Oct. 24, 1967 J. L. GRATZMULLER 3,349,207

ACTUATING MECHANISM FOR ELECTRIC CIRCUIT BREAKER COMPRISING A ROD SOLELY IN TENSION IN ALL POSITIONS THEREOF OR SOLELY UNDER COMPRESSION IN ALL POSITIONS THEREOF

Filed April 2, 1962

3 Sheets-Sheet 1

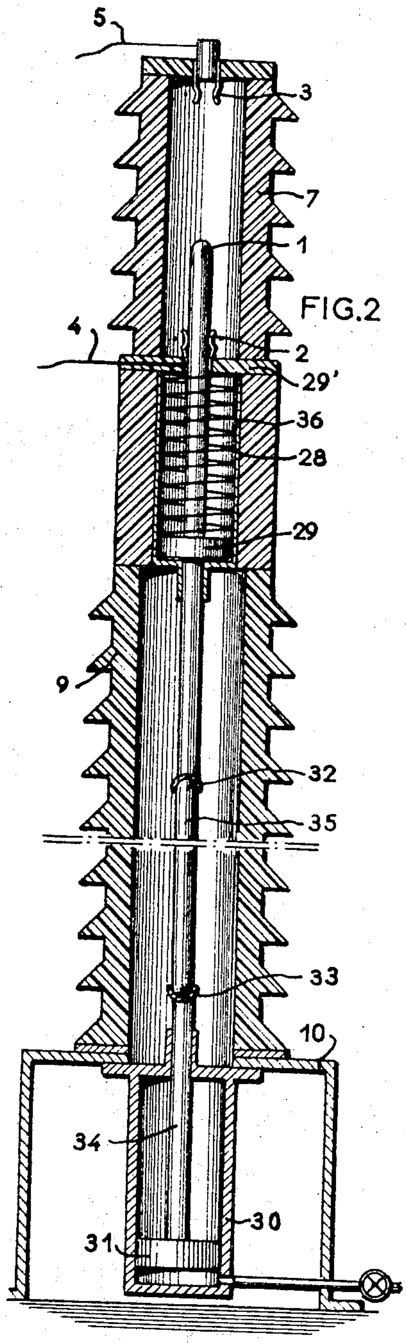


FIG. 2

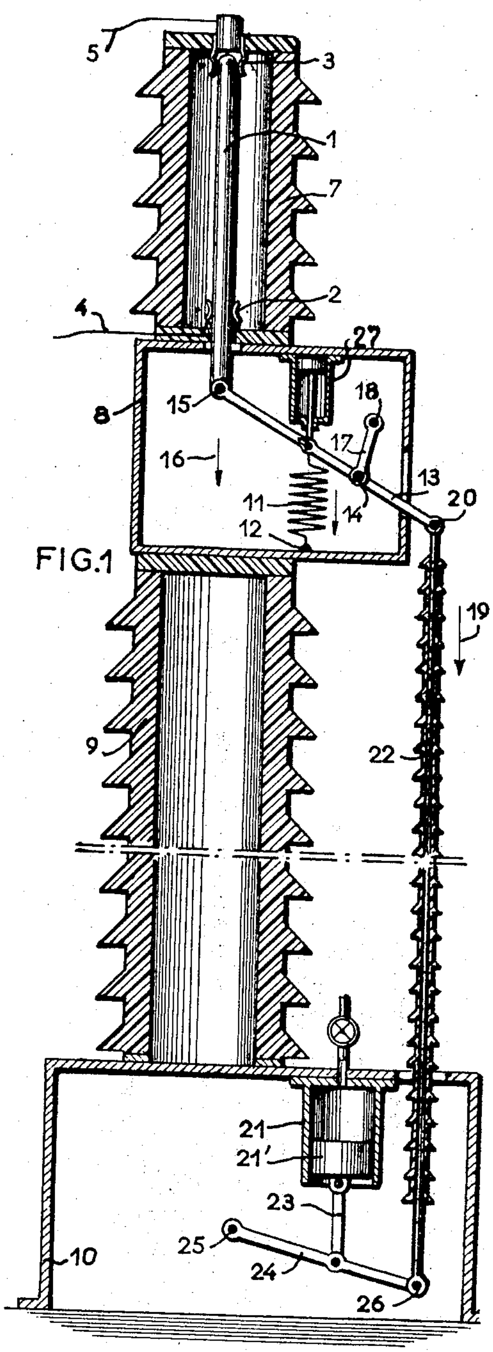


FIG. 1

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3 Sheets-Sheet 2

FIG 3

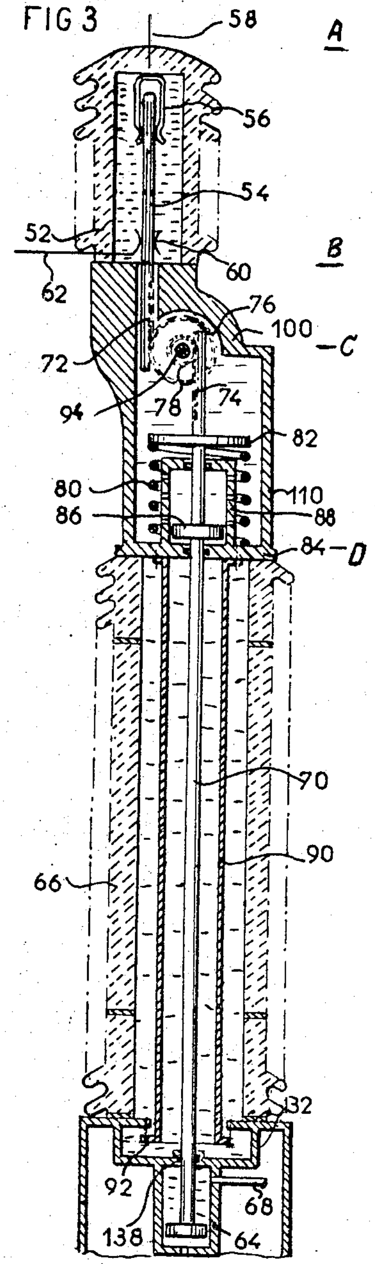


FIG.5

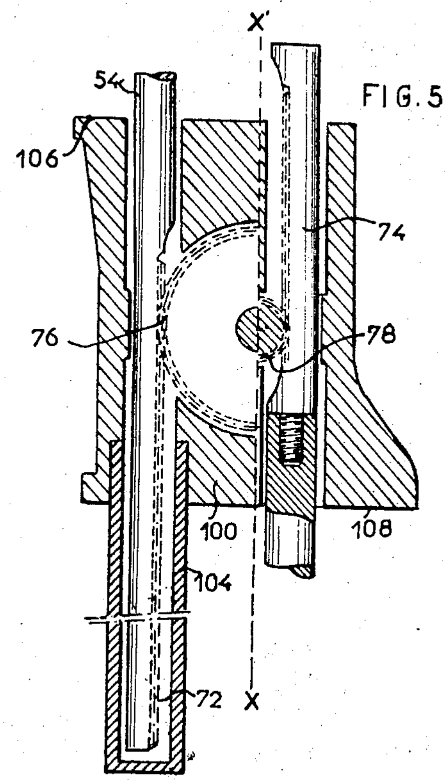


FIG.4

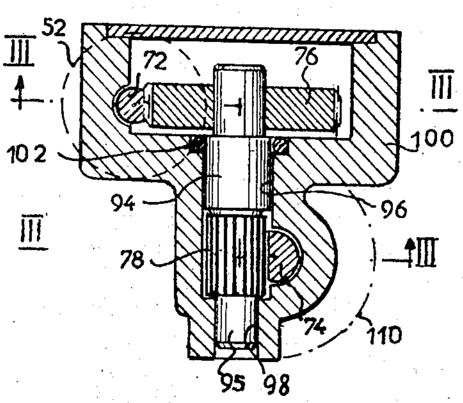


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FIG.9

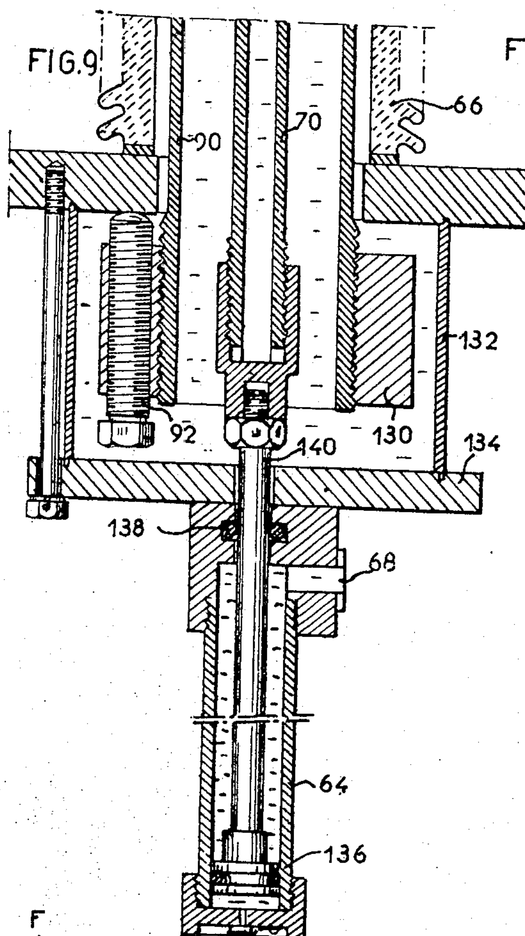



FIG.8

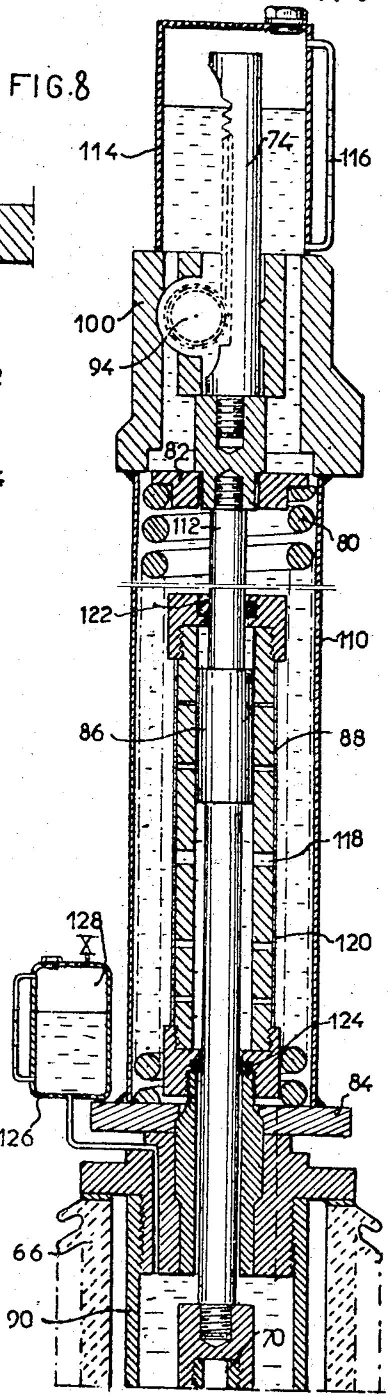



FIG. 6

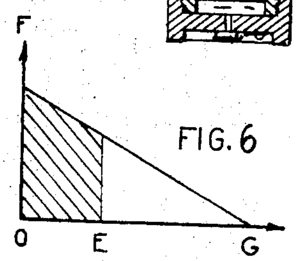
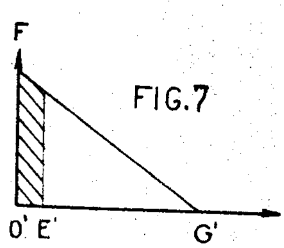



FIG.7

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1

3,349,207

# ACTUATING MECHANISM FOR ELECTRIC CIRCUIT BREAKER COMPRISING A ROD SOLELY IN TENSION IN ALL POSITIONS THEREOF OR SOLELY UNDER COMPRESSION IN ALL POSITIONS THEREOF

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2 Claims. (Cl. 200—150)

This invention relates to circuit-breaker apparatus more especially for use in connection with high and very high voltage power lines.

The invention is specifically directed to that class of circuit breaker wherein a movable contact member is continually being urged to its circuit-breaking position by resilient biasing means, and wherein actuator means, e.g. a pressure fluid actuator, is used to move the movable contact member to its circuit-making position in opposition to said bias.

In any circuit-breaker apparatus, it is evident that there is a section of the apparatus, including the movable contact or contacts, which is connected to the electrical power line, and there is another section of the apparatus, which must be at ground potential. Clearly then, the two sections of the apparatus must be interconnected by means capable of transmitting mechanical force but incapable of transmitting electric current. It is one object of this invention to provide improved mechanical interconnecting means for more efficiently transmitting motion from the actuator to the movable contact of a circuit-breaker, while providing safe electrical insulation therebetween.

Heretofore, considerable difficulties have been encountered in the construction of high-power circuit breaker mechanisms for efficiently transmitting motion while maintaining the high degree of electrical insulation between the two sections of the circuit-breaker at greatly differing electric potentials. These difficulties become especially serious as the power rating of the apparatus increases owing to the long distances the mechanical components have to move over, the high velocities required for efficient circuit breaking action, and the large masses involved. An investigation of this problem has led me to the conclusion that the difficulties involved in combining an efficient mechanical force-transmitting function with safe electrical insulation in conventional circuit-breaker construction, are largely due to the fact that the motion-transmitting means heretofore used have been required to be stressed in one direction, say in tension, during operation to the circuit-breaking position, and in the opposite direction, say in compression, during movement to the circuit making position, or vice versa. These reversals in stress coupled with the fact that the stressed elements had to be made from materials having high dielectric characteristics have resulted in large-sized, heavyweight interconnecting elements which still were prone to mechanical or electrical failure after a relatively short service life.

It is, therefore, an important object of this invention to provide improved circuit-breaker mechanism wherein the insulating force transmitting means interconnecting an actuator device to a movable contact member, will at all times be subject to a unidirectional mechanical stress throughout all stages of operation of the circuit-breaker, i.e. in both the circuit-making and circuit-breaking conditions thereof and during transition from either one to the other of said conditions.

A further object is to utilize the spring biasing force which normally serves to urge the movable contact member of circuit-breaker towards its circuit-breaking position, for permanently applying a unidirectional mechanical stress to an insulating force-transmitting link of the circuit-breaker linkage.

2

An object, especially valuable in connection with very high-power circuit-breakers, is to provide motion-transmitting mechanism that will at all times be stressed in tension. This makes it possible to utilize lightweight, high-tensile and high-dielectric materials such as glass fiber-reinforced polyester resins, as the insulating link.

Another object, more especially useful where moderate-power-rating circuit-breakers are concerned, is to provide, conversely, motion-transmitting mechanism that will at all times be stressed in compression. This simplifies the coupling between the various links of the motion-transmitting linkage and allows them to be simply "stacked" on top of one another without any positive mechanical connection between them, since large buckling forces are not encountered.

A further object is to incorporate the spring means serving to bias the movable contact member towards circuit-breaking position and simultaneously apply permanent stress to the insulating force-transmitting link member, within the section of the mechanism electrically connected to the power line, whereby the actuator means connected to ground potential will be required to act in a single direction on the insulating force-transmitting member. A related object, achieved simultaneously with the foregoing, is to render the end position of the movable contact member in its circuit-making and/or-breaking condition, independent of any variations in dimensional, elastic and other characteristics of the motion-transmitting linkage.

In the fulfilment of this object, the means, including limit stops and the like, serving accurately to determine the position of the movable contact member in its circuit-making and breaking positions, are incorporated in the section of the apparatus connected to the power line. The actuator means at ground potential are only required to develop a sufficient force for moving the contact to its end position but do not serve to determine this position with any degree of accuracy. This increases the reliability of the mechanism while considerably simplifying its construction and maintenance.

Another object relates to the provision of improved damping means for controlling the velocity of the movement of the movable contact to each of its positions.

Circuit breakers constructed in accordance with the invention offer outstanding advantages especially in the case of high and very high-power installations where the switch contacts are positioned at the top of a tall insulating post or column and hence a considerable distance from the actuating means, positioned at the base of the column. In such cases as earlier indicated the invention contemplates the use of an electrically-insulating, force-transmitting link stressed at all times in tension, and constituted by a relatively thin rod operating in the fashion of a stretched cable. Since, such a link will not require any high rigidity to withstand buckling and crushing forces. The inertia of the moving parts is thus reduced, and difficulties involving the precise alignment of the guide means for such link are eliminated, which is especially desirable where such link has to pass through a tall insulating post or column.

Further objects relate to the provision of improved motion-amplifying means between the actuator and the moving contact of the improved circuit-breaker, and to the provision of motion reversing means between the actuator and the moving contact. Such motion-amplifying and reversing means according to one form of the invention desirably comprise a pair of racks respectively movable with the moving contact and with the actuator rod, and a pair of coaxial pinions of different radius mounted on a common shaft and respectively meshing with said racks.

In cases where the invention is applied to circuit-breakers of the oil-filled type, according to a preferred embodiment the oil-filled casing support is subdivided into two separate, sealed-off sections, one of which is in flow communication with the switch chamber of the circuit-breaker and further contains the first rack and its meshing gear, while the other section contains the second rack and its meshing gear. An advantage of this arrangement is that in the oil-filled space including the switch chamber and the casing section containing the first rack and pinion, the movement of the mechanism components toward circuit-breaking and making positions will not result in any variations in the total oil volume, in contrast to what usually occurs when the moving contact rod projects from the switch chamber through a sliding seal. Such variations in oil volume have been extremely undesirable. Thus it has often happened with conventional circuit-breakers that as the moving contact disengages the stationary contact at high velocity, there is a lack of oil which tends to maintain the cut-off arc. Objects of this invention have been to eliminate these defects.

The rack-and-gear motion-reversing mechanism of the invention has a further advantage in that it results in considerably less hydraulic braking action, than would be the case with e.g. lever mechanisms at high operating speeds.

It is well-known that the moving contact member of a circuit-breaker should preferably have a very high velocity on disengaging the stationary contact. To achieve this result various arrangements have been proposed for converting and amplifying the movement imparted by the biasing spring to the movable contact member, in order that the spring shall complete a substantial proportion of its work within a small initial portion of the total travel of the moving contact and to ensure that the moving contact is traveling at high speed at the time it disengages the stationary contact. An object of this invention has been to achieve this result without any of the complicated means heretofore required. This is done according to the invention by the simple means of providing a stationary contact having a relatively large seating depth, i.e., depth of penetration of the movable contact rod thereinto. Preferably the said seating depth is within a range of approximately from ½ to ⅓ of the distance separating the fixed and movable contacts in the circuit breaking position.

With such an arrangement, the biasing spring is able to act directly on the movable contact, or more preferably on the second rack or some other member of the mechanism to provide movement-amplification between the spring and the movable contact member. During the non-negligible portion of displacement of the moving contact during which the latter is still engaging the stationary contact, the spring will develop a high proportion of its full energy content, e.g. half, thereby imparting an increased velocity to the moving contact at the instant it disengages the fixed contact.

It will be evident that the increase in seating depth brings with it a substantial increase in the full length of displacement of the moving contact, and such increase would be difficult to accommodate with conventional circuit-breaker actuator mechanism. In the mechanism of the invention however, this can be very easily accomplished by slightly increasing the stroke of the actuator member, e.g. the stroke of a hydraulic actuator piston connected with the permanently-stressed, insulating, force-transmitting link of the invention, and slightly increasing the length of the racks correspondingly. It will clearly be immaterial if the pinions meshing with the racks have to rotate an additional fraction of a revolution in such a mechanism, whereas if it were desired to obtain a similar result with a conventional leverage mechanism, the entire linkage would have to be increased in length to avert excessive angling of the levers.



Other objects of the invention are to provide an improved circuit-breaker structure wherein provision is made for separate casing sections sealed from one another and adapted to contain bodies of oils of different grades, each especially appropriate for a particular function, i.e. electric isolation, mechanical lubrication, and hydraulic damping, as may be required in each section of the apparatus.

Another object and advantage of the invention, is the positioning of the actuator means of the circuit-breaker at the lowermost point of the hydraulic circuit without any complication in the installation. Thus it is an object to reduce the over-all length of a circuit breaker installation while preserving its reliability and efficiency.

Examplary embodiments of the invention will now be described for purposes of illustration but not of limitation. While the embodiments shown all relate to circuit breakers having a single switch assembly, it is expressly to be understood that the invention is applicable to circuit-breakers having a plurality of switch assembly mounted on one or more insulating column supports. In such cases each of the movable contact members may be provided with its particular biasing spring and associated motion-reversing and damping means or alternatively such spring and other means may be common to two or more moving contacts. Also it should be understood that in some cases, as with circuit-breakers mounted on a plurality of columns, a plurality of separate insulating permanently-stressed motion-transmitting links according to the invention may be used. In the accompanying drawings:

FIG. 1 is a simplified view in vertical section of an improved circuit breaker in which the force transmitting link is permanently stressed in tension;

FIG. 2 similarly shows a modified apparatus wherein the force-transmitting link is permanently stressed in compression;

FIG. 3 is a general, simplified view of a preferred embodiment of a high-power circuit breaker;

FIG. 4 is a detail view in section on C—C, FIG. 3, showing the motion reversing mechanism using racks and gears;

FIG. 5 is a section on line III–III′, FIG. 4;

FIGS. 6 and 7 are graphs showing the amounts of energy dissipated by the biasing spring in the case of a deep-seating contact arrangement according to the invention and in the case of a conventional contact arrangement respectively;

FIG. 8 is a detail view in section of part of a circuit breaker according to the invention including the spring and damping means thereof; and

FIG. 9 is a sectional view showing the lower part of an insulating column support and the actuator device in a circuit breaker according to the invention.

Illustrated in FIG. 1 is a high-voltage cutoff switch apparatus which comprises a box frame base **10** resting on a suitable base plate or the like foundation means and having an insulator column **9** made of suitable ceramic material upstanding from it to a height commensurate with the voltage values to be handled by the system. Supported on the column **9** is a mechanism housing **8**, and from the top of this housing there projects an upper column section **7** in vertical alignment with the lower column section **9** and preferably oil-filled.

The cutoff mechanism comprises essentially a movable contact **1** in the form of a rod conductor extending coaxially in the upper column section **7** and slidably engaging a first annular stationary contact element **2** surrounding the rod **1** and suitably supported centrally within the column section **7** above the top of casing **8**. The upper end of rod **1** is adapted to engage into a second annular or cup-like stationary contact element **3** supported from the top cover of the column **7**. The stationary contacts **2** and **3** are respectively connected to the circuit conductors **4** and **5** between which the connection is to be made and broken by the switch device. FIG. 1 illustrates the rod-like contact 1 in its upwardly projected position, i.e. the circuit-making position.

The lower end of the rod contact 1 is at all times positioned within the housing 8 and has pivoted to it at 15 one end of a lever 13 having its other end 20 projecting outside the housing 8 through a vertically elongated opening formed in a side of the housing. The link 13 has an intermediate point 14 of it pivoted to one end of a shorter lever 17 the upper end of which is pivoted at 18 on a fixed horizontal axis in the housing 8. A tension spring 11 has its lower end anchored at 12 to the base of housing 8 and its upper end attached to a point of lever 13 between the pivots 14 and 15. Preferably, as shown, a dashpot damper 27 is supported from the top of housing 8 and has its plunger pivoted to lever 13 e.g. adjacent the point of attachment of spring 11.

The projecting end 20 of lever 13 is pivoted to the upper end of a vertical rod 22 of insulating material which projects at its lower end through an opening in the top of the base frame 10 and is pivoted at 26 to one end of a lever 24 having its opposite end pivoted on a fixed pivot 25. An intermediate point of lever arm 24 is connected to the projecting end of an actuator piston rod 23 projecting from a piston 21′ slidable in a pneumatic or hydraulic actuator cylinder 21 supported from the frame 10. As will be later understood the connecting rod 22 is operated at all times under tension in accordance with a basic feature of the invention. Conveniently said rod may be formed from a glass wool and polyester laminate, or any other material having high electrical insulating properties as well as high mechanical tensile characteristics, but which material is not required to have any substantial degree of compressional and crushing strength; hence the rod can be made of lightweight construction to reduce inertia and permit high-speed operation.

In the operation of this system, it will be understood that the tension spring 11 is at all times acting to pull the lever arm 13 and hence contact rod 1 in a downward direction and hence urging the switch to the circuit-breaking position in which the upper end of rod 1 is disengaged from upper stationary contact 3. In order to switch the device to the circuit-making condition shown in the drawing, fluid pressure is applied into the upper end of actuator cylinder 21, whereby the piston 21′ is displaced to a lowermost position shown, lever arm 24 is rotated clockwise about its pivot 25, insulating connecting rod 22 is pulled downwardly as indicated by arrow 19, lever 13 is rotated clockwise about its movable pivot 14 and contact rod 1 is made to slide upward into engagement with contact 3. All the foregoing movements are effected in opposition to the force of spring 11. Throughout the period it is desired to maintain the system in the circuit-making condition pressure is maintained in the top of cylinder 21, so that the linkage is forcibly held in the position shown in opposition to the ever-present force of spring 11. To bring the system to the circuit breaking position, the actuator cylinder 21 is connected with exhaust, manually or automatically. The linkage thereupon is allowed to perform the movements reverse from those described under the action of spring 11, and contact rod 1 is lowered to disengage fixed contact 3 and break the circuit.

It will be evident from the foregoing that in all of the operating stages of the system, i.e. both during the circuit-making condition and the circuit-breaking condition of the mechanism as well as during the shifting movements from circuit-making to circuit-breaking and vice versa, the connecting rod 22 is at all times maintained under tension.

It will further be noted that the accurate positioning of the movable contact in each of its end positions is determined by means provided exclusively in the energized section of the system and is independent of the positional accuracy in the grounded, control section. Thus no limiting stop means are required to be associated with the pressure actuator 21, and no mechanical latching means are required in any part of the system to define the accurate end position of the movable contact rod 1 in its circuit-making position. The accurate end position of the rod is inherently determined by its actual engagement with the stationary contact 3, and will be positively and precisely obtained regardless of any dimensional variations, due to thermal expansion, changes in elasticity or other mechanical characteristics, or from any other causes, in the rod 22 or any other part of the linkage.

It will be understood that the system shown in FIG. 1 and just described is mainly schematic and only parts essential to the invention have been shown. Also, various changes may be made therein while retaining the teachings of the invention. While only a single pair of contacts has been shown, the switch system may comprise two or more simultaneously acting switch devices, e.g. a system positioned in separate insulator casings, in vertical or inclined positions. The kinematic linkage means shown are exemplary only. Thus, while the linkage mechanism shown within the housing 8 will ensure a proper up-and-down linear movement for the contact rod 1 in response to the up-and-down movement imparted to the connecting rod 22, owing especially to the fact that the pivotal point 14 of lever 13 is able to assume limited displacements on swinging of lever 17 to accommodate rectilinear movement of pivot point 15, other means may be used to a similar end, including parallel linkages, dual lever systems, rack and gear devices and the like, all capable of providing the requisite movement reversal as between the displacements of contact rod 1 and actuating rod 22 under the conditions specified. It is generally desirable so to arrange matters that the displacements of control rod 22 will be smaller in amplitude than the displacements of contact rod 1 thereby reducing undesirable inertia in the connecting parts. The release spring 11 may be made to act on any suitable part of the transmission system, including direct action on the movable contact rod 1 (e.g. at pivot 15) or direct action on the tensioned connector rod 22 (e.g. at pivot 20). Instead of a traction spring as shown, compression springs may or course be used, provided the spring is so arranged as to urge at all times the movable contact towards its circuit-breaking position and simultaneously maintain the control rod 22 at all times under tension.

The dashpot 27 or equivalent damping means shown as acting on the lever 13 may be made to act on some other part of the mechanism, although it is preferred that any such damping and velocity control devices be associated with the energized section of the system rather than the grounded section.

In the further embodiment of the invention shown in FIG. 2, parts corresponding to those in FIG. 1 have been designated by the same reference numerals, and will only be described in respect to differences thereof over the arrangement in FIG. 1. The essential difference here is that the electrically-insulating, mechanical connecting member (corresponding to rod 22 in FIG. 1) is arranged to act at all times under compression rather than under tension as in the first embodiment.

Specifically, the movable contact rod 1, here shown in its lowermost circuit-breaking position, is adapted to engage the stationary upper contact 3 in the circuit-making position of the system. The contact rod 1 has a flange 29 secured on it which in the breaking condition shown rests upon an inner flange of the insulator casing or column of the device. A compression spring 28 has its lower end seated on flange 29 and its upper end engaging a fixed flange 29′ of the casing, and serves as the release spring corresponding to spring 11 in FIG. 1.

Mounted in the box frame 10 at the base of the structure is a pressure actuator comprising a cylinder in vertical coaxial alignment with the column 7–9 and a piston 31 slidable therein. From the top of piston 31 there projects a rod 34 axially aligned with contact rod 1. The upper ends of piston rod 34 is shown at 33 while the lower end of contact rod 1, extended beneath flange 29, is shown at 32. Axially connecting the contact rod 1 and piston rod 34 between points 32 and 33 is a connector rod 35 of electrically insulating material for transmitting the vertical movements of the actuator piston to the contact rod.

The operation of this simplified embodiment will be readily understood. The system is shown in its circuit-breaking position, towards which the rod 1 is at all times urged by the action of compression spring 28. To bring the system to the circuit making position, compressed fluid is delivered into the lower end of the single-action actuator cylinder 30, whereupon the assembly of aligned rods including piston rod 34, insulating conector rod 35 and contact rod 1 is bodily lifted in opposition to spring 28 to cause the upper end of rod 1 to engage into the upper stationary contact 3. It will be apparent that in all of the conditions of the system i.e. the circuit-breaking and circuit making conditions and in the transitions from either condition to the other, the intermediate connecting member 35 at all tmes remains stressed in compression by the force of spring 28. Just as in the first embodiment, moreover, no limiting stop means are required in connection with the control section of the system including actuator 30. The piston 31 may proceed on its upward stroke in the circuit making direction until such time as movable contact rod 1 engages and seats into the stationary contact cup 3, and the circuit-making position thus established is retained by continued application of pressure fluid into cylinder 30 without requiring any mechanical latching means. On relief of pressure from within the actuator cylinder 30, the spring 28 positively restores the system to its circuit breaking position while at all times maintaining the connector rod 35 under compression.

In this arrangement, the insulating connecting rod 35 would be made from a suitable, e.g. ceramic, material having high dielectric properties and high mechanical compression or crushing strength, but having but poor tensile characteristics. This arrangement is especially applicable to circuit breaker switches for low and moderate voltages where long displacements liable to result in buckling forces applied to the connecting member 35 are not encountered. The arrangement greatly simplifies the interconnection between the linkage components. Thus no positive pivotal or other type of coupling is required between the rods as at the points 32 and 33. The rods may simply be "stacked" over each other; and since this stacked assembly is contantly stressed in compression, it will not tend to come apart.

FIG. 3 illustrates in somewhat greater detail a preferred form of circuit breaker system according to the invention wherein the insulating connecting rod is continually stressed in tension, as in FIG. 1.

Mounted in the top casing section 52 of the apparatus, which is oil filled, is the upper stationary cup-like contact element 56 connected to one circuit terminal 58, and a lower stationary contact element 60 which may be formed as a pair of resilient jaws and is connected to the other circuit terminal 62. A movable contact rod 54 is vertically slidable in the casing chamber through the lower contact 50 in electric contact engagement with it, and into and out of electric contact engagement with the upper contact 56. The upper contact 56 is preferably constructed to provide a considerable depth of engagement for the movable contact rod 54 therein.

The upper casing section 52 is supported on top of a mechanism casing 100 which in turn is supported atop a lower casing section or column 66 of insulating material, and oil filled. The column 66 in turn is positioned on a base box frame in which a hydraulic actuator cylinder 64 is mounted in coaxial alignment with the column 66, and supplied with pressure fluid through a line 68 connecting with the upper end of the cylinder 64. Projecting upwards from the actuator piston is a long insulating rod 70 which may be made from a high-dielectric, high-tensile material as described in connection with rod 22 in FIG. 1. The up-and-down movements of rod 70 are transmitted to the contact rod 54 after motion-reversal and amplification by way of a rack-and-gear mechanism housed within the mechanism casing and hereinafter described in detail.



Also positioned within the mechanism casing 110 is a compression coil spring 80 seated at its lower end on a base flange 84 of the casing 110 and having its upper end bearing against the under side of a flange 82 projecting from the rod 70. The spring 80 surrounds a cylindrical hydraulic damper casing 88 in which a piston in the form of a flange secured on rod 70 is movable and having restricted parts in the side wall of cylinder 88 for retarding the flow of oil between the exterior and interior of the cylinder 88.

In the circuit making position shown in FIG. 3 where the upper end of contact rod 54 is fully engaged in upper contact 56, the spring 80 is compressed between flanges 82 and 84 and hence the insulating connecting rod 70 is under tension. For moving the system to the circuit breaking condition, hydraulic fluid pressure is relieved from the top of actuator cylinder 64, whereupon rod 70 rises under the action of spring 80 and through the motion-reversing rack-and-gear mechanism 74–76–78–72 causes a downward movement of contact rod 54 out of engagement with upper contact 56. The rate of this movement is controlled by damper 86–88. In the fully disengaged position, the spring 80 is arranged to retain a substantial degree of precompression. Hence it will be seen that in this as in the other embodiments described herein, the connecting member or rod 70 is at all times maintained in a common state of unidirectional stress (herein tension stress) in the circuit-making condition, in the circuit-breaking condition, and during the transitions from one to the other of these conditions.

The insulator column 66 is desirably of the precompressed type disclosed in my co-pending U.S. patent application Ser. No. 142,107 filed Oct. 2, 1961, now abandoned. The column may comprise one or more tie-members 90 of insulating material, having their upper ends attached to the base flange 84 of casing 110 and fitted at their lower ends with tension screw or turnbuckle means 92 adjustable so as to place the outer column structure 66 under permanent compressional stress while the tie members 90 are under an equivalent degree of permanent tension.

A preferred form of construction of the mechanism casing 110 with the motion-reversing and amplifying mechanism contained in it will now be described with reference to FIGS. 4 and 5. The structure illustrated in these figures is that corresponding to portion BC of FIG. 3. In FIG. 5, the part to the left of the axis X—X is a section on the line III—III in FIG. 4, while the part of FIG. 5 to the right of the axis X—X is a section on line III′—III′ of FIG. 4.

As shown, a large pinion 76 and a small pinion 78 (wherein the diameter ratio between the pinions may be within the range from 2/1 to 4/1) are supported on a common stub shaft 94 which is journalled in bearings 96 and 98 formed in the casing portion 100 which also serves to provide guide means for the two vertically movable rack members 72 and 74. Rack member 72 forms a downward extension of contact rod 54 and meshes with the larger pinion 76, while rack member 74 forms an upward extension of a connecting rod 70 and meshes with the smaller pinion 78, thereby providing for the requisite motion-reversing and amplifying effect as from rod 70 to rod 54. The casing 100 is subdivided into two separate compartments sealed from one another by means of an annular seal 102 surrounding stub shaft 94 and engaging a groove formed in the end of bearing 96. One of the two compartments receives larger pinion 76 and rack 72 meshing therewith, and is provided with a tubular extension

104 closed at its lower end to provide a well in which the bottom end part of rack 72 is slidable (note that in FIG. 5 the rack members are shown in the circuit-breaking position).

The upper switch casing section 52 is mounted upon the flat upper face 106 of casing 100 directly or through sealing means not shown, so that the space defined by the interior of top casing section 52 and the first-mentioned compartment of casing 100 is filled with a common body of oil and all moving components of the mechanism are at all times contained within said space. Thus there is no variation in the total volume of the space and the body of oil enclosed in it during the circuit-breaking and circuit-making movements, in view of the fluid-tight mounting of the coupling shaft 96.

As an aid to the understanding of the drawings, it may be pointed out that in FIG. 3 the subdivision of casing 100 into two separate compartments is not apparent since actually the two racks 72 and 74 lie in different planes. The arrangement described and illustrated has a further advantage in that it ensures at all times an adequate supply of oil throughout the length of the moving contact rod 54 during the circuit-breaking movement, and also prevents loss of oil from the switch chamber 52 to the exterior, as would occur in the case of a sliding seal surrounding the movable contact rod.

The second compartment of the casing 100 receives the smaller pinion 78 and its associated rack 74, and its bottom portion 108 is secured to (or integral with) the top of the lower casing section 110 (the portion CD in FIG. 3) which receives the release spring 80 and damper device, which assembly will be later described in detail.

As regards the upper section of the circuit breaker shown in FIG. 3 between lines A and B, this provides a small-capacity cut-off chamber generally conventional type and may include any of the conventional arc blow-out and other devices usually provided, and not shown herein since they form no part of the invention. However, an important feature in this part of the system of the invention is the construction of the upper stationary contact 56 to provide a large depth of seating engagement for the top of the movable contact rod 54. By way of example, in a circuit breaker switch according to the invention constructed for a 70,000 volt rating, and with a total length of movable contact displacement of 450 mm., the depth of engagement into the upper movable contact 56 is preferably of the order of 150 mm., whereas such depth is only about 50 mm. in conventional circuit breakers of similar character.

The importance of this feature will be understood from the following explanation with reference to the diagrams of FIGS. 6 and 7, which indicate the amounts of energy dissipated by the release springs respectively in the case of an improved deep-seating contact arrangement according to the invention (in FIG. 6) and in the case of a conventional contact arrangement (FIG. 7). In both diagrams, the spacing between the upper end of the movable contact rod and the end of the upper fixed contact in the circuit-breaking position is the same, being indicated as EG and EG′ respectively. However the depth of seating engagement in the case of the invention, represented by length OE, is about three times the depth in the conventional case represented by OE′. Assuming springs of equal force are used in the two cases, it will be apparent that at the instant of initial disengagement of the upper end of movable contact rod 54 from out of the fixed contact 56 (point E and point E′ respectively) about 55% of the spring energy as represented by the cross-hatched area under the curve has been released in the case of the deep-seating contact of the invention (FIG. 6), as against only about 25% in the case of the conventional, shallower contact arrangement (FIG. 7). It will be evident that in the arrangement of the invention the movable contact will be moving downwardly at full velocity at the instant of contact breaking, whereas it will only be gathering speed and traveling at a lower rate in the case of the conventional arrangement. Thus a faster circuit breaking action is obtainable with the arrangement described herein while making it possible if desired to use a weaker release spring.

FIG. 8 illustrates in greater detail a preferred construction of the hydraulic damper arrangement according to the invention, and shows the mechanism in the circuit breaking condition. Within the lower casing section 110 is shown an additional connecting rod 112 which in this construction is shown connected (e.g. threadedly) with the insulating connector rod 70 at its lower end and with the rack member 74 at its upper end. It be understood however that if desired the rod member 112 may form an integral part of the insulating rod 70 as suggested by FIG. 3. The interior of casing section 110 is in fluid communication with the second compartment of casing section 100 and also communicates with a sealed expansion chamber mounted on the top of casing portion 100 and provided with a side level gauge 116. The intermediate rod member 112 is slidable through an aperture in the lower end of the chamber 110 by way of a sealing gasket 124 which seals the lower end of the damper cylinder 88. Thus the inside spaces of casing section 110, the second compartment of casing section 100 and the upper expansion chamber define a sealed capacity containing a body of oil which serves to lubricate the switch mechanism, and damp the movements of the components. Damper cylinder 88 is formed through its side wall with a number of orifices 118 through which the oil expelled ahead of the damper piston 86 during displacement thereof is discharged into the oil-filled periphery of the chamber. The axial of damper piston 86 and the number, area and spacing of the calibrated orifices 118 are so predetermined as to provide the desired damping characteristics during the circuit making and circuit breaking movements of the mechanism. Damper cylinder 88 is shown surrounded with a fine wire mesh screen 120 to clean the oil flowing into the damper. Annular seals 122, 124 serve to seal the areas at which the rod 112 runs through the ends of the damper cylinder 88.

In this section of the circuit breaker switch system the oil serves lubricating and damping purposes rather than any electric insulating function, and may therefore be selected of a different grade from the oil filling the upper contact chamber. The oil in the contact chamber which tends to be oxidized and corroded and requires replacement at rather frequent intervals will not tend to contaminate the oil in the damping chamber, owing to the sealed relationship provided between the casing sections of the system.

The oil-filled insulating column 66 is preferably provided with protecting means for preventing the ingress of atmospheric moisture, which may be similar to the means disclosed in my French application filed Mar. 16, 1962 for "Improvements in Insulating Supports" and is shown as comprising a sealed reservoir 126 connected at its base with the interior of the column and filled with pressure nitrogen in the upper space 128 of said chamber to serve as an elastic gas cushion.

FIG. 9 illustrates in detail the lower part of the structure including insulator column 66 together with the tensioning screw means 92 for tensioning the insulating tie member 90 serving to place under permanent compression the stacked ceramic ring sections from which column 66 is made. In the illustrated embodiment, there is illustrated a single tensioned tie member 90 in the form of a tube made for example from a glass-araldite laminate and having its lower end provided with a reinforced, threaded section around which is screwed a ring 130 formed with tapped holes through which the tensioning screws 92 are adapted to be threaded for engagement against the under surface of the column 66 or, as shown, a plate on which the column is supported.

The tensioning means just described is enclosed within a sealed chamber **132** which communicates with the inner space of the column **66** and has a bottom wall or plate **134** provided with a hole containing a seal ring **138** through which the actuator piston rod **140** is slidable, with the upper end of rod **140** being threadedly coupled to the lower end of the insulating connecting rod **70**. The column **66**, its tank **126** and chamber **132** also constitute a sealed capacity without any communication with adjacent compartments, so that the oil filling said capacity can be selected with sole regard to its dielectric function, and will not be liable to become mixed with the different grades of oils contained in the upper casing section and the actuator section.

The hydraulic actuator **64** may be mounted directly below the closure plate **134** as shown in FIG. 9, or may be mounted on the end of a tubular coupling member whereby the actuator can be mounted at an even lower elevation with the advantage of reducing the vertical dimension of the hydraulic circuit as a whole, including the expansion chamber.

The actuator system used does not per se form a part of this invention and may assume any suitable form, but is desirably constructed as disclosed in my French Patent 1,098,233. Briefly, for bringing the switch system to its circuit-making position, pressure oil is delivered at a large flow rate through line **68** into the top of actuator cylinder **64**. The piston **136** is formed downwards until the movable contact rod **54** has been moved upwardly to its fully seated position in engagement with the upper contact. The circuit making position is retained by continued application of pressure oil in the actuator cylinder. In this position the actuator piston **136** is not required to occupy an accurately predetermined position but is able to shift slightly up and down to accommodate thermal expansion and contraction effects in the transmission system and possible changes in elasticity in the insulating connector rod **70** with time. To switch to the circuit breaking position the pressure in actuator cylinder **64** is rapidly exhausted whereupon spring **80** moves contact rod to its disengaged position at a rate controlled by damper **86–88**. In all stages of the operation of the system the insulating connector rod **70** is subjected exclusively to tensile forces.

It will be understood that the invention may be embodied in various forms other than the forms shown and described herein, as will be readily conceived by those familiar with the circuit-breaker art, while retaining the basic novel teachings of the invention. Thus, while the insulating connector members have been shown as being at all times stressed either in tension or in compression, it is contemplated that the invention can be embodied in circuit breaker mechanisms wherein such insulating connector member would be stressed at all times in torsion, or in flexion.

In the claims, it is to be understood that expressions designating space relationships such as "up" and "down" are used in a relative sense and primarily for convenience and that claims including such expressions are to be understood as covering structures in which such relationships are reversed or modified while preserving the basic geometric conditions disclosed in such claims.

What is claimed is:

1. Circuit-breaker apparatus comprising a support: a contact member at an elevated position on said support reciprocable between a circuit-making position and a circuit-breaking position; spring means operatively connected for urging said contact member toward said circuit breaking position; actuator means mounted adjacent the base of said support; motion transmitting means interconnecting said actuator, said transmitting means contact member and including motion-amplifying and reversing means and a member made of insulating material interconnected between said actuator and said motion amplifying and reversing means; said last means comprising a first rack movable with said contact member, a second rack movable with said actuator, and a first and second coaxially coupled pinions respectively meshing with said first and second racks, and wherein said support comprises a fluid-filled casing including an upper casing portion containing said contact member therein and including another casing portion containing said first rack and first pinion therein, communication means connecting said casing sections for fluid flow therebetween, and sealing means sealing said another casing portion from the exterior.

2. Circuit-breaker apparatus comprising a recessed columnar support including an upper casing portion and a contact member mounted therein for reciprocating movement between a circuit-making position and a circuit-breaking position; actuator means mounted adjacent the base of said support; motion-transmitting means interconnecting said actuator and contact member and including a vertical link made of insulating material and extending up from said actuator means; a lower casing portion in said support into which an upper section of said link extends; fluid damper means positioned in said lower casing portion and associated with said upper section of the link to damp the up and down movements thereof; said motion-transmitting means further including motion-amplifying and reversing mechanism comprising a first rack movable with said contact member, a second rack movable with said link, and a shaft having a first and second coaxial pinions thereon respectively meshing with said racks; said recessed support including a first recess containing said first rack and piston and in flow-communication with said upper casing portion, and a second recess containing said second rack and pinion and in flow-communication with said lower casing portion; sealing means surrounding said shaft and sealing said first recess and upper casing portion from said second recess and second casing portion; and spring means mounted in said lower casing portion and engaging said link for urging said contact member toward said circuit-making position and for stressing said link.

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