

Dec. 24, 1968

W. H. CHEEVER

3,418,530

ELECTRONIC CROWBAR

Filed Sept. 7, 1966

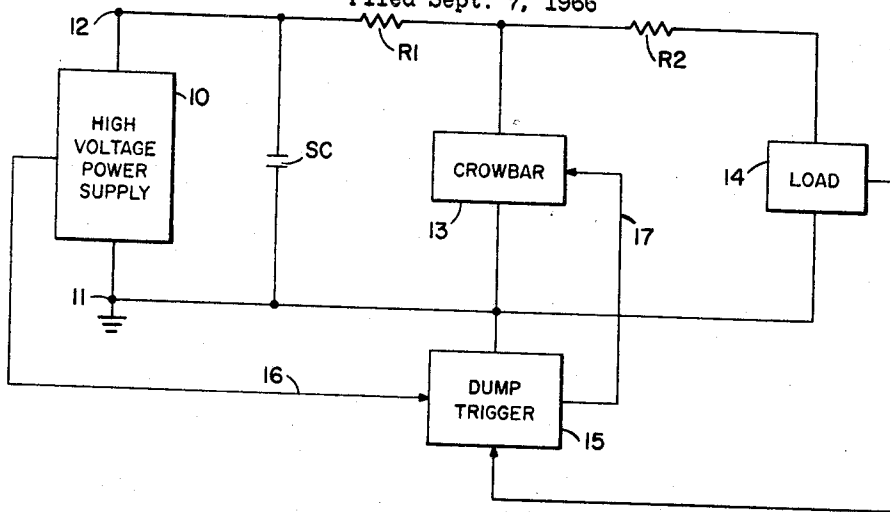


FIG. 1

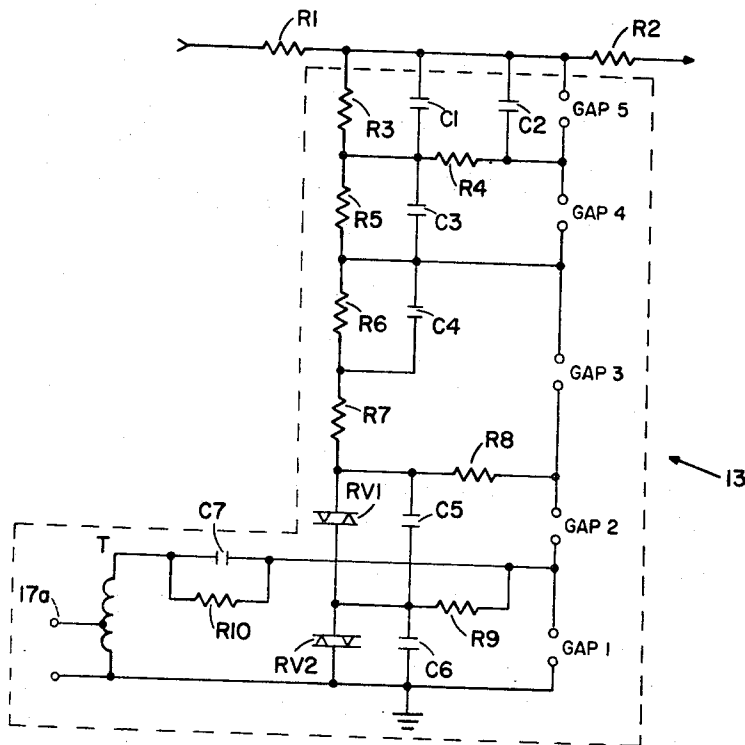


FIG. 2

William H. Cheever,
INVENTOR.

Harry M. Saragovitz
BY *Edward J. Kelly*
Herbert Paul
Aubrey J. Dunn

1

3,418,530

ELECTRONIC CROWBAR

William H. Cheever, Pennsauken, N.J., assignor, by mesne assignments, to the United States of America as represented by the Secretary of the Army

Filed Sept. 7, 1966, Ser. No. 578,424

1 Claim. (Cl. 317—16)

ABSTRACT OF THE DISCLOSURE

A plurality of spark gaps are provided between a high voltage source and ground. Each of the gaps has a resistor-capacitor combination thereacross. Varistors are connected across the gaps nearest ground to prevent discharges of the crowbar from gradual changes in the source voltage. A trigger means, in response to an abnormal condition, initiates a spark in the gap nearest ground. Successive gaps toward the source spark, until a low impedance path to ground is established from the source, through the gaps, to ground.

There is a need for some means for affecting rapid discharge of high voltage power sources, such as those used with long range radar. Such high voltage power sources use large filter or storage capacitors, and a sudden fault in loads attached to such sources can cause destructively high currents. Relays or fuses do not always provide sufficient protection, because of their relatively long reaction times. A crowbar, on the other hand, can provide an extremely rapid discharge path of a high voltage power source. Such a result is possible in view of the fact that a crowbar effectively provides a low impedance path across the high voltage source, and in parallel with the load. Such a low impedance path safely and rapidly discharges the power source and avoids damage to the load. High-power radar systems being operated or "debugged" for the first time (or having an output tube "seasoned") are prone to experience many faults at source voltages much less than the nominal operating value. Even these lower-voltage faults can cause severe damage if adequate protection is not available.

The invention crowbar employs a plurality of spark gaps in series across a high voltage source. Arcs are established in sequence across said gaps until a low impedance path is provided across the power source. Each of the gaps has impedances connected thereto. The gap nearest ground is caused to establish an arc by external means responsive to some load condition which would require operation of the crowbar. The establishment of an arc in the above gap induces an overvoltage for the next higher gap, which then establishes an arc, and so on up the line until a low impedance path is established across the power source; the impedances across each gap are so chosen that this action is possible.

An object of the invention is to provide a means for rapidly discharging a high voltage source.

Another object of the invention is to provide a means for protecting a load connected to a high voltage source in the event of a fault in the load.

The invention may be best understood by reference to the drawings, in which:

FIGURE 1 shows a schematic showing of a system in which the invention may be used, and

FIGURE 2 shows the inventive crowbar, in schematic form.

Referring to FIGURE 1, there is shown a high voltage power source 10 to connected to a storage capacitor SC. End 11 of the source is grounded, and the other end, 12,

2

is at a high potential above ground. A current limiting resistor R1 is connected from end 12 of source 10 to the junction of isolating resistor R2 and crowbar 13. Connected to the other end of R2 is a load 14, which load may be a high power radar system, etc. Each of the storage capacitors, the crowbar, and the load is connected to the same ground as source 10. There is also a dump trigger 15 which is connected to the load and is responsive to some abnormal or fault condition(s) therein, such as excessive current. Dump trigger 15 is supplied with power from high voltage source 10 through a path 16. When the abnormal condition occurs, dump trigger 15 provides a high voltage pulse and feeds it into crowbar 13 through a path 17, causing crowbar 13 to operate, and discharge capacitor SC to ground.

The operation of the crowbar 13 may be more easily seen by reference to FIGURE 2. Element 13 from FIGURE 1 is shown as a dotted line hexagon, also designated 13 in FIGURE 2. The circuit of FIGURE 2 has five spark gaps therein, designated 1-5, with R-C dividing circuits connected to each gap. Thus, there is connected across gap 5 resistor R3 and capacitors C1 and C2, with resistor R4 connected between one end of capacitors C1 and C2; connected across gap 4 is resistor R5 and capacitor C3, and so on. Across gap 1 is connected an autotransformer T, with one side of the transformer being grounded, and the other side connected through the parallel connection of C7 and R10 to the upper terminal of gap 1. Connected to a tap on transformer T is a terminal 17a, which would connect to path 17 of FIGURE 1. As explained above in the description of FIGURE 1, an abnormal condition of the load causes a high voltage pulse to be fed along path 17. Such a pulse is voltage multiplied in transformer T and provides a voltage across gap 1 sufficient to cause gap 1 to fire. Resistor R9 and capacitor C6 form an R-C discharge loop which overvolts gap 2, causing it to fire, and R8 and C5 likewise form another R-C loop to overvolt gap 3 and fire it. Capacity divider action fires gap 4, and gap 5 then fires. RV1 and RV2 are voltage sensitive Thyrite resistor units. These units redistribute any gradual voltage change occurring at the junction of SC and R1 (FIGURE 1) to prevent the crowbar gaps from firing except for sudden voltage changes, such as the high voltage pulse applied to transformer T. The utilization of the Thyrite units is significant to the design of this device. They provide the means whereby reliable triggering of the inventive crowbar is obtained over a much wider range of power supply voltages than would otherwise be possible. Thyrite has a nonlinear voltage-current characteristic, such that as voltage is applied thereacross, the current increases in an exponential manner (or the resistance effectively decreases in an exponential manner). In addition, Thyrite exhibits an extremely high value of resistance (thousands of megohms) in its under-voltaged state. Its application to this inventive device insures that the largest percentage (>90%) of initially applied voltage appears across gaps 1 and 2 because of the resultant resistor divider action. This distribution of voltage permits the two bottom gaps (1 and 2) to be reliably triggered. The resultant arc is sustained by the discharge of capacitors C5 and C6 through resistors R8 and R9 respectively. Once these gaps fire, the arc is propagated upward, as already explained.

A typical power source across which the crowbar of the invention may be used is one having a voltage of 140 kv. The energy stored in capacitor SC, which is 5 microfarads, is 56,000 joules. All of the spark gaps can be fired within one microsecond of the application of the pulse to transformer T, and within seven microseconds after the detection of a fault. The gaps are composed of

three inch diameter solid bronze balls, with the following spacings and approximate breakdown voltages:

	Inch	Kv.
gap 1	0.84	60
gap 2	0.44	34
gap 3	0.53	40
gap 4	0.28	23
gap 5	0.22	19

Bronze appears to be an optimal material for the gap balls. Because of the large amount of energy being dumped, materials such as Monel, nickel, stainless steel, etc., suffer rapid surface deterioration. Such deterioration is undesirable because it disrupts the geometry of the gaps and causes premature or random firings. Bronze solves this problem, since it apparently has a tough natural oxide coating thereon. In order for the underlying metal to be damaged, the oxide must first be penetrated. The oxide coating regenerates rapidly between firings. With bronze, there appears to be practically no limit to the number of firings possible with a given pair of balls.

Typical values of the resistors and capacitors of FIGURE 2 are as follows:

R1	ohms	6
R2	do	12
R3	megohms	96
R4, R7	kilohms	40
R5	megohms	144
R6	do	240
R8	ohms	125
R9	kilohms	15
R10	megohms	4360
SC	microfarads	5
C1, C2, C4, C7	picofarads	125
C3	do	333
C5	do	2000
C6	do	1000

The resistors are Glomar type SP.

While a specific embodiment of the invention has been shown and described, other embodiments may be obvious to one skilled in the art, in view of this disclosure. For example, the dump trigger could have a power supply different from source 10. More or less than five gaps may be used, depending upon the voltage and energy of the source. While the inventive crowbar is described for operation at a nominal 140 kv., it would be useful for voltages from 40 kv. to 160 kv. Adjustment of the gap spaces would permit operation down to 20 kv., with the upper voltage limit corresponding decreased. Any suitable varistor may be used in place of the Thyrite units discussed.

I claim:

1. An electronic crowbar for discharging a high voltage source, including a plurality of spark gaps in series from said source to ground, impedance means connected across each of said gaps, and arc initiation means connected across at least one of said gaps, said impedance means including individual impedance elements in parallel with each of said gaps, wherein said impedance elements are in the form of resistor-capacitor discharge paths, and varistor means connected across at least the gap nearest ground.

References Cited

UNITED STATES PATENTS

2,878,428	3/1959	Bockman et al.	317—16 X
3,348,100	10/1967	Kresge	317—70

JOHN F. COUCH, *Primary Examiner*.

J. D. TRAMMELL, *Assistant Examiner*.

U.S. Cl. X.R.

317—31, 70; 315—36