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ELECTRON TUBE PROTECTIVE SYSTEM

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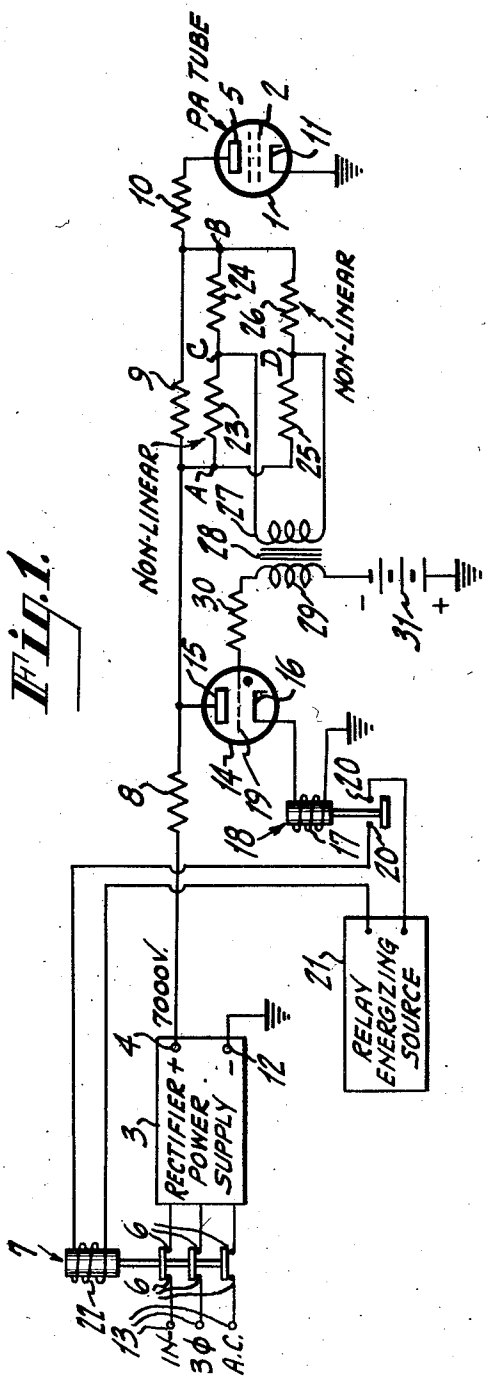


FIG. 1.

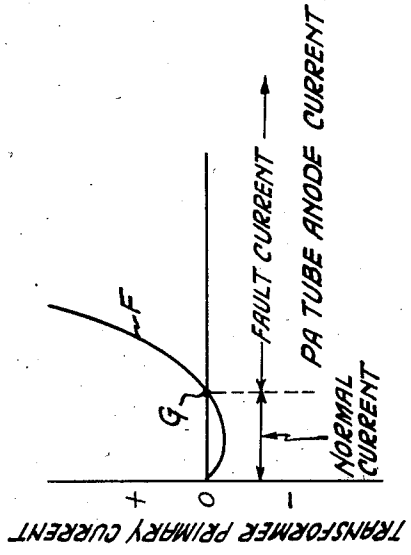


FIG. 2.

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ELECTRON TUBE PROTECTIVE SYSTEM

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15 Claims. (Cl. 250—27)

This invention relates to an electron tube protective system, and more particularly to a system for protecting such tubes against damage resulting from abnormally high current flow therein. Although not limited thereto, this invention is particularly suitable for the protection of the power amplifier (PA) tubes of a television transmitter, and the system of this invention will be explained with reference to this use.

Presently known high power electron tubes are designed to handle a very large quantity of power under normal operating conditions providing the tube current is distributed substantially uniformly over the tube electrodes. Such tubes can even handle uniformly distributed currents of abnormal value for the time required to operate conventional overload protection devices, e. g., electromechanical circuit breakers. However, a serious problem arises in the operation of such tubes when a tube fault causes abnormally high current to flow to a localized spot on one or more of the tube electrodes. In the usual case, such faults take the form of an arc discharge through stray quantities of gas in the tube. Occasionally, an internal short may develop between two tube electrodes, such as when one of the electrodes becomes sufficiently deformed, due to localized overheating or the like, to make contact with another tube electrode. In the case of a gas arc, the tube need not be damaged at all if the arc can be stopped quickly enough, while in the case of an internal short it is possible to save most of the tube elements if the source of power can be removed quickly enough. In either event, however, the high cost of such tubes makes it imperative to provide the maximum possible protection against these potentially destructive faults.

Since localized high current in a tube handling many kilowatts of power can totally destroy the tube in a matter of microseconds, it is necessary that the protective system for the PA tubes operate to remove the source of power from these tubes (i. e., to remove the anode voltage from these tubes) in ten microseconds or less after a tube fault occurs. Conventional protective systems of the circuit-opening type (such as electro-mechanical circuit breakers, or using a power supply of the grid-controlled type and applying a negative potential to the rectifier grids) are incapable of providing the necessary fast-acting protection.

If the high power electron tubes referred to are to be used in the power amplifiers of a television transmitter, the protective system, in addition to being extremely fast-acting, must satisfy certain other requirements. Ordinarily, a common power supply is used for both the visual and aural transmitters of the television transmission system. The fault must be detected in the positive (high voltage) feed line, rather than in the common negative lead of this power supply. This is because of the following: If protection is applied to both the visual PA and the aural PA, the location of the fault (whether in the aural or visual PA) would not be apparent to the sensing device if it were in the common negative lead.

The current of both the visual and aural transmitters must flow through the sensing device (e. g., resistor) if it were in the common negative lead; this would cause interaction between the two transmitters. Lastly, the type of tubes used in the transmitters requires that the cathodes of the power amplifier tubes must be connected directly to ground; a sensing resistor could therefore not be inserted in the cathode connection. In addition to the requirement that the fault be detected in the positive feed line, there are several other requirements which the protective system must satisfy. The protective system must not offer visual resonances to the visual PA, since otherwise the transmitted visual signal would be deleteriously affected. Also, an ordinary increase in PA tube current, the result for example of a television synchronizing pulse, must not energize the protective circuit.

An object of this invention is to provide a novel system for protecting high power electron tubes against damage due to high current faults.

Another object is to devise a novel system which acts substantially instantaneously to remove the anode voltage from a tube upon the occurrence of a fault therein.

Still another object is to devise a novel protection system for the power amplifier (PA) tubes of a television transmitter.

The objects of this invention are accomplished, briefly, in the following manner: Excessive current flowing through a resistor in series in the anode circuit of a tube to be protected causes unbalance of a bridge circuit which includes two non-linear resistors. This unbalance causes reversal of the current flowing through the primary of a pulse transformer which is connected across one diagonal of the bridge, the resulting pulse appearing in the secondary of this transformer being of such polarity as to fire a thyratron which short-circuits the anode power supply and thus removes anode voltage from the protected PA tube, substantially instantaneously after the occurrence of the fault in the protected tube. Firing of the thyratron also energizes an overload relay connected in the cathode circuit thereof, in turn opening the main circuit breaker of the anode power supply.

The foregoing and other objects of the invention will be best understood from the following description of an exemplification thereof, reference being had to the accompanying drawing, wherein:

Fig. 1 is a schematic circuit diagram of a protective system according to this invention; and

Fig. 2 is a curve useful in explaining the operation of Fig. 1.

Referring to Fig. 1, a power amplifier (PA) tube to be protected is shown as a tetrode **1** connected to amplify modulated voltages applied to its control grid **2** through any suitable input connection. Unidirectional energizing voltage for the tube is obtained from a rectifier power supply **3**, with the positive terminal **4** of the power supply **3** being connected to the tube anode **5** through three resistors **8**, **9** and **10**. The anode current of tube **1** thus flows through the resistors **8**, **9** and **10** in series. The purposes of the resistors **8**, **9** and **10** will appear hereinafter. To complete the energization circuit, the cathode **11** of tube **1** is connected to ground, as is the negative terminal **12** of the power supply **3**.

Tube **1** may be biased by any suitable means (not shown). Amplified voltages may be taken off from the anode **5** of tube **1** in any suitable manner.

The power supply **3** is provided with three input terminals **13** to which a suitable three-phase alternating voltage is applied. The input terminals **13** are coupled to the power supply **3** through the normally-closed contacts **6** of the main circuit breaker **7**. The power supply **3** is capable of furnishing a unidirectional voltage of the

order of seven kilovolts and is provided with an electro-mechanical main circuit breaker 7 which opens the three-phase A. C. input line to rectifier power supply 3 (in a manner to be hereinafter described in more detail) when excessive current is drawn from the said supply. This overload protective device 7, however, cannot respond rapidly enough to protect the tube 1 upon the occurrence of a localized high-current fault therein.

In accordance with the invention, fault protection for the tube 1 is provided by a normally non-conductive short-circuiting element consisting of a gas tube 14 connected in parallel with the power supply 3. As shown, the gas tube (which may, for example, be a thyratron triode) has an anode 15 which is connected to the junction of resistors 8 and 9, and thus through resistor 8 to the positive power supply terminal 4, and the gas tube cathode 16 is connected through the energizing winding 17 of an overload relay 18 to ground and thus to the negative terminal 12 of the power supply. The tube 14 is a so-called grid-controlled thyratron, in which firing is controlled by a grid electrode 19.

Tube 14 is normally non-conducting, but when this tube is fired by the application of a voltage of the proper magnitude and polarity to its grid 19, the power supply 3 is short-circuited through the low-resistance anode-cathode path of such tube (thus effectively removing the anode voltage from the PA tube 1 to be protected). The short circuit path includes winding 17 of the overload relay 18 which is energized by the short-circuit cathode current flowing therethrough, since the winding 17 is in series with the tube 14 across the power supply terminals 4 and 12.

The normally-open contacts 20 of relay 18 are connected in series between a relay energizing source 21 and the winding 22 of the main breaker 7 (shown as relay). Thus, when the cathode current flowing through winding 17 energizes relay 18, its contacts 20 close to energize the winding 22 of the main anode circuit breaker 7, opening the contacts 6 to deenergize the power supply 3. Resistors 8 and 10 are current limiting resistors which limit the current drawn from the power supply 3 when a fault condition exists in the tube 1, and when the gas tube 14 is conducting and presenting a low-resistance path across the power supply terminals 4 and 12. A fault in tube 1, for example in the form of an arc discharge through stray quantities of gas in the tube (gas ping), represents a short-circuit of a few ohms, and the anode-cathode path of tube 14, when conducting, also presents a low ohmic resistance. However, the power supply 3 is designed to withstand the short-circuit current (flowing through tube 14) for the few cycles (with reference to a 60-cycle alternating current supply) it takes for the contacts 6 to open, it being remembered that the opening of these contacts is initiated when tube 14 is fired in response to a fault in tube 1.

The protective action (the short-circuiting of the power supply 3 and the consequent removal of the anode voltage from tube 1) resulting from the firing of tube 14 has previously been explained; the arrangement for causing tube 14 to fire in response to abnormal or fault current in tube 1 will now be described.

Resistor 9, previously referred to as being in series in the anode circuit of tube 1 and through which the anode current of this tube passes, is a sensing resistor and may have a rather low value of resistance, for example about 10 ohms. A four-arm non-linear bridge circuit including resistors 23, 24, 25 and 26 is connected in a conventional way to provide two diagonally-opposite input terminals A and B and two diagonally-opposite output terminals C and D. The IR voltage drop across sensing resistor 9 (tube 1 anode current flowing through the resistance of resistor 9) is utilized as an input voltage source for the bridge circuit by connecting the two bridge input terminals A and B to opposite ends of resistor 9. The output voltage of the bridge circuit is applied to

the primary winding 27 of a pulse transformer 28, by connecting one end of said primary winding to bridge terminal C and the opposite end of the primary winding to bridge terminal D. Of the four resistors making up the bridge circuit, two (24 and 25) are ordinary resistors having a constant value of resistance, for example 1000 ohms each. Resistors 23 and 26 are non-linear, that is, they are made of compositions whose resistivities decrease sharply as the voltages applied thereto increase. An example of a suitable composition is that marketed by the General Electric Company under the name of "Thyrite."

By proper choice of the balancing resistors 23—26, as well as of the resistor 9, the bridge can be made to balance (i. e., zero current through primary winding 27) at any given anode current for tube 1. The input voltage to the bridge is developed across resistor 9 and is proportional to the anode current of tube 1. By way of example, if the resistors 23—26 are all equal and each has a value of 1000 ohms, the current through the primary winding 27 will be zero, since the bridge is then balanced and points C and D are therefore at the same potential. If, now, the resistances of the two resistors 23 and 26 change to 999 ohms each in response to a change in the applied potential, resistors 24 and 25 of course remaining at 1000 ohms each, the potentials at points C and D will be unequal and current will flow from point C through the primary winding 27 to point D. Let us call this the "positive" direction. If, on the other hand, the resistances of the resistors 23 and 26 change to 1001 ohms each, current will flow from point D through the primary winding 27 to point C, in the "negative" direction.

As previously stated, the resistances of resistors 23 and 26 will decrease rapidly at the voltage applied across them increases. For some voltage E (the IR voltage drop across resistor 9 due to anode current flowing through tube 1) the resistances of resistors 23 and 26 will be 1000 ohms; as an example, when 55 volts is applied to resistor 23 or resistor 26, the resistance will be 1000 ohms. This means that when E is two times 55 volts or 110 volts the bridge will be balanced and the current through primary winding 27 will be zero. As E is decreased below 110 volts, the resistance of resistors 23 and 26 will increase very rapidly and current will flow from terminal D to C, the "negative" direction. If E increases above 110 volts, the resistance of resistors 23 and 26 will decrease rapidly and current will flow from terminal C to D, the "positive" direction.

Knowing the resistance characteristics of resistors 23 and 26, the maximum negative (D to C) current that will flow in the primary winding 27 may be readily calculated. For the particular example, the maximum negative current is less than twenty milliamperes.

For a typical application of the system of the invention to a 12.5 kw. U. H. F. television transmitter, the anode current in PA tube 1 is five amperes for black level and seven amperes for "peak of sync," with the fault current being above eleven amperes. Under black level operation of tube 1 the voltage drop across resistor 9 produced by anode current in tube 1 will be 5 amperes times 10 ohms or 50 volts, and under "peak of sync" conditions the IR drop across resistor 9 will be 70 volts. For these two cases and for any PA tube anode current less than 11 amperes, the IR voltage drop across resistor 9 will be less than 110 volts and the current through winding 27 will flow from terminal D to C, the "negative" direction. Fig. 2 represents the current flowing through primary winding 27 with respect to the PA tube anode current. Under normal operating conditions of tube 1 (for the example given, below 11 amperes PA tube anode current) a small negative current will flow through winding 27, as just stated. This is indicated in Fig. 2 by the dipping of the primary current curve F below the zero axis, in the negative direction, to the left or low-current

side of point G, which latter point corresponds to 11 amperes of PA tube 1 anode current.

One end of the secondary winding 29 of pulse transformer 28 is connected through a current-limiting resistor 30 to the thyratron grid 19, while the other end of winding 29 is connected to the negative terminal of a source 31 of unidirectional bias potential, the positive terminal of which is connected to ground. Source 31 is illustrated for convenience as a battery, but it may be any other suitable source of unidirectional potential, such as a selenium rectifier energized from the alternating current source. The use of negative bias on grid 19 in this manner makes the thyratron 14 operate at the proper point on its characteristic and insures that small, extraneously-produced positive pulses which might appear in the secondary winding 29, will not fire thyratron 14.

Transformer 28 is so polarized that a negative direction current flow in its primary 27 (from terminal D to C) will produce a negative pulse in its secondary 29. Therefore, since a positive pulse on grid 19 is required to fire thyratron 14, any increase in PA tube anode current that is less than the fault current of 11 amperes (point G in Fig. 2) will produce a negative pulse on the grid 19 and will not energize the protective circuit, because for PA tube anode currents below point G in Fig. 2 the bridge is unbalanced in the negative direction and current is flowing through winding 27 in the negative direction. Therefore, "peak of sync" PA tube anode current and tube in-rush current will not operate the protective circuit.

If a fault develops in tube 1, the anode current in tube 1 exceeds 11 amperes and the IR voltage drop across resistor 9 increases above 110 volts, causing (due to the decrease of resistance of resistors 23 and 26) the bridge to rapidly become unbalanced in the opposite direction, thereby causing a pulse of current of flow in the reverse or positive direction (from terminal C to D) through transformer primary 27. In other words, the current through winding 27 then sharply reverses and increases rapidly in the opposite, positive direction. This is represented by curve F, Fig. 2, beyond or to the right of point G, which is the "fault-current" point (bridge balance point) for the PA tube 1 anode current of 11 amperes. This sharp reversal of primary current in transformer 28 produces a positive pulse in the secondary winding 29, which overcomes the negative bias on grid 19 and causes thyratron 14 to ionize. Thyratron 14 then fires and, as previously described, provides a very low impedance or short-circuit path for the high voltage from power supply 3 to ground through the anode-cathode path of this tube, removing the anode voltage from the PA tube 1. The time lag between fault occurrence and removal of anode voltage depends mainly on the ionization time of tube 14 and in practice has been found to be from 6 to 10 microseconds. Thus, upon the occurrence of a fault in the protected tube 1, the anode voltage is removed from this tube in a matter of microseconds.

As previously described, the firing of the thyratron 14 energizes the overload relay 18 in its cathode circuit, thus energizing the main circuit breaker 7 to open its series contacts 6 in the time of a few cycles of the 60-cycle power line frequency, thus deenergizing the power supply 3.

Since the fault current in the television transmitter as described must be detected in the positive anode voltage lead, the transformer 28 is used to isolate the grid 19 from the high unidirectional voltage of such lead.

As previously stated, the maximum negative current (from terminal D to C) that will flow in primary winding 27 is on the order of twenty milliamperes. Since only twenty milliamperes out of the total current of 5 amperes (black level) flows through winding 27, only about 0.4% of the PA tube anode current will have a reactive component caused by the transformer 28. Thus, the reactance of transformer 28 presented to tube 1 is very small and will not cause video resonance.

Fig. 1 illustrates the protective system used to protect tube 1 in the case of an anode current fault, but it may be used in a similar manner to protect any other electrode of this tube.

What is claimed is:

1. In a protective system for an electron tube energized from a unidirectional voltage source having positive and negative output terminals, an impedance in series between said positive output terminal and said tube, means coupled to said impedance for developing a voltage of predetermined polarity in response to an abnormally high voltage drop across said impedance, a pulse transformer having primary and secondary windings, means for applying said developed voltage to said primary winding, and means coupled to said secondary winding and responsive to a pulse of predetermined polarity appearing therein, for short-circuiting said source.

2. In a protective system for an electron tube energized from a unidirectional voltage source, a four-arm bridge network having a pair of input terminals and a pair of output terminals, means for generating a voltage proportional to the current drawn by said tube from said source, means connecting said generating means between said input terminals, said bridge being constructed and arranged to become unbalanced in a predetermined direction in response to abnormal current flow through said tube, and means coupled to said output terminals and acting in response to unbalance of said bridge in said direction, for short-circuiting said source.

3. In a protective system for an electron tube energized from a unidirectional voltage source, a four-arm bridge network having a pair of input terminals and a pair of output terminals, said bridge including at least one non-linear resistor whose resistance varies inversely with the voltage impressed thereacross; means for generating a voltage proportional to the current drawn by said tube from said source, means connecting said generating means between said input terminals, said bridge being constructed and arranged to become unbalanced in a predetermined direction in response to abnormal current flow through said tube, and means coupled to said output terminals and acting in response to unbalance of said bridge in said direction, for short-circuiting said source.

4. In a protective system for an electron tube energized from a unidirectional voltage source having positive and negative output terminals, an impedance in series between said positive output terminal and said tube, means coupled to said impedance for developing a voltage of predetermined polarity in response to an abnormally high voltage drop across said impedance, a pulse transformer having primary and secondary windings, means for applying said developed voltage to said primary winding, and means coupled to said secondary winding and responsive to a pulse of predetermined polarity appearing therein, for shortcircuiting said source, said last-mentioned means comprising a normally non-conductive gaseous discharge device connected in parallel with said voltage source and having an anode, a cathode, and a firing control electrode, and means coupling said firing control electrode to said secondary winding, to fire said device in response to said pulse of predetermined polarity.

5. In a protective system for an electron tube energized from a unidirectional voltage source having positive and negative output terminals, an impedance in series between said positive output terminal and said tube, means coupled to said impedance for developing a voltage of predetermined polarity in response to an abnormally high voltage drop across said impedance, said means comprising a non-linear bridge network having input terminals and output terminals, and means coupling said input terminals to said impedance; a pulse transformer having primary and secondary windings, connections between said bridge network output terminals and said primary winding for applying said developed voltage to said primary

winding, and means coupled to said secondary winding and responsive to a pulse of predetermined polarity appearing therein, for short-circuiting said source.

6. In a protective system for an electron tube energized from a unidirectional voltage source having positive and negative output terminals, an impedance in series between said positive output terminal and said tube, means coupled to said impedance for developing a voltage of predetermined polarity in response to an abnormally high voltage drop across said impedance, said means comprising a non-linear bridge network having input terminals and output terminals, and means coupling said input terminals to said impedance; a pulse transformer having primary and secondary windings, connections between said bridge network output terminals and said primary winding for applying said developed voltage to said primary winding, and means coupled to said secondary winding and responsive to a pulse of predetermined polarity appearing therein, for short-circuiting said source, said last-mentioned means comprising a normally non-conductive gaseous discharge device connected in parallel with said voltage source and having an anode, a cathode, and a firing control electrode, and means coupling said firing control electrode to said secondary winding, to fire said device in response to said pulse of predetermined polarity.

7. In a protective system for an electron tube energized from a unidirectional voltage source having positive and negative output terminals, an impedance in series between said positive output terminal and said tube, means coupled to said impedance for developing a voltage of predetermined polarity in response to an abnormally high voltage drop across said impedance, said means comprising a bridge network having input terminals and output terminals and also having at least one non-linear resistor whose resistance varies inversely with the voltage impressed thereacross, and means coupling said input terminals to said impedance; a pulse transformer having primary and secondary windings, connections between said bridge network output terminals and said primary winding for applying said developed voltage to said primary winding, and means coupled to said secondary winding and responsive to a pulse of predetermined polarity appearing therein, for short-circuiting said source.

8. In a protective system for an electron tube energized from a unidirectional voltage source having positive and negative output terminals, an impedance in series between said positive output terminal and said tube, means coupled to said impedance for developing a voltage of predetermined polarity in response to an abnormally high voltage drop across said impedance, said means comprising a four-arm non-linear bridge network having a pair of diagonally-opposite input terminals and a pair of diagonally-opposite output terminals, and means connecting said impedance between said pair of input terminals; a pulse transformer having primary and secondary windings, connections between said bridge network output terminals and the respective opposite ends of said primary winding for applying said developed voltage to said primary winding, and means coupled to said secondary winding and responsive to a pulse of predetermined polarity appearing therein, for short-circuiting said source.

9. In a protective system for an electron tube energized from a unidirectional voltage source having positive and negative output terminals, an impedance in series between said positive output terminals and said tube, means coupled to said impedance for developing a voltage of predetermined polarity in response to an abnormally high voltage drop across said impedance, said means comprising a four-arm bridge network having a pair of diagonally-opposite input terminals and a pair of diagonally-opposite output terminals, at least one arm of said network being a non-linear resistor whose resistance varies inversely with the voltage impressed thereacross, and means connecting said impedance between said pair of input terminals; a pulse transformer having primary and secondary windings, connections between said bridge network output terminals and the respective opposite ends of said primary winding for applying said developed voltage to said primary winding, and means coupled to said secondary winding and responsive to a pulse of predetermined polarity appearing therein, for short-circuiting said source.

10. In a protective system for an electron tube energized from a unidirectional voltage source having positive and negative output terminals, an impedance in series between said positive output terminal and said tube, means coupled to said impedance for developing a voltage of predetermined polarity in response to an abnormally high voltage drop across said impedance, said means comprising a bridge network having input terminals and output terminals and also having at least one non-linear resistor whose resistance varies inversely with the voltage impressed thereacross, and means coupling said input terminals to said impedance; a pulse transformer having primary and secondary windings, connections between said bridge network output terminals and said primary winding for applying said developed voltage to said primary winding, and means coupled to said secondary winding and responsive to a pulse of predetermined polarity appearing therein, for short-circuiting said source, said last-mentioned means comprising a normally non-conductive gaseous discharge device connected in parallel with said voltage source and having an anode, a cathode, and a firing control electrode, and means coupling said firing control electrode to said secondary winding, to fire said device in response to said pulse of predetermined polarity.

11. In a protective system for an electron tube energized from a unidirectional voltage source having positive and negative output terminals, an impedance in series between said positive output terminal and said tube, means coupled to said impedance for developing a voltage of predetermined polarity in response to an abnormally high voltage drop across said impedance, said means comprising a four-arm non-linear bridge network having a pair of diagonally-opposite input terminals and a pair of diagonally-opposite output terminals, and means connecting said impedance between said pair of input terminals; a pulse transformer having primary and secondary windings, connections between said bridge network output terminals and the respective opposite ends of said primary winding for applying said developed voltage to said primary winding, and means coupled to said secondary winding and responsive to a pulse of predetermined polarity appearing therein, for short-circuiting said source, said last-mentioned means comprising a normally non-conductive gaseous discharge device connected in parallel with said voltage source and having an anode, a cathode, and a firing control electrode, and means coupling said firing control electrode to said secondary winding, to fire said device in response to said pulse of predetermined polarity.

12. In a protective system for an electron tube energized from a unidirectional voltage source having positive and negative output terminals, an impedance in series between said positive output terminal and said tube, means coupled to said impedance for developing a voltage of predetermined polarity in response to an abnormally high voltage drop across said impedance, said means comprising a four-arm bridge network having a pair of diagonally-opposite input terminals and a pair of diagonally-opposite output terminals, at least one arm of said network being a non-linear resistor whose resistance varies inversely with the voltage impressed thereacross, and means connecting said impedance between said pair of input terminals; a pulse transformer having primary and secondary windings, connections between said bridge network output terminals and the respective opposite ends of said primary winding for applying said developed voltage to said primary winding, and means

coupled to said secondary winding and responsive to a pulse of predetermined polarity appearing therein, for short-circuiting said source, said last-mentioned means comprising a normally non-conductive gaseous discharge device connected in parallel with said voltage source and having an anode, a cathode, and a firing control electrode, and means coupling said firing control electrode to said secondary winding, to fire said device in response to said pulse of predetermined polarity.

13. In a protective system for an electron tube energized from a unidirectional voltage source having positive and negative output terminals, an impedance in series between said positive output terminal and said tube, means coupled to said impedance for developing a voltage of predetermined polarity in response to an abnormally high voltage drop across said impedance, a pulse transformer having primary and secondary windings, means for applying said developed voltage to said primary winding, means coupled to said secondary winding and responsive to a pulse of predetermined polarity appearing therein, for short-circuiting said source, said last-mentioned means comprising a normally non-conductive gaseous discharge device connected in parallel with said voltage source and having an anode, a cathode, and a firing control electrode, means coupling said firing control electrode to said secondary winding, to fire said device in response to said pulse of predetermined polarity; a relay having an operating winding and also having contacts which when closed effect deenergization of said voltage source, and means connecting said operating winding in series in the anode-cathode path of said device.

14. In a protective system for an electron tube energized from a unidirectional voltage source having positive and negative output terminals, an impedance in series between said positive output terminal and said tube, means coupled to said impedance for developing a voltage of predetermined polarity in response to an abnormally high voltage drop across said impedance, said means comprising a bridge network having input terminals and output terminals and also having at least one non-linear resistor whose resistance varies inversely with the voltage impressed thereacross, and means coupling said input terminals to said impedance; a pulse transformer having primary and secondary windings, connections between said bridge network output terminals and said primary winding, for applying said developed voltage to said primary winding, means coupled to said secondary winding and responsive to a pulse of predetermined polarity appearing therein, for short-circuiting said source, said last-mentioned means comprising a normally non-conductive gaseous discharge device connected in parallel with said voltage source and having an anode, a cathode, and a firing control electrode, and means coupling said firing control electrode to said secondary winding, to fire said device in response to said pulse of predetermined polarity; a relay having an operating winding and also having contacts which when closed effect deenergization of said voltage source, and means connecting said operating winding in series in the anode-cathode path of said device.

15. In a protective system for an electron tube energized from a unidirectional voltage source having positive and negative output terminals, an impedance in series between said positive output terminal and said tube, means coupled to said impedance for developing a voltage of predetermined polarity in response to an abnormally high voltage drop across said impedance, said means comprising a four-arm bridge network having a pair of diagonally-opposite input terminals and a pair of diagonally-opposite output terminals, at least one arm of said network being a non-linear resistor whose resistance varies inversely with the voltage impressed thereacross, and means connecting said impedance between said pair of input terminals; a pulse transformer having primary and secondary windings, connections between said bridge network output terminals and the respective opposite ends of said primary winding for applying said developed voltage to said primary winding, means coupled to said secondary winding and responsive to a pulse of predetermined polarity appearing therein, for short-circuiting said source, said last-mentioned means comprising a normally non-conductive gaseous discharge device connected in parallel with said voltage source and having an anode, a cathode, and a firing control electrode, and means coupling said firing control electrode to said secondary winding, to fire said device in response to said pulse of predetermined polarity; a relay having an operating winding and also having contacts which when closed effect deenergization of said voltage source, and means connecting said operating winding in series in the anode-cathode path of said device.

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