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(54) **A DIVERTER SWITCH OF RESISTOR TYPE, A METHOD FOR CONTROLLING THE DIVERTER SWITCH, AND AN ON-LOAD TAP CHANGER INCLUDING THE DIVERTER SWITCH**

(57) The present invention relates to a diverter switch (1) of resistor type for an on-load tap changer. The diverter switch comprises first and second connection points (6, 8) for connection to a tap selector (2), and a third connection point (4) for connection to an external contact, a main branch (10) and a transition branch (12) connected to the third connection point, and arranged alternating between the first and second connection points. The main branch comprises a main movable contact (14) arranged movable between the first and second connection points, and a vacuum interrupter (16) arranged in series with the main movable contact. The transition branch comprises a resistor movable contact (18) arranged movable between the first and second connection points, and a transition resistor (20) arranged in series with the resistor movable contact, and a control mechanism configured to perform, upon receipt of a signal (42) indicative of a desire to perform a tap changing operation, an switching sequence moving the main branch from the first connection point to the second connection point. The switching sequence comprises to commutate a load current from the main branch to the transition branch by first moving the resistor movable contact to the second connection point while the vacuum interrupter is closed, and then opening the vacuum interrupter while the resistor movable contact is connected to the second connection point and the main movable contact is connected to the first connection point, and to commutate the load current from the transition branch back to the main branch by moving the main movable contact to the second connection point, and then closing the vacuum switch.

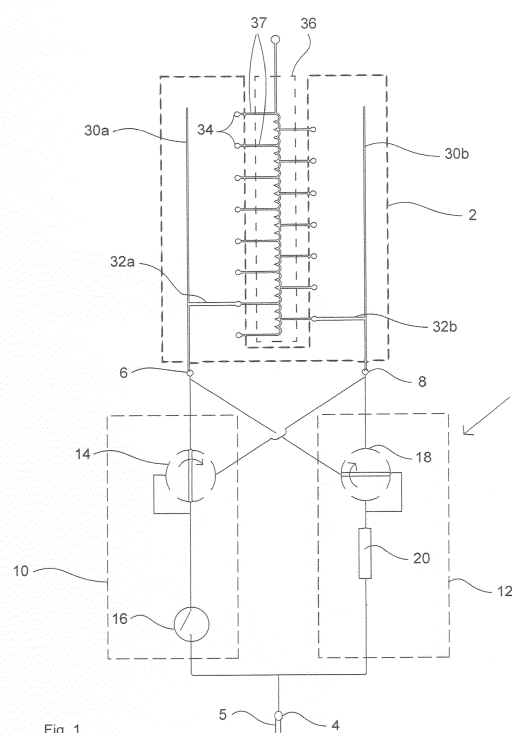


Fig. 1

Description

Field of the invention

[0001] The present invention relates to a diverter switch of resistor type for an on-load tap changer. The present invention further relates to a method for controlling a diverter switch of resistor type for an on-load tap changer. The present invention also relates to an on-load tap changer comprising a tap selector and a diverter switch.

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 fixed 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 fixed contacts at the other 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. An on-load tap changer (OLTC) generally comprises one or more of resistors or other impedances to prevent short-circuiting.

[0004] A mechanical tap changer is typically arranged so that upon changing taps, the new tap is physically connected before the old tap is disconnected. In order to avoid high circulating currents between the new and the old tap while both taps are connected, many tap changers include a switching device, by which a large transition resistor can be connected between the old and the new tap during the tap changing event.

[0005] There are numerous designs of switching devices which are arranged to provide electrical connection between at least one moveable contact and an external output of a tap changer, and by which smooth switching between different taps of the tap changer can be performed. In one type of tap changer, referred to as a diverter-switch type, the tap changer comprises a switching device referred to as a diverter switch, as well as a tap selector. Switches of a diverter switch can be sequentially operated to perform a switching operation between two taps. In a diverter-switch tap changer, 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.

[0006] In a diverter-type tap changer, the electrical connection between the fixed contact and the external

contact is typically formed by the switching device together with a tap selector. The switching device can provide at least one pair of branches wherein one of the branches of such pair, the main current branch, is of lower impedance than the other branch, the transition current branch. A main current branch will in the following be referred to as a main branch, while a transition current branch will be referred to as a transition branch. The impedance of the transition branch can be a resistance or an inductance or a combination of both. In a diverter switch of resistor type, impedance of the transition branch is normally a resistance. Both the main branch and the transition branch include a switch, so that each of the branches can be opened or closed.

[0007] During a tap changing operation, there will be a stage when two taps are connected to the external contact at the same time: one tap will be connected via the transition branch of high impedance, while the other is connected via the main branch of low impedance. The transition branch serves as a temporary connection between the external contact and one of the taps involved in the tap changing operation, until the new tap is connected to the external connection point via the main branch. In the transition stage, a circulating current will flow, via the switching device, between the two taps involved in the tap changing operation. The transition branch includes a transition switch, which will, upon opening, break the circulating current. The transition impedance ensures that currents circulating between the new and old taps during the transition stage will be of limited magnitude.

[0008] In operation of the tap changer there are contact breaks in the diverter switch during the tap switching sequence. The contact breaks give rise to arcing. In traditional tap changers, the arcing takes place within an insulating liquid and causes thermal degradation of the insulating liquid. To reduce this problem, vacuum switches, such as vacuum interrupters, are used in the transition branch and the main branch. The arcing that takes place during tap switching is then quenched in the vacuum switch, instead of in the insulating liquid. Vacuum on-load tap changer diverter switches of resistor type normally uses two or more vacuum interrupters per phase.

[0009] WO2008/024417 discloses a vacuum based diverter switch for a tap changer and an example of a vacuum switch that may be used in the diverter switch. The vacuum switch includes two contacts and a housing enclosing the contacts. The arcing that occurs during switching is between these contacts inside the housing. A disadvantage with vacuum interrupters is that they are expensive. Another disadvantage is that they are bulky and requires a lot of space.

[0010] WO2014/124771 shows examples of diverter switches of resistor type for an on-load tap changer. In one example, the diverter device comprises a main branch and a transition branch arranged alternating between first and second connection points, and an external connection point. The main branch comprises a main

movable contact adapted to be moved between being connected to the first connection point and connected to the second connection point, and a main switch arranged in series with the main movable contact. The transition branch comprises a resistor movable contact adapted to be switched between being connected to the first connection point and to the second connection point, a transition resistor and a transition switch arranged in series with the resistor movable contact. A control unit is configured to move, upon receipt of a signal indicative of a desire to perform a tap changing, the main branch from the first connection point to the second connection point by performing a switching sequence. The operating sequence commutates a load current from the main branch to the transition branch, and then back again to the main branch. The operating sequence comprises opening the main switch while the resistor movable contact and the main movable contact are connected to the first connection point. In a next step, the main movable contact is moved to the second connection point, and the main switch is closed. In a further step, the transition switch is opened. The resistor movable contact is moved to the second connection point while the transition switch is opened. In a last step, the transition switch is closed. Thus, during the switching sequence, the diverter switch moves the main movable contact first, and then the resistor movable contact.

[0011] Another type of tap changer, referred to as the selector-switch type, comprises a switching device referred to as a selector switch unit, provided to perform the switching between two taps. In a selector-switch type tap changer, the selector switch unit is used to perform both the selection of the tap and the commutation of the load current to the selected tap. In a selector-switch type tap changer, the components of the main branch and the transition branch are physically moved between the fixed contacts.

[0012] US 5,523,674 shows an example of a step switch for a tap changer of selector-switch type. The step switch comprises a main branch and a transition branch arranged alternating between a plurality of fixed contacts (n , $n+1$) and an external connection point. The main branch comprises a main contact (SKM) and a vacuum interrupter (SKV) arranged in series. The transition branch comprises a resistor contact (HKW), an auxiliary switch (HKM) and a transition resistor (R) arranged in series. During the tap changing sequence, the step switch moves the transistor contact first and then the main contact. The main branch and the transition branch, i.e. the main contact, the vacuum interrupter, the resistor contact, and the resistor, are physically moved between the fixed contacts. A disadvantage with the selector switch is that due to the large weight, it requires a lot of kinetic energy to move the components during the tap changing sequence.

Object and summary of the invention

[0013] It is an object of the present invention to provide an improved diverter switch of resistor type for an on-load tap changer. Another object is to reduce costs for an on load tap changers of diverter switch type.

[0014] This object is achieved by a diverter switch as defined in claim 1.

[0015] The diverter switch includes a first and a second connection point for connection to a tap selector, and a third connection point for connection to an external contact. The diverter switch further includes a main branch and a transition branch connected to the third connection point, and arranged alternating between the first and second connection points. The main branch comprises a main movable contact arranged movable between the first and second connection points, and a vacuum interrupter arranged in series with the main movable contact. The transition branch comprises a resistor movable contact arranged movable between the first and second connection points, and a transition resistor arranged in series with the resistor movable contact. The diverter switch further includes a control mechanism configured to perform, upon receipt of a signal indicative of a desire to perform a tap changing operation, a switching sequence moving the main branch from the first connection point to the second connection point. The invention is characterized in that the switching sequence comprises to commutate a load current from the main branch to the transition branch by first moving the resistor movable contact to the second connection point while the vacuum interrupter is closed, and then opening the vacuum interrupter while the resistor movable contact is connected to the second connection point and the main movable contact is connected to the first connection point, and to commutate the load current from the transition branch back to the main branch by moving the main movable contact to the second connection point, and then closing the vacuum switch.

[0016] This invention describes a diverter switch and a switching sequence using only one vacuum interrupter for each phase. Using only one vacuum interrupter per phase will reduce costs and save space needed for the diverter switch. The diverter switch is moving with the resistor contact first in the switching sequence. The diverter switch according to the invention will have simpler operating sequence, lower costs, and less space requirement than the prior art diverter switches. The advantages are achieved by allowing more contact wear in the remaining vacuum interrupter. Further, closing towards step voltage and circulating current in the resistor movable contact may create small pre-arc. However, this can easily be handled, for example, by adding some arc resistant material such as copper and/or tungsten on the closing surfaces of the resistor movable contact

[0017] This being a diverter switch meaning that the single vacuum interrupter main body, the first and second connection points, and the transition resistor are station-

any assembled, and not needed to be moved for achieving the switching sequence. It also means that the diverter switch is intended to be used in conjunction to a tap selector.

[0018] The transition branch does not contain any auxiliary switch arranged to open and close the transition branch, in addition to the resistor movable contact. It is not necessary to have any auxiliary switch in the transition branch when using the switching sequence of the invention.

[0019] According to an embodiment of the invention, a contact surface of the resistor movable contact is covered with a layer of arc resistant material. For example, the arc resistant material is made of copper and/or tungsten, or a combination thereof. This embodiment allows more wear on the contact surface of the resistor movable contact.

[0020] According to an embodiment of the invention, the resistance of the transition resistor is between 0.1 and 20Ω, and preferably the transition resistor is between 0.5 and 10Ω.

[0021] This object is also achieved by a method for controlling a diverter switch as defined in claim 9.

[0022] The method comprises performing, upon receipt of a signal indicative of a desire to perform a tap changing operation, a switching sequence for moving the main branch from the first connection point to the second connection point, comprising the steps:

- moving the resistor movable contact to the second connection point while the vacuum interrupter is closed,
- opening the vacuum interrupter while the resistor movable contact is connected to the second connection point and the main movable contact is connected to the first connection point,
- moving the main movable contact to the second connection point, and
- closing the vacuum switch while the resistor movable contact and the main movable contact are connected to the second connection point.

[0023] This switching sequence makes it possible to omit the vacuum switch in the transition branch, and accordingly to save costs and space.

[0024] Only one vacuum interrupter for each diverter switch is needed, with this circuit and sequence according to the invention, to avoid oil arcing when the auxiliary contacts are opened. The new solution will have simpler operating sequence, less cost, less space requirement.

[0025] This object is also achieved by an on-load tap changer comprising a tap selector and a diverter switch according to the invention. The tap selector includes a first and second current collector, and the first connection point of the diverter switch is connected to the first current collector and the second connection point is connected to second current collector. The tap changer needs one diverter switch for each phase. Thus, three diverter

switches are needed for three phases. Since the diverter switch according to the invention only needs one vacuum interrupter for each phase, three vacuum interrupters can be omitted for tap changers having three phases. Two or three phases can also be combined to one single diverter switch with one common output. This can, for example, be used when two regulating windings in different phases are placed close to a delta winding corner or three regulating windings of different phases are placed close to a star point. Thus, costs and space are reduced compared to prior art on-load tap changers of diverter type.

[0026] According to an embodiment of the invention, the impedance of the transition branch is within the range of $0.1 \cdot U_{\text{step}} / I_R$ to $10 \cdot U_{\text{step}} / I_R$, where U_{step} is the rated voltage between two adjacent taps of the on-load tap changer, and I_R is the rated load current of the tap changer.

[0027] According to an embodiment of the invention, the impedance of the transition branch is within the range of $0.3 \cdot U_{\text{step}} / I_R$ to $3 \cdot U_{\text{step}} / I_R$, where U_{step} is the rated voltage between two adjacent taps of the on-load tap changer, and I_R is the rated load current of the tap changer.

Brief description of the drawings

[0028] 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 schematically illustrates a tap changer which includes a diverter switch according to the invention.

Fig. 2 illustrates a switching sequence for the diverter switch according to the invention during a tap changing operation.

Fig. 3 illustrates a control mechanism for controlling the main movable contact, the resistor movable contact, and the vacuum interrupter during the tap changing operation.

Fig. 4 shows an example possible of timings of the switching sequence during the tap changing operation as shown in figure 2.

Fig. 5 schematically illustrates an example of a resistor movable contact provided with arc resistant material.

Detailed description of preferred embodiments of the invention

[0029] Figure 1 shown an example of a tap changer of diverter-switch type, also referred to as a diverter-switch tap changer, and a regulating winding of a transformer. The tap changer comprises a switching device in the form

of a diverter switch 1 and a tap selector 2. The switching device is designed to be part of the electrical connection between a fixed contact of the transformer and an external contact 5 of the tap changer. In a diverter-type tap changer, the electrical connection between the fixed contact of the transformer and the external contact is typically formed by the diverter switch together with the tap selector. A diverter switch can be sequentially operated to perform a switching operation between two taps. In a diverter-switch tap changer, the tap selector 2 is used to select the tap to which the load current is to be transferred, while the diverter switch 1 is used to perform the commutation of the load current from the presently connected tap to a tap selected by the tap selector. The diverter switch 1 is connected between an external contact 5 and the tap selector 2.

[0030] The tap selector 2 is connected to a regulating winding 36 of the transformer. The tap selector 2 has two current collectors 30a-b, two moveable contacts 32a-b, and a set of fixed contacts 34. The regulating winding 36 of the transformer has a set of different taps 37, and each of the fixed contact 34 is connectable to one of the taps 37 of the regulating winding 36. The regulating winding 36 is shown in figure 1 for illustrative purposes, and is normally not seen as a part of the tap changer.

[0031] The diverter switch 1 comprises a first connection point 6 for connection to one of the current collectors 30a of the tap selector, and a second connection point 8 for connection to the other current collector 30b of the tap selector 2, and a third connection point 4 for connection to the external contact 5 of the tap changer.

[0032] The diverter switch 1 disclosed in figure 1 comprises a main current branch 10 of lower impedance and a transition current branch 12 of higher impedance, connected between the tap selector 2 and the external contact 5. The main current branch will in the following be referred to as a main branch, while the transition current branch will be referred to as a transition branch. The impedance in the main branch is typically about $200\mu\Omega$, and the impedance in the transition branch is typically more than 0.1Ω . When both branches are connected to the same tap, the current in the main path is typically more than 500 times as large as the current in the transition path.

[0033] Each of the branches 10, 12 is at one end connected to the external contact 5 of the tap changer, and at the other connected to the first and second connection points 6, 8 connected to the current collectors 30a-b of the tap selector. The main branch 10 comprises a main movable contact 14 arranged movable between being connected to the first current collector 30a via the first connection points 6, and being connected to a second current collector 30a via the second connection point 8. The main branch 10 further comprises a main switch 16 in the form of a vacuum interrupter arranged in series with the main movable contact 14. The main switch 16 is, for example, a vacuum interrupter of the type disclosed in WO2008/024417. The vacuum interrupter includes

two contacts and a housing enclosing the contacts. The arcing that occurs during switching is between these contacts inside the housing. The main switch 16 has only one pair of contacts, i.e. only one breaking point.

[0034] The transition branch 12 comprises a resistor movable contact 18 arranged movable between being connected to the first connection points 6 and being connected to second connection point 8. The transition branch 10 further comprises a transition resistor 20 arranged in series with the resistor movable contact 18. The transition resistor 20 can for example be made of a resistor wire of any shape with a suitable length giving enough mass for taking up the energy generated during switching. This together with a suitable surface area and placement and design giving enough liquid flow will prevent overheating the resistor. The transition resistor 20 ensures that currents circulating between a new and an old tap during a tap changing operation will be of limited magnitude. The impedance of the main branch should be low enough so that the main branch can serve as a steady-state current branch, which continuously carries the load current when no tap changing operation is performed. Preferably, the resistance of the transition resistor 20 is between 0.1 and 20Ω . The impedance of the transition branch of the inventive switching device will fall within the range of:

$$0.1 * U_{\text{step}} / I_R \text{ to } 10 * U_{\text{step}} / I_R$$

[0035] More preferably, the resistance of the transition resistor 20 is between 0.5 and 10Ω . The impedance of the transition branch of the inventive switching device will fall within the range of:

$$0.3 * U_{\text{step}} / I_R \text{ to } 3 * U_{\text{step}} / I_R$$

[0036] U_{step} is the rated voltage between two adjacent taps 37 of the on-load tap changer, and I_R is the rated load current of the tap changer. This ensures that the voltage drop across the transformer, upon a tap changing operation, will be within an acceptable level for the end user.

[0037] The transition resistor 20 is connected to the external contact 5 via the connection point 4. The transition branch does not contain any switch for interrupting the transition branch, except for the movable contact 18. Due to the high impedance, the transition branch 12 will only carry small currents, in the order of mA, when no tap changing operation is performed. Typically, the current in the transition path is only a few thousandth of the load current in the main path.

[0038] The main switch 16 is connected to the external contact 5 via the connection point 4. The main branch 10 can provide two different main current paths, depending on to which current collector 30a-b the main movable

contact 14 is connected. The transition branch 12 can provide two different transition current paths, depending on to which current collector 30a-b the transition movable contact 18 is connected.

[0039] Moving the main movable contact between the first and second connection points 6, 8 does not cause any arcing during the movement. However, moving the resistor movable contact 18 between the first and second connection points may cause a short arcing before closing. The main movable contact and the resistor movable contact can be of different types, since the demand on them are different. The resistor movable contact should preferably be of a type that can resist some arcing.

[0040] In this embodiment, the movable contacts 14 and 18 are four-way contacts. A first contact point of the movable contacts 14, 18 is connectable to the first current collector 30a via the first connection point 6, while a second contact point of the movable contacts 14, 18 is connectable to the second current collector 30b via the second connection point 8. Hence, both the main branch 10 and the transition branch 12 can be connected to the first and second current collectors 30a-b, via the movable contacts 14 and 18, respectively. The third and fourth contact points of movable contact 14 are both connected to the main switch 16, while the third and fourth contact points of the movable contact 18 are connected to the transition resistor 20. However, the movable contacts 14, 18 can be other types of contact, such as two way or three way contacts, or combinations thereof.

[0041] While moving the tap changer from one tap to another tap, the load current will be forced in several steps to change current path without anytime interrupting the load current. This is done by always providing a new easier path for the load current in parallel to the old path, in the same time as the impedance is preventing a full step short circuit between the two taps. This is either achieved by opening of the present path and thus making it impossible for the current to continue to flow in this path. Forcing the load current to change path will cause arcing during this breaking operation. Another way is just to supply a significantly lower impedance path that do not need any breaking at all.

[0042] Figure 2 illustrates a switching sequence for the diverter switch 1 according to the invention during a tap changing operation. The switching sequence comprises five stages I-V. The bold lines indicate the load current during the different stages I-V of the switching sequence. The switching sequence disclosed in figure 2 moves the main branch 10 from the first connection point 6 to the second connection point 8. The switching sequence changes the connection between the external contact 5 and the current collector 32a so that the external contact 5 instead is connected to the current collector 32b.

[0043] During a tap changing operation, there will be a stage when two taps (an "old" tap and a "new" tap) are both connected to the external contact 5 at the same time: one tap will be connected via the transition branch of high impedance, while the other is connected via the

main branch of low impedance. Such stage will here be referred to as a transition stage. The transition branch serves as a temporary connection between the external contact 5 and one of the taps 37 involved in the tap changing operation (old or new), until the new tap is connected to the external connection point via a main branch. In the transition stage, a circulating current will flow between the two taps involved in the tap changing operation.

[0044] During stage I, the main movable contact 14 and the resistor movable contact 18 are both connected to the first connection point 6 and the main switch 16 is closed. Thus, the main branch 10 and the transition branch 12 are both connected to the first connection point 6 during stage I. Due to the high impedance of the transition branch 12, the load current passes through the main branch 10, as shown in figure 2 stage I.

[0045] The switching sequence starts upon receipt of a signal indicative of a desire to perform a tap changing operation. In a first step, as illustrated in the figure as stage II, the transition branch 12 is moved from first connection point 6 to the second connection point 8 while the vacuum interrupter is still closed. Thus is done by moving the resistor movable contact 18 from being connected to the first connection point 6 to being connected to the second connection point 8. In stage II, which is the transition stage, the main branch 10 is connected to the first connection point 6, and the transition branch 12 is connected to the second connection point 8. In this stage, circulating currents will flow between the new and old taps and accordingly between the connection points 6 and 8. The transition resistor 20 ensures that the circulating currents during the transition stage will be of limited magnitude. Due to the high impedance of the transition branch 12, most of the load current still passes through the main branch 10.

[0046] In stage III, the main switch 16 is opened while the main movable contact 14, and accordingly the main branch 10, is connected to the first connection point 6, and the resistor movable contact 18, and accordingly the transition branch 12, is connected to the second connection point 8. After stage III, the load current is moved from the main branch 10 to the transition branch 12.

[0047] In stage IV, the main movable contact 14, and accordingly the main branch 10, is moved to the second connection point 8 while the main switch 16 is still opened.

[0048] In stage V, the main switch 16 is closed while the resistor movable contact 14 and the main movable contact 18 are connected to the second connection point 8. During stage V, the load current is moved from the transition branch 12 back to the main branch 10.

[0049] The switching sequence will be the same in the other direction, i. e. while moving the main current branch 10 from the current collector 32b to the current collector 32a. Thus, during stage II, the resistor movable contact 18 is moved from the second connection point 8 to the first connection point 6 while the vacuum interrupter is closed. In stage II, the main branch 10 is connected to

the first connection point 6, the transition branch 12 is connected to the second connection point 8 and the main switch 16 is opened. In stage IV, the main branch 10 is moved to the first connection point 6 while the main switch 16 is still opened. In stage V, the main switch 16 is closed while the resistor movable contact 14 and the main movable contact 18 are connected to the first connection point 6.

[0050] The switching sequence is unidirectional meaning that the sequence goes in both directions, from connection point 6 to connection point 8 as well as from the connection point 8 to connection point 6, always starting with the resistor moving contact. Only one vacuum interrupter is needed, with this circuit and sequence, to avoid breaking in oil when the movable contacts 12, 14 are opened during movement of the contacts.

[0051] A diverter switch further comprises a control mechanism for initiation and control of the main movable contact 14, the resistor movable contact 18, and the vacuum interrupter 16 during a tap changing operation. Typically, the control mechanism is mechanical, for example, a spring loaded control mechanism including cams for moving the contacts. An example of a control mechanism for a tap changer is disclosed in US1732742. The control mechanism is configured to perform, upon receipt of a signal indicative of a desire to perform a tap changing operation, a switching sequence moving the main branch 10 from the first connection point 6 to the second connection point 8. The switching sequence comprises to commutate a load current from the main branch to the transition branch by first moving the resistor movable contact 18 to the second connection point 8 while the main switch 16 is closed, and then opening the main switch while the resistor movable contact 18 is connected to the second connection point 8 and the main movable contact 14 is connected to the first connection point 6, and to commutate the load current from the transition branch 12 back to the main branch 10 by moving the main movable contact 14 to the second connection point 8, and then closing the vacuum switch 16.

[0052] Figure 3 schematically illustrates an example of a control mechanism 40. The control mechanism 40 comprises a motor drive unit including a motor 50, a drive shaft and a gear system 52, a spring driven mechanism 54, and a cam system including plurality of cams 44, 46, 48 connected to the movable contacts 14, 18 and the vacuum switch 16. The control mechanism 40 is configured to receive a trigger signal 42 indicative of a desire to perform a tap changing operation. The control mechanism 40 can receive the trigger signal 42 via a manual interface, or from an automatic control system. The cam 44 is designed to cause the transistor movable contact 18 to be moved between the first connection point 6 and the second connection point 8. The cam 46 is designed to cause the main movable contact 18 to be moved between the first connection point 6 and the second connection point 8. The cam 48 is designed to open and close the vacuum switch 16.

[0053] The tap changer is normally operated by means of a motor drive unit. An operation starts with a trigger signal 42 from a control system or manually, giving the control mechanism 40 an order to perform a tap changing operation and either operate in lower or raise direction. The trigger signal makes the electric motor in the motor drive to start rotate in the desired direction towards next position. The shaft and gear system 52 transfer and transform this rotation to a suitable number of turns at the location of the tap changer. This rotation will via some intermediate gears directly operate the tap selector sequence and at the same time loading the spring driven mechanism 54 of the diverter switch. When the tap selector 2 has reached or is standing on the next position and the spring is fully loaded a trigger in the diverter switch will release the energy in the spring driven mechanism 54 that is connected to the cam system 44, 46, 48 operating the diverter switch, which performs the described sequence I - V for the movable contacts 14, 18 and the vacuum interrupter 16.

[0054] Figure 4 shows an example of possible timing in the switching sequence during the tap changing operation as described with reference to figure 2. Reference 60 illustrates opening and closing of the vacuum interrupter 16 as a function of the cam angle. Reference 58 illustrates movement of the main movable contact 14 as a function of the cam angle, and reference 56 illustrates movement of transistor movable contact 18 as a function of the cam angle. When the spring is released, the cam system is moved and thereby causing the described sequence I - V for the main movable contact 14, the vacuum interrupter 16, and transistor movable contact 18.

[0055] 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, different types of movable contacts can be used.

[0056] Figure 5a shows another example of a diverter switch according to the invention. In this example, the movable contacts are implemented by three -way contacts 14b, 18b. Figure 5b shows an enlarged view of the resistor movable contact 18b. In this example, the resistor movable contact is provided with arc resistant material. The resistor movable contact includes two fixed contact parts 70 (only one is shown in the figure) and a moving contact part 72 movable between the fixed contact parts 70. Each of the fixed contact parts 70 has a contact surface configured to be in contact with corresponding contact surface of the moving contact part 72. Thus, the moving contact part 72 has two contact surfaces arranged on opposite sides of the moving contact. The contact surface of each of the fixed contact parts 70 is provided with a layer 74 of arc resistant material, and each of the contact surfaces of the moving contact part 72 are provided with layers 76, 78 of arc resistant material. The arc resistant material is, for example, copper, tungsten or a combination of both. Figure 5b shows the movable contact 18b in a closed state. Figure 5c shows the movable contact 18b in a moving state, i.e. the moving contact

part 72 is moving between two fixed contact parts 70.

Claims

1. A diverter switch of resistor type for an on-load tap changer, wherein the diverter switch comprises:

- first and second connection points (6, 8) for connection to a tap selector, and a third connection point (4) for connection to an external contact,
- a main branch (10) and a transition branch (12) connected to the third connection point, and arranged alternating between the first and second connection points, the main branch comprises a main movable contact (14) arranged movable between the first and second connection points, and a vacuum interrupter (16) arranged in series with the main movable contact, the transition branch comprises a resistor movable contact (18) arranged movable between the first and second connection points, and a transition resistor (20) arranged in series with the resistor movable contact, and
- a control mechanism (40) configured to perform, upon receipt of a signal (42) indicative of a desire to perform a tap changing operation, an switching sequence moving the main branch from the first connection point to the second connection point, **characterized in that** the switching sequence comprises to commutate a load current from the main branch to the transition branch by first moving the resistor movable contact to the second connection point while the vacuum interrupter is closed, and then opening the vacuum interrupter while the resistor movable contact is connected to the second connection point and the main movable contact is connected to the first connection point, and to commutate the load current from the transition branch back to the main branch by moving the main movable contact to the second connection point, and then closing the vacuum switch.

2. The diverter switch according to claim 1, wherein at least a part of a contact surface of the resistor movable contact (18) is covered with a layer of arc resistant material.
3. The diverter switch according to claim 2, wherein the arc resistant material is made of copper or tungsten, or a combination thereof.
4. The diverter switch according to any of the previous claims, wherein resistance of the transition resistor (20) is between 0.1 and 20Ω.

5. The diverter switch according to any of the previous claims, wherein resistance of the transition resistor (20) is between 0.5 and 10Ω.

6. An on-load tap changer comprising a tap selector (2) including a first and second current collector (32a-b) and a diverter switch (1) according to any of the claims 1 - 5, and the first connection point (6) is connected to the first current collector (32a) and the second connection point (8) is connected to second current collector (32b).

7. The on-load tap changer according to claim 6, wherein the impedance of the transition branch is within the range of $0.1 \cdot U_{\text{step}} / I_R$ to $10 \cdot U_{\text{step}} / I_R$, where U_{step} is the rated voltage between two adjacent taps (37) of the on-load tap changer, and I_R is the rated load current of the tap changer.

8. The on-load tap changer according to claim 6, wherein the impedance of the transition branch is within the range of $0.3 \cdot U_{\text{step}} / I_R$ to $3 \cdot U_{\text{step}} / I_R$, where U_{step} is the rated voltage between two adjacent taps (37) of the on-load tap changer, and I_R is the rated load current of the tap changer.

9. A method for controlling a diverter switch of resistor type for an on-load tap changer, wherein the diverter switch comprises:

- a first and a second connection point (6, 8) for connection to a tap selector (2), and a third connection point (4) for connection to an external contact,
- a main branch (10) and a transition branch (12) connected to the third connection point, and arranged alternating between the first and second connection points, the main branch comprises a main movable contact (14) arranged movable between the first and second connection points, and a vacuum interrupter (16) arranged in series with the main movable contact, the transition branch comprises a resistor movable contact (18) arranged movable between the first and second connection points, and a transition resistor (20) arranged in series with the resistor movable contact, **characterized in that** the method comprises performing, upon receipt of a signal indicative of a desire to perform a tap changing operation, an switching sequence for moving the main branch from the first connection point to the second connection point, comprising the steps :
 - moving the resistor movable contact to the second connection point while the vacuum interrupter is closed,
 - opening the vacuum interrupter while the resistor movable contact is connected to the sec-

ond connection point and the main movable contact is connected to the first connection point,
- moving the main movable contact to the second connection point, and
- closing the vacuum switch while the resistor
movable contact and the main movable contact
are connected to the second connection point.

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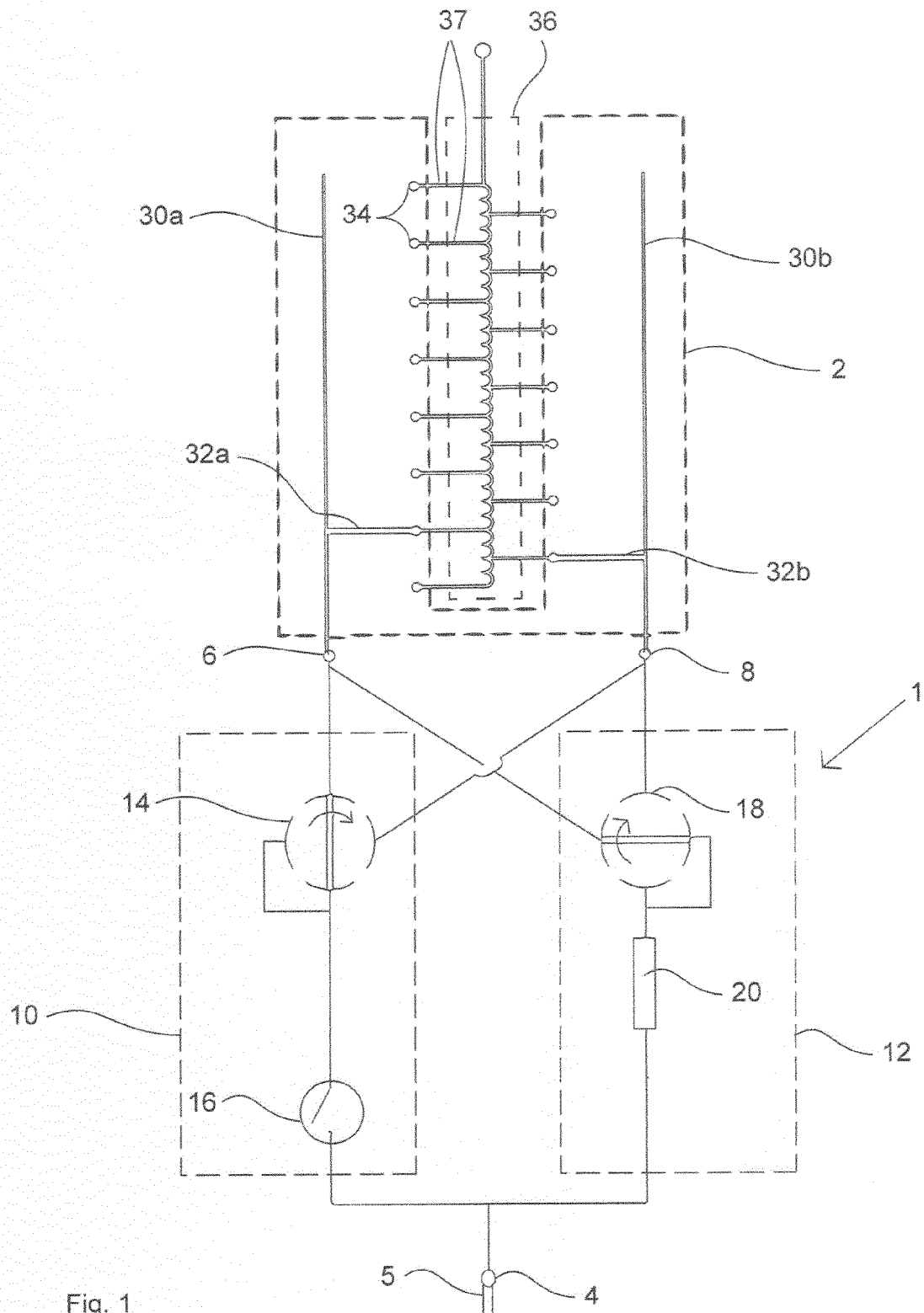
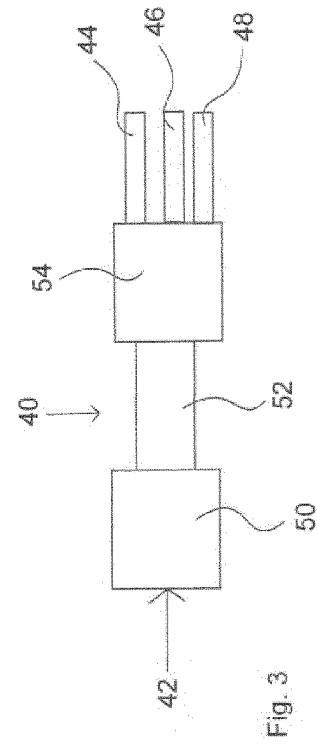
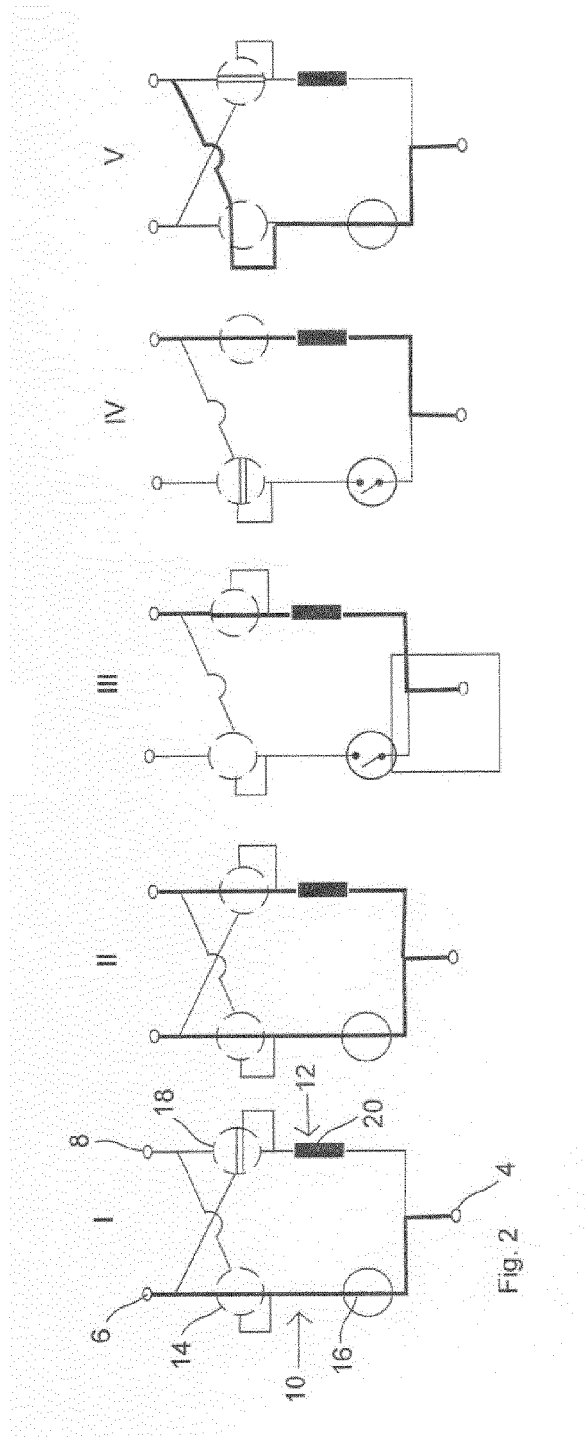
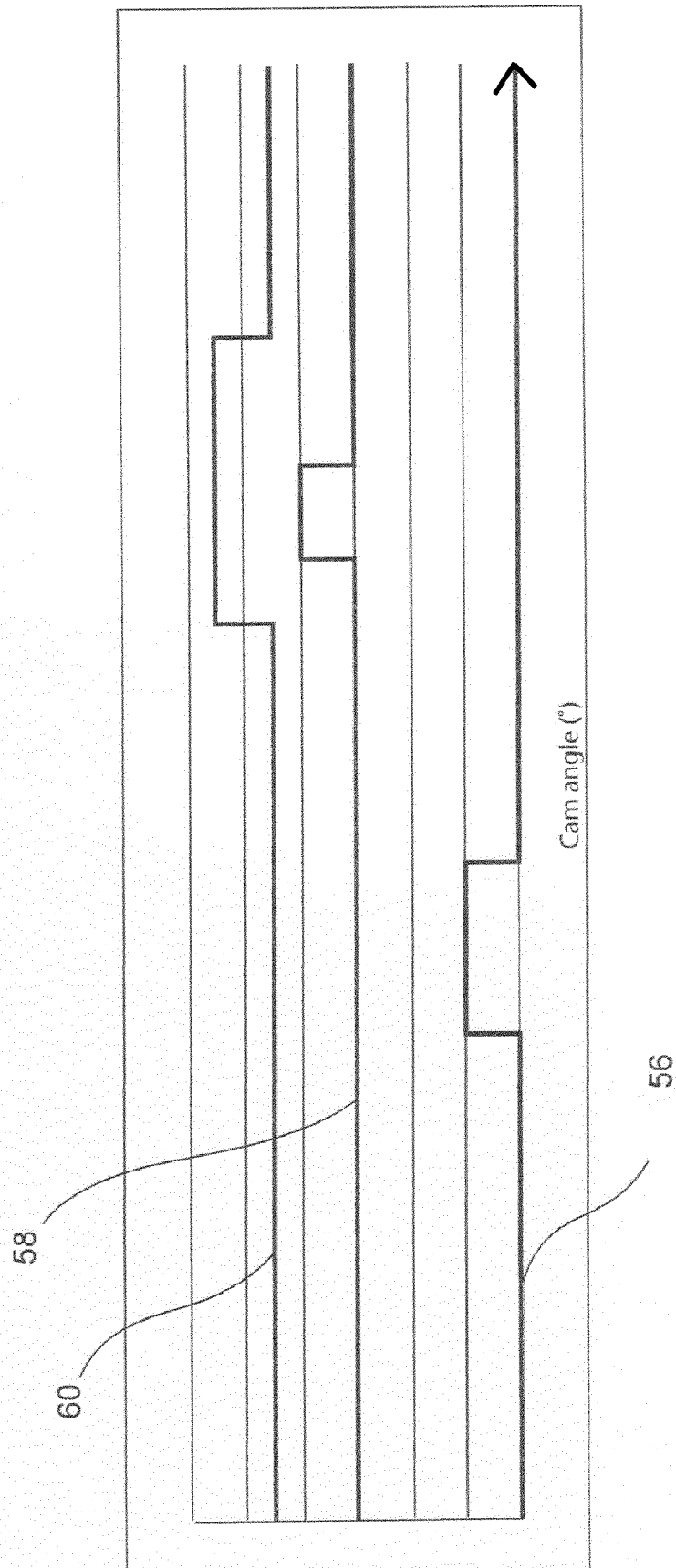
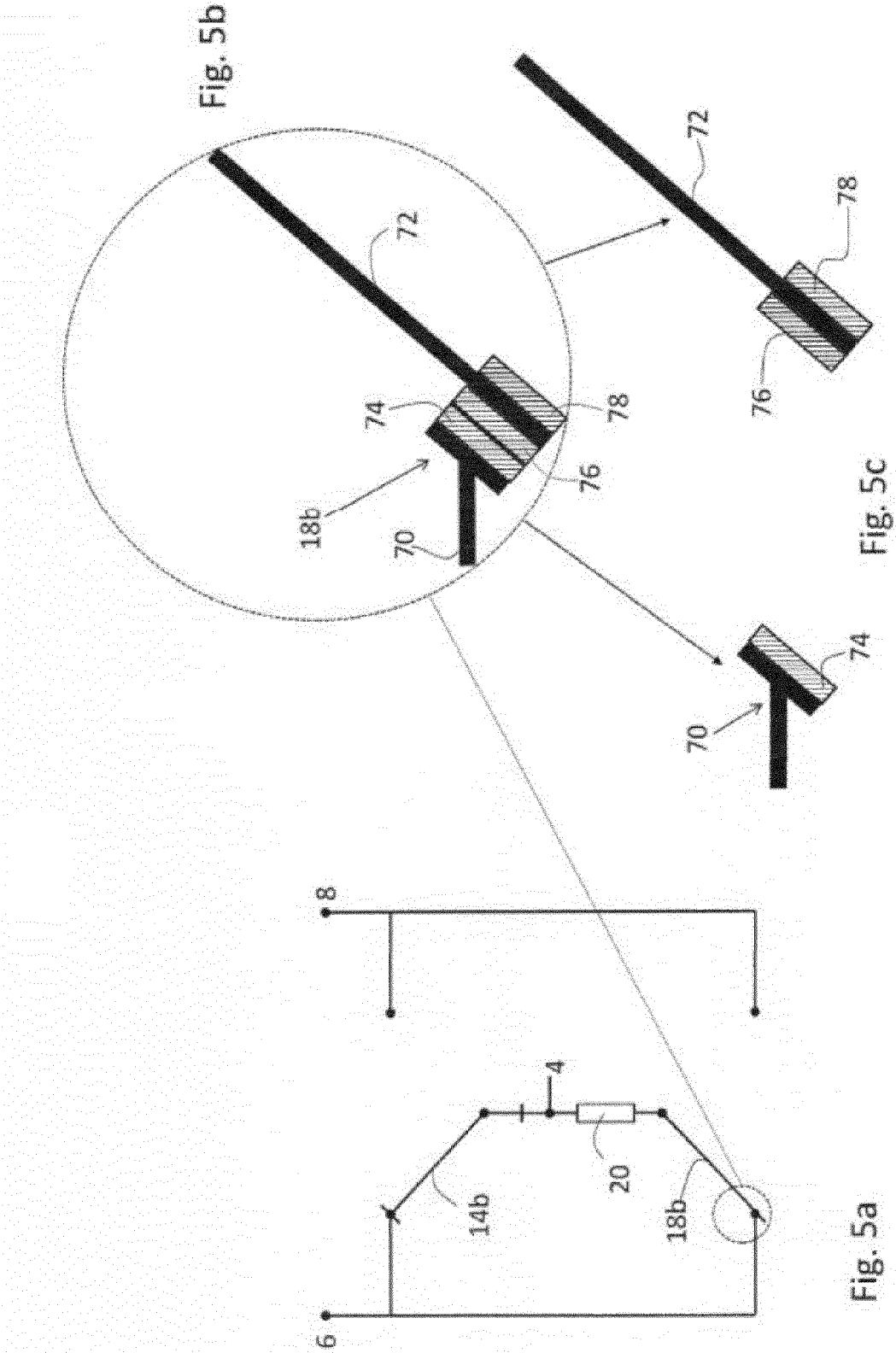


Fig. 1









EUROPEAN SEARCH REPORT

 Application Number
 EP 15 16 3399

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Place of search Munich		Date of completion of the search 9 October 2015	Examiner Ernst, Uwe
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**ANNEX TO THE EUROPEAN SEARCH REPORT
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5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
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