

THE SPALLATION NEUTRON SOURCE CRYOMODULE TEST STAND RF SYSTEM *

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Abstract

The Spallation Neutron Source (SNS) has recently commissioned a cryomodule test facility for the repair and testing of the superconducting radio-frequency (SRF) cavities. This facility utilizes the original 402.5/805 MHz Radio Frequency (RF) Klystron Test Stand as its power source along with dual Low Level RF (LLRF) control systems. One control system is based on the standard SNS Linac LLRF controls, with a second system for open-loop only control. The system is designed to allow simultaneous testing of devices in the test cave and other devices which can be tested outside of the enclosure. Initial tests have shown good results; some improvements are yet to be implemented.

INTRODUCTION

The Spallation Neutron Source (SNS) has constructed the facilities necessary to perform repairs of superconducting radio-frequency (SRF) cavities including a class 10,000/100/10 clean room and testing facilities for verification of cavity operation prior to reinstallation of repaired cryomodules into the accelerator tunnel. The new facility utilizes the existing Radio Frequency Klystron Test Stand for the RF power source along with dual low level radio frequency (LLRF) control systems capable of testing both 402.5 MHz and 805 MHz systems simultaneously. One of the control systems is based on the standard SNS Linac LLRF control system (shown in Figure 1) that is fully compatible with the normal operating conditions experienced by the cavities in the Linac, while the second control system only provides open-loop operation. Full personnel protection safety (PPS) and oxygen deficiency hazard (ODH) systems have been installed to ensure safe operation of the facility.

SYSTEM ARCHITECTURE

The SNS Cryomodule Test Stand RF System is an extension of the earlier RF Test Facility (RFTF) that was constructed during the initial SNS Linac construction as a flexible test-bed for high power RF components such as klystrons, windows, normal and super-conducting cavities and couplers [1]. The facility was initially equipped with a shielded cave that has been finished to include a movable door and the safety systems to allow for full cryomodule testing.

A block diagram is presented in Figure 2 and provides an overview of the RF paths. The heavy lines denote

waveguide runs while all other connections are made with .375" helix cables.



Figure 1: LLRF Control System

High Power RF Systems

The high power RF systems consist of two transmitters that are identical to the normal conducting systems installed in the Linac gallery, two high voltage (HV) tanks that accept a single klystron each, and an 8% duty, 11 MW peak pulsed high voltage converter modulator (HVCM) to power the klystrons. Currently, a 2.5 MW 402.5 MHz and a 5 MW 805 MHz klystron are installed, which can satisfy RF power level required for testing most high power RF components. The 805 MHz system is plumbed into the test cave as well as the original coupler testing area. The destination of the RF energy is easily selectable with the addition of a high power waveguide RF switch that is under configuration control for safety. The klystrons are isolated from the device under test (DUT) by the use of circulators and water loads that can accept full reflected power [1].

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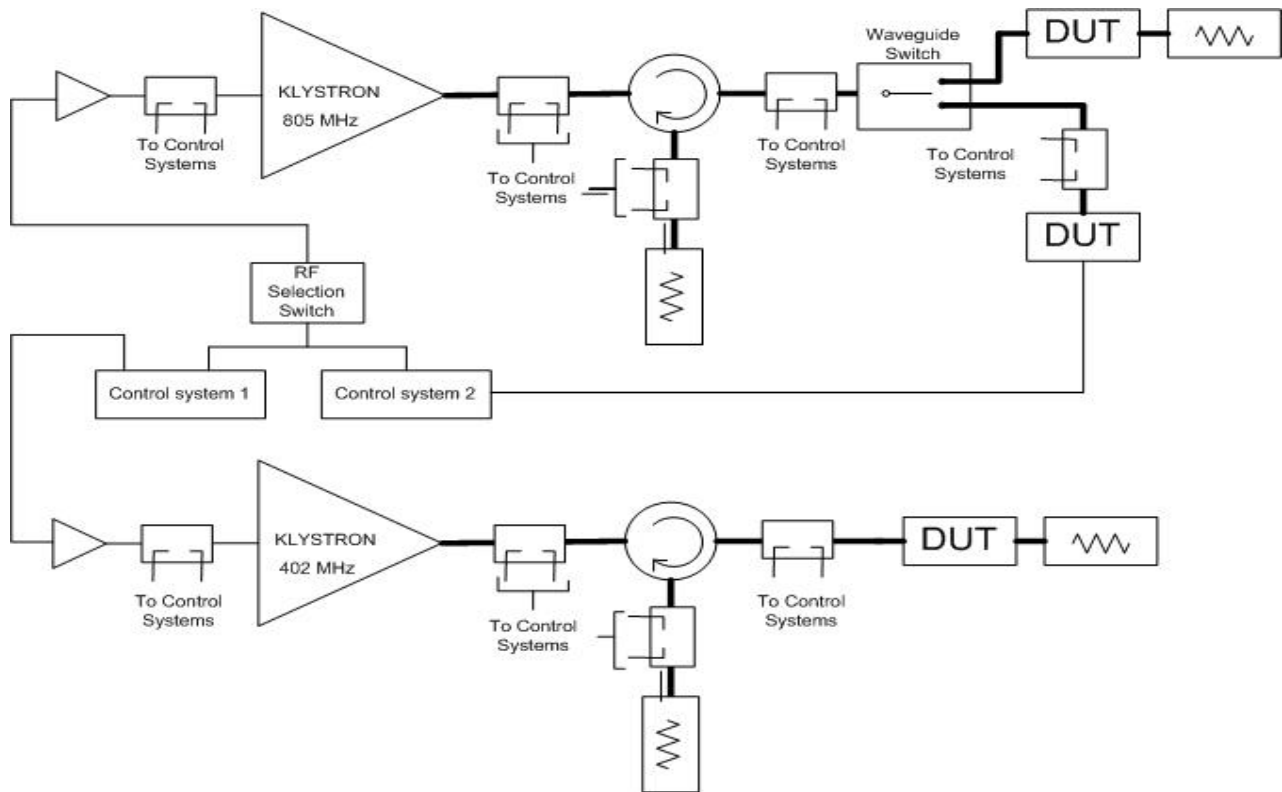


Figure 2: System Block Diagram

The transmitters provide the usual support and protection for the klystrons such as monitoring voltage and currents, and have independent RF monitoring circuits in case of circulator failure. Figure 3 shows the HVCM, the 805 MHz and 402.5 MHz klystrons from left to right.

Low-Level RF Control Systems

The two LLRF control systems installed for the RFTF are designed to be flexible so as to support frequencies other than the standard SNS 402.5 & 805 MHz. The first control system was designed for open-loop only testing to support the klystron site acceptance tests and the fundamental power coupler (FPC) conditioning. The system utilizes a commercial RF source to generate the needed pulsed RF drive signal with a standard High-power Protection Module (HPM) for interlock protection.

The second LLRF control system that was shown in Figure 1 uses the standard SNS Linac field control and high-power protection modules (FCM/HPM). The system allows for either open or closed loop testing of individual cavities and can shift the output frequency by up to ± 600 kHz as needed. The system uses a commercial dual output RF generator for the local oscillator (LO) and reference signals, and an external down-converter chassis to allow for ease in changing frequencies between 805 and 402.5 MHz. If needed, other frequencies can be used by changing the band pass filters to the desired setting; the system has been tested at 325 MHz and 1300 MHz without discovery of any major issues.

The control system allows for additional RF drive inputs via an external chassis while still maintaining system interlocks. This allows other RF sources, such as VCO-based systems, to be used easily without having to worry about damaging the DUT.



Figure 3: HPRF systems with 805 & 402.5 MHz klystrons

Interlocks

Personnel and equipment protection is the highest priority at the SNS, and test stands are always a concern because of the flexibility they provide. The cryomodule test stand required a full personnel protection system to be installed and certified to ensure that RF could not be

operated in the enclosure without it being properly secured. A bypass mode was installed so that the coupler and klystron test areas can be operated when the cave enclosure is not being operated.

With two control systems sharing one set of klystrons, the interlocks had to be either duplicated or shared. The RF signals were split to provide input for both control system interlocks. The arc detectors for the klystron windows and circulators required design of a custom interface. All other interlocks are test-specific and are connected to the appropriate control system being used for a specific test.

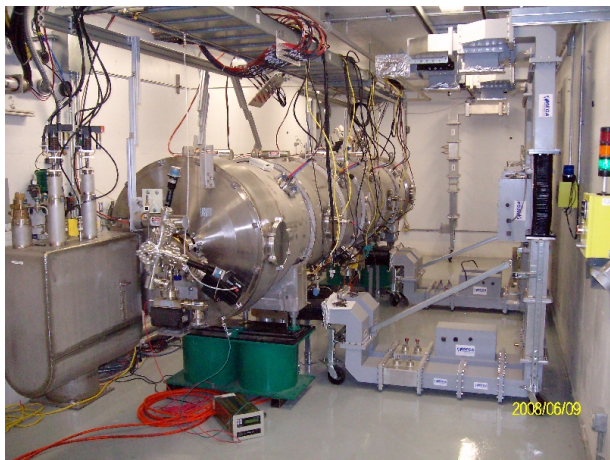


Figure 4: Cryomodule installed for test inside of cave

IMPROVEMENTS

After the first set of successful tests was completed, several improvements were suggested to increase the usefulness of the test facility. Three upgrades are currently being implemented for the next test cycle. First, a prototype continuous wave (CW) Voltage Controlled Oscillator (VCO)-based phase-locked loop (PLL) system to track the frequency of a single cavity during testing is in final assembly. This system will simplify the testing of cavities without concerns about resonance control systems and tuner motors. The VCO system will be integrated into the existing interlocks to ensure safe operation of the equipment. CW power will be provided by a 600 W broadband amplifier.

It is useful to have all cavities powered simultaneously to determine how the cavities interact, but the current RF system only provides for single cavity testing. The cavities are designed to operate with a 550 kW RF source, and with the test facility using a 5 MW 805 MHz klystron

adequate RF power is available to drive several cavities. A 4-way waveguide power splitter is being tested to allow for multiple cavity operation. Each leg of the split will provide approximately 25 percent adjustment of amplitude and 30 degrees of phase shift. Figure 4 shows one of the four cavity high-beta SNS cryomodule installed in the cave for testing. The high power test can be done one cavity at a time and then all four cavities together at the same time. This will allow open-loop testing with all cavities operating near design gradients.

Finally, a system to perform RF processing of cavities is being constructed. This system will provide the ability to experiment with both helium and plasma processing of RF cavities to improve the operating gradients available. Initial testing will be performed using the VCO and broadband amplifier mentioned earlier.

SUMMARY

Initial cryomodule tests in the facility have been successful in demonstrating both open and closed loop operation of individual cavities. The facility provides the ability to verify repairs and re-baseline cavity parameters prior to reinstalling a cavity into the Linac tunnel. Many improvements are planned for the facility to increase the functionality, including the ability to operate multiple cavities simultaneously. Additionally, a fully-instrumented control room is being constructed and will provide for a more convenient location to complete device testing in the future.

ACKNOWLEDGEMENTS

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