THE SNS LINAC RF SYSTEM, SYSTEM STATUS AND VENDOR RESULTS*

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Abstract

The Spallation Neutron Source being built at the Oak Ridge National Lab in Tennessee requires a 1 GeV proton linac. Los Alamos has responsibility for the RF systems for the entire linac. The linac requires 3 distinct types of RF systems: 2.5-MW peak, 402.5 MHz, RF systems for the RFQ and DTL (7 systems total), 5-MW peak, 805 MHz systems for the CCL and the two energy corrector cavities (6 systems total), and 550-kW peak, 805 MHz systems for the superconducting cavities (81 systems total). The RF system for the superconducting cavities is unique in that up to twelve klystrons are operated from one pulsed-power system, and up to six klystrons are controlled and interlocked by a single transmitter. The design of the SNS Linac RF system was summarized in the 2001 Particle Accelerator Conference in Chicago [1]. Vendors have been selected for the klystrons (3 different vendors), circulators (1 vendor), transmitter (1 vendor), high power RF loads (2 different vendors), waveguide (2 vendors), and High Voltage system (2 vendors). This paper presents the results of vendor procurements and early test results of the major components of the Linac RF system. In addition the plan for installation and commissioning of such a large system will be described.

Table 1: Summary of RF System Parameters

Section	Output (MeV)	Klystron quantity	Frequency (MHz)	Power (MW)
RFQ/DTL	86.8	7	402.5	2.5
CCL	186	4	805	5
SRF, Beta=0.61	387	33	805	0.55
SRF, Beta=0.81	1000	48	805	0.55
Energy Corrector	1000	2	805	5

1 OVERVIEW OF THE RF SYSTEM

The basic design of the RF system has not changed recently. The overall partitioning of the RF system, showing the klystron sizes, frequencies, and applications to the SNS linac are given in Table 1. The room temperature portion of the linac, representing the linac up to 186 MeV, allows at least 25% excess power availability in the klystrons in order to accommodate control of the accelerator field. In the superconducting portion of the linac, at least 40% excess power is available for field control. The extra control margin is needed to handle the increased level of disturbances coming from the higher percentage of beam loading in superconducting cavities and the additional disturbances of Lorentz force detuning and microphonics which are not issues for room temperature cavities.

Table 2. High Power RF Component Vendors and Status

402.5 Mhz, 2.5 MW klystron systems for the RFQ and DTL

Item	Vendor	Delivery status
klystron	Marconi	started
circulator	AFT	completed
high power load	Atlantic Microwave	completed
Transmitter	Titan Systems Corp.	started
Waveguide systems	Mega	completd
waveguide window	Thales	started

805 MHz, 5MW klystron for CCL and energy correctors

Item	Vendor	Delivery status
klystron	Thales	started
circulator	AFT	completed
high power load	Titan Beta	completed
Transmitter	Titan Systems Corp.	started
Waveguide for CCL	Mega	completd
Waveguide (energy corrector)	??	not started
waveguide window	Thales	started

805 MHz, 550 kW systems for Superconducting

Item	Vendor	Delivery status
klystron	CPI	started
klystron	Thales	not started
circulator	AFT	started
high power load	Mega	started
Transmitter	Titan Systems Corp.	not started
Waveguide (low beta)	Micro Communications	started
Waveguide (high beta)	Mega/??	started

The power supply design [2] is standardized as much as possible. Two fundamental designs are used, one for the high voltage klystrons on the room temperature cavities, and one for the relatively lower voltage klystrons in the superconducting sections. The peak and average powers of each high voltage system are approximately equal (about 10 MW peak and 1 MW average). To do this, a variable number of klystrons are connected to a high voltage system. In the 402.5 MHz systems, two 2.5 MW klystrons are connected to each supply (except for the first unit, in which the RFQ klystron and 2 DTL klystrons are all connected to one supply). In the CCL section, 1 klystron is connected to each supply. In the superconducting sections, either 11 klystrons (at full power) or 12 (at reduced power) connect to one supply.

The transmitters are designed to work with 1 klystron (in the room temperature systems) or 6 klystrons (in the superconducting systems).

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Every klystron/cavity pair has its own feedback/feedforward field control system [3]. Here again, the field control system is designed with as much commonality as possible. There is very little hardware difference between the system that controls a 5 MW klystron driving a CCL cavity and the system that controls a 550 kW klystron driving a pulsed superconducting cavity. The differences between the two are primarily in the firmware and software.

2 HIGH POWER COMPONENT VENDORS AND INITIAL RESULTS

The components and vendors for the major high power RF components are shown in Table 2. Table 2 also shows which items have started, not started, or have completed delivery.

2.1 Klystrons

Figure 1. CPI 550 kW klystron during assembly

The klystrons are being obtained from 3 different vendors.

Initial deliveries have been started for the Marconi 402.5 MHz klystrons, and the CPI 805 MHz, 550 kW klystrons (figure 1). All klystron vendors have had initial difficulties. Marconi's first iteration could not generate the required power level.

After significant effort, they achieved just under 2 MW. 2.5 MW was the specified level. We accepted 2 tubes at this level in order to stay on schedule, and because the first two sockets need significantly less power than the remaining sockets. The final solution involved several items, but the primary solution came from reworking the output cavity coupling to decrease the external Q, and to reduce the Q of the second cavity. Marconi has now delivered 2 full power klystrons (2.5 MW). The first CPI klystron (805 MHz, 550 kW) had excessive beam interception. Ultimately it was determined that there was a bend in the tube in the vicinity of the output cavity. The tube was reworked and then had difficulty reaching full efficiency (it obtained 62% efficiency rather than the specified 65%). This tube and a few subsequent tubes were accepted this way in order to maintain the schedule (and because they still meet the needs of the first few sockets). Thales' first 5 MW tube had difficulty with excessive body interception. Fixes include focus coil changes and a change in tuning of the penultimate cavity. The first acceptance test is scheduled for September of this year.

Figure 2. Transmitter components for the superconducting RF systems include the water manifold (upper left), the 3-klystron oil tanks (center and right), and the control racks (lower left).

2.2 Transmitters

Titan was the winning bidder for all transmitters (3 types). Initial problems were primarily in the area of software. Once this was solved, minor test issues developed, but once those were worked out, units have been coming very fast. Drawings of the main components of one superconducting transmitter system are shown in Figure 2.

The transmitters provide the following functionality:

-Klystron filament power, interlocks, and control
-Vac-Ion Pump Power Supply and Interlocks
-Solenoid Magnet Supplies, interlocks, and Control
-Local Control
-Interface to Remote Control
-Water Distribution, flow interlocks, and calorimetry
-Solid State Amplifier for Klystron drive
-Tube Support and Oil Tank
-HV Diagnostics
-High Power RF Diagnostics and Interlocks
-Klystron Window Air Cooling and Interlocks
-Arc Detection
-Temperature Compensation for the Circulator

3.3 Circulators/Loads

AFT is the vendor for all circulators (3 types). Testing at high power had to occur at LANL because AFT does not have that capability. The 805 circulators have been tested to high power using a 2.5 MW prototype klystron that we have at LANL. Eight each of the 550 kW circulators have been tested to full power, which fuldills our acceptance critieria for this item. We have to wait for the first 5 MW Thales klystron to test the 5 MW circulator to full power. We recently tested the 402.5 MHz circulators to full power after we received the first full power klystron from Marconi. The first two units have passed their acceptance tests.

Figure 3. 2.5 MW, 402.5 MHz Glycol/Water RF Load

The high power loads come from Titan, Atlantic Microwave, and Mega. Four 402.5 MHz loads and eight 550 kW loads have passed their acceptance tests. The 402.5 MHz loads use a glycol/water mix to improve the absorption and reduce the size (Figure 3). They would be unreasonably long if we used pure water.

3 HV AND LLRF SYSTEMS

The High Voltage System is described in a companion paper at this conference [2]. This system was subdivided into 4 parts for procurement (Table 3). ZTEC won the procurement for the control racks, and Dynapower won the procurement for the Input Substation, SCR controller, and Converter/Modulator. Deliveries of the subsystems have started. The first full system integration and test is scheduled for September of this year.

The Low Level RF (LLRF) system that does the feedback/feedforward control of the cavity field and the high power protect functions is also described in a companion paper at this conference [3]. This unit is based on VXI technology and is very close to going out for production. First tests of an integrated system will occur at Jefferson Lab in September when a system will be used in an integrated test of the RF control system and the JLAB cryomodule.

Table3. HV System Vendor and Delivery Status

Item	Vendor	Delivery status
Input substation	Dynapower	completed
SCR phase controller	Dynapower	completed
Converter/Modulator	Dynapower	started
Control Racks	ZTEC	started

4 INSTALLATION AND COMMISSIONING OF THE RF SYSTEMS

As a multi-lab collaboration, the SNS presents special problems when it comes to installation and commissioning. LANL has responsibility to deliver hardware, but not ultimately operate the systems, and therefore had to work with ORNL to define the handoff timing and criteria. These handoff criteria were defined in 3 documents, one each for the high power RF, the High Voltage power conditioning, and the LLRF. One document could have sufficed, but the 3 documents lent themselves well to the organizational structure under which the work was being done. These documents all have performance criteria for the major parts of each system, and they have a definition of the 2 labs' participation in the handoff. The roles for LANL start as leading for the first few systems, then LANL generally mentors for a few systems, and ends up in a consulting role with ORNL having the lead. An issue which remains is how to do this transition from lead to mentor to consult, but still have personnel available when beam commissioning begins for the full accelerator.

5 SUMMARY AND ACKNOWLEDGEMENTS

The RF system for SNS has moved from design and development to the procurement/fabrication phase. Installation and commissioning is imminent.

The authors wish to acknowledge all of the people on both LANL's and ORNL's RF teams who are responsible for all of the accomplishments reported on in this paper. There is not room to list them all, but their work is greatly appreciated.

6 REFERENCES

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