TRACKING TESTS FOR THE SNS FAST INJECTION BUMP POWER SUPPLY*

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Abstract

The tracking requirement of the SNS Fast Injection Bump power supplies is described. In addition to the usual tracking between the load current and the input reference of a power supply, these power supplies must also track between pairs of units under slightly different loads. This paper describes the use of a current-null test to measure tracking performances. For the actual tests, a single dummy magnet load was used to measure the tracking between the first two production units at the manufacturer's facility. Using the Yokogawa WE7000 PC-based measurement instrument, input and output waveforms are digitized and stored in data files. A program written for this application is then used to extract data from these files to construct, analyze the waveforms and characterize the power supply performance. Results of the measurements of two SNS Fast Injection Bump power supplies will be presented in this paper.

INTRODUCTION

The SNS Fast Injection Bump switch mode power supplies are pulsed current-regulated. In order to meet current tracking and current ripple requirements, the supply has an outer current loop bandwidth of about 2 kHz and an inner voltage loop bandwidth of 100 kHz. These two quadrant power supplies are peak rated at 1.12 MVA, +1400A, and +/-800V[1].

Two reference functions are used for testing the tracking performance of the power supplies. Both waveforms have the same rise and flat top of 2 millisec and 1 millisec respectively. The fall time, on the other hand, is 1 millisec for one and 250 microsec for the other. Within the pulse duration, besides the basic requirement of having the load current of individual power supply tracked the reference, load currents of pairs of power supplies must also track. In this case, because of the complex tasks involved in verifying tracking performance, a test system has been developed to gather, process, and analyze test data.

BASIC TEST SYSTEM

Figures 1 and 2 show the conceptual tracking tests based on signal-null.

For the reference vs. current tracking test, a WFG (Waveform Generator) feeds a pulse to the power supply and a programmable delay circuit. Signal picked up by the current detector is subtracted from a time-delayed version of the reference pulse to generate a tracking error waveform.

For the dual supplies tracking test, the WFG feeds both power supplies. In this case, signals from two current detectors are subtracted from one another to get the error waveform.

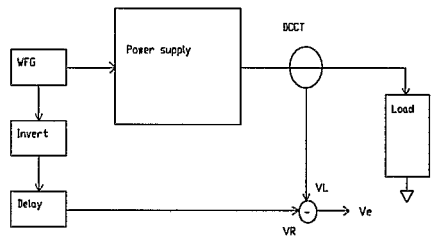

Fig. 1 Reference vs. current tracking test

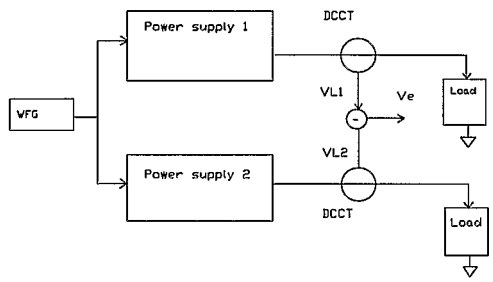

Fig. 2 Tracking between power supplies

Fig. 3 shows the basic elements of a practical test system, which consist of two programmable waveform generators and a 2-channel waveform digitizer.

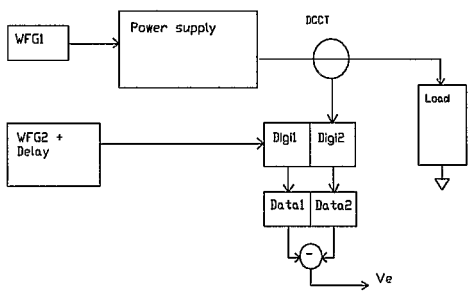

Fig. 3 Injection Bump P. S. tracking test system

For the reference vs. current tracking test, load current signal from the current detector is fed into one of the digitizers and, an identical but time-delayed version of the reference pulse is fed into the other. A tester can look at the real-time digitizer outputs, readjust the time delay of the WFG2 waveform if needed, and save the outputs to a file. A waveform-viewing program is then used to generate the tracking error based on the two data streams in the file. For the dual supplies tracking test, it is just a

simple matter of feeding two load current signals to the digitizers.

The PC-based measurement system consists of a single measuring station with an Ethernet Interface module, two Waveform Function Generator modules and one 2-channel 1Ms/s Isolated Digitizer module.

The measuring station communicates with a PC-laptop via Ethernet.

The custom written software consists of a Waveform Editor to make up two test functions (a normal one plus its inverted and programmable-delay version), a Controller to govern the behavior of the hardware, and a Waveform Viewer to look at the results captured by the Digitizers.

In this system, the matching of identical functions generated by the waveform function generators are within 0.1%. The A/D resolution of the digitizers is equivalent to 14 bits.

TEST ISSUES

The reference vs. current tracking of the Injection Bump power supply is specified as less than +/-0.5% during a 2millisec rise and 1millisec fall. The tracking between power supplies, on the other hand, is specified as less than +/-0.5% for any input profile.

Because of bandwidth limitation, the tracking error between reference and current will become much higher at the corners of the input pulse. Having studied the error profile through computer simulations during the power supply design phase, the largest error expected at the corners is less than 5%.

The tracking error between supplies also depends, apart from how similar the supplies are made, on the matching of magnet loads. Computer simulations show that the error is very sensitive to mismatch in inductance but less so with resistance. Hence, this tracking performance is verified as follows.

First, a reference power supply is pulsed into a dummy magnet load.

Second, power supply unit 1 is also pulsed into the same dummy load. Data taken from these two tests are then used to generate a tracking error profile, which should lie within +/-0.5%.

Third, the inductance of the dummy load is increased by about 6% and unit 1 is tested again. In this case, a simple gain adjustment in unit 1 is permitted to bring the error back to specification. The idea behind this is simple: Since the actual Injection Bump magnets are expected to match well within 5%, all power supplies should track within specification. In case one or two failed because of load mismatch, the gain adjustments should have enough range to make them pass.

Finally, to obtain a simplified error profile in the reference vs. current or current vs. current null, the tester is allowed to delay one of the waveforms by whatever amount needed to get the best result. This, in effect, should eliminate the tracking error due to the inherent time delay produced by the power supply.

TEST RESULTS

The reference vs. load current error without delay correction is shown in the bottom window of Fig. 4, which also depicts the graphic user interface of the Waveform Viewer program used by the tester to check that proper waveforms have been captured. Since a large portion of this error is caused by the time delay of the power supply, applying a proper time delayed to the reference pulse minimizes it.

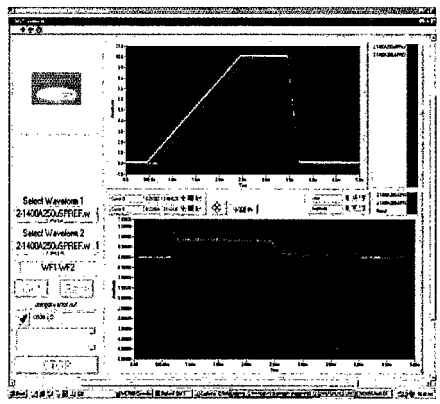

Fig. 4 Waveform Viewer

After processing the data with Microsoft Excel, test results for the first two production Injection Bump power supplies are as follows:

Fig. 5 shows the function generators are matched to within +/-0.1%. This error profile provides a base line for future comparison.

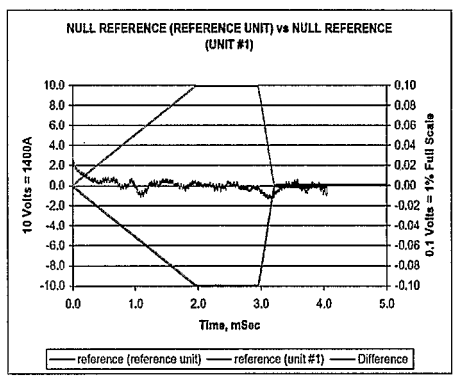

Fig. 5 Matching of waveform generators

In Fig. 6, the reference power supply has trouble tracking the corners of the reference pulse. The worst case hits –6% at the third corner. In order to reduce the error here, the current frequency response of the power supply has to be increased.

For unit 1, though tested on a slightly different load, it can duplicate the tracking performance exhibited by the reference unit with a current-loop gain change. Comparing to Fig. 6, the error profile in Fig. 7 looks almost identical.

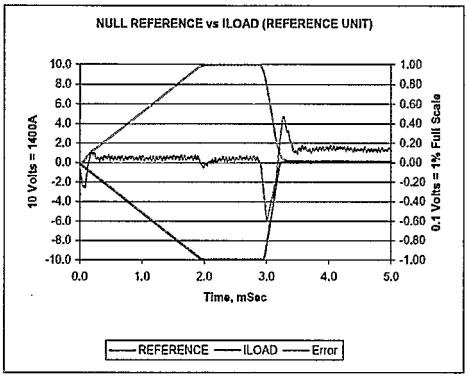

Fig. 6 Tracking error profile for reference unit

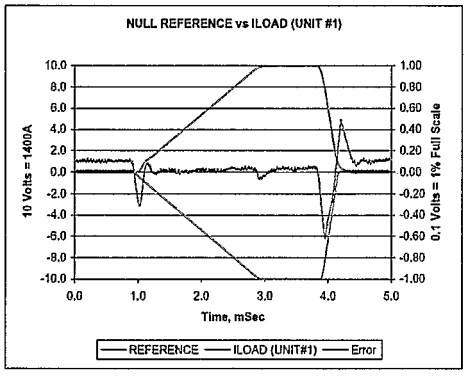

Fig. 7 Tracking error profile for unit 1

The reference unit has been tested with a load of 13 mOhm + 170 uH. For unit 1, the same load has its inductance increased to 180 uH.

To maintain the same tracking as the reference unit, however, a 10.7% increase in gain is needed for unit 1 to compensate for this load change. The tracking of load currents between the first two production units is shown in Fig. 8.

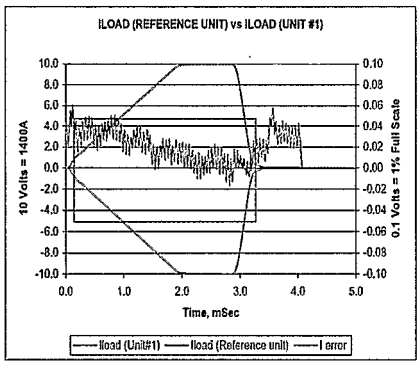

Fig. 8 Tracking between two power supplies

The tracking error between supplies lies within +0.5% and –0.2%.

Now, for the pulse with 1millisec fall, the power supplies are expected to track the reference better. This is shown in Fig. 9.

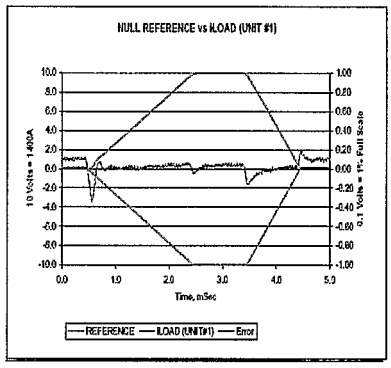

Fig. 9 Tracking error for unit 1

The tracking between supplies remains almost the same regardless of the change in fall time. This is shown in Fig. 10.

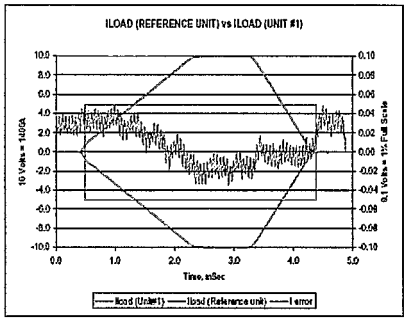

Fig. 10 Dual supplies tracking error profile

CONCLUSIONS

The use of two test functions and a PC-based measuring system has sped and simplified the verification of the tracking performance of the SNS Fast Injection Bump power supplies. The general tracking ability of the power supplies is checked with a pulse having a 1millisec fall. The worst case tracking is checked with a pulse having a 250microsec fall. The tracking results indicate that the first two production units satisfy SNS application requirements.

REFERENCES

[1] S. Dewan, et. al., "1.12 MVA Peak Two Quadrant Pulse Switch Mode Power Supply for SNS Injection Bump Magnet", Proceedings of EPA2002, Paris, France.

ACKNOWLEDGMENT

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