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PRECISELY COORDINATING THE OPERATION
OF WIDELY SPACED COMPONENTS

3,333,071

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2 Sheets-Sheet 1

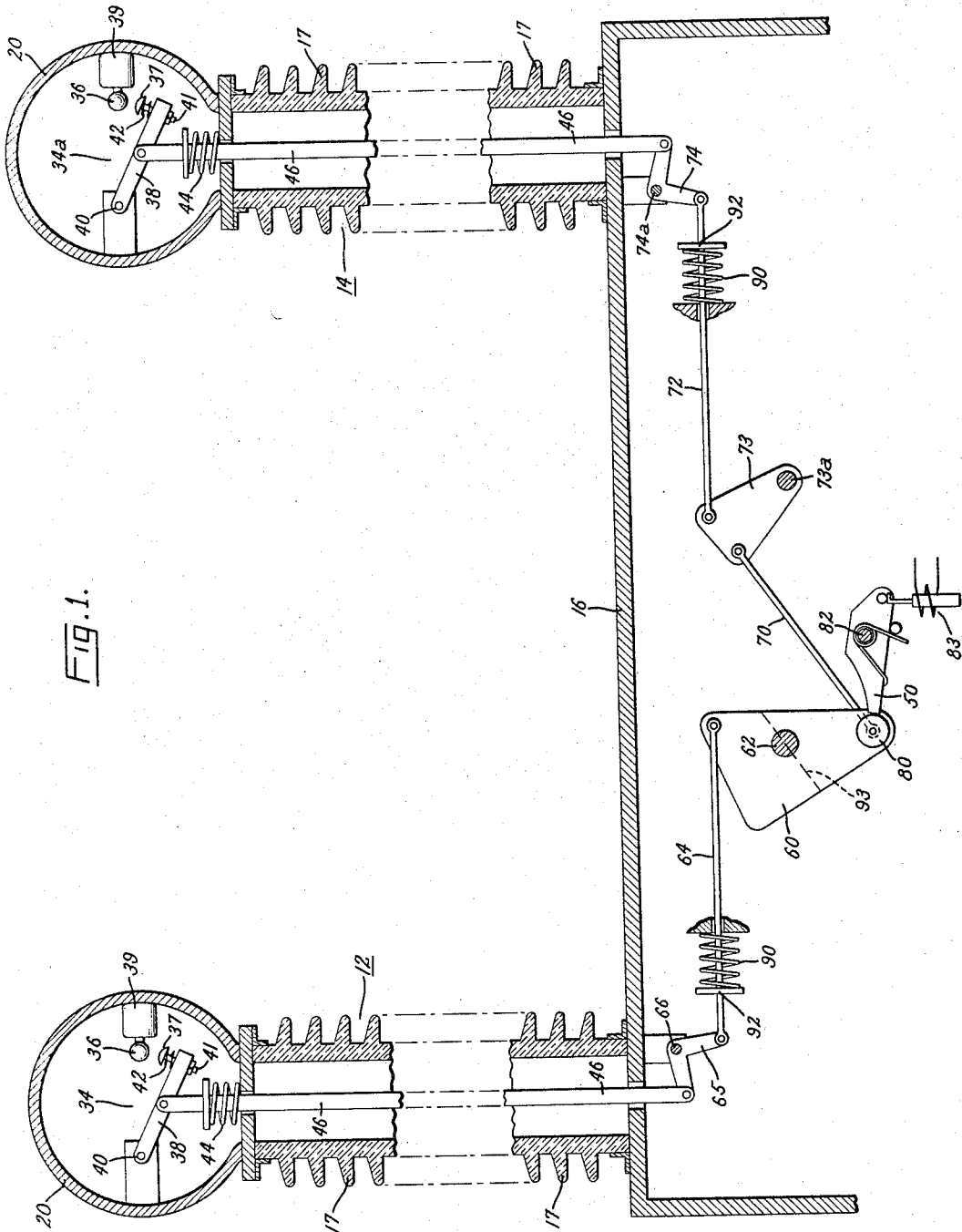


FIG. 1.

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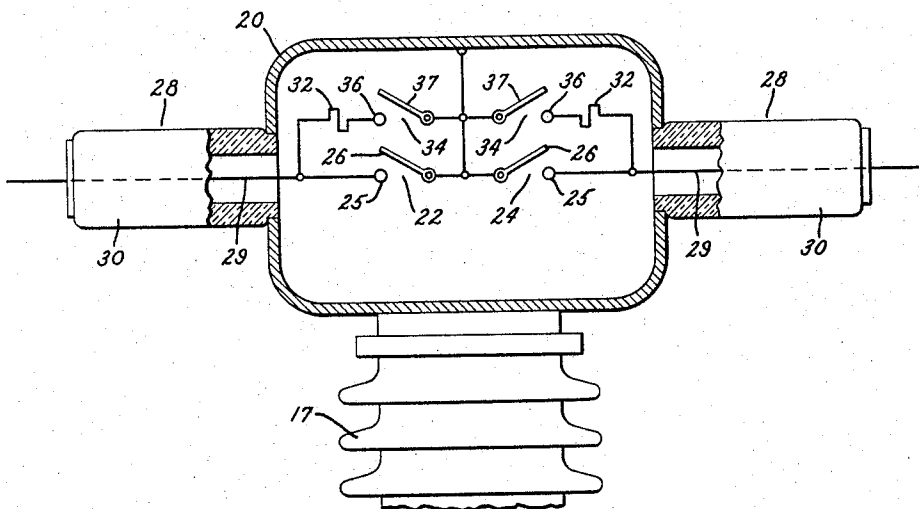
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Fig. 2.



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1

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HIGH VOLTAGE ELECTRIC CIRCUIT BREAKER WITH MEANS FOR PRECISELY COORDINATING THE OPERATION OF WIDELY SPACED COMPONENTS

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5 Claims. (Cl. 200—48)

This invention relates to a high voltage electric circuit breaker of the type comprising a plurality of widely-spaced switches that are mechanically coupled together to provide for precise coordination of the operation of the switches.

In application S.N. 434,270—Miller, filed Feb. 23, 1965, and assigned to the assignee of the present invention, there is shown a high voltage circuit breaker that comprises a plurality of widely-spaced switches, each comprising separable contacts one of which is movable. The movable contacts of the switches are mechanically coupled together to provide for synchronized operation of the switches. When the circuit breaker is open, the switches are held open by a suitable latch common to the switches. Circuit breaker-closing is effected by releasing this latch and allowing biasing means associated with each of the widely-spaced switches to drive its movable contact into closed position.

In a preferred form of the invention, the mechanical coupling between the movable contacts comprises a pair of linkages, each having one end restrained by the latch when the circuit breaker is open and the other end urged toward closed position by the biasing means. This arrangement results in the biasing means exerting a tensile force on the linkage.

In attempting to achieve synchronized closing of the switches upon release of the latch, we have found that certain oscillations develop in the linkages that interfere with the desired high degree of precision. These oscillations subject the driven end of each linkage to a small, but very significant, oscillatory component of motion as it moves through its closing stroke. This oscillatory component varies from one switch to the other despite the mechanical connection provided by the linkages and thus makes it very difficult to consistently achieve simultaneous contact-make at the widely-spaced switches.

Our studies of this problem indicate that these oscillations are due to the release of strain energy stored in the linkage when the latch is tripped. Since the linkage is very long and the spring forces are relatively high, a considerable amount of such strain energy is released on tripping of the latch. It is the release of this large amount of strain energy that appears to produce the objectionable oscillations.

An object of our invention is to facilitate synchronized closing of the switches of such a circuit breaker by reducing the severity of these oscillations.

Another object is to reduce the severity of these oscillations by reducing the amount of strain energy stored in the linkage when the circuit breaker is held open.

In carrying out our invention in one form, we provide a circuit breaker that comprises two widely-spaced switches, each comprising a movable contact. A pair of main biasing means for the respective switches are located at the switches for biasing the movable contact of the associated switch toward closed position. A pair of contact-controlling linkages are provided for the respective switches, and these linkages are mechanically connected together. A releasable latch prevents the main biasing means from operating to drive the respective movable contacts closed until the latch is released; but upon

2

latch-release, the main biasing means are permitted to drive their movable contacts toward closed position. For reducing the strain energy stored in said linkages when the circuit breaker is held open, we provide a plurality of auxiliary biasing means for the respective linkages which apply a switch-closing force to the associated linkage at an intermediate point located between the main biasing means and the latch. The various biasing means on each linkage each exert a tensile force on the linkage, but the auxiliary biasing means exerts no tensile force on the portion of the linkage ahead of said intermediate point, thus storing no strain energy in this portion of the linkage.

For a better understanding of the invention, reference may be had to the following description taken in conjunction with the accompanying drawings, wherein:

FIG. 1 is a schematic showing of a high voltage electric breaker embodying one form of our invention.

FIG. 2 is a schematic showing, principally a wiring diagram, illustrating one of the circuit controlling assemblies constituting the circuit breaker of our invention.

Referring now to FIG. 1, there is shown a high voltage circuit breaker that comprises a plurality of circuit-controlling assemblies 12 and 14, which are mounted on a rigid metal frame 16. Each circuit-controlling assembly comprises a metal tank 20 at a high voltage with respect to ground and a hollow insulating column 17 supporting the tank 20 and insulating it from ground. At its lower end, each insulating column 17 is suitably fixed to the frame 16.

In one embodiment of our invention, the circuit-controlling assemblies 12 and 14 are connected in series in one of the phases of a high voltage polyphase A-C circuit.

Each of the circuit-controlling assemblies 12 and 14 is preferably constructed in the manner disclosed and claimed in the aforesaid Miller application S.N. 434,270. Since the details of the circuit-controlling assemblies form no part of the present invention, many of the components have been omitted from the drawing, and those that are included are shown in a simplified schematic form. In the schematic showing of FIG. 2, a wiring diagram is provided to illustrate the components of the circuit-controlling assembly 12 or 14 that are located within the high voltage metal tank 20. More specifically, disposed within the tank 20 are two serially-connected pairs 22 and 24 of relatively movable main contacts. Each pair of main contacts comprises a stationary contact 25 and a movable contact 26. The two stationary contacts are supported on terminal bushings 28 projecting through opposite ends of the metal tank 20. These bushings 28 comprise conductive studs 29 for carrying current to and from the stationary contacts 25 and insulators 30 for insulating the conductors 29 and the stationary contacts 25 from the tank 20 when the circuit breaker is open, as shown in FIG. 2.

Shunting each pair of main contacts in FIG. 2 is the series combination of a resistor 32 and a resistor switch 34. The resistor switch 34 comprises a stationary contact 36 and a movable contact 37. The resistor 32, when connected across the main contacts 22 and 24, serves to control the rate of voltage build-up across the main contacts during a circuit-opening operation and also to control the magnitude of the voltage transient developed when the circuit breaker is closed. For performing this latter control function, each resistor switch 34 must be closed slightly ahead of the main contacts which it shunts.

In addition, the resistor switches in the two series-connected circuit-controlling assemblies must be closed substantially simultaneously in order to minimize the chances for a flashover of the insulation paralleling the last break to close. In this latter respect, it is required in certain circuit breakers that all the resistor switches in a given phase of a circuit make contact within approxi-

mately two milliseconds of each other during a closing operation. The present invention is concerned with means for facilitating this precise coordination, and such means will soon be described.

In FIG. 1, one resistor switch 34 is shown in one of the circuit-controlling assemblies 12, and an identical resistor switch 34a is shown in the other circuit-controlling assembly 14. Each of these resistor switches comprises a stationary contact 36 and a movable contact 37 corresponding to the similarly-designated contacts of FIG. 2. In each switch, the stationary contact 36 is connected to one end of the resistor and is supported on a suitable insulator 39 electrically insulating it from the tank 20 when the switch is open. The movable contact 37 is mounted on a contact-carrying arm 38 that is pivotally supported on the tank 20 by a stationary pivot 40. In the illustrated embodiment, the movable contact 37 has a mounting rod 41 connected to its back surface. This mounting rod 41 extends through a hole in the contact-carrying arm 38 and is slidably mounted in this hole. A compression-type wipe spring 42 urges the movable contact 37 toward the other contact 36, but an adjustable stop 42 on the back end of the rod 41 limits the extent of such movement. A suitable flexible conductor (not shown) is provided for carrying current between the contact 37 and its carrying arm 38.

In each of the tanks 20 there is a compression-type closing spring 44 for biasing the movable contact-carrying arms 38 in a counterclockwise direction toward a closed position where contacts 36 and 37 engage. This compression spring 44 acts through the upper end of a vertically-extending rod 46 of insulating material that is suitably coupled to the contact-carrying arm 38 of the switch. For holding both of the resistor switches 34 and 34a in their fully-open position of FIG. 1, a closing control latch 50 is provided substantially midway between the two circuit-controlling assemblies 12 and 14 beneath the frame 16. This closing control latch 50 acts to hold each of the vertically extending insulating rods 46 in its depressed position of FIG. 1 against the upward bias of closing spring 44. But when the latch 50 is released, the rods 46 are free to move upwardly, and the closing springs 44 can therefore expand to drive their associated contacts 37 through a closing stroke.

To assure that the contact-carrying arms 38 of the two switches 34 and 34a will move in unison through their respective closing strokes, the two contact-carrying arms 38 are mechanically tied together. This mechanical tie is provided by means of a crank 60 substantially midway between the two circuit-controlling assemblies beneath frame 16. The crank 60, which is pivotally mounted on a stationary pivot 62, has its upper end connected to the operating rod 46 of circuit-controlling assembly 12 and its lower end connected to the operating rod 46 of the other circuit-controlling assembly 14, as will soon be described.

For interconnecting the upper end of the central crank 60 and the operating rod 46 of the left hand circuit-controlling assembly 12, a tie link 64 and a bell crank 65 are provided. Bell crank 65, which is pivotally mounted on a stationary pivot 66, has one of its arms pivotally connected to the vertical operating rod 46 and its other arm pivotally connected to the tie link 64.

For interconnecting the lower end of the central crank 60 and the operating rod 46 of the right hand circuit-controlling assembly 14, a pair of tie links 70 and 72, and idler crank 73, and a bell crank 74 are provided. Cranks 73 and 74 are pivotally mounted on stationary pivots 73a and 74a, respectively. The tie link 70 is pivotally connected at its opposite ends to the central crank 60 and the idler crank 73. The other tie link 72 is pivotally connected at its opposite end to the idler crank 73 and one arm of the bell crank 74. The other arm of the bell crank is pivotally connected to the operating rod 46 of the right hand assembly 14.

The connection between the contact-carrying arms 34 and 34a of the two circuit-controlling assemblies 12 and 14 may be thought of as comprising two control linkages that are coupled together through the central crank 60. The control linkage for the left hand assembly 12 comprises parts 46, 65, 64 and a portion of crank 60. The control linkage for the right hand assembly comprises parts 46, 74, 72, 73, 70 and a portion of crank 60. The closing control latch 50 acts on a roller 80 carried by the central crank 60. This latch 50 is mounted for pivotal movement on a stationary pivot 82. When the latch 50 is driven counterclockwise from its position of FIG. 1, it releases the latch roller 80 and permits the two circuit-controlling assemblies 12 and 14 to close. A suitable solenoid 83 is provided to effect release of closing control latch 50.

As pointed out hereinabove, one of applicant's objectives is to assure substantially simultaneous contact-make at the two switches 34 and 34a at the end of a closing operation. The mechanical connection provided by the two linkages greatly facilitates such synchronization, but we have found that with very long linkages such as shown, oscillations may develop in the linkages which detract from the precise synchronization desired.

As pointed out hereinabove, these oscillations appear to result from the large amount of strain energy which is stored in each of the linkages prior to the above-described closing operation. Since each linkage is very long and high spring forces are involved, the linkage is, in effect, stretched by the spring force, resulting in strain energy being stored in the linkage. When the closing control latch 50 is released, this strain energy is released, and such release produces these oscillations. These oscillations manifest themselves in the form of an oscillatory component of motion at the driven end of the linkage as it moves through its closing stroke.

To reduce the amount of strain energy stored in each linkage, thereby reducing the amplitude of these oscillations, we provide auxiliary biasing means 90 acting on the linkage in a closing direction at a point 92 intermediate its length. This auxiliary biasing means 90 imposes a tensile force on the portion of the linkage between point 92 and the latch 50, but it imposes no tensile force on the portion of the linkage ahead of the point 92. Since the auxiliary biasing means 90 makes available a large closing force, we can reduce the size of the main biasing means 44. Thus, the portion of the linkage between the main biasing means 44 and the auxiliary biasing means 90 is relieved of a substantial portion of the strain energy that would otherwise have been stored therein. This reduction in strain energy reduces the amplitude of the aforesaid oscillations, thereby facilitating synchronized closing.

To realize full advantage from the auxiliary biasing means 90, it is important that its presence not produce any buckling effect in the long operating rod 46. Such buckling effect can set up its own oscillations which could seriously detract from the desired precise synchronization. To insure against such a buckling, we use for the main biasing means a spring 44 of a size sufficient to supply a high enough force to always maintain the operating rod 46 in tension. To achieve this result, the following relationship should be maintained at all times during closing:

$$F_2/M_2 \text{ should be greater than } F_1/M_1$$

where F_2 is the force exerted by the main biasing means 44, F_1 is the force exerted by the auxiliary biasing means 90, M_2 is the effective mass of the linkage between the main biasing means 44 and the auxiliary biasing means 90, and M_1 is the effective mass of the linkage between the auxiliary biasing means 90 and the connection between the two linkages, which may be considered as located along a dotted line 93.

By maintaining this relationship, the main biasing means 44 tends to accelerate the linkage mass ahead of the auxiliary biasing means 90 at a higher rate than the rate at which the auxiliary biasing means tends to accelerate the linkage mass behind it. This relationship maintains the linkage under tension, thus minimizing any undesirable buckling effect.

It is to be understood that the strain energy stored in the linkage can be still further reduced by providing additional auxiliary biasing means at additional points along the length of each linkage, but this, of course, adds complexity. If additional biasing means are used, the force exerted by the various biasing means should be so related that F/M for each biasing means is larger the nearer the biasing means is located toward the forward end of the linkage, i.e., the end inside the tank 20. More specifically, F/M for the forward or main biasing means should be greater than F/M for the next biasing means proceeding toward the rear of the linkage, which, in turn, should be greater than F/M for the next biasing means proceeding toward the rear of the linkage. In the immediately-preceding sentence, F represents force exerted on the linkage by a particular biasing means and M represents the effective linkage mass between the particular biasing means and the next one located at a point on the linkage behind it; or, if there is no biasing means behind, M is the effective linkage mass from the biasing means to the rear end of the linkage.

In the illustrated embodiment of our invention, the vertical operating rod 46 is of insulating material, e.g., fibre reinforced epoxy resin. As has been pointed hereinabove, this rod 46 is relieved of the force that is exerted on the linkage by the auxiliary biasing means 90 since rod 46 is ahead of the auxiliary biasing means. This is especially advantageous because the non-metallic material of rod 46 has a relatively low spring gradient compared to the metallic material of which the remainder of the linkage is composed. Generally speaking, the lower the spring gradient, the more strain energy is stored in a member for a given force. Hence, by relieving the insulating rod 46 of some of the closing force, a relatively large reduction in strain energy is effected.

By way of example and not limitation, in one actual embodiment of our invention, the vertical operating rods 46 are each approximately 22 feet long and the tie links 64 and 72 are each approximately 9 feet long. Despite this great length, we have been able, with the help of our invention, to consistently produce contact-make at the two switches within two milliseconds of each other.

While we have shown and described particular embodiments of our invention, it will be obvious to those skilled in the art that various changes and modifications may be made without departing from our invention in its broader aspects; and we, therefore, intend in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of our invention.

What we claim as new and desire to secure by Letters Patent of the United States is:

1. An electric circuit breaker comprising:

- (a) a plurality of tanks adapted to be at a high voltage with respect to ground,
- (b) a plurality of switches respectively located within said tanks,
- (c) each of said switches comprising a pair of separable contacts, one of which is movable,
- (d) a pair of main biasing means for the respective switches located at the respective tanks for biasing the movable contact of the associated switch toward engagement with the other contact when the switch is open,
- (e) a first linkage coupled to the main biasing means of one of said switches and extending from said biasing means to a point at substantially ground potential,

- (f) a second linkage coupled to the main biasing means of the other of said switches and extending from said biasing means to a point at substantially ground potential,
 - (g) means mechanically connecting said two linkages together,
 - (h) means including a releasable latch for said two linkages for preventing said main biasing means from operating to drive their respective movable contacts into closed position until said latch is released,
 - (i) means for releasing said latch to permit said main biasing means to drive their respective movable contacts toward closed position,
 - (j) and means for reducing the strain energy stored in said linkages when held open comprising a plurality of auxiliary biasing means for the respective linkages applying a switch-closing force to its associated linkage at an intermediate point located between said main biasing means and said latch,
 - (k) said main and auxiliary biasing means loading its associated linkage primarily in tension.
2. The circuit breaker of claim 1 in which during closing:
- (a) each of said main biasing means applies a force F_2 to its associated linkage and each of said auxiliary biasing means applies a force F_1 to its associated linkage,
 - (b) the portion of each of said linkages between its main biasing means and said intermediate point has an effective mass M_2 ,
 - (c) the portion of each of said linkages between said intermediate point and the rear end of the linkage has an effective mass M_1 ,
 - (d) each biasing means being so selected that at substantially any time during closing:

$$F_2/M_2 \text{ is slightly greater than } F_1/M_1$$

3. The circuit breaker of claim 1 in which said main biasing means exert a sufficiently high force relative to that exerted by said auxiliary biasing means to maintain its associated linkage under tension at substantially all times during closing.

4. The circuit breaker of claim 1 in which: the forces exerted by the various biasing means on their associated linkage are so related that F/M for each biasing means is greater the closer the biasing means is located toward the forward end of the linkage at said tank; F being the force exerted on the linkage by a given biasing means and M being the effective linkage mass behind the biasing means and ahead of the next succeeding biasing means, or if there is no succeeding biasing means, the effective linkage mass from the biasing means to the rear end of the linkage.

5. The circuit breaker of claim 1 in which:

- (a) said linkage comprises a relatively long member of insulating material and another portion connected mechanically in series with said insulating member,
- (b) said intermediate point on each of said linkages at which said auxiliary biasing means acts is located behind said insulating member, thereby relieving said insulating member of the closing force applied by said auxiliary biasing means.

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