HIGH OUTPUT CURRENT STABILITY OF POWER SUPPLY

Kuo-Bin Liu and Jeng-Tzong Sheu
Synchrotron Radiation Research Center
No. 1 R&D Road VI, Hsinchu Science-based Industrial Park, Hsinchu 30077, Taiwan R.O.C.

Abstract

Correction magnets of synchrotron storage ring are served with linear power supplies (correction power supply) with ±100 ppm long-term stability in Synchrotron Radiation Research Center (SRRC). Low efficiency of linear power supply would increase the temperature inside of rack of power supply such that current stability is difficult to maintain because devices of control circuitry are thermally sensitive. Keeping devices of control circuitry inside of constant temperature environment is straightforward but needs lots of electronic and mechanic works. Instead, devices with low temperature coefficient were used, and it is independent to the efficiency of linear power supply. With this technology, correction power supplies have been modified and ±50 ppm long-term current stability has been reached.

1 INTRODUCTION

In original, the long-term output current stability of power supply served for correction magnet at Synchrotron Radiation Research Center (SRRC) is ±1000 ppm, and the stability is improved to be ±100 ppm[1] after replacement of current feedback shunt with lower temperature coefficient.

The parameter of electronic device is thermally dependent, the temperature inside of rack of power supply will rise while power supply is in operation so output of devices of control circuitry will not keep stable and there is not good stability of output current. To keep devices of control circuitry of power supply in a temperature controlled environment is straightforward and is the best way to achieve high output current stability, but it needs lots of electronic and mechanic works and power supply is almost re-designed.

In this experiment, two ways were used to try to achieve higher long-term stability of output current of correction power supply. The first one is to replace original devices of control circuitry of correction power supply with lower temperature coefficient components. The second method is to increase the efficiency of correction power supply that will not let the temperature inside of rack of power supply rise so much and performance of devices of control circuitry may keep more stable.

There are several devices of control circuitry and each one of them makes different contribution on stability of output current of correction power supply, so measurement will be demonstrated for any replacement of device. Efficiency and power factor of power supply are improved by modification of circuitry of input power stage of correction power supply, performance and influence on long-term stability of output current of power supply will be discussed.

2 REFERENCE INPUT STAGE

The control interface of correction power supply is digital interface, current control and read-back are analog signals. Because current control crate and correction power supply are separated by a long distance so that ground loop between these two systems exists. Ground loop at times can be a source of noise, if the magnitude of noise is too large such that circuit operation is affected the performance of power supply degrade. The effect of ground loop can be eliminated or at least minimized by isolating the two circuits, isolation can be achieved by transformer, common mode choke, optical coupler, balanced circuitry, frequency selective grounding or isolation amplifier.

There are two current control reference input stages for correction power supply, remote control state and local control state. In normal remote control state the only concern is the long-term stability of power supply. The circuitry used as remote current control analog input stage is isolation amplifier BURR-BROWN ISO120BG[2]. The performance of isolation of BURR-BROWN ISO120BG is undoubted, but the temperature coefficient (include gain•input offset voltage•…etc.) seems too large such that better long-term current stability is impossible. Figure 1 shows the temperature effects on BURR-BROWN ISO120BG with respect to time.

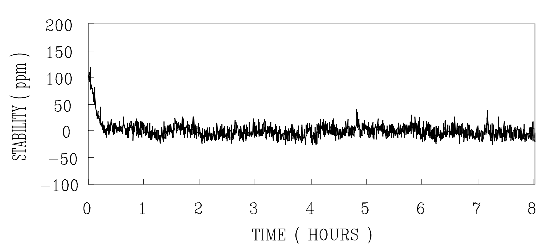


Figure 1: Original long-term stability of output current

Instead of isolation amplifier, the local reference input stage of correction power supply is a differential amplifier composed of four resistors and an OP177. As stated above, a differential amplifier is also able to eliminate or minimize the effect of ground loop. Furthermore, the temperature coefficient of OP177 is much lower than that of BURR-BROWN ISO120BG and the differential amplifier could be used in the reference input stage of correction power supply by changing some wiring. Long-term stability of output current of correction power supply is improved as figure 2 after OP177 was introduced.

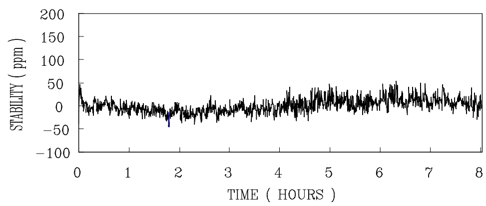


Figure 2 : Long-term stability of output current after modification of reference input stage

Improvement is obvious especially at start-up time. There is no need of warm-up time for output current of correction power supply to get into stabilization.

3 INSTRUMENTATION AMPLIFIER OF CURRENT FEEDBACK

The original instrumentation amplifier served for current feedback loop is BURR-BROWN INA110BG[2] and there is a pin to pin compatible instrumentation amplifier AD624CD. The differences between these two devices concerned about in this experiment are temperature coefficient of parameters. In the worst case, the temperature coefficient of parameters of AD624CD[3] are lower than that of BURR-BROWN INA110BG. Figure 3 shows the performance of correction power supply after usage of AD624CD as instrumentation amplifier of current feedback loop.

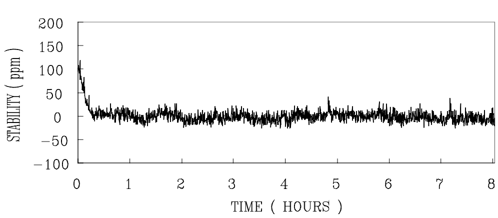


Figure 3 : Long-term stability of output current after replacement of instrumentation amplifier of current feedback

Long-term stability seems to be better after about 20 minutes warm-up time and stability in a short period is also improved. But it takes longer time to get into stabilization. Factors that dominate this phenomenon there should dealt with care for shortening the warm-up time.

The gain setting of AD624CD and BURR-BROWN INA110BG can be achieved through series and parallel combination of the internal resisters. Instead of setting gain by internal resisters there is a character of AD624CD that BURR-BROWN INA110BG do not has, the gain setting of AD624CD could be set by a external resistor.

The temperature coefficient of internal gain setting resistors of AD624CD are –15ppm/•. Instead of using internal resisters, a 5ppm/• resistor is used to set the gain of AD624CD to 100. Long-term stability and warm-up time of correction power supply as shown in figure 4 obviously improved as compared to that of figure 3.

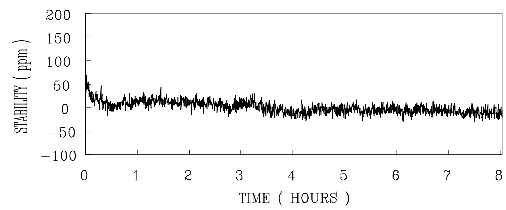


Figure 4 : Long-term stability of output current after gain setting resistor of instrumentation amplifier of current feedback is replaced by external resistor

4 REFERENCE INPUT STAGE WITH MORE BALANCED CIRCUITRY

As stated above, the long-term stability of output current of correction power supply is improved after usage of a differential amplifier made by four resistors and a OP177 as the remote current control analog input stage. But these four resistors are individual components and not well match trimmed, the temperature coefficient of gain of this differential amplifier is unknown.

The AMP-03[3] is a monolithic unity-gain, high-speed differential amplifier. Incorporating a matched thin-film resistor network, the AMP-03 features stable operation and high common mode rejection ratio over temperature without requiring expensive external matched components. Based upon features of AMP-03, it seems a good substitute for the differential amplifier made by four resistors and OP177 and figure 5 is the long-term stability of output current of correction power supply after the usage of AMP-03 as the remote current control analog input stage.

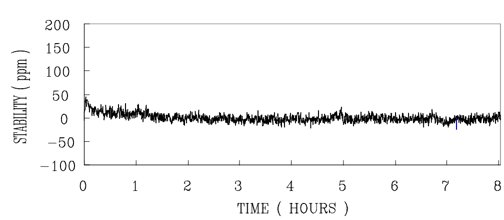
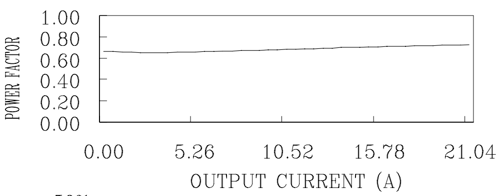


Figure 5 : Long-term stability of output current after more balanced circuitry is used in reference input stage

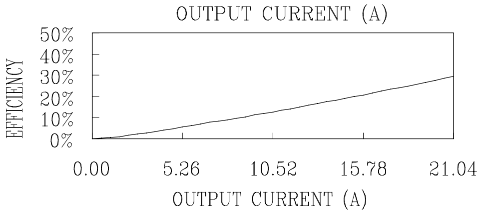
As shown in figure 5, the long-term stability is under 50 ppm from start-up to turn-off of correction power supply, after about 5 minutes warm-up time ±20 ppm long-term stability is achieved and stability in a short period is also improved.

5 EFFICIENCY

High stability output current of correction power supply has been reached after less thermal sensitive devices were used on control circuitry and the result almost make sure temperature rising is a main cause to output current drift of correction power supply. Correction power supplies used at SRRC are linear mode, low efficiency is inevitable and figure 6 shows the power factor and system efficiency under different current output.



(a)

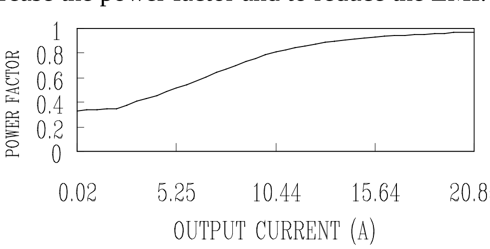


(b)

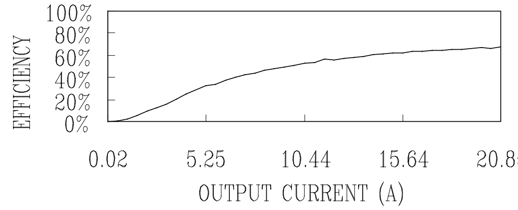
Figure 6(a) power factor V.S. output current
6(b) efficiency V.S. output current

The efficiency of correction power supply depends on output current of correction power supply, and the best is under 30%. Small portion of power is delivered to load under normal operation. Most of power lost would transfer into heat and rise temperature inside of rack of correction power supply. Improvement of efficiency of correction power supply could save power and the temperature inside of rack of correction power supply may not rise too much such that stability of control circuitry is obtained.

Insertion of a pre-regulator controlled by constant R_{DS} control strategy in series in front of power stage could highly increase the efficiency of correction power supply[4]. This pre-regulator is a switching mode DC-DC converter VICOR V375A24C600A with characteristics of low power factor and high EMI. Before it really application, there are power factor corrector module and EMI filter in series in front of VICOR V375A24C600A[5] to increase the power factor and to reduce the EMI.



(a)



(b)

Figure 7(a) power factor V.S. output current
7(b) efficiency V.S. output current

Figure 7a and 7b show power factor and efficiency of correction power supply after efficiency improvement respectively. Comparing figure 6b and figure 7b, efficiency is improved at least 2 times at 20A maximum current output. Although the heat rising in the cabin is reduced by efficiency improvement, the long-term stability remain the same as that of figure 5. This means the long-term stability of correction power supply is now dominated by temperature insensitive factors.

6 CONCLUSION

The long-term stability of correction power supply used at SRRC is improved by the usage of low temperature coefficient components that include reference input stage and instrumentation amplifier of current feedback and there is obvious contribution for every component. The efficiency of correction power supply is also improved by insertion of a pre-regulator controlled by constant R_{DS} control strategy in series in front of power stage. Temperature rising problem inside of rack of correction power supply was stabilized. More stable performance of correction power supply is expected if other temperature insensitive factors are further improved. Power factor correction module and EMI filter were inserted in front of pre-regulator to improve power factor and eliminate EMI on power line.

REFERENCES

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