

DEVELOPMENT OF A SIMULATION MODULE FOR THE CRYOGENIC SYSTEM

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Abstract

In NSRRC two 450W cryogenic systems were installed on the year 2002 and 2006, respectively. After long time operation some behaviour and setting parameters of the cryogenic system did not satisfy our requirement because of the deterioration of electrical sensors and valves. To ask the manufacturer to solve those problems, it took lots of time in the communication of problem description and the modification of control program. A simulation module for the cryogenic system is thus developed to trace the procedure before and after modification of the control program. This paper details the simulation module and shows the usefulness of this module on evaluation of the software modification for cryogenic system.

INTRODUCTION

At NSRRC the first helium cryogenic system, which is tailor-made for the cooling of the superconducting cavity, was finished at the end of October 2002[1]. The maximum liquefaction rate is 124 l/hrs with liquid nitrogen pre-cooling. The maximum liquefaction rate of second cryogenic plant is 134 l/hr with liquid nitrogen pre-cooling was installed at the end of the year 2005[2]. The mission of the second cryogenic plant is supplying the cooling power to five superconducting magnets and being a backup of the first cryogenic plant, which supplies liquid helium to the superconducting cavity in the electron storage ring. One multi-channel transfer line with length 75 m has already installed for the transfer of liquid helium and liquid nitrogen to the superconducting magnets and the vaporized helium gas to the cryogenic plant. One distribution valve box serves the switch function for the backup of the two cryogenic plants for each other, as indicate in figure 1.

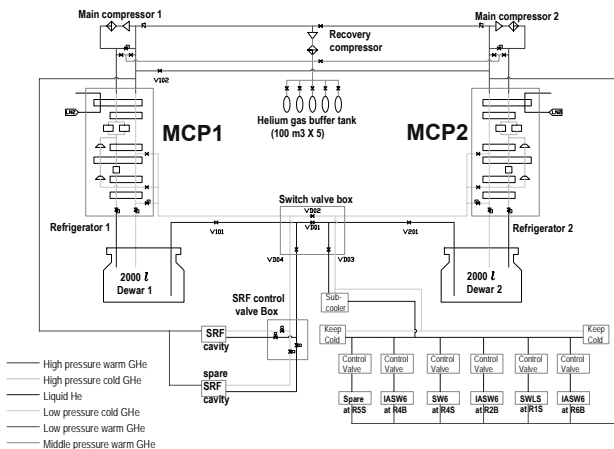


Figure 1: Configuration of the helium cryogenic system.

THE PLC-CONTROLLED SYSTEM OF THE CRYOGENIC PLANT

The helium refrigerator system in NSRRC is a fully automatic PLC-controlled system developed by AirLiquide DTA. The hardware of the control system was based on Siemens SIMATIC S7-318-2 CPU. The configuration of hardware and software shows in figure 2.

There are more than one hundred external analogical/digital I/O signals connect to the PLC I/O modules. The compressor controller locates at 200 meters far from cold box. The engineers operate all process and read the status of cryogenic system by one Siemens HMI control panel install in the control cabinet. All real time data of PLC controller download to one data acquisition server. A supervisor system had been developed by NSRRC for helping cryogenic engineers adjust the parameters.

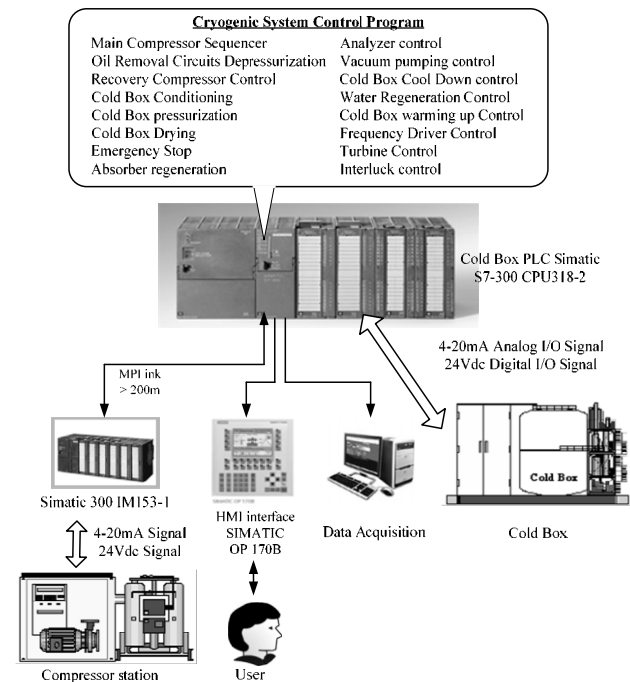


Figure 2: Configuration of the cryogenic control system.

A SIMULATION MODULE FOR THE CRYOGENIC SYSTEM

We have many experiences on maintenance and operation by the two cryogenic systems at NSRRC. But the PLC program is still like a “black box” to us. In case we need to modify apart of the PLC program to improve the system performance. It took lots of time in the

communication of problem description and the modification of control program with the engineers in AirLiquide DTA. After years we design to development a simulation module for our cryogenic system. This simulation module helps us to realize the PLC program much more than before. Figure 3 shows the configuration of the simulation module. We install PLC I/O modules, HMI panel, PLC-program all the same as the PLC control system at NSRRC. We use the industry equipment to simulate all analogical and digital signals in the cryogenic system. By programming the simulate signal, we can simulate all process and functions of the PLC program. We can modify, debug and test the PLC program any time. If we make sure all the modification of PLC program is correct. Then we will modify the PLC program on the operating cryogenic system by the results of the simulation module.

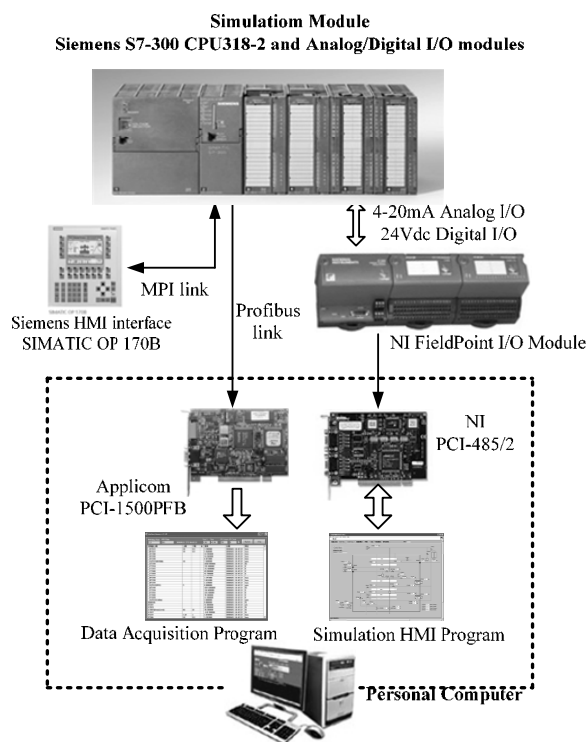


Figure 3: Configuration of the simulation module.

TWO TEST RESULT BY USING SIMULATION MODULE

In this section, we will describe how we using the simulation module to test the spare motor and modify parts of the PLC program to improve system stabilization.

VFD and Compressor Motor Test

We got some problems on the various frequency driver (VFD) and compressor of the cryogenic system. It causes large number of the cryogenic system trip events. Thus we speed lots time on maintenance, test and understand the operation between the VFD and the compressor. We have a spare VFD and several spare motors for recovery

the cryogenic system in the shortest time when cryogenic system trips. AS the both cryogenic system runs well, we connect the simulation module to the spare VFD and motors. We do the tests like temperature rising on motor bearing, voltage/current balance test, motor torque test, power test and no load test with different frequency test. Table 1 shows some test result. Some tests are under planning, like full load test, voltage drop avoided, motor temperature cooling, current balance improvement. We do all tests to make sure the VFD and motors runs well before we install them into operating cryogenic system.

Table 1: Motor Test Without Load

Frequency (Hz)	Motor current (A)	Motor Voltage (V)	Motor torque (NM)	Bearing temperature (°C)
31.2	172	207	21	39.2
40.9	172	272	23	40.8
50.36	172	334	25	41.5
54.4	171	361	27	41.3
55.8	171	370	28	41.5
57.6	163	370	29	41.6
59.3	157	370	30	41.6

Stability Improvement of Level Signal

The first cryogenic system at NSRRC operates more than five years. The problem of component deterioration will be getting worse because of the component life time. The error range of electrical sensors will get larger because of the deterioration. These kinds of phenomenon lead less performance and stabilization of the cryogenic system. It takes very long time to replace some important components and following performance test. Sometimes we can just modify the PLC program to solve this kind of deterioration of component. Before we modify the PLC program of running cryogenic system, we modify and debug the PLC program of simulation module according what problem we meet. We use an example to describe how we modify the PLC program of simulation module to improvement the stabilization of the system. In the cryogenic system, the turbine speed relate to ten system parameters automatically adjust for adjust liquid helium produce capacity. The relationship between turbine speed and parameters shows in the equation 1 and table 2.

$$WTS=NS \times V2 \times F1 \times F2 \times HP \times S1 \times S2 \times T1 \times T2 \times H1 \times LT \quad (1)$$

Table 2: Turbine Speed Parameters

item	parameter describe	range
WTS	Warm turbine speed set point	0~3200Hz
NS	Nominal speed of warm turbine	2770 Hz

V2	Cold turbine speed	1~0.1
F1	Warm turbine break temperature	1~0.1
F2	Cold turbine break temperature break	1~0.1
HP	Pressure in high pressure line	0.1~1
S1	Warm turbine outlet temperature	0.1~1
S2	Cold turbine outlet temperature	0.1~1
T1	Warm turbine dew point measurement	1~0.1
T2	Cold turbine dew point measurement	1~0.1
H1	Temperature in first heat exchanger	1~1.155
LT	Liquid helium level in the main dewar	1,0.95,0.9, 0.8,0.7

We can see the turbine speed adjust by the parameter LT in equation 1. As the helium level more than 82%, the parameter LT will become 0.95. Thus the turbine speed will decrease and the liquid helium liquefaction rate will decrease. To become 1 when helium level decrease less than 80%. If the level reached about 80%, and the fluctuation of level large than 2%. The turbine speed gets unstable because of the parameter LT change rapidly. The really situation on turbine speed of cryogenic system shows as figure 4.

For improving the stabilization of the system, we try to reduce the fluctuation of helium level signal. In figure 5(A), a virtual level with 2% fluctuation sent into the simulation PLC program. The parameter LT changes rapidly from 1 to 0.95 shows in figure 5(B). We create a new point in the program for calculating the average value of the level signal. Then we replace the level signal by this new average signal in the PLC program. The fluctuation of the new point is about 1% shows in figure 6(A). Thus the parameter LT will be always 1, as indicated in figure 6(B). The turbine speed set point will become smoothly.

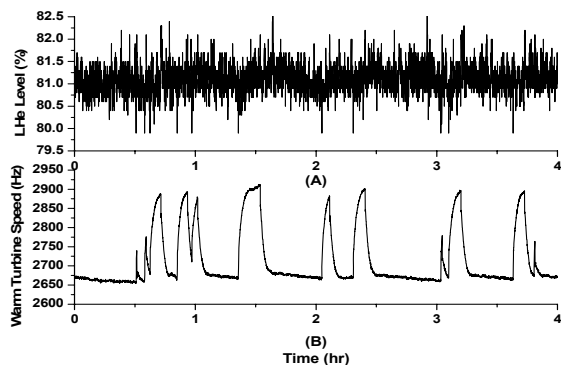


Figure 4: Real turbine behaviour due to level unstable.

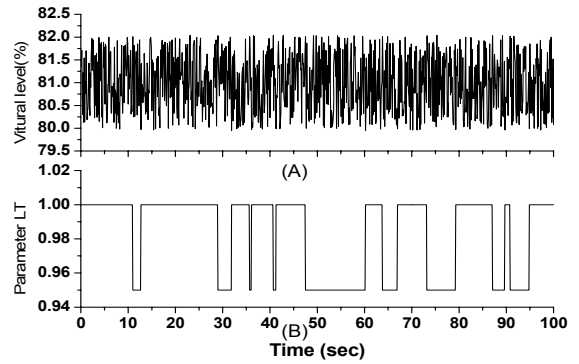


Figure 5: Virtual level signal simulation.

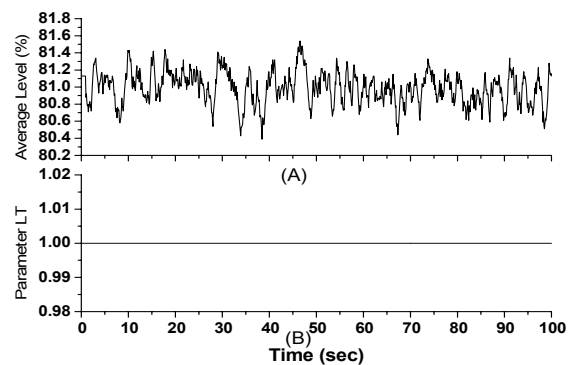


Figure 6: Simulation result.

CONCLUSION

This simulation module is a very useful tool to help us realize our equipment and its control program. By this simulation module we can do many tests and program debug to make sure everything correct before replace old components or modify PLC program.

REFERENCES

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- [2] H. C. Li, F. Z. Hsiao, S. H. Chang, W. S. Chiou, M. C. Lin, "The Cryogenic System for Superconducting Magnets at NSRRC", the 21th International Cryogenic Engineering Conference (ICEC21), Praha, Czech, July 17-21, 2006.