EXPERIENCE OF THE CRYOGENIC SYSTEM FOR TAIWAN LIGHT SOURCE

F. Z. Hsiao and C.S. Hwang, NSRRC, Hsinchu 30076, Taiwan

Abstract

In Taiwan light source a superconductive cavity and five superconductive magnets are installed in the storage ring. The cryogenic system provides liquid helium and liquid nitrogen with stable pressure. Failure events occurred on the components such as expansion turbine, compressor, and frequency inverter during the past years. A supervision system was developed to monitor the status of the cryogenic system and an automatic call out system was built to notify the operators when abnormal condition appears. To shorten the interruption period of liquid helium supply, the dewar keeps stable and continuous supply of liquid helium and the recovery compressor collets the evaporated helium gas from the cryostat for cases of several hours shutdown of the cryogenic system. Humidity, cleanness and helium leak tightness are items necessary to be well controlled before connecting new components or application devices to the cryogenic system. The matching between system cooling capacity and heat load is achieved via adjustment of turbine speed, precooling temperature, compressor speed, and heater power.

INTRODUCTION

It is the ninth year since the first run of cryogenic system for the electron storage ring of Taiwan light source (TLS) [1][2]. Two cryogenic plants are installed for the operation of superconductive devices. The first cryogenic plant (MCP1), which is operated at the refrigeration mode, provides the cooling to superconductive cavity; the second one (MCP2), which is operated at liquefaction mode, provides liquid helium to superconductive magnets. At current state MCP1 continuously provides 4.5K cooling to the superconductive cavity of TLS and supports cooling power, in short period, to the test station for the cavity project of Taiwan photon source (TPS) [3]; MCP2 supports the liquid helium to five superconductive magnets of TLS via a nitrogen-shielding helium transfer line with length 100 meters. Transfer length of liquid helium from the storage dewar to the cavity and the test station is 12 and 200 meters, respectively. Due to the concern of helium contamination and budget limitation, no liquid helium is provided for beamline usage.

PERFORMANCE

Variation of the cryostat pressure changes the length of the cavity so the operation frequency changes. The cavity cryostat needs to have a pressure variation within +/-3 mbar so the tuner can regulate the shift of operation frequency without difficulty. The superconducting magnets are operated at 4.3 K to acquire margin from the operation field to the critical field. To obtain a lower temperature compared to 4.5K, the magnet cryostat is connected to the suction line to obtain a low operation pressure and the vaporized helium is warmed up by a passive warmer before returning to the compressor. Since the magnet cryostat is operated in the liquefaction mode, a large loss occurs during the liquid helium transfer to the cryostat. Instead of continuous filling mode for cavity cryostat, liquid helium is filled into the magnet cryostat as the level below the setting value.

Each cryogenic plant can provide refrigeration capacity of 450W at 4.5K or liquid helium at a rate of 110 liter/hr. In the earlier period only one cryogenic plant was kept in operation to lower down the operation cost. The on-duty cryogenic plant can provide refrigeration power to the superconductive cavity in the storage ring and liquid helium to four superconductive magnets. As the fifth superconductive magnet is kept cold since the year 2010, both cryogenic plants need to be in operation. Performance of the cryogenic system at operation of one cryogenic plant and two cryogenic plants are shown in Fig. 1 and Fig. 2 respectively. A stable condition of the cryogenic plant makes it easier the control of the cryostat pressure via the control valves at the upstream side of the cryostat. The dewar pressure is kept constant to provide the liquid helium with constant source pressure, and a stable suction pressure near the compressor inlet is maintained. As expected, the helium circuit for the superconducting cavity being separated from that for the

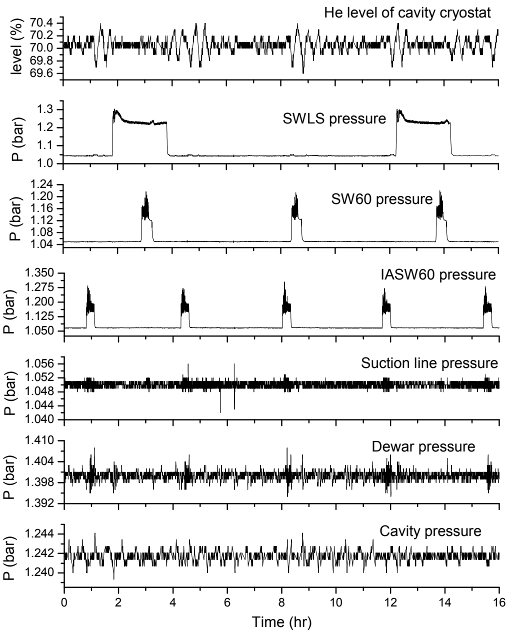

Figure 1: Status as one cryogenic plant in operation.

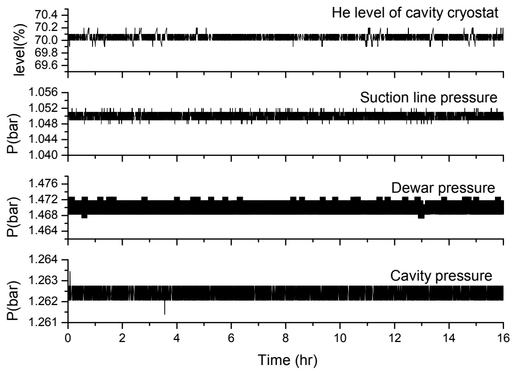

Figure 2: Status as two cryogenic plants in operation.

superconducting magnets shows more stable condition since there is no interaction between the cryostats. However, the pressure disturbance of the cold return gas will come from the adsorber regeneration, the re-cooling of standby adsorber, changing the power of heater in the dewar, different setting of precooling temperature, and unsteady flow of cold gas from the cavity cryostat or the long transfer line. It is found the temperature fluctuation of cold gas after long distance transfer will seriously decrease the capacity of the cold box when liquid helium is transferred to the test station.

RELIABILITY

Statistics of the unexpected shutdown of the cryogenic system is presented in Table 1. The number of unexpected shutdown is high in the fourth and fifth years, and decrease later to a number of twice a year. Analysis of the events to stop the cryogenic system shows that 25% from the compressor station, 25% from the cold box station, 17.5% from the human error, 30% from the utility supply, and 5% from the test of the cryogenic plant. During the past years the expansion turbine, the compressor's motor, and the frequency inverter had been damaged seriously. Our experience shows that the inverter and the expansion turbine are most likely subject to damage. The turbine failure always happened suddenly; there is no clear clue before the failure and it is hard to inspect the evidence. The possible cause may be the remained impurity due to the connection of new device or reconnection of component after the maintenance or the inspection requested from local regulation. Before connecting the device our procedure requires a cleanness for particle measurement satisfying clean room standard 100, a measured moisture content lower than 3 ppm, a helium leakage rate smaller than 1e-4 mbar-liter/sec as the device filled with helium at 1.5 times of its operation pressure, and more than three times purging and pumping down the device using pure helium gas.

To reduce the unexpected shutdown and improve the system reliability, a supervision system was developed to monitor the status of the cryogenic system. Fig. 3 shows the supervision system; where an automatic call out function was built in to notify the operators to take action in time to avoid the unexpected shutdown of the cryogenic plant when abnormal condition appears.

Table 1: Statistics of Trip Events for Cryogenic Plant

Year	Trip Number	Lost User Shift (hr)
'03Q4	1	(not in service)
'04	3	(not in service)
'05	4	15
'06	10	37.1
'07	12	11.5
'08	2	0
'09	6	6.5
'10	2	2.1

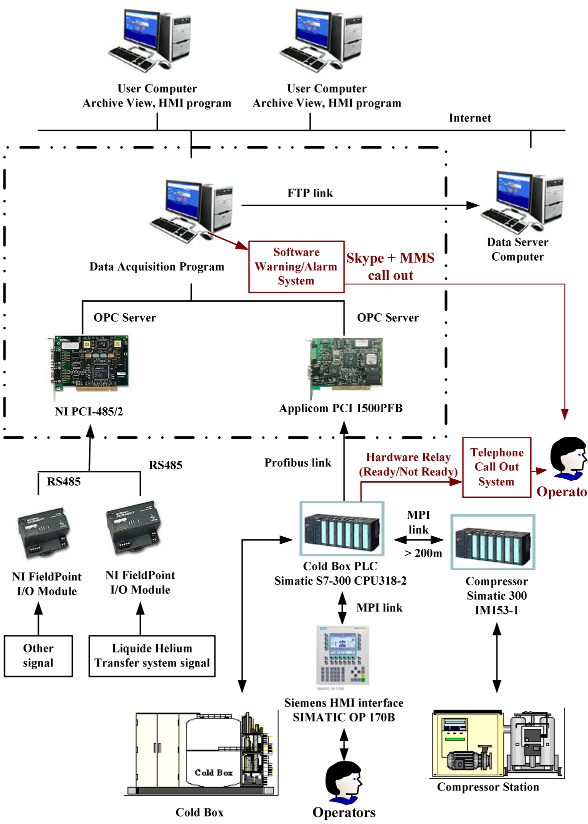

Figure 3: Configuration of the supervision system.

IMPROVEMENT OF AVAILABILITY

Both cavity cryostat and magnet cryostat require always being kept at cold condition. Operation of the cryogenic plant needs well planned to make sure continuous liquid helium supply the whole year. To keep high availability of the cryogenic system, it is necessary is to reduce the impact of long time shutdown due to maintenance. Arrangement of different shutdown periods for maintenance of the two cryogenic plants can shorten the interruption on liquid helium supply. Typically it takes less than one hour for switching the liquid helium source from one dewar to another dewar and then transferring liquid helium to the cavity cryostat. Since the cryogenic plant takes advantage of the high reliability of the central utility system to get continuously supply of the instrument air, the cooling water, and the electric power, maintenance of the central utility system will interrupt the operation of cryogenic plant. Auxiliary utility system is built up as a backup system during the shutdown period of the central utility system [4]. There is no interruption of the cryogenic plant when the supply of the instrument air and the cooling water are changed either from the auxiliary utility system or the central utility system. To avoid interrupting the operation of cryogenic plant as switching the electric power supply from the city power or the emergency power, it is required to have uninterruptible power supply (UPS) system. Small power on-line type UPS with AC type current output is individually installed for the cold box, the controller, and the monitor system. An off-line type UPS with DC type current output is adopted to compensate the shortage of DC current in the middle stage of the inverter for the helium compressor when the inverter encounters the voltage sag or power loss in the main power line. Test result demonstrates that the UPS can support the power required from the compressor more than 3 minutes for 240 kW loading or 30 seconds for 300 kW loading when the power line is cut off [5]. Using the power provided from the 500 kW generator for emergency power and with the support of the auxiliary utility systems and the UPS systems, the cryogenic system continuously keep the cavity cryostat and the magnet cryostat at cold condition, without the dynamic heat load, during the eight-hour annual maintenance of city power.

A method to further increase the availability of the cryogenic system is achieved via transferring liquid helium from the standby dewar to the cryostat during the restart period of the cryogenic plant [6]. The vaporized helium is warmed up by a warmer and returns to the compressor. The dewar pressure is built up by a heater with capacity 150W and regulated at 1.4 bar by a control valve placed in the return flow to the compressor.

MATCHING TO CRYOGENIC LOADS

Cooling capacity of the cryogenic system is larger than the heat load from the cavity cryostat and the magnet cryostat. The extra cooling power results in the rising level of liquid helium and the dewar will be fully filled if there is no level control. Conversely, during the cooling down phase the liquid helium required from all the cryostat is higher than the capacity of the cryogenic system and the dewar will be empty if the inventory is not enough. To keep the level in a suitable range it needs to adjust the cooling power of the cryogenic system via tuning the speed of the turbo expander in the cold box, the precooling temperature for the first heat exchanger in the cold box, the heating power of the heater in the dewar, and the operation frequency of the compressor [6][7]. Adjustment of the turbine speed depends on the difference between the set value and the measured liquid level; when the difference attains 2 %, the turbine speed is changed by 7 %. Adjustment of the precooling temperature is performed by tracing the level and following each increase of 10 % in dewar level for each increase of 15 K precooling temperature. The heater is turned on at a power rate proportional to the difference when the measured dewar level is higher than the set value. Changing the operation frequency of compressor is performed manually and it usually limits the available helium flow to the cold box and thus constrains the cooling power. In the current system the controller program is modified to perform the automatic adjustment of the turbine speed, the precooling temperature, and the heater power.

Some cautions must be noticed as performing the heat load matching algorithm. A high heater power induces too much flow into the cold box and causes difficulty for the return of cold gas from cavity cryostat due to its low upper-limit operation pressure. The turbine speed shall not be decreased too close to the critical speed to avoid damaging the turbine. Unsuitable low frequency operation for the compressor may induce the loss control of the pressure at the inlet side for return helium flow. It should avoid to changing the operation parameter too often since the time constant is close to two hours for the cryogenic plant to achieve a new steady state after changing the parameter.

CONCLUSION

The cryogenic system provides acceptable performance and heat load matching for the operation of superconductive devices at TLS. The efforts for improving the reliability and availability let the cryogenic system continuously supply liquid helium the whole year for 4.5 K cooling to the cavity cryostat and the magnet cryostat.

REFERENCES

[1] F. Z. Hsiao et al., “The Pilot-Runs of the Helium Cryogenic System for the TLS Superconducting Cavity”, PAC’03, Oregon, Portland, May 2003, p. 2402 (2003).

[2] Ch. Wang et al., "Operational Performance of the Taiwan Light Source", EPAC’08, Genoa, Italy, June 2008, p. 2124 (2008).

[3] M. C. Lin et al., "Installation and Commissioning of the 200m Flexible Cryogenic Transfer System", IPAC'10, Kyoto, Japan, May 2010, p. 3843 (2010).

[4] F. Z. Hsiao et al., "Continuous Operation of Cryogenic System for Synchrotron Light Source", EPAC’08, Genoa, Italy, June 2008, p. 2503 (2008).

[5] H. C. Li et al., ”Application of a 400-KW DC-Bank for the Cryogenic System at NSRRC", PAC’11, New York, USA, March 2011.

[6] H. C. Li et al., "Upgrade the Control of Cryogenic System at Taiwan Light Source", CEC-ICMC, Tucson, USA, June 2009.

[7] H. H. Tsai et al.,”Control of Liquid Helium Level for a Large Cryogenic System", CEC-ICMC, Tucson, USA, June 2009.