

[11] 3,553,395

[72]	Inventor	Dale White Sharpsville, Pa.
[21]	Appl. No.	792,349
[22]	Filed	Jan. 21, 1969
[45]	Patented	Jan. 5, 1971
[73]	Assignee	Westinghouse Electric Corporation Pittsburgh, Pa. a corporation of Pennsylvania

2,761,930	9/1956	Smith	200/34X
2,878,333	3/1959	McCarty et al.	200/34X
3,374,320	3/1968	Buhler et al.	200/34X

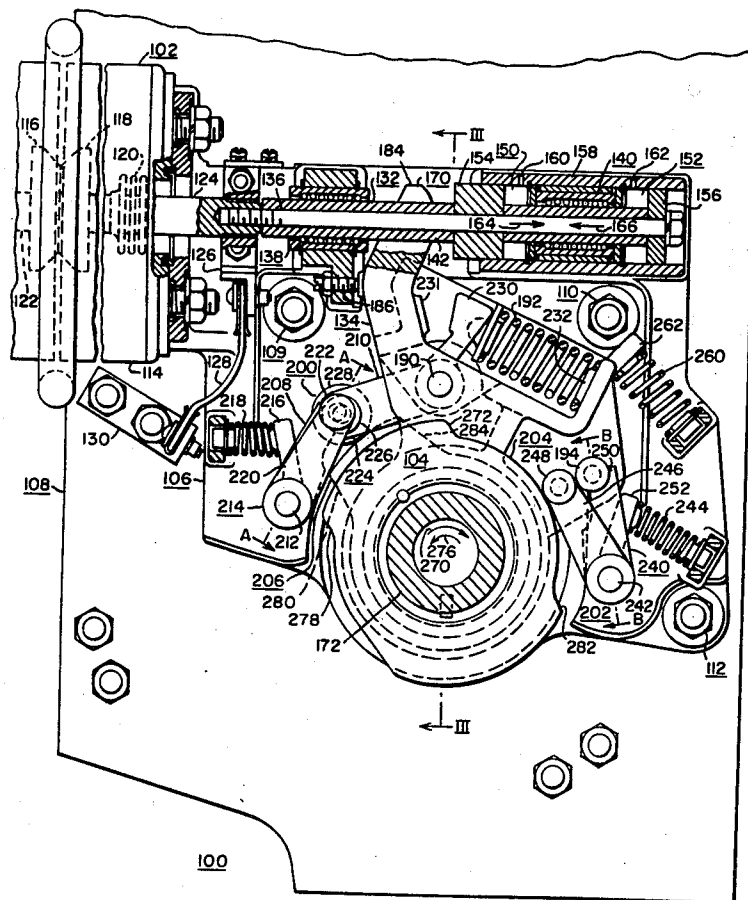
Primary Examiner—Robert K. Schaefer
Assistant Examiner—J. R. Scott
Attorneys—A. T. Stratton, F. E. Browder and Donald R. Lackey

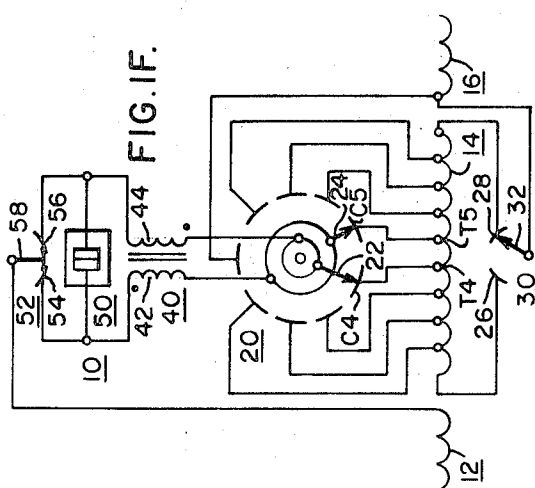
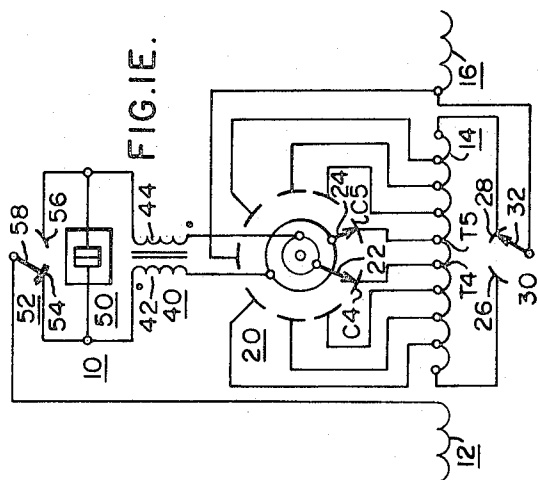
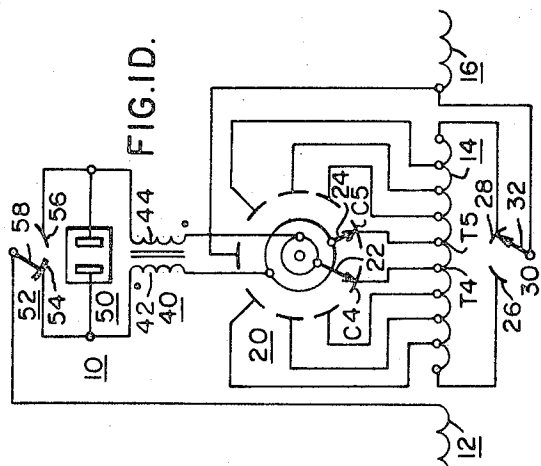
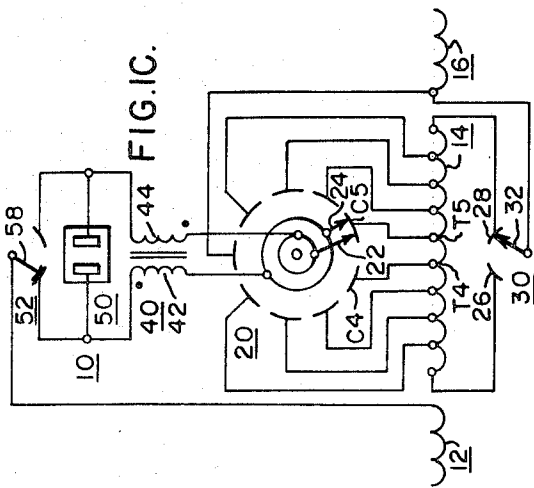
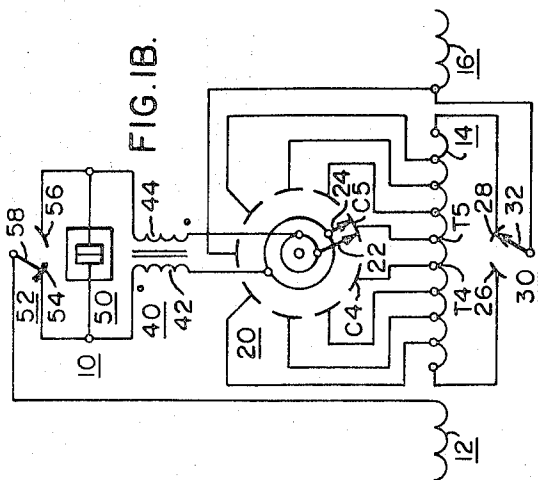
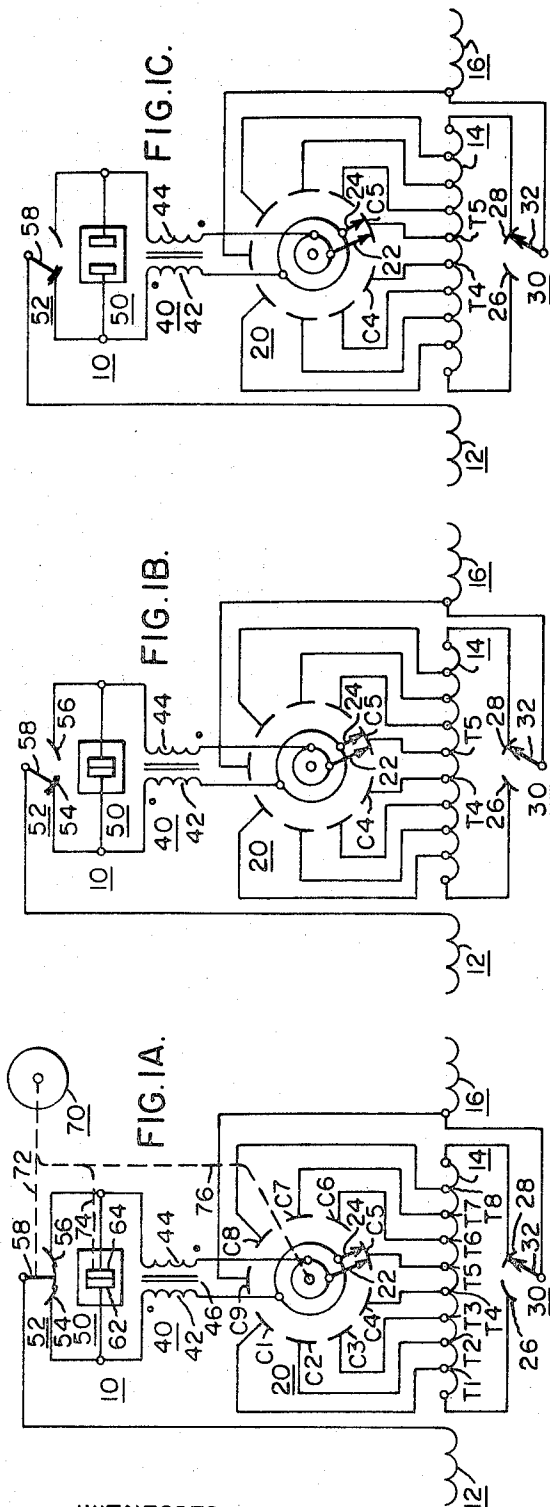
**[54] VACUUM SWITCH OPERATING MECHANISM
WITH PLURAL DASHPOT CONTROLLER MEANS
15 Claims, 11 Drawing Figs.**

[52]	U.S. Cl.....	200/18, 200/34, 200/11, 307/136
[51]	Int. Cl.....	H01h 3/00
[50]	Field of Search.....	200/153; 200/11TC, 17, 18, 34

[56] **References Cited**
UNITED STATES PATENTS
2,665,351 1/1954 Forwald 200/34X

ABSTRACT: A vacuum switch-operating mechanism suitable for use in tap changer systems. The operating mechanism includes a spring operated toggle mechanism, pivotally disposed on a control shaft. The toggle mechanism has set and trip positions, disposed to actuate an operating shaft connected to the movable contact of a vacuum switch, when it trips from its set position. The toggle is tripped and reset in a timed sequence for a predetermined to-and-fro rotational movement of the control shaft, opening the vacuum switch with a positive action and permitting reclosing by atmospheric pressure, while individually controlling both the opening and closing speeds of the movable contact.





WITNESSES:

Bernard R. Giequy
James F. Young

INVENTOR
Dale White

BY
Donald R. Lackey
ATTORNEY

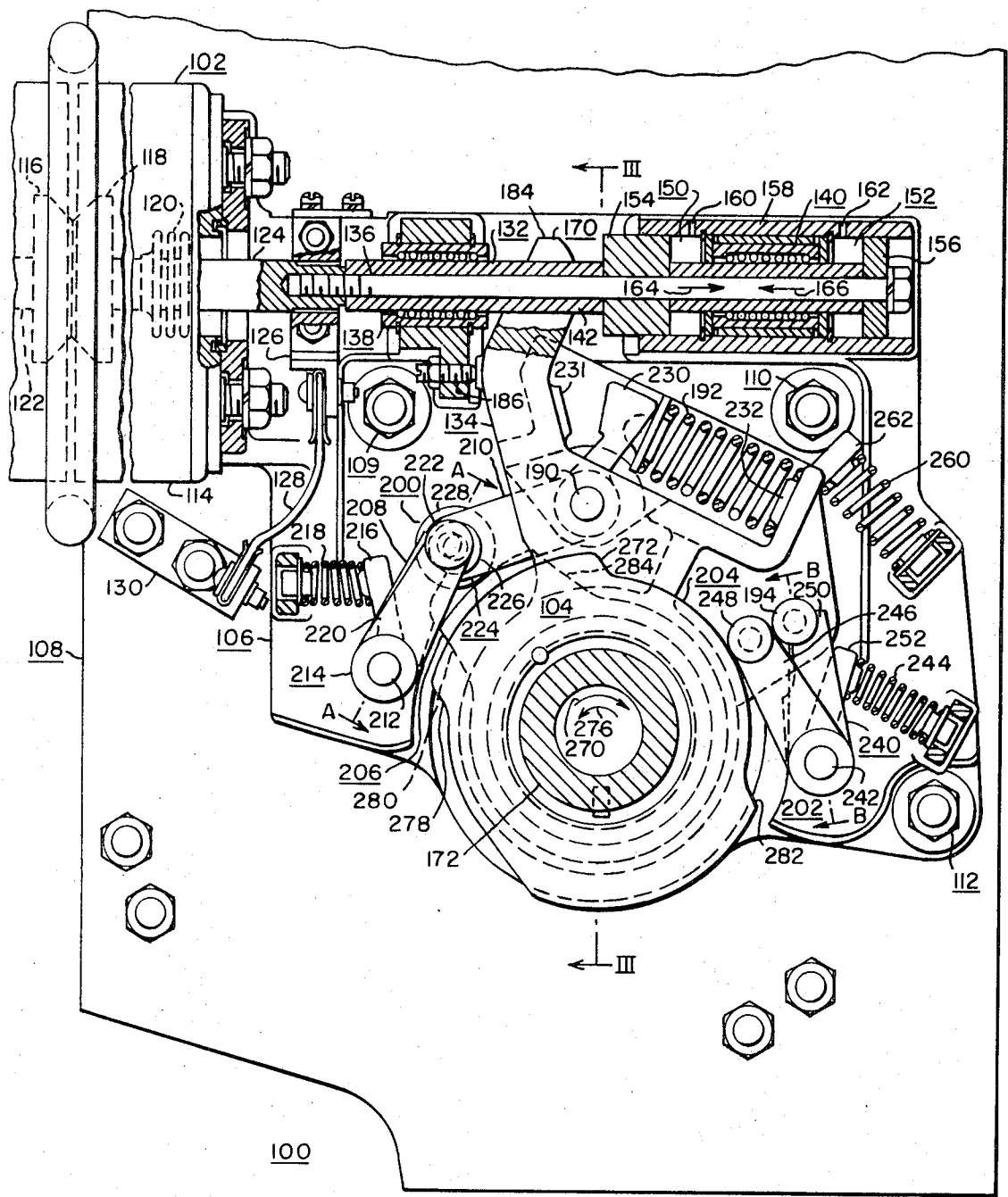


FIG. 2.

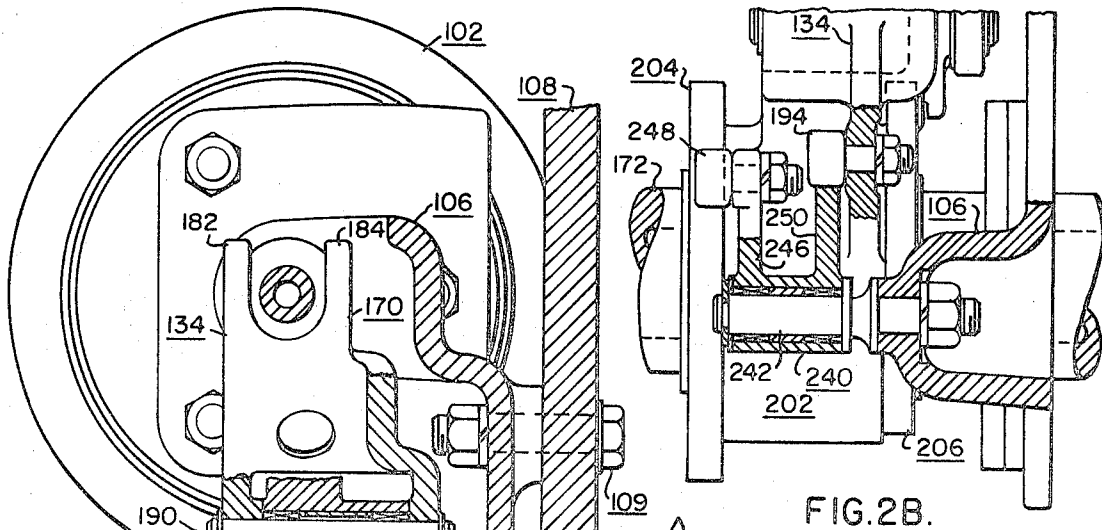


FIG. 2B.

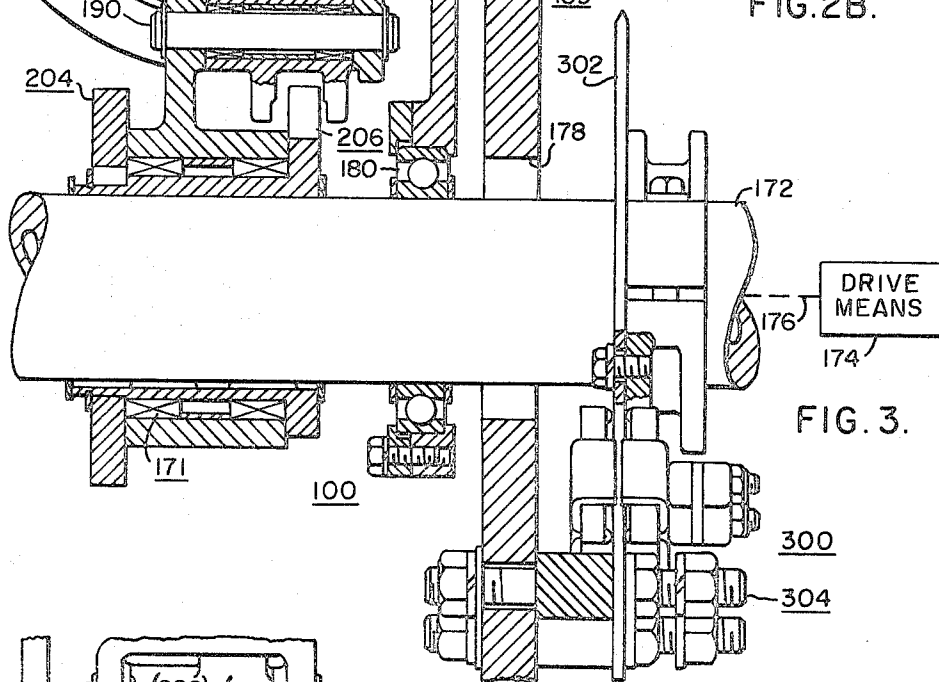


FIG. 3.

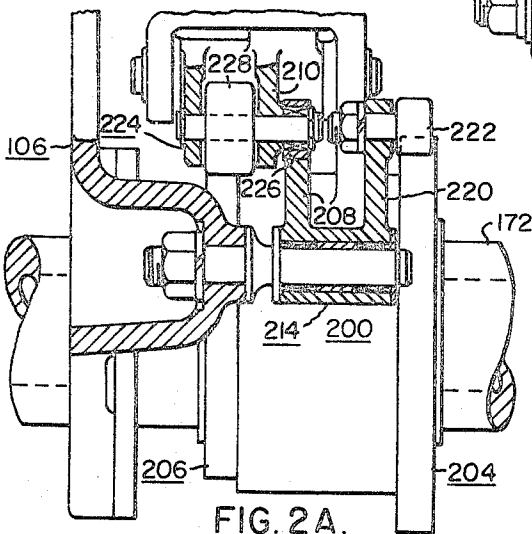


FIG. 2A.

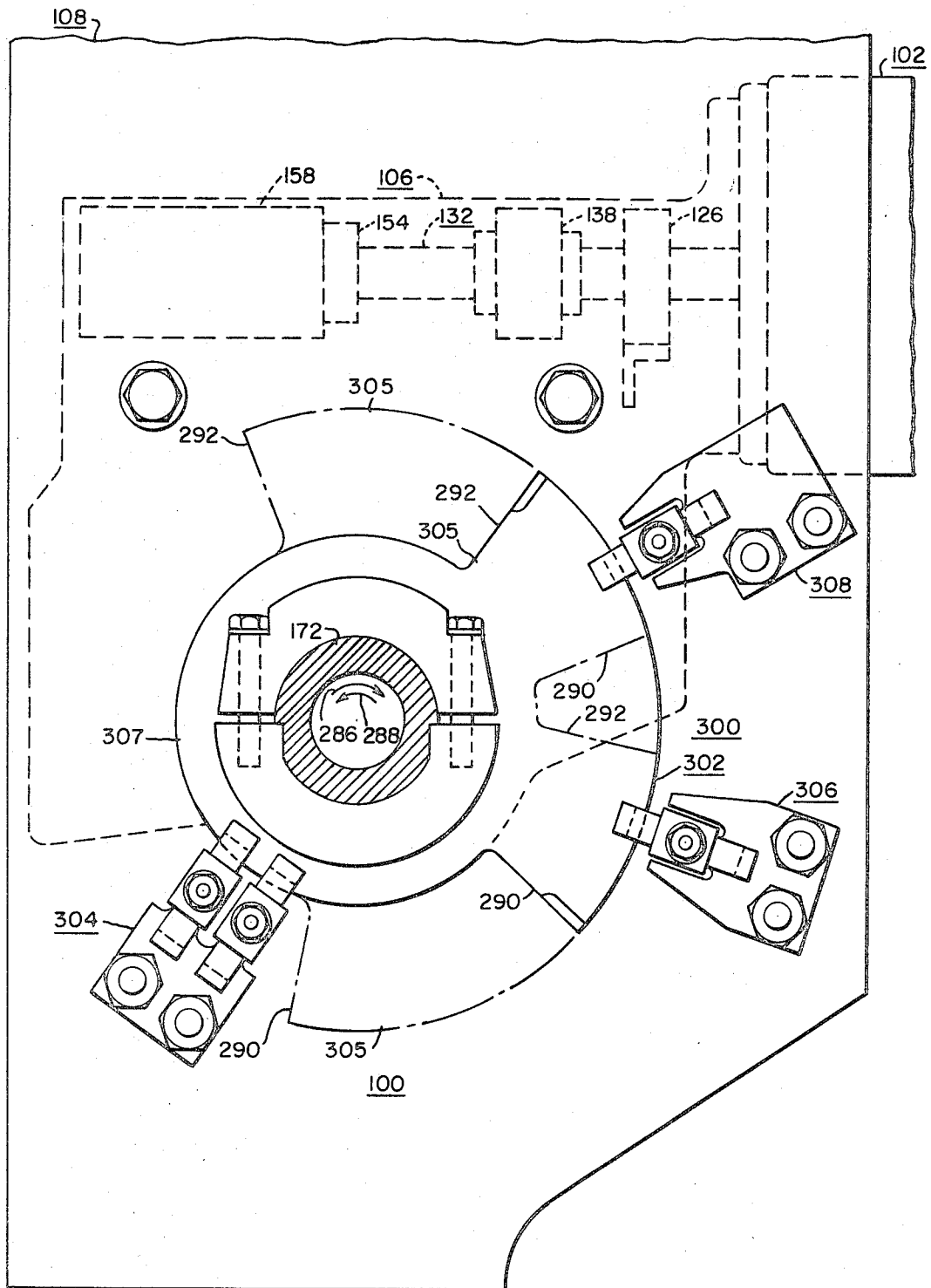


FIG. 4.

VACUUM SWITCH OPERATING MECHANISM WITH PLURAL DASHPOT CONTROLLER MEANS

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates in general to operating mechanisms for vacuum switches, and more specifically to operating mechanisms for vacuum switches utilized in load tap changer systems.

2. Description of the Prior Art

A vacuum switch, due to its construction wherein the movable contact is sealed with a metallic bellows, places stringent demands upon the characteristics of its operating mechanism, which must be met in order to obtain the normally expected operating life of the vacuum switch. For example, the movable contact of the vacuum switch should be guided by the operating mechanism, as there are no guides in the vacuum switch. The operating mechanism should operate the movable contact in a straight line, to prevent excessive flexing of the bellows. The opening speed of the movable vacuum switch contact should be controlled, to fully open the contacts in one-half cycle of the AC source voltage and extinguish the arc on either the first or second current zero, and this opening of the contacts must be further controlled to prevent overtravel and bellows vibrations, which would shorten the bellows life. The closing speed of the movable vacuum switch contact should be controlled to minimize contact bounce, and thus prolong the life of the contacts. The operating mechanism must open the contacts of the vacuum switch with a positive action which will break any welds that may have occurred between the stationary and moving contacts of the switch.

When the vacuum switch is utilized in a load tap changer system, the vacuum switch-operating mechanism should meet all of the hereinbefore enumerated requirements, and in addition must meet the demands placed upon the vacuum switch and its operating mechanism by the specific application. In a typical prior art load tap changer system which utilizes a single vacuum switch, a no-load type bypass switch shorts the vacuum switch when the tap changer is not being called upon to change taps, in order to reduce the heating of the vacuum switch contacts. The bypass switch is connected in two branch circuits between the tap selector switch and the main power circuit, and during a tap change opens one of the branch circuits without interrupting current flow therein, as the vacuum switch is connected between the two branch circuits, and it carries current once one of the branch circuits has been opened. The vacuum switch then opens its contacts to isolate the selected branch circuit, which allows the no-load tap changer switch contact arm connected in that branch circuit to move to a new tap position without arcing. The vacuum switch and the bypass switch then sequentially reclose to complete the tap change operation. Thus, once a tap change is initiated, the tap changer system must sequentially open one side of the bypass switch, open the vacuum switch, operate the tap selector switch, reclose the vacuum switch, and reclose the open side of the bypass switch. To insure that these steps of the tap change occur as required, and thus prevent a no-load switch from opening or closing at an improper time, the operation should be mechanically interrelated and interlocked to perform the desired sequence. Further, since the opening and closing sequence of the vacuum switch is identical, regardless of which side of the bypass switch is opened, the mechanical interrelation of the bypass switch and vacuum switch should be such that opening either side of the bypass switch will result in opening and closing the vacuum switch, without unduly complicating the vacuum switch operating mechanism.

SUMMARY OF THE INVENTION

Briefly, the invention is a new and improved vacuum switch-operating mechanism, and a new and improved tap changer arrangement utilizing the vacuum switch operating mechanism. The vacuum switch operating mechanism supports and guides an axially slidable operating shaft connected

to the movable contact of a vacuum switch, which supports and guides the movable contact throughout a straight line movement. Opening and closing dashpots disposed on the operating shaft control the opening and closing speeds of the movable contact of the vacuum switch, to obtain the fast opening required without overtravel and excessive bellows vibrations, and to obtain a closing speed which minimizes contact bounce.

The operating shaft is actuated by an operating arm assembly which is responsive to a spring operated toggle mechanism. The operating arm engages the operating shaft with an impact predetermined to break any contact welds, and continues to control the axial movement of the operating shaft to provide the desired clearance between the movable and fixed contacts of the vacuum switch in the full open position. The operating arm is pivotally mounted on a control shaft, which is driven by a reversible drive, and the bypass switch may be fixed to the same shaft. Cams disposed on the control shaft sequentially trip and reset the operating arm assembly and toggle for a predetermined to-and-fro rotational movement of the control shaft, regardless of the initial rotational direction of the control shaft. Thus, the bypass switch may open either of its two circuits, depending upon the initial direction of rotation of the control shaft, with the mechanics of tripping and resetting the toggle mechanism being the same regardless of which circuit of the bypass switch is open. The opening of the vacuum switch is positive, controlled by the operating arm and the toggle mechanism, and the closing may be entirely due to atmospheric pressure, or the closing may be spring assisted. The closing occurs when the operating arm is returned to its starting position. In order to conserve cycle time and enable all of the tap changer functions to be accomplished within an allotted short time period, the toggle mechanism is "broken" after it is tripped, separating one of the toggle linkages or arms from the cooperative toggle position, to remove the restraint on the operating shaft and allow a spring bias to return the operating arm to its starting position. This allows the vacuum switch to reclose prior to the reclosing of the open position of the bypass switch. Otherwise, the reclosing of the vacuum switch would be delayed by the resetting of the toggle mechanism.

BRIEF DESCRIPTION OF THE DRAWINGS

Further advantages and uses of the invention will become more apparent when considered in view of the following detailed description and drawings, in which:

FIGS. 1A through 1F are schematic diagrams which illustrate steps of a tap change for a load tap changer arrangement which may utilize the teachings of the invention;

FIG. 2 is a side elevational view, partially in section, illustrating a vacuum switch and vacuum switch-operating mechanism which is constructed according to the teachings of the invention;

FIG. 2A is a sectional view of a portion of the vacuum switch-operating mechanism shown in FIG. 2, taken along the line A-A, which illustrates the construction of a portion of a toggle mechanism;

FIG. 2B is a sectional view of another portion of the vacuum switch operating mechanism shown in FIG. 2, taken along the line B-B, which illustrates a portion of the vacuum switch-operating mechanism trip means;

FIG. 3 is a sectional view of the assembly shown in FIG. 2, taken along the line III-III; and

FIG. 4 is a side elevational view of a bypass switch assembly and operating arrangement which may be used.

DESCRIPTION OF PREFERRED EMBODIMENTS

Referring now to the drawings, and FIG. 1A in particular, there is shown a schematic diagram of a tap changer system 10 which may utilize the teachings of the invention. As illustrated in FIG. 1A, tap changer system 10 may be connected to the windings 12, 14 and 16 of an electrical transformer. The trans-

former may be single or polyphase, and of the auto transformer or isolated winding type, with only a portion of a single phase being illustrated in FIG. 1A, as other phases would be similarly arranged.

Tap changer system 10 is of the type which includes a no-load type tap selector switch 20, having a plurality of stationary contacts C1 through C8 connected to taps T1 through T8, respectively, on winding 14, and a stationary contact C9 connected to winding 16. Tap selector switch 20 has a pair of movable contact arms 22 and 24 for selectively and sequentially moving between the spaced stationary contacts C1 through C9. The ends of tapped winding 14 are connected to the stationary contacts 26 and 28 of a reversing switch 30, which has a movable contact 32 connected to winding 16, and thus to stationary contact C9 of tap selector switch 20. The reversing switch 30 may be actuated to change its movable contact 32 from one stationary contact to the other, when one of the movable contact arms 22 and 24 of the tap selector switch 20 is in engagement with the stationary contact C9, and the other contact arm is in transition to or from contact C9, to add the tapped voltage to, or subtract it from, the voltage of windings 12 and 14, depending upon the position of the reversing switch 30.

In order to enable the movable contact arms 22 and 24 to be connected to adjacent taps, and thus bridge a portion of winding 14, and also enable the tap changer system to operate continuously in the bridging position and obtain a voltage half way between the voltage of the two adjacent taps, the contact arms are connected to winding 12 through a split or divided preventive auto transformer or reactor 40 having windings 42 and 44 disposed on a common magnetic core 46. The windings are wound to present a high impedance to circulating currents, while providing very little impedance to power current flow in the same direction through the two windings.

A single arcing duty, normally closed vacuum switch 50, and a bypass switch 52, complete the tap changer system 10, with the bypass switch 52 having first and second stationary contacts 54 and 56, and a movable contact 58. The movable contact 58 is connected to winding 12, and the stationary contacts 54 and 56 are connected to winding sections 42 and 44 of reactor 40. The movable contact 58 is arranged to engage both stationary contacts 54 and 56, or to select either of the stationary contacts individually. The vacuum switch 50 has contacts 62 and 64 disposed within an evacuated envelope, with one of the contacts being movable relative to the other via a bellows, which maintains the vacuum seal. The vacuum switch 50 is connected across the contacts 54 and 56 of the bypass switch 52.

When the tap changer system 10 is in a steady state position, the power circuit of the transformer includes winding 16, the portion of winding 14 between the closed positions of the reversing switch 30 and the tap or taps selected by the contact arms 22 and 24, through the two branch circuits of the contact arms. One of the branch circuits includes contact arm 24, winding section 42, and the position of the bypass switch 52 which includes stationary contact 54; and, the other branch circuit includes contact arm 22, winding section 44, and the position of bypass switch 52 which includes stationary contact 56. The branch circuits combine in the movable contact 58 of bypass switch 52, and the power circuit continues to winding 12. Instead of having tapped winding 14 connected between two windings of the transformer, it may also be disposed at either end of a main transformer winding.

The vacuum switch 50 has its contacts closed, but since it is normally shorted by the bypass switch 50, there is negligible current flow therethrough. Therefore, the contacts of the vacuum switch are not heated by the current flowing in the transformer windings.

A tap change cycle for tap changer system 10 is illustrated in FIGS. 1B through 1F. Assuming that both tap selector arms are in contact with contact C5, and it is desired to operate on both contacts C4 and C5, such as signaled by a voltage-sensing circuit (not shown), tap changer drive means 70 will sequen-

tially operate the bypass switch 52, the vacuum switch 50, and the tap selector switch 20, via suitable mechanical means, generally indicated by dotted lines 72, 74 and 76, respectively. The first step in the tap change cycle is to open one side of the bypass switch 52. Since tap selector contact arm 22 must eventually move to operate in the hereinbefore described new position of the tap selector switch 20, the position of bypass switch 52 connected to contact arm 22 must open. This step is illustrated in FIG. 1B. The current flowing through winding 44 and contact arm 22 will not be interrupted, however, when the movable contact arm 58 of the bypass switch 52 opens the branch circuit which includes stationary contact 56 of the bypass switch, as the circuit through winding section 44 and tap selector switch contact arm 22 will be maintained through the vacuum switch 50. Thus, there will be very little arcing when the bypass switch 52 opens the branch circuit which includes its stationary contact 56.

The next step of the tap change cycle, shown in FIG. 1C, is to isolate the branch which includes contact arm 22, by opening vacuum switch 50. Since the current in the branch is interrupted by vacuum switch 50, arcing will occur but it will be quickly extinguished due to the vacuum surrounding the contacts. Now, as illustrated in FIG. 1D, contact arm 22 is free to move to contact C4 without arcing. The next step of the tap change cycle, shown in FIG. 1E, is to reclose the vacuum switch 50 to reestablish a circuit through winding section 44 and the movable contact arm 22 of the tap selector switch 20. The last step of the tap change cycle, shown in FIG. 1F, is to reclose the position of bypass switch 52 which includes its stationary contact 56. Thus, the vacuum switch 50 is again shorted by the bypass switch, and very little current will flow through the contacts of the vacuum switch. If the voltage-sensing circuit signals the tap changer system 10 to operate only on contact C4, the tap changer cycle would be similar to that already described, except bypass switch 52 would open its position which includes stationary contact 54, and contact arm 24 would move instead of contact arm 22.

As hereinbefore stated, the means for opening and closing the vacuum switch should support and guide the movable contact of the vacuum switch, while moving the contact in a straight line, it should control the opening and closing speeds of the movable contact, it must fully open the movable contact in one-half cycle of the AC source voltage, without overtravel, it must break any welds which may have occurred between the contacts of the vacuum switch, and it must be mechanically interlocked with the operation of the bypass switch and tap selector switch so that the bypass switch only operates when the vacuum switch is closed, and the tap selector switch only operates when the vacuum switch is open. Further, since the operation of the vacuum switch is the same regardless of which branch circuit is being interrupted, the vacuum switch operating mechanism should not be unduly complicated by the fact that the drive means may initially rotate in one direction to open one branch circuit, and in the opposite direction to open the other branch circuit. Further, the sequential steps of opening the bypass switch, opening the vacuum switch, moving the contact arm of the tap selector switch, reclosing the vacuum switch, and reclosing the open position of the bypass switch should be accomplished as rapidly as possible to enable the tap changer system to respond quickly to signals from a voltage-sensing circuit.

FIG. 2 is an elevational view of a vacuum switch and vacuum switch-operating mechanism assembly 100, constructed according to the teachings of the invention, which may be used on a load tap changer system, such as the tap changer system 10 shown in FIG. 1A, and which has all of the hereinbefore enumerated desirable features. Assembly 100 includes a vacuum switch 102, and a vacuum switch-operating mechanism 104. The specific location of the bypass switch is not critical, with FIGS. 3 and 4 illustrating the bypass switch mounted on the same drive shaft as the vacuum switch-operating mechanism 104. However, it may be mounted in any suitable manner, such as on a separate fixed shaft, with the bypass

switch being actuated via a connecting rod from the operating mechanism 104.

Assembly 100 includes a mounting member or base 106 which is disposed on an insulating support member 108, such as by nut and bolt assemblies 109, 110 and 112, and this assembly is disposed in a tank (not shown) containing a suitable liquid dielectric, such as oil or one of the synthetic insulating and cooling dielectrics.

Vacuum switch 102 includes a pair of separable contacts 116 and 118, disposed within an evacuated envelope 114. Contact 116 is fixed, being mounted on the end of a conductive rod 122 which is connected to a conductive end plate of the envelope. Contact 118 is movable, mounted on a conductive operating rod 124 which extends through the remaining end of the envelope through a flexible metallic bellows 120.

Vacuum switch 102 is bolted to mounting base 106, and the end of its movable operating rod 124 is connected to the vacuum switch operating mechanism 104. Electrically conductive rod 124 has a terminal 126 connected thereto, which is connected via a flexible conductor 128 to a stationary terminal 130 mounted on the insulating member 108.

The vacuum switch-operating mechanism 104 includes an operating shaft assembly 132 and an operating arm assembly 134. The operating shaft assembly 132 includes an operating shaft 136, which is fixed to the outwardly extending end of the movable conductive rod 124 of the vacuum switch 102, such as by threadably engaging the operating shaft 136 with the conductive rod 124. The longitudinal center line of the operating rod 124 and the longitudinal center line of the operating shaft 136 are in alignment. In order to guide the movable contact 118 of the vacuum switch 102, and to move the operating rod 124 with a straight line motion, which provides minimal flexing of the bellows 120 and thus maximum operating life, the operating shaft 136 is axially slidable in a pair of spaced bearing assemblies 138 and 140. The bearing assemblies 138 and 140 may be of any suitable construction, such as bearings of the linear ball-bushing type illustrated.

In order to control the opening and closing speeds of the movable contact 118 of the vacuum switch 102, to open the contacts to their full open position in one-half cycle of the AC source voltage while controlling and minimizing bellows vibrations and overtravel, and to close the contacts while minimizing contact bounce, opening and closing dashpots 150 and 152, respectively, are disposed on the operating shaft 136. The opening and closing dashpots 150 and 152 include pistons 154 and 156, respectively, disposed on the operating shaft 136, which are slidable with the operating shaft 136 in a common housing 158. The opening and closing dashpots 150 and 152 are separated by the bearing assembly 140, and each include a small opening or aperture in the common housing 158 which communicates with their piston chambers. For example, the opening dashpot 150 includes an aperture 160 disposed through the wall of housing 158, and the closing dashpot 152 includes an aperture 162. When the operating shaft 136 moves axially in the direction of arrow 164, under the influence of the operating arm assembly 134, to separate the contacts of the vacuum switch 102, liquid dielectric, which has filled the piston chambers from the liquid dielectric disposed within the tap changer tank, is forced outwardly from the chamber of piston 154 through the aperture 160. The piston, piston chamber and aperture are selected to provide the desired opening characteristics. When the operating shaft 136 moves in the direction of arrow 166, to close the contacts of the vacuum switch 102, the liquid dielectric disposed within the chamber of piston 156 is forced outwardly through aperture 162, to control the closing characteristics of the vacuum switch. In the specific embodiment of the invention shown in the figures, the opening of the vacuum switch 102 is positive, being controlled by the action of the operating arm assembly 134, starting with an impact on piston 154 predetermined to break any welds between the contacts of the vacuum switch 102, and opening with a force which greatly exceeds the force provided by atmospheric pressure on the bellows, which at-

tempts to keep the vacuum switch contacts closed, and also overcome the urging of a spring which may be used to help keep the contacts closed. Thus, the opening characteristic of the vacuum switch is almost entirely controlled by the opening dashpot 150, with any void which may occur in the chamber of piston 156, due to the inability of atmospheric pressure to force liquid into the aperture 162 fast enough to keep the piston chamber filled, having very little effect on the shaft opening characteristics.

The closing of the vacuum switch 102 is initiated by the return of the operating arm assembly 134 to the position shown in FIG. 2, which removes the restraint upon the operating shaft 136 and allows the vacuum switch contacts to close due to atmospheric pressure upon the bellows 120 and the urging influence of a return spring, if used. Thus, the opening dashpot 150 may aid the closing dashpot 152 in establishing the closing characteristics of the contacts, depending upon the relative sizes of apertures 160 and 162.

The operating arm assembly 134 must engage the operating shaft 136 when it is desirable to open or separate the contacts of the vacuum switch 102, with the initial force being sufficient to break contact welds, and the force on the operating shaft must continue until the contacts reach their full open position. The clearance between the contacts in the full open position will depend upon the operating voltage that the vacuum switch must interrupt and withstand when open, and may be a relatively small dimension, even for high voltages, due to the vacuum environment. Further, the operating arm assembly 134 must remove its restraint upon the operating shaft 136 at the proper time in the tap change cycle, to allow atmospheric pressure, and return spring, if used, to reclose the vacuum switch contacts, with the opening and the subsequent reclosing of the vacuum switch being coordinated with the bypass switch, to effect the proper sequential switching, as illustrated in FIGS. 1A through 1F.

In order to engage the operating shaft 136 and move it in the direction of arrow 164, a suitable radial projection may be provided on the operating shaft 136, with the piston 154 of the opening dashpot 150 being used, in this instance, as the radial projection which is engaged by the operating arm assembly 134. It will be understood, however, that other equally suitable means may be used to engage the operating arm assembly 134 with the operating shaft 136.

The operating arm assembly 134 includes an operating arm 170, which is pivotally disposed upon a control shaft 172 via a bearing assembly 171, which is shown more clearly in FIG. 3. FIG. 3 is a sectional end view of the assembly 100 taken generally along the line III-III of FIG. 2. The control shaft is driven by suitable tap changer drive means 174, such as by a reversible electrical motor, via a suitable linkage or coupling illustrated generally by the dotted line 176. The control shaft 172 as illustrated may be disposed through an opening 178 in the insulating support member 108, and rotatably secured to the mounting base 106 via bearing assembly 180.

The operating arm 170, as illustrated, is bifurcated, having two fingerlike extensions 182 and 184 disposed on opposite sides of operating shaft 136, such that a clockwise pivotal movement of operating arm 170 about the control shaft 172 will cause the fingers 182 and 184 to strike and engage the piston 154 of the opening dashpot 150. It will be understood that a single finger may be used, instead of two, if desired. Pivoting the operating arm 170 counterclockwise causes the operating arm 170 to strike an adjustable stop 186, which is fixed to the mounting base 106.

The operating arm assembly 134 is completed with a shaft 190, a spring 192, and a roller 194, the functions of which will be described in detail hereinafter.

The vacuum switch operating mechanism 104 includes a toggle mechanism 200, having set and trip positions, trip means 202, and trip and reset cams 204 and 206, respectively. Toggle mechanism 200 includes first and second toggle arms 208 and 210, respectively, with toggle arm 208 being pivotally mounted on mounting base 106 via shaft 212, and with toggle

arm 210 being pivotally mounted on the operating arm assembly 134 via shaft 190.

The first toggle arm 208 is one arm of a tripartite member 214, which in addition to the first toggle arm has an arm 216 which biases the tripartite member 214 clockwise by a spring 218 which is fixed to the mounting base 106, and an arm 220 which has a cam follower roller 222 rotatably fixed to its outwardly extending end. Arm 220 is disposed such that the cam follower roller 222 is aligned with the peripheral surface of the cam 204. This construction is more clearly illustrated in FIG. 2A, which is a cross-sectional view of the tripartite member 214, taken generally along the line A-A.

The second toggle arm 210 is one arm of a bipartite member 224, with the outwardly extending arm 210 having a roller 226 on its outwardly extending end which cooperates with the first toggle arm 208, and also a cam follower roller 228 which is aligned with the peripheral surface of cam 206. The rollers 226 and 228 are also more clearly shown in FIG. 2A. In addition to arm 210, the bipartite member 224 includes an arm 230 which extends outwardly from shaft 190 and restrains one end of spring 192. Spring 192, which is the main power spring for the vacuum switch-operating mechanism 104, has its other end fixed to a suitable spring base extension 232 disposed on the operating arm assembly 134. When the bipartite member 224 is pivoted clockwise about shaft 190, arm 230 will compress the power spring 192 against the spring base 232.

Trip means 202 includes a tripartite member 240, which is pivotally mounted on the mounting base 106 via shaft 242. The trip means 202 also includes roller 194 which is rotatably fixed to the operating arm mechanism 134, and a spring 244 which has one end fixed to the mounting base 106. Tripartite member 240 includes an arm 246 having a cam follower roller 248 rotatably fixed to its outwardly extending end, which rides on the peripheral surface of cam 204, 27 arm 250 which cooperates with roller 194 to hold the operating arm assembly 134 in its "set" position, until it is desired to trip or release the operating arm assembly 134, and an arm 252 which cooperates with spring 244 to bias the tripartite member 240 counterclockwise, when viewing the vacuum switch operating mechanism 104 in the direction of FIG. 2. FIG. 2B illustrates the tripartite member 240 in a sectional view, taken generally along the line B-B.

The vacuum switch operating mechanism 104 is completed with a spring 260 which has one end fixed to the mounting base 106, and its other end disposed against a spring base 262 which is part of the operating arm assembly 134. Spring 260 biases the operating arm assembly 134 counterclockwise.

The vacuum switch operating mechanism 104 is operated by a fractional turn of the control shaft 172 in a clockwise, or a counterclockwise direction, followed by returning the control shaft to its starting position. In other words, the vacuum switch-operating mechanism 104 is tripped and reset in timed sequence by a predetermined to-and-fro rotational movement of the control shaft 172, regardless of the initial rotational direction of the control shaft. In a vacuum switch-operating mechanism constructed according to the teachings of the invention, the shaft rotational movement was plus and minus 60°, but it may vary, depending upon the specific application. Before describing the operation of the vacuum switch-operating mechanism 104, it is important to note that the cooperating first and second toggle arms 208 and 210 of the toggle mechanism 200 are not permanently fixed to one another. The outwardly extending end of the first toggle arm 208 has a curved surface which contacts the roller 226 of the second toggle arm 210 for less than 180°, and in the specific embodiment is closer to 120°. The purpose of this construction will be hereinafter explained in the description of the operation of the vacuum switch-operating mechanism 104.

In explaining the operation of the vacuum switch operating mechanism 104, it will be assumed that the operating arm assembly 134 and toggle mechanism 200 are in their "set" positions, with the power spring 192 being compressed, and the operating arm assembly 134 being restrained from clockwise

rotation by the roller 194 on the operating arm assembly 134 and arm 250 of the tripartite member 240. Now, assume that a tap change has been called for by the voltage-sensing circuit, which requires the control shaft 172 to rotate clockwise in the direction of arrow 270, in order to operate a predetermined section of the bypass switch, as will be hereinafter explained. When control shaft 172 rotates clockwise, the bypass switch opens one of its circuits, as shown in FIG. 1B, the raised portions of cams 204 and 206 rotate away from the toggle mechanism 200, to enable the toggle mechanism to drive the operating arm assembly 134 clockwise at the proper time, without interference from the cams, and then rise 272 on cam 204 lifts the cam follower roller 248 and rotates the tripartite member 202 clockwise. When the rotational restraint on operating arm assembly 134 is removed, i.e., when arm 250 is no longer in engagement with roller 194, the operating arm assembly 134 is tripped and starts to rotate clockwise under the influence of the now extending power spring 192. The lever or arm 230 of the bipartite member 224 is rotated counterclockwise against the stop 231 on the operating arm assembly 134 by the spring 192 and the toggle 200 collapses, aligning its arms 208 and 210, suddenly lengthening the distance between shaft 212, which is fixed to mounting base 106, and shaft 190, which is fixed to operating arm assembly 134. Thus, the collapsing toggle causes the operating arm assembly 134 to rotate rapidly clockwise and cause the operating arm 170 to strike the piston 154 with a force which will break any welds between the contacts of the vacuum switch 102 and to continue the axial movement of the operating shaft 136 to separate the vacuum switch contacts to their full open position. Once the rise 272 on the trip cam 204 lifts the cam follower 248 and removes the restraint against clockwise rotation placed on the operating arm assembly 134, the hereinbefore described steps of the operation of the vacuum switch-operating mechanism 104 occur almost instantaneously. Dashpot 150 restricts the movement of shaft 136 by an amount calculated to dampen bellows vibrations and prevent overtravel of the opening contact of the vacuum switch 102. In other words dashpot 150 "cushions" the opening to provide the relatively fast opening necessary to separate the contacts full open in one-half cycle of the source voltage, without undue vibration of the metallic bellows due to a too sudden stop, and without overtravel of the opening contact. Spring 218 maintains its bias on arm 216 of the tripartite member 214, keeping toggle arm 208 engaged with toggle arm 210 after the toggle is tripped. Springs 260 and 244 are compressed when the operating arm assembly 134 is in its tripped position. The vacuum switch 102 is now open, as shown in FIG. 1C, but the control shaft continues to turn clockwise in the direction of arrow 270 for a predetermined number of degrees, to allow time for the tap selector switch to operate, as shown in FIG. 1D.

Now, the control shaft 172 reverses its rotational direction, turning counterclockwise in the direction of arrow 276. The rise 278 on the trip cam 204 lifts toggle arm 208 from engagement with the roller 226 on the second toggle arm 210, "breaking" the toggle, which removes the restraint on operating arm assembly 134 and allows the compressed spring 260 to bias the operating arm assembly 134 counterclockwise against the stop 186. As soon as the operating arm assembly 134 starts to rotate counterclockwise, the restraint on piston 154 is removed, and the contacts of the vacuum switch 102 will close due to the atmospheric pressure operating on the metallic bellows 120, and due to a closing spring, if used. Thus, the removal of the toggle arm 208 from its cooperative position in the toggle mechanism 200, allows the vacuum switch 102 to immediately reclose, as shown in FIG. 1E, with the closing speed being controlled by the closing dashpot 152 to minimize contact bounce, and the bypass switch may then immediately reclose its open position, as shown in FIG. 1F. This is important, as it would place a severe time restriction on the operation of the tap changer if the reclosing of the vacuum switch 102 were to be delayed by the resetting of the toggle 200,

which would then delay the reclosing of the open position of the bypass switch. By immediately "breaking" the toggle mechanism, and allowing the vacuum switch to reclose, the open side of the bypass switch can then close while the toggle mechanism 200 is being reset. This overlapping of functions may, in some instances, be the difference in being able to reclose the vacuum switch before the bypass switch closes its open position, which is essential to the proper operation of the tap changer system.

Once the operating arm assembly 134 is moved back to the "set" position by spring 260, spring 244 urges arm 250 against roller 194, again locking the operating arm assembly 134 against clockwise rotation. The resetting of operating arm assembly 134 and toggle mechanism 200 may then be started, with rise 280 on reset cam 206 engaging roller 228, pivoting bipartite member 224 clockwise and compressing the power spring 192 between arm 230 and the spring base 232. When bipartite member 224 is pivoted clockwise about shaft 190 by the cam 206, which cam has the function of resetting the toggle mechanism 200, a point is reached where the first toggle arm 208, which had been "broken" from its cooperative position with roller 226 by cam 204, will reengage roller 226, and the toggle mechanism 200 will be reset. Cam 206 maintains its position against cam roller 228, preventing premature tripping of the toggle. Before toggle mechanism 200 will collapse to its trip position, cam 206 must first rotate out of the way, which occurs during the first part of the rotational cycle of the operating shaft 172, as hereinbefore described.

The vacuum switch-operating mechanism 104 must be constructed to operate regardless of the initial direction of rotation of the control shaft 172, since in certain tap changes one side of the bypass switch opens, and in other tap changes the other side of the bypass switch opens. Further, this requirement should not unduly complicate the vacuum switch operating mechanism 104. The vacuum switch-operating mechanism 104, as constructed according to the teachings of this invention, operates in the same manner, regardless of the initial direction of rotation of the control shaft 172. If control shaft 172 initially starts to rotate counterclockwise in the direction of arrow 276, instead of starting to rotate clockwise, as hereinbefore described, the trip and reset cams rotate out of the way, and rise 282 on the trip cam 204 initiates the tripping, instead of rise 272. The tripping of the vacuum switch operating mechanism 104 then takes place exactly as hereinbefore described. When the control shaft 172 reaches the end of its counterclockwise rotation and starts to rotate clockwise, to return the shaft to its initial starting position, cam rise 272 of cam 204 moves the first toggle arm 208 to "break" the toggle, instead of the cam rise 278. The tripping cam rise 272 and the toggle breaking cam rise 278 exchange functions when the initial direction of rotation of the control shaft 172 is counterclockwise instead of clockwise. Thus, while cam 204 may be called the "trip cam," it also provides the function of breaking the toggle 200 prior to the reset portion of the tap change cycle. Continued clockwise rotation of control shaft 172 then causes cam rise 284 on the reset cam 206 to operate against roller 228, to reset the toggle mechanism 200, instead of cam rise 280 initiating this function. Otherwise, the resetting of the operating arm assembly 134 and the toggle mechanism 200 is exactly the same as hereinbefore described when the initial rotational direction of the control shaft 172 was clockwise, instead of counterclockwise.

FIGS. 3 and 4 illustrate a bypass switch 300 which may be used with the assembly 100. Bypass switch 300 has a blade type rotary contact 302, which in this instance is fixed to the control shaft 172, and circumferentially spaced fixed contacts 304, 306 and 308, which, in this instance, are bolted to the insulating support member 108. Rotary contact 302 has a fan-shaped projection 305 which contacts both stationary contacts 306 and 308 when the switch is in its steady state position, and a connecting circular portion 307 of smaller radius which contacts stationary contact 304. When a tap change has been signaled by the voltage sensing circuit and the control

shaft 172 starts to rotate in the direction of arrow 286, the circuit between stationary contact 304 and stationary contact 308 will be broken as the rotary blade 302 turns to the position of dotted line 290, while maintaining the circuit between contacts 304 and 306. Then, when the control shaft 172 returns to its starting position, the circuit between contacts 304 and 308 will be reestablished. When a tap change has been signaled and shaft 172 starts to rotate in the opposite direction, i.e., in the direction of arrow 288, the circuit between stationary contacts 304 and 306 will be broken, as the rotary blade 302 turns to the position of dotted line 292, while maintaining the circuit between contacts 304 and 308. When the control shaft 172 returns to its starting rotary position, the circuit between contacts 304 and 306 will be reestablished. The vacuum switch-operating mechanism 104, shown in FIG. 2, must perform all of its functions between the time the circuit between contact 304 and one of the other stationary contacts is broken, and the time in which the circuit is reestablished.

Instead of mounting bypass switch 300 on control shaft 172, it may be rotatably disposed on a separate fixed shaft, and actuated by an extension on cam 204, which is linked to the bypass switch 300 by an insulating connecting rod.

In summary, there has been disclosed a new and improved operating mechanism for a vacuum switch, and a new and improved tap changer system using a vacuum switch, bypass switch, and the new operating mechanism for the vacuum switch. The vacuum switch-operating mechanism operates the vacuum switch movable contact in a straight line while guiding and supporting the movable contact, and it controls both the opening and closing characteristics of the movable contact to prolong the life of the bellows and the contacts of the vacuum switch. Further, the vacuum switch-operating mechanism is coordinated with a tap changer system which utilizes a single vacuum switch and a bypass switch having two normally closed circuits, any one of which may be selectively opened. The vacuum switch-operating mechanism will operate for a predetermined to-and-fro rotational movement of a control shaft, with the bypass switch being responsive to movement of the control shaft. Further, the vacuum switch-operating mechanism will operate properly regardless of which rotary direction the control shaft starts to turn, which allows the two positions of the bypass switch to be selected by initiating the rotary direction of the control shaft in one direction to open one circuit, and in the other direction to open the other circuit of the bypass switch. Between the time that the bypass switch opens one of its positions and then closes it, the vacuum switch-operating mechanism opens the vacuum switch, operates the tap selector switch, and recloses the vacuum switch. Unique overlapping of certain functions of the vacuum switch-operating mechanism, wherein the toggle is "broken" to allow earlier reclosure of the vacuum switch, shortens the overall tap changing cycle.

Since numerous changes may be made in the above-described apparatus and different embodiments of the invention may be made without departing from the spirit thereof, it is intended that all matter contained in the foregoing description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

I claim:

1. An operating mechanism for a vacuum switch, comprising:
 - a vacuum switch having normally closed first and second contacts;
 - an axially slidable operating shaft connected to one of the contacts of said vacuum switch;
 - support means disposed to support and guide said axially slidable operating shaft in a straight line;
 - first means for axially moving said operating shaft relative to said support means, when it is desired to separate the contacts of said vacuum switch, said first means initiating the axial movement of said operating shaft with a force predetermined to break contact welds, continuing the

axial movement until the contacts of said vacuum switch have separated by a predetermined dimension, and restraining the operating shaft to maintain the contacts of said vacuum switch in their open position;

first dashpot means having a piston coaxially fixed to said operating shaft for controlling the axial speed of said operating shaft when moved by said first means; means for removing the restraint of said first means on said operating shaft when it is desired to allow the contacts of said vacuum switch to close;

and second dashpot means having a piston coaxially fixed to said operating shaft for controlling the axial speed of said operating shaft when the contacts of said vacuum switch are closing.

2. The operating mechanism of claim 1 wherein the first means engages the piston of the first dashpot means to axially move the operating shaft and open the contacts of the vacuum switch.

3. An operating mechanism for a vacuum switch, comprising:

a mounting base;

an axially slidable operating shaft disposed on said mounting base, adapted for connection to a contact of the vacuum switch;

a control shaft adapted for connection to reversible drive means;

an operating arm assembly pivotally disposed on said control shaft, said operating arm assembly including means for engaging said operating shaft when said operating shaft assembly pivots about said control shaft in a predetermined direction;

a spring having one end restrained by said operating arm assembly;

a toggle assembly having set and collapsed positions, said toggle assembly including first and second cooperative arm members pivotally mounted on said mounting base and on said operating arm assembly, respectively, said second arm member including a cam follower and means for storing energy in said spring in response to the cam follower;

first cam means disposed on said control shaft which cooperates with the cam follower of said toggle assembly, to set the toggle assembly and store energy in said spring;

trip means disposed on said mounting base, said trip means including means for releasably engaging said operating arm assembly, and a cam follower; and

second cam means disposed on said control shaft for cooperating with the cam follower of said trip means, to release the trip means from said operating arm assembly, whereby the stored energy in said spring is released, collapsing the toggle mechanism to pivot said operating arm assembly about said control shaft and engage and move said operating shaft in a direction which separates the contacts of the vacuum switch, and to restrain the operating arm assembly at the end of its pivotal movement to maintain the separation of the vacuum switch contacts.

4. The operating mechanism of claim 3 wherein the first and second cam means each include first and second spaced portions arranged to set the toggle assembly and store energy in the spring, and release the trip means, respectively, for predetermined rotational movements of the control shaft, regardless of the initial direction of rotation.

5. The operating mechanism of claim 3 wherein the first arm member of the toggle assembly is releasably engaged with the second arm member, and wherein the first member includes a cam follower, the first cam means cooperating with said cam follower of the first arm member to release the first arm member from the second arm member of the toggle assembly to remove the restraint on the operating assembly, after the toggle has collapsed, the first arm member of the toggle mechanism reengaging the second arm member of the toggle to set the toggle when the second cam means moves the cam follower of the second arm member of the toggle mechanism to a predetermined location.

6. The operating mechanism of claim 3 wherein the first and second cam means are disposed to actuate the trip means to release the operating arm assembly, collapse the toggle and reset the toggle mechanism with a predetermined to-and-fro rotational movement of the control shaft.

7. The operating mechanism of claim 6 wherein the first and second cam means are arranged to actuate the trip means and collapse the toggle, and reset the toggle mechanism, respectively, regardless of the starting direction of rotation of the control shaft.

8. The operating mechanism of claim 3 including stop means disposed on the mounting base for limiting the rotational movement of the operating arm assembly in the direction opposite to that in which the operating arm assembly is pivoted when the toggle mechanism collapses, and including means for removing the first toggle arm from engagement with the second toggle arm of the toggle mechanism to remove the restraint on the operating arm assembly, means for pivoting the operating arm assembly against said stop means when the restraint is removed therefrom, and means reengaging the trip means with the operating arm assembly when the operating arm assembly is moved against the stop means, whereby the operating shaft is free to move axially back to its initial position when the operating arm assembly is pivoted towards the stop means.

9. The operating mechanism of claim 3 including means for controlling the axial speed of the operating shaft as it is moved by the operating arm assembly when the toggle mechanism collapses.

10. The operating mechanism of claim 9 wherein the means for controlling the speed of the operating shaft is a dashpot disposed on the operating shaft.

11. The operating mechanism of claim 3 including means for controlling the axial speed of the operating shaft as it is moved by the operating arm assembly when the toggle mechanism collapses, means for returning the operating arm assembly to its starting position allowing the operating shaft to return to its initial position, means including atmospheric pressure for returning the operating shaft to its initial position, and means for controlling the speed of the operating shaft as it returns to its initial position.

12. Tap changer apparatus comprising:

a main conductor;

divided reactor means having first and second winding portions;

a tap selector switch having first and second movable contact arms selectively movable between a plurality of fixed contacts;

a bypass switch having first, second and third terminals, said bypass switch being actuatable to connect the third terminal to either one or both of the first and second terminals, the third terminal of said bypass switch being connected to said main conductor;

means serially connecting said first movable contact arm and said first winding portion to the first terminal of said bypass switch;

means serially connecting said second movable contact arm and said second winding portion to the second terminal of said bypass switch;

a vacuum switch having fixed and movable contacts, connected between the first and second terminals of said bypass switch; and

means for operating said bypass switch, said vacuum switch, and said tap selector switch, when the main conductor is to be connected in a different tap arrangement, said means including a vacuum switch operator mechanism which includes an operating shaft connected to the movable contact of said vacuum switch, and a control shaft connected to reversible drive means, said means sequentially operating said bypass switch, said vacuum switch, said tap selector switch, said vacuum switch, and said bypass switch, during a predetermined to-and-fro rotational movement of said control shaft, for either starting direction of rotation of said control shaft.

13

13. The tap changer apparatus of claim 12 wherein the operating shaft includes dashpot means for controlling its axial speed while moving the movable contact of the vacuum switch.

14. The tap changer apparatus of claim 12 wherein the bypass switch is mounted on the control shaft.

15. An operating mechanism for a vacuum switch, comprising:

- a mounting base;
- an axially slidable operating shaft disposed on said mounting base, adapted for connection to a contact of the vacuum switch;
- dashpot means for controlling the axial speed of said operating shaft;
- a control shaft adapted for connection to reversible drive means;
- an operating arm assembly pivotally disposed on said control shaft, said operating arm assembly including means for engaging said operating shaft when said operating shaft assembly pivots about said control shaft in a first predetermined direction;
- means urging said operating arm assembly in a direction opposite to the first direction;
- a spring having one end restrained by said operating arm assembly;
- a toggle assembly having set and collapsed positions, said toggle assembly including first and second cooperative toggle arm members pivotally mounted on said mounting base and on said operating arm assembly, respectively, said first toggle arm member including a cam follower and said second toggle arm member including a cam follower and means for storing energy in said spring in response to the cam follower, said first and second toggle arm members being releasably engaged;
- trip means disposed on said mounting base, said trip means including means for releasably engaging said operating arm assembly, and a cam follower;

14

first cam means disposed on said control shaft which cooperates with the cam follower of said toggle assembly, to set the toggle assembly and store energy in said spring; and

second cam means disposed on said control shaft for cooperating with the cam follower of said first toggle arm member and the cam follower of said trip means, to release the trip means from said operating arm assembly, whereby when said trip means is in engagement with said operating arm assembly, said toggle assembly is set, and energy is stored in said spring, a predetermined to-and-fro rotational movement of said control shaft, for either starting direction of rotation, will sequentially:

- a. actuate the cam follower of said trip means with said second cam means to release the trip means from said operating arm assembly, which releases the stored energy in said spring and collapses said toggle assembly, to pivot said operating arm assembly about said control shaft and engage said operating shaft to axially move it in a direction which separates the contacts of the vacuum switch;
- b. actuate the cam follower of said first toggle arm member with said second cam member, to disengage said first and second toggle arm members and remove the restraint on said operating arm assembly, allowing said urging means to return said operating arm assembly to its starting position and reengage said trip means, said operating shaft returning to its starting position, at least partially under the influence of atmospheric pressure, when said operating arm assembly is disengaged therefrom and returned to its starting position; and
- c. actuate the cam follower of said second toggle arm member, to reengage said first and second toggle arm members, compress said spring, and set said toggle assembly.

40

45

50

55

60

65

70

75