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(54) AN ON-LOAD TAP-CHANGER ADAPTED FOR LINEAR SWITCHING

(57) The present invention relates to an on-load tap-changer (33) adapted for linear switching comprising:
- a tap selector (34) including a first selector part (36) having a plurality of first stationary contacts (38) for connection to a regulating winding (40) and two movable contacts (VA, HA) adapted to connect to the stationary contacts, and a second selector part (42) having a plurality of second stationary contacts (44) for connection to the regulating winding and two movable contacts (VB, HB) adapted to connect to the second stationary contacts,
- a diverter switch (16) connected to the tap selector for providing tap changing, and
- two change-over selectors (46, 48) connected between the diverter switch (16) and the tap selector (34), and arranged to select between connecting the diverter switch to the first selector part and connecting the diverter switch to the second selector part.

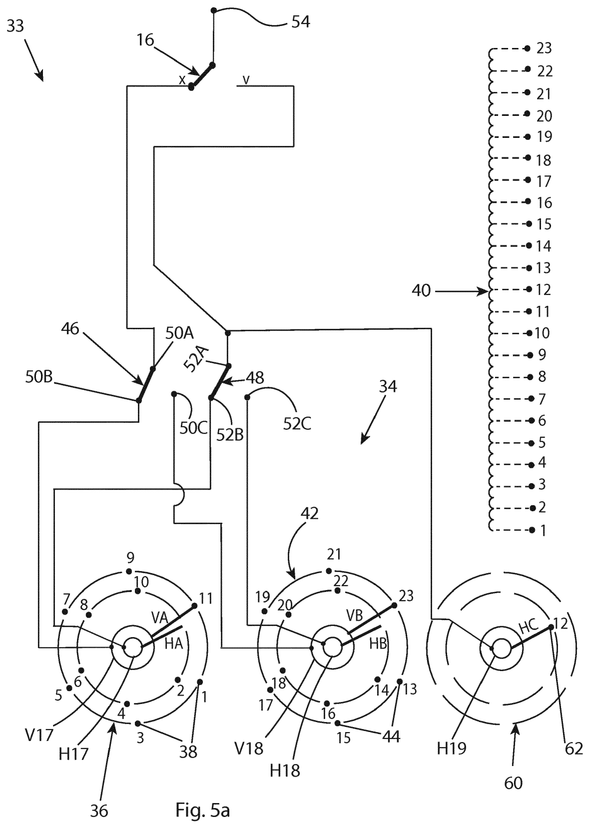


Fig. 5a

EP 3 258 475 A1

Description

Field of the invention

[0001] The present invention relates to the field of power regulation, and in particular to on-load tap-changers and voltage regulation of power transformers by means of on-load tap-changers.

Background of the invention

[0002] Tap-changers are used for controlling the output voltage of a transformer by providing the possibility of switching in or switching out additional turns in a transformer winding. A tap-changer comprises a set of stationary contacts which are connectable to a number of taps of a regulating winding of a transformer, where the taps are located at different positions in the regulating winding. A tap-changer further comprises at least one moveable contact which is connected to a current collector at one end, and connectable to one of the stationary contacts at another end. By switching in or out the different taps, the effective number of turns of the transformer can be increased or decreased, thus regulating the output voltage of the transformer.

[0003] Tap-changers are either on-load, i.e. operating while the transformer is energized, or off-load, i.e. operating while the transformer is not energized. In orderto avoid high circulating currents between the new and the old tap while both taps are connected, many tap-changers include a diverter device, by which a large transition resistor can be connected between the old and the new tap during the tap changing event. In a diverter-type tap-changer, the electrical connection between the stationary contacts and an external contact is typically formed by a diverter switch together with a tap selector. A diverter-switch tap-changer comprises a diverter switch as well as a tap selector. The tap selector is used to select the tap to which the load current is to be transferred, while the diverter switch is used to perform the commutation of the load current from the presently connected tap to the tap selected by the tap selector.

[0004] The transformer has a main winding and a regulating winding connected to the main winding. The regulating winding includes the taps. The regulating windings in the transformer can be connected to the main winding in different ways providing different types of regulation. For example, the windings can be arranged for linear regulation, plus-minus regulation, and coarse regulation.

[0005] Figure 1 shows an example of linear regulation of transformer windings. The windings comprise a main winding 1 and a regulating winding 2 connected to the main winding. The regulating winding 2 is provided with a plurality of taps 3 connected to different parts of the regulating winding. Each of the taps 3 is connected to stationary contact of a tap-changer. The tap-changer has a movable contact 4 for connection to the stationary contacts and accordingly to the taps 3. The movable contact 4 is being moved between the stationary contacts to connect different taps 3, and thereby choosing the number of connected turns of the regulating winding. The linear arrangement is generally used on power transformers with moderate regulating ranges up to a maximum of 20%. The tapped turns are added in series with the main winding and changes the transformer ratio. The rated position can be any of the tap positions. Linear connection is normally possible up to 18 positions. An advantage with the linear regulation is low load losses. However, a disadvantage with the linear regulation is the limited regulating range.

[0006] Figure 2a shows an example of a prior art on-load tap-changer 10 adapted for linear regulation having a regulation range of 18 positions. Thus, the on-load tap-changer 10 can suitably be connected to a regulating winding 12 having 18 taps. The on-load tap-changer 10 comprises a tap selector 14 and a diverter switch 16 connected to the tap selector 14 and configured to switch between a first connection point x and a second connection point v. The tap selector 14 comprises two current collectors in the form of a first contact ring H17 and a second contact ring V17 arranged at different vertical levels. The first connection point x is connected to the first contact ring V17 and the second connection point v is connected to the second contact ring H17. The tap selector 14 has 18 stationary contacts 19 given no. 1- 18 and two movable contacts denoted V and H. The stationary contacts 19 are arranged at a distance from the contact rings in different radial directions, and the movable contacts V and H are arranged rotatable about the contact rings and adapted to electrically connect the stationary contacts 19 one at a time with the contact rings V17, H17.

[0007] The movable contact V is movable between the stationary contacts 19 given odd numbers, and the movable contact H is movable between the stationary contacts 19 given even numbers. The stationary contacts 19 given odd numbers are arranged in a first horizontal plane, and the stationary contacts 19 given even numbers are arranged in a second horizontal plane arranged at a vertical distance from the first plane. The movable contacts V, H are arranged at different vertical levels. The movable contacts V and H are arranged to make electrical contact with the stationary contacts 19. Each of the stationary contacts 19 are electrically connected to one of the taps 1 - 18 of the regulating winding 12.

[0008] Figure 2b shows a table including, for each of the 18 positions, information on which one of the movable contacts is used in the position, which one of the stationary contacts is connected to the movable contact in the position, and the position of the diverter switch in the position. For example, in position 1, the movable contact V is electrically connected to the stationary contact 1, and the diverter switch 16 is connected to the first connection point x. In position 2, the movable contact H is electrically connected to the stationary contact 2, and the diverter switch 16 is connected to the second connection point v.

[0009] Figure 3 shows an example of plus-minus regulation of transformer windings. A change over-selector 5 is arranged between the main winding 1 and the regulating winding 2 so that the main winding 1 is connected to a plus position or a minus position of the regulating winding depending on the position of the change-over selector. The movable contact 4 is moving between the stationary contacts to connect different taps 3, and thereby choosing the number of connected turns of the regulating winding. The number of connected turns is selected by switching the connection between the plus and the minus positions of the regulating winding and stepping up and down among the taps. With plus-minus regulation, the regulating winding is added to or subtracted from the main winding so that the regulating range can be doubled, or the number of taps can be reduced. During the switching operation, the regulating winding is disconnected from the main winding. An advantage with the plus-minus regulation is the large regulating range, normally up to 35 positions. However, a disadvantage with the plus-minus regulation is that large load losses may occur. This is particularly the case in a position with minimum number of effective turns.

[0010] Figure 4a shows an example of a prior art on-load tap-changer 24 adapted for plus/minus regulation having a regulation range of 23 positions. Like or corresponding parts in the figures are indicated with like numerals. The on-load tap-changer 24 can suitably be connected to a regulating winding 26 having thirteen taps 27. The on-load tap-changer 24 comprises a tap selector 28 and a diverter switch 16 comprising a first connection point x and a second connection point v for connection to the tap selector 28. The on-load tap-changer 24 further comprises a change-over selector 5 connected between the regulating winding 26 and the tap selector 28. The tap selector 28 has 12 stationary contacts 30 given numbers 1 - 12 and two movable contacts V and H. The stationary contacts given odd numbers are arranged on a first horizontal plane, and the stationary contacts given even numbers are arranged on a second horizontal plane at a distance from the first plane. The movable contact V is movable between the stationary contacts 30 given odd numbers, i.e. no. 1, 3, 5, 7, 9, 11 and the movable contacts H is movable between the stationary contacts 30 given even numbers, i.e. no. 2, 4, 6, 8, 10, 12. The stationary contacts no. 1-11 are electrically connected to the taps 1 - 11 of the regulating winding, the stationary contact 12 is electrically connected to a tap 32 of the main winding, and the change-over selector 5 is configured to switch between a first position (20-21) where the tap 32 of the main winding is connected to an upper part of the regulating winding, i.e. tap no. 21 of the regulating winding, and a second position (20-22) where the tap 32 of the main winding is connected to a lower part of the regulating winding, i.e. tap no. 21 of the regulating winding.

[0011] Figure 4b shows a table including, for each of the 23 positions, information on the state of the change-over switch 5, which one of the movable contacts is used in the position, which one of the stationary contacts is connected to the movable contact in the position, and the position of the diverter switch in the position. For example, in position no. 1, the state of the change-over switch 5 is 20 - 21, the movable contact V is electrically connected to the stationary contact no. 1, and the diverter switch 16 is connected to the first connection point x. In position no. 12, the change-over switch 5 switches to another state, i.e. between 20 - 21 and 20-22, the movable contact H is electrically connected to the stationary contact no. 12, which is connected to the tap 32 of the main winding, and the diverter switch 16 is connected to the second connection point v.

[0012] Many customers value low load losses, both for long term economic reasons and environmental reasons. HVDC transformers often have a large regulation range, normally from 25 to 35 positions. The load losses are evaluated in a position near the minus position. Today most HVDC transformers are provided with plus/minus regulation that has higher load losses near the minus positions compared to linear or coarse regulations. The regulation is often placed close to the core. Linear connection is not possible due to the limited regulation range. Coarse regulation is often not possible for dielectric reasons or is too expensive since the regulation needs two windings.

[0013] One solution to this problem is disclosed in a book written by Dr-Axel Krämer with the title "ON-LOAD TAP-CHANGERS FOR POWER TRANSFORMERS" published 2014, ISBN 978-3-931954-47-5, chapter 5.1.2, page 198-199. A tap selector that enables linear regulation up to 35 positions is disclosed in the book. In the book it is proposed to double the tap selector contact levels, which means doubling the number of stationary and movable contacts compared to standard selector design. Thus, nearly twice the number of selector connecting points for the connection to the regulating winding can be achieved. A successive switching sequence of the stacked stationary contacts is accomplished by dividing the standard operating angle of the Geneva gear in half and using two electrically and mechanically coupled tap selector moving contacts staggered by this angle. Compared to a plus/minus connection, this solution grants lower load losses. However, this is a complex solution with two tap selectors connected with a mechanical shaft. A disadvantage of this solution compared to other linear solutions is that the distance between electrically adjacent contacts is relatively small due to the fact that a blind position is added in between the fixed contacts. A small distance between contacts leads to reduced withstand of voltage.

<u>Object and summary of the invention</u>

[0014] It is an object of the present invention to at least partly overcome the above problems, and to provide voltage regulation of power transformers with a large regulating range and low load losses.

[0015] According to one aspect of the invention, this object is achieved by an on-load tap-changer as defined in claim 1.

[0016] The on-load tap-changer is adapted for linear switching and comprises:

- a tap selector including a first selector part having a plurality of first stationary contacts for connection to a regulating winding and two movable contacts adapted to connect to the stationary contacts, and a second selector part having a plurality of second stationary contacts for connection to the regulating winding and two movable contacts adapted to connect to the second stationary contacts,
- a diverter switch connected to the tap selector for providing tap changing, and
- two change-over selectors connected between the diverter switch and the tap selector and arranged to select between connecting the diverter switch to the first selector part and connecting the diverter switch to the second selector part.

[0017] According to the invention, the on-load tap-changer comprises one tap selector with at least two tap selector parts and the change-over selectors are arranged to select which one of the tap selector parts is connected to the diverter switch. Thus, it is possible to provide linear regulation with twice as many positions as a traditional lineartap-changer. Traditionally, linear tap selectors have maximum 18 or 22 positions. By connecting the prior art tap selectors according to the invention, it is possible to achieve linear connection with up to 35 positions.

[0018] During a first half of the regulation range, the two change-over selectors connect the cables from the diverter switch to the first selector part in the selector unit. Thus, the tap-changer uses the first selector part to connect the regulating winding of the transformer to the diverter switch during the first half of the regulation range. When the tap-changer reached the highest position of the first selector part, the change-over selectors switch to connect the diverter switch to the second selector part of the selector unit. During a last half of the regulation range, the two change-over selectors connects the cables from the diverter switch to the second selector part in the selector unit. Thus, the tap-changer uses the second selector part to connect the regulating winding to the diverter switch during the last half of the regulation range.

[0019] The benefit using linear connection compared to plus/minus connection is lower losses in the minus positions. This can also decrease the need of cooling equipment. The invention is particularly useful for medium size High-Voltage Direct Current (HVDC) transformers, and will decrease the losses in the transformer in nominal position with more than 10% compared to the plus-minus connection.

[0020] The benefit of using linear connection compared to coarse fine regulation is that coarse fine regulation needs two regulating windings and is not always possible to employ because of dielectric sensibilities between the two windings and leakage flux limitations.

[0021] A further benefit is that a one-phase linear tap selector can be achieved by connecting a traditional plus/minus three-phase tap selector in a new way. Normally, the change-over selectors are connected between the regulating winding and the tap selector. According to the invention, the change-over selectors are connected between the diverter switch and the tap selector parts. It is easy to rebuild a plus/minus three-phase tap-changer to a linear tap-changer according to the invention. Since a tap-changer with change-over selectors and diverter switch are standard components it is not so much work needed to implement the invention.

[0022] A change-over selector is a switch configured to switch between a first and a second position.

[0023] According to an embodiment of the invention, the change-over selectors are configured to move between a first and a second position, and the first selector part is connected to the diverter switch when the change-over selectors are in the first position and the second selector part is connected to the diverter switch when the change-over selectors are in the second position. It can be advantageous to move the change-over selectors synchronously to achieve a more reliable solution.

[0024] According to an embodiment of the invention, the diverter switch is configured to switch between a first connection point x and a second connection point v, and a first of the change-over selectors is connected to the first connection point x and a second of the change-over selectors is connected to the second connection point v.

[0025] According to an embodiment of the invention, each of the change-over selectors is configured to switch between connecting the diverter switch to the movable contacts of the first selector part and connecting the diverter switch to the movable contacts of the second selector part. Each of the change-over selectors is connected to one of the movable contacts of the first selector part and to one of the movable contacts of the second selector part.

[0026] According to an embodiment of the invention, one of the change-over selector is configured to switch between connecting the first connection point of the diverter switch to one of the movable contacts of the first selector part and connecting the first connection point of the diverter switch to one of the movable contacts of the second selector part, and the other of the change-over selector is configured to switch between connecting the second connection point of the diverter switch to one of the movable contacts of the first selector part and connecting the second connection point of the diverter switch to one of the movable contacts of the second selector part.

[0027] According to an embodiment of the invention, each of the change-over selectors are two-way switches having three connection points, and a first of the connection points is electrically connected to the diverter switch, a second of the connection points is electrically connected to one of the movable contacts of the first selector part, and a third of the connection points is electrically connected to one of the movable contacts of the second selector part, and the change-over selectors are arranged to switch between electrically connecting the diverter switch to the movable contacts of the first selector part, and electrically connecting the diverter switch to the movable contacts of the second selector part. With a two-way switch is meant a device is configured to upon command switch between electrically connecting a first connection point to a second connection point, and connecting the first connection point to a third connection point.

[0028] According to an embodiment of the invention, the on-load tap-changer comprises a third selector part having one stationary contact for connection to the regulating winding, wherein the third selector part is connected to the diverter switch and is by-passing the change-over selectors during switching between the first and second selector parts. This embodiment makes it possible to switch between the first and second selector parts without breaking the current. When the tap-changer has reached the last position of the first selector part, the diverter switch is connected to the third selector part while the change-over selectors is switching to the second selector part. In the same way, when the tap-changer has reached the first position of the second selector part, the diverter switch is connected to the third selector part while the change-over selectors is switching back to the first selector part.

[0029] According to an embodiment of the invention, each of the first and second selector parts has at least 9 stationary contacts. This embodiment enables linear regulation up to 19 positions.

[0030] According to an embodiment of the invention, each of the first and second selector parts has at least 13 stationary contacts. This embodiment enables linear regulation up to 27 positions.

[0031] According to an embodiment of the invention, each of the first and second selector parts has at least 17 stationary contacts. This embodiment enables linear regulation up to 35 positions.

[0032] According to another aspect of the invention, this object is achieved by a method for switching the on-load tap-changer as defined in claim 10.

[0033] The method comprises:

- switching the two change-over selectors so that the diverter switch is connected to the first selector part,
- moving repeatedly the movable contacts of the first selector part to connect to the stationary contacts of the first selector part,
- switching the two change-over selectors so that the diverter switch is connected to the second selector part,
- moving repeatedly the movable contacts of the second selector part to connect to the stationary contacts of the second selector part.

The movable contacts of both selector parts can be moved at the same time, however only one of the selector parts will be galvanically connected to the diverter switch, and carry the load at any given point in time.

[0034] According to an embodiment of the invention, the diverter switch is connected to a stationary contact of a third tap selector part while the change-over selectors are switching between the first and second selector parts.

[0035] The on-load tap-changer according to the invention can be used for linear voltage regulation of a power transformer.

[0036] According to a further aspect of the invention, this object is achieved by system for voltage regulation of a transformer as defined in claim 13.

[0037] The system comprises a transformer having a main winding and a regulating winding provided with a plurality of taps and connected to the main winding in series, and a tap-changer according to the invention connected to the taps of the regulating winding.

[0038] According to an embodiment of the invention, a contact of the diverter switch is connected to the main winding. The benefits of this embodiment is that the regulating winding will be electrically closer to the main winding, and it is possible to place them physically closer to each other. Thus, the duct between regulating winding and main winding can be reduced.

[0039] According to an embodiment of the invention, the main winding is connected to one end of the regulating winding.

[0040] It can be advantageous to combine the tap-changer according to the invention with bias regulation to reduce the number of cables from the regulating winding.

Brief description of the drawings

[0041] The invention will now be explained more closely by the description of different embodiments of the invention and with reference to the appended figures.

Fig. 1 shows an example of prior art linear regulation of transformer windings.

Fig. 2a shows an example of a prior art on-load tap-changer adapted for linear regulation.

Fig. 2b shows a table illustrating possible regulation positions of the on-load tap-changer of figure 2a.

Fig. 3 shows an example of prior art plus/minus regulation of transformer windings.

Fig. 4a shows an example of a prior art on-load tap-changer adapted for plus/minus regulation.

Fig. 4b shows a table illustrating possible regulation positions of the on-load tap-changer of figure 4a.

Fig. 5a shows an on-load tap-changer adapted for linear regulation according to an embodiment of the invention.

Fig. 5b shows a table illustrating possible regulation positions of the on-load tap-changer of figure 5a.

Fig. 6 shows a system for voltage regulation comprising a transformer winding and a tap-changer according to an embodiment of the invention.

Detailed description of preferred embodiments of the invention

[0042] Figure 5a shows a one phase on-load tap-changer 33 adapted for linear regulation according to an embodiment of the invention. The on-load tap-changer 33 comprises a tap selector 34. The tap selector 34 is used to select to which tap of a transformer winding the load current is to be transferred. The tap selector 34 includes a first selector part 36, having a plurality of first stationary contacts 38 for connection to a regulating winding 40 and two movable contacts VA and HA adapted to connect to the stationary contacts 38. The tap selector 34 also includes a second selector part 42 having a plurality of second stationary contacts 44 for connection to the regulating winding 40 and a first and a second movable contact VB, HB adapted to connect to the stationary contacts 44. In this embodiment, each of the first and second selector parts 36, 42 has 11 stationary contacts for connection to the regulating winding 40 of the transformer. The regulating winding 40 of the transformer has a set of taps, and each of the fixed contact 38, 44 is connectable to one of the taps of the regulating winding 40. In this embodiment, the regulating winding 40 has 23 taps. The regulating winding 40 is shown in figure 5a for illustrative purposes, and is normally not seen as a part of the tap-changer.

[0043] The on-load tap-changer 33 also comprises a diverter switch 16. The diverter switch 16 is designed to be part of the electrical connection between the transformer and a connecting contact 54 of the tap-changer. The diverter switch 16 is connected to the tap selector 34 for providing tap changing. The diverter switch can be sequentially operated to perform a switching operation between two taps of the regulating winding 40. The diverter switch 16 is used to perform the commutation of the load current from the presently connected tap to a tap selected by the tap selector 34. The diverter switch 16 is connected between the connecting contact 54 and the tap selector 34. The diverter switch 16 comprises a first connection point x for electrical connection to a current collector of the tap selector, a second connection point v for electrical connection to another current collector of the tap selector, and a third connection point for electrical connection to the connecting contact 54 of the tap-changer.

[0044] The on-load tap-changer 33 comprises a first change-over selector 46 and a second change-over selector 48 connected between the diverter switch 16 and the first and the second selector parts 36, 42. The change-over selectors 46, 48 are arranged to select between connecting the diverter switch 16 to the first selector part 36 and connecting the diverter switch 16 to the second selector part 42. Suitably, the change-over selectors 46, 48 are switched synchronously. However, the change-over selectors can also be moved independently. Each of the change-over selectors 46, 48 can be two-way switches having three connection points 50A, 50B, 50C and 52A, 52B, 52C. This means that change-over selectors are configured to switch between electrically connecting a first connection point to a second connection point and connecting the first connection point to a third connection point. In this case, first connection points 50A, 52A are electrically connected to the diverter switch 16, second connection points 50B, 52B are electrically connected to one of the movable contacts VA, HA of the first selector part 36, and third connection points 50C, 52C are electrically connected to one of the movable contacts VB, HB of the second selector part 42.

[0045] The change-over selectors 46, 48 are arranged to switch between electrically connecting the diverter switch 16 to the movable contacts VA, HA of the first selector part, and electrically connecting the diverter switch to the movable contacts VB, HB of the second selector part.

[0046] The first connection point 50A of the first change-over selector 46 is stationary connected to the connection point x of the diverter switch 16. The first connection point 52A of the second change-over selector 48 is stationary connected to the connection point v of the diverter switch 16. Each of the change-over selectors 46, 48 comprises a movable arm having one end connected to the first connection point 50A, 52A. The other end of the movable arm is arranged movable between the second connection points 50B, 52B and the third connection points 50C, 52C. The second connection point 50B of the first change-over selector 46 is connected to the first selector part 36, and the third connection point 50C is connected to the second selector part 42. The second connection point 52B of the second change-over selector 48 is connected to the first selector part 36 and the third connection point 52C is connected to the second selector part 42. When the change-over selectors 46, 48 are connected to the second connection points 50B, 52B, the change-over selectors are in a first position, and when the change-over selectors are connected to the third connection points 50C, 52C, the change-over selectors are in a second position.

[0047] The change-over selectors 46, 48 are moving between the first and the second positions, and the first selector part 36 is connected to the diverter switch 16 when the change-over selectors 46, 48 are in the first positions and the second selector part 42 is connected to the diverter switch 16 when the change-over selector 46,48 are in the second position. Thus, the change-over selectors are configured to switch between connecting the connection points x and v of the diverter switch to the first selector part 36 and the second selector part 42.

[0048] The movable contacts VA, HA, VB, HB in the tap selectors 36, 42 are adapted to connect to different stationary taps. In this embodiment, the movable contact VA of the first selector part 36 is movable between the stationary contacts 38 given odd numbers, i.e. no. 1,3,5,7,9,11, and the movable contacts HA of the first selector part is movable between the stationary contacts 38 given even numbers, i.e. no. 2,4,6,8,10. The movable contact VB of the second selector part is movable between the second stationary contacts 44 given odd numbers, i.e. no. 13, 15, 17, 19, 21, 23 and the movable contact HB of the first selector part is movable between the second stationary contacts 44 given even numbers, i.e. no. 14, 16, 18, 20, 22.

[0049] Each of the first and second selector part 36, 42 comprises two current collectors V17, H17 and V18, H18. In this example, the current collectors are contact rings. Each of the movable contacts VA, VB, HA, HB, HC is connected to one of the current collector V17, H17, V18, H18, H19, such as a contact ring. The first selector part 36 comprises the current collectors V17 and H17, and the second selector part 42 comprises the current collectors V18 and H18. The current collector V17 is connected to the movable contact VA and the second connection point 50B. The current collector H17 is connected to the movable contact HA and the second connection point 52B. The current collector V18 is connected to the movable contact VB and the third connection point 52C. The current collector H18 is connected to the movable contact HB and the third connection point 50C. When changing between the first and the second positions of the change-over selectors, different stationary contacts become available for connection. The current collector H19 is connected to the movable contact HC and the first connection point 52A.

[0050] In one embodiment of the invention, the tap selector 34 may comprise a third selector part 60, as shown in figure 5a. The third selector part 60 has one stationary contact 62 for connection to the regulating winding 40. The stationary contact 62 represents position no 12. The third selector part 60 comprises a current collector H19 and a movable contact HC connected to the current collector H19. The movable contact HC is configured to connect the stationary contact 62 to the current collector H19. The third selector part 60 is electrically connected to the diverter switch 16. In this example, the current collector H19 of third selector part 60 is connected to connecting point v of the diverter switch 16. Thus, the third selector part can bypass the change-over selectors during switching between the first and second selector parts.

[0051] While switching between the first and the second selector parts 36, 42, the diverter switch is electrically connected to the stationary contact 62 in the third selector part 60 and is by-passing the change-over selectors 46, 48. In order to switch between the first and the second selector parts 36, 42 the movable contacts HA, HB must be in a blind position where they are not electrically connected to the regulating winding. In this embodiment, such positions of the movable contacts are shown in figure 5a. During the switching between the first and the second selector parts, the contact 62 is electrically connected to the connection point v at the diverter switch. In other positions the movable contact HC is in a blind positions. With a blind position is meant a position without any stationary contact. When the movable contact is in a blind position, the movable contact is not connected to any of the stationary contacts.

[0052] Figure 5b shows a table illustrating how the tap-changer is stepped up and down among the 23 positions. The table includes, for each of the 23 positions, information on the current position of the change-over selector, which one of the movable contacts is used in the position, which one of the stationary contacts is connected to the movable contact in the position, and the position of the diverter switch in the position. For example, in position no. 1, the change-over selectors 46,48 are in the first position, the movable contact VA is electrically connected to the stationary contact no. 1, and the diverter switch 16 is connected to the first connection point x. In position no. 12, the change-over selectors 46, 48 switch to the other position, i.e. between the first and second position, and the movable contact HC is electrically connected to the stationary contact 62 position no. 12, which is connected to the tap 12 of the regulating winding, and the second connection point v of the diverter switch 16 is connected to the current collector H19 of the third selector part.

[0053] When the tap-changer is stepped up from position 1 to position 11, the two change-over selectors are switched to the first position so that the diverter switch is connected to the first selector part, and the movable contacts 38 of the first selector part are repeatedly moved between stationary contacts of the first selector part, i.e. from the first stationary contact no. 1 until the movable contact VA has connected the last stationary contact no. 11 of the first selector part. Then the movable contact HA and the movable contact HB of the second selector part are moved to the blind positions and the movable contact HC is moving to position 12. The diverter switch is electrically connected to the third selector part 60 while the change-over selectors are switching between the first and second selector parts. The two change-over selectors are switched to the second position so that the diverter switch is connected to the second selector part. Then, the movable contacts 44 of the second selector part are repeatedly moved between stationary contacts of the second selector part, i.e. from the first stationary contact no. 13 until the movable contact VB has connected the last stationary contact no. 23 of the second selector part. The same procedure is repeated in reverse order when the tap-changer is stepped down from position 23 to position 1.

[0054] In one embodiment of the invention, the first and second selector parts 36, 42 are arranged on top of each other and at different vertical levels. For example, the first selector part 36 is arranged above then second selector part 42, or vice versa. This embodiment provides a compact tap selector and saves space. In the embodiment with three tap selector parts, all three tap selector parts 36, 42, 60 are arranged on top of each other and at different vertical levels in order to save space.

[0055] The regulation shown in figure 5a can be connected in two different ways. First alternative is to connect main winding to contact 23 of regulating winding 40 and contact 54 of the tap-changer 33 to terminal or other winding. The connection to contact 54 is normally a cable connected to a neutral terminal or another terminal. However, it is often an advantage to connect the regulation differently. Instead of connecting the contact 54 of the tap-changer 33 to a terminal and one end of regulation winding to the main winding, contact 1 of the regulation winding 40 is connected to a terminal, and the contact 54 of the tap-changer 33 is connected to the main winding. The advantage with this embodiment is that the duct between regulating winding and main winding can be reduced.

[0056] Figure 6 shows a system for voltage regulation comprising a transformer winding and a tap-changer according to an embodiment of the invention. The transformer has a main winding 1 and a regulating winding 40 provided with a plurality of taps 1- 23 and connected to the main winding 1 in series. The system further comprises the tap-changer 33 having 23 stationary contacts connected to the taps 1 - 23 of the regulating winding. The stationary contacts no. 1 - 11 of the first selector part are connected to the taps 1 - 11 of the regulating winding 40. The stationary contacts no. 13 - 23 of the second selector part are connected to the taps 13 - 23 of the regulating winding, and the stationary contact no. 12 of the third selector part is connected to the tap 12 of the regulating winding 40. In this embodiment, contact 23 of the regulating winding is connected to neutral terminal, and the contact 54 of the diverter switch 16 of the tap-changer 33 is connected to a bottom part of the main winding 1. The bottom part of the regulating winding can also be connected to a terminal. An advantage with this embodiment is that the duct between regulating winding and main winding can be reduced.

[0057] Some transformer designs may have problem with unwanted large oscillations in the regulating winding when few or no turns are carrying current. This can be decreased considerably by splitting the winding in two halves. For example, if this is done for the design described in figure 5a. The regulating winding 40 would be divided at contact 12. One additional contact is gained by splitting the winding. The additional contact is located on the part of the winding with the lower number of contacts. A third change-over selector is added. The third change-over selector is moved at the same time as the first and second change-over selectors. At position 1 to 11, the third change-over selector connects the additional contact to contact 12. At position 13 to 23 the third change-over selector connects the additional contact to contact 23. This solution can be done in a second version. By also changing the connection of V18 from contact 50C to 50A and H18 from 52C to 52A, the two halves will be connected in parallel in positions 13 to 23. This will decrease heating and the resistive losses by 50 % in the regulation winding for positions 13 to 23. Positions 13 to 23 are normally the positions with the most current. The second version is not an option if there may be circulating currents between the two parallel parts of the winding. When splitting the regulation winding like this, tie-in resistors may be needed in a middle position for the part of the winding with the lower contacts number.

[0058] The present invention is not limited to the embodiments disclosed but may be varied and modified within the scope of the following claims. For example, the first and second selector parts can have more than 10 stationary contacts. For example, the first and second selector parts may have 17 stationary contacts each. In this case, the number of possible regulation positions will be 35. The invention is not limited to transformer applications, but can also be used in other applications, such as for variable reactors.

Claims

1. An on-load tap-changer (33) adapted for linear switching comprising:

    - a tap selector (34) including a first selector part (36) having a plurality of first stationary contacts (38) for connection to a regulating winding (40) and two movable contacts (VA, HA) adapted to connect to the stationary contacts, and
    - a diverter switch (16) connected to the tap selector for providing tap changing, **characterized in that** the tap selector (34) includes a second selector part (42) having a plurality of second stationary contacts (44) for connection to the regulating winding and two movable contacts (VB, HB) adapted to connect to the second stationary contacts, and the on-load tap-changer comprises two change-over selectors (46, 48) connected between the diverter switch (16) and the tap selector (34) and arranged to select between connecting the diverter switch to the first selector part and connecting the diverter switch to the second selector part.

2. The on-load tap-changer according to claim 1, wherein the change-over selectors (46, 58) are configured to move between a first position and a second position, and the first selector part (36) is connected

to the diverter switch (16) when the change-over selectors are in the first position and the second selector part (42) is connected to the diverter switch (16) when the change-over selectors are in the second position.

3. The on-load tap-changer according to claim 1 or 2, wherein each of the change-over selectors (46, 48) is configured to switch between electrically connecting the diverter switch (16) to one of the movable contacts (38) of the first selector part (36) and electrically connecting the diverter switch (16) to one of the movable contacts (44) of the second selector part (42).

4. The on-load tap-changer according to any of the previous claims, wherein the diverter switch (16) is configured to switch between a first connection point (x) and a second connection point (v), and a first of the change-over selectors (46) is connected to the first connection point (x) and a second of the change-over selectors (48) is connected to the second connection point (v).

5. The on-load tap-changer according to any of the previous claims, wherein a first of the change-over selectors (46) is configured to switch between connecting the first connection point (x) of the diverter switch (16) to one of the movable contacts (VA, HA) of the first selector part (36) and connecting the first connection point (v) of the diverter switch (16) to one of the movable contacts (VB, HB) of the second selector part (42), and a second of the change-over selectors (48) is configured to switch between connecting the second connection point (v) of the diverter switch (16) to one of the movable contacts (VA, HA) of the first selector part and connecting the second connection point (x) of the diverter switch (16) to one of the movable contacts (VB, HB) of the second selector part.

6. The on-load tap-changer according to any of the previous claims, wherein each of the change-over selectors (46, 48) are two-way switches having three connection points, and a first of the connection points is electrically connected to the diverter switch (16), a second of the connection points is electrically connected to one of the movable contacts (VA, HA) of the first selector part (36), and a third of the connection points is electrically connected to one of the movable contacts (VB, HB) of the second selector part (42), and the change-over selectors are arranged to switch between electrically connecting the diverter switch to the movable contacts of the first selector part, and electrically connecting the diverter switch to the movable contacts of the second selector part.

7. The on-load tap-changer according to any of the previous claims, wherein the on-load tap-changer comprises a third selector part (60) having one stationary contact (62) for connection to the regulating winding, wherein the third selector part is connected to the diverter switch (16) and is by-passing the change-over selectors (46, 48) during switching between the first and second selector parts (36, 42).

8. The on-load tap-changer according to any of the previous claims, wherein each of the first and second selector parts (36, 42) has at least 9 stationary contacts (38, 44), and preferably at least 13 stationary contacts.

9. The on-load tap-changer according to any of the previous claims, wherein each of the first and second selector parts (36, 42) has at least 17 stationary contacts (38, 44).

10. A method for switching the on-load tap-changer according to claim 1, wherein the method comprises:

- switching the two change-over selectors (46, 48) so that the diverter switch (16) is connected to the first selector part (36),
- moving repeatedly the movable contacts (VA, HA) of the first selector part (36) to connect to the stationary contacts (38) of the first selector part,
- switching the two change-over selectors so that the diverter switch is connected to the second selector part (42), and
- moving repeatedly the movable contacts (VB, HB) of the second selector part (42) to connect to the stationary contacts (44) of the second selector part.

11. The method according to claim 10 for switching the on-load tap-changer according to claim 7, wherein the diverter switch (16) is connected to the third selector part (60) while said change-over selectors (46, 48) are switching between the first and second selector parts (36, 42).

12. Use of an on-load tap-changer according to any of the claims 1 - 9 for linear voltage regulation of a power transformer.

13. A system for voltage regulation comprising a transformer having a main winding (1) and a regulating winding (40) provided with a plurality of taps (1 - 23), **characterized in that** the system comprises a tap-changer according to any of the claims 1- 9, and the first stationary contacts (38) and the second stationary contacts (44) are connected to the taps of the regulating winding.

14. The system according to claim 13, wherein a contact

(54) of the diverter switch (16) is connected to the main winding (1).

15. The system according to claim 13, wherein the main winding (1) is connected to one end of the regulating winding (40).

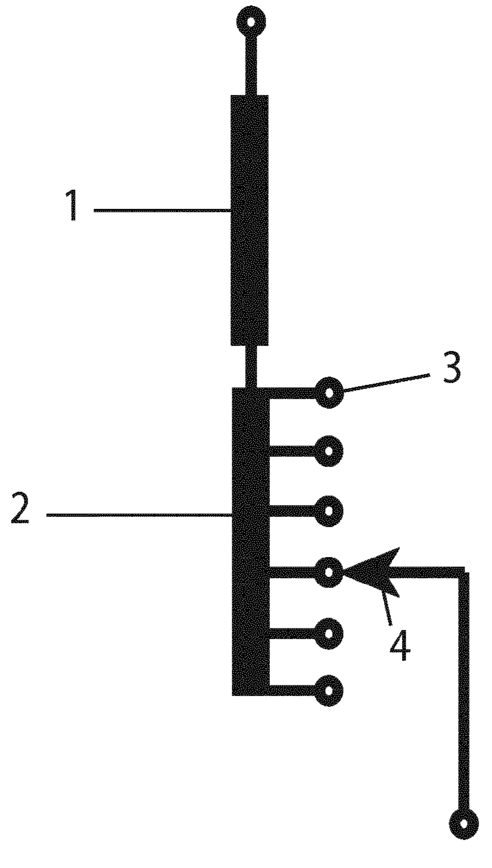


Fig 1
(Prior art)

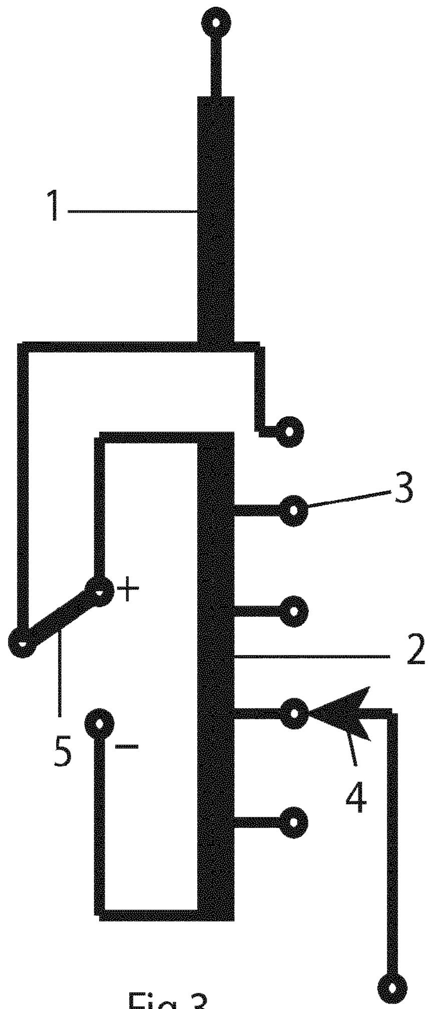


Fig 3
(Prior art)

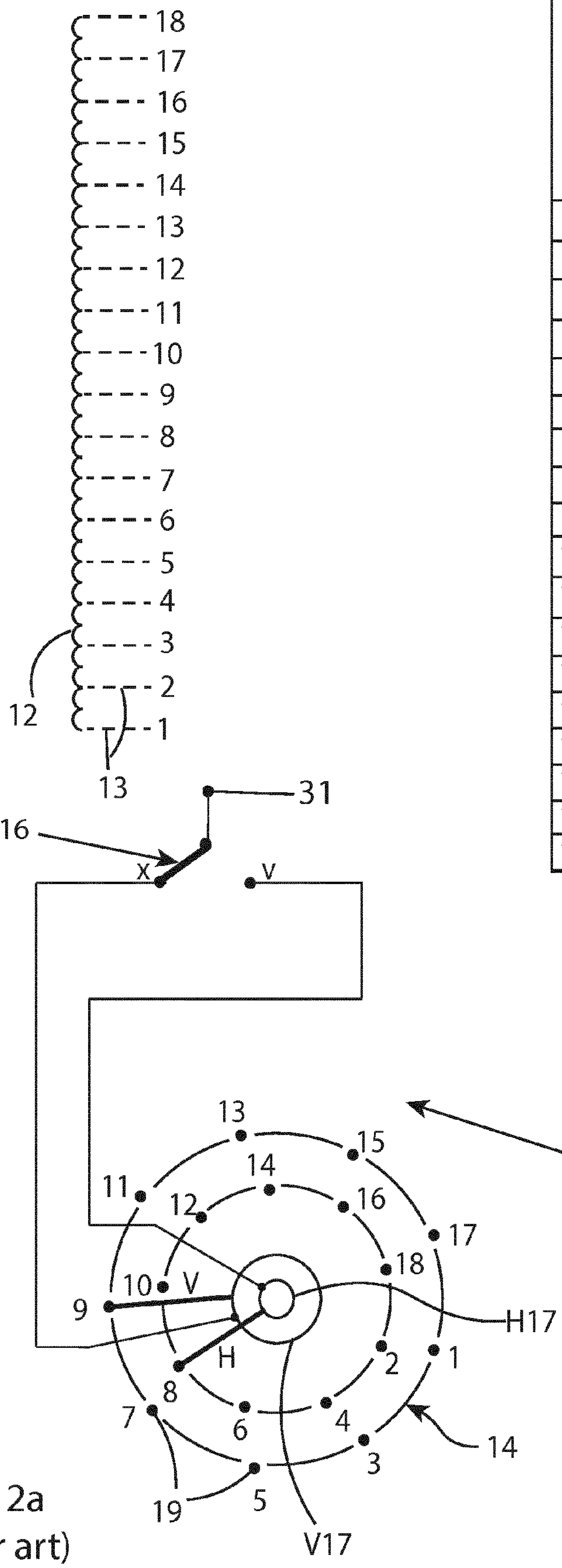


Fig. 2a
(prior art)

Pos	Tap-selector and diverter switch connect	
1	1-V-x	
2	2-H-v	
3	3-V-x	
4	4-H-v	
5	5-V-x	
6	6-H-v	
7	7-V-x	
8	8-H-v	
9	9-V-x	31
10	10-H-v	
11	11-V-x	
12	12-H-v	
13	13-V-x	
14	14-H-v	
15	15-V-x	
16	16-H-v	
17	17-V-x	
18	18-H-v	

Fig 2b
(prior art)

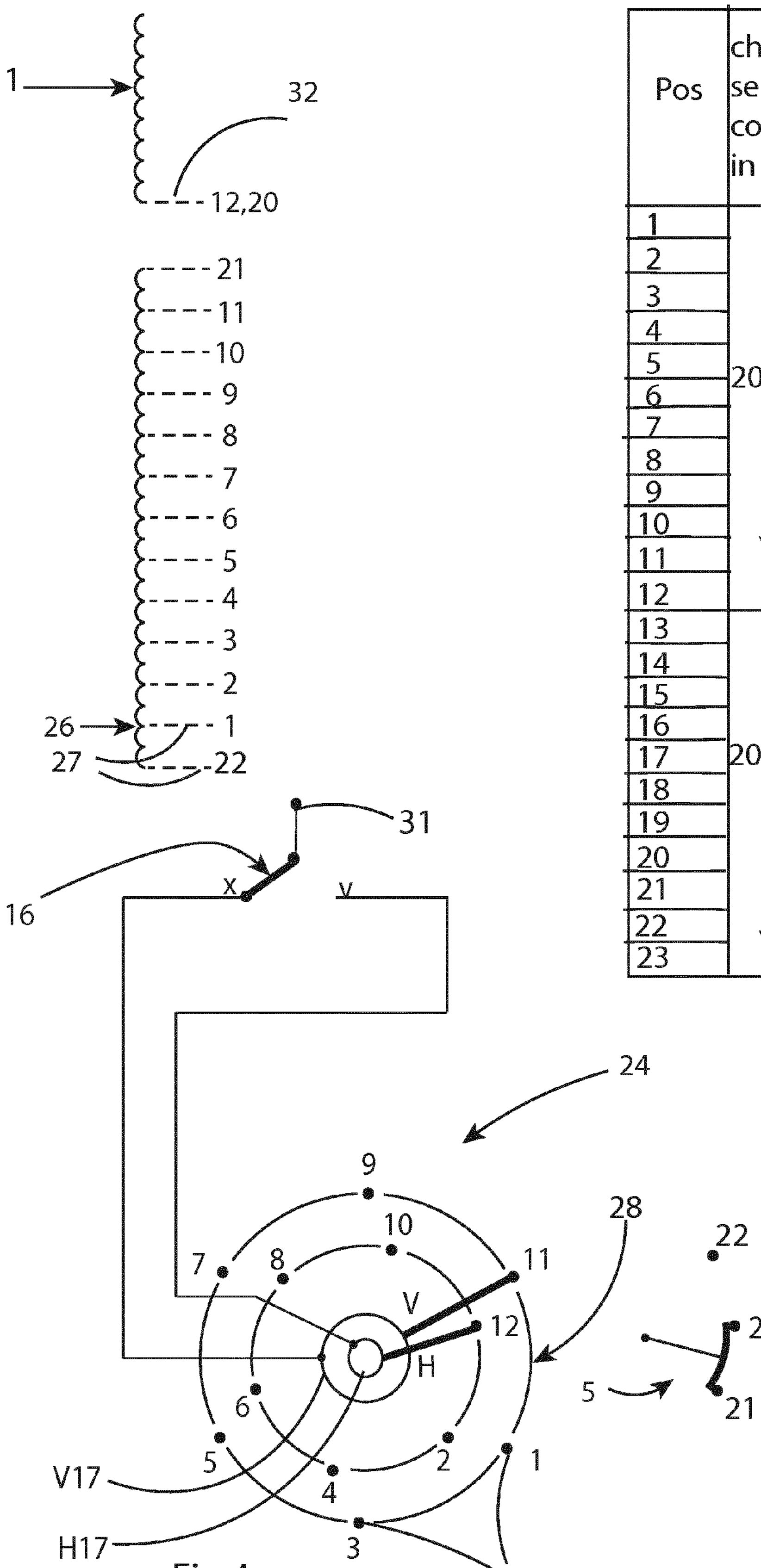
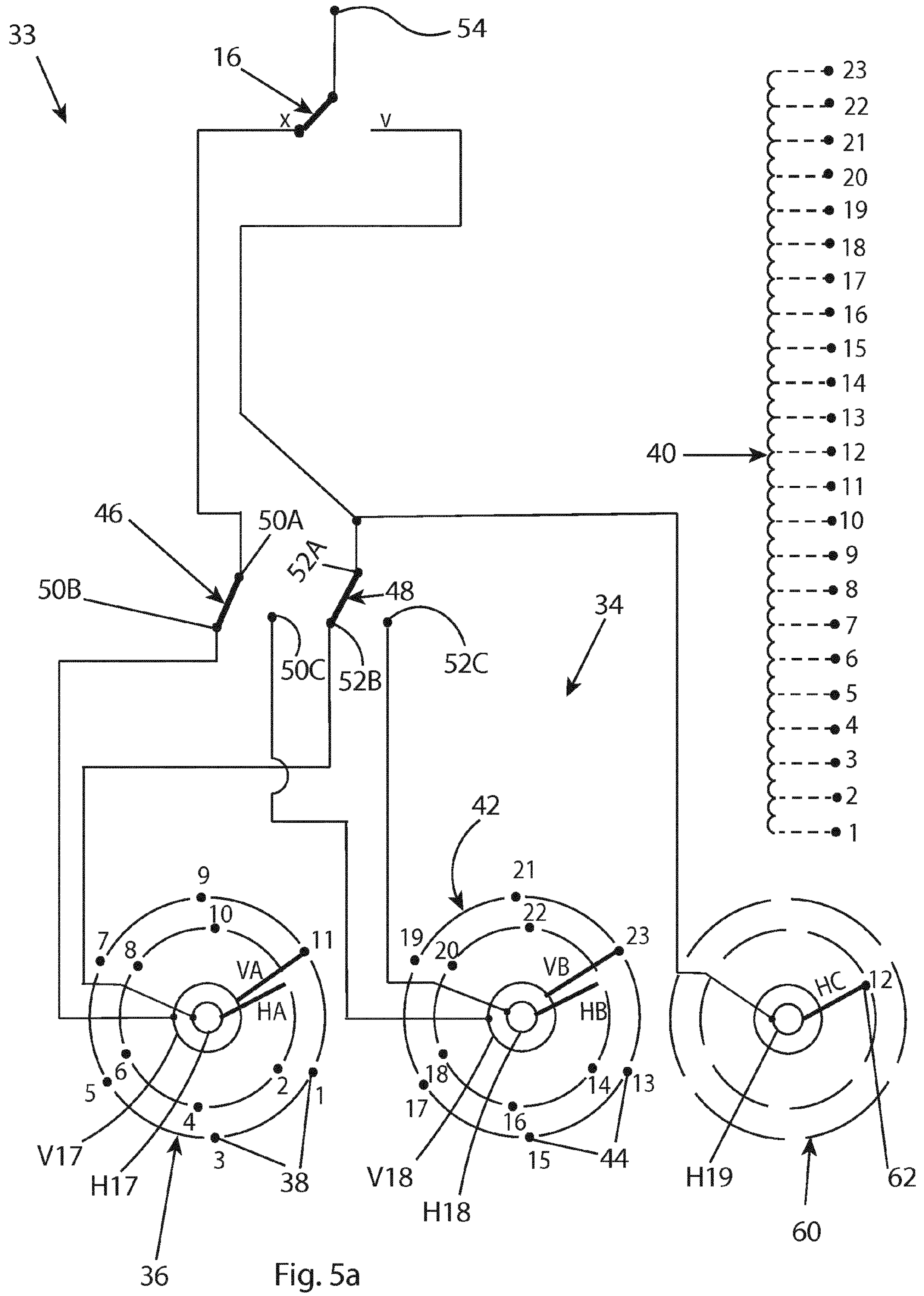


Fig 4a

Pos	change over selector connects in direction		Tap-selector and diverter switch connect	
1			1-V-x	
2			2-H-v	
3			3-V-x	
4			4-H-v	
5	20-21	20-21	5-V-x	
6			6-H-v	
7			7-V-x	
8			8-H-v	
9			9-V-x	
10			10-H-v	
11			11-V-x	31
12			12-H-v	
13			1-V-x	
14			2-H-v	
15			3-V-x	
16			4-H-v	
17	20-22	20-22	5-V-x	
18			6-H-v	
19			7-V-x	
20			8-H-v	
21			9-V-x	
22			10-H-v	
23			11-V-x	

Fig 4b

(prior art)



33
16
54
x
v
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
40
46
50A
50B
52A
48
50C
52B
52C
34
42
9
10
7
8
11
VA
HA
5
6
2
1
4
3
V17
H17
38
36
21
22
19
20
23
VB
HB
18
17
14
13
16
15
44
V18
H18
HC
12
H19
62
60

Fig. 5a

Pos	change over selector connects in direction		Tap-selector and diverter switch connect	
1	pos 1 ↓	pos 1 ↑	1-VA-x	54
2			2-HA-v	
3			3-VA-x	
4			4-HA-v	
5			5-VA-x	
6			6-HA-v	
7			7-VA-x	
8			8-HA-v	
9			9-VA-x	
10			10-HA-v	
11			11-VA-x	
12		pos 2 ↑	12-HC-v	
13	pos 2 ↓		13-VB-x	
14			14-HB-v	
15			15-VB-x	
16			16-HB-v	
17			17-VB-x	
18			18-HB-v	
19			19-VB-x	
20			20-HB-v	
21			21-VB-x	
22			22-HB-v	
23			23-VB-x	

Fig. 5b

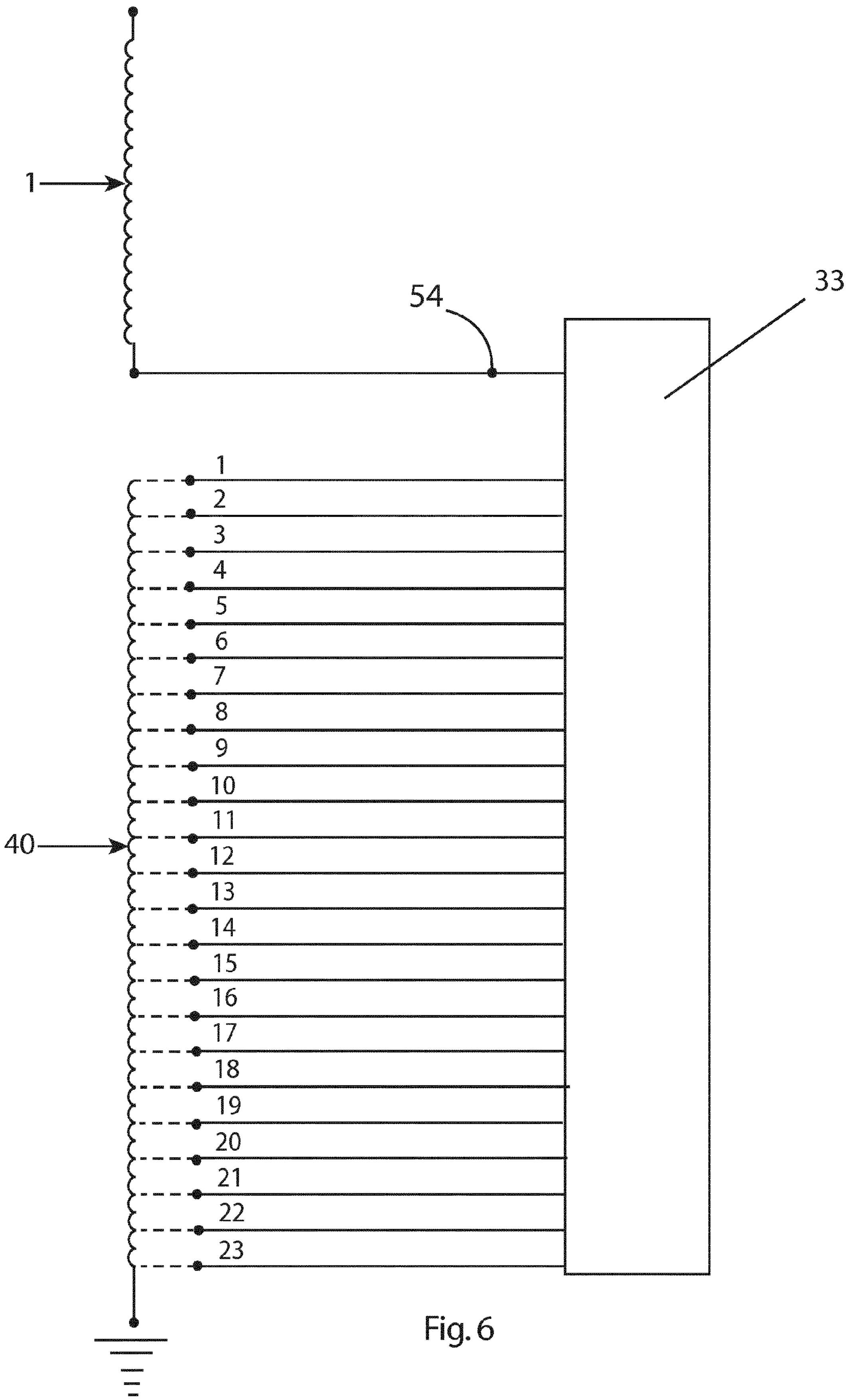


Fig. 6

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EUROPEAN SEARCH REPORT

Application Number
EP 16 17 5104

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X A	US 3 250 864 A (ALEXANDER BLEIBTREU ET AL) 10 May 1966 (1966-05-10) * column 2, line 27 - column 7, line 30; figures 1,2 * -----	1-3,8-15 4-7	INV. H01H9/00 H01H29/04
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H01H

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	6 December 2016	Ernst, Uwe

CATEGORY OF CITED DOCUMENTS

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