NEW HIGH POWER TEST FACILITY FOR VHF POWER AMPLIFIERS AT LANSCE*

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Abstract

A new test facility was designed and constructed at Los Alamos Neutron Science Center (LANSCE) for testing the Thales TH628 Diacrode® and TH781 tetrode power amplifiers. Anode power requirements for the TH628 are 28 kV DC, with peak currents of 190 Amperes in long pulses. A charging power supply was obtained by re-configuring a 2 MW beam power supply remaining from another project. A traditional ignitron crowbar was designed to rapidly discharge the 88 kJ-stored energy. The anode power supply was extensively tested using a pulsed tetrode switch and resistor load. A new Fast Protect and Monitor System (FPMS) was designed to take samples of RF reflected power, anode HV, and various tube currents, with outputs to quench the HV charging supply, remove RF drive and disable the conduction bias pulse to the grid of each tube during fault events. The entire test stand is controlled with a programmable logic controller (PLC), for normal startup sequencing and timing, protection against loss of cooling, and provision for operator GUI.

FACILITY

We have constructed a high power test facility simultaneously with the development of a new very high frequency (VHF) final power amplifier (FPA) for LANSCE. The test system is independent of the accelerator complex, allowing for continued operation of the original 200 MHz RF plant, while finishing the development, production and testing of new amplifiers. The facility will also be used for component and tube testing in the years ahead.

We were fortunate to have ample electrical and water-cooling utilities as part of the surplus Low Energy Demonstrator Accelerator (LEDA) RF plant. Not only was building space available but also an overhead crane and a two-megawatt DC power supply were in place. A steel platform was constructed at a work height for personnel to easily access the top of the final power amplifier for service. A water manifold was built at this level with instrumentation, valves and hose fittings for the amplifier. Below the platform are the cooling blowers and tuners for the amplifier. The amplifier can be rolled to the center of the platform through an opening. The platform also supports the end of the 22.8 cm diameter coaxial transmission line to the water load and the 7.9 cm line from the driving amplifier. In this manner it is a ‘docking station’ for the power amplifier (Figure 1).

Figure 1: FPA at platform with ancillary equipment

A block diagram of major components of the RF test facility is shown in Figure 2. The amplifiers have been discussed elsewhere and will not be described further in this report [1][2][3]. The power supplies and control systems for this test facility, with exception of the anode power supply, are the same as will be used in the installation of the new RF systems at the LANSCE DTL. The anode power supplies for the DTL RF systems use conventional three-phase AC transformer/rectifier sets with capacitor banks of the same stored energy as the test facility.

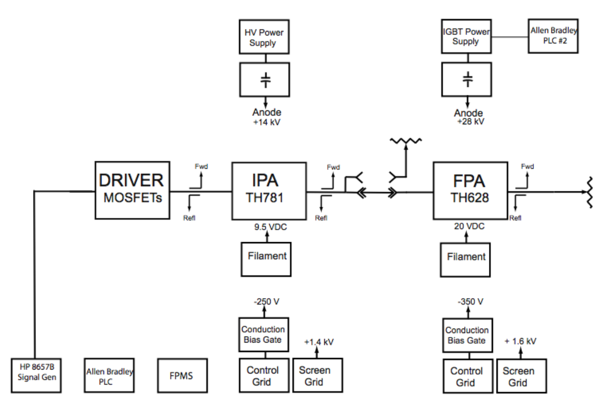

Figure 2: Block diagram of test system.

* Work supported by the United States Department of Energy, National Nuclear Security Agency, contract DE-AC52-06NA25396
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ANCILLARY SYSTEMS

Filament Power Supplies

The filament power supplies for both tubes provide DC to prevent hum modulation, as the cathode is DC grounded. For the TH628 Diacrode® the requirement is 19 Volts at 1000 Amperes, provided with a conventional thyristor-regulated mains supply. The TH781 tetrode requires 12 Volts at 350 Amperes, provided by a compact switch-mode power supply. Both have ramped-on and -off voltages to protect each filament from mechanical stresses during power up and switch-off.

Grid Power Supplies

Control grid bias voltage for each tube is supplied by a combination of a Glassman switch-mode conduction 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 cutoff to quiescent (class B) bias at the desired duty factor. The circuit uses three 1200V, 43A insulated-gate bipolar transistors (IGBT) that are optically driven from timing logic. A low value of shunt resistance is switched in during the conduction state only, using one IGBT, to minimize supply dissipation during the cutoff state.

Screen grid DC power for each tube is supplied by another switch-mode power supply with low stored energy but high peak current capability. For the TH781 it is a 3 kW power supply and for the TH628 it is rated at 10 kW.

Anode HV Power Supply

Anode DC power for the Diacrode® is provided from a capacitor bank containing 225 uF, charged to 23-28 kV DC, along with an ignitron crowbar device and resistors. The 88 kJ bank uses eighteen capacitors in parallel, each with series limiting resistors, in a very compact arrangement (Figure 3). The charging power supply is required to deliver up to 40 Amps. This represents a large, costly unit. The idle LEDA facility contained a two-megawatt CW klystron beam power supply, made by Continental Electronics [4]. As shown in Figure 4, it uses a series-arrangement of 96 1.1 kV DC power supplies, each powered by isolated transformer secondaries. The LEDA power supplies could provide up to -95 kV at 21 Amps. Design changes were recommended by the manufacturer and installed at LANSCE.

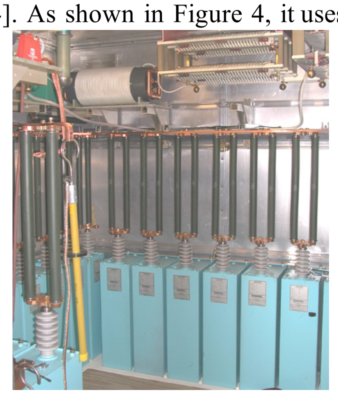

Figure 3: 88 kJ capacitor bank

The wiring of the individual IGBT-switched power modules was reconfigured to make a power supply capable of up to 45 kV at 40 Amps, with the negative terminal grounded as required for a gridded tube. The power supply and capacitor bank were successfully tested at maximum-pulsed current load (200 Amps) in December of 2009, using a ½ Megawatt tetrode-based pulsed modulator borrowed from the LANSCE RF equipment. This was done to validate the stability and regulation characteristics of the modified power supply before connecting it to the new amplifier.

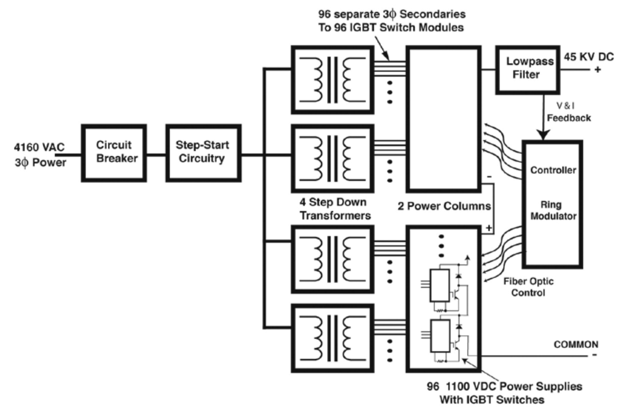

Figure 4: Diagram of TH628 anode power supply.

For the TH781 tetrode, a commercial (NWL) power supply has been borrowed from the LANSCE RF equipment to provide anode power.

RF Load

A coaxial water load system using a weak electrolyte solution was tested in a parallel program [5]. The water column load was originally made to operate with a higher concentration of sodium nitrite and water, but the new solution has lower solute content, less than 0.1%. This has been installed in the new test facility with a small heat exchanger and pump. There is a location for removing one section of coaxial transmission line to test a companion Y-junction circulator for the FPA, with addition of a second RF load.

CONTROLS

The test facility is controlled via two separate systems that tie together for critical functions. The lower level system is based on commercial programmable logic controller and handles slower equipment protection and control requirements. The higher level 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

This electronic control system is an Allen Bradley RSLogix® 5000 system. 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 5).

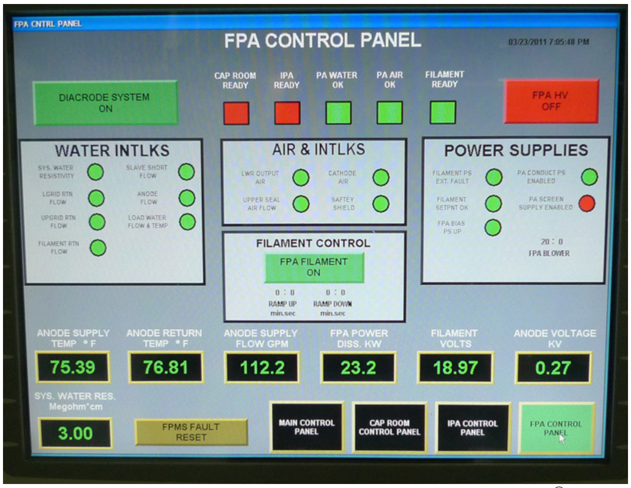

Figure 5: Power amplifer controls in Panelview®

FPMS

The Fast Protect and Monitoring System (FPMS) was designed in-house to provide fast protection of critical tube current and RF power faults. It also displays accurate RF peak power values for up to eight readings, referenced to a timing offset from the beginning of each RF pulse. The FPMS provides timing between the grid bias voltages and the RF pulses. In the event of faults, FPMS kills the pulses 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 that are set by firmware along with trip points. Combinatorial and sequential logic provide protection in coordination with the PLC. Front panel indicators provide status of the FPMS (Figure 6). 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 and single tube without extra driver stage, for the different DTL RF systems at LANSCE. Only the firmware must be changed, along with the overlay, to reconfigure FPMS.

Provisions are provided in the FPMS for the PLC to obtain its status. A serial data communication interface is also provided for EPICS data acquisition and setting of the timing offset of RF readings. FPMS supplies calibrated buffered outputs of all monitored analog signals. All I/O is routed through a RF filtering network before going to the main logic board. The temporal response of the signals is approximately 4 microseconds due to this filtering.

COMMISSIONING

The new test facility installation was completed in September of 2010. Minor changes were made to correct noise or grounding issues to FPMS, PLC and several power supplies. After safety reviews, calibrations, documentation and procedures were completed, testing began for the TH781 intermediate power amplifier. Testing of the TH628 FPA began in October. The only significant test facility downtime has been attributed to a failed RF load due to a loose connection and water quality problems with the load coolant.

CONCLUSION

A flexible high power test facility has been designed and constructed to allow testing of new RF power amplifiers. It was commissioned during the fall of 2010 and has allowed full power testing of a new FPA for LANSCE. We acknowledge significant collaboration between the AOT-Division radio frequency and mechanical groups that made this project successful.

Figure 6: FPMS

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