

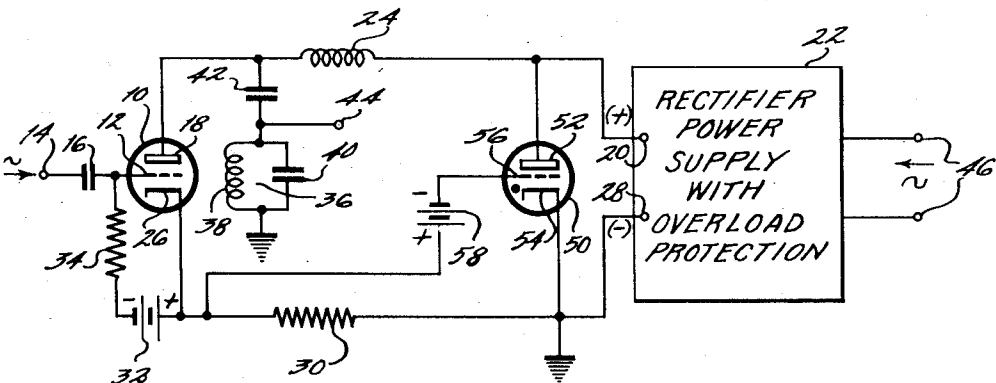
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ELECTRON TUBE PROTECTIVE SYSTEM

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ELECTRON TUBE PROTECTIVE SYSTEM

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This invention relates to improvements in protective systems for electron tubes, and particularly to a system for protecting such tubes against faults causing abnormal tube current flow.

Presently known high power electron tubes are designed to handle as much as a million watts of power under normal operating conditions provided the tube current is distributed substantially uniformly over the tube electrodes. Such tubes can even handle uniformly distributed abnormal currents for the time required to operate conventional overload protection devices. 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.

Conventional prior art protective systems generally consist of some arrangement for interrupting or shutting off the power supply to the protected tube upon the occurrence of a fault therein. Such systems have been found incapable of adequately protecting tubes against localized high currents since they cannot respond rapidly enough to remove the energizing voltage before the tube has been ruined. For example, the fastest-acting electromechanical circuit breakers require several hundredths of a second to operate after an initiating impulse is received, and arcs at the breaker terminal may increase the actual circuit-opening time. More rapid power-cutoff action can be obtained with a power supply of the grid controlled rectifier type, (see e. g. "Mercury Arc Power Rectifiers," Monti and Winograd, McGraw-Hill Book Company, 1930, pgs. 397-402), wherein the rectifier output can be cut off by applying a negative voltage to the rectifier grids. Even in this case, the cutoff time is not less than that required for the completion of a given half cycle of rectifying action. With a 60 cycle alternating current supply, for example, the cutoff

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time is of the order of one hundredth of a second. Since localized high current in a tube handling many kilowatts of power can totally destroy the tube in a matter of microseconds, it can be seen that conventional protective systems of the circuit-opening type are incapable of providing the necessary protection.

It is, accordingly, a general object of the present invention to provide an improved system for protecting high power electron tubes against high-current faults.

A more specific object of the invention is to provide a tube protection system which will act substantially instantaneously to arrest the flow of power to a tube upon the occurrence of a fault therein.

In accordance with the invention, the foregoing and other related objects and advantages are attained by providing a normally open substantially short-circuit path in parallel with the power supply through which current can flow upon the occurrence of a fault in a protected tube. Stated somewhat differently, the invention provides means for substantially instantaneously diverting high current from an inherently delicate electron tube by a circuit closing action upon the occurrence of a fault therein, as distinguished from relatively slow-acting circuit opening apparatus. Fault detecting means are coupled to the circuit of the protected tube for initiating the circuit closing action.

A preferred short-circuiting element for use in the protective system of the present invention comprises a gas tube having two principal electrodes (e. g. anode and cathode) and an auxiliary firing-control element (e. g. a control grid or an igniter electrode). As used herein and in the appended claims, the term "gas tube" is intended to mean an electron tube adapted to withstand relatively high voltages when nonconductive, and containing gas or vapor in such quantity that, when the tube is conducting, the voltage drop thereacross will have a low, substantially constant value characteristics of a gas or vapor discharge (e. g. a thyatron or an ignitron). This is in comparison with evacuated electron tubes in which the conducting voltage drop varies approximately as the two-thirds power of the tube current. The term "firing" is used herein and in the appended claims to denote initiation of current flow in a gas tube.

A more complete understanding of the invention can be had by reference to the accompanying drawing, the single figure of which illustrates

a tube protective system arranged in accordance with the invention.

Referring to the drawing, a tube to be protected is shown as a triode 10 connected to amplify alternating voltages applied to the control grid 12 thereof through an input terminal 14 and a coupling capacitor 16. Unidirectional energizing voltage for the tube 10 is obtained from a rectifier power supply 22, with the positive terminal 20 of the power supply 22 being connected to the tube anode 18 through a reactor 24, and the tube cathode 26 being connected to the negative terminal 28 of the power supply 22 through a resistor 30. The purpose of the reactor 24 and the resistor 30 will be described hereinafter. A bias voltage source, shown as a battery 32, is connected between the tube grid 12 and the cathode 26, in series with a grid resistor 34.

A resonant circuit 36 comprising a parallel connected inductor 38 and capacitor 40 is connected to the tube anode 18 through a blocking capacitor 42 in the usual manner, so that amplified alternating voltages will be made available at an output terminal 44. Although a conventional amplifier circuit has been shown for simplicity of illustration, it will be understood that the tube 10 could as well be connected in an oscillatory circuit by providing suitable feedback connections between the tube anode 18 and the tube grid 12. In either case, the tube 10 will act as an alternating voltage amplifier. Similarly, the protection of a tube in a high power modulation circuit or in a so-called buffer stage is deemed to be within the scope of the present invention.

The power supply 22 is provided with a pair of input terminals 46 through which a suitable alternating voltage can be applied to the rectifier. It is assumed that the power supply 22 is capable of furnishing a unidirectional voltage of the order of several kilovolts and is provided with suitable overload protection devices, such as electromechanical circuit breakers which will open the rectifier circuit when excessive current is drawn from the power supply (see e. g. "Mercury Arc Power Rectifiers," supra, page 336), or grid controlled rectifiers of the type previously referred to. As was mentioned, such overload protective devices cannot respond rapidly enough to protect the tube 10 upon the occurrence of a localized high-current fault therein.

In accordance with the invention, fault protection for the tube 10 is provided by a normally non-conductive short-circuiting element consisting of a gas tube 50 connected in parallel with the power supply 22. As shown, the gas tube anode 52 is connected directly to the positive power supply terminal 20, and the gas tube cathode 54 is connected directly to the negative terminal 28 of the power supply. The tube 50 is a so-called grid-controlled thyatron, in which firing is controlled by a grid electrode 56.

The fault detecting means provided in the embodiment shown comprises the resistor 30 connected in the protected tube circuit between the tube cathode 26 and the power supply terminal 28. The resistor 30 also is connected in the gas tube grid circuit in series with a bias voltage source, shown as a battery 58. The voltage of the bias source 58 is made sufficiently negative to prevent firing of the tube 50 during normal current flow through the protected tube 10. However, upon the occurrence of a high-current fault, such as an arc or short-circuit, in the tube 10, the voltage developed across the resistor 30

will be of sufficient magnitude to overcome the bias voltage of the source 58, driving the gas tube control grid 56 positive with respect to the cathode 54 to fire the tube 50. This action, which will occur within a very few microseconds after the beginning of a fault in the tube 10, will divert the current away from the tube 10 and through the tube 50 provided the conducting impedance of the tube 50 is less than that of the tube 10 after a fault develops. Under these circumstances, the voltage between the anode 18 and the cathode 26 of the tube 10 will be insufficient to sustain damaging current flow, and the tube 10 will be completely protected.

In order to insure that there will be sufficient voltage across the tube 50 to cause firing thereof upon occurrence of a fault in the tube 10, an impedance such as the reactor 24 preferably is connected between the tube anode 18 and the gas tube anode 52. The reactor 24 will serve to "hold up" the voltage on the gas tube anode 52, when a fault develops in the protected tube 10, long enough for the gas tube 50 to fire. It will be understood that the reactor 24 can as well comprise a resistor, although the use of a resistor will involve some power loss.

From the point of view of the power supply 22, a short-circuit in the form of current flow through the gas tube 50 is as undesirable as an arc or short-circuit in the protected tube 10. However, the protective devices in the power supply normally will operate rapidly enough to prevent damage since there ordinarily will be no localization of heavy current in the power supply as in the case of a fault in the tube 10.

It will, of course, be apparent that the protective system described herein will respond to and provide protection against abnormal current flow in the protected tube whether or not the current flow is localized with respect to one or more of the tube electrodes. While the present system is primarily important for the protection it will provide against localized abnormal currents which will destroy a tube if not eliminated almost instantly, it also will provide effective protection against unlocalized abnormal currents such as would accompany loss of grid bias or the like. Thus, while such unlocalized currents might be cut off by a circuit breaker before totally destroying the tube, more prompt protection will reduce the cumulative effects of repeated occurrences of unlocalized high currents and help to increase tube life.

As was previously mentioned, the present invention is not limited to the use of grid controlled gas tubes, as there are other well known firing control arrangements any one of which can be adapted for use in the present invention (see e. g. Reich—"Theory and Application of Electron Tubes," McGraw-Hill Book Company, 1930, pgs. 393-398). Special mention may be made of the mercury-pool cathode ignitron tube, in which firing is controlled by an igniter electrode partially immersed in the cathode pool. The ignitron tube is preferable for very high power applications because of its large current carrying capacity. Examples of the use of ignitron tube in protective systems embodying the principles of the present invention will be found in the co-pending application of W. N. Parker et al., Serial No. 148,688, filed March 9, 1950, and assigned to the same assignee as the present invention. Modified arrangements for detecting tube faults and for firing the protective gas tube also are

described and claimed in the foregoing Parker et al. application.

Since these and other changes could be made in the specific embodiment of the invention described herein, the foregoing is to be construed as illustrative, and not in a limiting sense.

What is claimed is:

1. In a protective system for an electron tube energized from a high voltage source, in combination, a normally nonconductive short-circuiting element comprising a gas tube connected in parallel with said voltage source, current responsive voltage generating means in circuit with said electron tube for generating a firing voltage of predetermined magnitude and polarity in response to the flow of current greater than a predetermined value through said electron tube, and means coupling said voltage generating means to said gas tube to fire said gas tube in response to said firing voltage.

2. A protective system for an electron tube connected to amplify alternating voltages and energized from a unidirectional voltage source, said system comprising a circuit connected in parallel with said voltage source and consisting of a normally non-conductive gas tube having an anode, a cathode, and a firing control electrode, current responsive voltage generating means in circuit with said electron tube for generating a voltage impulse of magnitude sufficient to fire said gas tube in response to abnormal current flow through said electron tube, and means coupling said voltage generating means to said firing control electrode to fire said gas tube upon the occurrence of a fault in said protected tube.

3. In an electron tube protective system, the combination with an electron tube connected to amplify alternating voltages and energized from a unidirectional voltage source, of a gas tube connected in parallel with said source and having an electrode for controlling firing of said tube, a resistor connected in series between said electron tube and said source, and a circuit connecting said resistor to said electrode to fire said gas tube in response to abnormal current flow through said electron tube and said resistor.

4. In a protective system for an electron tube connected to amplify alternating voltages and supplied with unidirectional operating voltage from a high voltage source, in combination, a

gas tube having an anode, a cathode, and a control grid, a circuit connecting said tube in parallel with said voltage source, a resistor connected between said electron tube and said voltage source, and a circuit connecting said control grid to said cathode and including said resistor and a voltage source for maintaining said control grid sufficiently negative with respect to said cathode normally to prevent current flow in said gas tube.

5. A protective system for an electron tube energized from a high voltage source, said system comprising a circuit connected in parallel with said voltage source and including a normally non-conductive element capable of withstanding relatively high voltage when non-conductive and having a low substantially constant voltage drop thereacross when conducting current, means to render said element conductive in response to a voltage impulse of predetermined magnitude, a resistor connected between said electron tube and said voltage source, and a circuit connecting said resistor to said means to furnish to said means voltage developed across said resistor by tube current, said last named circuit including a voltage source of polarity opposite to that of said voltage across said resistor.

6. A protective system for an electron tube energized from a high voltage source, said system comprising a circuit connected in parallel with said voltage source and including a normally non-conductive element capable of withstanding relatively high voltage when non-conductive and having a low, substantially constant voltage drop thereacross when conducting current, means to render said element conductive in response to a voltage of predetermined magnitude, current responsive voltage generating means in circuit with said electron tube for generating a voltage of said predetermined magnitude in response to the flow of current of greater than predetermined magnitude through said tube, and means coupling said voltage generating means to said first-named means to render said element conductive in response to said greater than predetermined magnitude current flow through said tube.

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(No references cited.)