This invention relates to an on-load tap changer for transformers, comprising a bank of contacts (tap contacts) on a stationary contact rail, each connected with a transformer tapping, and at least one switching assembly with two on-load tap selector and load-transfering contacts which move from tap to tap by first preparing the change by introducing a diverter member, such as a resistor, into the tapped circuit which is about to be selected, by then transferring the load by rupturing the existing tapped circuit and by finally completing the change by bridging or short circuiting the diverter resistor in the freshly selected tapped circuit.

In on-load tap changers hitherto known to the art the two functions involved in effecting a change-over from tap to tap, namely that of selecting the next tap and that of actually transferring the load, are performed by two separate switching elements, the selector element which prepares the change independently of the existing operational position and the generally separate load-transfering switching element—often even housed in a casing of its own—which transfers the load to the new tap independently of the selector element.

The major disadvantages inherent in these known forms of construction principally consist in their structural complexity and their consequent high production cost. Moreover, the accommodation of the selector and load-transfering switch elements in separate housings undesirably increases the proportions and size and weight of the apparatus. Furthermore, in known forms of construction maintenance and the possibly necessary replacement of components of the on-load tap changer are extremely complicated.

The present invention therefore contemplates a solution of the problem of overcoming the defects of known designs and of developing a type of on-load tap changing equipment which is simple and cheap to produce, which is more compact and requires much less space, and which is capable of high-speed operation since there is less wear of the contacts by burning. Moreover, the contemplated on-load tap changer is desired to be fault-free in operation—even in the event of failures in the network—and it should be capable of electric remote control.

The contemplated objects are achieved by the invention in that the movable switching assembly of the on-load tap changer comprises two switching elements which are independently movable in relation to the contacts of the stationary contact rail, and which in consecutive tap changes alternately perform the functions of preparing the change and of transferring the load.

This "dual function" of the switching elements of an on-load tap changer according to the invention permits the entire equipment to be of extremely simple and compact design. Apart from the fact that separate housings for a selector and a load-transferring switch means are not required, the necessary arrangements for driving the switching elements can be simplified considerably. The outstanding advantage afforded by the solution proposed by the present invention, in which the switching elements alternately perform the twin functions of preparing the change-over and of transferring the load, resides more especially in the fact that an idle period which arises in known forms of construction with a "following" load-transferring switch means cannot occur, because the switching element which has selected the next tap contacts and has thus prepared the change then changes its function and performs the transfer of the load, so that no "following" movement of the other switching element takes place.

A structurally very simple solution is afforded by embodying the invention in such a way that for the selection of a tap the switching elements of the movable contact assembly move parallel to and at a distance from the stationary tap contact bank and that for transferring the load they are displaceable perpendicularly to the traversing movement. According to the invention the independent traversing movements and the load-transferring movements which are performed substantially perpendicularly to the traversing movement are each produced by separate drive means, the drive means for effecting the load transferring movement being a high-speed drive—to reduce wear of contacts by burning.

In order to achieve a satisfactory tap change within the minimum of time it is arranged that the independently traversable switching elements should be mechanically or electrically coupled for the synchronous performance of the load-transferring movement.

To reduce contact deterioration by burning it has also been found advisable to provide the high-speed drive for effecting the load-transferring movement with control means which determine the instant of load transfer by reference to a phase shifting device in such a manner that the transfer of the load will be effected approximately when the current swings through zero.

As will be readily understood the on-load tap changer proposed by the invention can be readily adapted to the control of multiphase transformers in which the on-load tap change is effected in at least two transformer phases. To this end the invention provides a pair of switching elements for each tapped transformer phase, which work in synchronism.

In an on-load tap changer for multiphase transformers with star point voltage control, in which the movable switching assembly forms the star point, the solution offered by the invention consists in providing each of the switching elements with contact points equal in number to the number of phases joined at the star point, and in embodying the switching elements in spider-like members which cooperate with a stationary bank of tap contacts arranged concentrically about the common axis of the spiders.

A particularly compact design in a form of construction of this kind can be achieved if the stationary concentric bank of tap contacts are formed with contact faces on opposite sides and the two switching elements are arranged one on each side of said bank of tap contacts.

In an on-load tap changer in which the free ends of the independently rotatable switching elements, which cooperate with the bank contacts, are fitted with contact means comprising a main contact and a sparking contact, a further useful development of the invention consists in making the contact means independently movable perpendicularly to the direction of rotation of the switching elements. Since in such an arrangement it becomes unnecessary to move the switching elements in their entirety in order to break the connection with one tapping and to make a connection with another tapping, the inertia forces which must be overcome for effecting the change-over can be substantially reduced and the speed of operation correspondingly increased.

The contact means on the two switching elements are preferably coupled and operated by a common drive means adapted to shift them perpendicularly to the bank contacts. In an on-load tap changer comprising coaxial shafts for rotating the switching elements a particularly satisfactory arrangement consists in utilizing the inner shaft for the additional purpose of imparting the necessary
perpendicular movements to the two contact means by providing tiltable levers on the switching elements for transmitting the axial movements of the inner shaft to the contact means.

These and numerous other features of the invention will now be described in greater detail by reference to several illustrative embodiments shown in the accompanying drawings in which

FIGS. 1 to 3 diagrammatically illustrate the manner of operation of an on-load tap changer for the control of a single-phase transformer,

FIG. 4 is a longitudinal section of a practical embodiment of an on-load tap changer according to FIGS. 1 to 3,

FIGS. 5 and 6 are sections taken on the lines V—V and VI—VI in FIG. 4,

FIGS. 7 and 8 are detail sections (on a larger scale) of the switching elements and tap contacts in a tap changer constructed as shown in FIGS. 4 to 6,

FIG. 9 is a detail section of the switching elements and tap contacts in an alternative embodiment of the invention,

FIGS. 10 and 11 are schematic representations of an on-load tap changer for a three-phase transformer,

FIGS. 12 and 13 are a section and plan view respectively of an on-load star point tap changer according to the invention for a three-phase transformer,

FIGS. 14 to 16 and 17 to 19 are diagrammatic plan and elevational views of two three-phase transformers with built-in on-load tap changers of different forms of construction,

FIG. 20 is a sectional representation of part of an on-load tap changer in a form of construction representing a modification of that shown in FIG. 4,

FIG. 21 is a section taken on the line XXV—XXV in FIG. 20.

With reference now to FIGS. 1 and 2, these drawings diagrammatically illustrate the principle upon which the operation of the on-load tap changer according to the invention is based. The tap changer 1 comprises two switching arms 2 and 3 which are independently rotatable about coaxial vertical shafts 5 and 4, and turn in horizontal planes which remain at the same vertical distance from one another. The free ends of the two switching arms 2 and 3 carry contacts 6 and 7 adapted to cooperate with contacts 8 connected with the transformer tappings. These tap contacts 8 which are connected with the tapping of the controlled transformer 10 (cf. FIG. 3) are disposed in a circular bank about the two axes of rotation 4 and 5 of switching arms 2 and 3.

One of the two switching arms 2 or 3 is now rotated into alignment above or below a selected tap contact 8. The actual change-over from the previous tap to the freshly selected tap is then effected by lifting the switching arm which still aligns with the preceding tap, thus isolating the latter, and at the same time pushing the other switching arm vertically into contact with the freshly selected tap. To this end each switching arm 2 and 3 is associated with drive means 11 and 12 of its own (cf. FIG. 3), and each arm can thus be independently rotated.

Moreover, the two switching arms 2 and 3 are equipped with means 13 for jointly displacing them in the vertical direction, in other words for moving both arms 2 and 3 together longitudinally in relation to their axes of rotation 4 and 5. These vertical displacing means permit the two arms 2 and 3 to be moved into a position in which the contact point 6 or 7 of one of the arms will make contact with a bank contact 8, whereas the contact point of the other arm will be at a level at which no contact with the bank of tap contacts is possible, but in which it can be swung into alignment with the next bank contact that may be selected. When this latter switching arm is thus rotated into register with the next tap, a further joint axial displacement of both switching arms will cause contact with the next tap to be made and that with the preceding tap to be broken.

It follows from what has been said that the two switching arms continually alternate in function inasmuch as one arm will make contact when the other arm breaks contact, whereas during the following change the last mentioned arm will make and the first mentioned arm break, and so on.

As will be clear from FIG. 3, and as will be later described in greater detail, the on-load tap changer 1 including its drive means 11, 12, 13 and transmission 14 between drive means 12 and shaft 4 can be combined in an integral assembly with a transformer 10 which comprises windings 15 and a core 16, by mounting the tap changer inside or on the transformer casing.

FIGS. 4 to 6 show an embodiment of an on-load tap changing switch according to the invention for the control of a single-phase transformer. This will now be described in greater detail.

The tap changer is housed in a casing 18 made of an insulating or other appropriate material, and closed by a cover plate 19 bolted at 20 to a flange 21 secured to the casing 18 by angle irons 22 and rivets or screws 23. A floor 24 with an oil drain cock 26 forms the bottom of casing 18 and is likewise secured by bolts or rivets 25.

Moreover, affixed to cover 19 by bolts or rivets 27 is a hollow cylinder 28 from which a pressure-tight tank 29 is suspended by means of bolts or rivets 30.

The tap contacts 8 which carry contact faces 8a on both sides project into this pressure-tight tank 29. As will be understood by reference more particularly to FIG. 6 the tap contacts are disposed in a circular bank around the periphery of the cylindrical casing 18 and are connected with terminals 8b on the outside of the casing. Above and below the circular bank of tap contacts 8 are the switching arms 2 and 3 rotatably and vertically shiftedly mounted inside the tank.

The upper switching arm 3 is secured to a hollow shaft 4 which can be driven by a motor 12 through shaft 34, a transmission 32 and 33 and a pin 31 projecting from shaft 4.

The lower switching arm 2 is secured by means of pin 35 to a shaft 5 located inside the aforesaid hollow shaft 4 and adapted to be driven by a motor 11 through a transmission 36, 37.

To permit the switching arms 2 and 3 to be stepped from contact to contact the two wheels 32 and 36 are formed as Geneva wheels, as shown clearly in FIG. 5. A pin 33b affixed between two lobed extensions 33a on the cooperating wheel 33 engages slot-like recesses 32a in the wheel 32 and, in the course of each full revolution of shaft 34, steps the wheel 32 by the pitch of two neighbouring slots. The two wheels 36 and 37 in the transmission between motor 11 and shaft 5 are formed in exactly the same way as the wheels 32 and 33.

Vertical shift of shafts 4 and 5 (and hence of switching arms 2 and 3) is performed by a lifting mechanism 13 which, in the same way as the two motors 11 and 12, is mounted on the cover plate 19 of the casing. The axial coupling between the two shafts 4 and 5, which are independently rotatable as has been explained, is effected, on the one hand (when the shafts are lowered), by a wider collar-like upper portion 5a of shaft 5 which bears on a washer 38 on the upper end face of shaft 4 and, on the other hand (when the shafts are raised), by a lower wider portion 5b of shaft 5 which bears on a washer 39 at the bottom end face of hollow shaft 4.

When they are raised and lowered the two shafts are guided in that the bottom end 5b of shaft 5 slidably moves in a bush 40 affixed by a spider-shaped bracket 41 by means of screws 42 to the pressure-tight tank 29.

This spider 41 together with the hollow cylindrical
ring 43 at the upper end of casing 29 simultaneously serves to reinforce and stiffen the walls of the tank. The top of tank 29 is closed by a plate 44 which carries bearings for shaft 34 and a bearing plate 46 for mounting the star wheel 32.

As will be seen by reference to FIG. 6 the switching arms 2 and 3 are relatively narrow bars fitted with contact elements for cooperation with the bank of tap contacts 8. These contact elements consist of a movable sparking contact 47 and a main contact 48 formed as a flat annular plate. The sparking contact 47 which is insidiously slidable in relation to the main contact 48 is guided by its shaft 47a of which the free end is connected with a resistor 49. Each resistor 49 which forms a divider is connected by a clip 50 with a metal plate 51 which is mounted on switching arms 2 and 3 respectively and with which the main contact 48 makes a good metal to metal contact.

The main contacts 48 of the two switching arms 2 and 3 are interconnected by a solid metal loop 52a and a flexible conductor 52b leads to a terminal 53 which projects through casing 18 and casing 29.

The manner in which this on-load tap changer functions will at once be clear by reference to the drawings. In the position of the switching elements shown in FIG. 4 shafts 43 and 63 in their rear positions in which the lower switching arm 2 makes contact with one of the bank contacts 8. The sparking contact 47 of the lower arm 2 is fully depressed so that the circuit from terminal 53 is closed through cable 52b, plate 51, main contact 48 and sparking contact 47 of arm 2 to the selected bank contact 8. Assuming the tap is to be changed, then arm 3 will first be rotated into register with the neighbouring contact 8. The vertical shifting means 13 (for instance in the form of a double-acting solenoid and plunger) then lowers the entire switching assembly comprising shafts 4 and 5 and the two arms 2 and 3. This motion first causes the sparking contact 47 on the lower arm 2 to separate from the main contact 48, resulting in the introduction of resistor 49 into the circuit. In the course of the further downward movement of the selector assembly the sparking contact 47 on the upper arm 3 will make contact with the neighbouring bank contact 8. Consequently a fresh circuit is now completed from terminal 53 through cable 52b, loop 52a, resistor 49 and sparking contact 47 on the upper arm 3 to the neighbouring tap.

For a brief instant the transformer winding between the two taps will therefore be short-circuited through the two resistors 49 and 69 and the clamps 50 and 55. In the continued downward motion of shafts 4 and 5 the sparking contact 47 on the lower arm 2 will separate from the bank contact 8 which had so far been in circuit and current will flow exclusively through the fresh bank contact 8. In the final stage of the descent of shafts 4 and 5 sparking contact 47 on the upper arm 3 will be depressed until the current can flow through the main contact 48 of arm 3, the diverter resistor 49 being again short-circuited.

If the tapping position thus attained is not yet the desired position, then the tap change will be repeated in the manner that has been described. The two arms 2 and 3 function turn and turn about, each arm in turn preparing the change and taking over the load from the other arm.

In the upper portion of casing 18 contacts 55 are provided (cf. FIGS. 4 and 5) for optional use. These are electrically connected through an arm 56 with the outer hollow shaft 4.

Details of the manner in which the contacts are mounted on switching arms 2 and 3 as well as the disposition and manner of attachment of the bank contacts are illustrated in FIGS. 6 and 8. The bank contacts 8 which are provided with annular contact elements 8a are secured by flange-like fixing members 57 with rounded edges; these members 57 are secured by bolts 58 to the wall of chamber 29.

The sparking contacts 47 have shafts 47a which are slidably held in the switching arms 2 and 3 in insulated manner. Insulation is provided by insulating bushings 59, 60 and 61 with each provided with a sliding passage for the shaft 47a of the sparking contact 47. Inserted into the middle insulating bushing 60 is a metal plate 62 which intercepts a collar 47a on the shaft of the sparking contact 47.

The annular main contacts 48 are fitted into the metal plate members 51 of arms 2 and 3. Each main contact 48 enircles shaft 47a of the associated sparking contact. In the working position illustrated in FIG. 7 the current flows from plate 51 through main contact 48, sparking contact 47, to the bank contact 8. If arm 2 is lowered, sparking contact 47 will be lifted off the main contact by the action of a compression spring 63. When this happens the above mentioned diverter resistor 49 (cf. FIG. 4) will be cut out of the circuit. However, in addition to compression spring 63, another spring 65 acts on the intermediate plate 64 which carries the insulating bushing 60, said additional spring 65 enveloping a threaded pin 66. The sparking contact 47 will therefore rise when switch arm 2 breaks the circuit until the compression of spring 65 is equal to that of spring 63.

An alternative arrangement of the contact elements on switching arms 2 and 3 is shown in FIG. 9. Whereas in the example shown in FIG. 7 the sparking contacts 47 are embodied in plates which are inoperative position bear down on the ring-shaped main contact 48 so that the working current must flow through the sparking contact plates, the sparking contacts 47 in FIG. 9 are dome-headed contacts which are completely displaced into the interior of the ring-shaped main contacts 48 when arms 2 and 3 are in "make" position. This form of construction has the advantage that the working current passes directly from the bank contact 8 into main contact 48 on the relative switching arm, whereas the sparking contacts, which after prolonged periods of service always show signs of wear, do not carry the full load but merely work in parallel with the main contact 48. Since the diverter resistor 49 lies in series with the sparking contact practically the full load will be carried by the main contacts 48.

FIGS. 10 and 11 schematically illustrate two alternative arrangements for a tap changer according to the invention for use in conjunction with a three-phase transformer. In the tap changer shown in FIG. 10 the switching arms 2a, 2b, 2c and 3a, 3b, 3c respectively which are associated with the three phases are arranged in tiers the one above the other and they can be jointly raised and lowered by the two shafts 4 and 5. The tap contacts 8 associated with the several phases are in this case correspondingly disposed in three tiered banks.

In the alternative example shown in FIG. 11 a separate on-load tap changer (each with a pair of movable switching arms 2 and 3) is associated with each of the three phases. The switching arms 2 and 3 are collectively operated by common actuating means 67 and 69 connected by chain transmissions or other drive means with the switching arms 2 and 3 of each tap changer assembly. In its fundamental construction and in the manner of its operation this three-phase on-load tap changer is completely analogous to the single phase tap changers that have already been described if it is desired that the on-load tap changers associated with each of the three phases should effect the change when the current passes through zero, then separate drive means must naturally be associated with each of the tap changing assemblies 1a, 1b, 1c and two independently operable motors 67, 68 must be provided for each changer.

Whereas in the illustrative embodiment shown in FIG. 10 the tap contacts associated with the three phases of the transformer were arranged in tiers and in FIG. 11
separate assemblies side by side, the tap contacts 8 in a form of construction that will now be described are arranged in a single circular bank, a sector of 120° being associated with each phase.

In the on-load tap changer shown in FIGS. 12 and 13, the switching arms 2 and 3 are arranged to form the star point. Consequently they are formed with three electrically connected arms 2d, 2e, and 3d, 3e, 3f respectively, each arm cooperating with one of the three sectors 70, 71, 72. The bank contacts 8 in each of the sectors 70, 71, 72 are connected with the star point tappings in the three phases of the transformer.

The arms of switching members 2 and 3 which—see FIG. 12—are slightly arched towards the bank of tap contacts 8 carry insulated and freely slidable movable sparking contacts 47 at their ends as well as main contacts 48 which are electrically connected with the arms themselves. Divertor resistances 49 interposed between the sparking contacts 47 and the switching arms 2 and 3 are affixed to the underside of each arm 2d, 2e, 2f, and 3d, 3e, 3f respectively.

The switching arms 2 and 3 are joined to a common hub 73 and 74 which is fast on a shaft 75 and 76, respectively. These shafts 75 and 76 can be stepped from tap as required by driving means 88a, 88b, 88c of their own which project from the bottom of the tank 83 and which are therefore easily accessible when the transformer is in operation. In the embodiment according to FIGS. 20 and 21—contrary to the previously described forms of construction—the switching arms 2 and 3 are not themselves contrived to be moved perpendicularly to their plane of rotation. This movement is performed only by the contact assemblies 100 which naturally represent a much lighter weight and are thus capable of being moved with a much smaller effort.

To this end two levers 102 are provided which—cf. FIG. 21—have relatively offset ends. The centre portion of these levers has bosses 103 which fulcrum on a pin 104 between the sides of each shaft 8 and 9. The outer end of said levers engages the contact assemblies 100 by means of a pin 106 and slot 105 motion. The inner end of each lever 102, of which both ends are bifurcated, is provided with inward projections 107 which engage a similar slide way on the inner shaft 5, said slide way being formed by two closely adjacent flange-like collars 108. The levers 102 are thus vertically tiltably connected with shaft 5 without at the same time interfering with the rotatability of the shaft.

The on-load tap change mechanism in this embodiment actually proceeds in exactly the same way as has been explained by reference to FIG. 4. The two switching arms 2 and 3 alternately perform the function of selecting a fresh contact 8 and taking over the load, and the vertical displaeeable of the contact assemblies whilst the shaft arms remain rigid ensures that tap changing can be performed at very high speed.

In this form of construction provision is likewise made to permit the tank containing the switching assembly and the bank contacts 8 to be freely lifted out of the casing 18 which is fitted with the tapping terminals 53.

What I claim is:
1. A tap change mechanism which comprises stationary tap contacts arranged in a plane and uniformly distributed round the circumference of a circle, two spiders each having the same number of arms and each arranged on a respective side of said plane and mounted on a respective rotatable shaft extending at right angles to said plane, and switching elements supported on the ends of the arms, and in which said shafts are rotatable independently of one another and axially movable simultaneously with one another and in the same direction to bring the switching elements on each of said spiders respectively into and out of contact with said tap contacts, and in which said spiders are arched to define spaces between said spiders and said plane, and which further comprises separate electromagnetic means, accommodated in said spaces, for moving each of said shafts towards said plane, arresting means, also accommodated...
in said spaces, for retaining each of said spiders in positions in which said switching elements on said spiders are in contact with said tap contacts, and further separate electromagnetic means for moving each of said shafts away from said plane.

2. A tap change mechanism which comprises stationary tap contacts arranged in a plane and uniformly distributed around the circumference of a circle, a stationary terminal, a rotatable hollow shaft extending through and at right angles to said plane, two arms located on each side of said plane and rigidly secured to said hollow shaft, two switching elements each carried by a respective one of said arms and slidable in a direction at right angles to said plane, an axially movable inner shaft extending parallel to and inside said hollow shaft, and two levers each fulcrumed on a respective one of said arms and having an inner end pivotally and slidably connected to said inner shaft and an outer end connected by a pin and slot motion to the switching element on said one of said arms, and which further comprises a respective resistor for each of said switching elements, and in which each switching element comprises a sparking contact permanently connected to the stationary terminal by conductor means independent of the resistor, said sparking contact being insulated from said main contact and slidable relatively to said main contact and said tap contacts, and resilient means urging said sparking contact into a position between said tap contacts and said main contact.

3. A tap change mechanism as claimed in claim 2, in which the central shaft has two pairs of adjacent collars defining circular guideways, and each end of each lever is bifurcated, the inner end of each lever having projections engaging in one of said guideways.

4. A tap change mechanism which comprises a stationary row of tap contacts arranged in a plane, a stationary terminal, a pair of switching elements permanently electrically connected to the stationary terminal and disposed one on each side of said plane and movable independently of one another parallel to said plane and movable simultaneously with one another in each of two opposite directions at right angles to said plane, whereby simultaneous movement of both of said switching elements in either one of said directions can bring one of said elements into contact with one of said tap contacts in said row and the other one of said elements out of contact with one of said tap contacts in said row, and which further comprises a respective resistor for each of said switching elements, and in which each switching element comprises a sparking contact permanently electrically connected to the terminal through the resistor, a main contact permanently connected to the stationary terminal by conductor means independent of the resistor, said sparking contact being insulated from said main contact and slidable relatively to said main contact and said tap contacts, and resilient means urging said sparking contact into a position between said row of tap contacts and said main contact.

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