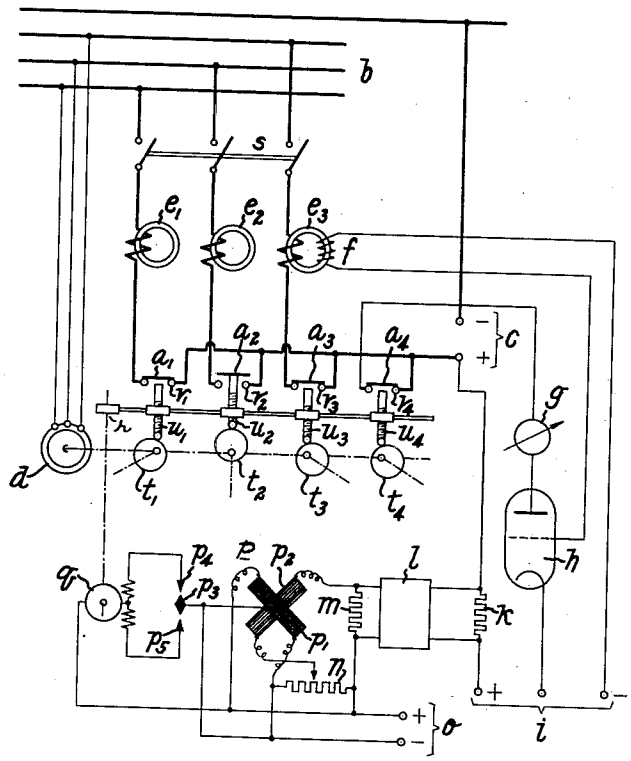
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APPARATUS FOR CONTROLLING THE TIMING
OF PERIODICALLY ACTUATED SWITCHES
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APPARATUS FOR CONTROLLING THE TIMING OF PERIODICALLY ACTUATED SWITCHES

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The present invention relates in general to electrical apparatus such as mechanical converters and the like which include periodically actuated switching devices for controlling the flow of current to a load, and is an improvement upon the converter apparatus described in our copending application Serial No. 664,396, filed April 23, 1946.

In the art of mechanical rectifiers for example, it has been conventional practice to incorporate an auxiliary control device such as a reactor in the primary side of the switch contacts for the purpose of effecting an interval of reduced primary current so that the contacts may be opened under relatively arc-free conditions. As the contacts are opened and closed periodically by a contact bridge actuated by a power drive which is synchronized with the alternations in the alternating current supply, it is obvious that the timing of opening of the contacts is important and that contact opening should occur at the instant the reactors or other current reducing means have produced their optimum effect.

In the above referred to application, control over the contact opening time is obtained by deriving a measured control quantity the magnitude of which varies as a function of the time interval between the beginning or alternatively the ending of the period of reduced current effected by the reactor and the opening or alternatively the closing of the rectifier contacts, comparing this control quantity with a reference quantity of fixed magnitude representative of the optimum condition to obtain the difference if any, and utilizing such difference to readjust the timing of the contacts until balance between the two compared quantities is reattained. The apparatus for producing the measured control quantity comprises a discharge tube of the grid control type having its anode-cathode circuit closed and opened periodically in timed relation with operation of the rectifier contacts, and its grid bias is likewise varied periodically in timed relation with operation of the reactor element. The arrangement is such that the grid bias, normally at a negative value sufficient to maintain the tube in a nonconductive state, is driven positive at the beginning of each interval of reduced current and shortly before the rectifier load contacts controlling the anode-cathode circuit of the tube are set to open. Current will thus flow in the anode-cathode circuit of the tube from the beginning of the period of reduced current until the rectifier contacts open. The average value of these periodic pulses of anode-cathode current thus become a measure of the time between the instant the reactor begins to produce the interval of reduced current and the instant at which the load contacts open.

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While this system is generally satisfactory, it does have one operating disadvantage which stems from the fact that the anode-cathode circuit passes through a switching device formed by one of the stationary rectifier load contacts and the movable contact bridge, and theoretically this anode-cathode circuit is broken at the instant the bridge lifts from the contact. In practice however it has been found that this arrangement for breaking the flow of current in the tube is satisfactory so long as the contacts operate in an arc-free manner. Arc-free operation cannot however always be obtained especially in applications where the load is subject to rapid fluctuations, and when arcing does occur it is obvious that the anode-cathode circuit of the tube will not be interrupted at the instant of load contact break but rather at a somewhat later instant when the arc between the contact and bridge has been extinguished. This then introduces a corresponding error in measurement of the average value of the anode-cathode current for the period desired which is reflected by a like error in response of the mechanism whose function is to adjust the timing of the contacts.

Moreover even under arc-free operating conditions of the load contacts, error in measurement is still possible because the contact bridge may not always lift from both stationary contacts at the same instant with the result that the rectifier load circuit through the contacts may be broken while the anode-cathode circuit of the discharge tube may yet be unbroken.

The object of the present invention is to overcome the foregoing disadvantage and the objective is obtained by providing an extra set of switching contacts operated synchronously with the load contacts of the rectifier and whose sole function is to periodically open and close the anode-cathode circuit of the discharge tube component of the interval measuring device.

One practical embodiment of the invention as applied to a polyphase rectifier system is illustrated in the accompanying drawing which shows the improved system in schematic form.

Referring now to the drawing, the movable contact bridges of a polyphase mechanical rectifier are designated by *a1*, *a2* and *a3* which coact with opposed sets of stationary contacts *v1*, *v2*, *v3*. The latter are connected on one side to an

alternating current network *b* through commutating reactors or chokes *e1*, *e2* and *e3* and switch S, and on the other side to feed a direct current load system C.

The drive for actuating the several contact bridges is a synchronous motor *d* connected to the network *b*. The motor shaft drives cams *t1*, *t2* and *t3* which through cam follower rods *u1*, *u2*, *u3* function to periodically lift the contact bridges *a1*, *a2*, *a3* out of engagement with their associated sets of fixed contacts *v1*, *v2*, *v3* in the proper sequence as related to the phase sequence of the polyphase power supply *b*.

The control quantity for regulating the contact timing is obtained through the use of the discharge tube *h* which is of the grid control type. Its anode-cathode circuit is arranged to be opened and closed in timed relation with operation of the load contact bridges *a1*, *a2*, *a3*, but instead of using the latter also as the switching device for the anode-cathode circuit as is done in the co-pending application Serial No. 664,396, an auxiliary set of contacts and bridge are employed especially for such purpose. The auxiliary contacts are designated *v4* and the associated auxiliary contact bridge *a4*. Bridge *a4* is actuated periodically in a manner similarly to the other contact bridges associated with the load contacts by means of cam *t4* and cam follower rod *u4* and is synchronized with the movement of contact bridge *a3*.

The grid of tube *h* is normally biased negatively from an auxiliary voltage source *i* and the grid circuit extends from the source *i* through a winding *f* inductively associated with the reactor *e3*. The use of reactors in the primary of the rectifier is well known and hence the theory of their operation need not be detailed here. It is sufficient to say that at the beginning of the interval of reduced current effected by reactor *e3*, the inductive effect inherent therein is sufficient to induce a potential pulse in winding *f3* which is so connected in the grid circuit of tube *h* that the grid bias is swung positive and renders the tube conductive. As this action takes plate at a time shortly before the contact bridges *a3* and *a4* operating synchronously are set for lifting from the respective sets of fixed contacts *v3* and *v4*, current will flow in the anode-cathode circuit of tube *h* from the beginning of the interval of reduced current in the phase served by load contacts *v3* until the latter and also contacts *v4* open. Thus as the rectifier operates and the load and auxiliary contacts periodically open and close, periodic pulses of direct current of constant amplitude flow in the anode-cathode circuit of tube *h* and hence it now becomes obvious that the average flow of current in this tube circuit, which can be observed by an ammeter *g* placed in the circuit, is a measure of the time between the instant at which the choke *e3* begins to produce its interval of reduced current and the instant at which load contact bridge *a3* lifts from its fixed contacts *v3*.

To measure the average current in the tube circuit a resistance *k* is connected therein and the drop in voltage across the resistance will hence vary with the current.

The potential across resistance *k* is used to regulate the timing of the rectifier contacts so that they always open at the optimum condition, i. e. substantially maximum current reduction in the primary line. For this purpose the voltage drop at resistance *k* is fed into an amplifying

device *l* which is of conventional construction and therefore has been illustrated in block schematic only. Connected across the output of amplifier *l* is a resistor *m* that is connected to a selected portion of a manually adjustable voltage dividing resistor *n* in such manner as to derive a voltage which represents the difference in the respective voltage drops across the two resistors.

An instrument type relay *p* of the crossed coil type is used in the control and the contacts of this relay control the operation of a reversible motor *q*. Coil *p1* is connected directly to an auxiliary source of direct current power indicated by conventional symbols and hence current through it remains constant. However coil *p2* is connected in the circuit between opposed resistors *m* and *n* and hence its current depends upon the unbalance between the voltage drop across these two resistors. The arrangement is such that when the current through coil *p1* of the instrument's moving system is equal to the current through coil *p2* which is at right angles to coil *p1*, the contact arm *p3* will take a position between and spaced from the stationary contacts *p4*, *p5* and the motor *q* will stand still since the circuits to both of the motor fields *q1* and *q2* are open. If however the two coil currents are unbalanced, the contact arm *p3* will be moved into engagement with one or the other of contacts *p4*, *p5*, dependent upon the direction of the unbalance, and hence will cause motor *q* to run in one direction or the other as determined by the alternatively energizable motor fields *q1* and *q2*.

A control mechanism *r* actuated by the shaft of motor *q* functions to adjust the timing of the contact bridges *a1*—*a4* relative to their respectively associated phase voltages of the polyphase power supply by changing the positions of the cam follower contact bridge actuating rods *u1*—*u4* relative to their actuating cams to *t1*—*t4* in one direction in which motor *q* is rotated.

The various operating components are adjusted so that when the load contacts of the rectifier are operating when optimumn condition, i. e. without arcing, the drop across resistance *k* and hence the resulting drop across resistor *m* is such that the current through relay coil *p2* is equal to that through coil *p1* and hence motor *q* will stand still. However should the desired timing of the rectifier contact bridge *a3* relative to the operation of the commutating reactor *e3* shift in one direction or the other which would therefore cause the contact bridge *a3* to arc as it lifts from the contacts *v3*, such shift will appear as a change in the conducting time of tube *h* and hence change the voltage drop across resistor *k*. In turn the current through instrument relay coil *p2* is changed and this causes relay *p* to effect rotation of motor *q* in such direction as will readjust the timing of the contacts to the optimum operating condition. When the correct timing is reached, the voltage drops across resistor *k* and *m* will have gained a rebalance and motor *q* will stop. The regulating action is thus entirely automatic and constantly maintains correct timing of the contact bridges.

Moreover since a separate set of switching contacts operating synchronously with one of the sets of load contacts on the rectifier are utilized solely to open and close the anode-cathode circuit of the control tube *h*, correct measurement of the interval between the beginning of the period of reduced load current and the actual

opening of the associated rectifier contacts will always be assured.

If desired, the discharge tube *h* can be associated with one of the other phases of the alternating current power supply *b* such as that controlled by contact bridge *a2* for example, in which case motion of contact bridge *a4* would be synchronized with bridge *a2* rather than bridge *a3*, and the winding *f* in the grid circuit of tube *h* would be transferred from reactor *e3* to reactor *e2*.

Another possible modification would be to associate the winding *f* with reactor *e2* or *e1* instead of *e3* as now illustrated leaving the auxiliary set of contacts *a4 v4* synchronized with contacts *a3 v3* of *e3*. In such case however a mean value of direct current proportional to a constant value (e. g. 60° if *e2* or 120° if *e1*) plus the time between the beginning of the reduced current interval and the disconnecting instant of the contact bridge will flow through the discharge tube and measuring instrument *g*.

We claim:

1. A mechanical current converter comprising a set of load contacts adapted to periodically open and close a circuit between a power source and a load, a control device in series with said contacts for effecting periodic intervals of reduced current to minimize contact arcing, a discharge tube having grid control, means controlling the grid bias on said tube in accordance with the operation of said control device to render said tube periodically conductive, an auxiliary set of contacts operated synchronously with said set of load contacts and connected in the anode-cathode circuit of said tube for periodically opening and closing said anode-cathode circuit, and means responsive to any deviation in the average current flow in the anode-cathode circuit of said tube from a selected value for regulating the timing of said load contacts in accordance with the sense and magnitude of said deviation to restore the average current to said selected value.

2. A current converter as defined in claim 1 wherein said auxiliary set of contacts open the said anode-cathode circuit simultaneously with opening of said load circuit by said load contacts.

3. A mechanical current converter for use on polyphase power systems comprising a set of load contacts individual to each phase of said system, means actuating said sets of load contacts

periodically in a predetermined sequence to periodically open and close the several phases connected to supply a common load, a control device in series with each set of load contacts for effecting periodic intervals of reduced current to minimize contact arcing, an auxiliary measuring circuit having therein a discharge tube, said tube having cathode and anode elements through which current flows in said measuring circuit and a grid element determining conductivity of said tube in accordance with the bias thereon, an auxiliary set of switching contacts connected in the anode-cathode circuit of said tube and actuated synchronously with one of said sets of load contacts to periodically condition the anode-cathode circuit of said tube for conduction therethrough, means controlling the grid bias on said tube in accordance with the operation of one of said load current reducing control devices to render said tube periodically conductive, and means responsive to any deviation in the average current flow in the anode-cathode circuit of said tube from a selected value for regulating the timing of said sets of load contacts in accordance with the sense and magnitude of such deviation to restore the average current to said selected value.

4. A mechanical converter as defined in claim 3 wherein said auxiliary set of switching contacts is actuated synchronously with that set of load contact associated with the said control device controlling the grid bias of said tube.

5. A mechanical converter as defined in claim 3 wherein said auxiliary set of switching contacts is actuated synchronously with a set of said load contacts other than the contact set associated with the said control device controlling the grid bias of said tube.

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