APPLICATION OF A 400-KW DC-BANK FOR THE CRYOGENIC SYSTEM AT NSRRC

H. C. Li, H. H. Tsai, F. Z. Hsiao, S. H. Chang, W. S. Chiou, and T. F. Lin
National Synchrotron Radiation Research Center
101 Hsin-Ann Road, Hsinchu 30076, Taiwan

Abstract

A power sag (>50 % drop) several times and an annual maintenance by the power company causes the cryogenic system to shut down, which takes hours to recover. We installed an AC UPS to maintain a steady power supplied to the control circuit and low-power devices to avoid such incidences. This AC UPS is, however, unsuitable for the 315-kW compressor with an inverter because of harmonic distortion and a small power factor. In 2010 we built two sets of 400-kW DC UPS (called a DC Bank system) to maintain two 315-kW compressors in full-load operation for at least 3 min when power sags or a power cut-off occurs. The DC Bank is connected in parallel with the inverter, thus not affecting the inverter operation when the DC Bank has maintenance or failure. Here we discuss the configuration of DC Bank and the test of the system. The results show that, when the inverter is operated at 242 kW with the mains power cut off, the helium compressor maintains a stable operation for 257 s with the DC Bank support.

INTRODUCTION

Since year 2002, a 450-W cryogenic system has been used at NSRRC for one 500-MHz superconducting cavity and three superconducting magnets. A second 450-W cryogenic system was installed and planned to support the three scheduled superconducting magnets in year 2006. The helium system includes one 315-kW compressor, one 10-kW refrigerator, one 2000-L Dewar, and three 100-m^3 buffer tanks for gaseous helium [1]. To save energy and to decrease the starting current of the compressor, the power of the compressor is supplied by a variable-frequency driver (VFD). In NSRRC one spare variable-frequency driver (VFD-3) that connects to the emergency power circuit can serve to back up each cryogenic system. The switching function is shown in figure 1.

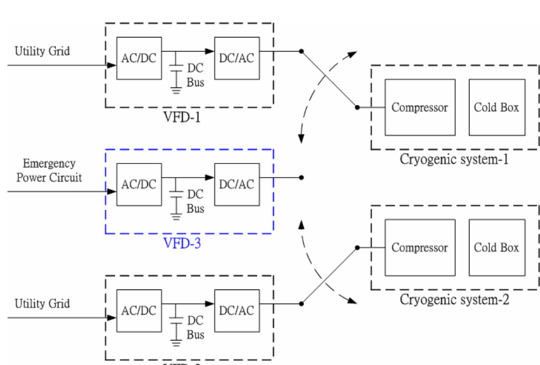

Figure 1: VFD back up function at NSRRC.

In the case that VFD-1 or VFD-2 cannot supply power to the compressor for any reason, we can readily switch one cryogenic system to VFD-3 and keep the system in operation. VFD-3 connected to the emergency power circuit can avoid a protracted cessation of the cryogenic system because of an electric circuit cut-off in the city.

The DC-Bank System

Every year a power sag (>50 % drop) several times and one maintenance by the power company causes the cryogenic system to shut down, taking hours to recover. We installed an AC UPS to maintain steady power to the control circuit and devices of small power to avoid such incidences, but the AC UPS is unsuitable for the 315-kW compressor with VFD because of harmonic distortion and a small power factor. In 2010 we built two sets of a 400-kW DC-Bank system to maintain two 315-kW compressors in full-load operation at least 3 min when a power sag or power cut-off occurs. The basic configuration of the DC-Bank system is shown in figure 2. In standby mode the charger module charges the DC battery and maintains full power; one booster module boosts the battery voltage to working voltage (about 90 % of the VFD DC-bus voltage), which is in our case about 480 VDC. The DC-Bank supplies NO power to the VFD. When a city electric circuit failure or a power sag causes the DC-bus voltage to decrease more than 10 %, the DC-Bank supplies DC power immediately to the DC-Bus of the VFD to keep the VFD output power system operating (active mode). When the city electric circuit returns to a normal condition, the DC-bus of VFD returns to normal (in our case about 520 VDC); the DC-Bank automatically stops supplying power to the VFD and stays in standby mode. The DC-Bank system is connected in parallel with the VFD system; a DC-bank failure, maintenance or disconnection for any reason does not affect the normal operation of the cryogenic system.

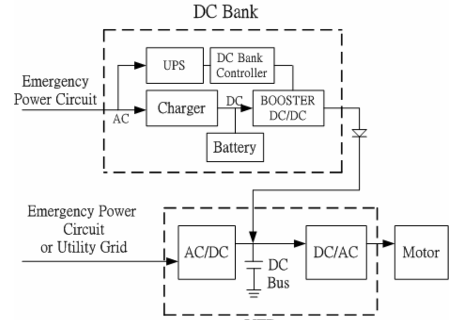

Figure 2: Configuration of the DC-Bank system.

Two 400-kW DC-Bank Systems at NSRRC

Two 400-kW DC-Bank systems for the cryogenic system at NSRRC are shown in figure 3. DC-Bank-1 is designed for the TLS cryogenic system and DC-Bank-2 for a future TPS cryogenic system [2]. The TPS cryogenic system will be installed and commissioned in 2012. The DC-Bank-2 currently connects to the spare VFD (VFD-3). There is only one charger for two battery modules because the battery module does not need to charge rapidly in the standby mode. In the active mode most power is supplied from the battery module, not from the charger.

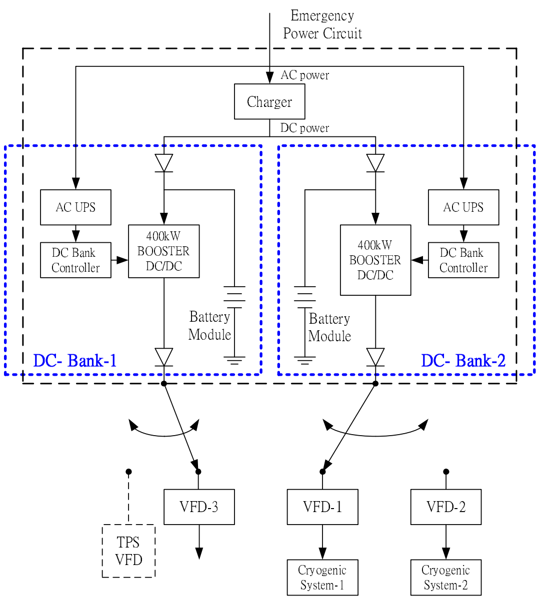

Figure 3: Configuration of the cryogenic system with the DC-Bank at NSRRC.

RESULTS

Test of Power Capacity

According to the design, the capacity of the DC-Bank should maintain two 315-kW compressors in full-load operation at least 3 min when the power is cut off, but most of the time the cryogenic system operates below 240 kW. The test of power capacity is hence that we keep the cryogenic system operating up to 240 kW and cut the power for 4 min. Figure 4(A), 4(B) and 4(C) show the power capacity test of the DC-Bank system connected to VFD-1, VFD-2 and VFD-3 respectively. At the beginning of the test, we increased the operating power to 240 kW while the voltage of DC-bus in VFD was about 520 V. The DC-Bank system was in the standby mode. We then turned off the input power of VFD. At this moment, the voltage of the DC-bus in VFD decreased to below 480V; the DC-Bank system was activated to supply DC power to maintain the voltage of the DC-bus in the VFD (active mode). The output power of the VFD kept in continuous operation with no problem. After 4 min we turned on the input power, the voltage of DC-Bus in VFD rose to 480 V; the DC-Bank system returned to standby mode.

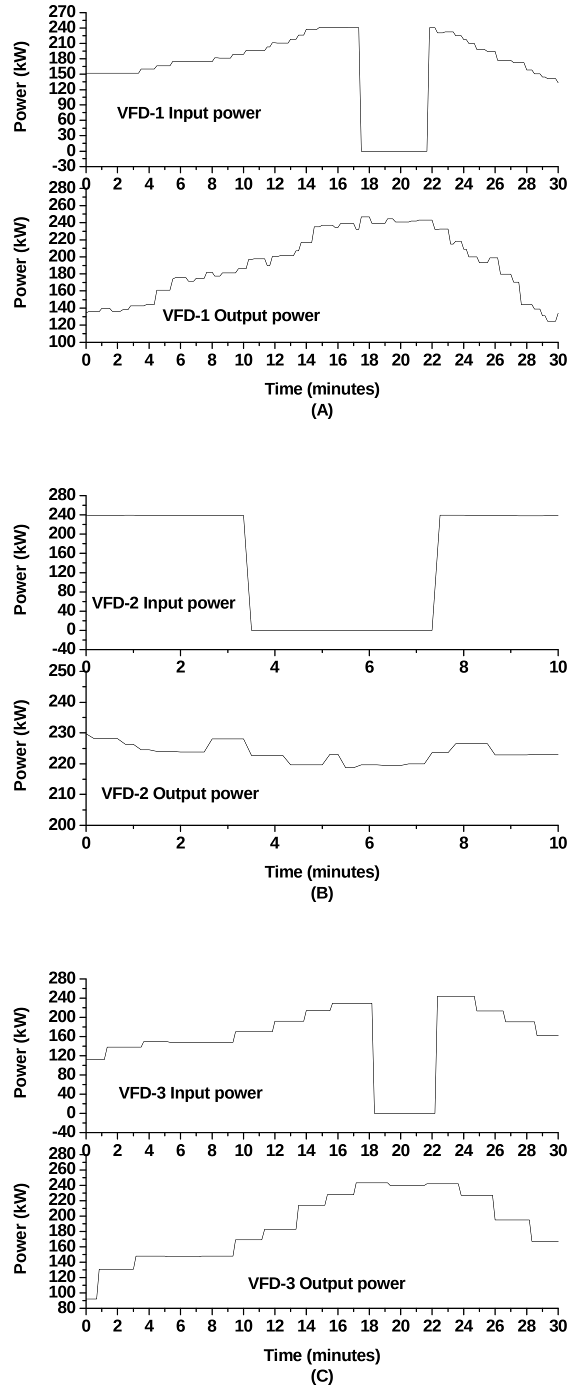

Figure 4: Test of the power capacity of the DC-Bank.

The Power Sag Test

In Taiwan, occasional power sags (> 50 %) because of earthquakes and typhoons cause the cryogenic system to shut down, taking hours to recover. The DC-Bank system can avoid a power sag of this kind. Figure 5 shows that the cryogenic system runs at full power about 300 kW; we quickly turned off and on the input power twice. The cryogenic system operated normally.

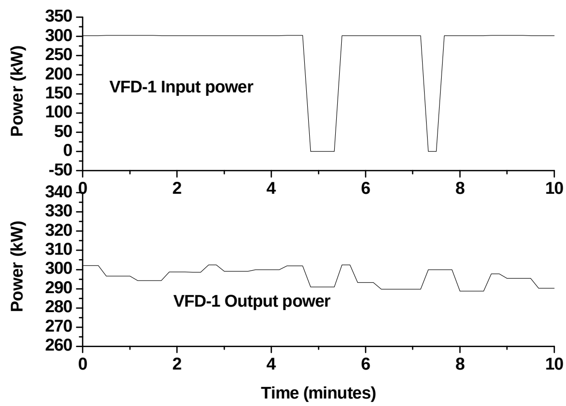

Figure 5: Test of power sag of the DC-Bank.

The City Electric Cut Off

The DC-Bank has been connected to the cryogenic system since its acceptance test in 2010 May. In 2011 January, the city electric circuits were cut off for 8 h for annual maintenance. In the past we had to shut down and restart the cryogenic system twice because of switching between the city electric circuit and the emergency power circuit, requiring much time and manpower to do this job. After we installed the DC-Bank to the cryogenic system, we have no needed to shut down the cryogenic system because of lack of power for a brief period. Figure 6(B) shows the city electric circuit cut-off at 8:00 AM; the DC-Bus voltage of the VFD dropped below 480 V, shown in fig. 6(A). The DC-Bank activated immediately to supply DC power to the VFD until the emergency power was ready, shown in fig. 6(D). The VFD output power had no effect at that moment, shown in fig. 6(C). At 16:00 h, the city electric power was restored, and the DC-Bank became active again to keep the cryogenic system operating continuously.

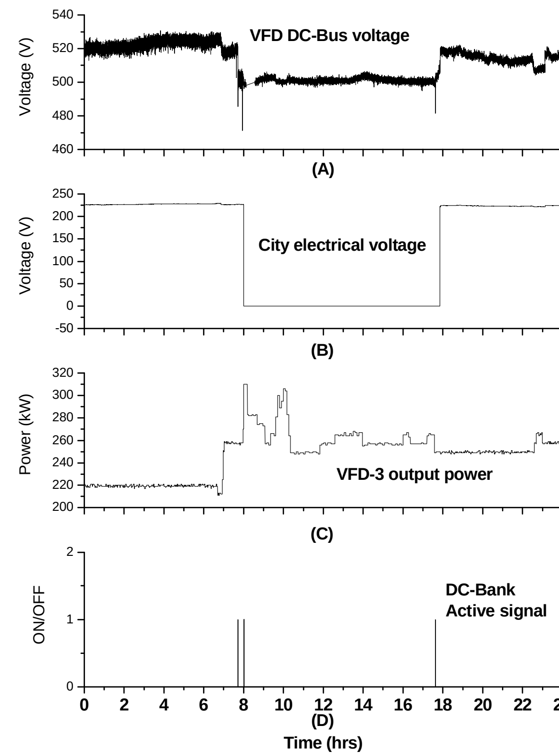

Figure 6: The city electric cut off.

SUMMARY

Two 400-kW DC-Bank systems have been tested and connected to the cryogenic system for several months, avoiding a power trip for the cryogenic system because of a power sag or a city electrical circuit cut-off. This system will also apply to the TPS cryogenic system.

REFERENCES

[1] F. Z. Hsiao, S. H. Chang, H. H. Tsai, H. C. Li, and W. S. Chiou, “Continuous Operation of a Cryogenic System for a Synchrotron Light Source”, EPAC08, Genoa, Italy, 2008 June.

[2] H. H. Tsai, F. Z. Hsiao, H. C. Li, W. S. Chiou, S. H. Chang, C. P. Liu, T. F. Lin and M. C. Lin, “The Current Status of the Cryogenic System Design and Construction for TPS," IPAC2010, Kyoto, Japan, 2010 May.