respectively. VHP-4 type is selected for burden resistors.

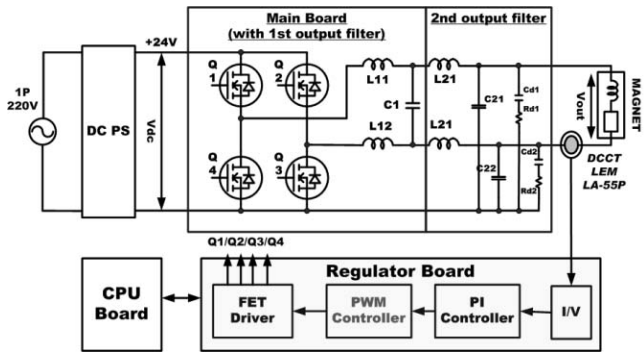

Figure 4: Circuit diagram of bipolar MPS.

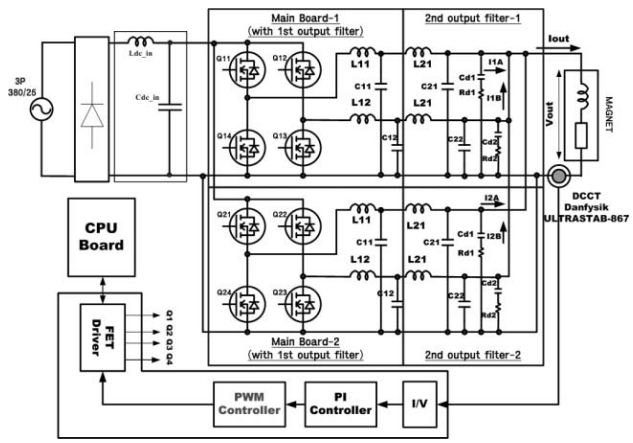

Figure 5: Circuit diagram of unipolar MPS.

CPU Board

MCF5282 Cold-Fire Processor is adopted as CPU of the MPS of the Linac. This process is the first micro-controller based on free-scale Semiconductor's 32-bit Cold-Fire core integrated with Ethernet, Flash, Rs232 and CAN. The MCF5282 was designed to simplify embedded Ethernet-networked micro-controller applications with its integrated 10/100 Mbps ethernet MAC and network-ready applications software. Therefore, the control system of the MPS can communicate through 100 Mbps ethernet.

Regulator Board

At regulator board, output current signal of DCCT converted voltage signal, and PWM signal for power conversion is generated by reference value and PI controller. MPS status also is monitored at the same time.

Main Board

A FET driver, a full-bridge 4Q DC/DC converter and 1st L-C output filter were installed on the main power board. This board is doing power conversion for magnet and filtering high frequency components of the square wave output for high stability output current. Frequency signal included in the output current is almost eliminated at 1st L-C output filter.

2nd Output Filter Board

This board include 2nd L-C output filter and R-C damping filter. Finally, frequency signal of output current is eliminated from this board.

Characteristics of Output Filter

Parameters of filter are L_1 = 128 μH, C_1 = 30 μF, L_2 = 64 μH, C_2 = 45μF, R_{damp} = 5Ω and C_{damp} = 33 μF. A dynamic signal analyser, Stanford Research SR780, were used for frequency characteristics measurement for filter and output current. Cut-off frequency of the output filter is measured about 1.5 kHz. Attenuation is more than –70 dB at 50 kHz. Therefore, frequency generated from PS is completely eliminated and clean DC current may be supplied to magnet. Figure 6 shows frequency characteristics of output filter measured from bipolar and unipolar MPS.

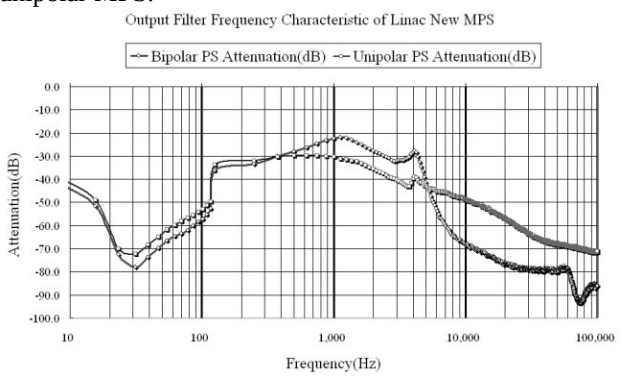

Figure 6: Frequency characteristics of the output filters.

Output Current Resolution and Stability

The measured points were output step resolution, long-term stability, and frequency characteristics that are important factors for determining PS performances. For the measurements of performance, Keithley2700 6.5digit digital multi-meter (DVM) were used. Figure 7 shows step response characteristics for 250 μA step reference of bipolar MPS. Figure 8(a) and (b) show 19-hours stability at 5 A and 10 A of bipolar and unipolar MPS, respectively. Long-term stability is keeping ±40 ppm and ±6.5 ppm during 19 hours by the bipolar and unipolar MPS.

SUMMARY

The new compact MPS with a full-bridge 4-quadrant DC/DC converter scheme has been developed for PAL Linac. In order to maintain easily, standardized PCB was used for both bipolar and unipolar mode in the power supply. Generated frequency from the power supply is perfectly eliminated by a specially designed output filter. Therefore, clean output DC current can be supplied to the magnets. Step resolution of output current is measured as 250 μA at bipolar MPS. Long-term stability is measured with ±40 ppm and ±6.5 ppm during 19 hours at bipolar and unipolar MPS. EPICS control system of MPS is also working very well through 100 Mbps ethernet.

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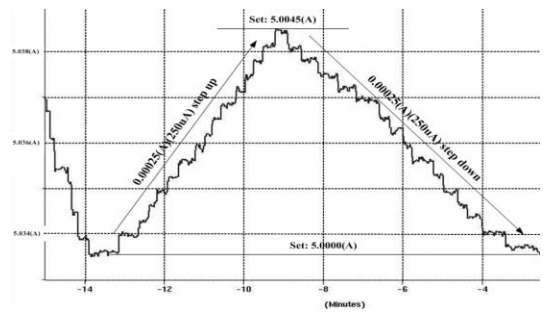
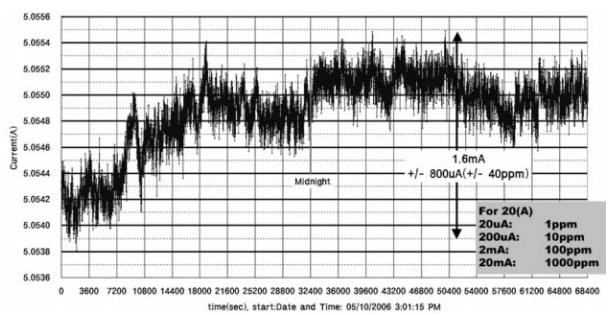
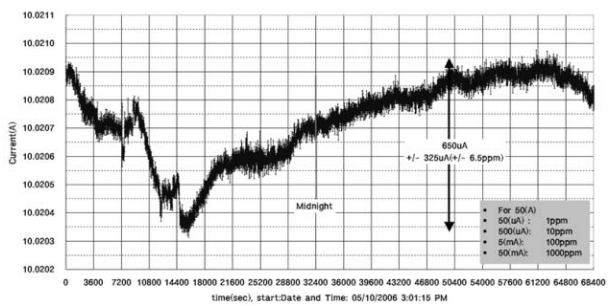


Figure 7: Output current step response of bipolar MPS.



(a) Bipolar MPS



(b) Unipolar MPS

Figure 8: Long-term stability of output current.