TPS CORRECTOR MAGNET POWER CONVERTER

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Abstract

Based on the requirement of beam stability for the third-generation synchrotron radiation light source is more stringent, lower ripple and higher bandwidth of output current of corrector magnet power converters should be developed to implement the closed orbit correction of Taiwan Photo Source (TPS). The ±10A/±50V corrector magnet power converter uses a full bridge configuration, the switching frequency of power MOSFET is 40 kHz, in that each bridge leg has its own independent PWM controller and the output current bandwidth is 1.5 kHz when connected with the corrector magnet load. Using a DCCT as the current feedback component the output current ripple of this converter could be lower than 5 ppm. In this paper, we will describe the hardware structure and control method of the corrector magnet power converter and the test results will be demonstrated.

INTRODUCTION

With the increasing demand of the high performance current output of corrector power converter for the TPS(Taiwan Photon Source) project, power supply group of NSRRC corporate with Center for Measurement Standards of Industrial Technology Research Institute (CMS, ITRI) to construct a new high performance small current power converter. The goal is not only to provide high performance power converters for corrector magnets of the future storage and booster ring of TPS, but also to reduce the maintenance labor and fee due to outsourcing.

This paper focuses on the design of a new type high performance low current corrector magnet power converter. The overall system can be divided into four functional sections：Power regulation and filtering, Error amplifier / offset circuit / PWM control, Fault diagnosis / protection / monitoring and high precision current feedback circuit. In the power converter, PWM controllers are driven by an offset circuit, with this offset circuit the non-linear performance of PWM control IC which results in low frequency output noise when the duty cycle is close to zero is well improved. Also with the Fault diagnosis / protection / monitoring circuit design, the system is capable of reading back not only the status for fault detection but also the real-time temperature values of temperature monitors on key components. Concerning the requirement of low ripple and high stability on output current, the Danfysik Ultrastab 866-20I DCCT is adopted as the current feedback senor. As a result, the output current performance of the power converter is greatly enhanced and meets the future need of TPS project.

THE STRUCTURE OF CORRECTOR MAGNET POWER CONVERTER

The 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 circuitry. The structure of corrector power converter is shown in figure 1.

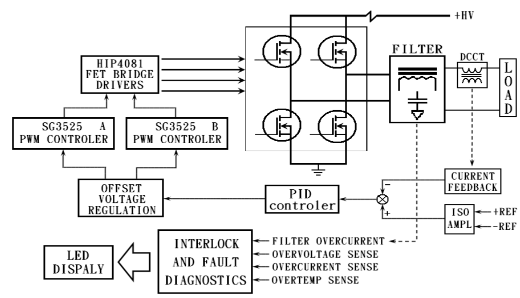

Figure 1: The structure of corrector power converter.

Power Regulation

The corrector power converter regulates the output current by controlling the pulse width of an H-Bridge power MOSFETs. The switching frequency is 40kHz. The H-Bridge shown in Figure 1 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 0 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 shows the ideal relationship between the switching duty cycles and output of error amplifier with H-Bridge PWM scheme.

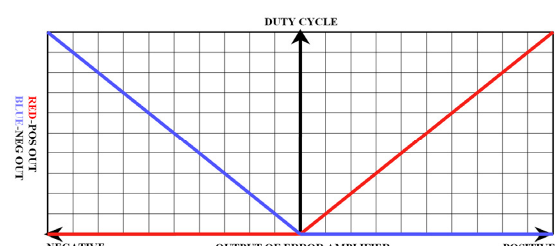

Figure 2: The ideal relationship between the switching duty cycles and the output current

Ideally, 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.

PWM CONTROLLER WITHOUT AN OFFSET CIRCUIT

The PWM controllers used in the corrector magnet power converter is two SG3525A[1] PWM controllers, the PWM comparator input threshold of SG3525A for zero duty cycle is 0.9V, and maximum duty cycle is 3.3V. It seems SG3525A hard to reach zero duty cycle, instead, there is a duty cycle jump when the PWM comparator input around 0.9V. Based on this input threshold parameter, the real relationship between the switching duty cycles and the output of error amplifier is shown as figure 3.

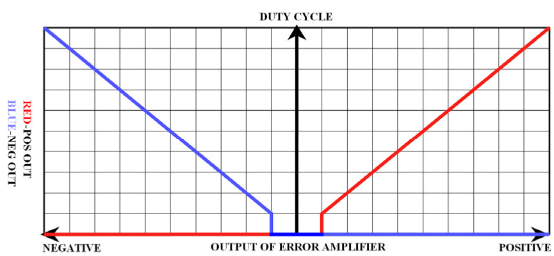

Figure 3: The real relationship between the switching duty cycles and the output of error amplifier

There is a large swim on output of error amplifier to control the duty cycles of two SG3525A PWM controllers when the corrector magnet power converter output a small current and that result in a very noisy spectrum on the output current as figure 4 shows.

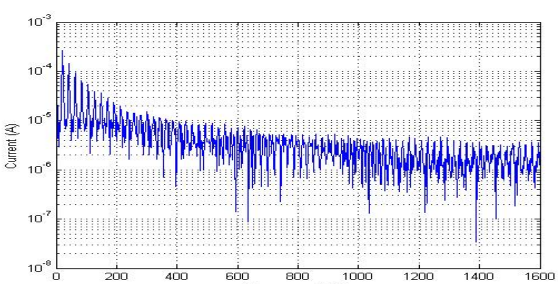

Figure 4: Output current spectrum of corrector magnet power converter, PWM controller without an offset circuit.

PWM CONTROLLER WITH AN OFFSET CIRCUIT

To solve this problem, there is an offset circuit inserted between error amplifier and two SG3525A PWM controllers allowing two SG3525A PWM controllers output constant duty cycle when zero current is demanded. Figure 5 shows this relationship between the switching duty cycles and the output of error amplifier, figure 6 shows the output current spectrum of corrector magnet power converter when there is an offset circuit inserted between the error amplifier and two PWM controllers.

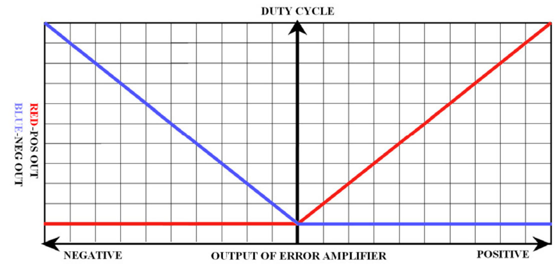

Figure 5: The relationship between the switching duty cycles and the output of error amplifier

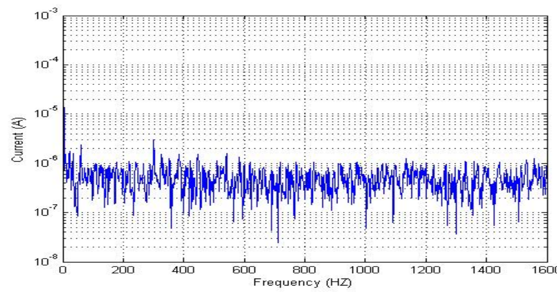

Figure 6: Output current spectrum of corrector power converter, PWM controller with offset circuit.

It is very obvious that the output current spectrum of corrector magnet power converter is well improven, the total ripple current intregated from 0 Hz~1 kHz is about 20uA that is 2ppm for ±10A maximum current output of corrector magnet power converter. Figure 7 is the offset circuit used to drive two SG3525A PWM controllers.

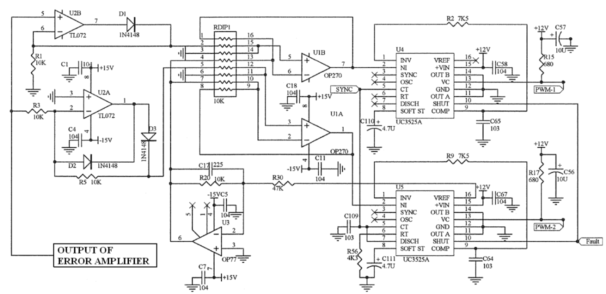

Figure 7: The offset circuit for two SG3525A PWM controllers.

HIGH PRECISION CURRENT FEEDBACK SYSTEM

Low ripple, high stability and accuracy output current are the requirements of the corrector magnet power converter. The key component of the corrector magnet power converter to meet requirements is the current sensor. Here we adapt the Danfysik Ultrastab 866-20I DCCT[2] (figure 8) as the current feedback element. The current transfer ratio of Danfysik Ultrastab 866-20I

DCCT is 250, in current feedback circuit there is a 25Ω burden resister in series with the output of DCCT and voltage signal on burden resister is amplified 10 times then fed into error amplifier to compare with current reference signal.

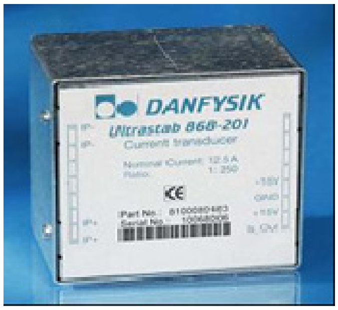

Figure 8: Danfysik Ultrastab 866-20I DCCT.

Figure 9 shows the output current stability within 15 hours of the corrector magnet power converter, and the stability is within 5ppm.

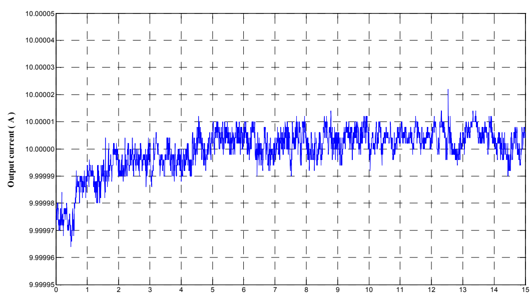

Figure 9: Stability of output current of the corrector magnet power converter within 15 hours

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. With suitable tuning on PI's value of error amplifier the frequency response bandwidth of the corrector magnet power converter is about 1.5 kHz, figure 10.

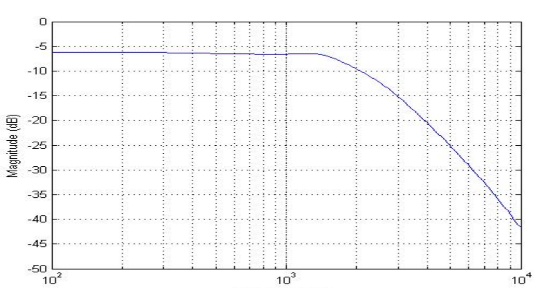

Figure 10: The frequency response of the corrector magnet power converter.

FAULT DIAGNOSIS, PROTECTION, MONITORING

The corrector magnet power converter provides four monitor signals and eight fault protections. Four monitor signals include output current, output voltage, temperature of MOSFET and temperature of power converter module, seven fault protections include output over-current, output over-voltage, input under-voltage, PWM controller input under-voltage, MOSFET over-temperature and two damping resisters of output filter over-temperature.

With these four monitor signals and seven faulty protections, the corrector magnet power converter could be easily remote monitoring and fault diagnosis. Figure 11 is the picture of corrector magnet power converter.

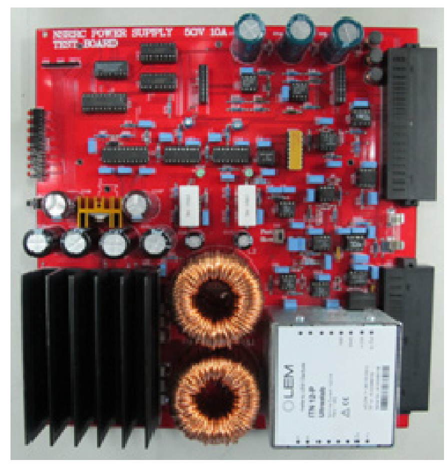

Figure 11: The picture of corrector magnet power converter.

CONCLUSION

With corporation between power supply group of NSRRC and Center for Measurement Standards of Industrial Technology Research Institute (CMS, ITRI), a new high performance corrector magnet power converter is fulfilled.

This corrector magnet power converter could output current with 5PPM stability within 15 hours, 20uA ripple (0~1kHz) and 1.5kHz high frequency response bandwidth. This corrector magnet power converter is versatile to meet any kind of requirements for magnets to be powered within ±10 amperes that include booster ring corrector (horizontal & vertical), trim coil of storage ring sextupole (include horizontal dipole, vertical dipole & skew quadrupole) and fast feedback corrector. By using this power converter to power all kinds of corrector magnets could save a lot of work in maintenance and quantity of spare parts is minimized.

REFERENCES

[1] SG3525A datasheet, Linear Technology
[2] Danfysik Ultrastab 866-20I, http://www.danfysikacp.com