

USING A HIGH PRECISION PROGRAMMABLE DC POWER SUPPLY OF TPS MAGNET

Yong-Seng Wong[#], Kuo-Bin Liu, Jhao-Cyuan Huang, Wu-Shien Wen,
NSRRC, Hsinchu 30076, Taiwan

Abstract

Taiwan government had been announcement to set up a third-generation synchrotron radiation light source in February 2010. It should be installed with 1032 sets of magnet power supplies for the storage ring and 152 sets for the injector. In the storage ring, high precision DC power supply for 48 quadrupole magnets, 240 quadrupole magnets and 168 sextupole magnets [1]. The main windings of quadrupole and sextupole magnets are powered by individual power supplies. In the booster rings, one set of dynamic power supply for the quadrupole magnets and four sets for quadrupole magnets run at the biased 3Hz quasi sinusoidal wave. The Taiwan photon source (TPS) plan was completed indication national synchrotron radiation research central (NSRRC) technical capability to build at its present site in seven years a 3~3.3 GeV electron energy, 518 meter circumference, low-emittance synchrotron storage ring which will offer one of the world's brightest synchrotron x-ray sources, provide cutting-edge experimental facilities and novel multidisciplinary scientific research opportunities, enhance world-class academic research, as well as create Taiwan's scientific research marvels in the twenty-first century.

INTRODUCTION

AC to DC inverters are getting used in portable applications. Example: laptop, Television, cell phones, etc. More and more electric element must had been a DC voltage to driver it. Thus, high efficiencies power converters are most important in our life. Biology and nano-science research are applied superconducting provide electronic light source. The light source must keep a high precise current at operation steady state. General the high current output precise have micrometer lever must be requirement.

Hundreds of power supplier will had been installed at TPS operation, it can separate to have two block based on the magnet sink current capability. The first one is AC and large magnet power supplies; storage ring quadrupole magnet and booster ring quadrupole would be need to the large current to keep the magnet electron can into forward correct way and normal operation. A large of number medium power supplier will use to storage ring quadrupole magnet and sextupole magnet. Separately, it will supply the energy for linux to boost(LTB) quadrupole & quadrupole, booster to storing(BTS) quadrupole & quadrupole and DC septum power supplies.

The medium power supplies use a Uni-polar power

supply. It is provided by Chroma ATE Inc. The 62075H-30 power supplies can product 7.5kW energy with the maximum loading. It will output current must be proven to be less than 100mA (root mean square) and the Voltage ripple less than 15mV (rms). The specifications of the power supply are listed in Table 1. 62075H-30 has serial and parallel operation with Master/Slave control function. Serial control function can connect 2 modules and maximum output voltage increase to 60V. Parallel control function can operation 10 modules at one moment, it can increase maximum output current to 2500A.

Table 1: Specifications of the 62075H-30 power supply[2].

Specification	Uni-polar Power Supply
Input Voltage	3 phase 380V \pm 10%
Current Control Range	0~250 Ampere
Voltage Control Range	0~30 Voltage
Maximum Output Power Energy	7500W
Current Stability	\pm 6.25mA p-p (0~30 mins) \pm 12.5mA p-p (0~8 hours)
Output Noise (P-P)	60mV
Voltage Ripple (rms)	15mV
Current Ripple (rms)	100mA
Voltage Slew Rate Range	0.001V~5V/ms
Current Slew Rate Range	0.001A~1A/ms or INF

Additional Analog programming interface (APG) and remote control communication function in 62075H-30 power supply. It program settings can divide voltage source, current source and resistant source to control machine. APG voltage control range in 0~5V/0~10V, current control range in 4~20mA and resistance control range in 0~5k Ω . Remote control communication function will use the network line (USB/Ethernet/RS485/RS232/GPIB) to connect main power supply and passing command. Detected the current data can using a trigger waveform by external pulse. The waveform data can up to 64k samples Post-mortem buffer shall be built inside and this buffer must record data of output current. Sampling rate must be adjustable and maximum sampling rate is 10ks/sec.

It can stored record 5000 points data in front of trigger waveform and behind. This function can let user understood the power supply operation information. Table 2 is the main parameters of specification of quadrupole and setupole magnet power supplies.

Table 2:Storage Ring Quadrupole and Sextupole Magnets

	Quadrupole	Sextupole
No.of magnets	240	168
Peak current	188A	135A
Inductance	13.6/23.5mH	5.8mH
Resistance	72.2/81.6m Ω	43.8m Ω

POWER SUPPLY OPERATION THEORY

Chroma 62075H-30 can divide by input power state (Fig. 1a) and output power state (Fig. 1b). Input power states have included a bridge rectifier; large inductance and capacitance. It will transform 3 phase 380V input voltage to DC bus. Output power stage includes hardware state and controller state. Hardware state has power switch module; full bridge circuit and a dummy load. The dummy load function to start at constant current source, it will adjustment dummy load current by output voltage and program voltage less than output voltage. Controller states have current feedback control, voltage feedback control; constant current mode and constant voltage mode (CC/CV) detect controller and isolated driver. Chroma 62075H-30 power supply power state and controller structure as shown to Fig. 1. Power switch and transformer will pass DC bus voltage energy to full bridge rectifier, using a twice serial capacitor to provide a low ripple output current and low ripple output voltage. This power supply has voltage feedback controller and current feedback controller through to AC/DC converter and DC/AC converter transfer the feedback data to IC UC3895. UC3895 is a phase-shift pulse width modulation (PWM) controller that implements control of a full-bridge power stage by phase shifting the switching of one half-bridge with respect to the other. It can be used either as a voltage mode or current mode controller and operation to provide high efficiency at high frequencies. In laboratory, we would be used a large inductance become a loading, it has maximum tolerate current 750A and 23.5mH /81.6m ohm, instrument setting had shown as Fig. 2. The picture has show chroma 62075H-30 power supply in iron brace (left side) and the quadrupole inductance load (right side)



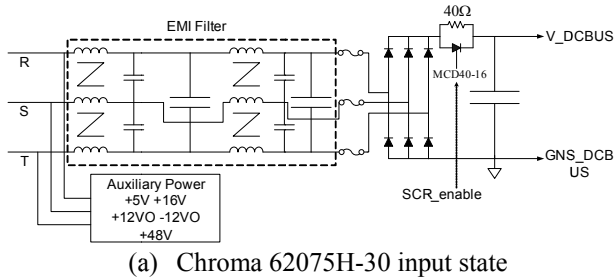
Figure 2: Chroma 62075H-30 power supply at laboratory

PROGRAM SEQUENCE FUNCTION

62075H-30 allows users to program the sequence for output in “list mode”. Each sequence in “list mode” can be edited with voltage setting, voltage slew rate, current setting, current slew rate, running time and trigger type. In “list mode” there are maximum 100 sequences that can be added liberally in one program. Testing a program sequence type is auto mode, it will step by step to carry out of program setting. Initial current 0A rising to 100A and slew rate is 0.1A/ms until 5 seconds after it will still rise the current to 250A and twice the same mode step. Detail information had been show as table 3 and testing waveform show as Fig. 3.

Table 3: Program Sequence Function Data

PROG No = 1	
RUN COUNT = 2	
SEQ No = 1	SEQ No = 2
Voltage = 10 (V)	Voltage = 10 (V)
Current = 100 (A)	Current = 250 (A)
Time = 5.000 (s)	Time = 5.000 (s)
SEQ Type = AUTO	SEQ Type = AUTO
VS.R. = 1.000 (V/ms)	VS.R. = 1.000 (V/ms)
I S. R. = 0.100 (A/ms)	I S. R. = 0.100 (A/ms)



(a) Chroma 62075H-30 input state

(b) Chroma 62075H-30 output state

Figure 1: Chroma 62075H-30 power supply circuit

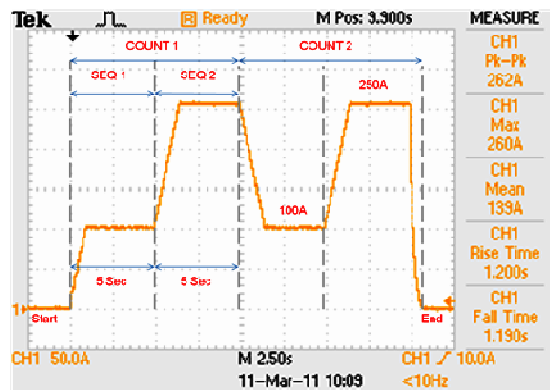


Figure 3: Program sequence testing waveform

TESTING WAVEFORM AND CURRENT RIPPLE

The light source must keep a high precision DC current at operation, current stability must within $\pm 1.25\text{mA}$ peak-peak at 0~30 minutes and within $\pm 2.5\text{mA}$ peak-peak at 0~8 hours. Using a large magnet low resistor quadrupole inductor to become power supply loading, it is composing by $50\text{mH} / 0.026\text{m}\Omega$ and maximum withstanding DC current 750A . Chroma 62075H-30 maximum output current is 250A , parallel 3 module and increase output current to 750A testing the waveform. Fig. 4 are show 750A long term current ripple of quadrupole magnet and current ripple within at $\pm 30\text{ppm}$.

The main ripple current containment are 3Hz , 60Hz , 180Hz . Using the Danfysik Ultrastab 866-20I DCCT at current feedback element and use to HP34410 multi-meter transfer and display voltage. At last, Agilent 35670A dynamics signal analyzer would analysis the data and show to the monitor. Testing the waveform about current ripple and frequency relationship, 250A single module 500A parallel twice module, 750A parallel three modules and 100A parallel four modules. Output current ripple and frequency bode plot has shown to Fig. 5, the peak current ripple is 3.319mA (output current 250A), 1.976mA (output current 500A), 1.274mA (output current 750A) and 0.817mA (output current 250A) at 60Hz and very low current ripple at high frequency.

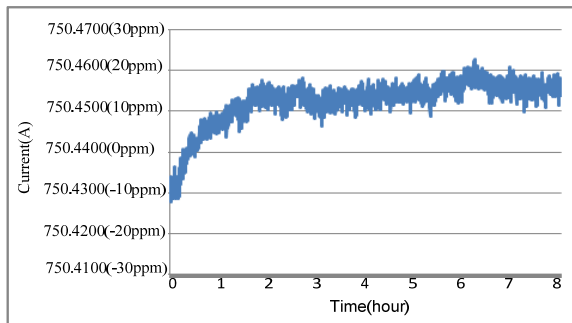


Figure 4: Long term current output ripple testing for 750A

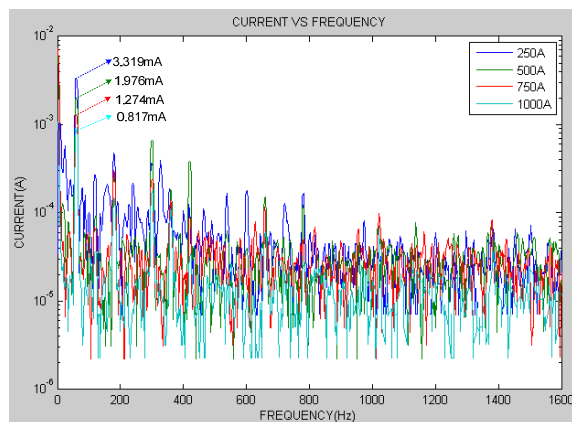


Figure 5: Output current ripple and frequency bode plot

REMOTE CONTROL AND DIGITIZING TRIGGER DATA

Chroma 62075H-30 series DC power supply can be controller remotely via USB, GPIB or RS-232 port. USB interface supports USB 2.0/USB 1.1 GPIB interface is an 8-bit parallel data bus that synchronizes with the host bus commands. RS232C is a serial bus with less powerful functions; however. Users can do remote control easily via simple programming. Ethernet (LXI) will be connection computer for power supply at this paper, it can using computer to make a command pass to power supplies. It can setting about output current data, output voltage data, sample time, sample point and internet trigger waveform etc. Chroma 62075H-30 series DC power supply also has synchronism controller function when the power supply to link another's for parallel and serial module. Master controller will send a command and setting the data to slave power supply. Master and slave module will use a CAN Bus to link data and communication. So that, we can use power supply saved data function to detect error message at stopping operation. Fig. 6 has shown a cut-off output current when the trigger rising at power supply broken. It can measure will be stopping at 3ms .

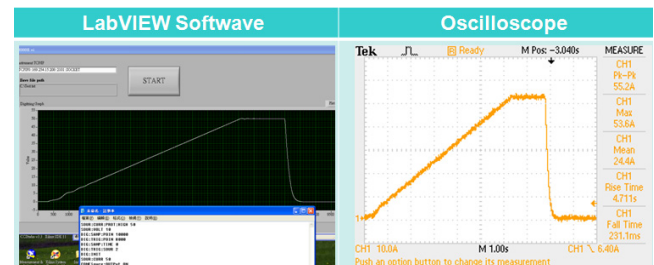


Figure 6: Compared record data and oscilloscope data

CONCLUSION

It is very important to design power supplies used in high precision current mode application with superconductor materials. It can program more function and record error message to help user easily detects machine operation stage. High precision and low ripple output current will improvement magnet electric fields stability to NSRRC light source for TPS project. A high class quality light source will advance search of biology medical and material science.

REFERENCE

- [1] Kuo-Bin Liu, Yi-Da Li, Bao-sheng Wang, Kuo-Tung Hsu, "TPS MAGNET POWER SUPPLY SYSTEM," APEC., pp3275-3277, 2010.
- [2] Chroma Ltd Mar 2008 Programmable DC Power Supply 62000P Series Operation & Programming Manual version 12.