ESS Klystron Production Test Stand

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***Abstract*— Diversified Technologies, Inc. (DTI) has delivered a new long-pulse modulator klystron test stand to Communication and Power Industries (CPI) in Palo Alto, CA for full power testing of production VKP-8292A klystrons for the European Spallation Source (ESS). The output is flat to less than 0.5% over 3.3 ms. This test stand was built using hardware and designs from an earlier SBIR effort for the Department of Energy, with modifications to support ESS requirements and klystron testing operation. Earlier versions of this design are in use at IPN Orsay and CEA Saclay in France to test RF components for ESS.**

Keywords—klystron, test stand, high voltage, modulator

I. Introduction

DTI has delivered a new long-pulse modulator klystron test stand (Fig. 1) to Communication and Power Industries (CPI) in Palo Alto, CA for full power testing of production VKP-8292A klystrons for the European Spallation Source (ESS). This test stand was built using hardware and designs from an earlier SBIR effort for the Department of Energy, with modifications to support ESS requirements and klystron testing operation. Earlier versions of this design are in use at IPN Orsay and CEA Saclay in France to test RF components for ESS.

This new klystron test stand allows testing of klystrons at the full ESS specifications: 120 kV, 50 A, 3.5 ms pulse, 14 Hz (Table 1), with margin for operating at voltages up to 130 kV. Fig. 2 shows a cathode pulse from the system. This design is based on a (patent pending) non-dissipative regulator that compensates for the capacitor droop voltage (~20%) during the pulse. This allows a much smaller capacitor than would nominally be required for the long ESS pulse, eliminating the need for a larger, more expensive capacitor bank. This test stand will speed delivery of ESS klystrons, and similar, long pulse, high power klystrons at CPI. Test voltages with and without the regulator are shown in Fig. 3 and Fig. 4.

II. Controls Cabinet

The control cabinet houses the main system controls and interface, as well as most of the power distribution. The cabinet is divided into separate compartments to accommodate AC power distribution, low voltage DC utility distribution, and the controls section which includes the control boards and the Programmable Logic Controller (PLC) for system sequencing and other functions.

A 19” rack contains power supplies for the transformer bias, solenoid, and vac-ion pump, and also the arc detector.

Fig. 1. ESS Klystron Test Stand, showing controls and auxiliary supplies in the left cabinet, the high voltage power supply (center-left), the high voltage modulator cabinets (center-right), and transformer (far right).

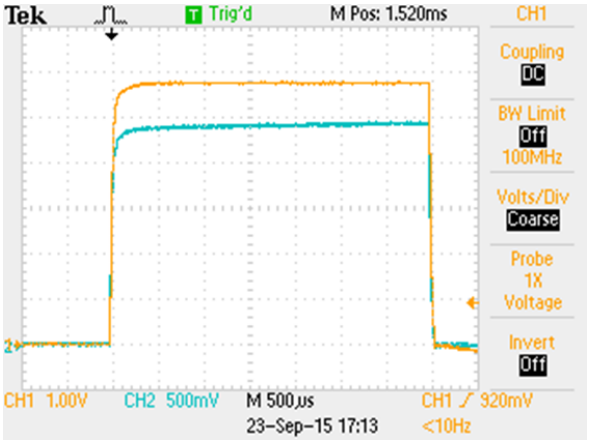

Fig. 2. Voltage and current waveforms of the ESS modulator.
Ch 1 (yellow) Voltage, 20 kV/div, 117 kV peak.
Ch 2 (blue) Current, 10 A/div, 48 A peak.
Time: 500 µs/div; pulse is 3.5 ms.

TABLE 1. TEST STAND SPECIFICATIONS

Specification	Parameters
Max. Output Voltage	130 kV
Max. Output Current	50 A
Maximum Frequency	50 Hz (limited to 240 kW avg.)
Maximum Duty Cycle	4 %
Maximum Pulse Width	4 ms
Flat-top	< 0.5 % over 3.28 ms
Pulse Rise time	130 µs 10-99 %
Pulse Fall time	60 µs 99-10 %
Cathode Pulser Voltage Range	30 kV – 120 kV

III. HIGH VOLTAGE POWER SUPPLY

The HVPS is a switching power supply assembly which operates at 6 kV DC at up to 40 A. The HVPS high voltage output is supplied to the capacitor bank in the modulator. This high stability/low noise unit operates from 480 VAC, 60 Hz three-phase input.

The HVPS uses an advanced PWM inverter to provide voltage and current regulation over the full output range. Nominal output behavior is 0.1% ripple and voltage regulation, with fast response to transients. Internal filter components reduce the line disturbance to modest levels. The high voltage section is built into a small tank filled with transformer oil. A heavy duty high voltage cable connects the power supply to the modulator. A front panel provides local controls, indicators, and voltage/current limits for the collector HVPS.

IV. MODULATOR

The modulator is enclosed within a NEMA cabinet. The bottom half of the cabinet contains all the high voltage capacitors and their resistive bleeds, as well as the main dump circuit. The top half of the cabinet is split into front and rear halves.

The front of the modulator contains the two regulator assemblies consisting of respective line transformers, switches, gate drives, capacitive banks, and dump circuits. The active reset circuit and the freewheeling diode are also located in the front section of the modulator cabinet. The rear of the modulator contains the main switch assembly with its gate drives and the HVPS feed with its related passive components.

V. TRANSFORMER

The pulse transformer is similar to a heavy-duty power distribution transformer. The windings are on two core legs with the primary windings closer to the core and a single secondary winding around each primary. The primaries are connected in parallel and the secondaries in series. The transformer is housed in a steel tank based on standard DTI practice. Diagnostics and cooling hardware are housed in the tank along with the high voltage cable terminations.

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Fig. 3. Pulse voltage without the regulator, 200 V/div, 250 µs/div.

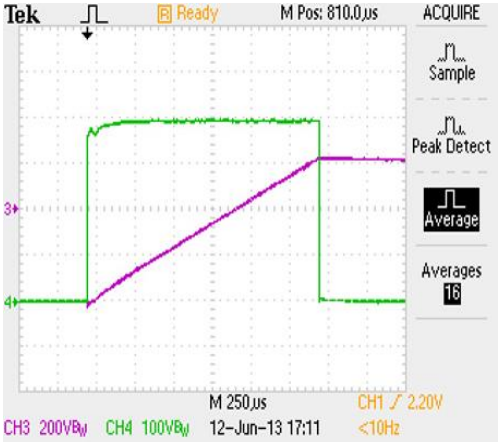

Fig. 4. Pulse voltage (green) and regulator voltage (purple) with the regulator, 200 V/div, 250 µs/div.