500 MW, 300 kW MODULATOR

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Abstract

A 522 MW, 310 kW, 50 Hz computer controlled modulator was delivered after successfully completing a continuous 24 hour factory heat run at full power. The modulator uses four parallel PFN's each with 20 stages. The PFN's are operating at 72 kV with voltage regulation of ±0.2%. The modulator delivers more than 6 kJ per pulse at -600 kV in a 12 microsecond pulse. It is fully computer controlled. This paper describes the design and gives the factory test results.

Introduction

There is a growing interest for high power klystrons that can operate in the range of hundreds of megawatts to a gigawatt. Applications of this very high peak power include high power microwave transmission and RF sources for linear colliders. This has generated a demand for high power modulators to operate these klystrons. This modulator was designed and tested to meet the specified peak power and average power requirements stated below. Another important requirement was for the modulator to be as compact as possible. Figure 1 shows the modulator system.

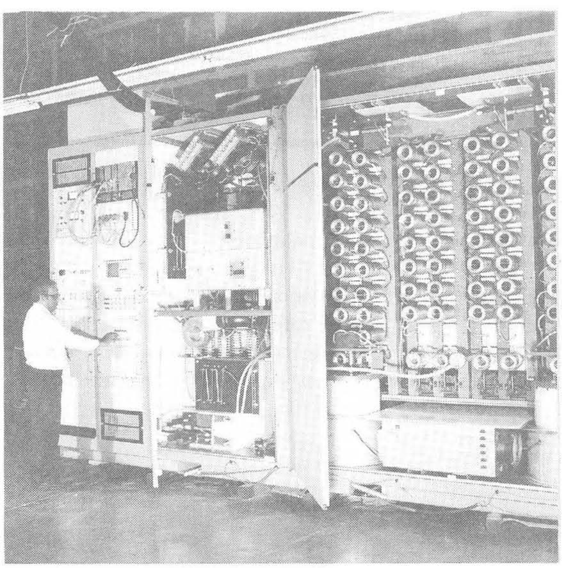

Figure 1

Specification

The modulator specifications are listed in Table 1.

Table 1

Pulsed Voltage	-600 kV peak maximum, adjustable between -200 kV and -600 kV
Pulsed Voltage Stability	±1200 V
Maximum Pulsed Current	-870 A @ -600 kV
Flat Top Width	10 microseconds
Flatness	±0.5%
Rise Time (10-90%)	1 microsecond
Pulse Width	12 μsec ESW
Continuous Repetition Rate	50 Hz maximum
PFN Impedance Mismatch	>5% at full load condition
Input Power Voltage	480V ±5%
Heat Rejection to Facility Air	12 kW maximum
Enclosure Dimensions	

Technical Description

Modulator Design

High Voltage Power Supply. The operating levels of the power supply are significantly higher than most systems, and this required special solutions. The high voltage power supply was designed for 42 kVDC at 10A and consists of a step-up transformer with rectifying diodes and filter caps on the output of the transformer. The primary of the transformer has a filter inductor to reduce harmonics in the AC power drop. A SCR controller is used on the front end of the transformer to help control the filter capacitor voltage. We were able to control the filter capacitor voltage to ±0.5%.

Resonance Charging System. The resonance charge system consists of a floating command charge chassis, a charging inductor with secondary winding for DeQing, blocking diodes and despiking circuit for transient protection. A thyratron is used for the command charging system.

PFN. There are four parallel PFN's in the system. Each PFN is a 20 stage unit with a characteristic impedance of 10 ohms nominal. The maximum operating voltage for the PFN is 72.5 kV. There is an end-of-the-line clipper used for each of the PFN's.

PFN Switching Thyratrons. Two high voltage thyratrons are used to discharge the PFN's. Each thyratron is connected to two of the four parallel PFN's. Because of the high operating voltage it took many hours to condition the thyratrons.

Cooling. The HV transformer enclosure, command charge thyratron, charging inductor enclosure, DeQing resistor and both PFN switching thyratron enclosures are cooled using circulating transformer oil which is cooled using an oil to water heat exchanger. In addition, four air to water heat exchangers are used to remove heat from the modulator enclosure.

Pulse Transformer Tank. The pulse transformer is closely coupled to the PFN's and has 15.75:1 turns ratio to provide the required output voltage and impedance match. Besides other auxiliary components, the tank also houses the dummy load, and voltage and current monitors.

Control System. The modulator is designed to be operated in either the Local Manual Control, Remote Manual Control or Remote Computer Control mode. The operator can remotely select any one of the three modes. Independent of the control mode, one can activate emergency off and HV off circuits for safety reasons. Independent of the control mode, the computer is capable of monitoring modulator status. All the faults are latched, typed and hardwired. The computer control mode has unique feature where pulsing of the modulator can be inhibited and enabled at full power. Analog fiber optic links are used to transmit critical signals to the remote location. The system has all the necessary diagnostics built into it and is available to the operator at the local control chassis.

Load Resistor. In addition to the development of the modulator a 500 kW, 600 kV load flowing liquid resistor system was developed in order to test the modulator at full power. This unit utilized a temperature regulated high fluid flow system that allowed resistance changes to properly match the PFN.

Test Results

After a conditioning period to bring the system to the full operating voltage the modulator was put through a series of performance tests. The modulator continuously ran for a twenty-four hour heat run and was operated into a dummy liquid resistor at full power. During this 24 hour heat run, the system had five arcs in the pulse transformer tank, six switching thyratron self breaks, one air arc in the PFN area, one control system noise related interlock trip, and one component breakdown problem. Operation of all the interlocks was also demonstrated. The load was a full power and also simulated an arc. PFN voltage regulation was demonstrated and was better than ±0.05%. Demonstration was also made of load voltage tunability and waveshapes. Maximum heat load from the modulator to the room was estimated to be less than 2.5 kW. Figure 2 shows the voltage and current waveforms at full power.

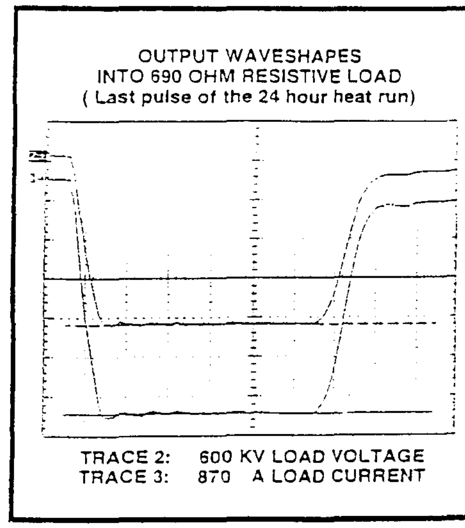

Figure 2

Conclusion

The line modulator can be used for the next generation of high power tubes as long as careful thought and consideration is given to designing the components and subsystems consistent with the higher average power and voltage regimes needed.