ABSTRACT: Discloses a high voltage vacuum-type circuit breaker which comprises a plurality of vacuum interrupters electrically connected in series. The interrupters are mounted on a skeletonlike structure that comprises a plurality of aligned tubular insulators respectively associated with the interrupters in laterally spaced, generally longitudinally aligned relationship with respect to the associated interrupter. Adjacent ones of the interrupters in the series circuit are disposed in laterally offset relation relative to each other. An operating rod extends through the aligned insulators, and a plurality of linkages respectively couple the operating rod to the interrupters.
COMMON PARALLEL OPERATING MEANS FOR SERIES-CONNECTED, LATERALLY OFFSET VACUUM SWITCHES

This invention relates to a high voltage vacuum-type circuit breaker, and, more particularly, relates to a circuit breaker of this type which comprises a plurality of vacuum-interrupting units electrically connected in series.

In certain prior circuit breakers of this type, the vacuum-interrupting units have been mounted in aligned relationship to form an assembly, and an insulating housing of tubular form is provided about the assembly to provide a weatherproof enclosure. The individual interrupting units of such an assembly have typically been operated by one or more movable operating rods extending longitudinally of the assembly and located within the weatherproof insulating enclosure. A disadvantage of such an assembly is that the enclosure diameter must be relatively large in order to accommodate both the interrupting assembly and the operating rods, and such large diameter enclosures are quite expensive. Another disadvantage is that the aligned relationship of the interrupters necessitates that the assembly and the surrounding enclosure be unduly long, thus further increasing costs.

An object of our invention is to arrange the vacuum-interrupting units in such a manner that there is no need for an expensive large diameter enclosure for enclosing the interrupters and their operating rods and also in such a manner that the assembly has a reduced length.

Another object is to provide a high voltage vacuum circuit breaker that lends itself to being constructed of modular units which can be used in varying numbers to provide circuit breakers of different voltage ratings.

Another object is to construct the circuit breaker in such a manner that individual interrupting units and the operating linkages therefor can be easily inspected, adjusted, and replaced, if necessary, without disturbing the remaining interrupting units and linkages and supporting structure therefrom.

In carrying out the invention in one form, we provide first, second, and third tubular insulators mounted in substantially axially aligned relationship. Associated with said first, second, and third tubular insulators are first, second, and third vacuum interrupters, respectively. Mounting means located at opposite ends of each of said insulators and projecting laterally therefrom is provided for mounting the vacuum interrupter associated with a given insulator in laterally spaced, generally longitudinally aligned relationship with respect to the associated insulator. The interrupters are electrically connected in series, the adjacent ones of the interrupters in said series circuit being disposed in a laterally offset relationship relative to each other. A longitudinally movable operating rod extends through said substantially aligned tubular insulators and a linkage is provided in association with each interrupter for coupling the movable contact rod thereof to said longitudinal movable operating rod.

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 side elevational view of a portion of a vacuum circuit breaker embodying one form of our invention.

FIG. 2 is a sectional view along the line 2-2 of FIG. 1.

FIG. 3 is a plan view of the circuit breaker of FIG. 1.

FIG. 4 is a sectional view along the line 4-4 of FIG. 2.

Referring now to FIG. 1, the circuit breaker shown therein comprises a horizontally extending interrupting assembly 12 and a pair of horizontally spaced vertical insulating columns 14 and 16 for supporting the interrupter assembly at its opposite ends. The metal housing 18 carries a metal housing 18 at its upper end to which the interrupter assembly 12 is suitably secured. This metal housing 18 and insulating column 14 form the enclosure for a high voltage current transformer of the type shown in U.S. Pat. No. 3,380,099 to Miller, assigned to the assignee of the present invention. The details of this current transformer assembly form no part of the present invention and are therefore not shown herein.

The vertical insulating column 16 at the right-hand end of the interrupter assembly 12 is a tubular member that forms a housing for the reciprocally mounted vertical operating rod 20 of the circuit breaker. Secured to the top of insulating column 16 is a metal housing 22 that is suitably secured to the right-hand end of the interrupting assembly 12. Referring to FIG. 4, within the metal housing 22 is a bellcrank 24 pivoted at 26 and having one arm pivotally connected to the vertical operating rod 20. The other arm of the crank 24 is pivotally connected to a horizontal operating rod 26, which will soon be described. A suitable operating mechanism (not shown) is connected to the lower end of the vertical operating rod 20 to drive it downwardly to close the circuit breaker, as will soon be explained.

Referring to FIG. 1, the interrupting assembly 12 comprises a plurality of tubular insulators 30, 31, 32 and 33 disposed with their longitudinal axes in substantially aligned relationship. At the right-hand end of each of these tubular insulators 30 to 33 is a metal housing 35 of elongated box form. These metal housings 35 are fixed with respect to the tubular insulators and project radially outward therefrom. A plurality of tie rods 38 (FIGS. 2 and 3) of insulating material extend through the aligned tubular insulator 30 to 33 and are relied upon to clamp the insulators and the metal housings 35 together so as to form a substantially rigid self-supporting assembly. This clamping action is produced by nuts 40 (FIG. 3) threaded onto opposite ends of the tie rods 38. Tightening of the nuts loads the tie rods in tension and the tubular insulators in compression. Suitable spring washers 42 beneath the nuts 40 at the left-hand end of the tie rods control the magnitude of the clamping forces.

The interrupting assembly 12 further comprises four vacuum-type circuit interrupters 50, 51, 52, and 53 electrically connected in series. Referring to FIG. 4, each interrupter is of a conventional design and, as such, comprises a highly evacuated tubular envelope 60 and a pair of separable contacts 62 and 63 located within the envelope. The envelope 60 comprises a tubular casing 66 of a suitable insulating material, such as glass, and metal end caps 64 and 65 at opposite ends of the casing joined to the casing by suitable glass-to-metal seals. The contact 62 is a stationary contact supported on a conductive rod 67 which extends in sealed relationship through end cap 64; and the other contact 63 is a movable contact supported on a reciprocally movable conductive contact rod 68 which extends through the other end cap 65. A flexible metal bellows 70 joined in sealed relationship at its opposite ends to the rod 68 and end cap 65 provides a seal between the rod 68 and permits it to be reciprocated without impairing the inside envelope 60. It will be noted that contact rod 68 is longitudinally movable in a direction parallel to the central longitudinal axis of surrounding insulating casing 66.

For providing a weatherproof enclosure about each interrupter, the envelope 60 of each interrupter is encapsulated in a suitable insulating material which forms a protective shell 72 about the envelope. The shell 72 is bonded to the exterior of the envelope and has peticcoats on its outer extreme to increase the electrical creepage distances therealong.

Each of these vacuum interrupters 50 to 53 is mounted adjacent one of the tubular insulators 30 to 33 and is disposed in a generally longitudinally aligned relationship with its associated tubular insulator. For example, referring to FIGS. 1 and 3, vacuum interrupter 50 is mounted adjacent tubular insulator 30 and is disposed in a generally longitudinal alignment therewith. A corresponding relationship is present between insulator 31 and interrupter 51; between insulator 32 and interrupter 52; and between insulator 33 and interrupter 53. The vacuum interrupter associated with a given tubular insulator is mounted, in part, on the associated box housing 35 that projects from the right-hand end of the tubular insulator. This is illustrated in FIG. 4, wherein nuts 76 on mounting studs 75 affixed to the right-hand end cap 65 of interrupter 50 are shown clamping the end cap to the left-hand end wall 76a of the adjacent box housing 35.
Referring to FIG. 3, it is to be noted that the interrupters 50, 51, 52, and 53 are so mounted that adjacent ones of the interrupters have their longitudinal axes laterally offset from each other and parallel to each other. Considered with respect to a vertical reference plane 77 passing through the longitudinal axes of aligned tubular interrupters 50—53, (as seen in FIGS. 2 and 3), adjacent interrupters are located on opposite sides of this reference plane. To locate the interrupters in this manner, the longitudinal centerlines 78 of adjacent box houses 35 projecting from the tubular insulators are disposed on opposite sides of the reference plane 77, as viewed in FIG. 2.

For supporting the left-hand end of each interrupter 50, 51, and 52, there is a metal bracket 90 secured to the exterior of the box housing 35 that supports the adjacent interrupter. Studs 92 on the left-hand end cap of the interrupter are used for attaching the left-hand end cap to the bracket 90. Bolts 93 (FIG. 2) are used for detachably securing the metal bracket 90 to the box housing 35 associated with the adjacent interrupter. Each bracket 90 may be thought of as a cantilever beam extending transversely of the longitudinal axis of its associated interrupter and secured to the end cap of the interrupter at its distal end and to the box housing 35 at its proximal end. Interrupter-closing forces are imparted to the cantilever beam 90 at its distal end.

For electrically connecting the interrupters in series, a plurality of conductive straps 95 are provided in locations between the interrupters. Referring to FIG. 2, each of these straps 95 is connected between the stationary conductive rod 67 of one of the vacuum interrupters and terminal structure 96 on the box housing 35 supporting an adjacent interrupter. Each comprises two parallel straps which are clamped together about the stationary contact rod 67 of the associated interrupter to provide a good electrical connection between these parts. Flexible conductive braid 98 is provided within each of the box housings 35 for connecting the terminal structure 96 thereon to the movable contact rod of the associated interrupter.

For mechanically operating the interrupters 50 and 53 are electrically connected to the terminals 102 and 106, respectively, of the circuit breaker through the conductors which can be of any suitable conventional form. For example, referring to FIG. 4, a conductor 103 of a generally U-form is used for connecting circuit breaker terminal 102 and the terminal structure 96 on the adjacent box housing 35 of interrupter 50. The other circuit breaker terminal 106 and the terminal structure 96 of the adjacent interrupter 53 are connected to this conductor 103 through the current transformer 18, 14. The inner end of this conductive stud, which is shown at 104, is mechanically and electrically connected to an adjacent metal housing 105. A suitable conductor 95a (FIG. 4) is connected between housing 105 and the stationary contact rod 67 of the interrupter 53 at the left-hand end of the interrupting assembly 12.

For mechanically operating the interrupters 50—53 substantially in unison, we provide for each interrupter an operating linkage 110 that couples the movable contact rod 68 of the interrupter to the horizontal operating rod 26. Each of these linkages 110 is located within the box housing 35 that supports the associated interrupter. Each linkage 110 comprises a first bellcrank 112 pivotally mounted on a stationary pivot 113 and having one arm pivotally connected to the horizontal operating rod 26. The other arm of the bellcrank 112 is connected through a suitable wipe mechanism 115 to an arm of a second bellcrank 118. The second bellcrank is pivotally mounted on a stationary pivot 120 and has its opposite arm pivotally connected to the movable contact rod 68 of the interrupter.

When the horizontal operating rod 26 is driven toward the right of FIG. 4 it acts through each of the linkages 110 to close the interrupter connected to that particular linkage. When the horizontal operating rod 26 is returned to its position of FIG. 4, operating forces are transmitted through linkages 110 to open the interrupters. It will be apparent from FIGS. 2 and 4 that the horizontal operating rod 26 extends substantially parallel to the horizontal contact rods 68 of the interrupters.

The wipe mechanism 115 has been shown in schematic form only since it can be of any suitable conventional type. An example of a suitable wipe mechanism is shown in FIG. 5 of U.S. Pat. No. 3,025,375 to Frank, assigned to the assignee of the present invention.

The operating force for opening the interrupters is derived from an opening spring 130 disposed in a metal housing 135 of box form located at the extreme left-hand end of the interrupter assembly 12. This opening spring 130 is a compression spring, the upper end of which bears against a stationary portion of the housing wall and the lower end of which bears against a shoulder 132 at the lower end of a reciprocally movable rod 134. The upper end of rod 134 is connected to the horizontal operating rod 26 through a bellcrank 136. This bellcrank has one of its arms pivotally connected to the spring assembly rod 134 and its other end pivotally connected to the horizontal operating rod 26. When the horizontal operating rod 26 is moved to the right from its position of FIG. 4 to close the interrupters, it acts to compress the opening spring 130. Suitable latch means (not shown) is provided at the lower end of the vertical operating rod 20 to hold the horizontal operating rod in its closed position, thereby holding the interrupters in the closed position and holding them in this compressed condition. When this latch means is released, the opening spring 130 is free to discharge, thus driving bellcrank 136 counterclockwise, moving the horizontal operating rod to the left, thereby opening the interrupters substantially simultaneously.

For distributing the total voltage approximately equally between the individual breaks of a multibreak circuit breaker, it is conventional to provide capacitors of suitable values in parallel with the breaks. These capacitors can be of any suitable conventional form, but we prefer to construct each capacitor as an assembly of stacked ceramic elements, as shown and claimed in U.S. Pat. No. 3,325,708 to Manhoff et al., assigned to the assignee of the present invention.

One of the capacitor assemblies is shown in FIG. 4 at 140 in a location between tubular interrupter 30. This assembly 140 is electrically connected between the two box housings 35 at opposite ends of the tubular interrupter 30. This capacitor assembly by virtue of these connections parallels the interrupter 50. Additional capacitor assemblies of the same design can also be mounted in the tubular interrupter 30. Capacitor assemblies of the same design are provided in other tubular interrupters 31, 32, and 33 to parallel the vacuum interrupters respectively associated with these tubular interrupters. Some of these capacitor assemblies 140 are shown in FIG. 1. The opposite terminals of each of these capacitor assemblies are respectively connected to the box housings 35 at the opposite ends of the associated tubular interrupter.

In a tubular interrupter 30 of relatively modest size, as seen in FIG. 2, there is ample room to accommodate centrally located operating rod 26, the tie rods 38, and the capacitor assemblies 140, inasmuch as all of these components are relatively long and slender. A tubular interrupter of much greater diameter would have been required had the vacuum interrupter 50 been located therein since the diameter of the vacuum interrupter is relatively great. By excluding the vacuum interrupter from this interior space, we are able to limit the diameter of the tubular interrupter to a reasonable size that is not dictated by the interrupter diameter.

A factor that contributes to reduced length of the interrupting assembly 12 is the laterally offset relationship of adjacent vacuum interrupters. This laterally offset relationship permits the interrupter units to be more closely disposed in overlapping relationship, thus conserving on the overall length of the interrupting assembly. In this respect, note in FIG. 3 that the structure projecting from the left-hand end of the vacuum interrupter 50 overlaps longitudinally of the assembly with the structure projecting from the right-hand end of the immediately adjacent interrupter 51. The same overlapping relationship is present between the other juxtaposed interrupter units.
If greater reductions in length are desired, the degree of overlapping can be made more pronounced. Had the interrupter units been mounted in aligned relationship, it would not have been feasible to provide any overlap for reducing the overall length of the interrupting assembly.

Another feature contributing to reduced length of the interrupting assembly is that the opening spring 130 (FIG. 4) has its long dimension disposed substantially perpendicular to the length of the interrupting assembly. Note that this opening spring 130 is disposed in a box housing 135 that projects radially outward from the longitudinal axis of the tubular insulators 30—33 in essentially the same manner as the other box housings 35. This perpendicular disposition of the opening spring renders the length dimension of the interrupting assembly substantially independent of the length of the opening spring.

To allow for inspection or adjustment of the linkages 110, each of the box housings 35 is provided with a large opening that is normally closed by a removable cover 150. Suitable fasteners (not shown) are provided to hold each cover in place. When cover 150 is removed, the associated linkage 110 is freely accessible.

It is a simple matter to remove and replace any of the interrupters of our circuit breaker assembly. Interrupter removal is accomplished by first removing the cover 150 adjacent the interrupter's right-hand end to expose the linkage 110, then disconnecting linkage 110 and hand 98 from the interrupter, and then removing the nuts 76 on interrupter mounting studs 75. Thereafter, the conductor 95 at the left-hand of the interrupter is disconnected from terminal 96, and the bolts 93 of FIG. 2 are removed; thus allowing the interrupter together with mounting bracket 90 and conductor 05 to be completely detached from the rest of the interrupter assembly. Interrupter replacement is accomplished by reconnecting these parts in essentially the reverse order. It is unnecessary to disturb any of the tubular insulators 30—33 or any of the structure mounted therein. It will be apparent that the tubular insulators 30—33 and the box housings 35, when clamped together by tie rods 38, form a skeletonlike structure that is self-supporting and does not rely upon the vacuum interrupters for support. Since this skeletonlike structure does not rely upon the parts of the interrupter assembly for its support or structural integrity, these other parts can therefore be freely removed and replaced without affecting the basic structural integrity of the skeletonlike structure. Related to the self-supporting character of the skeleton structure is the fact that the supporting columns 14 and 16 at opposite ends of the assembly support the skeleton independently of the interrupter. It will be apparent that our circuit breaker is constructed from substantially identical modules assembled together in a building block type of construction. In this regard, each module may be thought of as comprising one of the tubular insulators, such as 30, the associated box housing 35, the associated linkage 110, the associated interrupter 50, and the mounting bracket 90 at the other end of the interrupter. By adding modules of the same construction to the circuit breaker assembly of FIG. 1, a circuit breaker of a higher voltage rating can easily be constructed. Certain additional changes would also have to be made, such as providing greater spacing between the supporting columns 14 and 16 to accommodate the additional modules and increasing the height of columns 14 and 16 to accommodate the higher voltages; but the same basic modules as shown in FIG. 1 would still be used in the higher voltage breaker.

Although we prefer to dispose the interrupting assembly 12 so that it extends horizontally and is supported by insulating columns at its opposite ends, it is to be understood that our invention in its broader aspects comprehends an arrangement in which the interrupting assembly is disposed so that it extends vertically atop a single insulating structure.

While we have shown and described a particular embodiment 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. A vacuum-type circuit breaker comprising:
   a. first, second, and third tubular insulators mounted in substantially axially aligned relationship,
   b. first, second, and third vacuum interrupters respectively associated with said first, second, and third tubular insulators,
   c. each interrupter comprising an evacuated housing comprising a tubular mounting casing having a central longitudinal axis, a pair of separable contacts within said housing, and a conductive rod supporting a movable one of said contacts and projecting through one end of said evacuated housing, said rod being longitudinally movable along a path substantially parallel to said longitudinal axis,
   d. mounting means secured to said insulators, located at one end of each of said insulators and projecting laterally therefrom for mounting the vacuum interrupter associated with a given insulator in laterally spaced, generally longitudinally aligned relationship with respect to the associated insulator,
   e. means for securing said one end of the evacuated housing to its associated mounting means,
   f. means for connecting said interrupters electrically in series,
   g. adjacent ones of all of said vacuum interrupters in said series circuit being disposed in laterally offset relationship relative to each other with the longitudinal axes of their tubular casings disposed substantially parallel to each other,
   h. a longitudinally movable operating rod extending through said substantially aligned tubular insulators substantially parallel to the longitudinal axes of said insulating casings of said vacuum interrupters,
   i. a linkage associated with each interrupter and coupling the movable contact rod thereof to said longitudinally movable operating rod,

2. The vacuum circuit breaker of claim 1 in which said mounting means at one end of each insulator comprises a housing in which the linkage coupled to the movable contact rod of the associated interrupter is housed.

3. A vacuum-type circuit breaker comprising:
   a. first, second, and third tubular insulators mounted in substantially axially aligned relationship,
   b. first, second, and third vacuum interrupters respectively associated with said first, second, and third tubular insulators,
   c. each interrupter comprising an evacuated housing, a pair of separable contacts within said housing, and a conductive rod supporting a movable one of said contacts and projecting through one end of said evacuated housing,
   d. mounting means located at one end of each of said insulators and projecting laterally therefrom for mounting the vacuum interrupter associated with a given insulator in laterally spaced, generally longitudinally aligned relationship with respect to the associated insulator,
   e. means for securing said one end of the evacuated housing to its associated mounting means,
   f. means for connecting said interrupters electrically in series,
   g. adjacent ones of said vacuum interrupters in said series circuit being disposed in laterally offset relationship relative to each other,
   h. a longitudinally movable operating rod extending through said substantially aligned tubular insulators,
   i. a linkage associated with each interrupter and coupling the movable contact rod thereof to said longitudinally movable operating rod,
j. the linkage adjacent one end of a given vacuum interrupter occupying a predetermined space at said one end of said given interrupter,
k. the interrupter immediately adjacent said given interrupter on the linkage side of said given interrupter comprising structure that is disposed in overlapping relationship with said space, considered in a direction longitudinally of said tubular insulators.

4. The assembly of claim 1 in which electrically adjacent ones of said interrupters are disposed in overlapping relationship relative to each other, considered in a direction longitudinally of said tubular insulators, thus reducing the overall length of said assembly.

5. A vacuum circuit breaker as defined in claim 1 and further comprising:
a. an opening spring coupled to said longitudinally movable operating rod, said opening spring having its length dimension extending transversely of said operating rod,
b. and a housing adjacent one of said tubular insulators encasing said opening spring and projecting radially outward from the tubular insulator.

6. A vacuum circuit breaker as defined in claim 1 and further comprising voltage-dividing capacitors respectively connected in parallel with said interrupters, the capacitor paralleling a given interrupter being located in the tubular insulator that is generally longitudinally aligned with said given interrupter.

7. A vacuum-type circuit breaker as defined in claim 1 and further comprising means for clamping said tubular insulators and said mounting means together independently of said vacuum interrupters so as to form a rigid self-sustaining skeleton on which said vacuum interrupters are mounted, said vacuum interrupters being individually removable from said skeleton without affecting its self-sustaining character and without affecting the mounting of the other vacuum interrupters.

8. The vacuum circuit breaker of claim 1 in which:

a. said mounting means at one end of each insulator comprises a housing in which the linkage coupled to the movable contact rod of the associated interrupter is housed,
b. there is provided clamping means for clamping said tubular insulators and said linkage housing together independently of said vacuum interrupters so as to form a rigid, self-sustaining skeleton on which said vacuum interrupters are mounted,
c. said clamping means comprises insulating tie rods extending through said aligned tubular insulators, and
d. said vacuum interrupters are individually removable from said skeleton without affecting its self-sustaining character and without affecting the mounting of the other vacuum interrupters.

9. The vacuum-type circuit breaker of claim 1 in which:
a. said tubular insulators have horizontally extending longitudinal axes,
b. said interrupter casings have horizontally extending longitudinal axes, and
c. insulating support means is provided at each end of the assembly of claim 1 for supporting said tubular insulators and said mounting means independently of said interrupters.

10. The vacuum circuit breaker of claim 1 in which:
a. each interrupter has an end cap supporting the other of its contacts, and
b. means is provided for supporting said end caps on said tubular insulators comprising a plurality of mounting brackets respectively associated with said interrupters,
c. said mounting brackets extending transversely of the longitudinal axis of their associated interrupters, each bracket being secured at one point to the associated interrupter end cap and at a spaced point to structure connected to said tubular insulators.