Feb. 6, 1951 A. W. VINGERHOETS 2,540,558

ELECTROMAGNETIC POWER-CURRENT RELAY

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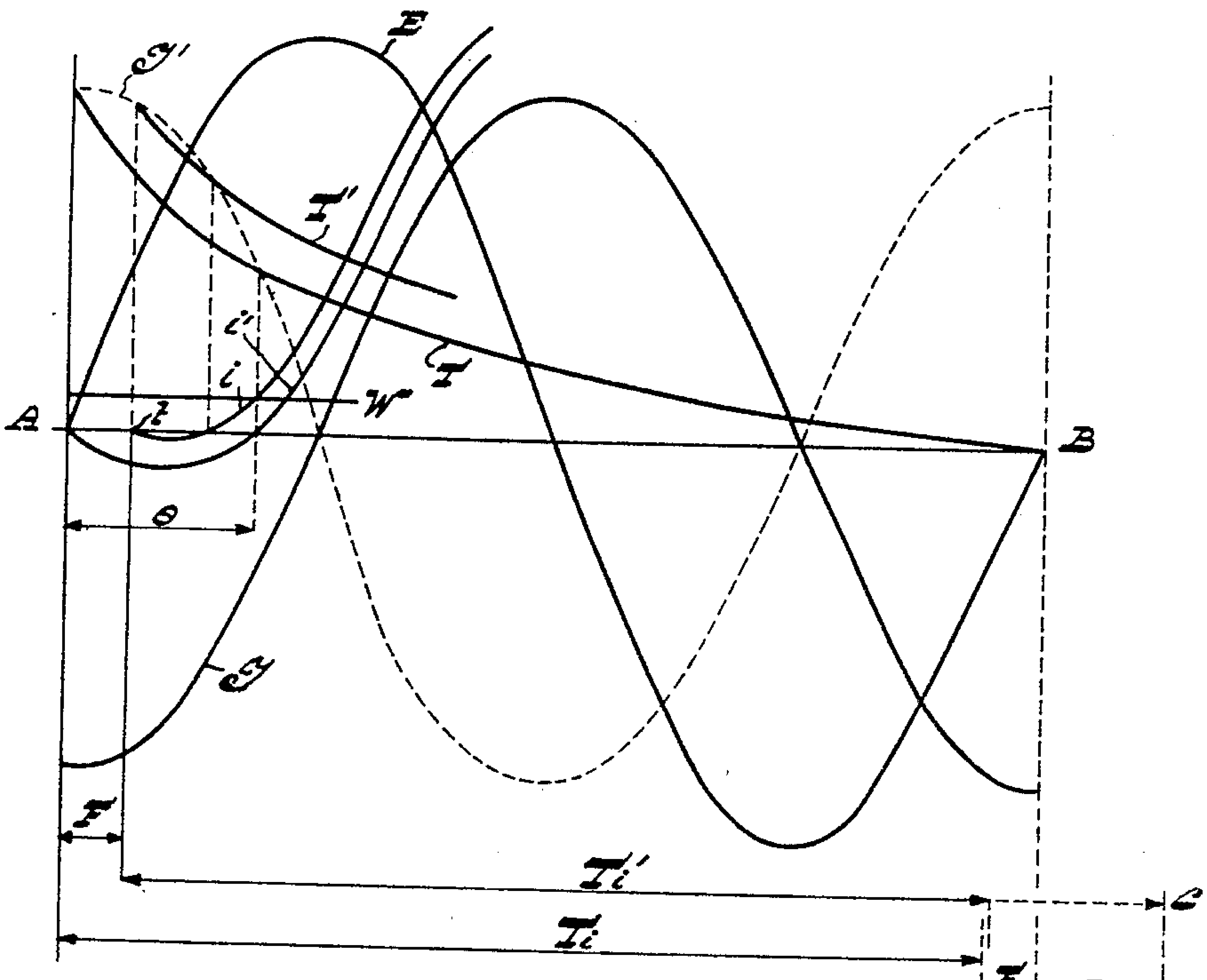

Fig. 1

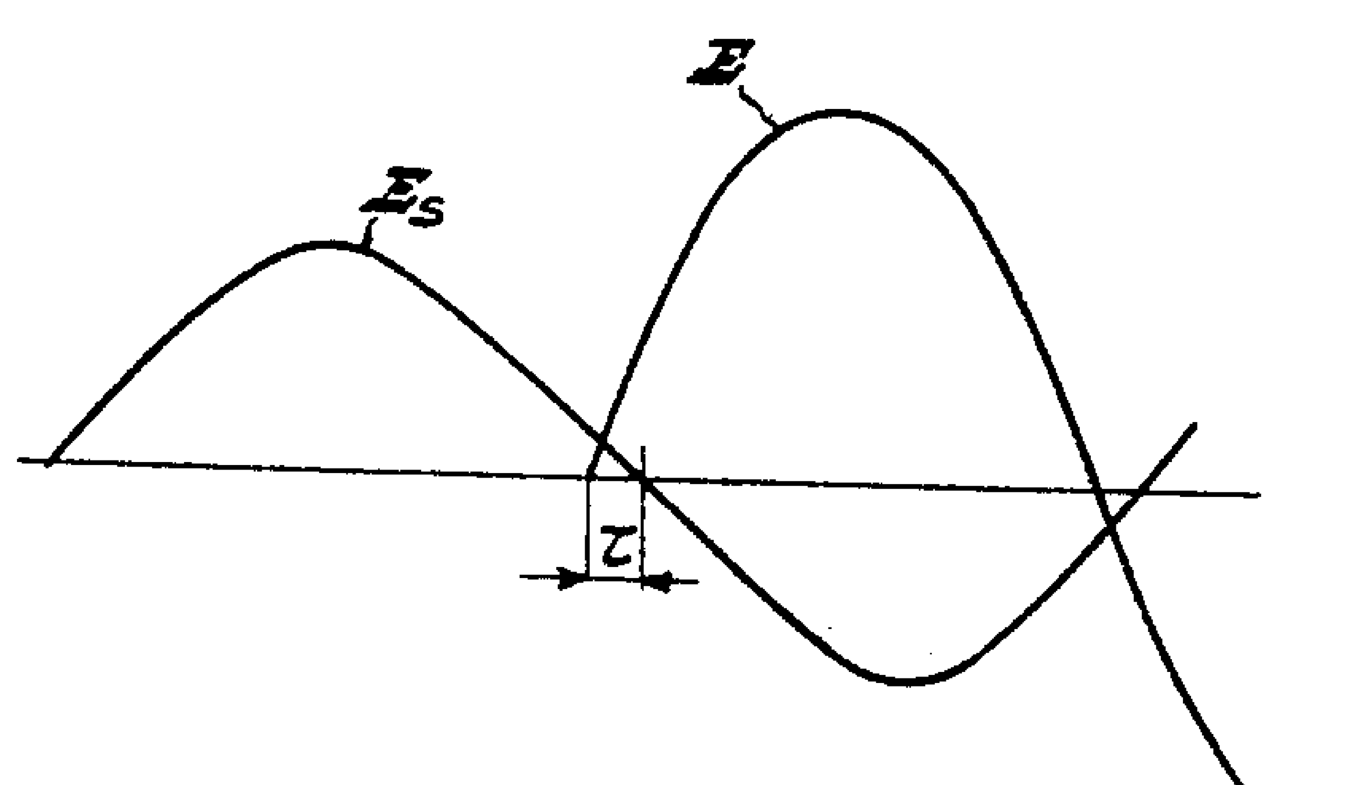

Fig. 2

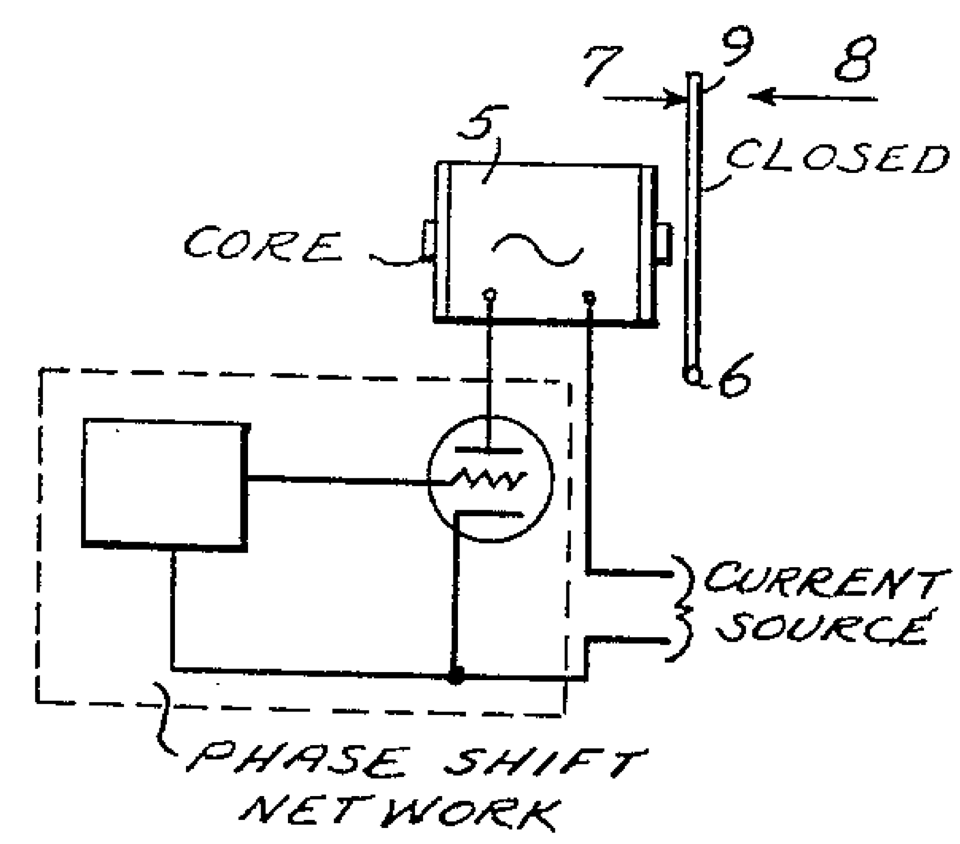

Fig. 3

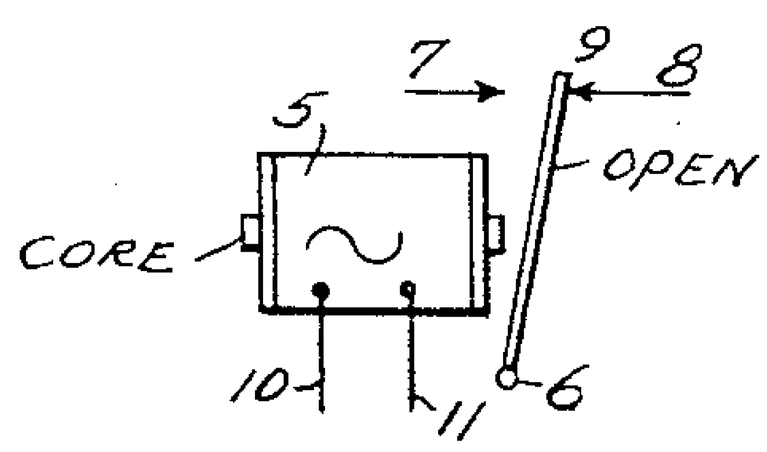

Fig. 4

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ELECTROMAGNETIC POWER-CURRENT RELAY

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In electromagnetic power-current relays fed on alternating current and controlled synchronously, which comprise mechanical contacts, it is a known phenomenon that the closing time of the relay is highly influenced by the place occupied at the moment when the energisation period of the coil of the relay begins relatively to the node of the energizing alternating current. The term closing time is to be understood here to mean the time which elapses between the said beginning of the energisation period of the coil and the moment when the mechanical contacts are closed.

The above-mentioned particularity is brought about by the so-called switching-in phenomenon which occurs when the switching-in is not effected exactly in the point of the natural node of the current. According as the beginning of the energisation period of the coil of the relay is chosen earlier than the said node with the preceding maximum of the current as a limit case, the energizing current is greater as a result of the occurrence of over-currents and the lifting time of the relay is correspondingly shorter. Since the circuit of the coil of a mechanical relay in practice generally exhibits such an inductive character that a phase difference of the order of 90° exists between the energizing current and the energizing voltage, a switching-in of the coil of the relay in a region located between the maximum and the subsequent node of the energizing alternating current practically corresponds to a switching-in between the node and the subsequent maximum of the energizing alternating current. Since the moment of switching-in of the coil of the relay falls in most cases within this region while it is also customary to choose the moment of switching-in as a function of voltage (for example when the coil is energized through a gas-filled or vapour-filled discharge tube which is normally made conductive in the first half of the positive half period of the anode voltage) the beginning of the energisation period of the coil for simplicity's sake will always be considered in this description in the lagging sense relatively to the node of the energizing voltage.

From the foregoing ensues that a later beginning of the energizing period of the coil of the relay relatively to the node of the energizing voltage results not only in the delay of the moment of closure of the mechanical contacts brought about already (which in definite cases may be utilized intentionally, for example for control purposes, and in other cases is due to imperfections of the control device), but as a con-

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sequence of the difference of energizing current results also in an "additional" delay which is felt as undesirable in practice. In fact, for this reason it is not possible for the mechanical contacts of such a relay to be switched-in synchronously or isochronally since small variations—as compared with the duration of a half period of the alternating voltage—in the beginning of the energisation period result in comparatively great variations in the moment of closure of the mechanical contacts. Such small variations may occur, for example, when the coil of the relay is energized by means of a controlled gas-filled or vapour-filled discharge tube in which the said beginning is determined by the control of the tube. Even with methods belonging to the so-called synchronized control of discharge tubes, for example with the aid of a steep wave-front or a peak voltage, such small variations, though to a smaller extent, are possible. They particularly occur, however, when use is made of the method wherein use is made of a control alternating voltage which in the lagging sense is dephased by slightly more than 180° relatively to the anode voltage of the tube. The number of degrees by which this phase displacement is in excess of 180° practically determines the region wherein ignition of the tube takes place. This region, the beginning of which is limited by the node of the anode voltage, cannot be reduced at will by varying the phase displacement of the control voltage since then there is a risk that the tube would not ignite any more due to displacement of characteristic or variations in anode voltage.

The present invention first of all purports to obtain a reduction of the above-mentioned additional delay in the moment of closure of the mechanical contacts, and this in such manner that in an electromagnetic power-current relay fed on alternating current and controlled synchronously, which comprises mechanical contacts, the time constant for the increase of current in the circuit of the coil is given a value smaller than a period of the energizing alternating current, and this so small that in a desired region up to at most 90° later than the node of the energizing alternating voltage a later beginning of the energisation period of the coil yields an effective current strength through the coil which is substantially equal or greater than with an earlier beginning. Such a relay can be used with particular advantage in devices for resistance welding in which the welding current is switched-in by the relay for exactly such a predetermined period as is desired. This must be effected in a reproducible manner.

By giving the said time constant a value smaller than a period there is already obtained a region in which a later beginning yields an effective current strength substantially equal or greater than with an earlier beginning that is that the lifting time of the relay with a later beginning is comparatively reduced as a result of the decrease of the above-mentioned additional time lag, which is brought about by the comparative increase in current strength. Further, by a correct choice of the smaller value of the said time constant the said region can cover a definite range desired.

The relation which exists between the values of the currents obtained with an earlier and a later beginning of the energisation period may also be influenced by a definite choice of the time constant. In addition, by means of a correct mechanical construction of the relay, the lifting time may be chosen such that the difference between the current strengths which according to the invention occur with a later beginning of the energisation period (greater current) and an earlier beginning (smaller current) has a comparatively greater influence than when the mechanical construction and hence the lifting time of the relay were different. It is evident that this influence is generally greater according as the moment of inertia of the movable parts of the relay and hence the lifting time is smaller. The foregoing will be explained more fully in the description of the Figure 1.

According to another characteristic of the invention, the time constant and hence the effective currents occurring with an earlier and a later beginning respectively of the energisation period, together with the friction and the lifting time of the relay are so chosen and adapted to one another that a synchronous switching-in of the mechanical contacts is obtained. This implies that the said additional delay is suppressed completely or almost completely, so that the closing time of the relay, no matter whether the coil is switched-in earlier or later, is constant. In dependence on the moment of the beginning of the energisation period of the coil it is thus possible to close the mechanical contacts on any desired point of the alternating voltage-curve and, consequently, to obtain a synchronised switching-in which is reproductible again.

According to the invention, however, it is possible to go even further with the choice of the above-mentioned factors by choosing them such that the difference in time between an earlier and a later switching-in relatively to the node of the energising alternating voltage is compensated completely or almost completely, so that an isochronal switching-in of the mechanic contacts is always ensured.

It is thus ensured that, when use is made of control means giving a more or less variable beginning of the energisation period, an isochronal closure of the mechanic contacts is nevertheless obtained. On the ground thereof the use of control means specially chosen, such as a steep wave-front of a peak voltage with controlled gas-filled or vapour-filled discharge tubes, the anode circuit of which serves to supply the coil of the relay, is rendered superfluous and simple known means suffice, for example the alternating control voltage previously referred to, which is dephased by slightly more than 180°. If nevertheless the said special control means are utilised the accuracy is increased by the invention.

In order that the invention may be more clearly understood and readily carried into effect it will be described more fully by reference to the accompanying drawing.

In the drawings:

Figure 1 is a diagrammatic presentation of the relation of the values of the currents obtained according to the inventions.

Figure 2 is a diagrammatic presentation of voltage and current relations when a gas-filled tube is used according to the invention.

Figure 3 is a schematic presentation of a relay in an open position and connected to a phase shift networks according to the invention.

Figure 4 is a schematic view of the relay of Figure 3 when in a closed position.

In Figure 1 the distance AB covers a period of the energizing alternating voltage E which is shown as a normal sinusoidal alternating voltage of mains frequency. The stationary current flowing upon excitation through the coil 5 of the relay of Figures 3 and 4 is shown as a current I which is lagging on the voltage by about 90°. In the Figure 1, this stationary current is shown again in dotted line in anti-phase and is indicated by I′. According to the invention, by giving the time constant for the increase of the current flowing through the coil, which is shown by the characteristic curve T, a value smaller than a period, in the region Θ which is limited, on the one hand, by the node of the alternating voltage at A and, on the other hand, by the point of intersection of curves I′ and T (from the continuation of the description it will appear that it is possible slightly to deviate from these limits in connection with definite factors) one obtains in principle a current strength which with a later beginning of the energisation period is substantially equal or greater than with an earlier beginning, so that the above-mentioned additional delay which is due to the switching phenomenon and which occurs with a later switching-in may be partly suppressed and is consequently less harmful. When the switching-in is effected, for example, at the moment *t*, which is represented by the beginning of the curve T′ of the time constant, the resulting current flowing through the coil of the relay will be represented by the curve *i*, which is shown as the difference between the ordinates of the curves I′ and T′. With an earlier beginning, for example in point A, the current curve *i′* will result as a difference between the ordinates of the curves I′ and T. From this it follows that the curves *i* and *i′* are variable with the choice of the curves of the time constants T and T′.

In the case of the curve *i′* (hence with an earlier beginning at A) it is true that that portion of the curve which extends below the C line is larger than in the first-mentioned case, but this has practically no influence since the effective value of the current during the whole so much longer lifting time is decisive for the closing time and the closure of the mechanical contacts 7 and 9 of Figure 3. In addition, these currents, which are small, are practically negligible for the response of the relay in connection with these currents exceeding a definite value, which is due to the friction of the relay. As can be seen from the further variation at the right of the range Θ, the current *i* is afterwards greater than the current *i′*, which occurs with an earlier beginning of the energisation period. Consequently, it is this region at the right of the region Θ which is essential in connection with the desired lifting time of the relay and in this region consequently occurs, as previously mentioned, the effective current desired in accordance with the invention, which is substantially equal or greater with a later beginning of the energisation period of the coil.

It is evident, however, that this region does not extend to the right unlimitedly, but is bound to a limit determined, for example, by a value equal to twice the time constant, when considered from the beginning of the period of energisation. Consequently, by means of a suitable mechanical construction of the relay the lifting time must be limited to a maximum interval and must not extend, for example, over several periods.

The said threshold value of the relay could be represented by the horizontal little line W, from which can be seen that currents smaller than the ordinate of W do not influence the response of the relay. Consequently, this threshold value also influences the ultimate lifting time of the relay.

From the foregoing ensues that in definite cases, which are mentioned in the preamble of the description, a correct adaptation between the currents, the closing time of the contacts of Figures 3 and 4 and the friction of the relay should be aimed at in order to attain the object in view, viz. a synchronous or an isochronal closure of the mechanic contacts.

Since, as mentioned already before, the region Θ is determined by the point of intersection of the characteristic T and the stationary-current curve I′, the region Θ may be chosen at will by a correct choice of the variation of curve T, for which again the time constant of the circuit of the coil is decisive.

At the bottom of the Figure 1 is shown, in addition, the closing time of the relay T_1 and T_1' with an earlier beginning (at A) and with a later beginning (at t) of the energisation period. In the case shown the mechanical contacts of the relay are switched-in substantially isochronally, which ensues from the small difference between the final points of the times T_1 and T_1'. The point C, which is the final point of the extension shown in dotted line of the lifting time T'_1 which occurs with a later beginning of the energisation period indicates where the mechanical contacts would close, for example, in the case of a relay of the usual type in which the invention is not utilised. The distance D indicates the additional delay mentioned several times in the preamble of the description while the time which elapses between the earlier and the later beginning of the energisation period is indicated by F, which is thus equal to the distance A—t.

It is mentioned in this connection that it is possible to switch in the coil a short time before the node of the voltage E, but any variation in the moment of closure of the mechanical contacts is thus not obtained since the current during the first moments even then is so small that the lifting time is practically not influenced thereby, which as before may be due to the said threshold value which must be surpassed before the relay can respond.

On the other hand, the relay may also be switched-in a little later outside the range Θ if the friction of the relay which is to be considered as the cause of the above-mentioned threshold value indicated by the line W admits this. If, due to a greater friction, the line W lies higher than in the current region wherein the currents are greater than the ordinate of W, it is possible by switching-in later a little at the right of the range Θ to obtain a current strength substantially equal to that obtained with an earlier switching-in, the more so as the steepness of the current curve associated with the said later switching-in may be greater than the steepness of the current curve corresponding to an earlier switching-in.

Figure 2 shows a voltage E which serves as an anode voltage of a gas-filled or vapour-filled controlled discharge tube while the coil of the relay is included in the anode circuit of it. The control voltage at the grid of the tube is indicated by E_s and is dephased relatively to the anode voltage by something more than 180°, i. e. by τ° more than 180°. Consequently, the region wherein the ignition of the tube can take place amounts to τ°. In view of displacements of the ignition characteristic of the tube—which may be more or less the case during the life thereof—and in view of variations in anode voltage the region τ cannot be reduced at will since then there is a risk that the tube would not ignite any more. It appears from practice that the ignition does not always take place at the same moment within the region τ, which results in comparatively large deviations from the lifting time. However, by utilizing this control method in a relay according to the invention, it is possible to obtain a substantially isochronal switching-in of the mechanical contacts and it is superfluous to utilize a steep wave-front or a peak voltage which in addition are themselves also exposed to displacements harmful in the said respect.

What I claim is:

1. Electromagnetic relay apparatus, comprising a relay having a core portion, a winding portion mounted on said core, an armature portion adapted to be moved to and from said core portion and contact portions adapted to be opened and closed by the movement of said armature portion, switching means to apply a source of alternating current to said relay for energizing said relay, said relay having a time constant having a value smaller that the period of the voltage impressed on the said coil, said time constant being so relatively small that in a desired range not exceeding 90° later than the node of the energizing alternating voltage, a later beginning of the energizing period of the said coil will cause an effective current to flow through the said coil which is substantially equal to an earlier beginning of the said energizing period of the said coil and means to actuate said switching means to energize said relay at a time period subsequent to said voltage node.

2. Electromagnetic relay apparatus, comprising a relay having a core portion, a winding portion mounted on said core, an armature portion adapted to be moved to and from said core portion and contact portions adapted to be opened and closed by the movement of said armature portion, switching means to apply a source of alternating current to said relay for energizing said relay, said relay having a time constant having a value smaller that the period of the voltage impressed on the said coil, said time constant being so small that in a desired range not exceeding 90° later than the node of the energizing alternating voltage, a later beginning of the energizing period of the said coil will cause an effective current to flow through the said coil

which is substantially equal to an earlier beginning of the said energizing period of the said coil, said time constant and therewith the effective currents occurring with an earlier and a later beginning of the said energizing periods, and said contacts having a friction component and a closing time correlated to said time constant that the said contacts are switched in synchronously with an energisation of the said coil and means to actuate said switching means to energize said relay at a time period subsequent to said voltage node.

3. Electromagnetic relay apparatus, comprising a relay having a core portion, a winding portion mounted on said core, an armature portion adapted to be moved to and from said core portion and contact portions adapted to be opened and closed by the movement of said switching means to apply a source of alternating current to said relay for energizing said relay, said relay having a time constant having a value smaller that the period of the voltage impressed on the said coil, said time constant being so relatively small that in a desired range not exceeding 90° later than the node of the energizing alternating voltage, a later beginning of the energizing period of the said coil will cause an effective current to flow through the said coil which is sub-

stantially equal to an earlier beginning of the said energizing period of the said coil, said time constant and the effective currents occurring with an earlier and a later beginning of the said energization periods and said contacts having a friction component and a closing time correlated to said time constant that the difference in time between an earlier and a later beginning of the energisation period is substantially neutralized and the said contacts switched in isochronally and means to actuate said switching means to energize said relay at a time period subsequent to said voltage node.

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