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3,238,320

TRANSFER SWITCH FOR TAP CHANGERS FOR REGULATING TRANSFORMERS
INCLUDING A CYLINDRICAL INSULATING HOUSING, A
SQUIRREL-CAGE CONTACT-SUPPORTING STRUCTURE
AND CONTACT BRIDGES INSULATINGLY
SUPPORTED BY CONTACT
BRIDGE CARRIERS

Original Filed Jan. 31, 1963

5 Sheets-Sheet 1

FIG. 1

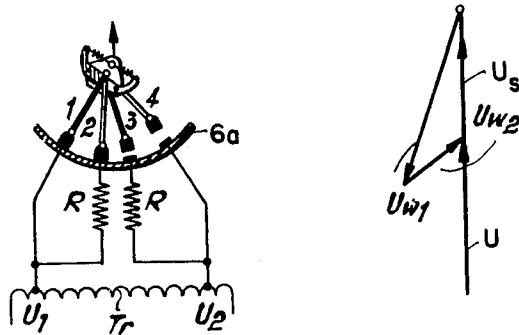


FIG. 2

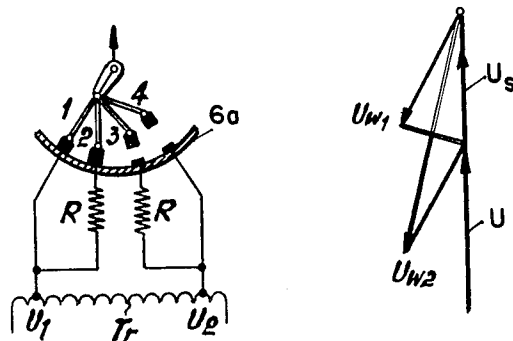
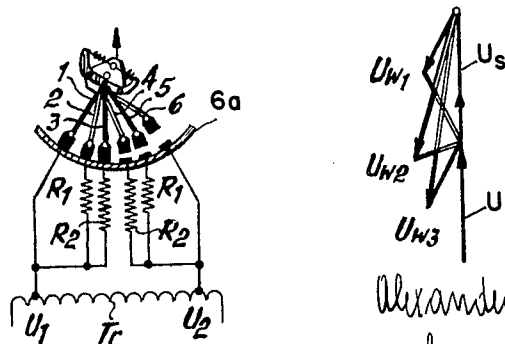


FIG. 3



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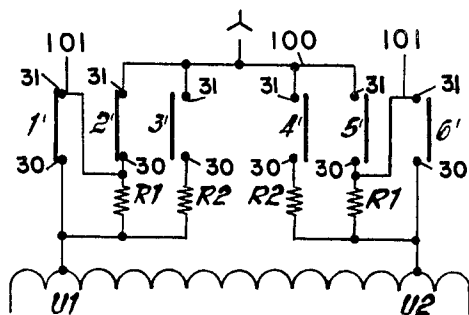


FIG. 4

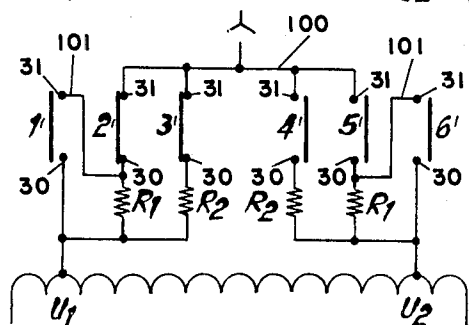


FIG. 5

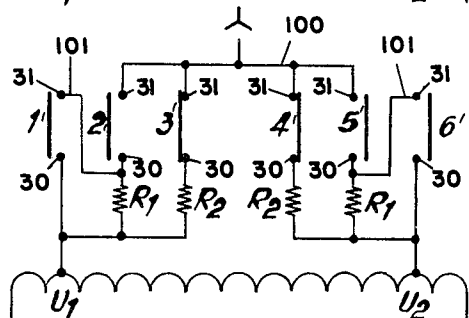


FIG. 6

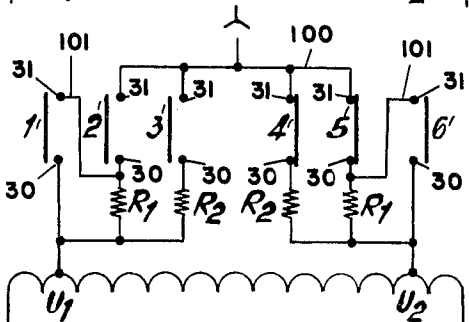


FIG. 7

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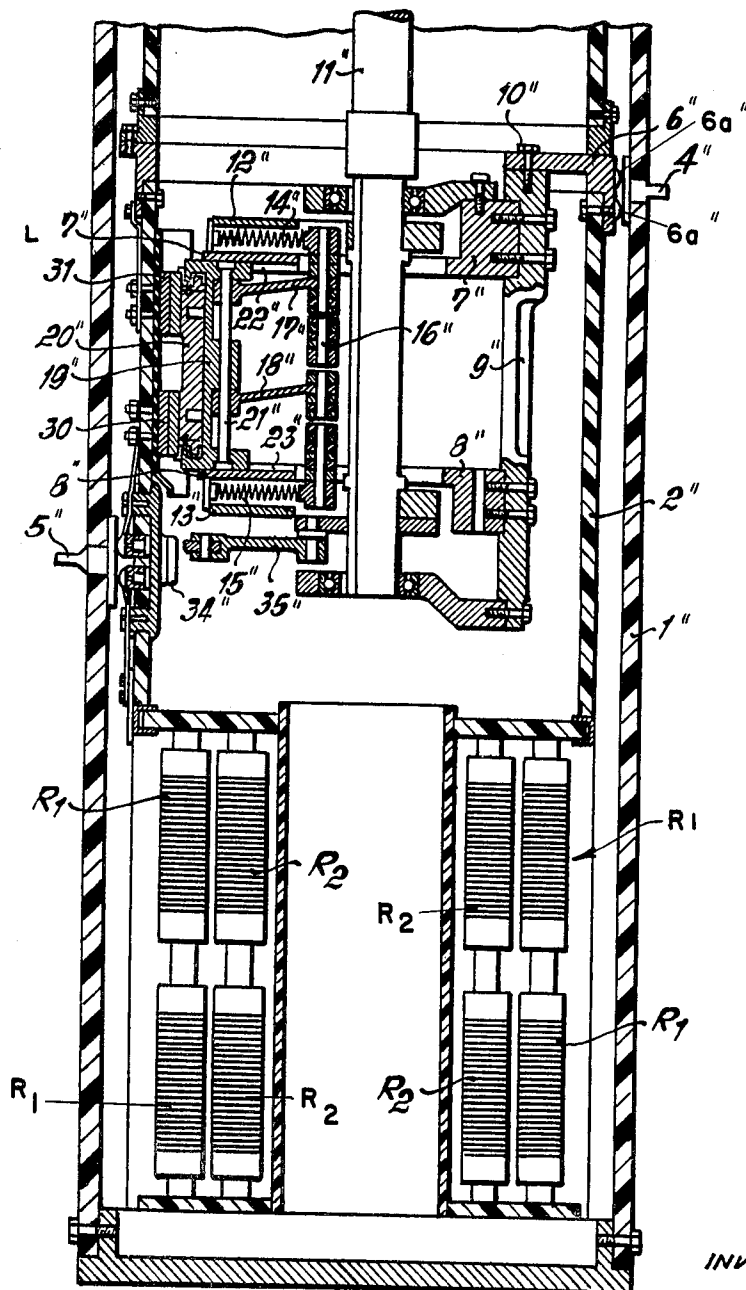
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FIG. 8

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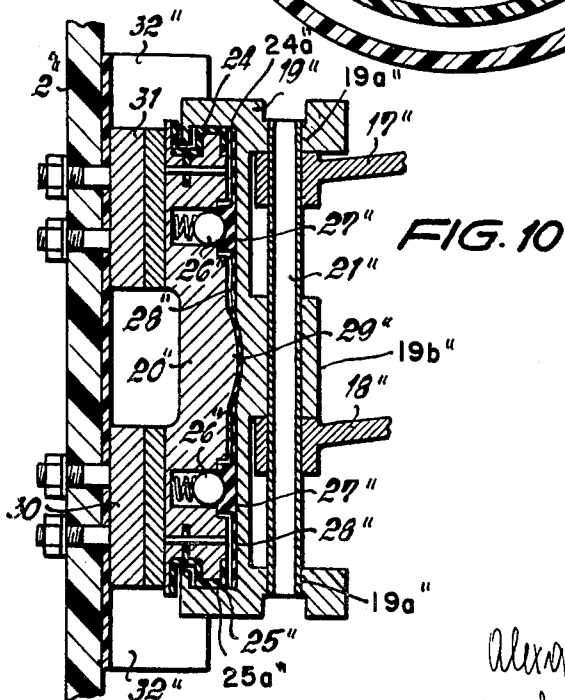
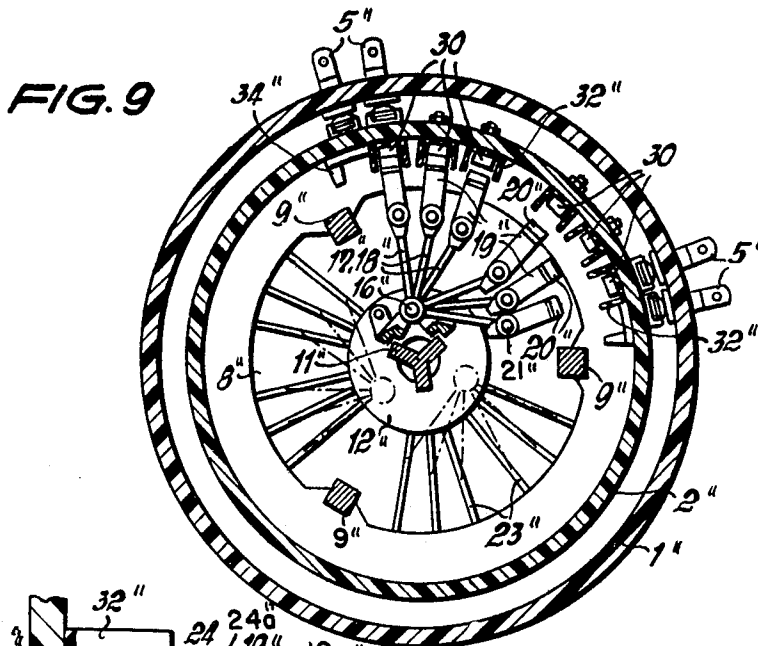
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FIG. 11

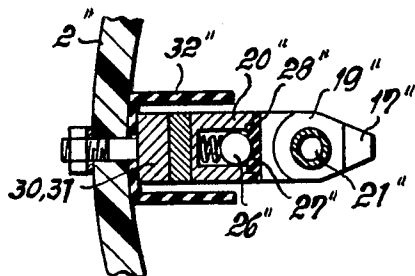
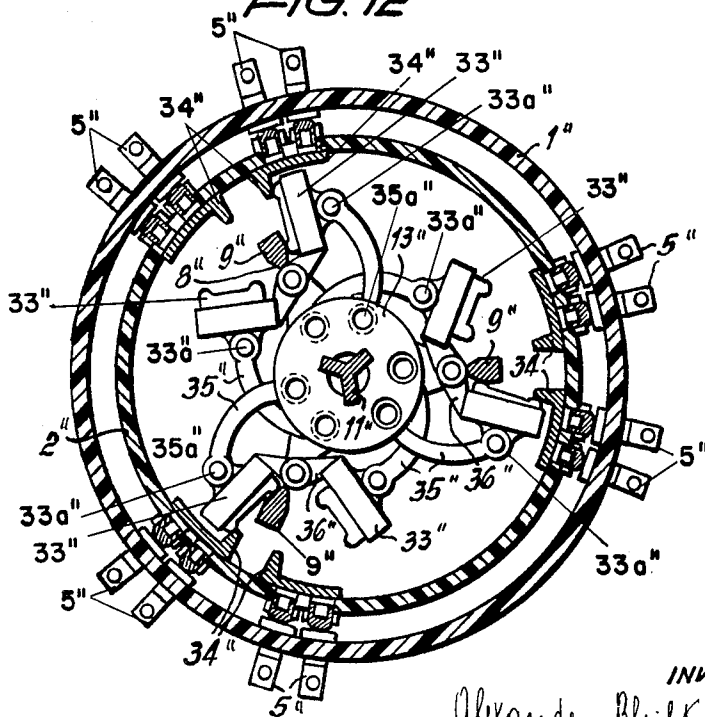


FIG. 12



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TRANSFER SWITCH FOR TAP CHANGERS FOR REGULATING TRANSFORMERS INCLUDING A CYLINDRICAL INSULATING HOUSING, A SQUIRREL-CAGE CONTACT-SUPPORTING STRUCTURE AND CONTACT BRIDGES INSULATINGLY SUPPORTED BY CONTACT BRIDGE CARRIERS

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Original application Jan. 31, 1963, Ser. No. 255,291, now Patent No. 3,174,097, dated Mar. 16, 1965. Divided and this application Feb. 26, 1964, Ser. No. 359,806 Claims priority, application Germany, Feb. 8, 1962, M 51,739

9 Claims. (Cl. 200—11)

This application is a division of the copending patent application of Alexander Bleibtreu, filed January 13, 1963, Ser. No. 255,291 for Transfer Switch for Tap Changers for Regulating Transformers, now United States Patent 3,174,097; issued March 16, 1965.

This invention is concerned with transfer switches for tap changing regulating transformers.

It is a general object of this invention to provide improved transfer switches for tap-changing regulating transformers capable of effectively handling relatively high load currents, and also overload currents.

It is another object of this invention to provide improved transfer switches of the type wherein each switching operation comprises the formation of two serially related points of break, which points of break have a significant spatial separation, thus resulting in a reduction of the recovery voltage per break, and minimizing the danger of contamination of some points of break by products of arcing formed at other points of break.

It is another object of this invention to provide an improved circuitry for transfer switches for tap-changing regulating transformers which circuitry makes it possible to substantially increase the switching rating of such transfer switches to the order of, say 200% to 300% of the rated current carrying capacity thereof.

Another object of this invention is to provide improved transfer switches for tap-changing transformers wherein pitting of the contacts and erosion of the contacts is precluded even in case of onerous duty cycles involving frequent switching operations and large overload currents.

Another object of this invention is to provide improved transfer switches for so-called Jansen type tap-changing regulating transformers.

Transfer switches according to the present invention may be constructed either for single phase service or for polyphase service.

Tap-changing regulating transformers include selector switches and transfer switches. The selector switches serve the purpose of selecting a particular tap on a tapped transformer winding intended to be connected into an electric circuit. Selector switches are not required to interrupt, or close, on current carrying circuits. This task is performed by the transfer switches. The latter perform all switching operations under load. Therefore all arcing is kept away from the selector switches and occurs only at the transfer switches. It is, therefore, of considerable importance that the transfer switches be designed to effectively cope with power arcs resulting from load switching operations and overload switching operations.

The above and additional objects and advantages of the invention will become more apparent from the ensuing description thereof when read in connection with the accompanying drawings wherein:

FIG. 1 shows a prior art transfer switch known as the

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PENNANT transfer switch and the voltage vector diagram pertaining to that kind of transfer switches;

FIG. 2 shows the prior art transfer switch known as the FLAG transfer switch and the voltage vector diagram pertaining to that kind of transfer switches;

FIG. 3 shows the prior art transfer switch known as FLAG-PENNANT transfer switch and the voltage vector diagram pertaining to that kind of transfer switches;

FIGS. 4-7, inclusive, show diagrammatically a transfer switch embodying the present invention in various successive operating positions thereof;

FIG. 8 is mainly a vertical section through a transfer switch embodying the present invention, some parts thereof being shown in front elevation rather than in vertical section;

FIG. 9 is a horizontal section through the structure of FIG. 8 showing the main contacts and the auxiliary contacts thereof in top-plan view;

FIG. 10 shows a detail of FIG. 8 on a substantially larger scale;

FIG. 11 is a section along 11—11 of FIG. 10; and

FIG. 12 is a horizontal section through the structure of FIG. 8 taken at a lower level than the section shown in FIG. 9.

The aforementioned terms PENNANT transfer switch, FLAG transfer switch and FLAG-PENNANT transfer switch have been coined by Bernhard Jansen to whom the development of these three types of transfer switches is due. The reasons why Bernhard Jansen coined these terms will be readily apparent from the ensuing consideration of FIGS. 1-3. For reasons of brevity the term P-transfer-switch will be used hereinafter as an abbreviation of the term PENNANT transfer switch, the term F-transfer-switch will be used as an abbreviation of the term FLAG transfer switch and the term FP-transfer-switch will be used as an abbreviation of the term FLAG-PENNANT transfer switch.

FIGS. 1-3 show a portion T_r of a tapped transformer winding. The P-transfer-switch comprises four movable contacts 1, 2, 3, 4. A cylindrical contact support 6a of insulating material supports four fixed contacts adapted to be cooperatively engaged by the aforementioned movable contacts 1, 2, 3, 4. The taps U_1 , U_2 of the tapped portion of winding T_r are directly connected by appropriate leads to the outer or fixed main contacts of the P-transfer-switch. The taps U_1 , U_2 are further connected by the intermediary of ohmic resistors R to the inner or fixed auxiliary contacts of the P-transfer-switch. The movable contacts land 3, on the one hand, and the movable contacts 2 and 4, on the other hand, form part of separate or different contact operating systems. This makes it possible to adjust the operating times of movable contacts 1 and 3 relative to the operating times of movable contacts 2 and 4. In the position of the contacts shown in FIG. 1 tap U_1 is directly connected to the load, the flow of the load current being indicated by a small arrow. Changing the connection of the load from tap U_1 to tap U_2 involves a closing operation of movable auxiliary contact 3 preceding the separation of the left movable main contact 1 from its cooperating fixed main contact. Since the fixed auxiliary contact cooperating with the movable auxiliary contact 3 is connected to tap U_2 by the intermediary of right resistor R, the closing operation of contact 3 gives rise to a circulating current. This circulating current is superimposed upon the load current. As mentioned above, contact 1 parts subsequent to engagement by movable contact 3 of its cooperating fixed contact. Parting of contact 1 from its cooperating fixed contact is followed by engagement by contact 4 of its fixed cooperating contact and by separation of contact 2 from its fixed cooperating contact. The gist of P-transfer-switches of which

FIG. 1 shows but one of many possible embodiments resides in the fact that prior to interrupting a load circuit including a given tap, another pre-selected tap is being connected into the load circuit by the intermediary of an ohmic resistor. As a result, the difference in potential between taps U_1 and U_2 gives rise to a circulating current, and it is the algebraic sum of this circulating current and of the load current which must be interrupted by the P-transfer-switch. This is a relatively onerous interrupting duty. On the other hand, operation of a P-transfer-switch has little effect upon the system voltage.

Referring now to FIG. 2, the same reference characters have been applied in FIG. 2 as in FIG. 1 to indicate like parts. The F-transfer-switch shown in FIG. 2 differs from the P-transfer-switch shown in FIG. 1 in regard to the sequence of switching operations. In the F-transfer-switch the movable contact 1 parts from its cooperating fixed contact subsequent to engagement by movable contact 2 of its cooperating fixed contact which is connected by the intermediary of left ohmic resistor R with tap U_1 of transformer winding T_r . Hence no circulating current is established incident to engagement between the movable contact 2 and its cooperating fixed contact. The gist of an F-transfer-switch is seen in that in such a transfer switch a contact is closed to connect a resistance into the circuit extending from the active tap to the load before another contact is closed establishing a current path from a pre-selected tap (the one to which a direct connection is to be made) to the load. Since an F-transfer-switch does not give rise to the flow of circulating currents, only the load current is interrupted when movable contact 1 parts from its cooperating fixed contact. While the interrupting duty or switching duty of an F-transfer-switch is relatively easy, its reaction on the system voltage is relatively significant.

Referring now to FIG. 3 illustrating a FP-transfer-switch, the fixed contacts thereof are arranged on a cylindrical contact support 6a and the movable contacts 1, 2, . . . 5, 6 are operated by two separate lever systems. One of these lever systems includes contacts 1, 3 and 5 and the other of these lever systems includes contacts 2, 4 and 6. The tap U_1 is directly connected to the fixed contact cooperating with movable contact 1. Tap U_1 is further connected to the fixed contact cooperating with movable contact 2 by the intermediary of an ohmic resistor R_1 and to the fixed contact cooperating with movable contact 3 by the intermediary of ohmic resistor R_2 . In a similar fashion tap U_2 is directly connected to the fixed contact cooperating with movable contact 6 and tap U_2 is connected by the intermediary of ohmic resistors R_2 , R_1 with the fixed contacts cooperating, respectively, with movable contacts 4 and 5. Movable contact 1 parts from its cooperating fixed contact after movable contact 3 has engaged its cooperating fixed contact. Upon completion of the aforementioned sequential operations of movable contacts 1 and 3 tap U_1 —i.e. the tap to be disconnected—and resistors R_1 and R_2 are connected into the load circuit, resistors R_1 and R_2 being connected in parallel. Thereupon movable contact 4 engages its cooperating fixed contact and movable contact 2 parts from its cooperating fixed contact. Finally fixed contact 6 engages its cooperating fixed contact and movable contact 4 parts from its cooperating fixed contact. In this position of the FP-transfer-switch tap U_1 is entirely disconnected, and tap U_2 is connected into the load circuit of the transformer.

Referring now to the vector diagram at the right of FIG. 1, reference letter U has been applied to indicate the transformer voltage, i.e. the voltage of the windings of the transformer which are not involved in the tap-changing operation, reference characters Uw_1 and Uw_2 have been applied to indicate the vectors of the voltages across the resistors which are inserted into the circuit during a tap changing operation and the reference character

U_s has been applied to indicate the vector of the voltage between the two taps U_1 and U_2 . The angular relation of the above vectors depends upon the phase angle ϕ prevailing in the particular circuit under consideration. However this phase angle ϕ may be, the vector diagram of the voltages involved is generally in the shape of a pennant, the vector U forming the pole thereof. Hence the term PENNANT transfer switch, or P-transfer-switch, which was coined for the transfer switch structure shown in FIG. 1 and described in connection with that figure.

In the vector diagram to the right of FIG. 2 reference letter U has been applied to indicate the vector of the voltage across the windings of the transformer not involved in the tap changing operation, reference character U_s has been applied to indicate the vector of the voltage across taps U_1 and U_2 , and reference characters Uw_1 and Uw_2 have been applied to indicate the vectors of the recovery voltages across the resistors which are inserted into the circuit during the tap-changing operation. The angular relation of the above vectors depends again upon the phase angle ϕ prevailing in the particular circuit under consideration, and the vector diagrams of FIGS. 1-3 have been drawn assuming that $\cos \phi = .8$. Interconnecting the ends of the voltage vectors shown in FIG. 2 by appropriate lines results in an outline which is generally in the shape of a flag. Hence the term FLAG transfer switch, or F-transfer-switch, which was coined for the transfer switch structure shown in FIG. 2 and described in connection therewith.

In the vector diagram to the right of FIG. 3 showing the voltage vectors of the transfer switch shown in FIG. 3 reference characters Uw_1 , Uw_2 and Uw_3 have been applied to indicate the vectors of the recovery voltages across the various resistor combinations which are inserted into the load circuit during a tap-changing operation. Interconnecting the ends of the voltage vectors by appropriate lines results in an outline which is generally in the shape of a combination of a flag and a pennant. Hence the term FLAG-PENNANT transfer switch, or FP-transfer-switch, which was coined for the kind of transfer switches shown to the left of FIG. 3 and described in connection therewith.

Prior art P-transfer-switches as well as prior art F-transfer-switches and prior art FP-transfer-switches are capable of safely switching currents in the order of their rated current-carrying capacity, and have a life commensurate to that of the regulating transformer with which they are associated. However, such transformer switches are not capable of switching effectively overload currents of, say 2 to 3 times the rated current. Switching of currents of such magnitude is conducive to excessive arcing tending to cause short-circuits between immediately adjacent transformer taps with resulting danger to the transfer switch as well as to the regulating transformer itself. The novel transfer switch diagrammatically shown in FIGS. 4-7 removes the aforementioned limitations of prior art transfer switches.

The transfer switch shown in FIGS. 4-7 comprises six movable contact bridges 1', 2', 3', 4', 5', 6'. These contact bridges may be arranged in cylindrical segment patterns, as explained more in detail in connection with FIGS. 8 and 9. Contact bridges 1', 2' . . . 5', 6' are adapted to cooperate with a system of upper fixed contacts 31, and with a system of lower fixed contacts 30. The transfer switch is associated with a tapped transformer winding of which but one section situated between two taps U_1 and U_2 has been shown. Tap U_1 is directly connected by a lead to fixed contact 30 cooperating with contact bridge 1'. Tap U_1 is further connected by the intermediary ohmic resistors R_1 and R_2 to the fixed contacts 30 cooperating with contact bridge 2' and 3', respectively. Tap U_2 is directly connected by a lead to fixed contact 30 cooperating with contact bridge 6'. Tap U_2 is further connected by the intermediary of ohmic resistors R_2 and R_1 to the fixed contacts 30 cooperating with

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contact bridge 4' and 5', respectively. The fixed contacts 31 cooperating with contact bridges 2', 3', 4' and 5' are conductively interconnected by lead 100.

Assuming that the transformer winding of which the section between taps U_1 and U_2 forms a part is a phase winding of a three phase Y-connected transformer, then lead 100 is conductively connected to the neutral point of the Y-connected transformer. This has been indicated by placing an inverted Y adjacent to lead 100.

The fixed contact 31 cooperating with contact bridge 1' is conductively connected to the fixed contact 30 cooperating with contact bridge 2' by lead 101. In a like fashion the fixed contact 31 cooperating with contact bridge 6' is conductively connected to the fixed contact 30 cooperating with contact bridge 5' by a lead 101.

In the position of the parts shown in FIG. 4 tap U_1 is active and tap U_2 is inactive. An electric circuit is established which includes tap U_1 , fixed contact 30 cooperating with contact bridge 1', contact bridge 1', fixed contact 31 cooperating with contact bridge 1', lead 101, fixed contact 30 cooperating with contact bridge 2', contact bridge 2', fixed contact 31 cooperating with contact bridge 2', lead 100, neutral point.

The first tap-changing step which is shown in FIG. 5 consists in engagement of fixed contacts 31, 30 by their cooperating contact bridge 3' and in separation of contact bridge 1' from its fixed cooperating contacts 31, 30. Separation of contact bridge 1' from its fixed cooperating contacts 31, 30 results in the formation of two series breaks in the circuit. These series breaks are shunted by ohmic resistor R_1 , resulting in instability of the two arcs formed at the two points of break.

The second tap-changing step which is shown in FIG. 6 consists in engagement of the fixed contacts 31, 30 cooperating with contact bridge 4' by the latter. The contact operating mechanism may be designed in such a way that sufficient time elapses to allow extinction of the arcs formed at the two aforementioned breaks at contact bridge 1' before contact bridge 4' engages its cooperating fixed contacts 31, 30. This calls for arc extinction at the first natural current zero and can readily be achieved if the current is not in excess of the rated load current of the transfer switch. Upon engagement of the fixed contacts 31, 30 cooperating with the contact bridge 4' by the latter a current path for a circulating current is established which current path comprises tap U_1 , serially connected resistors R_2 and tap U_2 . Another current path which exists at this point of time extends from tap U_1 through left resistor R_1 , contact bridge 2', and lead 100 to the neutral point of the Y-connected system.

The third tap-changing step which is shown in FIG. 7 consists in engagement of the fixed contacts 31, 30 cooperating with the movable contact bridge 5' by the latter and in separation of the movable contact bridge 3' from its fixed cooperating contacts 31, 30. Separation of contact bridge 3' from its fixed cooperating contacts 31, 30 results in interruption of the current path of the circulating current. The main current path established by the third tap-changing step includes tap U_2 , resistors R_1 and R_2 in parallel, contact bridges 5' and 4' in parallel, lead 100, and the neutral point of the Y-connected system.

The fourth and final tap-changing step consists in parting of contact bridge 4' from its cooperating fixed contacts 31, 30 and engagement by contact bridge 6' of its cooperating fixed contacts 31, 30. This establishes a direct current path including tap U_2 , contact bridge 6', lead 100 and the neutral point of the Y-connected system. Some of the four tap-changing steps referred to above include two switching operations. There is a total of six switching operations, as follows: contact bridge 3' closes; contact bridge 1' opens; contact bridge 4' closes; contact bridge 2' opens; contact bridge 6' closes; contact bridge 4' opens.

As mentioned above, arc extinction can readily be achieved at the first natural current zero at the points

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of break formed by contact bridge 1' if the current flowing through contact bridge 1' is equal to, or not substantially in excess of, the rated load current of the transfer switch. If the current carried by contact bridge 1' is significantly larger, the arcing time is longer and arcing continues at the two breaks formed between contact bridge 1' and its fixed cooperating contacts 31, 30 while contact bridge 4' performs its closing operation. Under extremely severe switching conditions the arcing time at the two breaks formed between contact bridge 1' and its two cooperating fixed contacts 31, 30 may extend up to the points of time at which contact bridges 5' and 6' perform their respective closing operation.

Normally excessive arc duration at one of the points of break of a transfer switch is a danger condition likely to result in a short-circuit between two immediately adjacent taps. This danger is, however, avoided in the transfer switch of FIGS. 4-7. Assuming that the arcs formed at the two points of break of contact bridge 1' are not extinguished at the times contact bridge 4' engages its cooperating fixed contacts 31, 30 and contact bridge 2' parts from its cooperating fixed contacts 31, 30. Parting of contact bridge 2' from its cooperating fixed contacts 31, 30 results in the formation of two breaks which are serially related to the two breaks formed by contact bridge 1'. Formation of these two additional breaks greatly increases the total or aggregate arc voltage and is thus conducive to more rapid arc extinction. The left resistor R_1 shunts the two breaks formed between contact bridge 1' and its cooperating fixed contacts 31, 30.

The design of the transfer switch of FIGS. 4-7 may be carried out in such a way that the length of the two breaks formed between contact bridge 1' and its cooperating fixed contacts 31, 30 exceeds the length of the two breaks formed by contact bridge 2' and its cooperating contacts 31, 30. Under such circumstances, in case of a restrike, or re-ignition, the dielectric breakdown of the two breaks formed by contact bridge 2' will precede the dielectric breakdown of the two breaks formed by contact bridge 1'. In case of a dielectric breakdown of the two breaks formed by contact bridge 2', two parallel current paths are established of which one comprises resistor R_1 and contact bridge 2', and the other comprises resistor R_2 and contact bridge 3'. The voltage drop across resistor R_2 and contact bridge 3' limits the flow of current through resistor R_1 and contact bridge 2', and the voltage drop across resistor R_1 and contact bridge 2'—which is small on account of the limitation of the flow of current through resistor R_1 —limits the recovery voltage across the two series breaks formed by contact bridge 1'. This, in turn, minimizes the danger of a dielectric breakdown of the two series breaks formed by contact bridge 1'.

It will be apparent from the foregoing that transfer switches of the kind illustrated in FIGS. 4-7 increase their interrupting or switching capacity automatically if arcing persists on the two first-formed breaks on account of the presence of a current in excess of the rated load current of the transfer switch.

It will be further apparent from the foregoing that the transfer switch shown in FIGS. 4-7, inductive, operates as a FP-transfer-switch as long as the current to be switched is in the order of the rated load current, and that it operates as P-transfer-switch having four serially related breaks if the current to be switched substantially exceeds the rated load current.

FIGS. 8-12, inclusive, refer to a preferred structural embodiment of the transfer switches diagrammatically illustrated in FIGS. 1-7.

The transfer switch shown in FIGS. 8-12 comprises a cylindrical tank 1'' accommodating in the upper portion thereof the coaxial cylindrical transfer switch housing 2'', while the lower portion of tank 1'' houses the switching resistors R_1 , R_2 , R_3 , R_4 . Tank 1'' contains a body of oil (not shown) and is preferably made of an appropriate

casting resin. Terminals 4" and 5" are integral with tank 1". Terminals 5" are intended to connect the transfer switch to the selector switch of the regulating transformer, and terminals 4" are intended to connect the transfer switch to the neutral point of the transformer. The aforementioned terminals are arranged in pairs in view of the high current carrying duty imposed upon these parts. If tank 1" is made of a casting resin terminals 4" and 5" are formed by inserts in the casting.

Flange element 6" is arranged in the upper portion of transfer switch housing 2". Element 6" is provided with contacts 6a" cooperatively engaging with terminals 4". A structure substantially in the shape of a squirrel-cage is suspended on flange element 6" by means of screws 10". The above mentioned structure substantially in the shape of a squirrel-cage comprises the upper guide plate 7", the lower guide plate 8" and the conductive vertical bars 9" extending parallel to the common axis of tank 1" and housing 2". The upper end plate 12" and the lower end plate 13" are fixedly arranged substantially at right angles to housing 2" and mounted upon main operating shaft 11" which is arranged in coaxial relation to tank 1" and housing 2". Rod or auxiliary shaft 16" is spaced from main operating shaft 11" and extends parallel to shaft 11". The upper end and the lower end of rod or shaft 16" is loosely guided by the upper end plate 12" and the lower end plate 13", respectively. The upper end of rod or shaft 16" is mechanically connected to the upper end plate 12" by means of a helical tension spring 14". In like fashion the lower end of rod or shaft 16" is mechanically connected to the lower end plate 13" by means of a helical tension spring 15". Reference numeral 17" has been applied to indicate a plurality of upper contact operating arms and reference numeral 18" has been applied to indicate a plurality of lower contact operating arms. Each contact operating arm 17", 18" has a radially inner bearing and a radially outer bearing. Rod or shaft 16" extends through the radially inner bearings of contact operating arms 17", 18". The radially outer ends of each pair of contact operating arms 17", 18", support a vertical auxiliary shaft 21" which, in turn, supports pivotally a contact carrier 19". Each contact carrier 19" is provided with axially outer bearings 19a" and a central bearing 19b" for receiving one of a plurality of vertical auxiliary shafts 21" (see FIG. 10). Contact carriers 19" support contact bridges 20" which—since supported by contact carriers 19"—are adapted to be pivoted about vertical auxiliary shaft 21". The aforementioned upper and lower guide plates 7", 8" are arranged substantially at right angles to housing 2" provided on juxtaposed sides thereof with radially extending slots or grooves 22" and 23", respectively, engaged by and guiding the upper and the lower ends of contact carriers 19". Because of this function of plates 7" and 8" the same have been referred to as guide plates. The contact carriers 19" are provided with upper grooves 24" and with lower grooves 25" intended for insertion of contact bridges 20" into the same. The contact bridges 20" of FIGS. 8-12 are the same parts to which reference characters 1', 2' . . . 5', 6' have been applied in FIGS. 4-7. Grooves 24" and 25" are sufficiently large to provide a predetermined amount of clearance between contact carriers 19" and contact bridges 20". Each contact bridge is provided with a pair of horizontal dead-end passageways each receiving a helical spring for biasing a steel ball 26". An insulating plate 28" arranged at the radially outer surface of each contact carrier 19" is provided with a pair of concave recesses 27" adapted to be engaged by steel balls 26". Thus each of the contact bridges 20" is firmly yet resiliently held in position in its respective contact carrier 19". Each of the aforementioned insulating plates 28" engages a concave recess 29" in one of the contact carriers 19" and each of the contact bridges 20" has a convex projection

on its back engaging recess 29" in one of the contact carriers 19" and one of the insulating plates 28", respectively. Grooves 24" and 25" are provided with insulating inserts 24a" and 25a" for insulating contact bridges 20" from the contact carriers 19" at the upper and lower points where the former are inserted into the latter. The upper end of each contact bridge 20" and the lower end of each contact bridge 20" is adapted to cooperate with a pair of fixed contacts 31 and 30. Contacts 30 and 31 are supported by the wall of the switch housing 2" and include terminal elements which are arranged on the radially outer surface of the switch housing 2". Pairs of fixed contacts 31, 30 are arranged or semi-enclosed in vertically extending channel members 32" of insulating material insulating contiguous pairs of contacts 31, 30 from each other. Because of the provision of channel-shaped member or insulating barriers 32" the angular spacing of pairs of contacts 31, 30 may be small, and yet flashovers between pairs of contacts 31, 30 which are at different potentials are effectively precluded by the presence of channel-shaped insulating barriers 32".

The circuitry of FIGS. 4-7 calls for the provision of six contact carriers 19" and of six contact bridges 20" and of six pairs of contacts 31, 30 per phase. In other applications the number of contact carriers, contact bridges and of pairs of fixed contacts per phase may be smaller than six or larger than six. The fixed contacts 31, 30 of each phase and the contact bridges of each phase are arranged in form of a sector of a circle. The fixed contacts 31, 30 at the ends of each such sector are main arcing contacts and the fixed contacts of each such sector arranged between main contacts are auxiliary arcing contacts to be connected to the switching resistors R_1 , R_2 arranged in the lower portion of switch housing 2". FIG. 9 shows all the arcing contacts pertaining to one phase, omitting the arcing contacts of the other phases. The linkages for operating the movable arcing contacts not shown have been diagrammatically indicated in FIG. 9 by dash-and-dot lines.

When a tap-changing operation has been completed, the main tap-changing arcing contacts which are designed to perform switching operations should preferably be shunted by main current carrying contacts which are specially designed to perform this particular duty, as distinguished from current switching duty. FIG. 12 fully illustrates the arrangement of the aforementioned main current carrying contacts. The fixed main current-carrying contacts are also shown in FIG. 9.

Reference numeral 33" has been applied to indicate six movable main current carrying contacts. These contacts 33" are arranged remotely from the main and auxiliary switching or arcing contacts 31, 30 and at a lower level than the latter. The movable main current-carrying contacts 33" form current-carrying bridges conductively interconnecting conductor bar 9" and angular main current-carrying contacts 34". The transfer switch comprises six fixed main current carrying contacts 34", a pair of such contacts for each phase of a three phase circuit. The phase groups of the movable main current-carrying contacts and the fixed main current-carrying contacts are angularly displaced 120 degrees. FIG. 12 shows three movable main current-carrying contacts 34" in the closed position thereof and three such contacts in the open position thereof. The fixed main current-carrying 34" are secured to the inner surface of cylindrical switch housing 2". Each fixed main current-carrying contact 34" is conductively connected to a pair of terminals 5". FIG. 12 shows three groups of terminals 5", each of these three groups pertaining to one phase of a three phase circuit. The above groups of terminals 5" are angularly displaced 360/3 deg.=120 deg. Terminals 5" are intended for connection of the transfer switch to a pair of taps of a tapped transformer winding such as, for instance, taps U_1 and U_2 of FIGS. 4-7. FIG. 12 shows to the right two movable

main current-carrying contacts 33'' of which one is in the closed position and the other in the open position thereof. The closed contact 33'' of FIG. 12 performs the function of shunting contact bridge 1' of FIG. 4 in the position of the parts shown in that figure. The open contact 33'' of FIG. 12 performs the function of the shunting contact bridge 6' of FIG. 4 subsequent to engagement by that contact bridge of its cooperating fixed contacts 31, 30, i.e. following the step shown in FIG. 7 of a tap changing operation. As shown in FIG. 12 each movable main current-carrying contact 33'' is pivotally attached at 33a'' to an operating lever 35''. The operating levers 35'' are pivotally secured at 35a'' to lower end plate 13''. Each pair of movable current-carrying contacts 33'' associated with one phase of a polyphase circuit is under the control of a lever 36'' having a pair of pivotable operating arms. These arms are operatively related to one pair of contacts 33'' pertaining to one phase of a polyphase circuit. Levers 36'' are pivotally supported on the lower guide plate 8''. Since the lower end plate 13'' follows the rotary motions of shaft 11'', rotary motions of the latter cause engagement of contacts 33'' with, and disengagement of contacts 33'' from, conductive bars 9'' and contacts 34''.

The current path of the structure of FIGS. 8-12 is the same as explained in detail in connection with FIGS. 4-7. The current path begins at terminals 5'', extends through resistors R₁, R₂, R₁, R₂, includes lower arcing contacts 30, contact bridges 20'' and upper arcing contacts 31''. Contacts 31'' are conductively connected to a conductive strap L arranged on the outside of housing 2'' by conductors projecting through housing 2''. Strap L is connected to flange element 6'' which is the structural equivalent of lead 100 of FIGS. 4-7 and terminals 4'' are applied to connect flange element 6'' to the neutral point of the system.

The sequence of operating steps of contact bridges 20'' of the structure of FIGS. 8-12 is the same as the sequence of operating steps of the contact bridges 1', 2' . . . 5', 6' of FIGS. 4-9 described in connection with these figures. The kinematic theory underlying the structure of FIGS. 8-12 is set forth in detail in United States Patent 2,680,790 to Bernhard Jansen, June 8 1954 for Load Changeover Switch for Tapped Transformers Using a Combination of Contact Movements (see particularly FIG. 5 and column 6, line 55 to column 7, line 23) and reference may be had to that patent for additional information regarding this subject.

It will be apparent from the foregoing that transfer switches embodying the present invention achieve a relatively high interrupting capacity, or switching capacity, without resorting to auxiliary arc-quenching means such as, for instance, magnetic blow-outs or forced oil circulation.

It will further be apparent from the foregoing that transfer switches embodying the present invention dispense entirely with flexible connections or braids for energizing the movable contact segments including contact bridges 20''.

Since contact bridges 20'' are insulated from their supports 19'', all the movable parts within the transfer switch may be made of metal rather than of insulating material, which greatly contributes to the ruggedness of transfer switches embodying the present invention. The ruggedness of such transfer switches is due in particular to the presence of the squirrel-cage type structure comprising guide plates 7'', 8'' and the three conductive bars 9''.

The particular arrangement of the movable main current carrying contacts 33'' shown makes the same readily accessible for servicing operations and renewal. The three conductive bars 9'', in addition to providing a sturdy frame supporting the movable parts of the switch, offer current paths of relatively large cross-section and minimal resistance for connecting taps of tapped polyphase transformer windings to the neutral point of the polyphase system.

It will be further apparent that the entire transfer switch is supported as a self-sustained structural unit at a single point, namely at the flange element 6''. Upon removal of the transfer switch from the transformer tank with which it is normally associated and upon removal of the tap-changing or switch-over resistors R₁, R₂ the transfer switch structure proper may be withdrawn from housing 2'' in downward direction upon loosening the supporting screws 10''.

Although I have shown and described a specific structure, it is to be clearly understood that the same was merely for the purpose of illustration, and that changes and modifications may readily be made by those skilled in the art without departing from the spirit and scope of the invention.

I claim as my invention:

1. A transfer switch for tap-changers for regulating transformers comprising in combination:

- (a) a cylindrical switch housing of insulating material;
- (b) a plurality of pairs of fixed contacts inside said housing, each pair of said plurality of pairs of fixed contacts being arranged along a generatrix of said housing and angularly spaced from a contiguous pair of said plurality of pairs of fixed contacts;
- (c) a plurality of contact bridges arranged inside of said housing, extending in a direction longitudinally thereof and each juxtaposed to one of said plurality of pairs of fixed contacts to conductively interconnect said one of said plurality of pairs of fixed contacts;
- (d) a plurality of contact carriers movably supported inside said housing each supporting one of said plurality of contact bridges, each of said plurality of contact carriers defining an upper groove and a lower groove engaged by one of said plurality of contact bridges to support said one of said plurality of contact bridges;
- (e) a plurality of spring means each interposed between one of said plurality of contact bridges and one of said plurality of contact carriers biasing each of plurality of contact bridges away from one of said plurality of contact carriers and allowing resilient adjustment of each of said plurality of contact bridges relative to one of said plurality of contact carriers;
- (f) a plurality of insulating means each electrically insulating one of said plurality of contact bridges from one of said plurality of contact carriers; and
- (g) an operating mechanism including a plurality of operating linkages each mechanically connected to one of said plurality of contact carriers to move each of said plurality of contact bridges by the intermediary of one of said plurality of contact carriers into and out of engagement with one of said plurality of pairs of fixed contacts.

2. A transfer switch for tap-changers for regulating transformers comprising in combination:

- (a) a cylindrical switch housing of insulating material;
- (b) a plurality of pairs of fixed contacts supported by said housing and arranged on the inner surface thereof, each of said plurality of pairs of fixed contacts being aligned along a generatrix of said housing and angularly spaced from a contiguous pair of said plurality of pairs of fixed contacts;
- (c) a plurality of insulating channels supported by said housing arranged on the inner surface thereof and extending in a direction longitudinally thereof, each of said plurality of insulating channels semi-enclosing one of said plurality of pairs of fixed contacts and thereby separating said one of said plurality of pairs of fixed contacts from a contiguous pair of said plurality of pairs of fixed contacts;
- (d) a plurality of contact bridges arranged inside said housing, extending in a direction longitudinally thereof each juxtaposed to one of said plurality of pairs of fixed contacts to conductively interconnect

- said one of said plurality of pairs of said fixed contacts;
- (e) a plurality of contact carriers movably supported inside said housing each including means for resiliently supporting one of said plurality of contact bridges;
 - (f) means for electrically insulating each of said plurality of contact bridges from the contact carrier thereof;
 - (g) a pair of spaced fixed guide plates arranged inside said housing substantially at right angles to said inner surface thereof, said pair of guide plates defining at juxtaposed sides thereof a plurality of radially extending pairs of grooves, each of said plurality of pairs of grooves being engaged by the upper end and by the lower end of one of said plurality of contact carriers;
 - (h) a plurality of angularly spaced conductive bars extending in a direction longitudinally of said housing for supporting and spacing said pair of guide plates; and
 - (i) operating means for said plurality of contact bridges including a pivotable shaft arranged inside of said housing in coaxial relation thereof, said operating means further including linkage means operated by said shaft for causing radial movement of said plurality of contact carriers relative to said pair of guide plates to cause a predetermined sequential engagement of each of said plurality of pairs of fixed contacts by one of said plurality of contact bridges.
3. A transfer switch for tap-changers for regulating transformers comprising in combination:
- (a) a cylindrical switch housing of insulating material;
 - (b) a plurality of registering pairs of fixed contacts supported by said housing arranged on the inner surface thereof, each pair of said plurality of pairs of fixed contacts being aligned along a generatrix of said housing and angularly spaced from a contiguous pair of said plurality of pairs of contacts;
 - (c) a plurality of contact bridges arranged inside said housing, extending in a direction longitudinally thereof each juxtaposed to one of said plurality of pairs of fixed contacts to engage and conductively interconnect said one of said plurality of pairs of fixed contacts;
 - (d) a plurality of movable contact carriers inside said housing each including means for resiliently supporting one of said plurality of contact bridges, each of said plurality of contact bridges being electrically insulated from the contact carrier thereof;
 - (e) a plurality of radial guide means each for one of said plurality of contact carriers to guide each of said plurality of contact carriers radially inside of said housing;
 - (f) a plurality of angularly displaced shafts inside of said housing extending in a direction longitudinally thereof each pivotally supporting one of said plurality of contact carriers;
 - (g) a shaft inside said housing pivotable about the axis of said housing arranged in spaced relation and parallel to said axis; and
 - (h) a plurality of pairs of contact operating arms, each of said plurality of pairs of contact operating arms having radially inner bearings mounted on said shaft and having radially outer bearings mounted on one of said plurality of shafts to convert pivotal motions of said shaft into radial motions of said plurality of contact bridges.
4. A transfer switch for tap-changers for regulating transformers comprising in combination:
- (a) a cylindrical switch housing insulating material;
 - (b) a plurality of pairs of fixed contacts supported by and arranged on the inner surface of said housing, each pair of said plurality of pairs of fixed contacts being aligned along a generatrix of said housing and

- angularly spaced from a contiguous pair of said plurality of pairs of contacts;
 - (c) a plurality of contact bridges arranged inside said housing, extending in a direction longitudinally thereof each juxtaposed to one of said plurality of pairs of fixed contacts to engage and conductively interconnect said one of said plurality of pairs of fixed contacts;
 - (d) a plurality of contact carriers movably arranged inside said housing each including means for resiliently supporting one of said plurality of contact bridges and each of said plurality of contact bridges being electrically insulated from the contact carrier thereof;
 - (e) an upper fixed guide plate arranged at substantially right angles to said switch housing and defining a plurality of radial groove means each engaged by the upper end of one of said plurality of contact carriers;
 - (f) a lower fixed guide plate arranged at substantially right angles to said switch housing and defining a plurality of radial groove means each engaged by the lower end of one of said plurality of contact carriers;
 - (g) a main operating shaft for operating said plurality of contact bridges and for operating said plurality of contact carriers arranged inside said housing in coaxial relation thereto;
 - (h) a pair of spaced end plates fixedly mounted on said main operating shaft for joint operation with said main operating shaft;
 - (i) a first auxiliary shaft arranged parallel to said main operating shaft in spaced relation therefrom having ends resiliently attached to said pair of end plates;
 - (j) a plurality of pairs of contact operating arms, each pair of said plurality of pairs of contact operating arms having a pair of radially inner bearings mounted on said first auxiliary shaft and having a pair of radially outer bearings; and
 - (k) a plurality of auxiliary shafts arranged parallel to said first auxiliary shaft in spaced relation therefrom each pivotally connecting one of said plurality of contact carriers to said radially outer pair of bearings of one of said plurality of pairs of contact operating arms.
5. A transfer switch for tap-changing regulating transformers comprising, in combination:
- (a) a cylindrical tubular switch housing of insulating material;
 - (b) a plurality of pairs of spaced fixed contacts on the inner surface of said housing, each of said plurality of pairs of fixed contacts being arranged along one of a plurality of angularly displaced generatrices of said housing, said plurality of pairs of fixed contacts including two outer pairs of fixed main contacts and inner pairs of fixed auxiliary contacts arranged between said two pairs of fixed main contacts;
 - (c) a plurality of parallel contact bridges having two ends, each of said plurality of contact bridges being arranged at a predetermined level inside of said housing, extending in a direction longitudinally thereof and each being juxtaposed to one of said plurality of pairs of fixed contacts to engage with, and part from, said one of said plurality of pairs of fixed contacts, said plurality of contact bridges including two main contact bridges each arranged to engage with, and to part from, one of said two pairs of fixed main contacts, and said plurality of contact bridges further including auxiliary contact bridges each arranged to engage with, and to part from, one of said pairs of fixed auxiliary contacts;
 - (d) operating means for said plurality of contact bridges for moving each of said plurality of contact bridges in a predetermined sequence into engagement and out of engagement with one of said plurality of pairs of fixed contacts;

- (e) means for conductively interconnecting each of a pair of said fixed auxiliary contacts situated adjacent to one of said two ends of said plurality of contact bridges;
- (f) a plurality of ohmic resistors arranged inside of said housing below said predetermined level, one end of each of said plurality of ohmic resistors being conductively connected to one of a pair of fixed auxiliary contacts situated adjacent the other of said two ends of said plurality of contact bridges and the other end of each of said plurality of resistors being conductively connected to one of said two pairs of fixed main contacts;
- (g) a pair of movable main current carrying-contact means each for shunting one of said pair of main contact bridges, said pair of main current carrying contact means being arranged inside of said housing at a level situated between said plurality of contact bridges and said plurality of resistors; and
- (h) operating means for said main current-carrying contact means for moving said main current-carrying contact means to a shunting position thereof and away from a shunting position thereof.
6. A transfer switch for tap-changing regulating transformers comprising, in combination:
- (a) a cylindrical tubular switch housing of insulating material;
- (b) a plurality of pairs of spaced fixed arcing contacts on the inner surface of said housing, each of said plurality of pairs of fixed arcing contacts being arranged along one of a plurality of angularly displaced generatrices of said housing, said plurality of pairs of fixed arcing contacts including two outer pairs of fixed main arcing contacts and inner pairs of fixed auxiliary arcing contacts arranged between said two pairs of main arcing contacts;
- (c) a plurality of parallel contact bridges arranged inside said housing, extending in a direction longitudinally thereof, each juxtaposed to one of said plurality of pairs of fixed arcing contacts to engage with, and part from, said one of said plurality of pairs of fixed arcing contacts, said plurality of contact bridges including two main contact bridges each arranged to engage with, and to part from, one of said two pairs of fixed main arcing contacts, and said plurality of contact bridges further including auxiliary contact bridges each arranged to engage with, and to part from, one of said pairs of fixed auxiliary arcing contacts;
- (d) operating means for said plurality of contact bridges for moving in a predetermined sequence each of said plurality of contact bridges into engagement, and out of engagement with, one of said plurality of pairs of spaced fixed arcing contacts, said operating means including a pivotable driving shaft arranged in said switch housing in coaxial relation thereto, a pair of spaced end plates fixedly mounted on and jointly pivotable with said shaft and a plurality of linkage means for transmitting the pivotal motion of said pair of end plates to said plurality of contact bridges;
- (e) means for shunting selectively either of said two main contact bridges, said shunting means including a plurality of fixed current-carrying contacts on the inner surface of said housing at a lower level than said plurality of pairs of fixed arcing contacts and said shunting means further including a plurality of movable current-carrying contacts, each arranged to engage with, and to part from, one of said plurality of fixed current-carrying contacts; and
- (f) linkage means operable by said driving shaft and by one of said pairs of end plates for moving said movable current-carrying contacts to a shunting position thereof and away from said shunting position thereof.

7. A transfer switch for tap-changing regulating transformers comprising, in combination:
- (a) a cylindrical tubular switch housing of insulating material;
- (b) a plurality of pairs of spaced fixed arcing contacts on the inner surface of said housing, each of said plurality of pairs of fixed arcing contacts being arranged along one of a plurality of angularly displaced generatrices of said housing;
- (c) a plurality of contact bridges arranged inside said housing extending in a direction longitudinally thereof and each juxtaposed to one of said plurality of pairs of fixed arcing contacts to engage with, and to part from, said one of said plurality of pairs of fixed arcing contacts;
- (d) a pair of grooved spaced guide plates supported by said housing for guiding the upper ends and the lower ends of said plurality of contact bridges;
- (e) a plurality of conductive bars extending parallel to said plurality of contact bridges and conductively interconnecting said pair of guide plates and jointly forming with said pair of guide plates a squirrel-cage-like supporting structure for said plurality of contact bridges;
- (f) operating means for said plurality of contact bridges to cause engagement of each of said plurality of contact bridges with, and parting of each of said plurality of contact bridges from, one of said plurality of pairs of fixed arcing contacts in a predetermined sequence, said operating means including a driving shaft arranged in said switch housing in coaxial relation thereto, a pair of spaced end plates having a larger spacing than said pair of guide plates and fixedly mounted on and jointly pivotable with said shaft and a plurality of linkage means for transmitting the pivotal motion of said pair of end plates to said plurality of contact bridges;
- (g) means for electrically insulating said plurality of contact bridges from said squirrel-cage-like supporting structure and from said plurality of linkage means;
- (h) means for shunting some of said plurality of contact bridges, said shunting means including a plurality of fixed current-carrying contacts on the inner surface of said housing, and said shunting means further including a plurality of movable current-carrying contacts each for conductively interconnecting one of said plurality of fixed current-carrying contacts and one of said plurality of conductive bars; and
- (i) linkage means operable by said shaft and by one of said pair of end plates for moving said plurality of movable current-carrying contacts to a shunting position thereof and away from said shunting position thereof.
8. A transfer switch for tap-changing regulating transformers comprising, in combination:
- (a) a cylindrical tubular switch housing of insulating material;
- (b) a plurality of pairs of spaced fixed arcing contacts on the inner surface of said housing, each of said plurality of pairs of fixed arcing contacts being arranged along one of a plurality of angularly displaced generatrices of said housing;
- (c) a plurality of contact bridges arranged in said housing, extending in a direction longitudinally thereof and each juxtaposed to one of said plurality of pairs of fixed arcing contacts to engage with, and to part from, said one of said plurality of pairs of fixed arcing contacts;
- (d) a plurality of contact bridge supports each for one of said plurality of contact bridges, each of said plu-

- ality of contact bridge supports having an upper guiding extension and a lower guiding extension;
- (e) electrical insulating means arranged between each of said plurality of contact bridges and one of said plurality of contact bridges supports to electrically insulate each of said plurality of contact bridges from the contact bridge support thereof;
- (f) a pair of spaced guide plates defining grooves at the juxtaposed surfaces thereof engaged by said upper guiding extension and by said lower guiding extension of said plurality of contact bridge supports for guiding the upper ends and the lower ends of said plurality of contact bridges;
- (g) a plurality of conductive bars extending parallel to said plurality of contact bridges conductively interconnecting said pair of guide plates and jointly forming with said pair of guide plates a squirrel-cage-like supporting structure for said plurality of contact bridges and said plurality of contact bridge supports;
- (h) operating means for said plurality of contact bridges and for said plurality of contact bridge supports to cause engagement of each of said plurality of contact bridges with, and parting of each of said plurality of contact bridges from, one of said plurality of pairs of fixed arcing contacts in a predetermined sequence, said operating means including a driving shaft arranged in said switch housing in coaxial relation thereto, a pair of spaced end plates having a larger spacing than said pair of guide plates and fixedly mounted on and jointly pivotable with said shaft and a plurality of linkage means for transmitting the pivotal motion of said pair of end plates to said plurality of contact bridge supports;
- (i) means for shunting some of said plurality of contact bridges, said shunting means including a plurality of fixed current-carrying contacts on the inner surface of said housing arranged at a lower level thereof than said plurality of fixed arcing contacts, and said shunting means further including a plurality of movable current-carrying contacts each adapted for conductively interconnecting one of said plurality of fixed current-carrying contacts and one of said plurality of conductive bars;
- (j) linkage means operable by said shaft and by one of said pair of end plates for operating said plurality of movable current-carrying contacts to a shunting position thereof and away from said shunting position thereof; and
- (k) a plurality of ohmic switching resistors arranged in said housing at a lower level thereof than said plurality of fixed current-carrying contacts, each of said plurality of resistors being conductively connected with one end thereof to one of said plurality of pairs of fixed arcing contacts,

9. A transfer switch for tap-changing regulating transformers comprising, in combination:
- (a) a cylindrical tubular switch housing of insulating material;
- (b) a plurality of pairs of spaced fixed contacts on the inner surface of said housing, each of said plurality of pairs of fixed contacts being arranged along one of a plurality of angularly displaced generatrices of said housing, said plurality of pairs of contacts including two outer pairs of fixed main contacts and inner pairs of fixed auxiliary contacts arranged between said two pairs of fixed main contacts;
- (c) a plurality of parallel contact bridges having two ends, each of said plurality of contact bridges being arranged inside of said housing, extending in a direction longitudinally thereof and each being juxtaposed to one of said plurality of pairs of fixed contacts to engage with, and to part from, said one of said plurality of pairs of fixed contacts, said plurality of contact bridges including two main contact bridges each arranged to engage with, and to part from, one of said two outer pairs of fixed main contacts, and said plurality of contact bridges further including auxiliary contact bridges each arranged to engage with, and to part from, one of said inner pairs of fixed auxiliary contacts;
- (d) operating means for said plurality of contact bridges for moving said plurality of contact bridges in a predetermined sequence radially into and out of engagement with one of said plurality of pairs of fixed contacts;
- (e) means for conductively interconnecting each of a pair of said plurality of pairs of fixed auxiliary contacts situated adjacent to one of said two ends of said plurality of contact bridges; and
- (f) a plurality of ohmic resistors each conductively connected with one end thereof to one of said pair of fixed auxiliary contact situated adjacent to the other of said two ends of said plurality of contact bridges, each of said plurality of resistors being conductively connected with the other end thereof to one of said two pairs of fixed main contacts.

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