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(71) Applicant: The Superior Electric Company
383 Middle Street
Bristol Connecticut 06010(US)

(72) Inventor: Lenzing, Richard Steven
35 Garden Street
Farmington Connecticut(US)

(74) Representative: Bannerman, David Gardner
Withers & Rogers 4 Dyer's Buildings Holborn
London, EC1N 2JT(GB)

(54) Stepping-brush electrical device.

(57) An electrical device having a commutating surface formed of segments of electrical conductors upon which a contact brush is movable while in electrical engagement therewith. Means are provided to "step" the brush between segments, so that when at rest, the brush contacts no more than one segment, thus reducing short-circuiting currents and overheating.

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STEPPING-BRUSH ELECTRICAL DEVICE

This invention relates to electrical devices of the type having a commutating surface upon which a contact brush is movable while in electrical engagement therewith, and more particularly to means for reducing the power loss experienced at the brush-commutating surface interface.

Typically, in such devices, the commutating surface along which the brush is moved comprises a plurality of closely spaced segments of an electrical conductor, which are at different electrical potentials. As the brush is moved along the commutating surface, the output from the device varies. All hitherto known existing designs of such devices allow the brush to rest at any point along the path of the commutating surface. These designs also permit the brush to contact at least two segments simultaneously, so as to eliminate the possibility of discontinuity in output from the device as the brush is moved along the commutating surface. Since there exists an electrical potential between segments of the conductor, there exists a circulating short-circuit current through the brush between simultaneously contacted segments. Because the brush can span segments indefinitely, the brush/commutating surface contact resistance must be high enough to limit the resultant circulating current to a level that will not overheat the windings and the brush. This contact resistance must also be low enough so as to be able to carry the load current without overheating the brush. Under these conditions, the minimum possible power loss, and consequent heat gain, from this contact resistance is the product of the voltage between contacted commutator segments and the load current. Since the power loss must be limited to prevent burn-out, the load current and the voltage between commutator segments must be limited. Limited load current restricts the power that can be handled by the device at any given voltage and limited voltage between commutator segments dictates a design that uses material inefficiently.

One design which eliminates the short-circuit current was disclosed in U. S. Patent 4,189,672. There, the conductor is arranged so that all even-numbered segments comprise one commutating surface and all odd-numbered segments comprise a separate commutating surface. Each commutating surface has a separate brush of such size as to be able to contact only one segment; however, the brushes are arranged so that at least one of the brushes is in contact with one segment at all times, thus eliminating discontinuity in output. The brushes are connected through one or more sets of back-to-back diodes to eliminate short-circuit current, provided that the segment-to-segment potential is less than the potential drop across two diodes in series. The result is a device which has no short-circuit current, but which is more complicated to construct than most previous devices.

The present invention substantially eliminates the limitations of prior art designs by controlling the movement of a single brush such that, when at rest, the brush contacts one, and only one, commutator segment; but, when being moved, the brush is, at all times, in contact with one or two segments, thereby preventing discontinuity in output; however, the period of time the brush is in contact with any two segments is very brief. As a result, the brush "steps" from one commutator segment to the next. Means for providing the stepping motion may be either mechanical or electromechanical.

The present invention permits such a device to be designed with lower brush-commutating surface resistance because the circulating current exists for only a brief period of time, greatly reducing power loss and the consequent overheating. Also, the load current and the voltage between segments can both be increased. Thus, the resulting device can be made smaller, lighter, less expensive, more efficient, and able to handle more power than equivalent prior art designs.

Referring to the Drawing, FIGURE 1 is a perspective depicting a mechanical stepping embodiment of the present invention as applied to a conventional, manually-operated, variable autotransformer. A wound core 10 is insulatively mounted on a base 11. A terminal board 12 carries terminals 13 for external electrical connection. A brush 14 is fixed to, and held in slidable electrical engagement with commutating surface 15 by, a ventilated radiator plate 16. The radiator plate 16 and an insulated knob 17 are fixed to shaft 18 which is mounted centrally of core 10 for rotational movement with respect to the core. A detent block 19 is fixed to an unwound portion of the core 10. FIGURE 2 depicts the underside of radiator plate 16 containing a circular row of adjacent, rounded hollows 20 near the outer periphery of the plate. The number of hollows 20 is equal to the number of commutator segments 23 (FIGURE 4 A and B) to be contacted. The angular displacement between hollows 20 relative to the central axis of the shaft 18 is equal to the angular displacement between commutator segments 23 relative to the central axis of the shaft. FIGURE 3 is an elevation depicting details of the detent block 19 fixed to the core 10. In block 19 is a spring 21 which urges a round-ended shaft 22 into close-fitting engagement with hollows 20 in plate 16. The hollows 20 are closely spaced such that when the spring-loaded shaft 22 is not in engagement with a hollow, it biases the radiator plate 16 toward such engagement. FIGURE 4 is an elevation depicting the brush 14 in engagement with the commutator surface 15. FIGURE 4A depicts the brush 14 in simultaneous contact with two commutator segments 23 and FIGURE 4B depicts the brush in contact with one commutator segment. The width of the brush 14 is such that it can contact one or two, but no less than one nor more than two, segments 23 at any given position on the commutator surface 15.

The relative dimensions and configurations of the hollows 20, the commutator segments 23, and the brush 14 are such that when the plate 16 is at rest, the shaft 22 engages a hollow, lightly locking the plate in that position, with the brush contacting only one segment, as depicted in FIGURE 4B. When the plate 16 is being rotated, the brush 14 may be momentarily in contact with two segments 23, as depicted in Figure 4A, but is always in contact with at least one segment, as depicted in FIGURE 4B. The present invention contemplates that any other type of mechanical detent mechanism may be employed, such as a shaped, spring-biased shaft engaging notches on the periphery of the plate 16, or a mechanical detent mechanism cooperating directly with the shaft 18.

One embodiment of the present invention includes an electromechanical detent mechanism based on a well-known characteristic of some AC synchronous motors. A typical AC synchronous motor includes a rotor and a stator. The stator includes identical, annular, pole-forming members, with windings adapted to magnetize the pole-forming members, and the pole-forming members having radially inwardly projecting pole pieces with teeth on the inner ends thereof. The rotor includes a permanent magnet structure, axially magnetized, with teeth on the outer ends thereof. When AC voltage is applied to the stator windings, the polarity of the windings changes sequentially such that the rotor revolves in one direction. However, when DC voltage is applied to the windings, a constant polarity results and the rotor will move to the nearest one of a number of "detent positions" and will be held in that position by the interaction of the rotor and stator magnetic fields. The number and location of the detent positions is dependent on the relationship of the rotor teeth to the stator teeth. In the present invention, such a motor is mechanically coupled to the shaft 18 and the relationship of segments 23 and the holding positions of the rotor is arranged such that, at each holding position, the brush 14 is in contact with only one segment. Thus, as with a purely mechanical detent, when the brush 14 is contacting two segments 23, it will always be urged toward the nearest segment, and, when in contact with one segment, it will be held in that position.

While the above-described electromechanical detent may be employed satisfactorily with a manually rotated shaft 18, it is preferred that the AC synchronous motor also be used to rotate the shaft and, therefore, vary the output from the device. Using conventional AC circuitry including reversing switching means, the motor is operated as an AC synchronous motor clockwise or counterclockwise, moving the brush 14 along the commutating surface 15, until the desired output of the device is reached. At that point, the switching means is changed to the "off" state which removes the AC voltage from, and applies a DC voltage to, the stator windings, thus holding the output at the desired value and maintaining the brush 14 in contact with only one segment 23. When the switching is changed to "clockwise" or "counterclockwise" states, the DC voltage is disconnected. The switching means may be mechanical, electromechanical, or electronic.

A further electromechanical embodiment of the present invention is to employ a conventional stepping motor mechanically coupled to the shaft 18 to rotate the shaft in either direction. The stepping motor is so selected, and its drive circuitry so programmed, that the required stepping movement is produced.

In one construction of the present invention, employing an electromechanical detent mechanism essentially as described, applied to an adjustable autotransformer of the same physical size as a conventional unit rated at 28 amperes output for a given temperature rise, the improved transformer averaged 47.5 amperes output at the same temperature rise. Thus, the invention produced an increase in output of 70 percent.

Since certain changes may be made in carrying out the above described invention without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying Drawing shall be interpreted as illustrative and not in a limiting sense.

It is also to be understood that the following Claims are intended to cover all of the generic and specific features of the invention herein described, and all statements of the scope of the invention which, as a matter of language, might be said to fall therebetween.

CLAIMS:

1. In an electrical device of the type having a commutating surface formed of a plurality of relatively closely-spaced segments of an electrical conductor, upon which a contact brush, fixedly mounted on brush-holding means, is movable while in electrical engagement therewith, the improvement comprising indexing means cooperating with the brush-moving means, so that when at rest, the brush is in electrical engagement with no more than one of the segments.

2. An improved electrical device, as defined in Claim 1, wherein the indexing means is mechanical.

3. An improved electrical device, as defined in Claim 2, wherein the mechanical indexing means comprises a biasing member shaped to successively engage indentations formed upon the brush-moving means, lightly locking the brush-moving means in place while in such engagement, the indentations being closely spaced so that the biasing member urges engagement with an indentation when not so engaged, the indentations being so arranged that, when the biasing member is in engagement with any indentation, the brush is in electrical engagement with no more than one of the segments.

4. An improved electrical device, as defined in Claim 1, wherein the indexing means is electromechanical.

5. An improved electrical device, as defined in Claim 4, wherein the electromechanical indexing means comprises an AC synchronous motor adapted to move the brush-moving means, the motor having a rotor and a stator, the rotor having a permanent magnet structure, axially magnetized, with teeth on the outer ends thereof, the stator having identical, annular, pole-forming members and windings adapted to magnetize the pole-forming members, the pole-forming members having radially inwardly projecting pole pieces with teeth on the inner ends thereof, the relationships between the teeth and between the motor and

the brush-moving means being such that, when DC voltage is applied to the stator windings, the rotor will rotate to, and be magnetically held in place at, a detent position, and the brush will be in contact with no more than one of the segments.

6. An improved electrical device, as defined in Claim 5, wherein the AC synchronous motor is controlled through switching means, the switching means having an off state and first and second operating states, so that, when the switching means is in the first operating state, AC voltage is applied to the stator windings to rotate the rotor in one direction, when the switching means is in the second operating state, AC voltage is applied to the stator windings to rotate the rotor in the other direction, and when the switching means is in the off state, DC voltage is applied to the windings.

7. An improved electrical device, as defined in Claim 4, wherein the electromechanical indexing means comprises a stepping motor and drive means, the motor being adapted to move the brush-moving means, and the drive means being programmed such that, when the brush is at rest, the brush is in contact with no more than one of the segments.

8. An improved electrical device, as defined in Claims 1, 2, 3, 4, 5, 6, or 7, wherein the electrical device is an adjustable voltage transformer.

9. An adjustable voltage transformer, comprising

(a) An electrically conductive coil wound upon a magnetic annular core and having upon the coil an arcuate commutating surface corresponding to the path of a contact brush, the commutating surface being formed of a succession of exposed segments of the windings of the coil;

(b) A circular radiator plate upon which the contact brush is fixedly mounted, the radiator plate being rotatably positioned to maintain the contact brush movable with respect to the commutating surface and in electrical engagement therewith, and the radiator plate having an arcuate row of closely spaced indentations essentially equal to the number of segments to be contacted; and

(c) a spring-biased shaft, shaped to successively engage the indentations, lightly locking the radiator plate in place while in such engagement and urging the radiator plate toward such engagement when not so engaged, the indentations being so arranged that, when the spring-biased shaft is so engaged, the brush is in electrical contact with no more than one segment.

10. An adjustable voltage transformer, comprising :

(a) An electrically conductive coil wound upon a magnetic annular core and having upon the coil an arcuate commutating surface corresponding to the path of a contact brush, the commutating surface being formed of a succession of exposed segments of the windings of the coil;

(b) a radiator plate upon which the contact brush is fixedly mounted, the radiator plate being rotatably positioned to maintain the contact brush movable with respect to the commutating surface and in electrical engagement therewith; and

(c) an AC synchronous motor adapted to move the radiator plate, the motor having a rotor and a stator, the rotor having a permanent magnet structure, axially magnetized, with teeth on the outer ends thereof, the stator having identical, annular, pole-forming members and windings adapted to magnetize the pole-forming members, the pole-forming members having radially inwardly projecting pole pieces with teeth on the inner ends thereof, the relationships between the teeth and between the motor and the brush-moving means being such so that when DC voltage is applied to the stator windings, the rotor rotates to, and is magnetically held in place at, a detent position, and the brush is in contact with no more than one of the segments.

11. An adjustable voltage transformer, as defined in Claim 10, wherein the AC synchronous motor is controlled through switching means, the switching means having an off state and first and second operating states, so that, when the switching means is in the first operating state, AC voltage is applied to the stator windings to rotate the rotor in one direction, when the switching means is in the second operating state, AC voltage is applied to the stator windings to rotate the rotor in the other direction, and when the switching means is in the off state, DC voltage is applied to the windings.

12. An adjustable voltage transformer, comprising:

(a) an electrically conductive coil wound upon a magnetic annular core and having upon the coil an arcuate commutating surface corresponding to the path of a contact brush, the commutating surface being formed of a succession of exposed segments of the windings of the coil;

(b) a radiator plate upon which the contact brush is fixedly mounted, the radiator plate being rotatably positioned to maintain the contact brush movable with respect to the commutating surface and in electrical engagement therewith;

(c) a stepping motor and drive means, the motor being adapted to move the brush-moving means, and the drive means being programmed such that, when the brush is at rest, the brush is in contact with no more than one of the segments.

FIG. 1

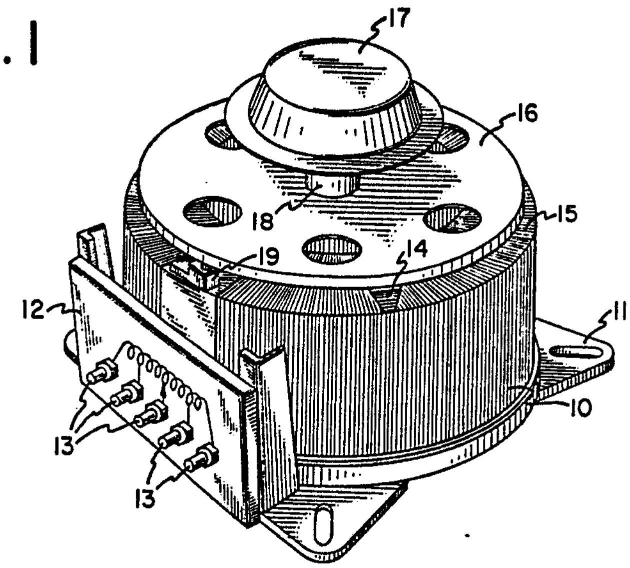
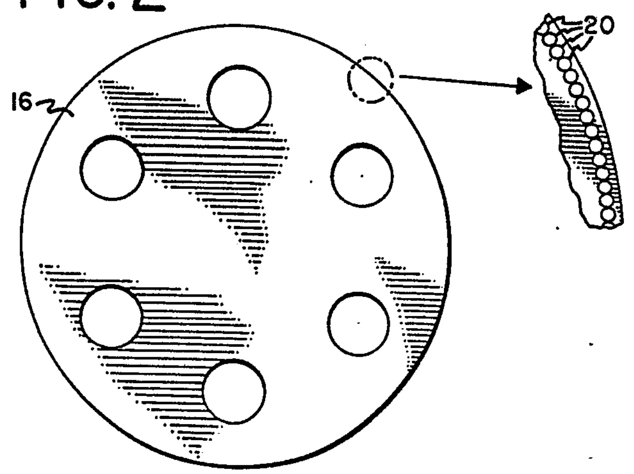


FIG. 2



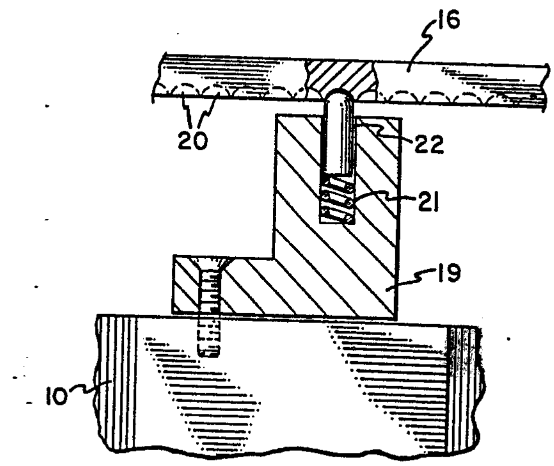


FIG. 3

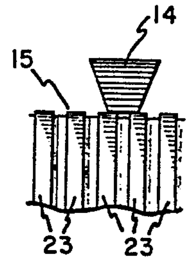


FIG. 4A

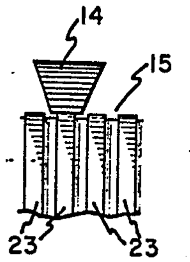


FIG. 4B