Nov. 3, 1964 G. A. WILSON, JR 3,155,782

SWITCH ACTUATING MECHANISM FOR CONTROLLED SPEED TAP CHANGER

Filed May 1, 1959 4 Sheets-Sheet 1

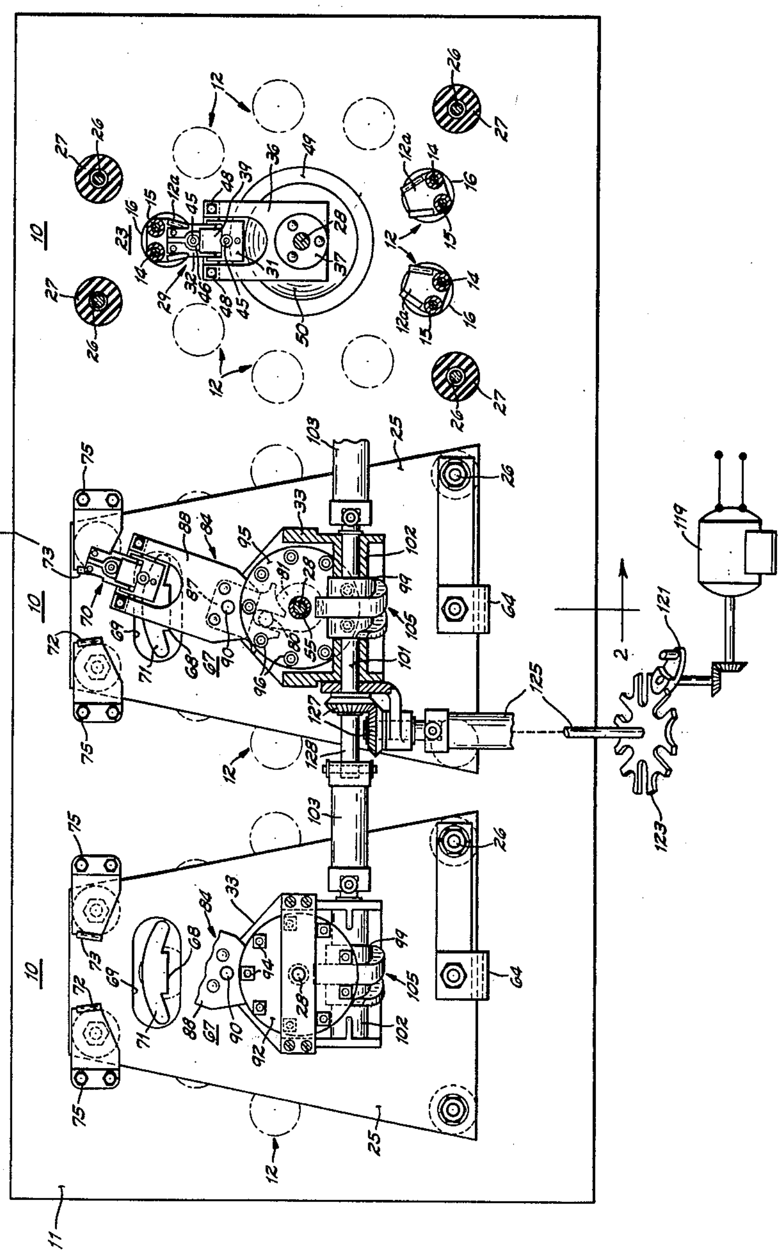

Fig. 1

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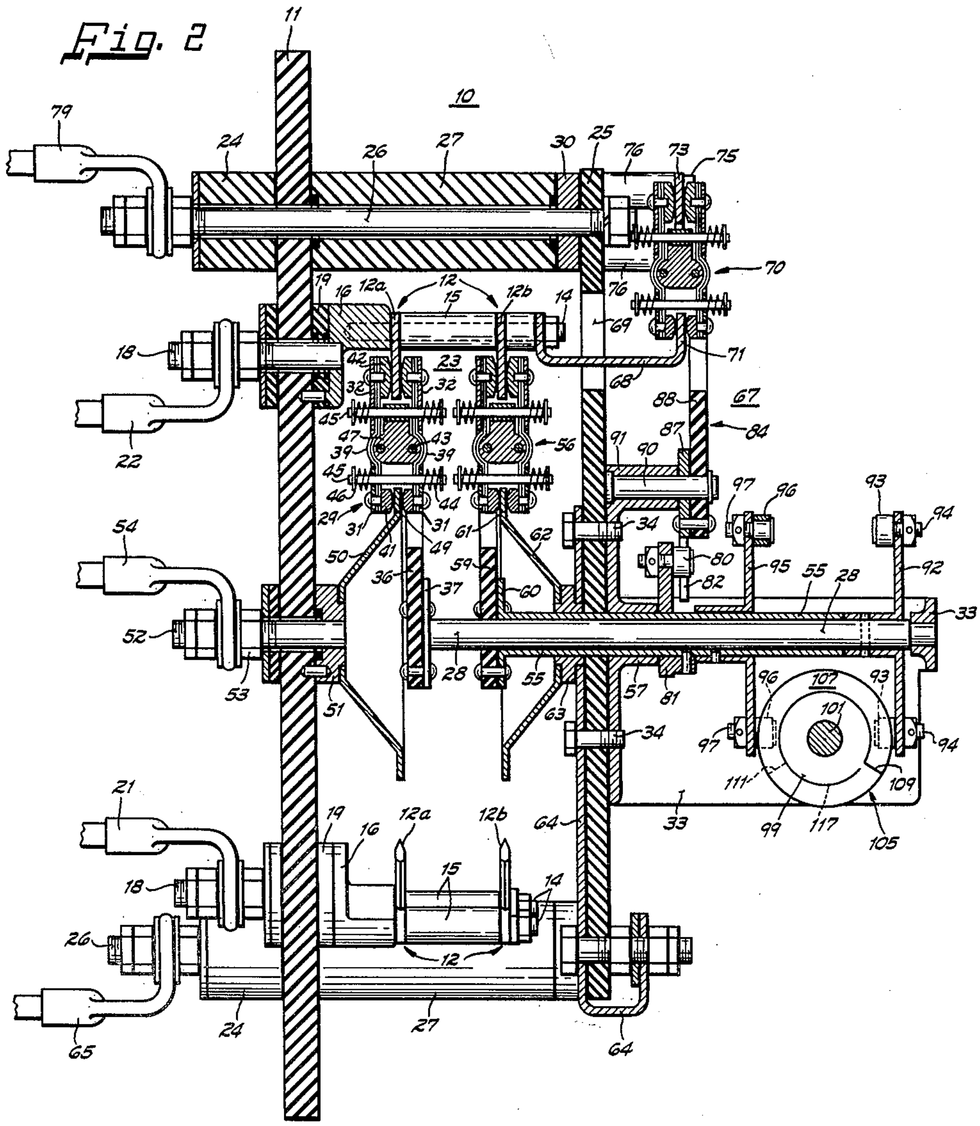
Fig. 2



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SWITCH ACTUATING MECHANISM FOR CONTROLLED SPEED TAP CHANGER

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Fig. 3

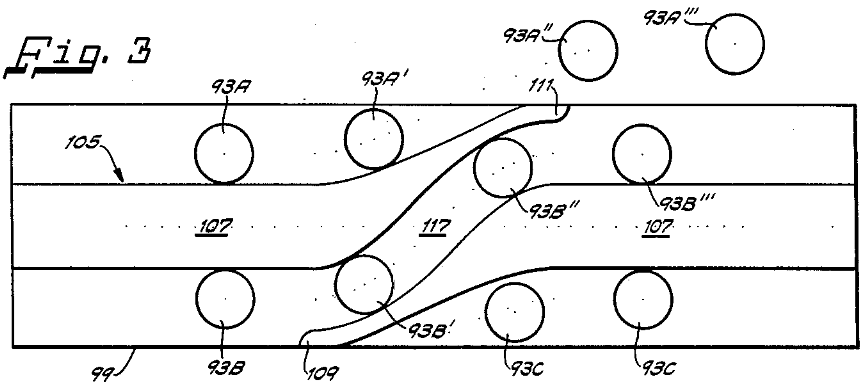

Fig. 4

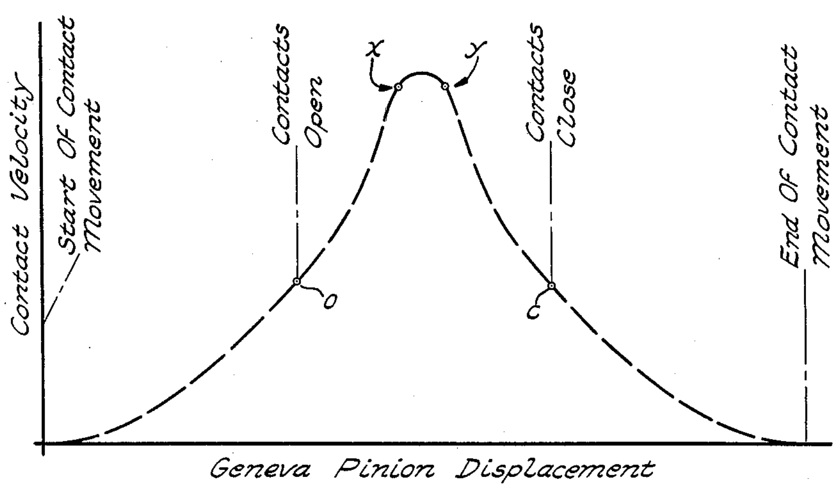

Fig. 5

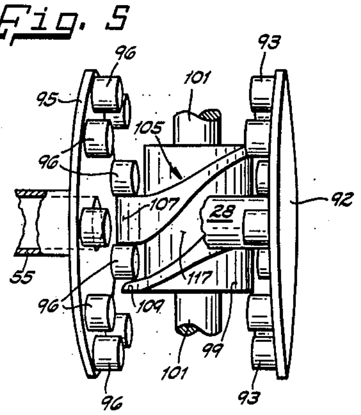

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Fig. 6

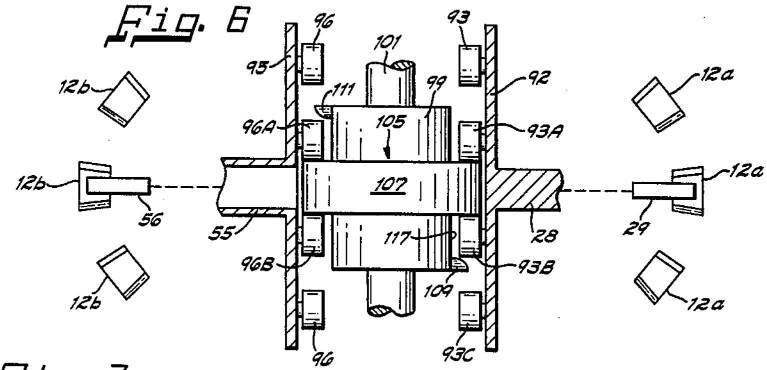


Fig. 7

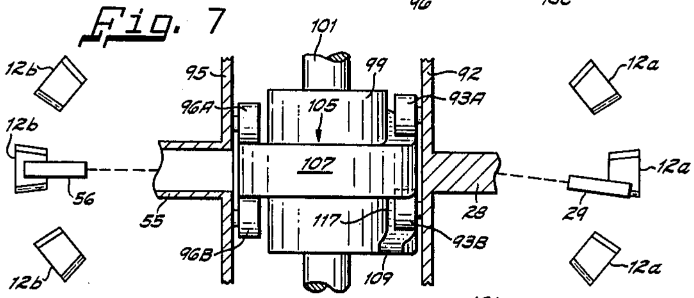


Fig. 8

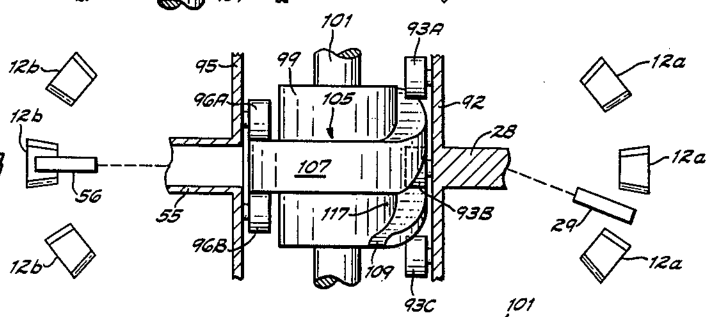


Fig. 9

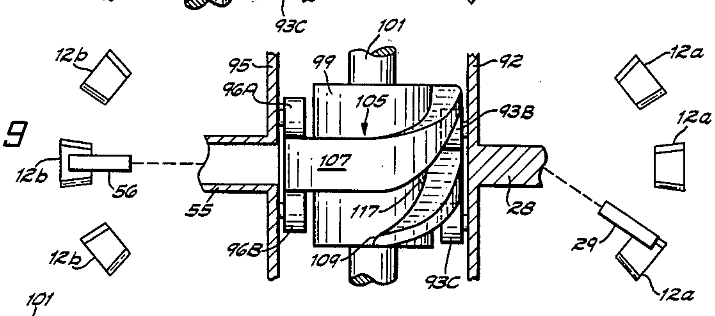
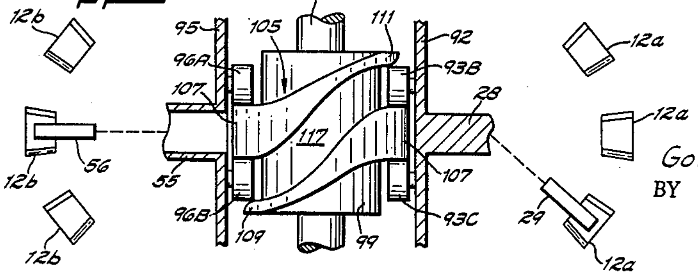


Fig. 10



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SWITCH ACTUATING MECHANISM FOR CONTROLLED SPEED TAP CHANGER

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21 Claims. (Cl. 200—11)

This invention relates to switching mechanisms and more particularly to tap changers for stationary induction apparatus.

A tap changer is often utilized to accomplish voltage regulation of stationary induction apparatus. Usually the tap changing mechanism is operated under load while the stationary induction apparatus is electrically energized, and the contact movement should therefore be at a relatively high speed to minimize contact erosion. Heretofore it has been conventional to utilize a drive mechanism in the tap changer incorporating a resilient energy storage means that actuates the movable contact with a snap action. Such spring-drive mechanisms are not entirely satisfactory in that they do not positively control the speed of contact movement but act only as initiators of motion. The movable contact is not disengaged from the preceding stationary contact with optimum speed to insure minimum contact erosion, and the movable contact is brought into engagement with the succeeding stationary contact at maximum velocity with the result that contact bounce occurs drawing repeated arcs between movable and stationary contact until the movable contact finally comes to rest. As a consequence contact life is relatively short and the mechanical shock, vibration, and unbalanced inertial forces accompanying the snap action necessitate frequent servicing and maintenance of the tap changer and result in short mechanical life thereof. Further, conventional load tap changing equipment utilizing resilient stored-energy drive means is unnecessarily bulky and heavy.

It is an object of the invention to provide a direct-drive tap changing mechanism which positively controls the speed of switching and thus insures maximum contact life.

Another object of the invention is to provide an improved tap changer which positively indexes the movable contacts from one stationary contact to a succeeding stationary contact and inherently insures positive mechanical interlocking of the movable contacts.

Still another object of the invention is to provide a tap changing mechanism in which the movable contact starts slowly and is thereafter rapidly accelerated to optimum velocity for efficient arc interruption as the contacts open.

A still further object of the invention is to provide a tap changer in which the movable contact is not snapped at maximum velocity into engagement with a succeeding stationary contact but rather is decelerated to a fraction of its maximum velocity before the contacts close.

It is a further object of the invention to provide a tap changing mechanism which decelerates the movable contact to a fraction of its maximum velocity before the movable contact engages a succeeding stationary contact and positively constrains the movable contact as it is slowed down and until it is brought to rest in engagement with said succeeding stationary contact, whereby contact bounce is eliminated and mechanical shock and vibration are minimized.

A still further object of the invention is to provide a switching mechanism which gradually accelerates the movable contact during the initial portion of the indexing thereof, which rapidly accelerates the movable contact to optimum velocity for efficient interruption before the contacts open but provides gradual change of velocity over a substantial portion of the velocity-time characteristic on both sides of the maximum velocity point where slowing down of the contact begins, and which gradually decelerates the movable contact during the final portion of the motion as the movable contact approaches its final position at rest with a succeeding stationary contact, whereby switching action is smooth and shock, unbalanced inertial forces, and vibrational effects are minimized.

Still another object of the invention is to provide a tap changing mechanism wherein the slope of the midportion of the velocity-time characteristic of the movable contact changes gradually from plus one through zero to minus one, whereby inertial forces are minimized in the indexing of the movable contact.

Another object of the invention is to provide a tap changing mechanism which alternately indexes a pair of movable contacts and is adapted to lock one movable contact at rest while simultaneously actuating the other movable contact and to positively control the speed of said other movable contact while indexing it into engagement with a succeeding stationary contact. A further object is to provide such a tap changing mechanism having novel means for positively indexing and controlling contact speed including a rotatable index plate carrying a plurality of cam followers and a positive-motion cam adapted to sequentially engage and peripherally displace the cam followers. A still further object is to provide such a tap changing mechanism wherein the cam is rotatably driven in a series of steps to index a movable contact between stationary contacts and is adapted to positively engage a cam follower and displace it in the first step before the contacts open to a position most advantageous for rapid acceleration of the movable contact during the succeeding step, to start the cam follower slowly and then accelerate it rapidly during contact interruption and decelerate the cam follower while positively constraining it to close the contacts slowly and prevent contact bounce during the second step, to positively remain in engagement with the cam follower during the third step until the cam engages a succeeding cam follower, and also to positively lock the movable contact at rest.

Still another object of the invention is to provide an improved tap changing mechanism wherein the gradual acceleration and deceleration at the ends of the motion transmitted by an intermittent motion device are superimposed upon the motion of a cam having gradual change of velocity near the midportion of the velocity-time characteristic to provide smooth action of the rotatable contact and which also permits the prime mover to start without load.

A further object of the invention is to provide a load tap changing mechanism that is substantially smaller in size and lighter in weight than conventional spring-drive tap changing mechanisms.

Another object of the invention is to provide a load tap changing mechanism that is much simpler in construction and much more rugged than prior art spring-drive load tap changing units.

A specific object of the invention is to provide a tap changer wherein the intermittent motion of a Geneva gear is superimposed upon that of a simple harmonic motion cam to index the movable contact and provide smooth action thereof.

These and other objects and advantages of the invention will be more apparent from the following detailed description when read in conjunction with the accompanying drawing in which:

FIG. 1 is a front view of a preferred embodiment of the invention with the drive mechanism of one phase broken away to illustrate the contacts;

FIG. 2 is a cross sectional view taken on line 2—2 of FIG. 1;

FIG. 3 is a development of a cylindrical cam utilized in the embodiment of FIG. 1;

FIG. 4 is the velocity-time characteristic of the movable contact of the embodiment of FIG. 1;

FIG. 5 is a perspective view of the novel means for positively indexing the movable contacts from one stationary contact to a succeeding stationary contact; and

FIGS. 6–10 schematically illustrate sequential positions of the cam and index plates of the direct-drive means at different steps of a tap change.

The underload tap changing mechanism of the invention will be described as incorporated in a three phase load tap changing transformer. The tap changers 10 of all three phases are identical and only one will be described. The tap changers 10 for all three phases are enclosed within an oil-filled compartment (not shown) on the sidewall of the main transformer tank which houses the three phase transformer core and coil assembly. The tap changers 10 for all three phases are mounted on an insulating panel 11 preferably of low power factor, low loss dielectric material which forms an oil-tight barrier between the main transformer tank and the oil-filled compartment.

A plurality of arcuately positioned stationary contacts 12 mounted on panel 11 include a first coplanar set of nine metallic stationary contact members 12*a* disposed in a circle and spaced from a second coplanar set of nine metallic stationary contact members 12*b* arranged in a circle. Corresponding stationary contact members 12*a* and 12*b* of the two sets are electrically commoned. The corresponding contact members 12*a* and 12*b* of each stationary contact 12 have clearance holes for receiving threaded metallic studs 14 and are spaced apart by tubular metallic members 15 surrounding the studs 14. The studs 14 threadably engage a metallic contact supporting member 16 which is rigidly secured to a threaded metallic pin 18 extending through panel 11. An insulating collar 19 surrounds pin 18 between member 16 and panel 11, and a nut threaded onto pin 18 on the side of panel 11 within the transformer tank fixedly mounts contact supporting member 16 and stationary contact 12 on insulating panel 11. The insulating collar 19 mounts stationary contact 12 on an insulating projection away from the insulating barrier provided by the panel 11 between the transformer and the tap changing switch 10, and this construction transfers the dielectric stress from the insulating barrier to the oil and permits reduction in the size of the tap changing apparatus. A nut threadably engaging stud 14 rigidly clamps metallic stationary contact member 12*b* against the metallic sleeve 15 and also rigidly clamps the stationary contact member 12*a* between contact support member 16 and tubular support 15.

Electrical leads 21 connect eight of the stationary contacts 12 to individual taps (not shown) in the tapped series winding of the corresponding phase of the transformer, and a lead 22 electrically connects the ninth, or "neutral" contact 23 to the main winding.

Three insulating panel boards 25 within the oil-filled compartment, one associated with each of the phases, are mounted in spaced relation to the panel 11 by electrically conductive support studs 26 surrounded by insulating sleeves 27. Each sleeve 27 is positioned between panel 11 and a metallic member 30 secured by suitable means such as brazing adjacent one end of a stud 26. A tubular insulating member 24 surrounds the end of each support stud 26 within the transformer tank, and nuts threadably engaging the ends of studs 26 clamp the panel 11 against one end of the insulating sleeves 27 and panel board 25 against the members 30 to mount panel boards 25 in spaced relation to panel 11.

A rotatable shaft 28 carrying a movable contact 29 adapted to sequentially engage the stationary contact members 12*a* extends through an opening in the panel board 25 with its axis coincident with the center of the circumferentially arranged stationary contact members 12*a*. One end of shaft 28 is journalled in a mounting bracket 33 secured by bolts 34 to panel board 25. A bifurcated switch arm 36 affixed by suitable means such as rivets to a radially extending flange 37 on shaft 28 carries the rotatable electrical contact 29. Rotatable contact 29 includes a pair of opposed, generally radially extending, laminated copper shunts 39. Each copper shunt 39 has a contact button 41 at the radially inward end thereof and an arcing contact button 42 at the radially outward end thereof. Rear swivel plates 31 and front swivel plates 32 positioned against the radially inward and radially outward portions respectively of each shunt 39 have inwardly formed portions (not shown) pivotally connected together by swivel pins 43 which extend through a thrust piece 47. Thrust piece 47 has circumferentially extending portions secured by bolts 48 to the arms of bifurcated switch arm 36. The arcing contact buttons 42 are opposed and urged together by compression springs 44 surrounding pins 45 protruding through clearance holes in the copper shunts 39 and in the front swivel plates 32 and compressed between heads 46 on the ends of the pins 45 and the front swivel plates 32. Similarly the radially inward contact buttons 41 are opposed and urged together by compression springs 44 surrounding pins 45 projecting through clearance holes in the copper shunts 39 and in the rear swivel plates 31. The springs 44 resiliently urge arcuate portions of laminated copper shunts 39 against thrust piece 47 and also urge the arcing contact buttons 42 against opposite sides of stationary contact members 12*a*. The contact buttons 41 at the radially inward end of shunts 39 are resiliently urged by the helical springs 44 against a collector ring 49 formed by the circumferential flange on a conical member 50 of a suitable metallic material. The collector ring flange 49 is coplanar with the stationary contact members 12*a*, and the conical metallic member 50 is rigidly secured to a metallic support member 51 which is disposed against panel 11 and, in turn, is affixed to a metallic stud 52 which extends through insulating panel 11. A nut 53 threadably engaging the end of stud 52 within the transformer tank fixedly mounts conical member 50 on insulating panel 11, and the end of metallic stud 52 within the transformer tank is connected by a lead 54 to one end of a preventive autotransformer (not shown) enclosed within the transformer tank.

A sleeve 55 rotatably surrounding the shaft 28 carries a rotatable contact 56 identical to rotatable contact 29 and adapted to sequentially engage the stationary contact members 12*b*. The sleeve 55 is journalled within a tubular portion 57 of support casting 33. A bifurcated switch arm 59 identical to switch arm 36 is secured by suitable means such as rivets to a radially extending flange 60 on sleeve 55, and switch arm 59 carries the rotatable contact 56.

Rotatable contact 56 carried by sleeve 55 is adapted to sequentially engage stationary contact members 12*b* and to electrically connect them to a collector ring formed by a circumferential flange 61 on a conical member 62 of a suitable metallic material. The circumferential flange 61 is in the plane of the stationary contact members 12*b*, and the conical metallic member 62 is rigidly affixed to a metallic support member 63 surrounding sleeve 55 and fixedly mounted on a copper strap 64. Copper strap 64 is rigidly secured to insulating panel board 25 by bolts 34 which mount bracket 33. Copper strap 64 extends along the surface of insulating panel board 25. The lower end of copper strap 64 is bent beneath the lower edge of panel board 25 and is electrically connected to a support stud 26. The end of conductive support stud 26 within the transformer tank is electrically connected by a lead 65 to the other end of the preventive autotransformer (not shown).

Shaft 28 and sleeve 55 are actuated independently in a manner to be described later so that rotatable contacts

29 and 56 are individually operable. Inasmuch as stationary contact members 12a engaged by rotatable contact 29 and stationary contact members 12b engaged by rotatable contact 56 are electrically commoned, the rotatable contacts 29 and 56 can be indexed to a "bridging" position wherein each of the rotatable contacts 29 and 56 is on one of two adjacent stationary contacts 12 and the voltage obtained is midway between the taps, or to a "symmetrical" position wherein both movable contacts 29 and 56 are on the same stationary contact 12. A tap changer 10 and associated series winding provide plus or minus ten percent voltage regulation, and inasmuch as eight stationary contacts 12 are electrically connected to eight taps in the series winding, a 1¼ percent variation in voltage occurs when both rotatable contacts 29 and 56 are indexed to a succeeding stationary contact. Movement of only one rotatable contact 29 or 56 to a succeeding stationary contact 12 results in a voltage midway between the taps, or ⅝ percent regulation, and full plus or minus 10 percent voltage regulation is accomplished in thirty-two ⅝ percent steps.

A reversing switch 67 includes a U-shaped metallic contact 68 affixed to the metallic stud 14 of "neutral" stationary contact 23 and extending through an aperture 69 in panel board 25 and also includes a movable electrical contact 70. The stationary contact 68 has a circumferentially elongated arcuate portion 71, and movable contact 70 is adapted to electrically bridge between arcuate portion 71 and reversing switch stationary contact members 72 and 73. Each stationary contact 72 and 73 is secured by bolts 75 surrounded by insulating sleeves 76 threadably engaged within tapped holes in a metallic member 30 disposed adjacent the transformer side of panel board 25. As described hereinbefore member 30 is rigidly secured to a conductive support stud 26. The stationary contact members 72 and 73 of the reversing switch 67 are each electrically connected through the support studs 26 to electrical leads 79 which are connected to opposite ends of the tapped series winding within the transformer tank.

When tap changer 10 has both movable contacts 29 and 56 on neutral contact 23, and thus the reversing switch 67 is out of the load circuit, an axially extending driving pin 80 carried by a reversing link 81 affixed to and rotatable with the sleeve 55 is adapted to engage on open-end slot 82 at the lower end of a pivoted switch arm 84 carrying the movable contact 70 to pivot the switch arm 84 and thus disengage the movable contact 70 from one stationary contact 72 or 73 and actuate it into engagement with the other stationary contact. Switch arm 84 includes a locking member 87 in which open-end slot 82 is formed and a bifurcated insulating member 88 carrying movable contact 70 and secured to locking member 87 by suitable means such as rivets. A pin 90 extending through members 87 and 88 is journalled within a sleeve portion 91 of support bracket casting 33 to pivotally mount the reversing switch 67. The reversing switch 67 changes the connections to the tapped series winding from "lower" to "raise" and vice versa and thus doubles the voltage range of the tap changer. The reversing switch 67 is only actuated when both movable tap changer contacts 29 and 56 are engaging the neutral contact 23.

Although the electrical elements are not shown, the electrical circuit of the load tap changing transformer may be traced through a tap changer 10 from the transformer secondary phase winding through the lead 22; the neutral contact 23; U-shaped stationary contact 68 of the reversing switch 67; reversing switch movable contact 70 to either stationary contact strip 72 or 73; through a support stud 26 and a lead 79 to one end of the series winding within the transformer tank; a portion of the series winding; a tap in the series winding; a lead 21 to a stationary contact 12; movable contacts 29 and 56 (assuming both are on the same stationary contact); collector rings 49 and 61 to the preventive autotransformer; and from the midtap of the preventive autotransformer to the load.

A circular index plate 92 is fixed to the end of the shaft 28, preferably by a splined connection, to provide a positive and nonresilient connection with rotatable contact 29. Index plate 92 carries nine equiangularly spaced apart cam follower rollers 93 fixed thereto by bolts 94. A second index plate 95 coaxial with plate 92 and axially spaced therefrom is connected to the sleeve 55, preferably by a splined connection. The index plate 95 is also provided with nine equiangularly spaced apart cam follower rollers 96 fixed thereto by bolts 97. A positive-motion cylindrical cam 99 disposed between index plates 92 and 95 is fixed, preferably by a splined connection, to a horizontally extending shaft 101 the ends of which are journalled within spaced apart portions 102 of support casing 33. The direct-drive means of the invention for indexing the movable contacts between stationary contacts includes the cam 99 and the index plates 92 and 95 alternately driven thereby.

The tap changer 10 of each of the three phases of the load tap changing transformer includes a cylindrical cam 99 splined to a shaft 101, and the shafts 101 of the three tap changers are connected by couplings 103 so that the three cams 99 are rotatably driven simultaneously. The cylindrical cam 99 of each tap changer 10 is disposed between the index plates 92 and 95 with its axis at right angles to and spaced below the axis of the index plates 92 and 95. As shown in FIG. 5, the cam followers 93 and 96 are disposed on the surfaces of the index plates 92 and 95 which face each other, and the cam followers of each index plate 92 and 95 are adapted to be sequentially engaged and peripherally displaced by the cam 99 and also the cam followers 93 and 96 of each pair of index plates are adapted to be alternately engaged and tangentially displaced by cam 99.

The indexing means of the invention includes two relatively rotatable members one of which has a single means in continuous positive engagement with the other member, and in the preferred embodiment such single means includes a raised, axially advancing, camming surface means 105 extending circumferentially more than 360 degrees around the peripheral surface of the cylindrical, or drum, cam 99. The peripherally longest portion 107 of camming surface means 105, which in the preferred embodiment encompasses approximately 260 degrees of the circumference, is preferably in a plane substantially at right angles to the axis of the cam 99 and intermediate the camming surface end portions 109 and 111 which overlap and diverge on opposite sides of said plane. End portions 109 and 111 extend over approximately 100 degrees of the circumference and advance in a generally axial direction along the cylindrical surface of drum cam 99 and terminate at the opposite edges thereof. The end portions 109 and 111 are similar and the inner faces thereof are complementary and define a double-edge, approximately S-shaped cam track portion 117 of the camming surface means 105. In the preferred embodiment the cam track portion 117 is adapted to impart simple harmonic motion to a cam follower 93 or 96. The cam 99 is reversible and can be driven in either a clockwise or counterclockwise direction to peripherally displace the cam followers 93 and 96.

The camming surface means 105 alternately engages the cam followers 93 and 96 of the pair of index plates 92 and 95. When cylindrical cam 99 is rotated, the midportion 107 remains in a plane radially of the index plates 92 and 95 and thus applies no force tending to displace cam followers 93 and 96. However, the approximately S-shaped double-edge cam track portion 117 advances tangentially with respect to the index plates 92 and 95 and thus circumferentially displaces the cam followers 93 and 96 to cause rotation of index plates 92 and 95.

As one cam follower, e.g. 93, on index plate 92 is being tangentially displaced by approximately S-shaped double-edge cam track portion 117 to index movable contact 29 to a succeeding stationary contact 12, the midportion 107 of camming surface means 105 is disposed between two cam followers 96 on the other index plate 95 to lock the rotatable contact 56 at rest while the index plate 92 and associated rotatable contact 29 is being indexed from one stationary contact 12 to a succeeding one. The double-edge cam track portion 117 positively constrains a cam follower 93 while tangentially displacing it in order to provide a direct and nonresilient connection between cam 99 and index plate 92. Concurrently the midportion 107 of camming surface means 105 is disposed between two cam followers 96 of the index plate 95 to provide a direct and nonresilient connection between index plate 95 and cam 99 and thus lock rotatable contact 56 at rest. It will thus be appreciated that direct and nonresilient indexing of the movable contacts 29 and 56 is accomplished through cylindrical, or scroll, cam 99 and index plates 92 and 95 which inherently insures positive mechanical interlocking of the rotatable contacts 29 and 56.

The direct drive of the rotatable contacts through the cam 99 results in positively controlled contact speed which insures the most efficient arc interruption. As explained hereinafter, the movable contacts 29 and 56 start slowly and are accelerated rapidly to the optimum speed for arc interruption before the contacts open. Instead of being snapped at maximum velocity into engagement with the succeeding stationary contact in the manner of the prior art spring-drive tap changers, the rotatable contacts 29 and 56 are decelerated to a fraction of their maximum velocity before engaging the succeeding stationary contact 12 and are positively constrained by the direct and nonresilient connection between cam 99 and the cam followers 93 and 96 in order to close the contacts gently without contact bounce and with minimum mechanical shock and vibration. The control of contact speed is obtained through the coordination of the cam 99 and the gear train which rotatably drives cam 99.

The motive force for scroll cam 99 is derived from a reversible electric motor 119 which drives the coupled shafts 101 through intermittent motion means preferably including a Geneva stop and pinion 121 rotatably driven by the electric motor 119 and a Geneva gear 123 actuated by the Geneva pinion 121. The intermittent motion means is operatively connected to the cams 99 of all three phases through a vertical operating shaft 125 connected to the Geneva gear 123, and a pair of miter gears 127 one of which is affixed to shaft 125 and the other of which is secured to an extension 128 on the shaft 101 of the middle tap changer 10.

In the embodiment of the invention illustrated in the drawing, three steps of the Geneva gear 123 produce 180 degree rotation of the cylindrical cam 99 to positively index one of the rotatable contacts, e.g., 29, from one stationary contact 12 to a succeeding stationary contact 12. The combination of cylindrical cam 99 and Geneva gear 123 permits the electric motor 119 to start without load during each step of cam 99.

The movement of the cam followers of one index plate, e.g., 92, relative to the cam 99 is schematically illustrated in FIG. 3 wherein it is represented that prior to the tap change, two cam followers 93A and 93B are disposed on opposite sides of midportion 107. The first step of Geneva gear 123 during the tap change rotates cam 99 sixty degrees so that the initial, gradually sloping portion of double-edge, approximately S-shaped, cam track portion 117 positively engages one cam follower and effects minimum peripheral displacement thereof to a position 93B′. At this position the tap changer contacts have not opened and the cam follower is at the beginning of the steeper-sloped portion of cam track 117 which is the most advantageous position to effect rapid opening of the contacts during the second step. Geneva gear 123 then rotates cam 99 through another sixty degree step to displace the cam follower along the steepest-slope portion of double-edge cam track 117 to a position denoted 93B″. During the second step of Geneva gear 123, the cam follower is tangentially displaced from position 93B′ to position 93B″ to rotate plate 92, and thus index rotatable contact 29, from one stationary contact 12 to a succeeding stationary contact 12. At the end of the second step, the cam follower 93B at position 93B″ is still positively engaged by double-edge cam track portion 117 but cam follower 93A at position 93A″ is disengaged from camming surface means 105. The third step of Geneva gear 123 rotates cam 99 through another sixty degrees to displace cam follower 93B along the gradually sloping final portion of double-edge cam track portion 117 to a position denoted 93B‴. It will be noted that only a minimal tangential displacement of the cam follower occurs in moving from position 93B″ to the final position 93B‴ wherein the contacts are at rest and also that in this final position the cam follower 93B and a succeeding cam follower 93C are disposed on opposite sides of the midportion 107 of camming surface means 105 to thus lock rotatable contact 29 at rest while cam 99 is peripherally displacing a cam follower 96 to index rotatable contact 56 into engagement with a succeeding stationary contact.

Although the camming surface means 105 is shown as a raised portion on cam 99, it will be apparent that the camming surface means 105 can equally well be a groove in the surface of cam 99.

As mentioned hereinbefore, the camming portion 117 is the preferred embodiment of the invention is adapted to impart simple harmonic motion to the cam followers 93 and 96. During the first sixty degree step of simple harmonic motion, a cam follower 93 or 96 is displaced along the relatively flat, gradually sloped portion of the camming surface means 105 to position the cam follower 93 or 96 at the beginning of the middle, steeper-sloped portion of the simple harmonic motion camming track 117 which is most advantageous for rapid opening of the contacts during the second step of cam 99. During the second sixty degree step of simple harmonic motion, the movable contact 29 or 56 is accelerated to an optimum velocity for efficient arc interruption before the contacts open, is further accelerated to a maximum velocity, and is then decelerated to a fraction of the maximum velocity before engaging the succeeding stationary contact 12. Simple harmonic motion has the highly desirable characteristic that the change in velocity occurs gradually at the midportion of the velocity-time characteristic where the velocity is a maximum. Consequently, mechanical shock, inertial force, and vibration are a minimum when the movable contact is being slowed down at the midportion of the velocity-time characteristic.

The intermittent motion of a Geneva gear has the desirable characteristic that acceleration and deceleration are a minimum at the initial and final portions of the motion respectively, but the time-velocity characteristic of a Geneva gear is similar to a sharply-pointed inverted-V where change of velocity is a maximum on both sides of the midportion thereof and consequently severe vibratory effects, inertial force, and mechanical shock occur at the midportion of the travel.

In accordance with the invention, the midportion of the simple harmonic motion of cam 99, characterized by gradual change in velocity, is superimposed upon the velocity-time characteristic of the intermittent motion device 123, characterized by gradual acceleration and deceleration at the ends of the motion, to obtain smooth action of rotatable contacts 29 and 56 with minimum unbalanced forces and vibration effects during the second step of cam 99 when the rotatable contact is being indexed from one stationary contact to a succeeding stationary contact. The resultant time-velocity characteristic of the rotatable contacts 29 and 56 during the second step of cam 99 is illustrated in FIG. 4 wherein velocity of the rotatable contact is plotted against degrees rotation of the Geneva pinion 121. It will be noted that the tremendous acceleration and deceleration at the ends of the motion characteristic of simple harmonic motion, or of constant acceleration motion, are absent and that motion of the rotatable contacts 29 and 56 is initiated slowly with gradual acceleration and is also slowed with gradual deceleration at the final portion of the motion to bring the rotatable contacts gently at rest in engagement with a succeeding stationary contact. During the second step the rotatable contacts 29 and 56 are rapidly accelerated to almost half of their maximum velocity and to an optimum speed for efficient arc interruption before the contacts open as indicated at point "O" on the velocity-time characteristic of FIG. 4. It will be noted that the midportion of the velocity-time characteristic illustrated in FIG. 4 is approximately sinusoidal in contrast to the "inverted-V" characteristic of an intermittent motion device. The acceleration, indicated by the slope of the velocity-time characteristic, diminishes gradually as the velocity of the rotatable contact approaches a maximum at the midpoint of the characteristic and further the change of velocity occurs gradually as slowing down of the contact is begun. The slope of the midportion of the velocity-time characteristic of the rotatable contacts 29 and 56 changes gradually from plus one adjacent point "X" through zero at the maximum velocity point and to minus one adjacent point "Y." Consequently, the action of the rotatable contacts 29 and 56 is smooth, and the unbalanced inertial forces and severe shock and vibratory effects inherent in the "inverted-V" velocity-time characteristic of a Geneva gear drive are avoided.

During the final portion of the second step, the movable contact 29 or 56 is decelerated to less than half its maximum velocity before the movable contact engages the succeeding stationary contact as indicated at C in FIG. 4, and the rotatable contact is positively constrained by the direct and nonresilient connection between cam track portion 117 and the cam follower 93 or 96 as the contact is gradually brought to rest at the end of the motion in engagement with a succeeding stationary contact 12. Contact bounce is thus entirely eliminated, no pitting of the contacts occurs due to the drawing of repeated arcs during contact bounce as in prior art spring-drive tap changers, and electrical life of the tap changer contacts is greatly increased in comparison to prior art mechanisms. The minimum vibration, minimum unbalanced forces, and minimum mechanical shock inherent in the direct, positive and nonresilient indexing of contacts results in a much more rugged mechanism which requires greatly reduced maintenance in comparison to prior art devices and has considerably greater mechanical life.

During the third step of cam 99, the cam follower 93B is moved along the relatively flat, gradually-sloped final sixty degree portion of the simple harmonic motion camming surface means 105 to a position indicated at 93B'''. The rotatable contact 29 is slowly brought into its final position at rest in engagement with the succeeding contact 12 during the third step, and it will be noted that cam track portion 117 is disengaged from cam follower 93B at the end of the third step.

Although the invention has been described with reference to the superimposition of a simple harmonic motion and that of an intermittent motion device, the smooth action with minimum shock and vibration can also be obtained by other combinations of motion, for example, a constant-acceleration motion having minimum acceleration at the midpoint thereof superimposed on the intermittent motion of a Geneva gear.

FIGS. 6-10 schematically illustrate the alternate actuation of indexing plates 92 and 95 and the inherent mechanical interlocking thereof. In order to more clearly illustrate the cam track, the shaft 28 and sleeve 55 are illustrated as extending in opposite directions in FIGS. 6–10, whereas in the preferred embodiment the sleeve 55 surrounds the shaft 28. FIG. 6 shows the conditions prior to the first step of Geneva gear 123 wherein the rotatable contacts 29 and 56 are still in engagement with stationary contacts 12, the midportion 107 of the camming surface means 105 of the cylindrical cam 99 is disposed between a pair of adjacent cam followers 93A and 93B of index plate 92 and is also disposed between a pair of adjacent cam followers 96A and 96B on index plate 95. Consequently the index plates 92 and 95 are locked against rotation and the rotatable contacts 29 and 56 cannot open. FIG. 7 shows that after the first sixty degree step of Geneva gear 123, cam follower 93B of index plate 92 is in positive engagement with the double-edge cam track portion 117 and the movable contact 29 has been displaced slightly on stationary contact 12 but is still in engagement therewith. Cam followers 96A and 96B are still disposed on opposite sides of midportion 107 which does not advance axially as cam 99 is rotated, and consequently movable contact 56 is still locked at rest. FIG. 8 illustrates the condition midway through the second step of cam 99 after thirty degree further rotation of Geneva gear 123 wherein the rotatable contact 29 is disengaged from one stationary contact 12 and is midway between adjacent stationary contacts 12, cam follower 93B is midway through the steeper-slope portion of the double-edge cam track 117 and positively held therein, and cam follower 93A is out of engagement with the camming surface means 105. At the end of the second step after thirty degree further rotation of Geneva gear 123 as shown in FIG. 9, the rotatable contact 29 is in engagement with a succeeding stationary contact 12 and cam follower 93B has passed through the steeper-slope portion of, but is still in engagement with the double-edge cam track portion 117, and a succeeding cam follower 93C of index plate 92 is ready to come into engagement with the camming surface means 105. After the third step of Geneva gear 123 as shown in FIG. 10, the rotatable contact 29 has been displaced into its final position at rest on succeeding stationary contact 12; cam follower 93B has been disengaged from the double-edge cam track portion 117; and cam followers 93B and 93C are disposed on opposite sides of midportion 107, thus locking the index plate 92 against rotation and positively holding the rotatable contact 29 at rest. It will be noted in FIGS. 6–10 that during the three operating steps of Geneva gear 123, the index plate 95 is locked against rotation by the midportion 107 which throughout the three steps is disposed between the cam followers 96A and 96B, thereby holding the movable contact 56 at rest. At the end of the three steps of Geneva gear 123, the cam follower 96B is disposed in a position relative to the double-edge cam track portion 117 identical to that of cam follower 93B prior to the first step. Consequently the next three steps of Geneva gear 123 will peripherally displace cam follower 96B to rotate plate 95 and index the movable contact 56 between stationary contacts. The direct-drive means including cylindrical cam 99 and index plates 92 and 95 is thus capable of positively and nonresiliently indexing one of the movable contacts 29 or 56 at a controlled speed while concurrently holding the other rotatable contact at rest, of locking both rotatable contacts 29 and 56 at rest simultaneously and alternately driving the index plates 92 and 95 to alternately index the rotatable contacts 29 and 56 between stationary contacts 12.

Although only a single preferred embodiment of the invention has been illustrated and described, many modifications and variations thereof will be apparent to those skilled in the art, and therefore it is intended in the appended claims to cover all such modifications and variations as fall within the true spirit and scope of the invention.

I claim:

1. An electrical tap changing under load mechanism comprising, in combination, a plurality of arcuately arranged stationary contacts, a movable contact for sequentially engaging said stationary contacts, and intermittent motion transmitting means including a pair of

relatively movable members the first of which is positively and nonresiliently connected to said movable contact and the second of which drives said first member for indexing said movable contact with accelerated motion from one stationary contact to a succeeding stationary contact, said movable contact interrupting current under load when it is disengaged from said one stationary contact and competing an electrical circuit under load when it engages said succeeding stationary contact, one of said members having a single means in continuous positive engagement with the other of said members both during actuation of said movable contact and while said movable contact is at rest and said second member positively driving and directly controlling the speed of sid movable contact at all times while it is being indexed between said stationary contacts, whereby contact bounce is avoided.

2. An electrical tap changing under load mechanism comprising, in combination, at least three arcuately arranged stationary contacts connected to taps of an electrical winding, a movable contact for sequentially engaging said stationary contacts, and means including a pair of members the first of which is positively and nonresiliently connected to said movable contact and the second of which drives said first member for indexing said movable contact from one stationary contact to a succeeding stationary contact, said movable contact interrupting current under load in the electrical circuit to one of said taps when it is disengaged from said one stationary contact and completing an electrical circuit under load to an adjacent tap when it engages said succeeding stationary contact, one of said members having a single cam track means in continuous positive engagement with the other of said members both during actuation of said movable contact and while said movable contact is at rest, said second member positively driving and directly controlling the speed of said movable contact at all times while it is being indexed between said stationary contacts and decelerating said movable contact to a fraction of its maximum velocity before said movable contact engages said succeeding stationary contact and also decelerating said movable contact to a final position at rest in engagement with said succeeding stationary conact, said one member being in continuous positive engagement with the other of said members during said deceleration, whereby contact bounce of said movable contact is eliminated.

3. An electrical tap changing under load mechanism comprising, in combination, at least three stationary contacts arranged in an arcuate path, a movable contact adapted to sequentially engage said stationary contacts, and means including a rotatable member carrying cam follower means disposed away from the axis thereof and being positively and nonresiliently connected to said movable contact for indexing said movable contact with accelerated motion from one stationary contact to a succeeding stationary contact, said movable contact interrupting current under load when it is disengaged from said one stationary contact, said means for indexing also including an intermittent motion transmitting device characterized by gradual acceleration and retardation at the ends of the motion and rapidly accelerated and decelerated motion therebetween and a positive-motion cam in continuous engagement with said cam follower means and positively driving and directly controlling the velocity of said movable contact at all times while it is being indexed between said stationary contacts, the motion transmitted by said cam being characterized by gradual change of velocity in the vicinity of the maximum velocity and the motion of said cam being superimposed upon that of said intermittent device and producing smooth action of said movable contact, said indexing means starting said movable contact slowly and accelerating it to a substantial portion of its maximum velocity before it is disengaged from said one stationary contact.

4. An electrical tap changing under load mechanism comprising, in combination, at least three stationary contacts arranged in an arcuate path and connected to taps of an electrical winding, a movable contact adapted to sequentially engage said stationary contacts, and means including a rotatable member carrying cam follower means disposed away from the axis thereof and being positively and nonresiliently connected to said movable contact for indexing said movable contact from one stationary contact to a succeeding stationary contact, said movable contact interrupting current under load in the electrical circuit to one of said taps when it is disengaged from said one stationary contact and completing an electrical circuit under load to an adjacent tap when it engages said succeeding stationary contact, said means for indexing also including an intermittent motion transmitting device characterized by relatively gradual acceleration and retardation adjacent the ends of the motion and rapidly accelerated and decelerated motion intermediate said ends and a simple harmonic positive-motion cam in continuous engagement with said cam follower means and being rotatably driven in three sixty degree steps by said intermittent device to index said movable contact between said stationary contacts, said cam follower means during the first step being displaced to the beginning of the steeper slope portion of said simple harmonic motion cam and the opening and reclosing of said contacts occurring during the second step of sixty degrees of simple harmonic motion transmitted by said cam, the motion of said intermittent device being superimposed on that of said cam and effecting smooth action of said rotatable contact during said indexing.

5. An electrical tap changing under load mechanism comprising, in combination at least three arcuately arranged stationary contacts, a movable contact adapted to sequentially engage said stationary contacts, and means including a pair of rotatable members the first of which is positively and nonresiliently connected to said movable contact and the second of which displaces said first member in a peripheral direction for indexing said movable contact with rapidly accelerated motion from one stationary contact to a succeeding stationary contact, said movable contact interrupting current under load when it is disengaged from said one stationary contact and completing an electrical circuit under load when it engages said succeeding stationary contact, one of said members having a single means in continuous positive engagement with the other of said members both during indexing of said movable contact and while said movable contact is at rest and said second member positively driving and directly controlling the velocity of said movable contact at all times while it is being indexed between said stationary contacts, the midportion of the velocity-time curve of the motion transmitted by said indexing means to said movable contact being approximately sinusoidal with maximum velocity occurring during said midportion, said indexing means gradually accelerating and gradually decelerating said movable contact at the initial and final portions of said motion and changing the velocity of said movable contact gradually adjacent the maximum velocity point of said midportion of said velocity-time characteristic.

6. An electrical tap changing under load mechanism comprising, in combination, at least three arcuately arranged stationary contacts, a movable contact for sequentially engaging said stationary contacts, and means for indexing said movable contact from one stationary contact to a succeeding stationary contact, said movable contact interrupting current under load when it is disengaged from said one stationary contact, said means including a prime mover, an intermitent motion transmitting device operatively driven by said prime mover, said intermittent motion device being characterized by gradual acceleration and retardation at the ends of the motion and rapid acceleration and deceleration in the midportion thereof, and a simple harmonic motion transmitting device between said intermittent motion device

and said movable contact, said simple harmonic motion device positively driving and directly controlling the speed of said movable contact at all times as it is indexed between said stationary contacts, whereby said prime mover may start without load and gradually accelerating and gradually decelerating motion is imparted to said movable contact at the ends of said indexing and the velocity of said movable contact is changed gradually as the velocity-time characteristic of said movable contact changes from a positive to a negative slope.

7. An electrical tap changing under load mechanism comprising, in combination, at least three arcuately arranged stationary contacts connected to taps of an electrical winding, a movable contact for sequentially engaging said stationary contacts, and means for indexing said movable contact from one stationary contact to a succeeding stationary contact, said movable contact interrupting current under load in the electrical circuit to one of said taps when it is disengaged from said one stationary contact and completing an electrical circuit under load to an adjacent tap when it engages said succeeding stationary contact, said means including a prime mover, an intermittent motion Geneva gear operatively driven by said prime mover, and a motion transmitting device having the characteristic of gradual change of velocity with time at the midportion of the velocity-time characteristic thereof disposed between said Geneva gear and said movable contact, the superimposition of said Geneva gear and said device providing smooth action of said movable contact with minimum vibration and shock effects.

8. An electrical tap changing under load mechanism comprising, in combination, a plurality of arcuately arranged stationary contacts, a pair of individually operable movable contacts for sequentially engaging said stationary contacts, means for alternately indexing said movable contacts from one stationary contact to a succeeding stationary contact including first and seond rotatable members positively and nonresiliently connected to individual ones of said movable contacts, each said movable contact interrupting current under load when it is disengaged from one stationary contact and completing an electrical circuit under load when it engages said succeeding stationary contact, and a motion transmitting member simultaneously continuously directly engaging said first and second members both during indexing and at rest and when operated alternately displacing said first and second members to actuate said movable contacts with accelerated motion and said motion transmitting member positively driving and directly controlling the velocity of said movable contacts at all times as they are indexed between said stationary contacts.

9. An electrical tap charging under load mechanism comprising, in combination, a plurality of circumferentially disposed stationary contacts, a pair of individually operable movable contacts adapted to sequentially engage said stationary contacts, a shaft carrying one of said movable contacts, a sleeve rotatably surrounding said shaft and carrying the other of said movable contacts, means for alternately indexing said movable contacts between said stationary contacts including first and second rotatable members one of which is in positive and nonresilient connection with said shaft and the other of which is in positive and nonresilient connection with said sleeve, and a rotatable motion transmitting member in continuous positive engagement with said first and second rotatable members and being adapted to alternately rotatably drive said first and second members to alternately index said movable contacts from one stationary contact to a succeeding stationary contact, each said movable contact interrupting current under load when it is disengaged from said one stationary contact and completing an electrical circuit under load when it engages said succeeding stationary contact.

10. A tap changing under load mechanism comprising, in combination, at least three circumferentially disposed stationary contacts connected to taps of an electrical winding, a movable contact operative to sequentially engage said stationary contacts, and means for indexing said movable contact from one stationary contact to a succeeding stationary contact including an index plate positively and nonresiliently connected to said movable contact and having a plurality of circumferentially spaced apart cam followers and a cam adapted to sequentially engage and displace said cam followers to rotate said index plate and being in positive engagement with at least one of said cam followers at all times and positively driving and directly controlling the velocity of said movable contact at all times as it is indexed between said stationary contacts, said movable contact interrupting current under load in the electrical circuit to one of said taps when it is disengaged from said one stationary contact and completing an electrical circuit under load to an adjacent tap when it engages said succeeding stationary contact.

11. A tap changing under load mechanism comprising, in combination, a plurality of circumferentially disposed stationary contacts, a pair of individually operable rotatable contacts adapted to sequentially engage said stationary contacts, a first indexing plate positively and nonresiliently connected to one of said rotatable contacts, a second indexing plate spaced from and coaxial with said first indexing plate and positively and nonresiliently connected to the other rotatable contact, a plurality of circumferentially spaced apart cam followers on each of said indexing plates, and a positive-motion cam disposed between said indexing plates successively engaging and displacing said cam followers on each of said plates and indexing said rotatable contacts between said stationary contacts each said rotatable contact interrupting current under load when it is disengaged from one of said stationary contacts and completing an electrical circuit under load when it engages a succeeding stationary contact, said cam alternately engaging and displacing a cam follower on said first indexing plate and a cam follower on said second indexing plate and positively engaging at least one of said cam followers on both of said plates at all times, whereby motion of said cam is directly transmitted to said rotatable contacts and said cam locks said rotatable contacts at rest.

12. In a tap changing under load mechanism, the combination with at least three circumferentially disposed stationary contacts connected to taps of an electrical winding and a rotatable contact for sequentially engaging said stationary contacts, of means for indexing said rotatable contact between said stationary contacts including a rotatable index plate positively and nonresiliently connected to said rotatable contact and carrying a plurality of circumferentially spaced apart cam followers and a cylindrical cam disposed adjacent said index plate and having camming surface means thereon a portion of which is in a plane substantially perpendicular to the axis of said cam and at least one end of said camming surface means diverging from said plane, said camming surface means sequentially engaging and displacing the cam followers of said index plate when said cylindrical cam is actuated to actuate said index plate, said camming surface means positively engaging at least one of said cam followers at all times, whereby said cam indexes said rotatable contact between stationary contacts and also locks said rotatable contact at rest, said rotatable contact interrupting current under load in the electrical circuit to one of said taps when it is disengaged from one of said stationary contacts and completing an electrical circuit under load when it engages a succeeding stationary contact.

13. In a tap changing under load mechanism, the combination with a plurality of circumferentially disposed stationary contacts and a pair of rotatable contacts individually operable to sequentially engage said stationary contacts; of a pair of rotatable, axially spaced apart, coaxial index plates each having a plurality of circumferentially spaced apart cam followers and being positively

and nonresiliently connected to one of said rotatable contacts, and a cylindrical cam disposed between said index plates having camming surface means thereon the end portions of which diverge axially relative to said cam, one of said diverging end portions sequentially engaging said cam followers on each of said plates and alternately engaging and displacing said cam followers on said pair of plates when said cam is rotated in the forward direction and the other said diverging end portions doing so when said cam is rotated in the reverse direction, the portion of said camming surface means between said end portions being in positive engagement with the cam followers of one of said index plates while a cam follower of the other of said index plates is being displaced by one of said end portions, each said rotatable contact interrupting current under load when it is disengaged from one stationary contact and completing an electrical circuit under load when it engages a succeeding stationary contact.

14. In a tap changing under load mechanism, the combination with a plurality of circumferentially disposed stationary contacts and a pair of coaxial, spaced apart, individually operable rotatable contacts for sequentially engaging said stationary contacts; of a rotatable shaft carrying one of said rotatable contacts and a sleeve rotatably surrounding said shaft and carrying the other of said rotatable contacts, a pair of rotatable, axially spaced apart, coaxial index plates each carrying a plurality of circumferentially spaced apart cam followers, one of said plates being positively and nonresiliently connected to said shaft and the other of said plates being positively and nonresiliently connected to said sleeve, and a cylindrical cam disposed between said plates with its axis substantially at right angles to the axis thereof and having camming surface means adapted to sequentially engage the cam followers of each of said index plates and to alternately engage and displace said cam followers of said pair of plates to index said rotatable contacts alternately between said stationary contacts, each said rotatable contact interrupting current under load when it is disengaged from one of said stationary contacts and completing an electrical circuit under load when it engages a succeeding stationary contact.

15. A tap changing under load mechanism comprising, in combination, a plurality of circumferentially disposed stationary contacts, a pair of coaxial, axially spaced apart, rotatable contacts, a shaft carrying one of said rotatable contacts, a sleeve rotatably surrounding said shaft and carrying the other of said rotatable contacts, a pair of coaxial, axially spaced apart, rotatable index plates each having a plurality of circumferentially spaced apart cam followers, one of said plates being positively and nonresiliently connected to said shaft and the other of said plates being positively and nonresiliently connected to said sleeve, and a cylindrical cam disposed between said index plates and having a raised camming surface thereon extending circumferentially more than 360 degrees around the periphery of said cam, a midportion of said camming surface being in a plane substantially perpendicular to the axis of said cam and the end portions of said camming surface diverging from said plane axially relative to said cam axis and when said cam is rotated sequentially engaging and peripherally displacing the cam followers on each of said plates and alternately engaging and peripherally displacing the cam followers on said pair of plates to index said rotatable contacts alternately between said stationary contacts, each said rotatable contact interrupting current under load when it is disengaged from one of said stationary contacts and completing an electrical circuit under load when it engages a succeeding stationary contact, said midportion being disposed between and positively engaging an adjacent pair of said cam followers of one of said index plates when a cam follower of the other of said index plates is in engagement with said end portions, whereby one of said index plates is positively held by said midportion to lock one of said movable contacts at rest while the other of said index plates is being rotated by said end portions to index the other of said rotatable contacts between stationary contacts.

16. A tap changing under load mechanism, comprising, in combination, a plurality of circumferentially disposed stationary contacts a pair of individually operable rotatable contacts adapted to sequentially engage said stationary contacts, a pair of rotatable index plates positively and nonresiliently connected to individual ones of said rotatable contacts and each carrying a plurality of circumferentially spaced apart cam followers, and a positive-motion cam having camming surface means for sequentially engaging said cam followers of each said index plate and for alternately engaging and peripherally displacing said cam followers of said pair of index plates, said camming surface means when said cam is rotated transmitting motion to one of said cam followers in a series of steps in the first of which said camming surface means positively engages said one cam follower and displaces it to the beginning of the portion of said camming surface having the steeper slope and which is most advantageous for rapid acceleration of the rotatable contact associated therewith during the succeeding step and in the second of which said one cam follower is peripherally displaced along said steeper slope portion of said camming surface to index said rotatable contact from one stationary contact into engagement with a succeeding stationary contact, said cam accelerating said rotatable contact to maximum velocity between said stationary contacts and the slope of said steeper portion changing gradually in the vicinity of said maximum velocity, each said rotatable contact interrupting current under load when it is disengaged from said one stationary contact, said cam positively constraining said one cam follower during all of said steps and concurrently positively constraining said cam followers of said other index plate during all of said steps, and a Geneva gear, said Geneva gear transmitting motion with relatively low acceleration and retardation adjacent the initial and final portions of the motion, the superimposition of the motion of said cam on the motion of said Geneva gear providing smooth action of said rotatable contact with minimum vibration and shock.

17. In a tap changing mechanism in accordance with claim 16 wherein during said second step said cam is adapted to accelerate said rotatable contact to a substantial portion of its maximum velocity before it is disengaged from said one stationary contact and to decelerate said rotatable contact to a fraction of its maximum velocity before it engages said succeeding stationary contact and to positively constrain said one cam follower during said deceleration, whereby contact bounce of said rotatable contact is eliminated.

18. A tap changing under load mechanism comprising, in combination, at least three circumferentially disposed stationary contacts connected to taps of an electrical winding, a rotatable contact adapted to sequentially engage said stationary contacts, a rotatable member positively and nonresiliently connected to said rotatable contact and carrying a plurality of circumferentially spaced apart cam followers disposed away from the axis thereof, and a positive-motion cam having an approximately S-shaped cam track adapted when said cam is rotated to sequentially engage said cam followers and to transmit motion to each said cam follower in a series of steps in the first of which said cam track positively engages said cam follower and displaces it to a position at the beginning of the steeper portion of said cam track wherein said cam follower is in the most advantageous position to rapidly accelerate said contact during the succeeding step and in the second of which said cam follower is peripherally displaced by said steeper portion to index said rotatable contact from one stationary contact into engagement with a succeeding stationary contact, said rotatable contact interrupting current under load in the electrical circuit to one of said taps when it is disengaged

from said one stationary contact and completing an electrical circuit under load to an adjacent tap when it engages said succeeding stationary contact, said cam track positively constraining said cam follower during said series of steps and said positive motion cam positively driving and directly controlling the velocity of said rotatable contact at all times as it is indexed between said stationary contacts.

19. An electrical tap changing under load mechanism comprising, in combination, at least three circumferentially disposed stationary contacts, first and second individually operable rotatable contacts adapted to sequentially engage said stationary contacts, and indexing means including a positive-motion cam for alternately indexing said first and second rotatable contacts from one stationary contact to a succeeding stationary contact so that said rotatable contacts are rapidly accelerated to a substantial portion of their maximum velocity before they disengage said one stationary contact and are retarded to a fraction of said maximum velocity before they engage said succeeding stationary contact, each said rotatable contact interrupting current under load when it is disengaged from said one stationary contact and completing an electrical circuit under load when it engages said succeeding stationary contact, said positive-motion cam positively driving one of said rotatable contacts and positively controlling its speed at all times as it is indexed between said stationary contacts and locking the other rotatable contact at rest while indexing said one rotatable contact.

20. In a tap changing under load mechanism, the combination of at least three arcuately arranged stationary contacts connected to taps of an electrical winding, a movable contact adapted to sequentially engage said stationary contacts, and indexing means including a positive motion cam and cam follower means connected to said movable contact and driven by said cam for initially wiping said movable contact at relatively low velocity along one stationary contact and for accelerating said movable contact to a substantial portion of its maximum velocity before it disengages said one stationary contact and for decelerating said movable contact to a fraction of its maximum velocity before it engages a succeeding stationary contact, said movable contact interrupting current under load in the electrical circuit to one of said taps when it is disengaged from said one stationary contact and completing an electrical circuit under load to an adjacent tap when it engages said succeeding stationary contact, said indexing means wiping said movable contact along said succeeding stationary contact at relatively low velocity into its final position with said succeeding contact and said cam positively driving and directly controlling the velocity of said movable contact at all times as it is indexed from said one stationary contact to said succeeding stationary contact, whereby bounce of said movable contact relative to said succeeding stationary contact is eliminated and arcing therebetween is reduced.

21. In a tap changing under load mechanism, in combination, a plurality of circumferentially disposed stationary contacts, a rotatable contact for sequentially engaging said stationary contacts, intermittent motion transmitting means including a pair of members the first of which is positively and non-resiliently connected to said rotatable contact and the second of which rotatably drives said first member for indexing said rotatable contact from one stationary contact to a succeeding stationary contact so that it is initially accelerated gradually and then accelerated rapidly to a substantial portion of its maximum velocity before it is disengaged from said one stationary contact, said movable contact interrupting current under load when it is disengaged from said one stationary contact and completing an electrical circuit under load when it engages said succeeding stationary contact, said means for indexing including means for changing the velocity of said rotatable contact relatively gradually in the vicinity of the maximum velocity point on its time-velocity characteristic, one of said members having a single means in continuous positive engagement with the other of said members both during indexing of said rotatable contact and while said rotatable contact is at rest and said second member positively driving and directly controlling the velocity of said rotatable contact at all times during the indexing thereof between stationary contacts and decelerating said rotatable contact to a fraction of its maximum velocity before it engages said succeeding stationary contact.

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