April 10, 1956 T. WASSERRAB 2,741,735

CONTACT RECTIFIER FOR POLYPHASE ALTERNATING CURRENT SYSTEM

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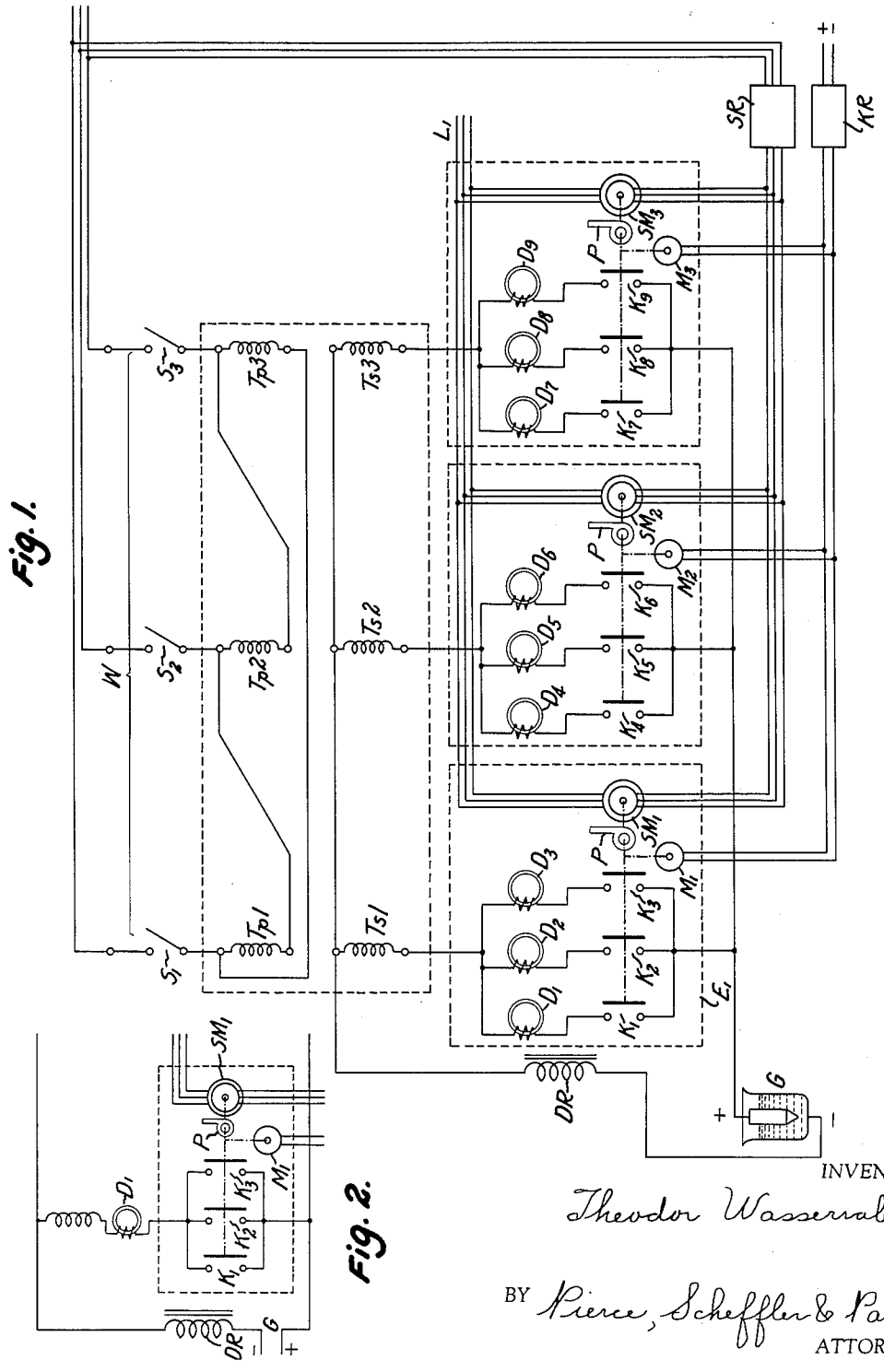


Fig. 1.

Fig. 2.

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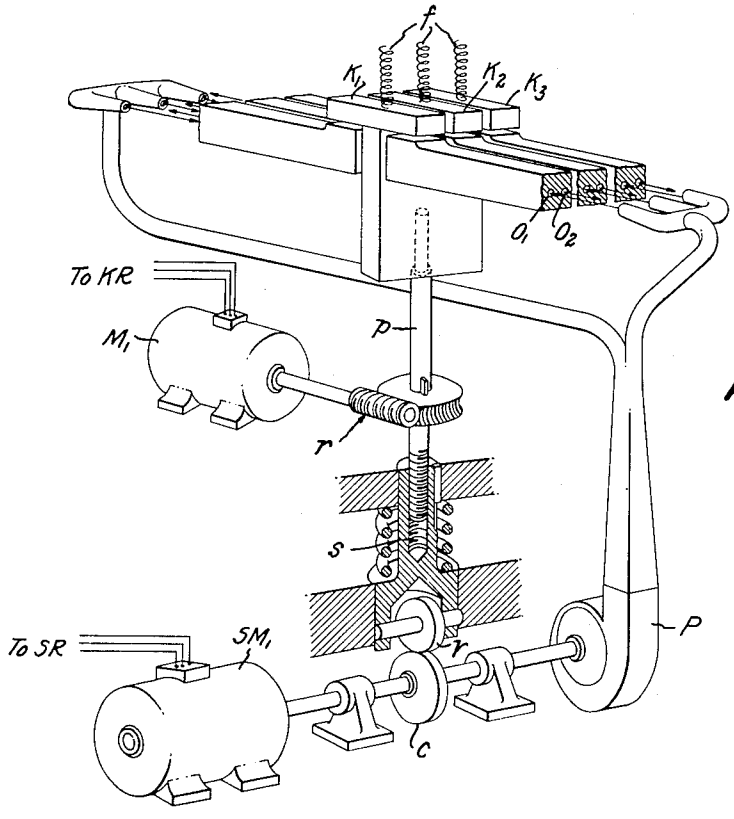


Fig. 3.

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CONTACT RECTIFIER FOR POLYPHASE ALTERNATING CURRENT SYSTEM

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9 Claims. (Cl. 321—48)

The present invention relates to electrical rectifier systems and in particular to those of the movable contactor type for converting a polyphase alternating current into high amplitude direct currents at comparatively low voltage such as are required for electrolytic installations.

Since power losses attributable to current conduction through the electrical parts and losses across the rectifier contacts increase with the square of the current, it is therefore of utmost importance in the interest of high efficiency for applications in which very high currents are involved, to keep such losses as low as possible. This requirement is met by making all lines of connection as short as possible and by eliminating all unnecessary contact points and connection pieces.

In contact rectifiers, the contact resistance is determined by the type of material utilized and by the pressure applied between the contacts. Also, the electrical losses in the leads to the contacts play an important part. In conventional rectifiers, six or twelve contacts belonging to one unit, as far as wiring is concerned, are actuated by a common synchronous motor and lodged with the contacts and necessary auxiliary devices in a common casing. This arrangement has the advantage that those auxiliary devices necessary for each contact such as drive, regulation, control, cooling and supervision are in common. However it has a disadvantage, especially in the case of high current strengths, that the heat loss occurring in the contacts and their leads is difficult to remove and also that a production unit once established, which requires a very careful and detailed development, can be thereafter modified only by lengthy reconstruction work. Moreover, the manufacture of contact rectifier equipment requires very accurate machines and extremely accurate assembly. All of this makes the cost of a movable contactor rectifier, which must be regarded as a precision machine, relatively high.

In order to produce the highest possible direct currents with a minimum of contact loss, it is necessary to provide a large number of contacts connected in parallel. The reason for this is that the contact losses increase with the square of the current strength. Thus a division of the total current over n number of contacts causes a reduction of the contact losses to $1/n$, as compared with the losses which otherwise would be caused were the entire current to be conducted over one contact. Conventional contact rectifiers are usually designed so that the entire current to be transformed flows over one or at most two contacts connected in parallel for each phase of the alternating current supply source. Accordingly, in consideration of the maximum tolerable heat loss in the contacts, the current rating of movable contactor rectifiers of present design is limited to about ten or at most twenty kiloamperes. In electrolytic applications however, current strengths of about one hundred kilo-amperes are often required for the baths necessitating a parallel connection of at least five to ten complete movable contactor rectifier units of conventional manufacture. Apart from the

fact that the cost of such a parallel connection of a large number of rectifier units is very high, the electrical losses in the leads is also considerable since these individual units must necessarily be arranged only in the manner dictated by their structural form, so that the rail lengths are fixed from the start.

It is the primary object of the present invention to provide an improved structural arrangement for a movable contactor rectifier designed for applications requiring high current amplitudes which will not only be cheaper than conventional practice for an equivalent current production but will also be more efficient to operate in that the electrical losses will also be less. Such objective is realized by sectionalizing the rectifier such that the contacts for each phase are structurally separate from those of the other phases. Separate synchronous drives are provided for the contacts of each phase and all drives are synchronized with, and preferably also receive power from, the multi-phase alternating current supply source with the proper phase interrelation so that the phase contacts operate in the proper sequence and at the proper instants coordinated to their respective phase.

Practical embodiments of the invention are illustrated in the accompanying drawings wherein Fig. 1 is a schematic view showing an arrangement wherein each of the plurality of parallel connected contacts for each phase of the alternating current supply source to be rectified is provided with a current-reducing choke. Fig. 2 is also a fragmentary schematic view similar to Fig. 1 except that only one current-reducing choke is provided for each phase. And Fig. 3 is a diagrammatic view in perspective showing the essential detailed structural arrangements for the rectifier associated with one of the three phases to be rectified.

With reference now to Fig. 1, the alternating current to be rectified is seen to be constituted by a three phase network W which feeds into the primary side of a three phase transformer T, the three primary windings Tp1–Tp3 of the transformer being arranged in delta and connected to the proper phase of the network through switches S1, S2 and S3. In accordance with the invention, the contacts and associated auxiliaries for each phase of the rectifier are constituted as structurally and operatively independent units as indicated diagrammatically by the three broken-line rectangles E1, E2 and E3. Within rectangle E1 are shown three rectifier contacts K1, K2 and K3, each having a current-reducing choke D1, D2, D3 connected respectively in series therewith. The contacts K1–K3 together with their series connected chokes D1–D3 are arranged in parallel and connected to one side of secondary winding Ts1 of transformer T. The other side of winding Ts1 is connected through a smoothing choke DR to the direct current load G and thence to the contacts K1–K3. Contacts K1–K3 are arranged to be opened and closed periodically in timed relation with the alternating voltage wave of transformer winding TS1 and this is provided for by actuating the contacts K1–K3 simultaneously by means of a synchronous motor SM1 which is connected through a conventional phase regulator SR preferably to the network W thus automatically assuring the proper rhythmic opening and closing of the contacts K1–K3 in the rhythm of the periodic rise and fall of the alternating voltage wave of the network W. The field component of motor SM1 is arranged to be energized from any convenient source of direct current fed into the field winding of the machine over conductors L.

The electrically paralleled and simultaneously acting contacts K1–K3 include a device wherein the duration of contact, i. e. the length of time the contacts are closed, is regulated continuously. Essential details for contact duration control are shown in Fig. 3 where it is seen that a reversible motor M1 is connected in such manner as to

adjust, through worm and wormwheel coupling *r*, the effective length of the plungers *p* in sleeves *s* which actuate the contacts, the sleeves *s* being reciprocated by cams *c* driven by motor SM1 and which engage cam follower rollers *v* journalled in the sleeves. Motor M1 is connected to the regulator KR and is arranged to rotate in one direction or the other to lengthen or shorten the closed contact time as the case may require. Reference can also be made to U. S. Patent No. 2,375,416, issued May 8, 1945, to Jokob Huber and assigned to the assignee of the present application for further detail of the plunger-sleeve construction. Regulator KR has been shown only in block form since the details thereof do not constitute a part of the invention claimed herein. If however a more detailed knowledge of the contact duration regulator is desired, reference can be made to U. S. Patent No. 2,557,740, issued June 19, 1951, to Alexander Goldstein et al., and also assigned to the assignee of the present application. Contacts K1–K3 can also be provided with cooling means in the manner customary for conventional contact rectifiers shown in Fig. 2 as comprising a centrifugal pump P which circulates a fluid coolant through ducts O1, O2, in the stationary contacts.

A second, structurally independent rectifier unit designated by rectangle E2 is provided for the phase of the alternating voltage network associated with transformer windings T*p*2 and T*s*2, and a third unit E3 is provided for the phase associated with transformer windings T*p*3 and T*s*3. These units are identical with rectifier unit E1. Thus rectifier unit E2 includes parallel arranged rectifier contacts K4–K6, chokes D4–D6, contact driving synchronous motor SM2 and contact duration regulating motor M2. Similarly, rectifier unit E3 includes parallel arranged rectifier contacts K7–K9, chokes D7–D9, contact driving synchronous motor SM3 and contact duration regulating motor M3.

It will be seen that contact duration regulating motors M2 and M3 are connected in common with motor M1 to the same regulator device KR. Thus all three of these motors behave in the same manner and provide identical regulation for all three phase units E1, E2 and E3.

Likewise all three of the contact driving motors SM1–SM3 are connected to the same source of field current and to the common phase regulator SR. Thus any phase change in the applied voltage which may become necessary is made simultaneously and to the same degree in the armatures of such motors. The armatures of all these motors are connected electrically in such manner as to form synchronous tie. It is to be noted that the symbols used on the drawing to indicate the motors shows them to be of the rotary synchronous type of similar construction to the conventional alternating current generator. However other types of motors capable of actuating the rectifier contacts in synchronism with the alternating voltage wave of the network W can be utilized if desired. A suitable reciprocating type of motor is described in U. S. Patent No. 2,471,729, issued May 31, 1949, to Eduard Diebold and also assigned to the same assignee as the present invention.

Rectifier units E1–E3 may each be provided with a control circuit connected in parallel with the contacts to minimize arcing of the contacts. Such circuits have not been shown but a typical arrangement can be found in U. S. Patent No. 2,583,263, issued January 22, 1952, to Alexander Goldstein and assigned to the assignee of the present invention.

Each of the rectifier units E1–E2 may also provide comparison and supervision of the switching operation by means of a conventional guide contact, not illustrated in the schematic views of the drawing.

Operation of the improved rectifier arrangement according to the present invention wherein structurally and operatively independent rectifier units individual to and coordinated with each phase of the multi-phase alternating

voltage supply source to be rectified is basically similar to conventional multi-phase movable contactor rectifiers and hence no detailed explanation is thought to be necessary, The three sets of contacts K1–K3, K4–K6 and K7-K9 are periodically opened and closed in sequence and in rhythm with the voltage waves of their respectively associated phases of the power supply network W such that each phase is rectified in sequence and the rectified current fed to the load G.

As explained at the outset, the principal structural difference between the conventional movable contactor rectifier and the improvement according to this invention is that whereas in the former, the contacts for all phases of the power supply to be rectified were structurally integrated into a single assembly along with a common drive motor for the contacts, and all other necessary auxiliary equipment, the improved construction now structurally separates the various phases into substantially independent rectifier units and provides each with the necessary auxiliaries. The new arrangement makes possible a most favorable spatial arrangement of the contact units in the installation with short connections and hence greatly reduced output losses. Such contact units can be inserted at any point in the line where it seems advisable with a view to short connections and small losses. Moreover by breaking up the entire three phase rectifier equipment into separate phase units, removal of the contact heat is greatly simplified. While in the past, the rectified output per contact device was severely restricted because of the limitations allowed in temperature rise of the equipment, the present invention, by separating the contacts, makes it possible to dissipate the heat at a faster rate than heretofore possible. Hence the contacts can now be given a higher current rating and the designer has a greater latitude in selecting the best design by proper selection of the wiring, number of contacts to be actuated in parallel, etc. These advantages far outweigh the disadvantages involved in the higher cost of providing the contacts of each phase with its own contact duration regulating motor and the synchronous motor for actuating the contacts.

The present invention is of special significance in application to installations where the line is formed by cylindrical hollow conductors. In such case, a radial arrangement may result, the individual contacts being arranged radially and actuated from the axis of symmetry by way of plungers. Alternatively, an axial arrangement can be produced wherein the individual contacts will be arranged longitudinally of the conductor at the periphery thereof and actuated axially. The drive for the contacts can be provided by a synchronous motor for each contact element, arranged inside or outside the tubular conductor.

In the case of tubular conductors, the short-circuiting device (preferably one short-circuiting device per phase) is preferably arranged in such a way that either an annular short-circuiting element bridges annular flanges in the space between two concentric tubes per phase, several holding coils and springs being used, or several short-circuiting elements are provided symmetrically distributed in this space, each of which has its own actuation coils and springs.

For an electrolytic installation wherein the bath i. e. load G requires very high current amplitudes, several such movable contact or rectifier elements can be connected in parallel and grouped in such a manner that the individual contact rectifier elements feed radially into the bath. In the case of very large rectifier installations, the latter solution is advisable because a six-phase reaction on the multi-phase alternating voltage network has undesirable consequences.

The embodiment shown in Fig. 2 is similar to that shown in Fig. 1, the only difference being that instead of having a current-reducing choke in series with each of the rectifier contacts that are connected in parallel, only one current-reducing choke for each parallel group of rectifier contacts are used. That is, each group of parallel

arranged rectifier contacts for each phase has one current-reducing choke D' connected in series with the group. There is no difference in operation.

In conclusion it is desired to be understood that while the foregoing description and related drawings are directed to preferred embodiments of the invention, other changes therein in the construction and arrangement of the component parts may be made without however departing from the spirit and scope of the invention as defined in the appended claims.

I claim:

1. A movable contactor type rectifier for converting a polyphase alternating current supply network of a given frequency into direct current for feeding a load requiring high amplitude currents wherein the movable contacts are actuated to open and closed positions periodically in synchronism with the network frequency characterized by the fact that the contacts coordinated to each phase of the network to be rectified are structurally separate from the contacts coordinated to the other phases, the contacts of each phase including cooling means individual to each phase and the contacts of each phase being actuated by a synchronous drive individual to such phase, said drives being connected to said network to receive power therefrom and forming a synchronous tie thereby to operate in synchronism with the network frequency and with the proper phase interrelationship therebetween and means for adjusting the phase relationship between the network frequency and the periodic operation of the rectifier contacts.

2. A movable contactor rectifier as defined in claim 1 wherein said synchronous drives are each constituted by a synchronous motor and said contacts are actuated by push rods reciprocated by said synchronous motors.

3. A movable contactor rectifier as defined in claim 1 wherein each phase to be rectified has at least two sets of contacts operating in parallel.

4. A movable contactor rectifier as defined in claim 1 and which further includes means individual to the contacts of each phase for regulating the period during which such contacts are closed.

5. A movable contactor rectifier as defined in claim 4 wherein the means individual to each phase for regulating the closed period of the contacts is comprised of a reversible motor and said motors are controlled from a common regulating device.

6. A movable contactor rectifier as defined in claim 1 and which further includes means individual to the contacts of each phase for regulating the period during which such contacts are closed, said regulating means comprising a plunger for actuating the contacts and reversible motor means for adjusting the effective length of the plunger.

7. A movable contactor rectifier as defined in claim 1 wherein each phase to be rectified has at least two sets of contacts connected in parallel and which further includes a current-reducing choke individual to each set of contacts and connected in series therewith.

8. A movable contactor rectifier as defined in claim 1 wherein each phase to be rectified has at least two sets of contacts connected in parallel and which further includes a current-reducing choke common to said sets of contacts and connected in series therewith.

9. A movable contactor rectifier as defined in claim 1 wherein said synchronous drives are constituted by synchronous motors connected through a phase regulator common to all such motors to said network to receive power therefrom.

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