DEVELOPMENT OF DIGITAL CONTROLLED CORRECTOR MAGNET POWER CONVERTER WITH A SHUNT AS A CURRENT SENSING COMPONENT

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Abstract

In Taiwan light source (TLS), Bira's MCOR30 power converter modules are adopted as the corrector magnet power converters, the output is regulated by analog PWM IC that caused nonlinear behavior at zero cross and the adjustment of compensator for different kind of magnet load is inconvenient. To fulfill digital regulation control, the analog regulation IC of Bira's MCOR30 is replaced by a fully digital regulation control circuit. With plugging the homemade fully digital regulation control card into MCOR30 that the current sensing component is a shunt that save cost of the power converter, the switching losses and output current ripple were reduced and stability of output current is improved. With the fully digital regulation control circuit, the parameters of the compensator for different magnet load are very easy to adjust.

In addition, the feasibility and validity of MOSFET switching algorism is simulated with Matlab simulink and the performance of this power converter is verified, the output current ripple of this power converter could be within 10ppm, which is beyond the requirement of current TLS corrector power converter and qualified to be used in the future TPS facility.

INTRODUCTION

In TLS the corrector magnet power converters under operation are Bira's MCOR30As, the output current be haves nonlinearly at zero cross with analog regulation control loop inside. The original PWM regulation circuit of MOSFET is replaced by the fully digital regulation control card. The PWM regulation of DSP adopted flexibly control method for better performance of output current and the switching power loss of MOSFET is reduced. The development of this DSP-based digital regulation control card of TLS's storage corrector magnet power converters is based on the framework of Bira's MCOR30A converter with a shunt as a current sensing component that could reduce the cost to fulfill the fully digital regulation control. [1,2]

Matlab simulink is used to simulate the characteristic of the full bridge construction, the function of compensator and the PWM regulation algorism, and the accuracy of the control policy is confirmed.

With the full bridge power stage construction of MCOR30A as the platform, the original analog regulation control loop circuit is replaced with a homemade digital regulation control circuit board, includes Texas Instruments DSP, ADC and gate drives of MOSFETs, the digital regulation control is implemented and the output current ripple is well controlled within ±10ppm that satisfies the specification requirement of TPS corrector magnet power supply.

THE STRUCTURE OF CORRECTOR MAGNET POWER CONVERTER

The corrector magnet power converter could be roughly divided into five functional sections: Power regulation and L-C filter / high resolution ADS8382 18-bitsanalogytodigital converter / high performance DSP TMS320F28335 controller, USB, JTAG, RS232, and Ethernet transmission interface, as shown at figure 1.

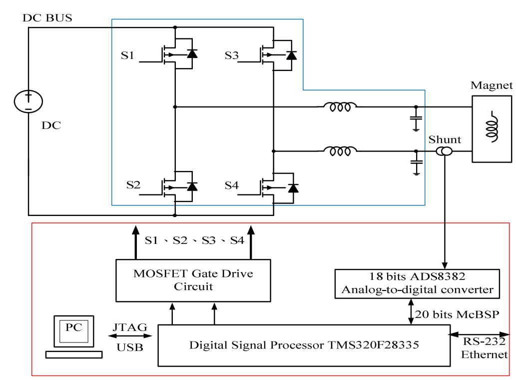

Figure 1: The structure of corrector magnet power converter.

PWM REGULATION METHOD

The PWM switching regulation method was programmed inside of DSP controller and DSP could output two kinds of switching pattern, the first one is one arm switching pattern, reduces switching power loss and with a better efficiency; the second one is the pair arms switching pattern, which improves the nonlinear behaviour of power converter at zero cross. Both figure 2(a) and figure 2(b) are operation positive current modes, figure 2(a) is one arm switching pattern and figure 2(b) is the pair arms switching pattern. The switching pattern of positive output current PWM regulation is shown in table1, which D_π is delay angle of duty cycle regulation.

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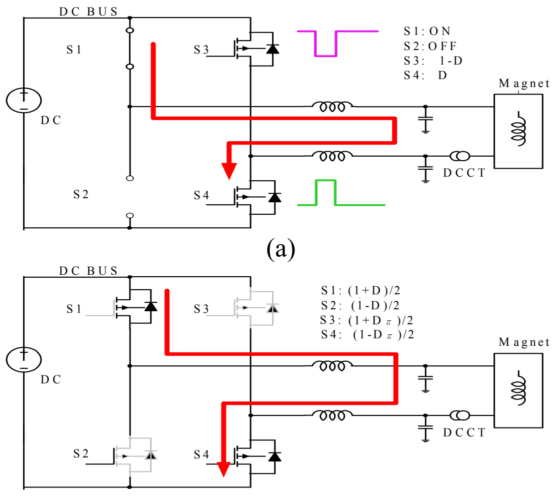


(a)

(b)

Figure 2: The operation of switching pattern (a) one arm (b) pair arms.

Table 1: The Switch Pattern of PWM Regulation

MOSFET switch	One arm method		pair arm method	
Output pole	(+)	(-)	(+)	(-)
S1	High	Low	(1+D)/2	(1-D)/2
S2	Low	High	(1-D)/2	(1+D)/2
S3	1-D	D	$(1-D_{\pi})/2$	$(1+D_{\pi})/2$
S4	D	1-D	$(1+D_{\pi})/2$	$(1-D_{\pi})/2$

DIGITAL CONTROL CARD DESIGN

The digital signal processor, high resolution analog to digital converter and voltage signal transfer converter are embedded into the digital control card. The program code of DSP includes the interruptive event, A/D timing, compensation, digital filtering, and the PWM switching arm regulation method. The ADS8382EVM card is adopted as the high resolution analog to digital converter and the shunt signal of Bira's MCOR30A is transferred to digital value. The TTL signals of DSP were level transferred by a voltage transfer converter to drive MOSFET. The picture of digital control card is shown in Fig. 3.

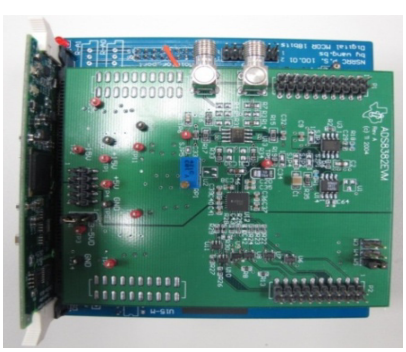
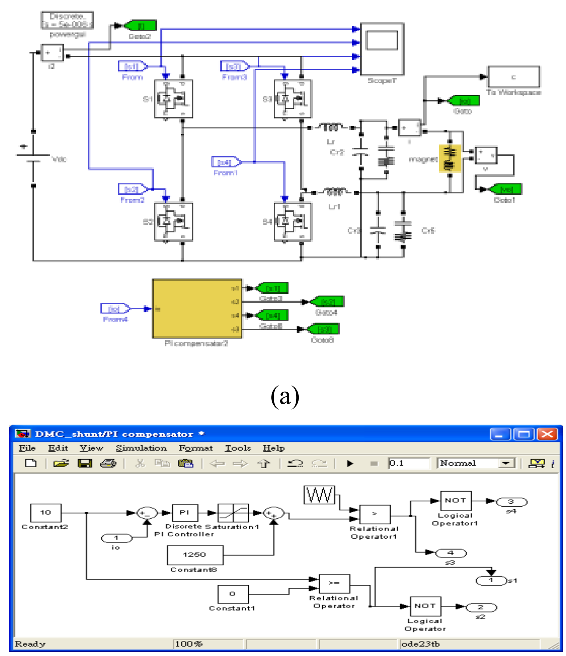


Figure 3: The picture of digital control card.

MATLAB SIMULINK

To confirm the accuracy of the control policy that applied in the digital regulation control circuitry, the characteristic of circuitry, the P-I compensator and the PWM regulation algorism are simulated with MATLAB SIMULINK. Figure 4(a) is the diagram of power converter circuit for simulation, this diagram includes the full bridge power stage, he output L-C filter, the P-I compensator and PWM regulation block.

Figure 4(b) is the block diagram of P-I compensator and PWM regulation, P-I compensator will generate an error signal, proportional to the difference between current command and current feedback signal, and import into the comparator to compare with the triangle carrier and the PWM signal would be generated to drive MOSFETs.



(a)

(b)

Figure 4: Simulation diagram (a) power converter scheme (b) internal block of compensator.

EXPERIMENTAL RESULT

The function of the digital regulation power converter is well simulated but the real performance should be tested, the PWM arm regulation and nonlinearity of output current at zero cross and output power for the different arm PWM regulation method and spectrum analysis of output current and long-term stability are measured in this experiment.

The PWM waveform of one arm regulation method for power converter at the positive output current is shown in the figure 5.The zero cross response of output current are shown in the figure 6.The voltage command was adjusted from -0.006 to 0.006 volt with a step of 0.0004 volt.

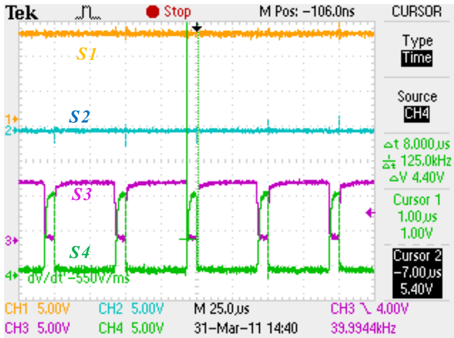


Figure 5: The PWM waveform of one arm regulation.

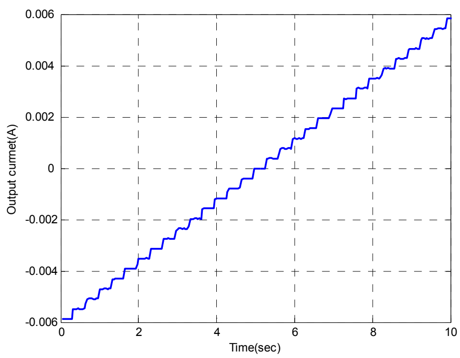


Figure 6: The zero cross of output current.

The power converter is operated at two different PWM regulation algorisms, one is one arm method and the other is pair arms method, and the relation between input power and output current of power converter is measured and shown in figure 7. It is clear that the switching loss is less with one arm PWM regulation method is adopted.

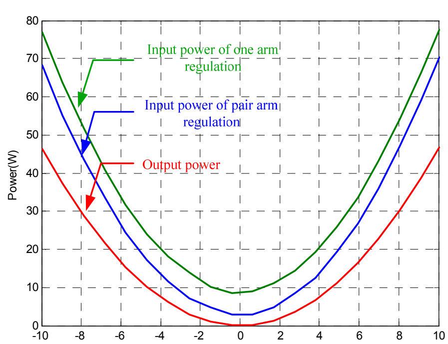


Figure 7: Input and output of power converter.

The power converter was set to output 10 amperes, spectrum and long-time drift of output current were measured. Figure 8 shows the output current spectrum of corrector magnet power converter.The output current drift of the corrector magnet power converter within 8 hours is shown at figure 9, and the stability is within 10ppm.

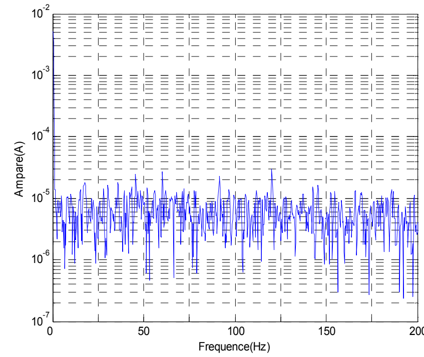


Figure 8: Output current spectrum of corrector magnet power converter.

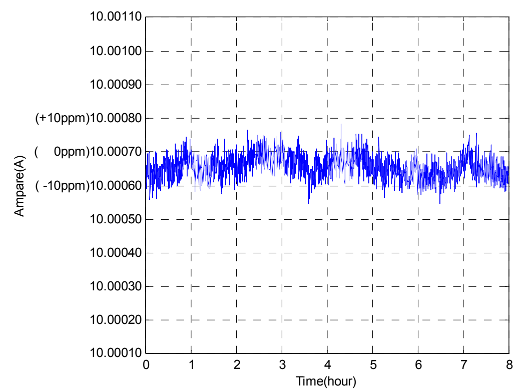


Figure 9: Stability of output current of the corrector magnet power converter within 8 hours.

CONCLUSION

Bira's MCOR30 as the TLS's corrector magnet power supply is upgraded with plugging a digital control card and fully digital regulation control is fulfilled. There are some advantages for the digital control card, such as low cost, improvement on the nonlinear output current at zero cross and convenience to adjust compensator. The output current ripple of the fully digital controlled corrector magnet power converter is within ±50uA, and long-term stability is within ±10ppm. This digital regulation control card is designed by power supply group but there are some functions should be added. In the future, temperature compensation and the protection circuit will be integrated into the power converter for system stability and easy to control.

REFERENCES

[1] William J. Palm III,"MATLAB for Engineering Applicatons", McGraw-Hill,Inc, 1999.

[2] MS320F283xDSP Technical Reference, http://www.ti.com.

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