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ELECTROMAGNETIC SWITCHING CIRCUITS

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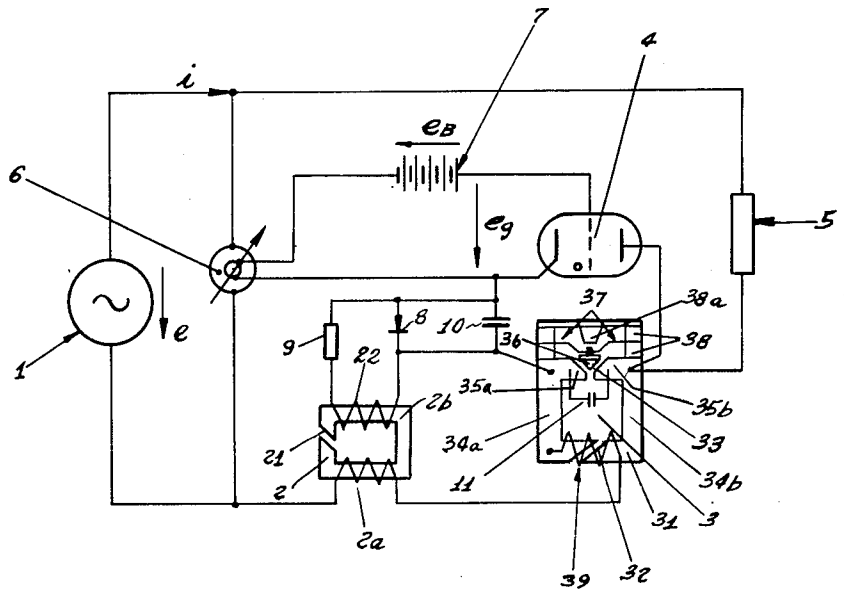


FIG. 1

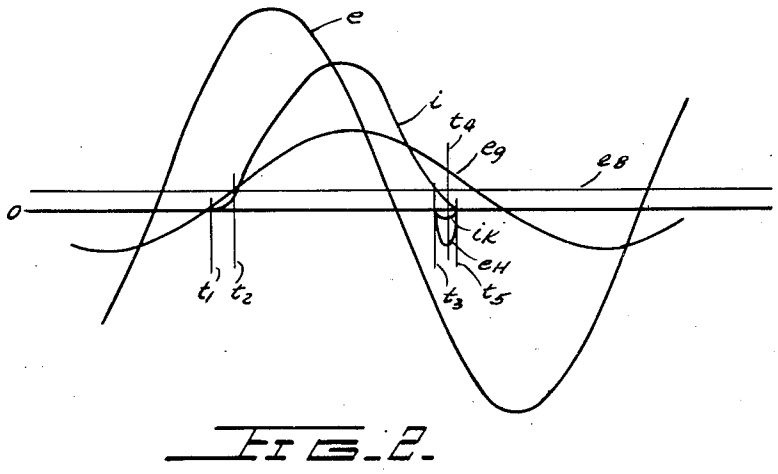


FIG. 2

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ELECTROMAGNETIC SWITCHING CIRCUITS

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1 Claim. (Cl. 321—48)

My present invention relates to an electromagnetic switch, and more particularly to an electromagnetic switch utilizing a tube in parallel with switching contacts providing a rectified current.

It is necessary when switching currents at the rate of even 60 cycles per second that the current switched be of relatively low value. If the switched current is greater than even one-half an ampere, the contacts melt, become welded, and are torn apart when opened. It is evident that this action soon destroys the contacts, rendering the switch inoperative.

Heretofore in the prior art, various tube rectifiers or mechanical motor-driven rectifiers were utilized. The tubes, however, introduce substantial resistance into the conducting circuit which in some situations is highly deleterious and the electromechanical rectifier commutates prohibitive currents.

My invention attempts to overcome these difficulties by providing a saturable core transformer in series with an electromagnetic switch and a tube in parallel with the contacts of the switch. This combination of elements supplies a compensating current across the contacts when they are opened so that the current through the contacts is essentially zero even though the current through the exciter coil is still substantial.

This compensating current supplied by the saturable core transformer and its associated circuitry offsets the decreasing current through the contacts making the resultant current substantially zero so that the contacts may be opened without any harmful effects.

It is then an important object of my invention to provide a compensating current through the contacts when they are opened.

Another important object of my present invention is to provide a step in the current when the contacts are closed.

Still another important object of my invention is the provision of a rectifier having a rectifying tube which is operative when the magnetic switch is turned on or off.

Still another important object of my present invention is the provision of a novel rectifying circuit providing a current step when the contacts are opened.

Further objects and advantages will become evident upon consideration of the description in conjunction with the figures wherein

Figure 1 is a circuit diagram of a modification of my present invention.

Figure 2 is a series of voltage and current curves with respect to time illustrating the principles of my present invention.

Referring now to Figure 1, an alternating current source 1 is connected through a saturable core transformer 2 and an electromagnetic switch 3 parallelled by the gas-filled triode 4 to the load 5 which is connected to the other side of the alternating current source 1.

The load 5 is assumed to be inductive in the present

modification and so the current i as shown in Figure 2 lags the voltage e supplied by the alternating current source 1.

Consider the beginning of operation to be at t_1 in Figure 2 or when the current i is at zero. The voltage e across the alternating current source 1 is already quite high and is applied across the gas-filled triode 4 which, being positively biased by the battery 7, ignites.

The current commences to flow from the alternating current source 1 through the load 5, thence through the tube 4, the rectifier 8, down the arm 34*a*, through the exciter coil 39 of the electromagnetic switch 3, through the primary 2*a* of the saturable core transformer 2 and back again to the alternating current source 1.

The saturable core transformer 2 is provided with a core 2*b* and an air gap 21. The core 2*b* saturates at relatively low values of current and thus provides a step in the increasing current. Somewhere in this step at time t_2 the exciter coil 39 supplies enough flux through the arms 34*a* and 34*b* to cause the switching element 36 to be pulled down against the stationary contacts 35*a* and 35*b*.

The magnetic circuit of the electromagnetic switch 3 is electrically insulated by the air gaps 32 and 33. The stationary contacts 35*a* and 35*b* are an integral part of the magnetic circuit as well as being the stationary electrical contacts. The switching element 36 is a prismatically shaped member constructed of magnetic material and is fastened to a spring 37 which resiliently restrains it in the open position. The spring 37 is rigidly fastened between the insulating pieces 38 to the legs 34*a* and 34*b*. The switching element 36 is provided with a detent 38*a* which positions it against the contacts. The contacts 35*a* and 35*b* are bridged by a condenser 11 to quench any formed arcs across the gap.

When the switch 3 is closed as described above, the current through the load flows through the switch element 36 short-circuiting the triode 4 which thus stops conducting. The current passes through the switch element 36 down the leg 34*a* through the exciter coil 39 and the primary 2*a* to the alternating current source 1.

The core 2*b* of the saturable transformer 2 becomes quickly saturated and thus the impedance through the primary 2*a* becomes negligible. During the non-saturated closing contact portion of the cycle described above, a voltage is induced in the secondary 22, and current flows in the secondary through the rectifier 8.

The current flows through the remainder of the cycle in the manner described above through the contacts 35*a* and 35*b* until its magnitude decreases to a critical value designated in Figure 2 at the time t_3.

By a suitable ratio of battery voltage e_B to grid voltage e_g, the tube 4 remains positive during its period of non-conduction. The grid voltage e_g is supplied from the phase shifter 6 so as to have a lagging characteristic as shown in Figure 2, but which is adjustable.

At the time t_3, the saturable core transformer 2 has its core 2*b* reach the unsaturated region and thus presents some impedance to the current i.

A voltage is induced across the secondary 22 of the saturable core transformer 2 in response to its change of flux linkages therethrough and supplies a voltage through the resistor 9 to capacitor 10 which is across rectifier 8 described above. This voltage across the rectifier 8 is essentially also across the tube 4. The voltage is designated as e_h in Figure 2 and is so directed that the tube 4 is ignited.

When the tube 4 ignites, the compensating current i_k also shown in Figure 2 flows across the switching contacts 35*a*, 36 and 35*b* in the opposite direction to the reducing main current i. As the switching contacts are opened, the sum of the currents therethrough is practically

zero and so the harmful effects of commutating substantial amounts of currents are avoided.

The switching element 36 opens when the current through the exciter coil 39 is sufficiently low and the main current is commutated to the tube 4 which maintains a discharge until the time t_5 which is the time when the current is practically zero.

Even though a substantial current flows through the exciting coil, the sum of the currents through the contacts becomes zero and remains at this low value until the current through the exciting coil 39 falls to its releasing value.

In order to eliminate the harmful effect of the inductivity of the secondary coil 22, it is bridged by the condenser 10. The times t_1 and t_2 indicate the beginning and the end respectively of the step caused by the saturable transformer 2 when the current is increased.

Modern tubes have been designed which are shaped suitably for the present purpose described in reference to the triode 4. These tubes are characterized by small ignition potentials and high blocking voltages. The small ignition potentials of such tubes make possible the commutation of the current in the tube circuit with small contact movement. This is possible as long as the electromagnetic switch is premagnetized having a hysteresis loop as nearly rectangular in shape as possible.

This factor is necessary upon consideration of the sloped hysteresis loop shape of the saturable core transformer 2 to keep the current step sufficiently small. Under these conditions the need for an anode battery is then unnecessary.

Metal vapor rectifiers having ignition potentials of approximately 10 volts are especially suited for this purpose.

Cathode tubes with alkali vapor, which can be either oxide or adsorption cathodes, have proven very satisfactory.

The small ignition potentials are achieved by glow cathode tubes filled with caesium vapor having adsorption cathodes. In such tubes the ignition potential may be smaller than 4 volts with a blocking potential of 1000 volts.

In the present application the tube is a triode having a grid so that in addition to the usual voltage control of the electromagnetic switch, additional possibilities for this purpose by means of suitable grid control are possible.

The tube 4 described above is ignited during the making contact period by a suitable rise of grid potential and during the breaking contact period by a rise of anode current as described above.

In the foregoing I have described my invention solely in connection with specific embodiments thereof. Since many variations and modifications of my invention will now be obvous to those skilled in the art, I prefer to be bound not by the specific disclosures herein contained but only by the appended claim.

I claim:

An electromagnetic switching circuit for energizing a D.-C. load from an A.-C. source comprising a saturable core transformer, an electromagnetic switch and a mercury vapor rectifier tube; said electromagnetic switch comprising a core assembly, a switching element and an energizing coil; said energizing coil being wound on said core assembly, said core assembly having a first and second portion; said first and second portions being positioned to form a magnetic loop with first and second series connected air gaps; the opposed surfaces of said first and second portions forming said first air gap comprising a first and second stationary contact for bridging contact cooperation with said switching member; a resilient restraining means; said resilient restraining means being operatively connected to said switching member; said resilient restraining means being constructed to resiliently restrain said switching member from entering into bridging contact engagement with said first and second stationary contacts; said switching member being at least partially constructed of magnetic material; said switching member being movable into contact engagement with said first and second contacts responsive to the magnetic field created by energization of said energizing coil; said second air gap being positioned to prevent electrical conduction through the core material adjacent to said second air gap to thereby prevent current flow in parallel with said first air gap irresponsive of the position of said switching member; said saturable core transformer comprising a magnetic core having an air gap therein and a primary and secondary winding; said A.-C. source, D.-C. load, second portion of said electromagnetic switch core assembly, switching element, first portion of said electromagnetic switch core assembly, energizing winding and said saturable transformer primary winding being connected in series; said rectifier tube comprising a plate, a control grid and a hot cathode; said rectifier tube having a saturating current of at least one ampere; a rectifier and a capacitor; said rectifier and said capacitor being connected in parallel with one another and in series with said first air gap and said plate and cathode of said rectifier tube; said parallel connection of said rectifier and said capacitor being connected in series with said saturable transformer secondary winding; a source of grid voltage for said rectifier tube; said source of grid voltage for said rectifier tube being constructed to impress an alternating potential having a positive direct component between said grid and cathode of said rectifier tube; said source of said grid voltage being further constructed to adjustably shift the phase of the alternating voltage component with respect to the phase of the voltage of said A.-C. source to thereby control the time of contact engagement with respect to said A.-C. source; said saturable core transformer supplying the plate potential for said rectifier tube during the interval immediately preceding contact disengagement so that the current through said contacts is substantially smaller than the current through said energizing coil.

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