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CURRENT INTERRUPTING CIRCUIT

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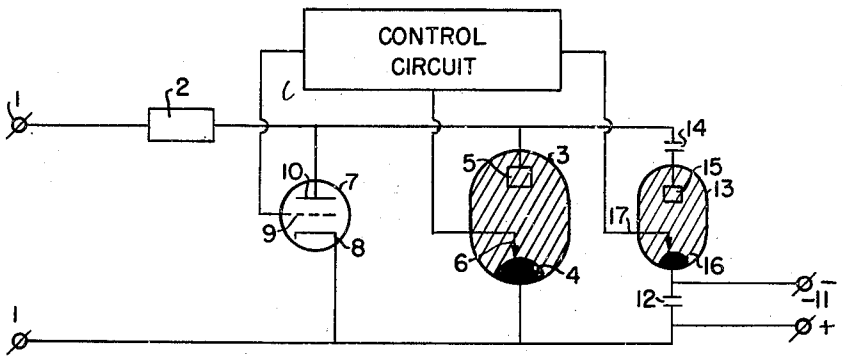


FIG. 1

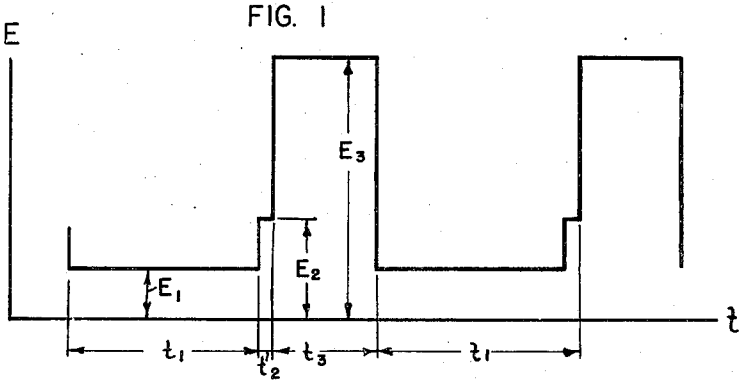


FIG. 2

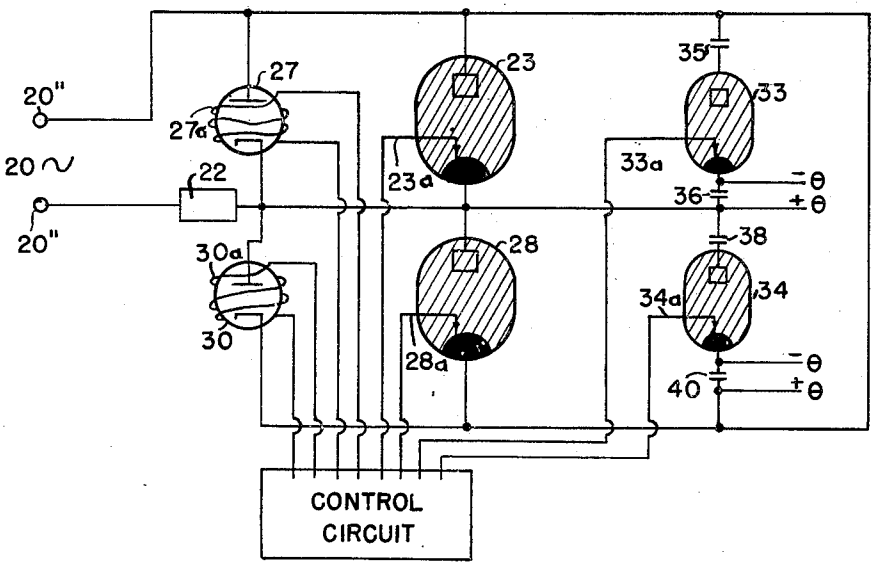


FIG. 3

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CURRENT INTERRUPTING CIRCUIT

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4 Claims. (Cl. 315—340)

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It is known that the difficulties experienced in interrupting an electric current by means of a gas- or vapour-filled discharge tube, capable of being extinguished, increase as the voltage across the tube after extinction is increased. This is due to the fact that, as a result of the subsisting residual ionization, the risk of re-ignition of the tube and of the production of a glow discharge is also greater with an increase in voltage. This holds true both in regard to tubes utilizing a voltage applied to a control electrode to aid extinction and tubes that are extinguished by means of a voltage impulse on the anode and/or an auxiliary anode.

In cases occurring in practice, for instance in the transmission of direct current energy having a high voltage and a high power, in which case this energy is to be converted at the end of the line into alternating-current energy whose voltage is n times lower, voltages of some tens of kilovolts to hundreds of kilovolts and higher and currents of several amperes to tens of amperes are concerned.

The present invention has for its purpose to meet the above drawbacks in regard to the extinction of a converting tube.

To this end, in the device according to the invention, a high-vacuum tube (auxiliary tube) capable of being controlled is connected in parallel with the discharge tube to be extinguished (main tube), which auxiliary tube at the moment of extinction is capable of taking over practically the whole current of the main tube for a short time at such a low voltage that undesired re-ignition of the main tube, due to residual ionization in the main tube, cannot occur. When the current is to be interrupted the auxiliary tube is made conductive just prior to the moment of extinction of the main tube, and is kept conductive for such a time, of the order of magnitude of 10^{-4} to 10^{-5} sec., that de-ionization has sufficiently progressed in the main tube to prevent re-ignition.

In order that the invention may be clearly understood and readily carried into effect it will now be described more fully with reference to the accompanying drawing in which one form of construction is represented by way of example.

Fig. 1 represents the circuit arrangement of a device in which the main tube is connected in series with a load to a direct voltage supply.

Fig. 2 illustrates the voltage set up at the main tube and the auxiliary tube during operation as a function of time.

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Fig. 3 is a circuit diagram of an alternative embodiment of the invention.

In Fig. 1 the reference number 1 designates the terminals of a supply of direct voltage of, say, several tens of kilovolts with which are connected in series a load 2 and a discharge tube 3 having a mercury cathode 4 and an anode 5. The tube is equipped with an ignition electrode 6 for which is chosen in the present case a semi-conductor continuously immersed in the cathode mercury.

In parallel with the (main) tube 3 is connected a high vacuum triode (auxiliary tube) 7 having an incandescent cathode 8, a grid 9 and an anode 10.

A device for extinguishing this tube is also connected in parallel with the main tube. In the present example this device consists of the series-connection of an extinguishing condenser 12 connected to a direct voltage supply 11, a gas- or vapour-filled tube 13 and a smaller condenser 14. The tube 13 is equipped with an anode 15 and a mercury cathode 16 and can be ignited, similarly to the main tube, through a voltage impulse by means of an auxiliary electrode 17 immersed in the mercury and consisting of a semi-conductor. The grid 9 and the starting electrodes 6 and 17 are connected to a control circuit, indicated by a block in the drawing. Conventional types of control circuits for applying the desired voltage pulses at the desired times are known and may be employed.

The operation of this circuit is as follows. When starting from the state in which the tube 3 is conductive, the tube 7 is kept blocked by a negative voltage on the grid and the extinguishing device 12, 13, 14 is out of service, the voltage set up at the two tubes 3 and 7 corresponds to the arc voltage of the tube 3, i. e. about 20 to 30 volts.

Shortly before the moment at which the current through the load 2 is to be interrupted by extinction of the discharge in the tube 3, the voltage set up at the grid 9 of the tube 7 is made less negative, e. g. positive, in such a manner that the tube becomes conductive and is capable of taking over for a short time substantially the full load current of the tube at an anode voltage of the order of magnitude of 500 to 1000 volts. As long, however, as the tube 3 has not been extinguished, so that the anode voltage of the tube 7 still corresponds to the operating voltage of the tube 3, by far the greater part of the current will pass through tube 3.

After that the discharge in the tube 3 is extinguished which takes place by ignition of the

tube 13 by means of the ignition electrode 17. In this case the extinguishing condenser 12 previously charged, which is connected with the negative side to the tube 13, discharges through the tube 13, and the initially uncharged condenser 14 charges through the tube 3 as a result of which the potential of the anode 5 is reduced for a short time relatively to that of the cathode or even becomes negative in such a manner that the discharge is extinguished.

Since, however, the tube 7, which has previously been made conductive, is connected in parallel with the tube 3 the full mains voltage does not directly return to the tube 3 in this state of reduced breakdown security, but the tube 3 is first exposed to the much lower anode voltage of the tube 7 of, say, 500 to 1000 volts. Despite the subsisting, though decreasing, residual ionization in the tube after extinction, re-ignition or other disturbances in the state of the tube are not to be feared at this voltage. Only after the de-ionization has progressed to a sufficient degree, which requires a time of the order of 10^{-4} to 10^{-5} sec. and the tube 3 has acquired again its full voltage security, the passage of current through the tube 7 is blocked and the full mains voltage returns to the tubes 3 and 7. The condenser 14 serves to absorb this voltage for the greater part in the parallel branch, so that only a fraction thereof is set up at the condenser 12.

In the present state of the art the conditions imposed on the high-vacuum tube can be satisfied for a generous range of voltages and currents. It is not necessary to make use of a tube with grid-control. One may also use a tube with magnetic control, which has the advantage that the grid losses are avoided and the control energy is materially reduced.

Fig. 2 illustrates the voltage variation of the tubes 3 and 7 as a function of time. t_1 represents the time during which the tube 3 and, shortly before the end also the tube 7, is conductive, so that the voltage E_1 set up at the tubes corresponds to the operating voltage of the tube 3. During t_2 the tube 3 is extinguished and the voltage E_2 set up at the tubes corresponds to the anode voltage of the tube 7. t_2 is of the order of magnitude of 10^{-4} to 10^{-5} sec. in such manner that in this time the residual ionization disappears in the tube 3. The tube 7 is now blocked so that during t_3 the full mains voltage E_3 returns to the tubes. After that a new cycle begins with the ignition of the tube 3, as appears from Fig. 2.

From Fig. 2 it also appears that by periodical ignition and extinction, and blocking respectively of the tubes 3 and 7 the circuit according to the invention is adapted, in principle, for use as an alternating current converter, its load being e. g. a transformer for converting a high direct voltage into a lower alternating voltage. In this case the periodicity in the succeeding variations in condition of the tubes is to be chosen in accordance with the frequency of the generated alternating voltage.

As an alternative, however, the circuit of the invention may be used for switching on and off alternating currents which may or may not be periodic. Such an alternative is illustrated by the circuit of Fig. 3. A source 20 of alternating current has terminals 20' and 20'' and a load 22 one side of which is connected to the terminal 20''. A mercury vapor tube 23 and high vacuum tube 27 are connected in parallel; that is with their anode terminals connected together and their cathodes connected together. The anodes are connected to terminal 20'. Another mercury vapor tube 28 and a high vacuum tube 30 are also connected in parallel with their anode terminals connected to the other side of load 22 and to the cathodes of tubes 23 and 27. The anode terminals of tubes 23 and 27 are connected to the cathode terminals of tubes 28 and 30 as shown. The tubes 27 and 30 are controlled respectively by the magnetic fields of coil 27a and and coil 30a which are connected to the control circuit. Mercury vapor tubes 23 and 28 have mercury pool cathodes and control electrodes 23a and 28a respectively which are also connected to the control circuit. Tubes 33 and 34 are mercury vapor tubes having mercury pool cathodes. The anode of tube 33 is connected to a condenser 35 which is connected to the anode of tube 23. The cathode of tube 33 is connected to a condenser 36 across which is a direct current source with the polarity shown. The other side of the condenser 36 is connected to the cathode of tube 23. The anode of tube 34 is connected to a condenser 38, the other side of which is connected to the anode of tube 28. The cathode of tube 34 is connected to a condenser 40, the other side of which is connected to the cathode of tube 28. Across condenser 40 is a direct current source with the polarity shown. The control electrodes 33a and 34a of tubes 33 and 34 repectively are connected to the control circuit. As conventional forms of the control circuit are known to the art, the circuit is not completely illustrated. The tubes 23 and 28 of Fig. 3 may be of the same type as tube 3 of Fig. 1 and the tubes 33 and 34 of Fig. 3 may be of the same type as tube 13 of Fig. 1. Tubes 27 and 30 are high vacuum tubes controlled by the magnetic field of coils 27a and 30a. In operation, the circuit allows currents of alternating polarity to pass through the load 22. For example, the source 20 may have a sinusoidal voltage form and the current passing through the load 22 may be controlled to permit passage of the current during any desired phase period of each half cycle. The coils 27a and 30a receive pulses from the control circuit in such a manner that when the tube 23 or 28 is to be extinguished, the tube 27 or 30, as the case may be, conducts very heavily for a time of the order of 10^{-4} or 10^{-5} seconds to permit substantially complete deionization of tubes 23 and 28. The functions of tubes 33 and 34 and their associated condensers and the direct current sources across the condensers 36 and 40 is analogous to the function of tube 13 and its associated circuit in Fig. 1 and will be understood from what has been said hereinbefore.

What I claim is:

1. An electrical circuit arrangement comprising a vapor-filled discharge tube having a cathode and an anode, a load impedance connected in series with the cathode and anode of said tube and a source of electric power, an arc-extinguishing device connected in parallel with said vapor-filled discharge tube, and means to prevent re-ignition of said tube, said latter means comprising a high vacuum electron discharge tube having a cathode and an anode connected in parallel with said vapor-filled tube and having an electron discharge control element, and a source of a control potential coupled to said control element to render said high vacuum tube conductive substantially during the period of extinction of said vapor-filled tube.

2. An electrical circuit arrangement compris-

ing a vapor-filled discharge tube having a cathode, an ignition electrode and an anode, a load impedance connected in series with the cathode and anode of said tube and a source of electric power, means coupled to said ignition electrode to periodically ignite said tube, an arc-extinguishing device connected in parallel with said vapor-filled discharge tube to extinguish said tube, and means to prevent re-ignition of said tube immediately following the extinction thereof, said latter means comprising a high vacuum electron discharge tube having a cathode and an anode connected in parallel with said vapor-filled tube and having a control grid, and a source of a control potential coupled to said control grid to render said high vacuum tube conductive for a period of the order of 10^{-4} seconds during the period of extinction of said vapor-filled tube.

3. An electrical circuit arrangement comprising a first vapor-filled discharge tube having a cathode, an ignition electrode and an anode, a load impedance connected in series with the cathode and anode of said tube and a source of electric power, a control circuit coupled to said ignition electrode to periodically ignite said tube, a series circuit comprising a second vapor-filled discharge tube having an anode, a cathode and an ignition electrode and first and second capacitors, means to connect said series circuit in parallel with said first discharge tube, means to connect a charging potential to one of said capacitors, a control circuit coupled to the ignition electrode of said second discharge tube to ignite the same and extinguish said first discharge tube, and means to prevent reignition of said first tube immediately following the extinction thereof, said latter means comprising a high vacuum electron discharge tube having a cathode and an anode connected in parallel with said first discharge tube and having a control grid, and a source of a control potential coupled to said control grid to render said high vacuum tube conductive for a period of the order of 10^{-4} seconds during the

period of extinction of said first discharge tube.

4. An electrical circuit arrangement comprising a first vapor-filled discharge tube having a cathode, an ignition electrode and an anode, a load impedance connected in series with the cathode and anode of said tube and a source of electric power, a second vapor-filled discharge tube having a cathode, an ignition electrode and an anode, means to connect the anode of said first tube to the cathode of said second tube and the cathode of said first tube to the anode of said second tube, a control circuit comprising means coupled to said ignition electrodes to periodically ignite said tubes selectively, first and second arc-extinguishing devices connected in parallel with said first and second vapor-filled discharge tubes respectively to extinguish said tubes, and means to prevent re-ignition of said tubes immediately following the extinction thereof, said latter means comprising a first high vacuum electron discharge tube having a cathode and an anode connected in parallel with said first vapor-filled tube and having a control element, a second high vacuum electron discharge tube having a cathode and an anode connected in parallel with said second vapor-filled tube and having a control element, and a source of control voltage derived from said control circuit coupled to said control elements to render said high vacuum tubes conductive substantially during the period of extinction of the associated vapor-filled discharge tube.

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