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SPARK-GAP CROWBAR FOR HIGH-VOLTAGE POWER SUPPLY*

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Summary

A new crowbar circuit employing a pressurized spark gap has been designed to replace the existing ignitron crowbar that protects a 500-kW klystron tube when it arcs. The spark gap offers definite performance advantages when compared to the conventional ignitron circuits. The small overall size makes the spark gap more convenient and the very few components make it more reliable than the ignitron crowbar.

Introduction

The pressurized spark gap is designed to protect a Varian klystron that delivers 500 kW cw at 2380 MHz. The beam supply to the tube at switch-on time is 28 kV and is continuously variable up to 65 kV. The EG&G spark gap GP-15B is suitable for the voltage ranges described above. The spark gap, the high-voltage pulse transformer, and the limiting resistor are all mounted in an oil tank. The tank has been tested to withstand 90 kV before any appreciable breakdown occurs. This is a satisfactory safety margin because the dc voltage on the spark gap will never exceed 65 kV. Figure 1 shows the spark gap and associated components out of the oil tank.

Figure 2 is the schematic of the spark-gap crowbar and firing circuit where the klystron has been replaced by the load. When the tube arcs, that is,

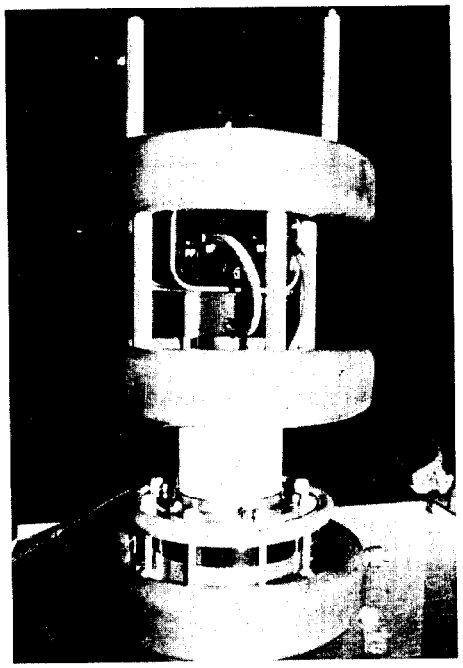

Fig. 1. The pressurized spark-gap assembly.

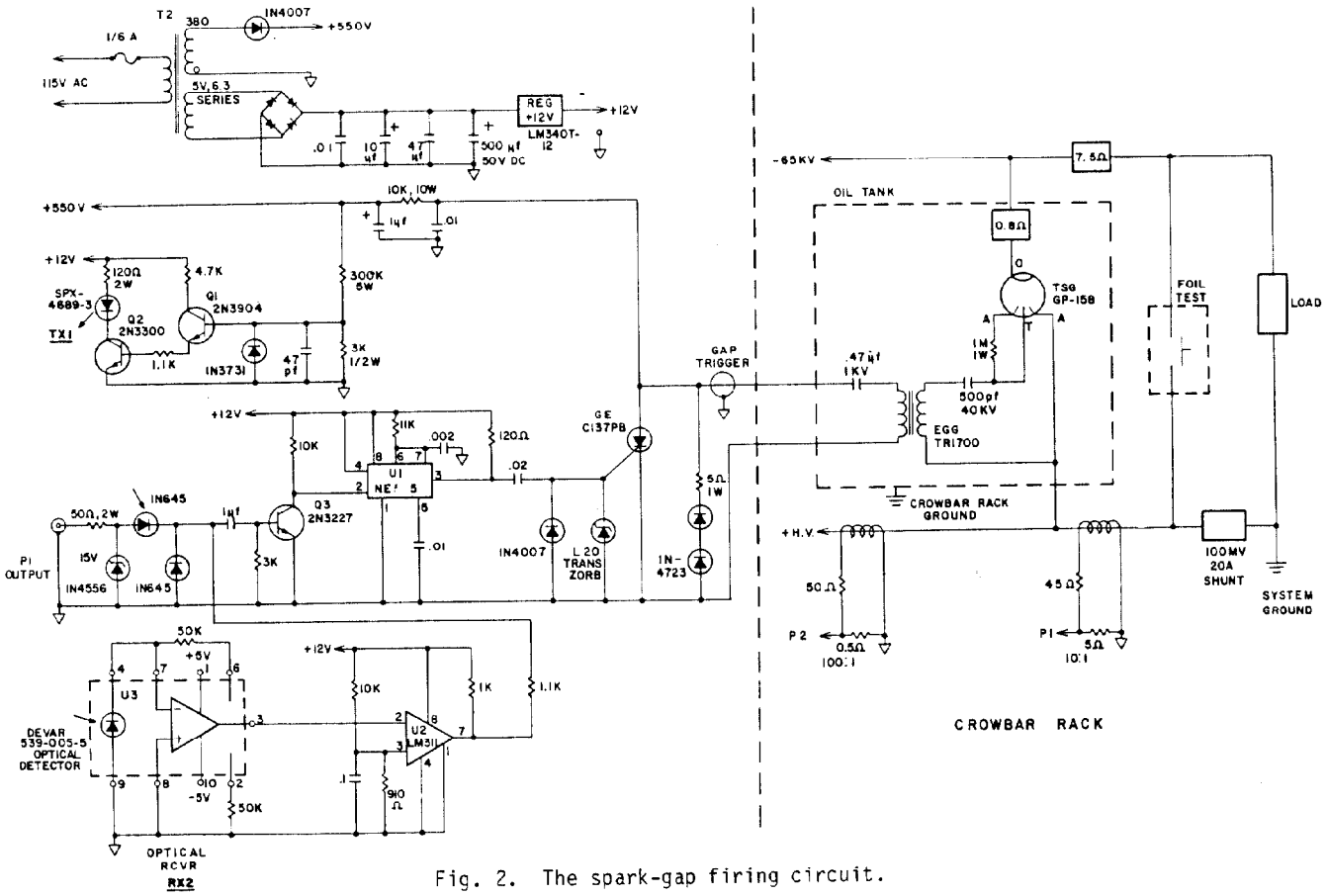

Fig. 2. The spark-gap firing circuit.

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when the load is momentarily shorted, current transformers P_1 and P_2 will produce a one-shot output at Pin 3 of 555 (U1), which in turn fires the SCR. The pulse transformer, EG&G TR 1700, produces 27 kV at the secondary terminals when the primary is at 500 V. The 27 kV will fire the spark gap, and, within 1 μs, the current surge flowing through the load is removed. The spark-gap firing circuit is enclosed in a separate box and can be conveniently located in or on the crowbar rack.

The current transformers P_1 and P_2 are also used for test and diagnostic purpose. The transmitter (TX1) is always on except when the 550-V power supply fails. The schematic shown in Fig. 3 is packaged in a NIM module, which is located in a rack 30 m from the spark-gap crowbar unit. The various system conditions are indicated by LEDs on the NIM module. Table I gives the complete list of sequences under different conditions.

Tests

The spark gap has been tested with the scheme shown in Fig. 4. The 5.5-μF capacitor is charged through a 4-MΩ resistor by the high-potting unit. A thin aluminum foil is kept on the foil tester, and the ball is dropped to simulate an arc through the tube. This test has been repeated from 28 kV to 40 kV, and a pin hole or no hole has been obtained on the foils; this indicates that the spark gap fired without damaging the foil (that is, the tube). The voltage was limited to 40 kV, the voltage rating of the capacitor. The NIM circuit was tested also and was found to function as anticipated.

TABLE I

CIRCUIT CONDITIONS OF SPARK GAP CROWBAR

CONDITION	LED INDICATION	INTERRUPT
SCR power supply failure	"READY" OFF	Ready interrupt Disables high-voltage power supply
Test fire	"READY" ON "TEST" ON "FIRED" ON	High-voltage interrupt Opens vacuum circuit breaker
Klystron arc	"READY" ON "FIRED" ON	High-voltage interrupt Opens vacuum circuit breaker
Spare gap pre-fire	"READY" ON "PRE-FIRED" ON	High-voltage interrupt Opens vacuum circuit breaker

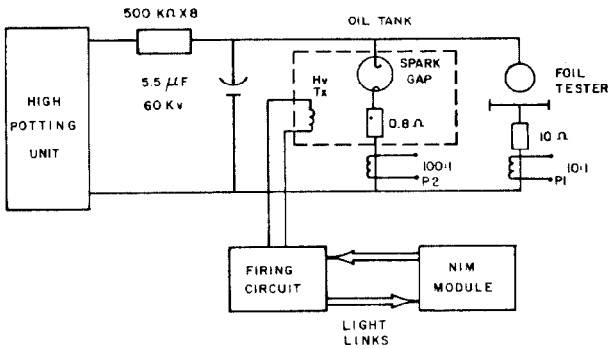

Fig. 4. Schematic of spark-gap crowbar test.

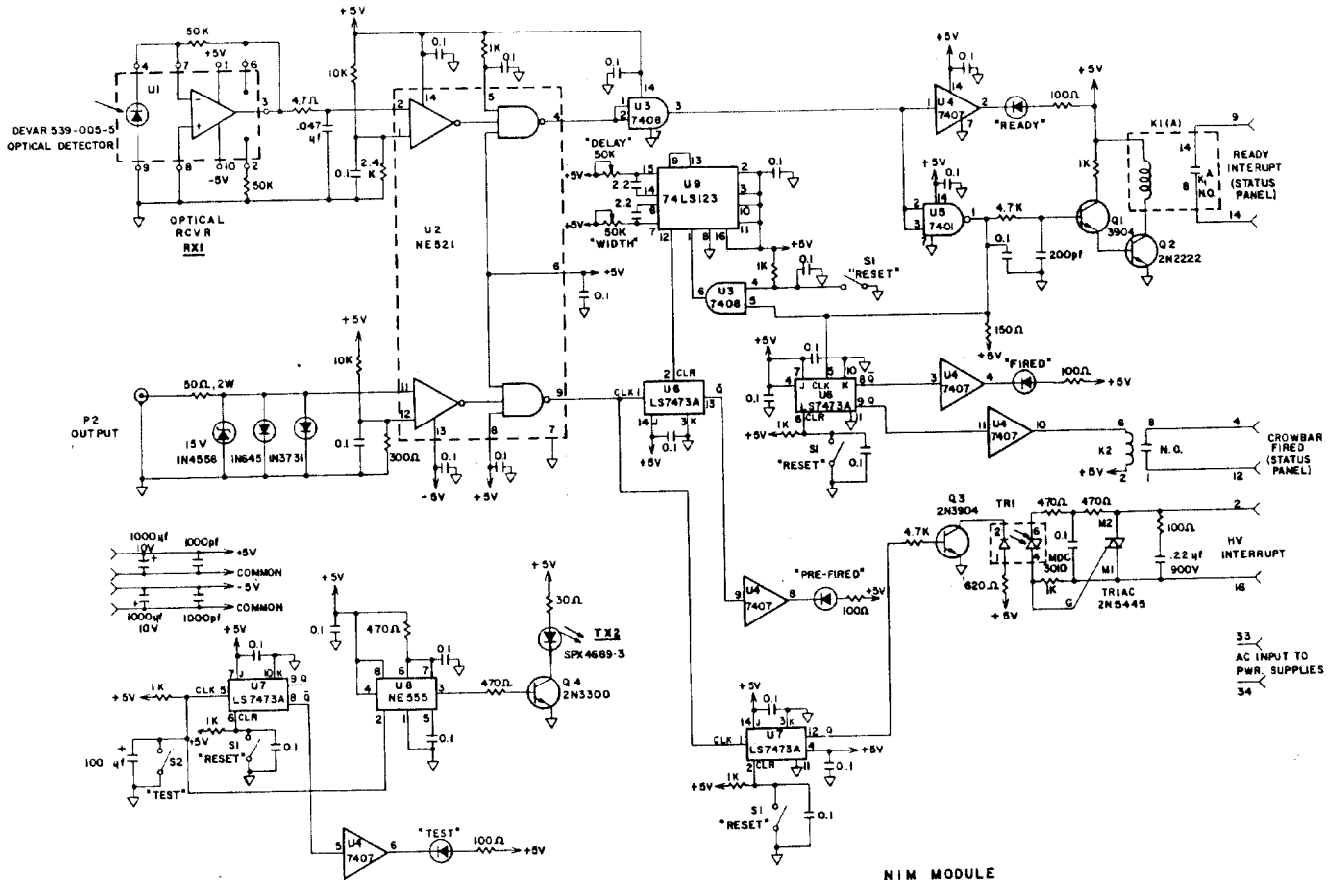

Fig. 3. Schematic of test and diagnostic circuit for the spark-gap crowbar.

The total delay measured between P_1 voltage output and the pulse transformer primary voltage is less than 1 μs. The delay between the trigger voltage (27 kV peak) and the spark-gap conduction is 120 ns, the manufacturer's specification. Hence, total time lapse between the tube arc and spark-gap conduction is ∿1 μs. This time lapse changes by a few per cent, depending on the magnitude of high voltage applied to the gap. The spark gap has yet to be tested with the klystron power supply that can be continuously varied from 28 to 65 kV and with the klystron tube replacing the load.

Remarks

The spark gap has distinct advantages over the ignitron crowbar because the response time, the number of components, and overall size are reduced by more than a factor of 4. An added advantage of the spark-gap circuit is that the SCR firing circuit is isolated from the high-voltage power supply. The reliability of the circuits is further improved because light links and insulated current transformers are used for firing, testing, and diagnostic purposes.

The spark gap, however, does not conduct reliably when the dc voltage is less than 26 kV. Also, if the power supply filter creates an underdamped case when the gap fires, the subsequent oscillations will not be handled by the gap. This shortcoming can be overcome, either by adding a series resistor to make the circuit overdamped or by a multiple firing scheme. The ignitron crowbar is superior in this respect because the length of conduction in an ignitron can be as long as 20 ms, and the ignitron will not extinguish if the current goes through zero.

Acknowledgments

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