A HIGH POWER TEST FACILITY FOR NEW 201.25 MHZ POWER AMPLIFIERS AND COMPONENTS*

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Abstract

A new test facility was designed and constructed at Los Alamos Neutron Science Center (LANSCE) for testing a new Thales TH628 Diacrode final power amplifier and associated driver stages. Anode power requirements for the TH628 are 29 kV DC, with 160 A in millisecond pulses, supplied by a 225 uF capacitor bank with a crowbar circuit to rapidly discharge 88 kJ of stored energy. Charging current was obtained by re-configuring a 2 MW beam power supply remaining from another project. The power tubes are operated with DC anode voltage, and beam pulsing is done with control grid bias switching at relatively low power. A new Fast Protect and Monitor System was designed to take samples of RF reflected power, anode HV, and various tube currents, with logic outputs to promptly remove high voltages, RF drive and beam pulsing during faults. The entire test system is controlled with a programmable logic controller through an operator GUI, for normal startup sequencing and protection against loss of cooling.. This test facility has been used over the past year to test the amplifiers along with high power coaxial components such as hybrid couplers and various water loads.

FACILITY

We have constructed a high power test facility simultaneously with the development of a new 201.25 MHz final power amplifier (FPA) for the LANSCE Risk Mitigation project. The facility has been available for development, production and testing of new amplifiers and has also been used for power supply, controls, coaxial component and tube testing for the new production systems. A block diagram of major components of the RF test facility is shown in Figure 1. As they have been discussed elsewhere [1][2], the power amplifiers will not be described further in this report.

We were fortunate to have ample electrical and water-cooling utilities in the former Low Energy Demonstrator Accelerator facility. Not only was building space available but also a pure water cooling plant, an overhead crane and a two-megawatt DC power supply were in place.

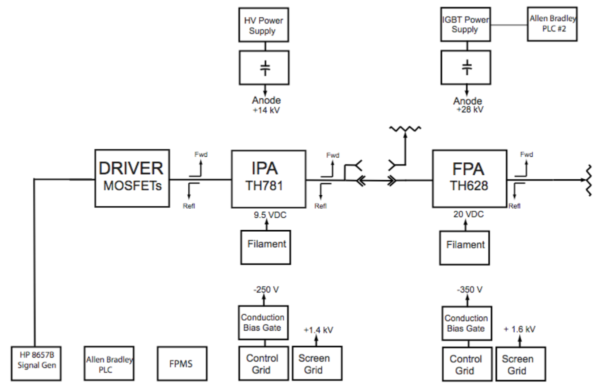

Figure 1: Block diagram of test arrangement.

A permanent steel platform was constructed for safe and convenient access to the top of the FPA. A water manifold was installed at this level with valves, flow sensors, and hose fittings. The platform supports the end of the 22.8 cm diameter coaxial transmission line to an RF load. Below the platform are two cooling blowers, tuner mechanisms, a resistive RF load, and a 7.9 cm diameter coaxial line from the driving amplifier. The FPA can be rolled through an opening into the center of the platform for testing, as shown in Figure 2.

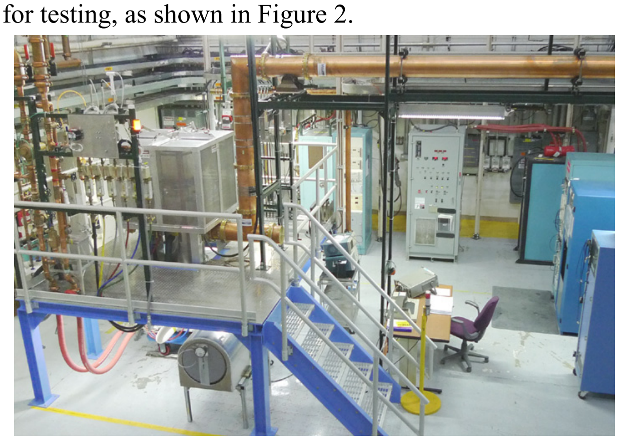

Figure 2: FPA at platform with ancillary equipment.

All power supplies and control systems for this test facility, with exception of the anode power supply, are the same as will be used for the three new RF systems at the LANSCE DTL. The anode power supplies for each FPA in the DTL RF systems use conventional three-phase AC transformer/rectifier sets with capacitor banks of the same stored energy as the test facility.

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ANCILLARY COMPONENTS

Filament Power Supplies

The filament power supplies for both tubes provide direct current. The TH628 Diacrode for the FPA requires 19 V at 950 A, provided with a pair of master-slave parallel Sorensen SGA switch-mode power supplies. The TH781 tetrode for the intermediate power amplifier (IPA) requires 12 V at 350 A, provided by another SGA power supply. The master controller provides a slow ramped control voltage for the supplies, to protect the filaments from mechanical stresses during power up and switch-off.

Grid Power Supplies

Control grid (g_1) bias voltage for each tube is supplied by a combination of a Glassman switch-mode power supply, along with a unique circuit that switches between cutoff (-650V) and high-current conduction levels, to modulate each tube's electron beam from zero current to quiescent (class B) anode current at the desired duty factor. The circuit uses three 1200V, 43A insulated-gate bipolar transistors that are optically driven by timing logic. A low value shunt resistance is switched into use only during the quiescent period to minimize power required during the cutoff state.

Screen grid (g_2) DC power for each tube is supplied by another Glassman switch-mode power supply with low stored energy and high peak current capability. For the TH781 it is a 3 kW power supply and for the TH628 it is rated at 10 kW. Fourteen control grid and screen grid power supplies have already been tested in the facility to be ready for installation beginning in 2013.

Anode Power Supplies

Anode DC power for the FPA under test is provided from a capacitor bank containing 225 uF, charged to 22-29 kV DC. Installation of the compact 88 kJ bank was completed in 2008, using 18 parallel capacitors, an ignitron crowbar device and current limiting resistors. The charging power supply must deliver up to 40 Amps DC. The idle LEDA facility contained several two-megawatt CW klystron beam power supplies from Continental Electronics, rated for 95 kV at 21 Amps. They use a series-arrangement of 96 1.1 kV DC power supplies, each powered by isolated transformer secondaries [3].

The company provided a modification to reverse the polarity and change the output to 40 kV at 40 Amps DC for one of the power supplies. The capacitor bank and power supply were successfully tested at maximum-pulsed current load (200 Amps) in December of 2009, using a ½ Megawatt tetrode-based pulsed anode modulator borrowed from the LANSCE RF equipment. This validated the stability of the modified power supply/capacitor bank before connecting it to the new amplifier.

A spare anode power supply made by NWL has been borrowed from the LANSCE RF equipment to provide anode power for the TH781 tetrode IPA. Six of these power supplies are being rotated into the new test facility to be tested with pulsed high current operation.

RF Coaxial Components

A coaxial water load using a weak electrolyte solution was tested in a parallel program [4]. The 22.8 cm diameter water load was originally made to operate with a higher concentration (30%) of sodium nitrite in water, while the new solution using a commercial corrosion inhibitor has less than 0.3% of solute. This has been installed in the new test facility with a small heat exchanger and pump remaining from another project. The heat exchanger has limited the maximum average power to 250 kW so far, so is being replaced with a larger unit to remove this limitation.

A 3 dB branch hybrid employing 30.5 cm diameter coaxial line has been fabricated by Mega Industries, to power combine a pair of FPAs at each RF station for the LANSCE linac. The first hybrid has been tested as a power splitter by feeding it through one port, with two water loads and a resistor load at the remaining three ports. Figure 3 shows the device being fed power from the FPA. Because of the heat exchanger limitation, 3 MW peak power testing was done at reduced duty factor. The hybrid was successfully tested at 2 MWp at 12% DF, or 240 kW average power.

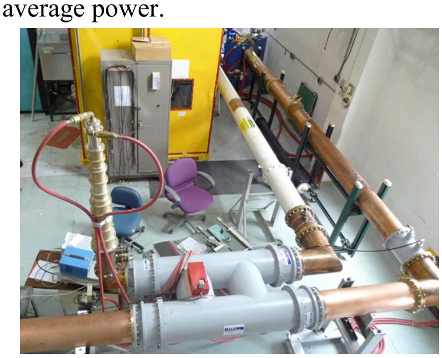

Figure 3: High power coaxial hybrid in test.

A 3-dB hybrid employing 7.9 cm diameter coax and a mechanical phase shifter were also supplied by Mega Industries. They will be used to divide output of a single IPA to feed a pair of FPAs, and adjust the phasing between the two FPAs. The first items will be tested in 2012 with the TH781 IPA driving an Altronic Research resistive load mounted under the work platform.

CONTROLS

The test facility is controlled with two separate systems that work together for critical protection functions. The master controller is a commercial programmable logic controller and handles slower equipment protection and control requirements. The second control system is called Fast Protect and Monitor System (FPMS). Both systems have firmware that can be updated to reflect improvements to the control scheme and to implement configuration changes such as various test modes.

Programmable Logic Controller

An Allen-Bradley RSLogix 5000 system has been used in the test facility initially, during the development and testing of new amplifiers and components. It handles cooling measurement, equipment access interlocks, power supply control and monitoring, and timing of the turn-on and turn-off sequences. Approximately 85 channels of analog and digital signals are wired into the PLC through standard I/O subsystems. The PLC provides a human-machine interface for system operation and status display through AB Panelview (Figure 4). For the production systems, a new logic controller is in development using National Instruments cRIO-standard hardware. This will first be implemented in the test facility in 2012 to replace the original master controller.

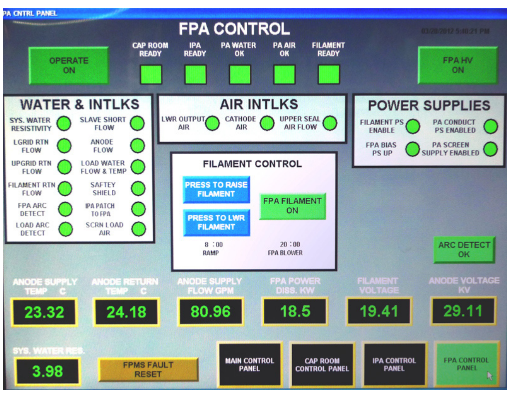

Figure 4: FPA controls in Panelview.

FPMS

The FPMS was designed to provide fast protection of critical tube current and RF power faults. It also displays meaningful RF peak power levels for up to eight readings, referenced by a selectable sample gate during the RF pulse. FPMS provides timing for the grid bias voltage pulses and the RF drive. In the event of faults, FPMS stops the grid pulses and RF drive in less than 6 µS, and passes the information to the PLC for fault display and further shutdown of power supplies.

The logical elements are designed with two Altera Cyclone III FPGAs to allow for future flexibility. Final calibration of various analog read backs is provided by multiplying DACs for gain setting along with setting trip points. Combinatorial and sequential logic provide protection in coordination with the PLC. Front panel indicators provide status of the FPMS (Figure 5). The front panel legends are printed on a film overlay. In this manner, the basic FPMS chassis can be used in a variety of amplifier applications, such as dual/combined or a single tube without a driver stage, for the different DTL RF systems at LANSCE. Only the firmware must be changed, along with the overlay, to reconfigure FPMS.

Provisions in FPMS provide for the PLC to obtain its status. A serial data communication interface is provided for EPICS interface. FPMS supplies calibrated buffered outputs of all monitored analog signals for local oscilloscopes. All I/O is routed through a RF filtering network before going to the main logic board.

Figure 5: FPMS front panel.

The original LANSCE 201 MHz RF plant used modified Narda peak power sensors of analog design, for display of RF power levels throughout the cascade of amplifiers. They have limited dynamic range (30 dB) and are very expensive for multiple locations. For the new systems, a sensor head was developed based on an Analog Devices power detector IC that has sufficient accuracy and wide dynamic range, having calibration terms and offset values stored in look-up tables. FPMS can query the values of each sensor through a differential digital interface for display on the front panel and through EPICS.

CONCLUSION

A flexible high power test facility has been designed and constructed to allow testing of new RF power amplifiers and components at 201 MHz. It was commissioned during the fall of 2010 and has allowed full power testing of a new FPA. It will operate independently during the lifetime of the LANSCE facility, which is being extended through the installation of new RF systems and other upgrades.

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