ANALYSIS AND COMPENSATOR DESIGN OF MAGNET CORRECTION POWER SUPPLY

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Abstract

This paper presents a new method for the analysis and design of compensators for magnet correction (MC) power supply. The system has to need controllers to satisfy required gain and phase margin specifications and compensator by adding to circuit controller and switch. The gain-phase margin tester method can transform of the controller and find solutions on the figure. According to circuit frequency response and transfer function by theory analysis and simulation design new method compensators to improved anti-disturbance and stability of the system.

INTRODUCTION

The MCOR 30 series is a multi-channel corrector magnet driver system, capable of providing precision bi-polar output currents with minimal zero-crossover distortion. The light source must keep a high precise current at operation steady state. Therefore, a number of correction magnets are required for the APS machine to correct the beam [1]. However, MCOR 30 has been limited for the frequency to be stability when valid the machine output current load. Design a compensator to observe the circuit gain margin and phase margin. MCOR 30 frequency setting at 24.5kHz and the cross frequency is 5kHz. The experiments and plots presented here are all done in Simplis software, and experiments result measurements are obtains from the various output current data.

CORRECTION POWER SUPPLY OPERATION THEORY

Figure1 has show the machine control block. The power modules are controlled using -10V to +10V analog command signals sent to different amplifier, the signal will be compare feedback signal from output current. Therefore, error amplifier can provided a PWM signal to control the switch and produce a high precision bi-polar current source. Bi-polar correction power supply equivalent circuit construction as shown Figure 2. The correction power supply regulates the DC output current by controlling the pulse width of an half bridge power N-MOSFET array. For positive output current, Q1 and Q4 switch are turn on and input energy will be charge energy and linear increase current for output load. When Q1 turn off the output current decay thought the Q4 and d3 turn on. For negative current is same to the mode [2].

Use to 4-terminal Kelvin connection Magnet shunt resistors will had been a high precision output current. These are 10 milliohm shunts have an absolute tolerance of 0.1%, it can make sure output current noise under 100uArms at the high load conditions (30A).

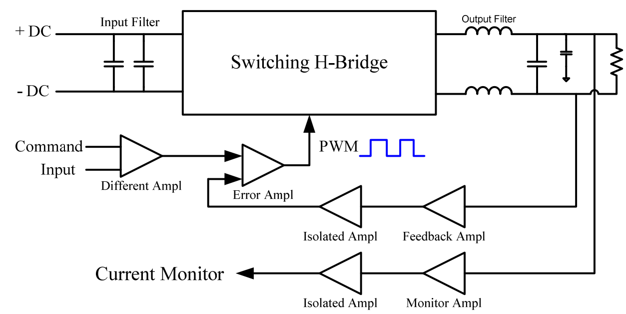

Figure 1: Correction power supply block diagram.

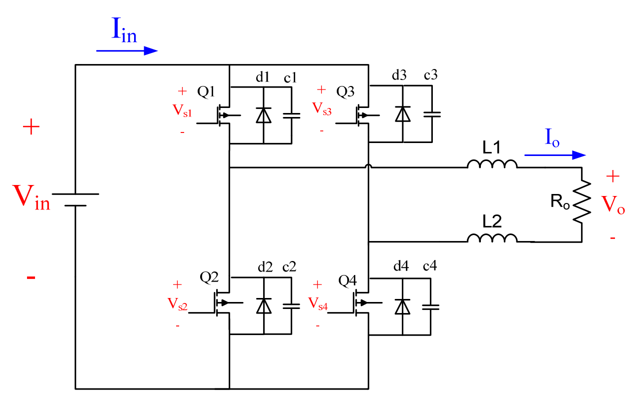

Figure 2: Correction power supply equivalent circuit.

DESIGN PROCEDURE FOR COMPENSATOR

All of the switch power supply must be design a compensator in the frequency domain generally is to satisfy specifications on steady-state accuracy and phase margin. Measurement of the system stability with frequency response is normally and easily method. The frequency response closed loop control function block as shown figure3. The feedback voltage through the output voltage divided resistance into the adder signal. Both of the feedback signal and refer voltage signal to sum, it will be compared a pulse width modulation (PWM) signal into power switch transfer with error amplifier and compensator. Closed loop control function gain margin and phase margin can be written as (1),(2). Among, ω_c is the cross frequency with correction power supply[3]~[5].

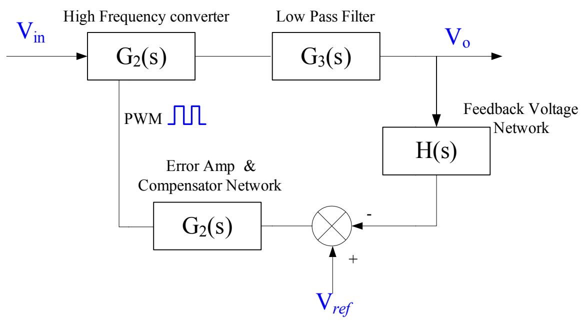

Figure 3: Correction power supply equivalent circuit.

$$\text{Gain Margin} = 20\log_{10}\frac{1}{G(j\omega_c)H(j\omega_c)} \quad (1)$$

$$\text{Phase Margin} = 360^{\circ} + \angle G(j\omega_g)H(j\omega_g) \quad (2)$$

Using to dynamic signal analysis 35670A scan 51.2Hz ~51.2kHz frequency response with correction power supply. It was gain margin and phase margin as shown figure4. The gain margin curve (upper line) initial value is 27.63dB after decay 20dB/dec, cross frequency (4.5kHz) is -6.86dB and 2.67kHz is 0dB and phase margin is 57degrees. Compensator network could be increase the gain margin and phase margin of converter power system.

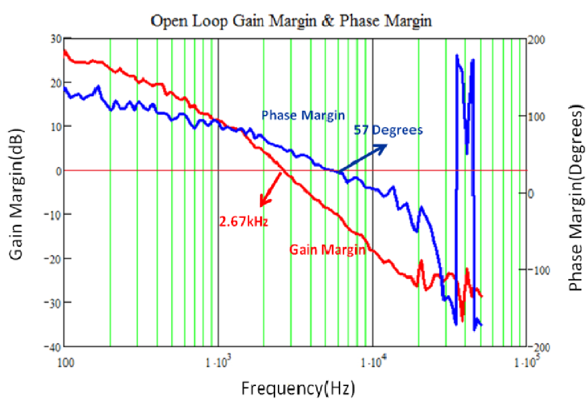

Figure 4: Open loop transfer function control to output bode plot.

Compensator network equivalent circuit as shown figure5 and transfer function can be written as (3). Therefore, we can found zero frequency $f_{z1} = \frac{1}{2\pi C_1 R_2}$, $f_{z2} = \frac{1}{2\pi C_3 R_1}$ and plot frequency $f_{p1} = f_{cross}$, $f_{p2} = \frac{1}{2\pi C_3 R_3}$, $f_{p3} = \frac{1}{2\pi C_2 R_2}$. Setting $R_1 = 5.1\text{k}\Omega$, $R_2 = 240\text{k}\Omega$, $R_3 = 360\Omega$ and $C_1 = 200\text{nF}$, $C_2 = 33\text{pF}$, $C_3 = 270\text{pF}$ .Therefore, $f_{z1} = 3.3\text{Hz}$, $f_{z2} = 115.6\text{kHz}$, f_{p1}=4.5kHz, $f_{p2} = 20\text{kHz}$, f_{p3}=1.64MHz. The compensator network experiment result waveform as shown figure6.

$$\frac{V_c(s)}{V_I(s)} = \frac{(1+SC_2R_2)(1+SC_1R_1)}{(SC_2R_1)(1+SC_1R_3)} \quad (3)$$

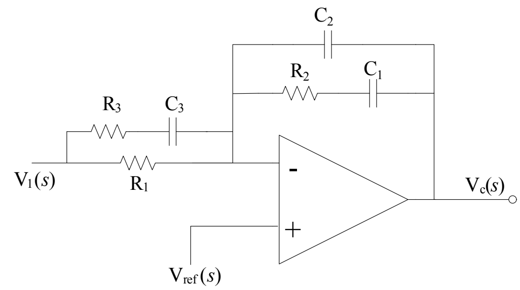

Figure 5: Compensator lead-lag equivalent circuit.

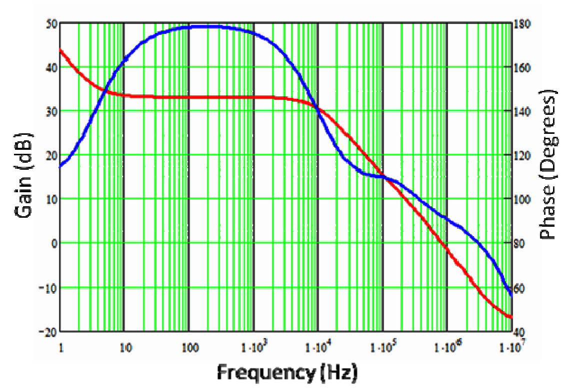

Figure 6: Simulation compensator lead-lag equivalent circuit gain margin and phase margin curve.

CONTROL LOOP TRANSFER FUNCTION AND EXPERIMENT RESULT

Additional compensator lead-lag equivalent circuit, design fc=4.5kHz and measure the power converter system can stability of a system with feedback controller. Figure7 and Figure8 to shown close loop transfer function control to output gain margin curve (upper line) initial value is 26.83dB after decay 20dB/dec, cross frequency(4.5kHz) is 0dB and control to output Phase Margin is 23.5 degrees. Compensator network could be increase the gain margin for converter power system.

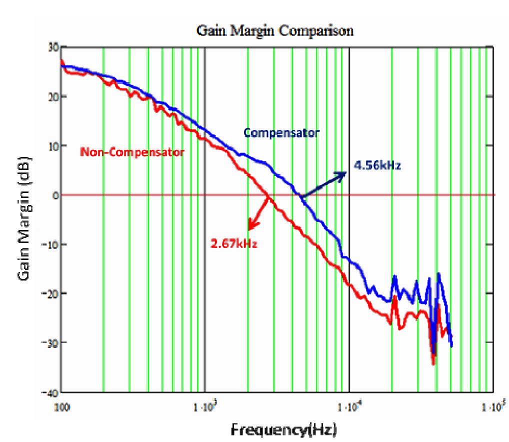

Figure 7: Open loop and close loop control to output Gain Margin bode plot.

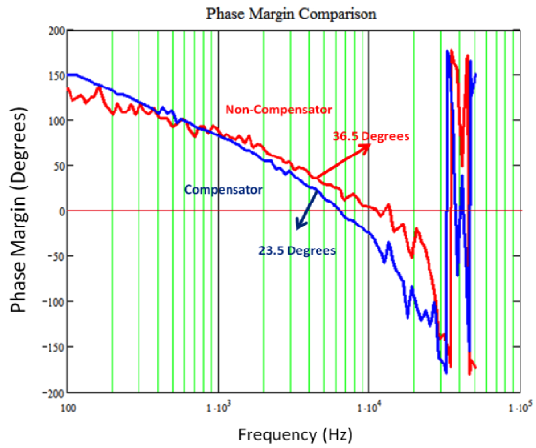

Figure 8: Open loop and close loop control to output Phase Margin bode plot.

Additional a compensator will increase system bandwidth as shown figure9, Non-compensator system initiation values is 10dB decade to 7dB at 60Hz. In other way, additional a compensator decade to 7dB at 180Hz. Bandwidth has set up 120Hz at this correction power supply.

Following the filter stage are four precision 4-terminal Kelvin connection Manganin shunt resistors. These 10 milliohm shunts have an absolute tolerance of 0.1%, and a temperature stability of 13ppm/℃ typical. Input power system to use chroma 62150H-40 and Keithley 263 calibrator source supply a high precision refer voltage to adjust the output current. Output load is a pure resistor and the value is 0.25omh. Setting input refer 10V to control block, it will produce 10A current into the load. Using to high precision multi-meter to measurement current ripple. Figure10 has shown current ripple under +-15ppm at long team testing for the correction power supply.

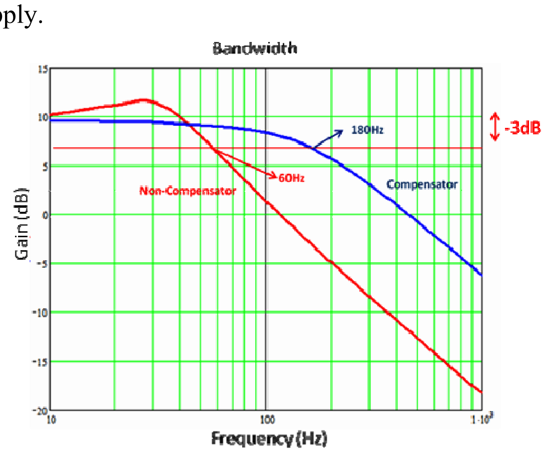

Figure 9: Compensator and non-compensator bandwidth curve.

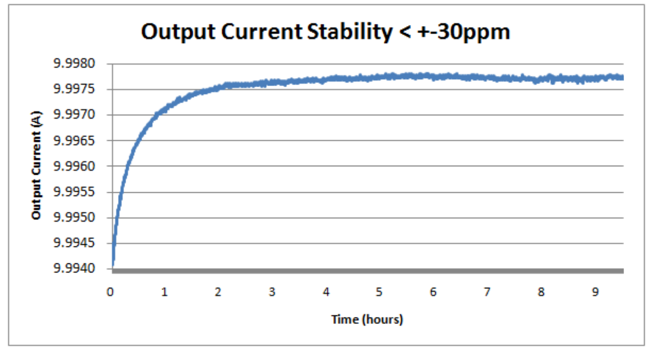

Figure 10: Correction power supply current ripple.

CONCLUSION

It is very important to design power supplies used in high precision current mode application with superconductor materials. Adjustment correction power supply compensator of bandwidth, gain and phase margin a great improvement. On the other hand, it's can product a high precision output current in source current mode.

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