

# UPGRADE OF THE CRYOGENIC CONTROL SYSTEM FOR SRF MODULES AT THE TAIWAN LIGHT SOURCE

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## Abstract

An upgrade of the cryogenic control system for superconducting radio-frequency (SRF) modules of the Taiwan Light Source (TLS) has been completed. The biggest challenge was to recover all protection and operational functions, while minimizing the quantity of vented helium from SRF modules while replacing valve controllers. Gradually, this work was finished within several one- and ten-day scheduled machine shutdown periods for accelerator maintenance. No large helium vent nor pollution of the cryogenic system occurred during all component replacements and function verifications. Functions of the cryogenic electronics were improved, whereas the valve controllers are upgraded to new versions to increase reliability and availability. Communications with the data acquisition system was also secured by buffered signal processing module so that device shutdown of the data acquisition system will not interrupt the cryogenic valve operation.

## INTRODUCTION

An SRF module of the CESR-type [1] is now in operation at the Taiwan Light Source (TLS) since 2005 [2]. This SRF module was manufactured and integrated by the German company ACCEL, with technical support from Cornell University. To ensure proper operation, the cryogenic control system also depended heavily on the CESR system, including control modes for cryogenic valves and protection logics. Even the PID controllers of cryogenic valves rely on the same Omega products as the CESR system does. Ten years later, it became apparent that an upgrade to the cryogenic control system was due since the PID controller of that version is not anymore available on the market and almost out of stock at the NSRRC.

It is risky to interrupt the cryogenic system operation for a long time to replace all controllers at the same time. Therefore, we scheduled the upgrade over the whole year of 2017 by replacing controllers one by one. In 2017, the TLS was scheduled to undergo a one-day maintenance shutdown every week and occasionally longer shutdown periods, say 10 days, were made available for major accelerator component replacements, if necessary. Thus, a single PID controller could be replaced with a new model during a one-day shutdown, including function tests and parameter optimization to be completed as well. Integration tests and general parameter optimization under various operational conditions were mostly pursued during longer

shutdown periods. Helium venting due to both, the replacement of valve controllers and safety protection tests of SRF modules, was thus minimized. Details on schedule, layout, major upgraded components and function improvements are presented here.

## SCHEDULE AND LAYOUT

### Schedule of System Upgrade

Table 1: Time Schedule for Main Upgrade Activities

Schedule	Items
2016.12~2017-03	Signal integration and planning
2017-03~04	Design of panel and interface
2017-05~08	Panel production and purchase of controller
2017-09	Interface test
2017-09~10	Replacement of PID controllers
2017-10	Documentation of parameters
2017-11	Integration verification

As the time schedule of the system upgrade shows in Table 1, evaluation of the upgrade plan started at the end of 2016. This upgrade is based on decentralized construction, as being determined by mounting mechanism design, electronic modularization, establishment of auxiliary system and final integration verification. Not only all cryogenic valve controllers were replaced with new models, but also local control modules for cryogenic transfer and safety were revised. It took several weeks in October, 2017 to complete controller and module replacements. To reduce the risk of malfunction, only a single controller was replaced during each weekly one-day maintenance shutdown since long-time verification and parameter optimization for cryogenic-related operation is crucial. All the updated tables for the PID controllers are uploaded to the ELOG database of the TLS for easy tracing and checking.

### Panel Layout

The original PID cryogenic valve controllers are a Omega product of model CN2001 and were built and operated since the end of 2004. The spare parts at the NSRRC were depleted gradually and market replacements became more and more difficult to obtain. Meanwhile, the cryogenic electronics for the KEKB-type SRF modules [3] in the Taiwan Photo Source (TPS) uses a new version of PID controllers, an Omron product of model E5AC-CX2ASM-004, that supports long-term current output of 4-20 mA. The Omron controller is shorter than the Omega controller

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but with the same frontal dimensions of 96(H) × 96(W) mm, benefiting the integration into the existing panel, though not supporting hot swapping. To unify the controllers and solve the stock problem, the PID controllers were all to be replaced with Omron controllers. As shown in Fig. 1, several additional meters were also installed to clearly show valve status, whereas three controllers were replaced with mere indication meters since their regulation function was never used anyway. With this new layout, the signal processing modules could be integrated in a compact 8U-module rack.



Figure 1: Original and updated panel arrangement.

### CRYOGENIC SAFETY

Safety is always the most important issue for cryogenics related operation. The PID controller for cryogenic valves in cold helium gas return lines is not only responsible for regulating the helium vessel pressure of the SRF module but also embedded with both a high-pressure setting to open the pneumatic safety valve of the helium vessel and a low-pressure setting to shut off all the cryogenic valves in order to prevent the cryogenic system from potential pollution by isolating the SRF module. Some other safety-related settings are also embedded in the PID controller of the liquid helium supply valve and several indication meters.

However, the power must be turned off during controller replacement, thus activating safety settings which would vent helium in order to protect the SRF cavity from overpressure. A local controller unit was thus built with full functions to regulate major cryogenic valves and activate safety protections. Shown in Figs. 2 and 3 are the block diagram and the photo of this local controller, respectively. Before shutting off electric power to the PID controller, this local control unit was connected to all input and output signals to handle cryogenic-related operations. Helium venting was thus almost completely avoided.

Additional protection mechanisms and circuits were gradually added to the cryogenic SRF electronics at the TLS since 2005. More complexity is the penalty for improvements of reliability and safety. It is essential to completely transfer all protection functions and settings to the upgraded control system. Numerous checks and tests verify that all settings are correctly embedded into the new controllers and indication meters. Thus it takes several hours for safety checks after replacement of every controller and indication meters to ensure proper communication

between the controllers, indication meters and safety-related circuits.

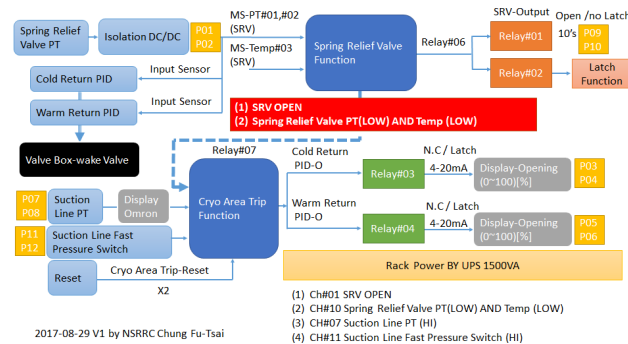


Figure 2: Block diagram for the local control unit.

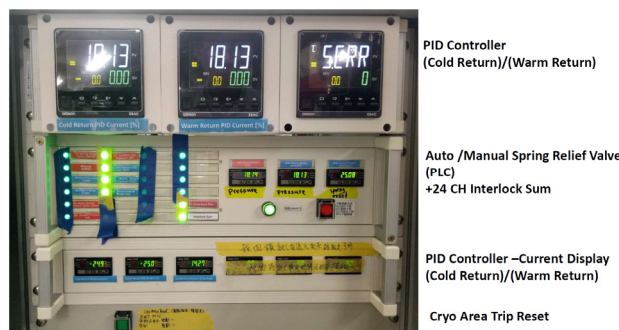


Figure 3: Local control unit.

### SIGNAL PROCESSING

Some signals essential to SRF operation and cryogenic stability are listed in Table 2, including physical name, range, and source type for each signal. These signals are integrated with a buffered signal processing, communications with other devices such as LCD heater power controller and LED display for status of the helium compressor, as well as proper transmission to data acquisition systems.

Table 2: List of Signals to be Processed

Display-Meter-CH	Signal explanation or Name-Mark [Unit]	Range	Source V/A
#01	LHe Vessel Level [%]	0-10V -> 0-100	Δ
#02	SRF He Return Pressure [PSIA]	0-10V -> 0-30	Δ
#03	SRF He Bypass Pressure [PSIA]	0-10V -> 0-30	Δ
#04	Hex Line Pressure #2 [psia]	0-10V -> 0-30	V
#05	SRF HEX line flow rate [std Lit/min]	0-10V -> 0-250	Δ
#06	Temp of HEX line helium flow [oC]	0-10V -> 0-150	Δ
#07	SIHEX line heater power [%]	0-10V -> 0-100	Δ
#08	Temp of Exhausted GN2 [oC]	0-10V -> 0-150	Δ
#09	LN2 flow rate [std Lit/min]	0-10V -> 0-250	Δ
#10	SI LHe supply valve opening [%]	0-10V -> 0-100	Δ
#11	SI GHe cold return valve opening [%]	0-10V -> 0-100	Δ
#12	SI GHe warm return valve opening [%]	0-10V -> 0-100	Δ
#13	SI LHe vessel heater Voltage [V]	0-10V -> 0-100	V
#14	SI LHe vessel heater Current[A]	0-5V -> 0-5A	Δ

The original Omega controller transmits status values in a serial transmission mode by RS232 interface. Accordingly, a special interface was established for the data acquisition system to receive and store these signal values in the TLS-History database. But the Omron controller does not include an RS232 interface. Thus fourteen indication meters had to be constructed first, as shown in the upper-right corner of Fig. 1, to translate analogue signals, as listed in Table 2, to proper RS232-type signal format and then feed them to the original interface, so that no modification on

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the data acquisition system was required after controller upgrade.

### Particular Devices and Modules

**Buffered Signal Processing module** To guarantee correct signal sources and for fast checks of wiring problems, a buffered signal processing module was implemented. As illustrated in Fig. 4, the signal processing module receives the signal input of current-loop and generates a voltage output. With this transfer buffer between input and output signals, we can identify any input or output wiring error easily. In addition, also a short in the output loop due to a downstream device reset would not affect the input signal loop to create a wrong status and trigger cryogenic safety settings.

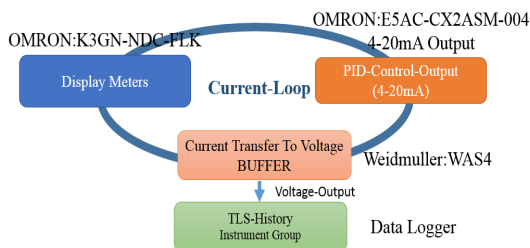


Figure 4: Design of the buffered signal processing module.

**LCD Heater-Power Controller** To keep a constant heat load on the liquid helium vessel in the SRF module, the helium pressure must be very stable. Since the heat load on the SRF cavity wall depends on RF conditions and thus may fluctuate from time to time, a resistor type heater is installed on the bottom of the helium vessel. A heater controller reads the applied RF field strength and response with corresponding current output to generate a constant heat load on the helium vessel. A heater controller with LCD display for both DC voltage and current output replaced the original knob-type heater controller. This LCD heater-power controller is not equipped with signal outputs. Output voltage and current to the heater were thus processed to generate reading signals.

As shown in Fig. 5, the current signal is generated by the circuit board ACS712-5A IC, whereas the voltage signal by a home-made 10:1 resistor divider. These two signals are then individually processed with a buffered signal processing module. Calibration was done with the multi-function calibration kit CA71. Figure 6 shows both the voltage and current outputs are linearly dependent to corresponding inputs, not only with a proper proportional ratio but also with a tiny constant shift. These modules and related circuit boards for the LCD heater-power controller are all packed in the same 8U-module rack for indication meters shown in the upper-right corner of Fig. 1. The inside of this 8U-module rack is quite dense as demonstrated in Fig. 7.

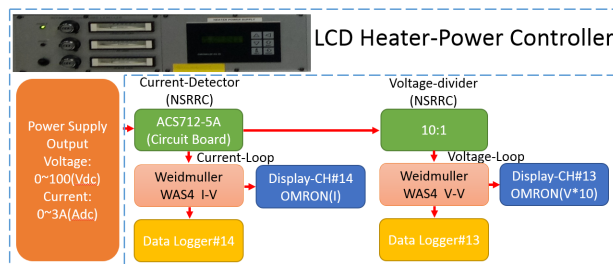


Figure 5: Integration of the LCD heater-power controller.

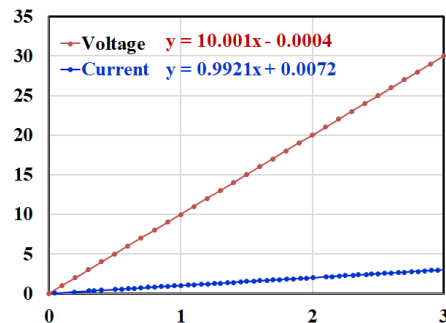


Figure 6: Calibration of voltage and current output of the LCD heater-power controller.

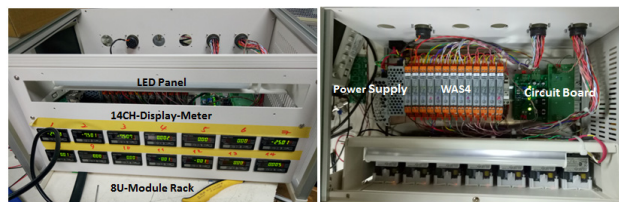


Figure 7: The 8U-module rack for indication meters.

## CONCLUSION

It took one year to upgrade the cryogenic control system for the SRF modules. Detailed technical evaluation and preparation were essential for this success. Fortunately, not only could we replace the old controllers with market-available ones, but all functions were also completely transferred and partly improved. Thanks to the local control unit, helium venting was almost completely avoided while replacing the components. Since the upgrade in 2017, this improved control system works without problems.

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