IMPROVEMENT OF OUTPUT CURRENT CHARACTERISTICS FOR BIRA MCOR30 CORRECTION MAGNET POWER SUPPLY

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Abstract

The correction magnet power supplies installed at the Taiwan light source (TLS) are Bira Systems MCRO 30 power modules, a full-bridge configuration power stage converting the unregulated DC bulk power into a bi-polar current source. The MCOR 30 is theoretically regulated under a very fine control method, with this control method the Bira MCOR 30 should overcome the zero crossover distortion of a standard H-Bridge PWM schemes is used and result in a low frequency noise signature on the output when the magnet current is close to zero. The PWM control circuitry embedded in MCOR 30 theoretically but not really fulfills the purpose what the MCOR 30 want to achieve. With a home-made PWM control circuitry installed into MCOR 30, the width of real pulses can smoothly drop to zero, the MCOR 30 could output current not only with a low frequency noise signature but also with much higher bandwidth of frequency response and much lower Total Harmonic Distortion no matter what output current is demanded.

INTRODUCTION

The bipolar corrector magnet power supplies used in National synchronous radiation research center are BiRa systems MCOR 30 power modules[1]. The MCOR 30 is a modular product, designed to achieve high switching efficiency and small size, the maximum output about ± 50V / ± 30A, the output current with about 100Hz bandwidth should improve the overall speed of the electron beam orbit feedback system. The PWM control IC of MCOR 30 is a UC3856, in theory this PWM control IC is zero-crossing distortion, but in fact it is not, that results nonlinear behavior in low current output. In this paper, the IC LM555 presents a linear saw-tooth wave and combines an OP-AMP circuit to complete the full-bridge PWM control. The MCOR 30 could output current not only with a low frequency noise signature but also with much higher bandwidth of frequency response and much lower Total Harmonic Distortion no matter what output current is demanded.

THE STRUCTURE OF CORRECTOR MAGNET POWER CONVERTER

The MCOR 30 regulates the DC output current by controlling the pulse width modulation of an H-Bridge power MOSFET. This corrector magnet power converter could be roughly divided into four functional sections： Power regulation and filtering, Error amplifier, offset circuit, PWM control, Fault diagnosis, protection, monitoring and high precision current feedback system, as figure 1 shows. MCOR 30 is a full-bridge converter as figure 1 shows. The corrector power supply regulates the DC output current by controlling the pulse width of a half bridge power N-MOSFET array. For positive output current, Q1 and Q4 switch turn on and input DC source will charge energy and linear increase current to 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].

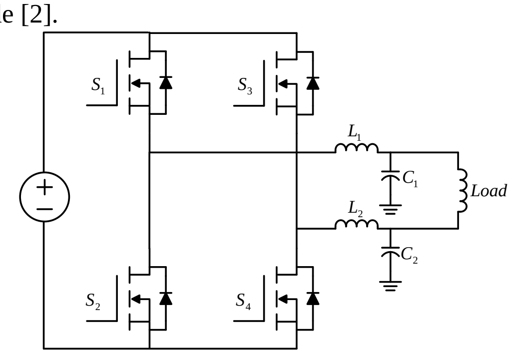

Figure 1: MCOR 30 circuit configuration.

POWER REGULATION OF MCOR 30

The MCOR 30 H-Bridge can actually be viewed as two independent buck converters, in that each bridge leg has its own independent PWM controller. Each leg of the H-Bridge can operate at an independent duty cycle, between zero and maximum duty cycle. The output voltage of each leg is unipolar, yet the output current is bipolar depends on the difference of duty cycle of each leg. Figure 2[1] shows the ideal relationship between the switching duty cycles and output of error amplifier of H-bridge PWM scheme. Positive magnet current occurs when the duty cycle of positive output leg is operated, and negative magnet current occurs when the duty cycle of negative output leg is operated.

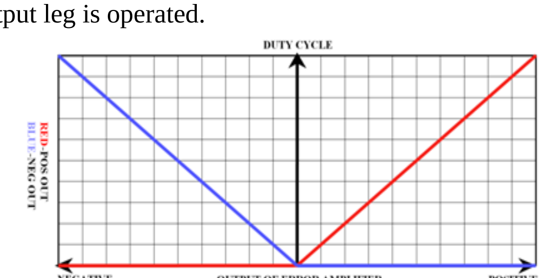

Figure 2: The ideal relationship between the switching duty cycles and the output curren.

There are two UC3856 PWM controllers embeded in the MCOR 30 power converter. So the zero crossover distortion is an important issue with standard H-Bridge

PWM schemes is adapted. Since the width of real pulses can't smoothly drop to zero, the standard PWM circuit starts 'pulse robbing' as the magnet current nears zero -- effectively dropping the switching frequency. This results in a low frequency noise signature on the output when the magnet current is close to zero. To solve this problem, the MCOR30 controls each H-Bridge leg independently, allowing the pulse width of the active MOSFETs to be a small yet controllable value as the magnet current passes through zero. Figure 3[1] shows this relationship between the switching duty cycles and the magnet current.

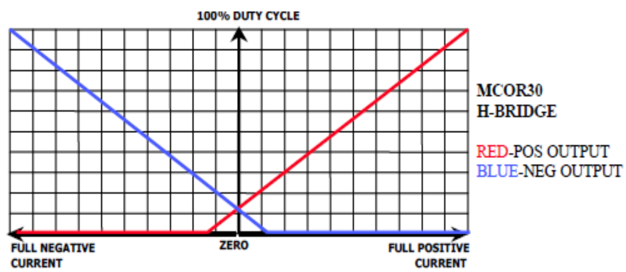

Figure 3: MCOR 30 PWM Transfer Function.

SOLUTION FOR REGULATION CONTROL OF MCOR30

Figure 4 shows the PWM controller of MCOR 30 can't achieve the transfer function (pulse width between S1 and S2 is different at 0A output) as MCOR30 designed to be. Therefore, the original two UC3856 PWM controllers of the MCOR 30 are replaced by two LM555 and an OP amplifier(figure 5). With this home-made PWM control circuitry installed into MCOR 30, the pulse width can smoothly drop to zero as shown figure 6, the MCOR 30 could output current not only with a low frequency noise signature but also much with higher bandwidth of frequency response and much lower Total Harmonic Distortion no matter what output current is demanded.

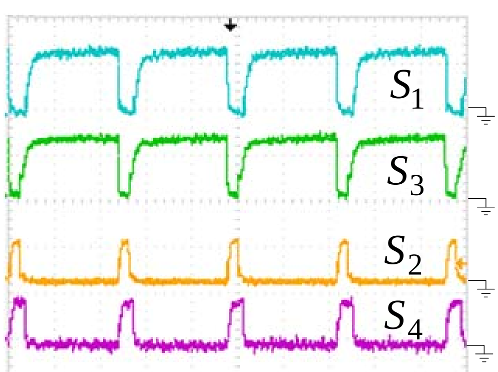

Figure 4: Duty cycle of MCOR 30 PWM controller at 0A output.

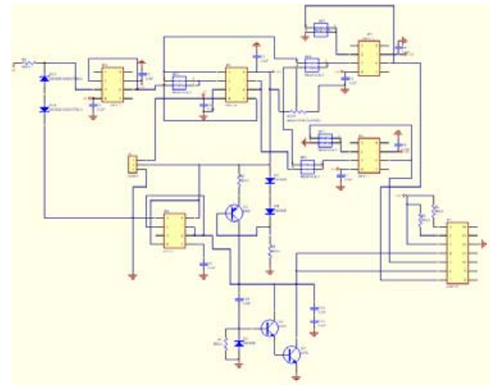

Figure 5: The home-made PWM control circuitry.

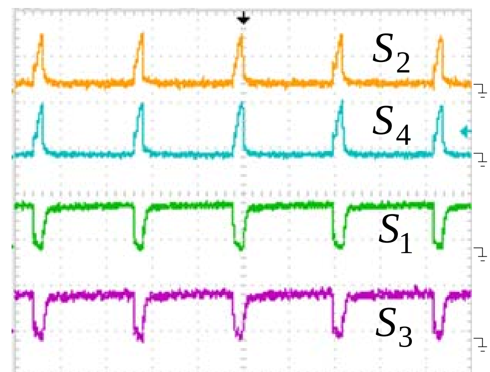

Figure 6: Duty cycle of the home-made PWM control circuitry at 0A output.

FREQUENCY RESPONSE

The goal of the corrector magnet power converter is to meet requirements to power booster ring corrector (horizontal & vertical) 、 trim coil of storage ring sextupole (include horizontal dipole 、 vertical dipole & skew quadrupole) and fast feedback corrector, so exclude high stability and low ripple of output current, the frequency response is another important parameter. Original frequency response of MCOR30 system is shown in figure 7, improvement on frequency response of MCOR 30 is shown in Figure 8.

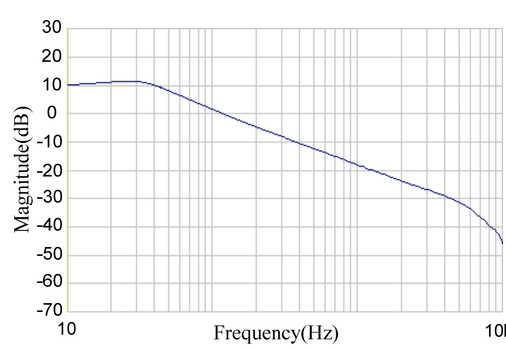

Figure 7: Frequency response of MCOR 30 before modification.

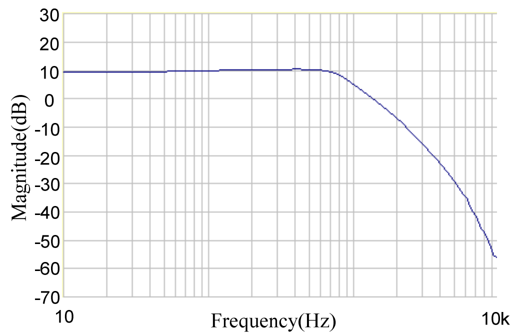

Figure 8: Frequency response of MCOR 30 after modification

THD

The HP 35670A dynamic signal analyzer provides 100mVpk 30Hz sinusoidal current reference waveform to MCOR30. Figure 9 is the output current spectrum before modification on MCOR 30, there are a lot of harmonics. Figure 10 is the output current spectrum after modification on MCOR 30, it is obvious there is almost no harmonic contents.

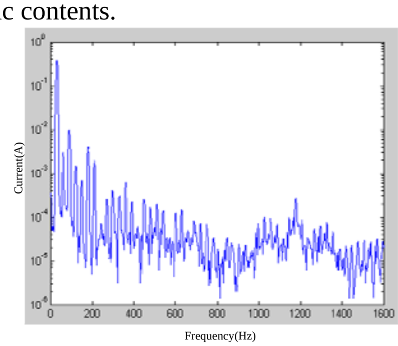

Figure9: Harmonic output current spectrum before modification.

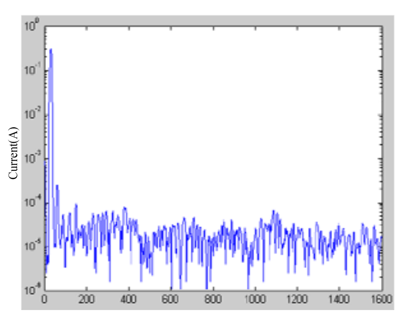

Figure10: Harmonic output current spectrum after modification.

OUTPUT CURRENT SPECTRUM

The PWM control IC of MCOR30 is a UC3856, in theory this PWM control IC is zero-crossing distortion, but in fact it is not, that results nonlinear behavior in low duty cycle. The IC LM555 presents a linear saw-tooth wave and combines an OP-AMP circuit to complete the full-bridge PWM control. Figure 11 is the output current spectrum of original MCOR30 corrector magnet power converter. Figure 12 is the output current spectrum of MCOR30 corrector magnet power converter after modification on the PWM controller.

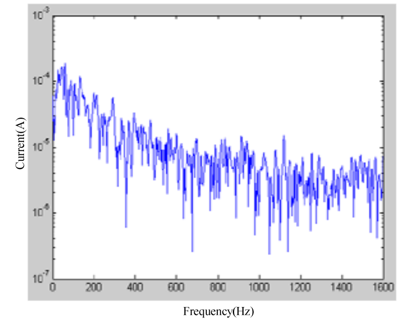

Figure11: MCOR 30 Output current spectrum.

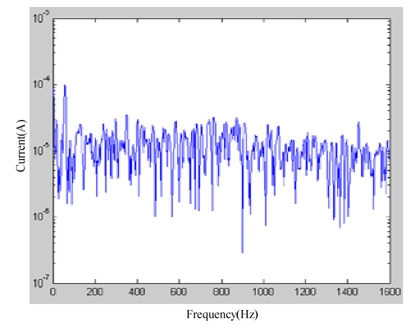

Figure12: MCOR 30 Output current spectrum after modification on the PWM controller.

CONCLUSION

With a home-made PWM control circuitry installed into MCOR30, the pulse width can smoothly drop to zero, the MCOR30 could output current not only with a low frequency noise signature but also much with higher bandwidth of frequency response and much lower Total Harmonic Distortion no matter what output current is demanded. So with the modified MCOR30 for the TLS storage ring magnet power supply, there will be a very positive help.

REFERENCES

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[2] Sandeep Babel, Stanley Cohen, BiRa Systems and Albuquerque, "Digital Control Interface for Bipolar Corrector Power Supplies for LCLS", *APEC.*, pp428-430, 2007.

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