

SOLID STATE TRANSMITTER FOR A 2 MW KLYSTRON

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Abstract

Diversified Technologies, Inc. (DTI) built, tested, and shipped a transmitter for a 2 MW, 500 MHz klystron manufactured by Communications and Power Industries, Inc. (CPI). The transmitter design is based upon a hard switch topology that DTI previously delivered to the ISIS Front End Klystron Test Stand at Rutherford Appleton Laboratory, UK. The complete transmitter power system, pictured in Figure 1, consists of two 200 kW switching power supplies, a capacitor bank, a 100 kV solid-state hard switch modulator, control racks, and RF output and monitoring hardware. The modulator's specifications are shown in Table 1. A simplified schematic is shown in Figure 2.

ARCHITECTURE

The klystron beam power is generated by two high voltage power supplies, each capable of producing 200 kW CW power at 100 kV, with $\sim 0.1\%$ regulation. DTI has provided supplies of this type in a number of high power radar transmitters. In this design, the transmitter can operate at lower average power in the unlikely event a single power supply goes off-line.

The capacitor bank is sized to meet the 3% droop specification without the need for additional compensation or regulation. The $11.25 \mu\text{F}$ capacitor bank requires its own oil tank, which includes the bleed and dump resistors required for safe operation of the system.

Table 1. Specifications 2 MW Klystron Transmitter.

| Parameter | Modulator Specification |
|--------------------|-------------------------|
| Cathode Voltage | -100 kV |
| Cathode Current | 50 A |
| Voltage Regulation | 0.1% |
| PRF | Up to 1 kHz |
| Beam Pulse Width | 20 to 500 μs |
| Droop | 3% |
| Duty Cycle | 5% maximum |

This represents a large capacitor bank for a DTI transmitter system. If the required pulsewidth were longer than 500 μs , or the droop specification were tighter than 3%, this system would have been built with either a LC bouncer circuit, or an active regulator, to maintain the flat-top of the pulse.

The main solid-state switch consists of a series stack of commercial IGBTs, built with DTI's patented approach to series switching (Figure 3). This switch presents a very low impedance, low voltage drop ($\sim 320 \text{ V}$) path between the capacitor bank and the cathode, so the cathode voltage remains constant, independent of the beam current.

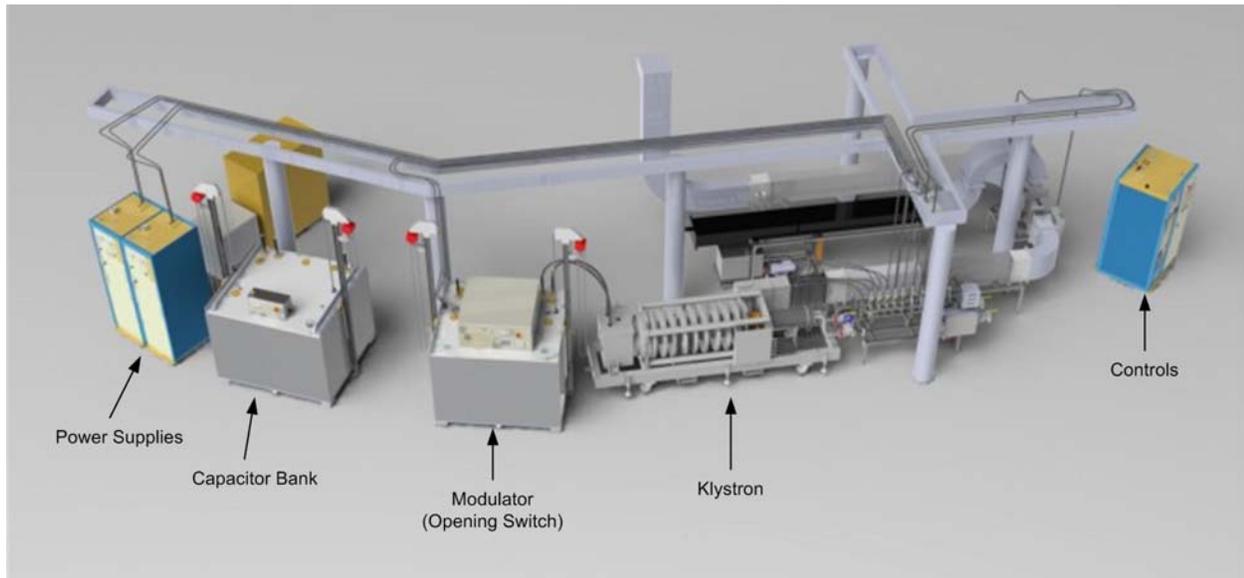


Figure 1. Rendering of full system assembly.

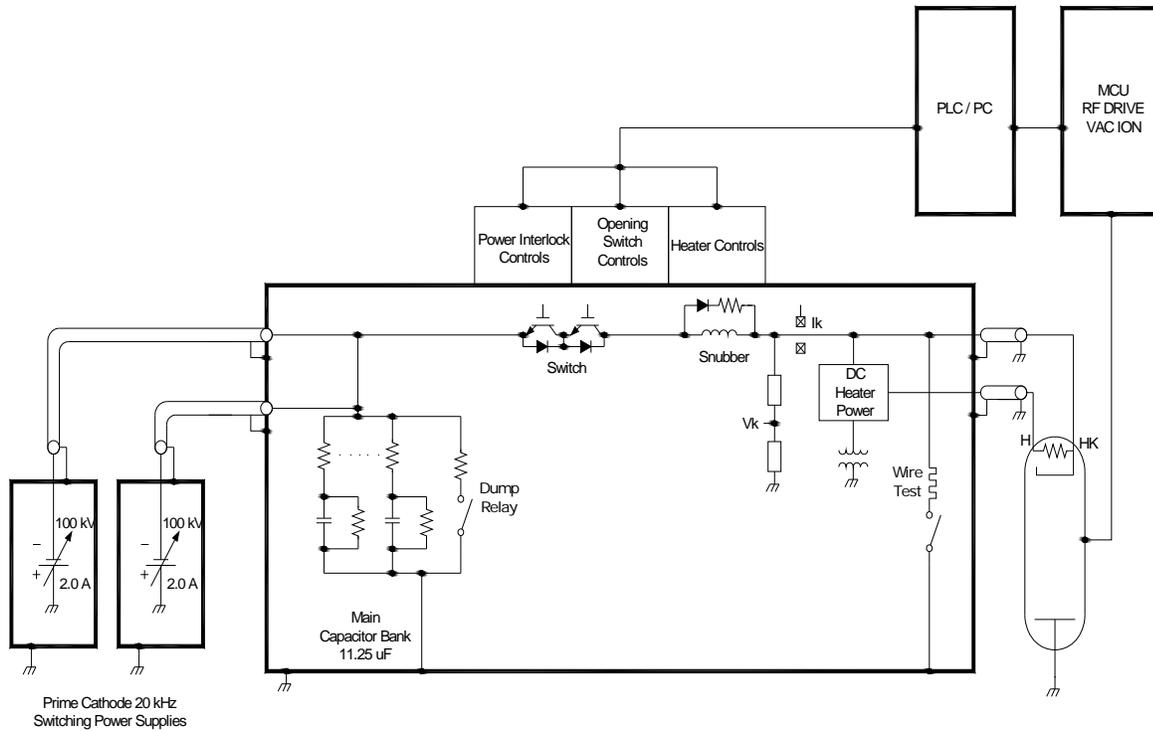


Figure 2. Simplified diagram of the 2 MW klystron transmitter.



Figure 3. Switch plate array in the transmitter's modulator. The entire assembly is submerged in oil.



Figure 4. Solid State Modulator tank, with controls located on the lid.

The modulator tank containing the solid-state switch is shown in Figure 4. The entire modulator assembly lifts directly out of the oil, without the need to disconnect any cables, for service.

The main solid-state switch serves two functions. First, it delivers HV pulses to the cathode of the klystron under normal operation conditions. Figure 5 shows a test pulse into a resistive load at 100 kV, 50 A, and 500 μ s. Rise and

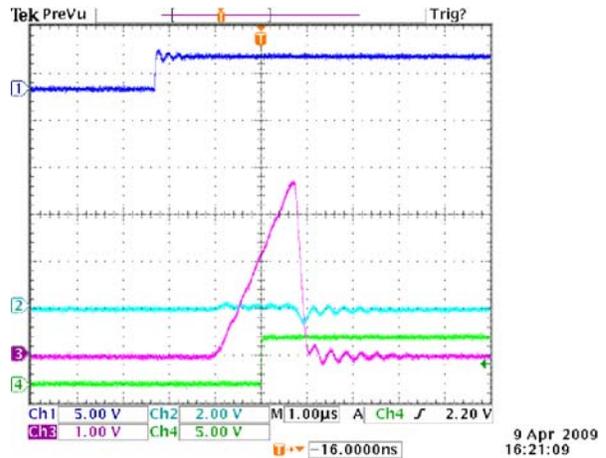


Figure 5. Scope trace shows shorting the cathode to ground through a length of #40 AWG wire. DTI's rapid fault detection and current limiting circuitry, leaves the wire intact. Switch opening occurs approximately 700 ns after the threshold current limit is reached, and the peak current remains below ~150 A.

fall times are $< 1 \mu\text{s}$. Secondly, the solid-state switch protects the klystron against arc damage. Fast current sensors in the modulator recognize the presence of an arc when the current in the switch exceeds a preset fault threshold value. When this occurs, the switch responds by opening in $\sim 1 \mu\text{s}$ to disconnect the high voltage from the klystron (Figure 5).

CONTROLS

The entire 2 MW klystron transmitter is controlled and monitored (Figure 6) through a three-level system, similar to other DTI transmitter control system designs. The first level, fast control and monitoring, provides fast response, hard-wired fault detection, and safety shutdown. The second level provides supervisory automatic controls and slower response fault detection via a commercial programmable logic controller (PLC). The third level consists of a PC based Graphical User Interface for local operator control and monitoring.

Interactive Touch Screens

DTI's transmitter control system offers several important features:

The baseline DTI operator interfaces use standard WindowsCE/Intel integrated color touch screen monitors (Figure 7). Communication between displays and PLCs is by standard Ethernet, using readily available switches.

All personnel safety interlocks (including the Kirk key system, door interlocks, capacitor discharge relays, and "panic" shutoff buttons) are fail-safe hardwired, with status monitored by the PLC. The PLC cannot reset or override such safety switches.

The automatic control system has four main sequential modes of operation, representing the major steps in transmitter activation (or, in reverse, shutdown). The control system handles all status checks, system enables, and other operations required for activating (in turn) Control Power, Filament Heaters, High Voltage, or Modulator/RF Enable. The system will automatically



Figure 6. Controls racks for the 2 MW klystron transmitter.

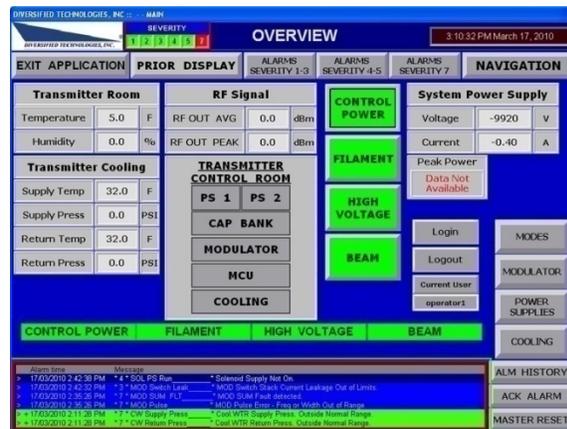


Figure 7. Screen shot of the transmitter overview touch screen control.

enforce sequencing through the modes required to reach each level of operation - for example, high voltage cannot be turned on before the filament is on and warmed up. Faults will shut the system down only as far as necessary

STATUS/CONCLUSION

The entire transmitter has been tested at DTI and successfully completed the customer's Factory Acceptance Test. Figure 8 shows a typical pulse. The transmitter is presently being installed and integrated with CPI's klystron at the customer's site.

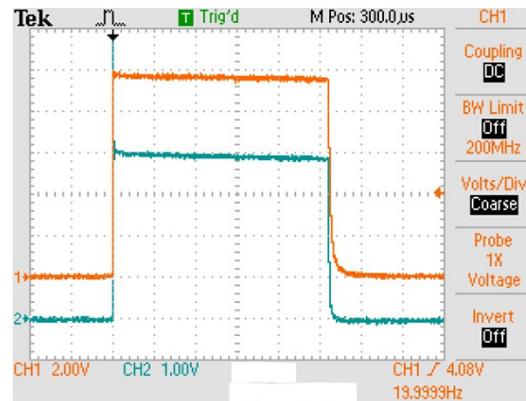


Figure 8. Scope shot of 100 kV pulse into resistive load, 520 μsec Ch1 V_k 99 kV (10 kV/div); Ch2 I_k 41A (10A/div).