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COMPACT MEGAWATT AVERAGE POWER PULSE GENERATOR.(U)
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COMPACT MEGAWATT AVERAGE POWER PULSE GENERATOR

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November 1978

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Abstract:

A compact, lightweight, burst mode pulse generator has been designed and evaluated at a megawatt of average power. The modulator, occupies a volume of 0.81 cubic meters (m^3) and weighs 225 kilograms (kg). The recently developed MAPS 40 thyratron[1] and two high energy density pulse forming networks[2] (PFN) are used as the switch and energy store. A solid state end of line clipper circuit is included and was found to be essential at high average power loadings. The modulator has been evaluated using a copper sulphate load at 40 kilovolts (kV) peak voltage, 40 kiloamperes (kA) peak current, 10 micro-second (μs) pulse width, 40 kA per μs rise time, and 50 amperes (A) of average current at a repetition rate of 125 hertz (Hz). Repeated burst on times of 5 seconds in a 35 second time period have been demonstrated.

COMPACT MEGAWATT AVERAGE POWER PULSE GENERATOR*

By

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Summary

A compact, lightweight, burst mode pulse generator has been designed and evaluated at a megawatt of average power. The modulator, occupies a volume of 0.81 cubic meters (m^3) and weighs 225 kilograms (kg). The recently developed MAPS 40 thyratron[1] and two high energy density pulse forming networks[2] (PFN) are used as the switch and energy store. A solid state end of line clipper circuit is included and was found to be essential at high average power loadings. The modulator has been evaluated using a copper sulphate load at 40 kilovolts (kV) peak voltage, 40 kiloamperes (kA) peak current, 10 micro-second (μs) pulse width, 40 kA per μs rise time, and 50 amperes (A) of average current at a repetition rate of 125 hertz (Hz). Repeated burst on times of 5 seconds in a 35 second time period have been demonstrated.

Introduction

During the past few years, ERADCOM has been developing technology aimed at reducing the size and weight of line type modulators for high average power burst mode applications. In a typical burst mode system the on-time is relatively short, of the order of tens of seconds, while the off-time is from one to two hours. Since the on-time is short, the internal heat capacity of a component can be used as a heat sink and then normal conduction and convection cooling can be used during the off-period to remove the stored heat. Thus, an increased dissipation density in a low mass device can be sustained allowing the device momentarily to operate at higher energy and average power loadings than it would normally be rated for. This assumes that the device is otherwise designed for the voltage stress and can provide the peak, average and root mean square currents. While a detailed discussion of the pros and cons of various power conditioning approaches is not considered appropriate for this paper, it can be readily argued that the most feasible approach to high energy/high average power conditioning with moderate repetitive rate capabilities is that of a line type modulator circuit. Figure 1 shows the circuit. Although many factors influence this conclusion, the most important are system efficiency, high repetition rate capability and state-of-the-art component technology. Of these, the recent availability of high power thyratrons and high energy density pulse forming networks now gives a high probability of success with respect to achieving compact, lightweight megawatt (MW) pulse generators. The purpose of this paper is to demonstrate the availability of this new technology.

Megawatt Pulse Generator Design

The MW pulse generator is designed to be consistent with the performance characteristics of the MAPS-40 thyratron and the 4 kilojoule (kJ) PFN. Although the design was principally aimed at generating a 10 μs pulse the pulser is easily modified to produce a 20 μs pulse. Table 1 summarizes the basic electrical characteristics while Table 2 lists the overall mechanical characteristics and auxiliary requirements.

* This work was partially supported by US Army Missile Research and Development Command, Air Force Aero Propulsion Laboratory, and Naval Surface Weapons Center, Dahlgren Laboratory.

Table 1

Basic Characteristics of Compact Megawatt Pulse Generator

	Cond. A	Cond. B
Peak Voltage (kV)	40	40
Energy (kJ)	8	8
Peak Current (kA)	40	20
Peak Power (MW)	800	400
Average Current (A)	50	50
Average Power (MW)	1	1
Pulse Width (μs)	11	22
Rise Time (μs)	1	< 1
Pulse Repetition Rate (Hz)	125	125
Anode Delay Time (μs)	< 0.2	< 0.2
Anode Delay Time Drift (μs)	< 0.1	< 0.1

Table 2

Mechanical Characteristics and Auxiliary Requirements

Total Weight	225 kg
Volume	0.8 m^3
Grid Driver	2 kV, 50 ohm, 0.5 joules
Heater Power	1 kW at 15 volts ac
Reservoir Power	0.5 kW at 10-12 volts ac
Blower	50 watts

Figure 2 shows the layout of the PFN and switch. The switch, the MAPS-40 thyratron is located between the two PFNs. The thyratron cathode is electrically connected to the aluminum ground plate by four 2 x 15 centimeter (cm) posts spaced 90° apart. The thin cylindrical metal housing surrounding the base of the switch is a plenum wherein there is an ambient air flow around the base which is then directed onto the lower ceramic. Although this air flow is not essential for operation, it reduces the rate of oxidation at the heater and reservoir connections. In addition, on-time reliability is improved by keeping the ambient temperature of the ceramic envelope below 200°C.

A side view of the modulator, shown in Figure 3, shows the end of line clipper circuit. This circuit consists of a solid state diode[3] in series with a matched load. The series combination is connected in parallel with the end capacitors of the PFNs. The diode is made up of 40 each Westinghouse compensated diodes, type 1N4594. These diodes are rated for 1000 V peak inverse voltage at 150 A. The value of the resistor is 0.5 ohms, obtained by parallelling two one ohm resistor stacks, and it matches the impedance of the parallelled networks. Four Carborundum washer resistors (0.25 ohms each), type No. 916WSR25L, are stacked in series and then parallelled with an identical configuration to give the 0.5 ohms.

Not visible in the photograph are the filament and reservoir transformers which are mounted between the PFNs. For convenience, 60 Hz heater power was used. We have used 400 Hz power on another system which uses the MAPS-40 and in that case the combined weight of the filament supplies was reduced by a factor of two. External variacs are presently used to adjust heater power although ultimately it is expected that they will not be required.

The grid drive for the MAPS-40 is obtained from a EG&G TM30 which dimensionally is 14 x 10 x 30 cm and weighs approximately 7 kg. It provides a 3 μs wide 2 kV pulse from a 50 ohm source and its designed to operate up to 250 Hz. It also provides a negative bias of 125 volts to the control grid and a keep alive supply of 160 volts at 50 milliamperes (mA) to the auxiliary grid. The negative bias is not necessary for recovery at the 125 Hz rate, but the auxiliary keep alive discharge is necessary to assure achieving the anode delay time and anode delay time drift values listed in Table 1.

The sizes and weights of the various components making up the megawatt pulse generator are listed in Table 3. The dimensions include mounting structures when used.

Table 3

Size and Weight of Components

Component	Dimensions cm	Volume m^3	Weight kg
MAPS-40	23 Diam x 37	0.015	20
PFN (1)	53 x 16 x 88	0.075	57
PFN (2)	53 x 16 x 88	0.075	57
Clipper Diode	53 x 32 x 11	0.019	11.4
Clipper Load	27 x 29 x 13	0.010	9.1
Plenum	31 Diam x 15	0.011	3.9
Blower	9 Diam x 10	0.0006	1
Filament Transformer	17 x 15 x 20	0.005	15
Reservoir Transformer	12 x 24 x 14	0.004	6.5
Base	137 x 92 x 1	0.012	19
Totals		0.215	200*

* This weight does not include the lucite sides and top, wiring, and mounting hardware.

The aluminum base and lucite sides and top comprise the housing. It is planned to use external shielding which would be attached to the housing to reduce EMI. Overall dimensions of the pulse generator are 137 x 92 x 64 cm. Inside the housing, a conservative voltage stress of 4 kV/cm was used which permits operation in normal air environment. The resulting packing factor is 0.27 could be increased by 20-30 percent by employing more plane to plane surfaces in the high voltage areas or by the use of atmospheres such as sulphur hexafluoride. Both approaches would permit a higher voltage stress to be used thereby reducing the overall volume of the housing.

Performance Characteristics

Full power testing of the MW pulse generator was done using a 30 kV - 50 A dc power supply, operating with burst on times of up to 5 seconds. A 0.75 henry inductor was used to resonantly charge the networks to 40 kV while a liquid load[4] was used to terminate the pulser. The liquid load was a copper sulphate-sulphuric acid mixture contained in a low inductance assembly and it was adjusted to have an impedance of 0.45 ohms at room temperature.

Peak current/voltage waveforms under condition A are shown in Figure 4 (a) and (b), respectively which were taken during a one MW average power run. Figure 4 (a) shows peak current at 1 and 2 μs/cm. The peak current waveform was obtained using a Pearson current transformer. The vertical sensitivity is 20 kA/cm. The pulse width at the 70 percent value is 11 μs and the rise and fall times measured between the 10-90 percent values are 0.9 μs and 2.9 μs, respectively. The load voltage waveform shown in Figure 4 (b) was obtained using a resistance divider having a ratio of 10,600:1. PFN lifetimes in excess of 0.8 x 10^6 pulses have been demonstrated. One MW pulse generator has operated for over 300,000 pulses without a component failure.

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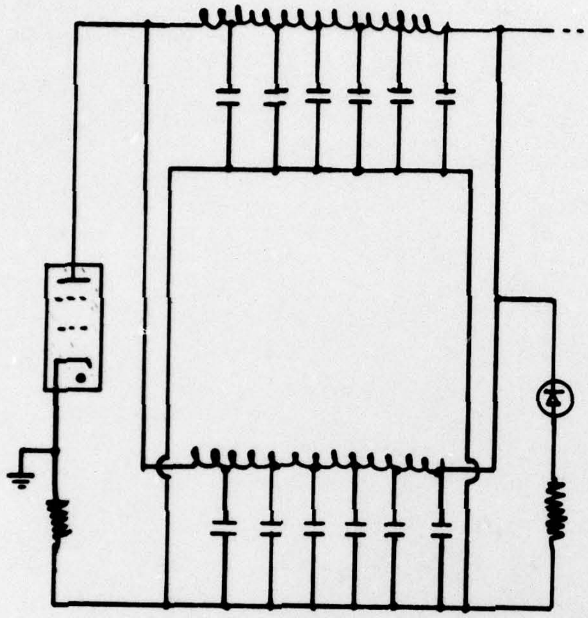

Fig. 1 Line type modulator, R_L = 0.5 ohms, R_C = 1.0 ohm, C_N = 5 μf, each individual capacitor equals 0.84 μf.

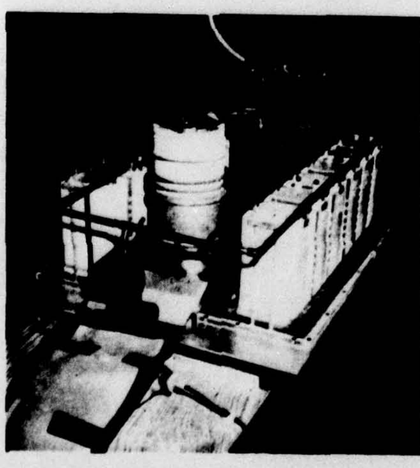

Fig. 2 View showing switch and PFN layout.

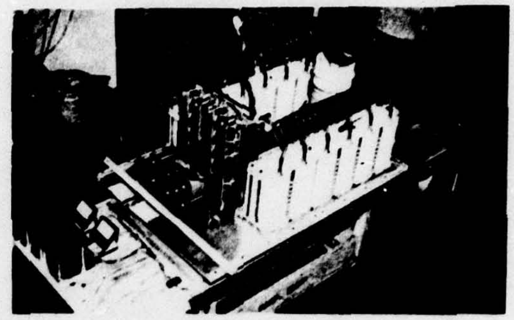

Fig. 3 View showing end of line clipper layout.

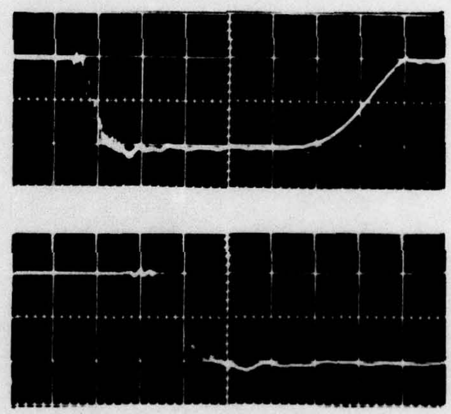

Fig. 4 (a) Peak current waveform at 5 and 1 μs/cm sweep speed.

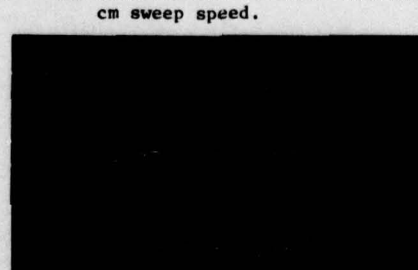

Fig. 4 (b) Peak current and load voltage at sweep speed of 5 μs/cm.