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(54) Coil actuator for a switching device and related correction method

(57) A coil actuator for an electric switching device which can be actuated during its operation from an open position to a closed position so as to allow a current flowing therethrough and from the closed position to the open position so as to interrupt such current flowing.

The coil actuator is adapted to cause actuations of the switching device and comprises electronic means arranged to:
- count a first operation time associated to a first actuation of the switching device caused by the coil actuator;
- determine a correction time by using the counted first operation time;
- use the correction time to correct an operation time associated to at least one subsequent actuation of the switching device caused by the coil actuator and occurring after the first actuation;
- count the corrected operation time associated to said at least one subsequent actuation.

The correction time is suitable to at least reduce the difference between a target operation time and the counted corrected operation time associated to said at least one subsequent actuation.

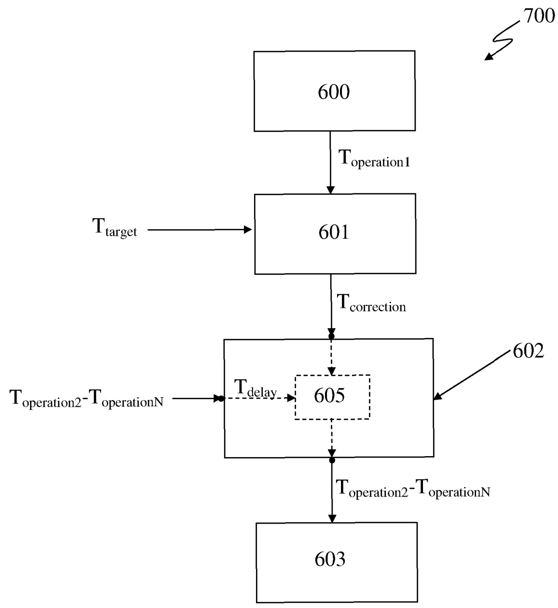

Fig. 6

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Description

[0001] The present invention relates to a coil actuator for a switching device and to a related method for correcting operation times which are counted by the coil actuator and which are associated to actuations of a switching device, actuations caused by the coil actuator itself.

[0002] As known, switching devices used in electrical circuits, such as in low or medium voltage electric circuits, typically circuit breakers, disconnectors and contactors, are devices designed to allow the correct operation of specific parts of the electric circuits in which they are installed, and of the associated electric loads. For the purpose of the present disclosure the term "low voltage" is referred to applications with operating voltages up to 1000V AC/1500V DC, and the term "medium voltage" is referred to applications in the range from 1 kV to some tens of kV, e.g. 50 kV.

[0003] Switching devices can be actuated during their operation from an open position to a closed position so as to allow a current flowing therethrough, and from the closed position to the open position so as to interrupt such current flowing.

[0004] In particular, the switching devices comprise one or more electrical poles, or phases, each having at least a contact movable between a first position, or coupled position, in which it is coupled to a corresponding fixed contact (switching device in the closed position), and a second position, or separated position, in which it is spaced away from the corresponding fixed contact (switching device in the open position).

[0005] A suitable operating mechanism is operatively associated to the movable contacts so as to cause the displacement of such movable contacts between the coupled and separated positions.

[0006] Coil-based actuators, hereinafter indicated as "coil actuators", are frequently used in switching devices, for example in mechanical operated switching devices for low or medium voltage circuits; mechanically operated switching have an operating mechanism of the known "stored-energy" type, wherein the energy required for opening the switching device is stored in suitable elastic means, such as springs.

[0007] A typical use of a coil actuator is to release mechanical parts of the associated switching device, e.g. corresponding parts of the operating mechanism, so as to open or close the switching device itself, following an opening or a closure command and/or event. Examples of such coil actuators are opening shunt releases, closure shunt releases or undervoltage shunt releases, which are all devices well known in the art.

[0008] Generally, an operation time associated to opening and/or closure actuation of the switching device is measured for various tasks, e.g. to implement a diagnostic function about the reliability of the switching device.

[0009] Each measured operation time comprises the activation time of the coil actuator and the time required by the operating mechanism to cause the actuation of the switching device upon the interaction with the coil actuator.

[0010] In the state of the art the operation times are measured by means of portable instruments for service tasks, or IEDs ("intelligent electronic devices") with advanced diagnostic functionalities, or electronic protection relays, or dedicated diagnostic and/or monitoring instruments operatively, which are all operatively connected to the switching device.

[0011] The use of such additional equipment implies a series of disadvantages, among which: complex wiring and cabling, high installation costs, and encumbrance due to the large volume occupied by the additional equipment.

[0012] Furthermore, considering a sequence of actuations of the switching device caused by a coil actuator, the counted operation times associated to the actuations of such sequence are distributed around a desired target operation time for the switching device, generally following a Gaussian statistical distribution.

[0013] As known, this undesired effect is mainly due to the dependence of the operation time to be measured to the time required by the operating mechanism to cause the actuation of the switching device. In particular, such required time can widely vary due for instance to production variances, as well as other variables influencing the performance of the operating mechanism, such as degradation of mechanical parts or the environment temperature.

[0014] The variance of the measured operation times with respect to the target value is generally not negligible in view for example of the diagnostic functionality and a correct operating of the switching device.

[0015] Therefore, at the current state of the art, although known solutions perform in a rather satisfying way, there is still reason and desire for further improvements.

[0016] Such desire is fulfilled by a coil actuator for an electric switching device which can be actuated during its operation from an open position to a closed position so as to allow a current flowing therethrough and from the closed position to the open position so as to interrupt such current flowing. The coil actuator is adapted to cause actuations of the switching device and comprises electronic means arranged to:

- count a first operation time associated to a first actuation of the switching device caused by the coil actuator;
- determine a correction time by using the counted first operation time;
- use the correction time to correct an operation time associated to at least one subsequent actuation of the switching device caused by the coil actuator and occurring after the first actuation;
- count the corrected operation time associated to said at least one subsequent actuation.

[0017] The correction time is suitable to at least reduce the difference between a target operation time and the counted corrected operation time associated to said at least one subsequent actuation. Such desire is also fulfilled by a method for correcting operation times counted by a coil actuator and associated to actuations of a switching device which are caused by the coil actuator. The method comprises:

- counting a first operation time associated to a first actuation of the switching device caused by the coil actuator;
- determining a correction time by using the counted first operation time;
- using the correction time to correct an operation time associated to at least one subsequent actuation of the switching device caused by the coil actuator and occurring after the first actuation; and
- counting the corrected operation time associated to said at least one subsequent actuation.

[0018] The correction time is suitable to at least reduce the difference between a target operation time and the counted corrected operation time associated to said at least one subsequent actuation. Another aspect of the present disclosure is to provide a switching device comprising at least a coil actuator such as the coil actuator defined by the annexed claims and disclosed in the following description; another aspect is to provide a switchgear comprising at least a switching device and/or at least a coil actuator according to the annexed claims and disclosed in the following description.

[0019] Further characteristics and advantages will be more apparent from the description of exemplary, but non-exclusive, embodiments of the coil actuator, the related switching device, and the related correction method according to the present disclosure, illustrated in the accompanying drawings, wherein:

- figure 1 is a schematic view of a switching device comprising three coil actuators according to the present disclosure;
- figure 2 is a schematic view of a first possible coil actuator according to the present disclosure;
- figure 3 is a schematic view of the coil actuator of figure 2 operatively connected to a power supply and to a trip circuit supervisor according to the present disclosure;
- figure 4 is a plot showing the time dependence of the voltage applied at the input of the coil actuator in figure 2 during its operation;
- figure 5 is a schematic view of a second possible coil actuator according to the present disclosure;
- figure 6 is a block diagram illustrating a method of correction related to a coil actuator according to the present disclosure;
- figure 7 illustrates a first example of implementing a step of the method illustrated in figure 6;
- figure 8 illustrates a second example of implementing a step of the method illustrated in figure 7.

[0020] It should be noted that in the detailed description that follows, identical or similar components, either from a structural and/or functional point of view, have the same reference numerals, regardless of whether they are shown in different embodiments of the present disclosure; it should also be noted that in order to clearly and concisely describe the present disclosure, the drawings may not necessarily be to scale and certain features of the disclosure may be shown in somewhat schematic form.

[0021] With reference to the exemplary embodiments of figures 1-5, a coil actuator 1 according to the present disclosure is adapted to be installed in a switching device 100, such as for example a low or medium voltage circuit breaker 100, comprising at least a pole 101 having one or more movable contacts 102 with associated corresponding fixed contacts 103. Contacts 102 are movable between a coupled position, wherein they are coupled to the corresponding fixed contacts 103, and a separated position wherein they are spaced away from the corresponding fixed contacts 103.

[0022] The switching device 100 can be actuated during its operation from an open position to a closed position so as to allow a current flowing therethrough and from the closed position to the open position so as to interrupt such current flowing.

[0023] In particular, the displacement of the movable contacts 102 from the separated position towards the coupled position allows a current flowing through the coupled movable and fixed contacts 102, 103 (closure actuation of the switching device), and the displacement of the movable contacts 102 from the coupled position towards the separated position causes the interruption of such current flowing (opening actuation of the switching device).

[0024] Figure 1 schematically illustrates a switching device 100 having for example three poles 101, each comprising a movable contact 102 and a corresponding fixed contact 103; such an embodiment has to be understood only as an illustrative and non limiting example, since the principles and technical solutions introduced in the following description can be applied to switching devices 100 having a number of poles 101 different with respect to the illustrate one, such as for example a switching device 100 with a single pole 101, or two poles 101, or four poles 101.

[0025] An operating mechanism 104, for example an energy-stored operating mechanism 104, is operatively connected to the movable contacts 102 so to cause the movement of such contacts 102 between the coupled and separated positions with respect to the corresponding fixed contacts 103, and therefore to cause the actuation of the switching device 100 between its closed position and its open position.

[0026] The coil actuator 1 according to the present disclosure is adapted to cause actuations of the switching device 100 where it is installed.

[0027] According to the exemplary embodiments of figures 1-5, the coil actuator 1 comprises a coil electromagnet 2 arranged to move between a rest position (or released position) and an actuating position (or launched position), wherein the movement from the rest position to the actuating position is suitable to cause an actuation of the switching 100.

[0028] In particular, the coil actuator 1 according to the present disclosure can be installed and used into the switching device 100 as a closure actuator 1, wherein the movement of its coil electromagnet 2 from the released to the launched position causes the closure of the switching device 100, i.e. the actuation of the switching device 100 itself from the open position to the closed position.

[0029] The coil actuator 1 according to present disclosure can be installed and used in the switching device 100 as an opening actuator 1, wherein the movement of its coil electromagnet 2 from the released to the launched position causes the opening of the switching device 100, i.e. the actuation of the switching device 100 itself from the closed position to the open position. According to the exemplary embodiment of figure 2 and to the exemplary embodiment of figure 5, the coil electromagnet 2 of the coil actuator 1 comprises one or more parts 3 which are arranged to move, during the movement of the coil electromagnet 2 itself from the released to the launched position, so as to interact with one or more corresponding parts of the switching device 100; such operative interaction between the movable parts 3 of the coil electromagnet 2 and the corresponding parts of the switching device 100 causes the actuation of the switching device 100 itself.

[0030] The coil actuator 1 according to the present disclosure comprises for example a case which houses the coil electromagnet 2 and which is configured for allowing a part 3 of the coil electromagnet 2 itself, e.g. an anchor or plunger 3, to move between a first stable position, or retracted position, wherein it is retracted into the case (coil electromagnet 2 is in the released, or rest, position), and a second stable position, or launched position, wherein at least a portion of the movable part 3 is launched outside the case (coil electromagnet 2 is in the launched, or actuating, position).

[0031] The movable part 3 of the coil electromagnet 2 is arranged to release, through its movement from the retracted to the launched position, one or more corresponding mechanical parts of the operating mechanism 104 of the switching device 100, so as to cause the actuation of the switching device 100 itself.

[0032] The opening actuator 1 according to the present disclosure is installed into the switching device 100 in such a way that the interaction between the movable parts 3 of its electromagnet 2 and the corresponding parts of the switching device 100, e.g. parts of the operating mechanism 104, causes the opening of the switching device 100, i.e. the actuation of the switching device 100 itself from its closed to position to its open position.

[0033] The closure actuator 1 according to the present disclosure is installed into the switching device 100 in such a way that the interaction between the movable parts 3 of its electromagnet 2 and the corresponding parts of the switching device 100, e.g. parts of the operating mechanism 104, causes the closure of the switching device 100, i.e. the actuation of the switching device 100 itself from its open position to its closed position.

[0034] For example, the switching device 100 illustrated in figure 1 comprises at least an opening actuator 1a and a closure actuator 1b.

[0035] With reference to the exemplary embodiments of figures 2 and 5, the coil actuator 1 according to the present disclosure comprises electronic means 1000, embedded inside the coil actuator 1 itself.

[0036] The electronic means 1000 are advantageously arranged to count an operation time $T_{operation}$ associated to each actuation of the switching device 100 caused by the coil actuator 1 itself. The counted operation time $T_{operation}$ is indicative of the duration of the associated actuation of the switching device 100, since that the operation time $T_{operation}$ comprises:

- an activation time of the coil actuator 1 (i.e. the time elapsed between a detection by the coil actuator 1 of an intervention request, or need, and the end of the consequent movement of the coil electromagnet 2, from the rest to the actuating position); and
- a time required by the operating mechanism 104 to cause the actuation of the switching device 100, upon the intervention on it of the coil actuator 1.

[0037] It is to be set forth that if the coil actuator 1 is installed and used in the switching device 100 as an opening actuator 1, the operation time $T_{operation}$ to be counted is an opening operation time. In that case the counted opening operation time $T_{operation}$ is indicative of the duration of the actuation of the switching device 100 from the closed to the open position, since that it comprises the time required by the operating mechanism 104 to move the contacts 102 from the coupled to the separated position with respect to the corresponding fixed contacts 103.

[0038] If the coil actuator 1 is installed and used in the switching device 100 as a closure actuator 1, the operation time $T_{operation}$ to be counted is a closure operation time. In that case the counted operation time $T_{operation}$ is indicative of the duration of the actuation of the switching device 100 from the open to the closed position, since that it comprises the time required by the operating mechanism 104 to move the contacts 102 from the separated to the coupled position with respect to the corresponding fixed contacts 103.

[0039] For example, in the switching device 100 illustrated in figure 1 the opening actuator 1a and the closure actuator 1b comprise corresponding electronic means 1000 which are arranged to count opening operation times and the closure operation times of the illustrated switching device 100, respectively.

[0040] Preferably, each operation time $T_{operation}$ associated to a corresponding actuation of the switching device 100 comprises a configurable delay time T_{delay}. The delay time T_{delay} is set to have operation times $T_{operation}$ according to a required target operation time T_{target} of the switching device 100.

[0041] In particular, the target operation time T_{target} may vary due to different normatives or to different typologies of switching device 100 where the coil actuator 1 could be installed; the operation times $T_{operation}$ to be counted are accordingly adapted to the required target operation time T_{target} through a suitable initial setting of their configurable delay time T_{delay}.

[0042] For instance, the required target opening operation time T_{target} for a mechanically operated medium voltage circuit breaker 100 is generally comprised in the range between 50 and 73 ms, while the required target closure operation time T_{target} is typically comprised in the range between 50 and 70 ms.

[0043] Preferably, the electronic means 1000 are arranged to receive and store such delay time T_{delay} as a configurable parameter.

[0044] Preferably, the electronic means 1000 are arranged to associate the configurable delay time T_{delay} to the activation time of the coil actuator 1, for example introducing such delay T_{delay} between the detection by the coil actuator 1 of the intervention request, or need, and the consequent electrical driving of the coil electromagnet 2 (to cause the movement thereof from the rest to the actuating position).

[0045] With reference to the exemplary embodiment of figures 6-8, the present disclosure is also related to a method 700 for advantageously correcting the operation times $T_{operation}$ counted by the coil actuator 1 and associated to the actuations of the switching device 100 which are caused by the coil actuator 1 itself.

[0046] The electronic means 1000 of the coil actuator 1 are arranged to carry out the method 700 according to the present disclosure.

[0047] In particular, according to the exemplary embodiment of figure 6, the electronic means 1000 are arranged to:

- count a first operation time $T_{operation1}$ associated to a first actuation of the switching device 100 caused by the coil actuator 1 (step 600 of the method 700);
- determine a correction time $T_{correction}$ by using the counted operation time $T_{operation1}$ (step 601 of the method 700);
- use the correction time $T_{correction}$ to correct an operation time $T_{operation2}$, $T_{operation3}$,...$T_{operationN}$ associated to at least one subsequent actuation of the switching device 100 caused by the coil actuator 1 and occurring after the first actuation (step 602 of the method 700);
- count the corrected operation time $T_{operation2}$-$T_{operationN}$ associated to said at least one subsequent actuation (step 603 of the method 700).

[0048] The determined correction time $T_{correction}$ is advantageously suitable to at least reduce the difference between the target operation time T_{target} required for the switching device 100 and the counted corrected operation time $T_{operation2}$-$T_{operationN}$.

[0049] Preferably, the electronic means 1000 are arranged to receive and store the target operation time T_{target} for the switching device 100 as a configurable parameter.

[0050] Preferably, the electronic means 1000 are arranged to determine the correction time $T_{correction}$ by comparing the target operation time T_{target} to the counted operation time $T_{operation1}$ associated to the first actuation of the switching device 100. Accordingly the step 601 of the method 700 comprises determining the correction time $T_{correction}$ by comparing the target operation time T_{target} to the counted operation time $T_{operation1}$.

[0051] For example, the correction time $T_{correction}$ is given by the difference between the target operation time T_{target} and the counted operation time $T_{operation1}$. In that case, the correction time $T_{correction}$ could be positive or negate, depending if the counted operation time $T_{operation1}$ is greater or smaller than the target operation time T_{target}.

[0052] According to the exemplary embodiment of figure 6, the electronic means 1000 of the coil actuator 1 are arranged to apply at least an amount of the correction time $T_{correction}$ to the configurable delay time T_{delay} of the operation time $T_{operation2}$-$T_{operahonN}$ which is associated to said at least one subsequent actuation of the switching device 100 occurring after the first actuation.

[0053] Accordingly the step 602 of the method 700 comprises the step 605 of applying at least an amount of the correction time $T_{correction}$ to the configurable delay time T_{delay} of the operation time $T_{operation2}$-$T_{operationN}$ associated to said at least one subsequent actuation.

[0054] In this way, the configurable delay time T_{delay} of such operation time $T_{operation2}$-$T_{operationN}$ is modified by applying thereto at least an amount of the correction time $T_{correction}$. Such modification is the correction suitable for at least reducing the difference between the target operation time T_{target} and the counted corrected operation time $T_{operation2}$-$T_{operationN}$.

[0055] According to the exemplary embodiment of figure 7 and considering the first actuation and a second subsequent actuation of the switching device 100, the electronic means 1000 are arranged to use the determined correction time $T_{correction}$ to correct the operation time $T_{operation2}$ associated to such second actuation. In particular, the electronic means 1000 are arranged to apply the overall determined correction time $T_{correction}$ to the configurable delay time T_{delay} of the operation time $T_{operation2}$ (method step 605 illustrated in figure 7).

[0056] Preferably, the overall correction $T_{correction}$ is directly added the configurable delay time T_{delay} of the operation time $T_{operation2}$.

[0057] According to the exemplary embodiment of figure 8 and considering the first actuation and a plurality of subsequent actuations of the switching device 100, the electronic means 1000 are arranged to:

- divide the determined correction time $T_{correction}$ into a plurality of addends T_{add1}, T_{add2},....T_{addN-1} (method step 604 illustrated in figure 8); and
- apply each addend T_{add1}, T_{add2},.... T_{addN-1} to the configurable delay time T_{delay} of a corresponding operation time $T_{operation2}$, $T_{operation3}$,...$T_{operationN}$ which is associated to an actuation of said plurality of subsequent actuations (method steps 605_1, 605_2,... 605_N illustrated in figure 8).

[0058] For example, it is considered a sequence of four consecutive actuations of the switching device 100 caused by the coil actuator 1. Basing on the counted operation time $T_{operation1}$ associated to the first actuation of the sequence, the electronic means 1000 firstly determine a correction time $T_{correction}$, having for instance a value of 6 ms.

[0059] Then the electronic means 1000 apply:

- 2 ms (first addend T_{add1}) to the configurable delay time T_{delay} of the operation time $T_{operation2}$ associated to the second actuation of the sequence, occurring after the first actuation;
- 2 ms (second addend T_{add2}) to the configurable delay time T_{delay} of the operation time $T_{operation3}$ associated to the third actuation of the sequence, occurring after the second actuation; and
- 2 ms (third addend T_{add3}) to the configurable delay time T_{delay} of the fourth actuation of the sequence, occurring after the third actuation.

[0060] With reference to the exemplary embodiment of figure 2 and to the exemplary embodiment of figure 5, the electronic means 1000 of the coil actuator 1 according to the present disclosure comprise:

- detection means 11 arranged to detect a first event, or launch event, which is indicative of a request, or need, for an actuation of the switching device 100;
- driving means 10 operatively associated to the detection means 11 and connected to the coil electromagnet 2 of the coil actuator 1.

[0061] The driving means 10 are arranged to electrically drive the coil electromagnet 2 to cause at least the movement thereof from the released position to the launched position upon the detection of the launch event by the detection means 11. The detection means 11 of the coil actuator 1 are arranged to detect also a second event which is indicative of the end of the actuation of the switching device 100, wherein such actuation is caused by the coil actuator 1 itself upon the detection of the launch event and the consequently movement of its coil electromagnet 2.

[0062] The electronic means 1000 of the coil actuator 1 further comprise counting means 20 which are operatively associated to the detection means 11 and are arranged to count the operation time $T_{operation}$ associated to each actuation of the switching device 100 caused by the coil actuator 1 itself upon the detection of a launch event.

[0063] Again it is set forth that when the coil actuator 1 is conceived and used in the switching device 100 as an opening actuator 1, the counted operation time $T_{operation}$ is an opening operation time associated to the actuation of the switching device 100 from the closed to the open position. When instead the coil actuator 1 is conceived and used in the switching device 100 as a closure actuator 1, the counted operation time $T_{operation}$ is a closure operation time associated to the actuation of the switching device 100 from the open to the closed position.

[0064] The counting means 20 are arranged to start counting the operation time $T_{operation}$ when the launch event is detected by the detection means 11, and to stop such counting when the second event is detected by the detection means 11. Therefore, the detection of the launch event and the detection of the second event trigger the start and the end, respectively, of the counting performed by the counting means 20.

[0065] Preferably the driving means 10 are arranged to apply the configurable delay time T_{delay} of the operation time $T_{operation}$ to be counted between the detection of the launch event and the consequent electrical driving of the coil electromagnet 2.

[0066] In particular, considering the implementation of the step 605 of the method 700, the driving means 10 are arranged to apply the configurable delay time T_{delay} as modified by applying thereto at least an amount of the previously determined correction time $T_{correction,}$ in such a way to correct the operation time $T_{operation}$ to be actually counted.

[0067] Preferably, the electronic means 1000 of the coil actuator 1 according to the present disclosure comprise comparing means 21 operatively associated to the counting means 20 and arranged to compare the counted operation time $T_{operation}$ with a temporal acceptance range T_{range} which is indicative of an acceptable value for the switching device 100.

[0068] Preferably, the comparing means 21 are arranged to receive and store the acceptance range T_{range} as a configurable parameter.

[0069] Preferably, the coil actuator 1 is arranged to cause the generation of an alarm signaling, e.g. the generation of at least an alarm signal and/or indication, when the counted operation time $T_{operation}$ exceeds the associated temporal range T_{range}.

[0070] The coil actuator 1 according to the exemplary embodiment of figure 2 can be installed and used in the switching device 100 as a shunt opening release 1 (such as for example the coil actuator 1a in figure 1) configured for opening the switching device 100 following an opening command and/or signal, or alternatively can be installed and used in the switching device 100 as a shunt closure actuator 1 (such as for example the coil actuator 1b in figure 1) configured for closing the switching device 100 following a closure command and/or signal.

[0071] The opening and closure commands and/or signals can be generated automatically by suitable means or by an operator, and can be generated inside the switching device 100 or received by remote. For example, an opening, or trip, command can be generated by a protection device installed into the switching device 100 upon the detection of an electrical fault.

[0072] The driving means 10 of the coil actuator 1 according to the embodiment of figure 2 are arranged to electrically drive the coil electromagnet 2 so as to hold it in the launched position and so as to allow the return thereof from the launched position to the release position upon the detection of the second event, or release event, by the detection means 11.

[0073] Preferably, such driving means 10 comprise a power input circuit 12 arranged to be operatively connected to and receive an input voltage V_{in} from at least a power source, e.g. a power associated to the switching device 100 and/or to the electric circuit into which the switching device 100 itself is installed, for example a power line 200 associated to the switching device 100 (see figure 3).

[0074] The power input circuit 12 is arranged to use the received input voltage V_{in} to provide a suitable power supply to several components and/or elements of the coil actuator 1, in particular to its electronic means 1000.

[0075] For instance, the power input circuit 12 may comprise one or more input filters and a rectifier to convert the AC voltage received from the power line 200 to a DC input voltage.

[0076] With reference to figures 2-4, the detection means 11 are arranged to continuously sense a voltage indicative of the input voltage V_{in}, i.e. to sense directly the voltage V_{in} applied to the power input circuit 12, or indirectly through a voltage generated in the coil actuator 1 and depending on such input voltage V_{in}.

[0077] In particular, the detection means 11 are arranged to detect, by means of the sensed voltage, a first threshold value, or launch threshold value $V_{th-launch}$, and a second threshold value, or release threshold value $V_{th\_release}$, of the input voltage V_{in}, wherein the launch threshold value V_{th_launch} is preferably higher than the release threshold value $V_{th\_release}$.

[0078] The driving means 10 are operatively associated to the detection means 11 so as to electrically drive the coil electromagnet 2 for moving and holding the coil electromagnet 2 itself in the launched position upon the detection of the launch threshold value $V_{th-launch}$. The launch and hold operations of the coil electromagnet 2 are executed by the driving means 10 using the power drawn from the input voltage V_{in}, having a value above the launch threshold value V_{th_launch}.

[0079] The driving means 10 are operatively associated to the detection means 11 so as to at least reduce, preferably interrupt, the electrical driving of the coil electromagnet 2 for allowing the return thereof from the launched position to the release position, upon the detection of the release threshold value $V_{th\_release}$ by the detection means 11.

[0080] The detection of the launch threshold value $V_{th-launch}$ and the detection of the release threshold value $V_{th\_relesase}$ are the launch event and the release event which trigger the start and the end, respectively, of the counting performed by the counting means 20 (see the plot illustrated as an example in figure 4).

[0081] In the exemplary embodiment of figure 2, the coil actuator 1 comprises a single coil electromagnet 2, i.e. a coil electromagnet 2 having a single electromagnetic coil 4 operatively associated to the movable part 3 and electrically connected to the driving means 10; in particular, the driving means 10 are arranged to: generate a launch current I_L flowing through the electromagnetic coil 4 so as to generate a magnetic force suitable for moving the part 3 from the retracted to the launched position; and consequently reduce and maintain the launch current I_L at a holding current I_H suitable for holding the movable part 3 in the launched position.

[0082] The driving means 10 illustrated in figure 2 advantageously comprise a first control unit 31 and a second control unit 32, wherein the second control unit 32 is suitable for controlling the current flowing through the single coil electromagnet 2 and the first control unit 31 is operatively connected to the second control unit 32 for setting the current which has to flow through the single coil electromagnet 2. By using the single coil electromagnet 2 and the associated first and second control units 31, 32, the number of electromagnetic variables is reduced, therefore reducing the manufacturing and handling costs.

[0083] The first control unit 31 can be any electronic device suitable for receiving and executing software instructions, and for receiving and generating output data and/or signals through a plurality of input and/or output ports. For example, the controller 31 may be a microcontroller 31, such as the MSP430 microprocessor produced and made available in commerce by Texas Instruments®.

[0084] The driving means 10 comprise a power circuit 37 operatively connected to the single coil electromagnet 2 and to the second control unit 32 so as to generate the current flowing through the single coil electromagnet 2 according to the control performed by the second control unit 32. In the embodiment of figure 2 the second control unit 32 is for example a PWM ("Pulse width modulation") controller 32 and the associated power circuit 37 comprises: an electronic power switch 40 to electrically drive the single coil electromagnet 2, such as a power MOS-

FET ("metal-oxide-semiconductor field-effect transistor"); a freewheeling diode 41; and a sense resistor 43 for measuring the current flowing through the single coil electromagnet 2. In practice, the PWM controller 32 is configured for driving the power switch 40 through a PWM signal 400 so as to regulate the current flowing through the single coil electromagnet 2 according to the settings received from the control unit 31.

[0085] The power input circuit 12 is operatively connected to the power circuit 37, the first control unit 31 and the second control unit 32 to provide them the power required to operate; preferably, a power converter 35 is provided to convert and adapt the voltage outputted by the power input circuit 12 into values suitable for supplying the first and second controllers 31, 32.

[0086] The controller 31 stores instructions which, when executed by the controller 31 itself, carry out the method 700 according to the present disclosure. In particular, the stored instructions are suitable to implement all the functionality blocks required to carry out the method, among them the detection means 11 and the counting means 20. If provided, the stored instructions are also suitable to implement the comparing means 21.

[0087] In particular, the controller 31 is arranged to receive and store configurable parameters, for example through a software download operation, comprising at least the launch and release voltage threshold values V_{th_launch}, $V_{th\_release}$ of the detection means 11, the target operation time T_{target}, the configurable delay time T_{delay} and the temporal range T_{range} of the comparing means 21.

[0088] A jumper 39 can be operatively connected to the controller 31 to allow the resetting of at least a stored configurable parameter.

[0089] In order to implement the detection means 11, an input port 302 of the controller 31 is associated to the implemented detection means 11 and is electrically connected at the electrical point where the input voltage V_{in} is applied to the power input circuit 12 (as shown schematically in figure 2), so as to continuously and directly sense such input voltage V_{in}. Alternatively to the exemplary embodiment of figure 2, the coil electromagnet 2 may comprise two electromagnetic coils, or windings, operatively associated to the movable part 3, wherein the driving means 10 connected to such coil electromagnet 2 would be arranged to selectively energize the two coils for moving the part 3 from the retracted to the launched position and for holding such movable part 3 in the launched position, until a release event is detected by the detection means 11.

[0090] With reference to figure 3, the power input circuit 12 of the shunt release 1 illustrated in figure 2 is operatively connected to the power source 200 through cables 13 and at least a contact 201 is placed along the power delivery path from the power source 200 to the power input circuit 12 so as to realize or interrupt such delivery path according to its closure or opening, respectively.

[0091] In particular, if the coil actuator 1 of figure 2 is installed and used into the switching device 100 as an open shunt release 1 (such as for example the actuator 1a in figure 1), the closure of the contact 201 is driven by an opening command and/or signal 202. If the coil actuator 1 of figure 2 is installed and used into the switching device 100 as a closure shunt release 1 (such as for example the actuator 1b in figure 1), the closure of the contact 201 is driven by a closure command and/or signal 202.

[0092] For instance, the contact 201 may be a contact of a protection relay, closed upon the occurrence of a fault event detected by the protection device itself, or may be a button actuable by an operator.

[0093] The electrical connection between the power input circuit 12 and the power supply 200 through the closure of the contact 201 causes the rising of the input voltage V_{in} above the launch threshold value $V_{th\text{-}launch}$, in such a way that the driving means 10 are supplied with the power required to perform the launch and hold operations of the coil electromagnet 2.

[0094] The launch operation of the coil electromagnet 2 causes the opening of the switching device 100 if the coil actuator 1 is installed and used in the switching device 100 as a shunt opening release 1, or causes the closure of the switching device 100 if such coil actuator 1 is installed and used in the switching device 100 as a shunt closure release 1.

[0095] Accordingly, the counting means 20 starts counting the operation time $T_{operation}$.

[0096] Placed along the power delivery path realized by the closure of the contact 201 there is also at least an auxiliary contact 203 which is operatively connected to one or more movable contacts 102 of the switching device 100 so as to move between an open operative status and a closed operative status according to the movement of the contacts 102.

[0097] The auxiliary contact 203 is suitable for interrupting the associated delivery path when it moves from its closed to its open status. In particular, if the coil actuator 1 of figure 3 is installed and used in the switching device 100 as a shunt opening release 1, the auxiliary contact 203 is operatively connected to the corresponding movable contacts 102 so as to be in its closed status while the switching device 100 is in its closed position, and to reach its open status at the end of the opening operation of the switching device 100 caused by the shunt opening release 1 itself, i.e. when the movable contacts 102 reach their separated position with respect to the corresponding fixed contacts 103.

[0098] If the coil actuator 1 of figure 3 is installed and used in the switching device 100 as a shunt closure release 1, the auxiliary contact 203 is operatively connected to the corresponding movable contacts 102 so as to be in the closed status while the switching device 100 is in its open position, and to reach its open status at the end of the closure of the switching device 100 caused by the shunt closure release 1, i.e. when the movable contacts 102 reach their coupled position with respect to the corresponding fixed contacts 103.

[0099] With reference to the exemplary embodiment of figure 5, the coil actuator 1 according to the present disclosure can be conceived and installed into the associated switching device 100 to operate as a shunt undervoltage release 1, i.e. to intervene for opening and/or the switching device 100 upon the detection of an undervoltage condition. For example, the switching device 100 in figure 1 comprises a shunt undervoltage release 1c.

[0100] According to the exemplary embodiment of figure 5, the driving means 10 of the electronic means 1000 embedded in the undervoltage shunt release 1 are operatively connected to at least a power source (depicted in figure 5 by the block indicated with the numeral reference 500) that is associated to the switching device 100 and/or to the electric circuit into which such switching device 100 is installed. In particular, the undervoltage shunt release 1 is connected to the power source 500 so as to receive therefrom the power required to hold the coil electromagnet 2 in its released (or rest) position, e.g. the power required to keep the movable part 3 of the coil electromagnet in the retracted position against a force generated by compressed elastic means.

[0101] The detection means 11 of the electronic means 1000 embedded in the undervoltage release 1 are arranged to detect a condition, or event, indicative of the occurrence of the undervoltage condition. For instance, the detection means 11 are arranged to:

- continuously sense a voltage associated to the power source 500, i.e. to sense directly the supply voltage V_{supply} of the power source 500 or indirectly through a voltage generated in the shunt release 1 and depending on such voltage V_{supply};
- detect the undervoltage condition, by means of the sensed voltage, when the supply voltage V_{supply} falls below a predetermined undervoltage threshold value.

[0102] The driving means 10 are arranged to at least reduce, preferably interrupt, the energizing of the coil electromagnet 2 so as to cause the movement of the part 3 from the retracted to the launched position upon the detection of the undervoltage condition.

[0103] The detection of the undervoltage condition by the detection means 11 is the launch event that triggers the start of the counting of the opening operation time $T_{operation}$ by means of the counting means 20 provided in the electronic means 1000.

[0104] The detection means 11 are also arranged to detect the event indicative of the end of the opening of the switching device 100, opening operation caused by the shunt undervoltage release 1; such detection is the event that triggers the end of the counting of the opening operation time $T_{operation}$.

[0105] For example, the detection means 11 in figure 5 are arranged to detect an electrical signal 501 suitable for signaling the end of the opening operation of the switching device 100 caused by an undervoltage condition, such as a signal 501 generated by the closure of a contact 302 operatively connected to one or more of the movable contacts 102 of the switching device 100 so as to close when such one or more movable contacts 102 reach their separated position with respect to the corresponding fixed contacts 103.

[0106] Preferably the driving means 10 are arranged to apply the configurable delay time T_{delay} of the operation time $T_{operation}$ to be counted, between the detection of the undervoltage condition and the consequent electrical driving of the coil electromagnet 2 (to cause the movement of the part 3 from the retracted to the launched position).

[0107] In particular, considering the implementation of the step 605 of the method 700, the driving means 10 are arranged to apply the configurable delay time T_{delay} as modified by applying thereto at least an amount of the previously determined correction time $T_{correction}$, in such a way to correct the operation time $T_{operation}$ to be counted.

[0108] The undervoltage shunt release 100 illustrated in figure 5 further comprises: the comparing means 21 for comparing the counted opening operation time $T_{operation}$ with the temporal range T_{range}; and alarm generating means 510 operatively associated to the comparing means 21 and arranged to generate an alarm signal and/or indication if the counted opening operation time $T_{operation}$ exceeds the temporal range T_{range}.

[0109] The coil actuator 1 according to the present disclosure is arranged to provide a continuous power supply to its electronic means 1000, at least for a time required to implement the various steps of the method 700 according to the present disclosure.

[0110] If the comparing means 21 are provided, the coil actuator 1 is also arranged to provide a continuous power supply to such comparing means 21, at least for a time required to complete the comparison operation.

[0111] For example, the undervoltage shunt release 1 according to the embodiment of figure 5 comprises at least a backup capacitor 511 suitable for storing energy drawn by the V_{supply} applied to the undervoltage shunt release 1 and connected at least to the electronic means 1000 so as to release the stored energy thereto, starting from the occurrence of the undervoltage condition.

[0112] It is to be set forth that the backup capacitor 511 (or alternatively other suitable energy storage means) is also connected to: the detection means 11, so as to provide them the power required to detect the signal 501 indicative of the end of the opening operation of the switching device 100, even during the undervoltage condition; and the alarm generating means 510, so as to provide them the power required to generate the alarm signaling, even during the undervoltage condition.

[0113] According to a first exemplary solution, the coil actuator 1 according to the embodiment of figure 2 can comprise a backup capacitor connected to the power input circuit 12 so as to be charged while the input voltage V_{in} is applied to the coil actuator 1 itself by the power source 200. Advantageously, the backup capacitor may be the smoothing capacitor used in the power input circuit 12 to rectify the AC voltage received from the power line 200 to a DC input voltage.

[0114] With reference to figure 3, at the opening of the auxiliary contact 203 the application of the input voltage V_{in} to the power input circuit 2 of the coil actuator 1 stops, and the backup capacitor releases the stored energy to supply the electronic means 1000.

[0115] According to a second exemplary solution, the electronic means 1000 of the coil actuator 1 according to the embodiment of figure 2 are operatively connected to the power input circuit 12 of the driving means 10. The power input circuit 12 is in turn arranged to be operatively connected to the associated power source 200 so as to receive therefrom the power required to continuously supply at least a minimum input voltage V_{in_min} to the electronic means 1000; the minimum input voltage V_{in_min} is suitable for providing the electronic means 1000 with the power required to complete at least the required steps of the method 700.

[0116] With reference to figures 2-3, the coil actuator 1 is advantageously arranged to be operatively connected a trip circuit supervisor 150 installed into the switching device 100.

[0117] The trip circuit supervisor 150 is arranged to check the integrity of the coil electromagnet 2, e.g. the integrity of the electromagnetic coil 4 in the coil actuator 1 illustrated figure 2, and of the driving means 10 associated thereto (coil supervision and feedback routine). For example, the trip circuit supervisor 150 may be a supervision relay of the type well known in the art, and therefore not further described herein.

[0118] According to the exemplary embodiment of figure 2, the power input circuit 12 of the coil actuator 1 is arranged to be operatively connected to the trip circuit supervisor 150 so as to continuously receive, through such trip circuit supervisor 150, the power required to supply the minimum input voltage V_{in_min} to the electronic means 1000.

[0119] For example, the power input circuit 102 in figure 2 provides, through the trip circuit supervisor 150, the minimum input voltage V_{in_min} to the first control unit 31, the PWM controller 32, and the power circuit 37. In practice, the input minimum voltage V_{in_min} is suitable to supply the minimum power required from the coil actuator 1 to work and perform its main functionalities.

[0120] With reference to figure 3, the trip circuit supervisor 150 is placed along a power delivery path from the power source 200 to the power input circuit 12 of the coil actuator 1, wherein such delivery path is parallel with respect to the power delivery path comprising the contact 201 and the auxiliary contact 203. In this way, when the contact 201 or the auxiliary contact 203 interrupts the associated power delivery path, the coil actuator 1 remains powered to work through the trip circuit supervisor 150.

[0121] The detection means 11 of the coil actuator 1 according to such embodiment are also arranged to detect the minimum input voltage V_{in_min} and the driving means 10 are arranged to electrically drive the coil electromagnet 2 to generate a coil supervisor current I_{cs} flowing through such coil electromagnet 2 when the input voltage V_{in} is detected to be in the range comprised between the minimum input voltage $V_{in_min}$and the release threshold value $V_{th\_release}$. The coil supervisor current I_{cs} is lower than the currents generated by the driving means 10 to perform the launch and hold operations of the coil electromagnet 2; for example, the supervisor current I_{cs} is lower than the launch current I_L and the hold current I_H flowing through the electromagnetic coil 4 of the coil actuator 1 illustrated in figure 2.

[0122] The current I_{tc} flowing through the trip circuit supervisor 150 depends on the supervisor current I_{cs} flowing through the coil electromagnet 2; the driving means 10 are arranged to: monitor the current I_{cs} or at least a parameter associated to such current I_{cs}; check the integrity of the coil electromagnet 2 basing on such monitoring of the supervisor current I_{cs}; at least reduce, preferably interrupt, the current I_{cs} upon the checking of a failure in the coil electromagnet 2.

[0123] The trip circuit supervisor 150 is configured for: sensing the current I_{tc} flowing therethrough; detecting the reduction of the such current I_{ts} below a first predetermined threshold, wherein the reduction of the current I_{ts} is due to the reduction of the supervisor current I_{cs}; and generating an alarm signaling 151 upon such detection.

[0124] In the exemplary embodiment of figure 2 an input port 300 of the controller 31 is operatively connected to the output 301 of the PWM controller 32 from which the PWM signal 400 is sent to the MOSFET 40; for example, a low pass filter 38 is used to convert the PWM signal 400 into a voltage suitable for being measured by the controller 31.

[0125] The controller 31 measures the duty cycle "D" of the PWM signal 400, such duty cycle D depending on the input voltage V_{in}, the current set by the controller 31 and the coil impedance of the single coil electromagnet 2 (i.e. the electrical impedance associated to electromagnetic coil 4).

[0126] Therefore, the measurement of the duty cycle D provides an indication on the integrity of the single coil electromagnet 2. In particular, the controller 31 is configured for comparing the measured duty cycle D to a predetermined acceptance range, preferably a configurable acceptance range, and for changing the current settings sent to the PWM controller 32 to at least reduce, preferably interrupt, the current I_{cs} flowing through the single coil electromagnet 2 when the measured duty cycle D exceeds the acceptance range.

[0127] The current I_{tc} is therefore reduced so as to activate the alarm signaling 151 of the trip circuit supervisor 150. In particular, the current I_{tc} flowing through the trip circuit supervisor 150 can be calculated as follows:

$$Itc = Ics \cdot D + Iq,$$

wherein Iq is a quiescent current, i.e. the current needed by the coil actuator 1 to stay active and work.

[0128] Hence, if the supervision current I_{cs} is interrupted by the controller 31 due to a failure in the single coil electromagnet 2, the current I_{tc} is reduced to the quiescent current Iq which has a value below the set first predetermined threshold for activating the alarm signaling 151. According to the exemplary embodiment of figure 2, the comparing means 11 and the driving means 10 of the coil actuator 1 are operatively associated each other (in particular in the coil actuator 1 of figure 2 are both implemented by the controller 31), and the driving means 10 are advantageously arranged to at least reduce, preferably interrupt, the supervisor current I_{cs} when the comparing means 11 detect that the counted operation time $T_{operation}$ exceeds the temporal range T_{range} of the comparing means 21.

[0129] In this way the supervisor current I_{cs} is reduced by the driving means 10 so as the current I_{tc} flowing through the trip circuit supervisor 150 falls below the first predetermined threshold. In practice, such reduction of the supervisor current I_{cs} simulates the detection of a failure in the coil electromagnet 2 and consequently activates the alarm signaling 151 already provided in the trip circuit supervisor 150.

[0130] Alternatively, the shunt trip supervisor 150 may be configured for discriminating between a first condition wherein a fault occurs in the supervised coil electromagnet 2 and a second condition wherein the counted operation time $T_{operation}$ exceeds the temporal range T_{range}.

[0131] In this way, the shunt trip supervisor 150 can be arranged to generate two different alarm signaling, one indicative of the first condition and the other of the second condition. For example, the driving means 10 can be arranged to reduce the supervisor current I_{cs} so as the current I_{tc} flowing through the trip circuit supervisor 150 falls below a second predetermined threshold, different with respect to the first threshold, when the comparing means 11 detect that the counted operation time $T_{operation}$ exceeds the temporal range T_{range} of the detection means 11.

[0132] In particular, if such second threshold is set above the first threshold, the shunt trip supervisor 150 is arranged to detect when the current I_{tc} which has fallen below the second threshold also falls below the first threshold; if the current I_{tc} falls below also to the first threshold, the trip circuit supervisor 150 is arranged to generate the alarm signaling 151 indicative of a fault in the supervised coil electromagnet 2. If the current I_{tc} does not fall below also to the first threshold, the trip circuit supervisor 150 is arranged to generate an alarm signaling, different to the above mentioned alarm signaling 151, which is dedicate for signaling the exceeding of the temporal range T_{range}.

[0133] If the second threshold is set below the first threshold, the shunt trip supervisor 150 is arranged to detect when the current I_{tc} which has fallen below the first threshold also falls below the second threshold; if the current I_{tc} falls below also the second threshold, the trip circuit supervisor 150 is arranged to generate an alarm signaling indicative of the exceeding of the temporal range T_{range}. If the current I_{tc} does not fall below also to the second threshold, the trip circuit supervisor 150 is arranged to generate the alarm signaling 151 indicative of a fault in the supervised coil electromagnet 2.

[0134] In practice, it has been seen how the coil actuator 1, and the related switching device 100 and method 700 according to the present disclosure allow achieving the intended object offering some improvements over known solutions.

[0135] In particular, the coil actuator 1 is arranged to count by itself the operation times $T_{operation}$ associated to the actuations of the switching device 100, therefore providing an easy and economical solution that does not require other additional or external equipments connected to the switching device 100. In this way, additional and complex cabling and wiring, extra-costs, and encumbrance into the switching device 100 are avoided.

[0136] Furthermore, the disclosed method 700 (carried out by the electronic means 1000 of the coil actuator 1) is suitable to correct the operation times $T_{operation}$ associated to the actuations of the switching device caused by the coil actuator 1, in such a way as the counted corrected operation times $T_{operation}$ remain all close to the required target operation time T_{target} of the switching device 100, despite of the variations manly introduced by the operation of the operating mechanism 104.

[0137] In this way, the operative live of the switching device 100 is improved because all the operations/ functionalities which are associated to the switching device 100 and synchronized to the counted operation time $T_{operation}$ can occur more correctly about at the required target time T_{target}.

[0138] The correction method 700 also improves the adaptability of the coil actuator 1 to different switching devices 100, having the same required target operation time T_{target} but different times required by their operating mechanisms 104 to actuate the switching device themselves. In that case, the method 700 automatically corrects the operation times $T_{operation}$ to remain close to the target operation time T_{target}, despite of the time difference between the times required by the actuating mechanism 104 of the first and second switching devices 100. Furthermore, a trip circuit supervisor 150 can be advantageously connected to the coil actuator 1 in such a way that, after the auxiliary contact 103 opens, the coil actuator 1 remains powered to work.

[0139] In particular, the coil actuator 1 may be configured for activating the alarm signaling 151 already provided in the trip circuit supervisor 150 for signaling failures in the associated electromagnetic coil 2, so as to signal also undesired conditions of unduly operation long times for closing or opening the switching device 100.

[0140] Such results are achieved thanks to a solution which in principle makes the coil actuator 1 and the related switching device 100 according to the present disclosure easy to be used in connection with a switchgear. Hence, the present disclosure also encompasses a switchgear comprising at least a switching device 100 and/or at least a coil actuator 1 according to the present disclosure.

[0141] Moreover, all parts/components can be replaced with other technically equivalent elements; in practice, the type of materials, and the dimensions, can be any according to needs and to the state of the art.

[0142] For example, alternatively to the exemplary embodiment of figure 2 the controller 31 may be arranged to directly generate an alarm signaling upon the detection of a counted operation time $T_{operation}$ exceeding the predetermined temporal range T_{range}.

[0143] Further it is to be understood that the functional blocks in the coil actuator 1 according to present disclosure, i.e. the driving means 10, the counting means 20, the detection means 11, and the comparing means 21, may be all implemented in a single electronic unit through the execution of suitable instructions, or alternatively one or more of such functional block may be implemented by dedicated electronic means and/or units suitably connected each other. For example, the counting means 20 may be implemented by a digital counter 20 triggered by the detection means 11, which in turn may be implemented for example by an electronic circuit comprising a comparator.

[0144] Although the controller 31 has been indicated to be for example a microprocessor, such controller 31 can also be a microcomputer, a minicomputer, a digital signal processor (DSP), an optical computer, a complex instruction set computer, an application specific integrated circuit, a reduced instruction set computer, an analog computer, a digital computer, a solid-state computer, a single-board computer, or a combination of any of theses.

[0145] Further, instructions, data, signals and parameters can be delivered to the controller 31 via electronic data carts, manual selection and control, electromagnetic radiation, communication buses, and generally through any suitable electronic or electrical transfer.

Claims

1. A coil actuator (1) for an electric switching device (100) which can be actuated during its operation from an open position to a closed position so as to allow a current flowing therethrough and from said closed position to said open position so as to interrupt such current flowing, said coil actuator (1) being adapted to cause actuations of said switching device (1) and **characterized in that** it comprises electronic means (1000) arranged to:

   - count (600) a first operation time ($T_{operation1}$) associated to a first actuation of the switching device (100) caused by the coil actuator (1);
   - determine (601) a correction time ($T_{correction}$) by using the counted first operation time ($T_{operation1}$);
   - use (602) said correction time ($T_{correction}$) to correct an operation time ($T_{operation2}$-$T_{operationN}$) associated to at least one subsequent actuation of the switching device (100) caused by the coil actuator (1) and occurring after said first actuation;
   - count (603) the corrected operation time ($T_{operation2}$-$T_{operationN}$) associated to said at least one subsequent actuation;

   wherein said correction time ($T_{correction}$) is suitable to at least reduce the difference between a target operation time (T_{target}) and the counted corrected operation time ($T_{operation2}$-$T_{operationN}$) associated to said at least one subsequent actuation.

2. The coil actuator (1) according to claim 1, wherein said electronic means (1000) are arranged to determine said correction time by comparing (601) said target operation time (T_{target}) to said counted first operation time ($T_{operation1}$).

3. The coil actuator (1) according to claim 1 or 2, wherein said first operation time ($T_{operation1}$) and the operation time ($T_{operation2}$-$T_{operationN}$) associated to said at least one subsequent actuation comprise a configurable delay time (T_{delay}).

4. The coil actuator (1) according to claim 3, wherein said electronic means (1000) are arranged to apply (605) at least an amount of said correction time ($T_{correction}$) to the configurable delay time (T_{delay}) of the operation time ($T_{operation2}$-$T_{operationN}$) associated to said at least one subsequent actuation, so as to modify said configurable delay time (T_{delay}).

5. The coil actuator (1) according to claim 4, wherein said at least one subsequent actuation comprises at least a second actuation of the switching device occurring after said first actuation, and wherein said electronic means (1000) are arranged to apply (605) said correction time ($T_{correction}$) to the configurable delay time (T_{delay}) of the operation time ($T_{operation2}$) associated to said second actuation.

6. The coil actuator (1) according to claim 4, wherein said at least one subsequent actuation comprises a plurality of subsequent actuations of the switching device (100), and wherein said electronic means (1000) are arranged to:

- divide (604) said determined correction time ($T_{correction}$) into a plurality of addends (T_{add1}-T_{addN-1}); and
- apply (605_1-605_{N-1}) each addend of said plurality of addends (T_{add1}-T_{addN-1}) to the configurable delay time (T_{delay}) of a corresponding operation time ($T_{operation2}$-$T_{operationN}$) which is associated to an actuation of said plurality of subsequent actuations.

7. The coil actuator (1) according to one or more of the preceding claims, comprising a coil electromagnet (2) arranged to move between a rest position and an actuating position, wherein the movement from the rest position to the actuating position is suitable to cause the actuation of said switching device (100), and wherein said electronic means (1000) comprise:

- detection means (11) arranged to detect a first event;
- driving means (10) operatively associated to said detection means (11) and operatively connected to said coil electromagnet (2), said driving means (10) being arranged to electrically drive the coil electromagnet (2) to cause the movement of such coil electromagnet (2) from the rest position to the actuating position upon the detection of said first event by the detection means (11), said detection means (11) being arranged also to detect a second event which is indicative of the end of the actuation of the switching device (100) caused by said movement of the coil electromagnet (2) from the rest position to the actuating position;
- counting means (20) operatively associated to said detection means (11) and arranged to start counting when said first event is detected by the detection means (11) and to stop such counting when the second event is detected by the detection means (11).

8. The coil actuator (1) according to claim 7, wherein said driving means (10) are arranged to apply said configurable delay time (T_{delay}) between the detection of said first event and the consequent electrical driving of the coil electromagnet (2).

9. The coil actuator (1) according to claim 7 or claim 8, wherein said driving means (10) comprise a power input circuit (12) arranged to be operatively connected to and receive an input voltage (V_{in}) from at least a power source (200), said detection means (11) being arranged to sense a voltage indicative of said input voltage (V_{in}) and to detect a first threshold value (V_{th_launch}) and a second threshold value ($V_{th\_release}$) of such input voltage (V_{in}), wherein the detection of said first threshold value (V_{th_launch}) and the detection of said second threshold value ($V_{th\_release}$) correspond to said first event and said second event, respectively.

10. The coil actuator (1) according to claim 7 or 8, wherein said driving means (10) are operatively connected to at least a power source (500) so as to receive therefrom the power required to hold the coil electromagnet (2) in the rest position, and in that said detection means (11) are arranged to detect the falling of a voltage (V_{supply}) associated to said at least a power source (500) below a predetermined undervoltage threshold value, wherein the detection of such voltage falling corresponds to said first event.

11. A switching device (100) **characterized in that** it comprises at least a coil actuator (1) according to one or more of claims 1-10.

12. A switchgear **characterized in that** it comprises at least a switching device (100) according to claim 11 and/or at least a coil actuator (1) according to one or more of claims 1-10.

13. A method (700) for correcting operation times ($T_{operation1}$-$T_{operationN}$) counted by a coil actuator (1) and associated to actuations of a switching device (100) which are caused by said coil actuator (1), the method **characterized in that** it comprises:

- counting (600) a first operation time ($T_{operation1}$) associated to a first actuation of the switching device (100) caused by the coil actuator (1);
- determining (601) a correction time ($T_{correction}$) by using the counted first operation time ($T_{operation1}$);
- using (602) said correction time ($T_{correction}$) to correct an operation time ($T_{operation2}$-$T_{operationN}$) associated to at least one subsequent actuation of the switching device (100) caused by the coil actuator (1) and occurring after said first actuation;
- counting (603) the corrected operation time ($T_{operation2}$-$T_{operationN}$) associated to said at least one subsequent actuation;

wherein said correction time ($T_{correction}$) is suitable to at least reduce the difference between a target operation time (T_{target}) and the counted corrected operation time ($T_{operation2}$-$T_{operationN}$) associated to said at least one subsequent actuation.

14. The method (700) according to claim 13, wherein determining said correction time ($T_{correction}$) comprises:

- comparing (601) said target operation time (T_{target}) to said counted first operation time ($T_{operation1}$).

15. The method (700) according to claim 13 or 14, wherein said first operation time ($T_{operation1}$) and the operation time ($T_{operation2}$-$T_{operationN}$) associated to said at least one subsequent actuation comprises a configurable delay time (T_{delay}).

16. The method (700) according to claim 15, wherein using (602) said correction time to correct the operation time ($T_{operation2}$-$T_{operationN)}$ associated to said at least one subsequent actuation comprises:

- applying (605) at least an amount of said correction time ($T_{correction}$) to the configurable delay time (T_{delay}) of the operation time ($T_{operation2}$-$T_{operationN}$) associated to said at least one subsequent actuation, so as to modify said configurable delay time (T_{delay}).

17. The method (700) according to claim 16, wherein said at least one subsequent actuation of the switching device (100) comprises at least a second actuation occurring after said first actuation, and wherein applying (605) said at least an amount of the correction time ($T_{correction}$) comprises:

- applying (605) said correction time ($T_{correction}$) to the configurable delay time (T_{delay}) of the operation time ($T_{operation2}$) associated to said second actuation.

18. The method (700) according to claim 16, wherein said at least one subsequent actuation of the switching device (100) comprises a plurality of subsequent actuations, and wherein applying (605) at least an amount of said correction time ($T_{correction}$) comprises:

- dividing (604) said correction time ($T_{correction}$) into a plurality of addends (T_{add1}-T_{addN-1});
- applying (605_1-605_{N-1}) each addend of said plurality of addends (T_{add1}-T_{addN-1}) to the configurable delay time (T_{delay}) of a corresponding operation time ($T_{operation2}$-$T_{operationN}$) which is associated to an actuation of said plurality of subsequent actuations.

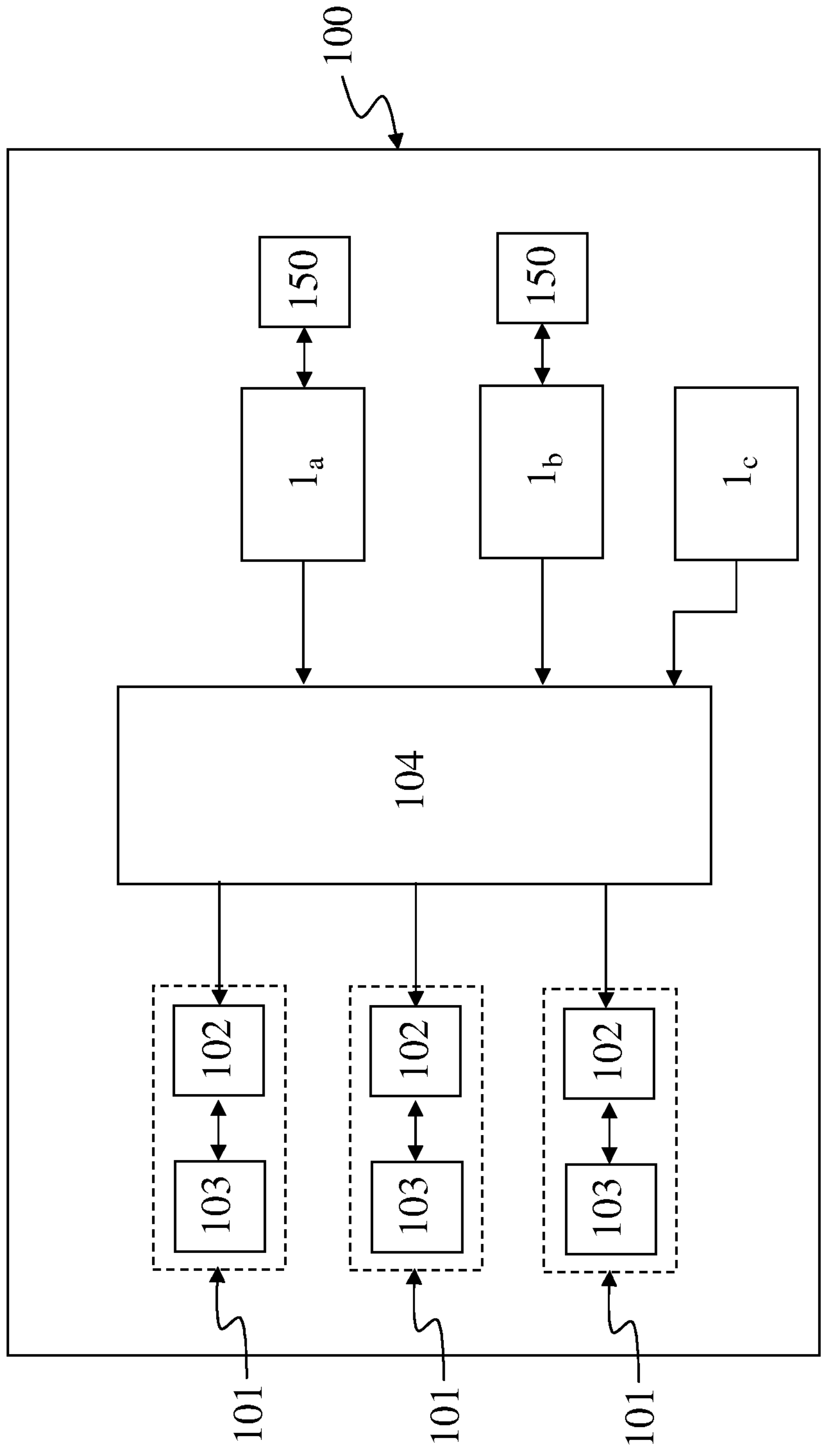


Fig. 1

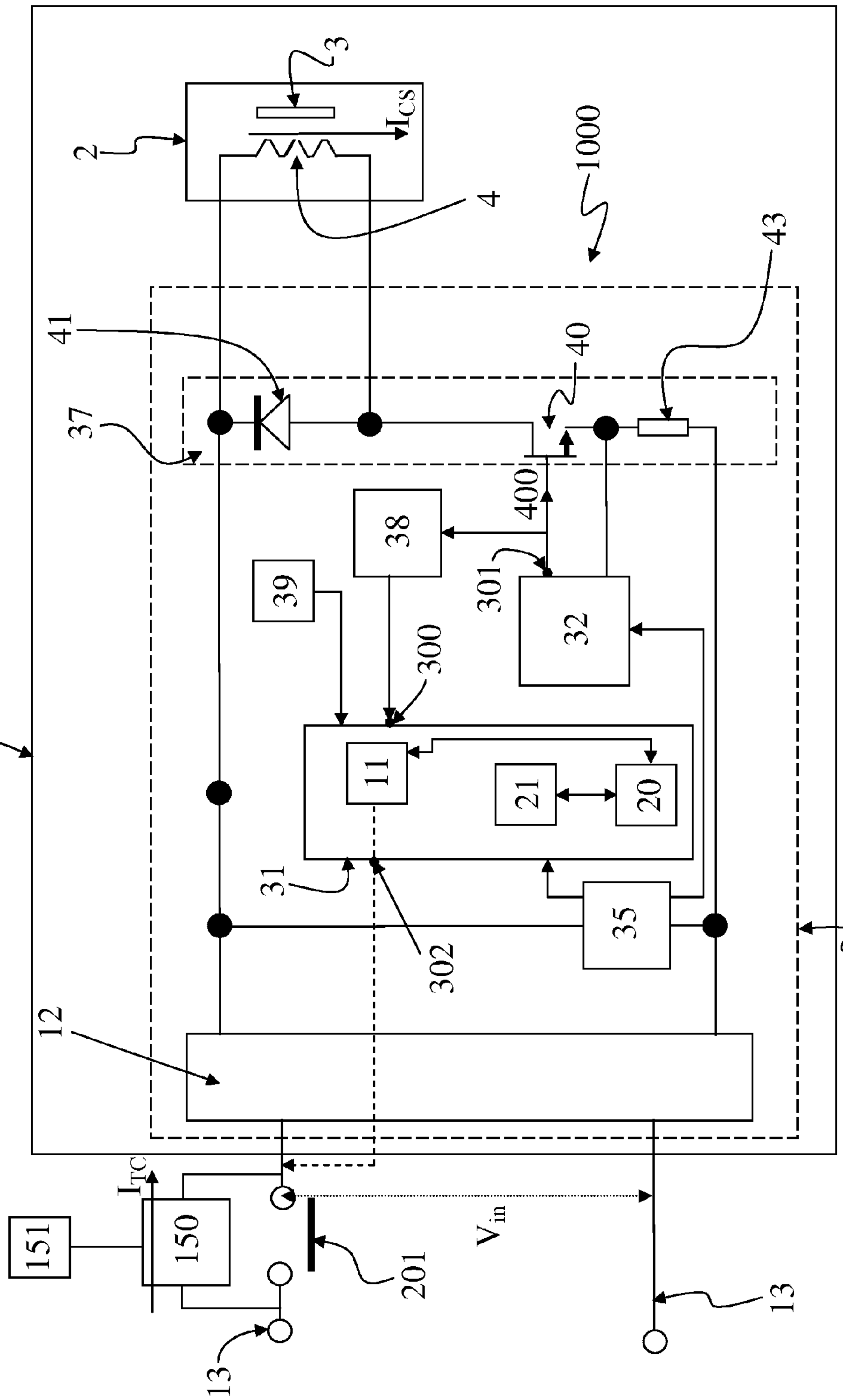

1
2
3
I_{CS}
4
1000
41
40
43
37
400
38
39
301
32
300
11
21
20
31
302
35
10
12
I_{TC}
151
150
201
V_{in}
13
13

Fig. 2

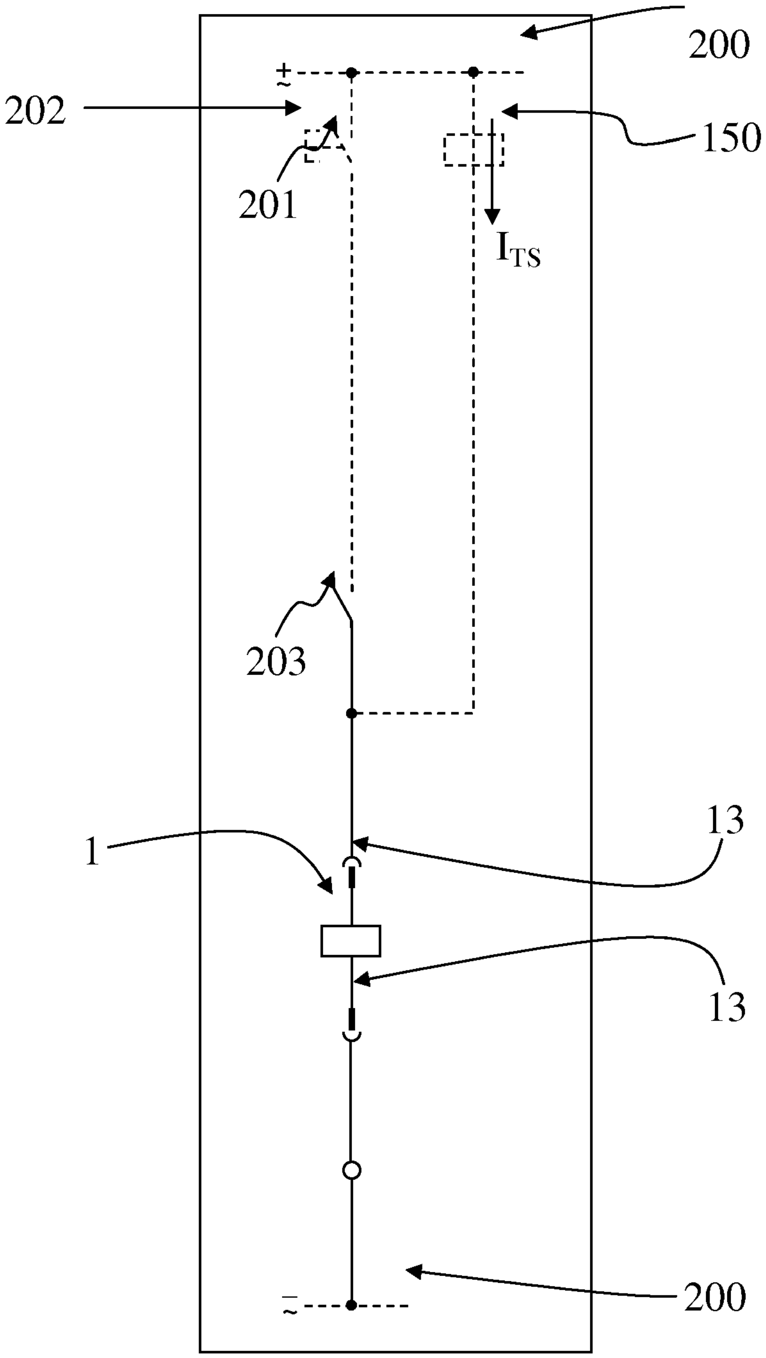


Fig. 3

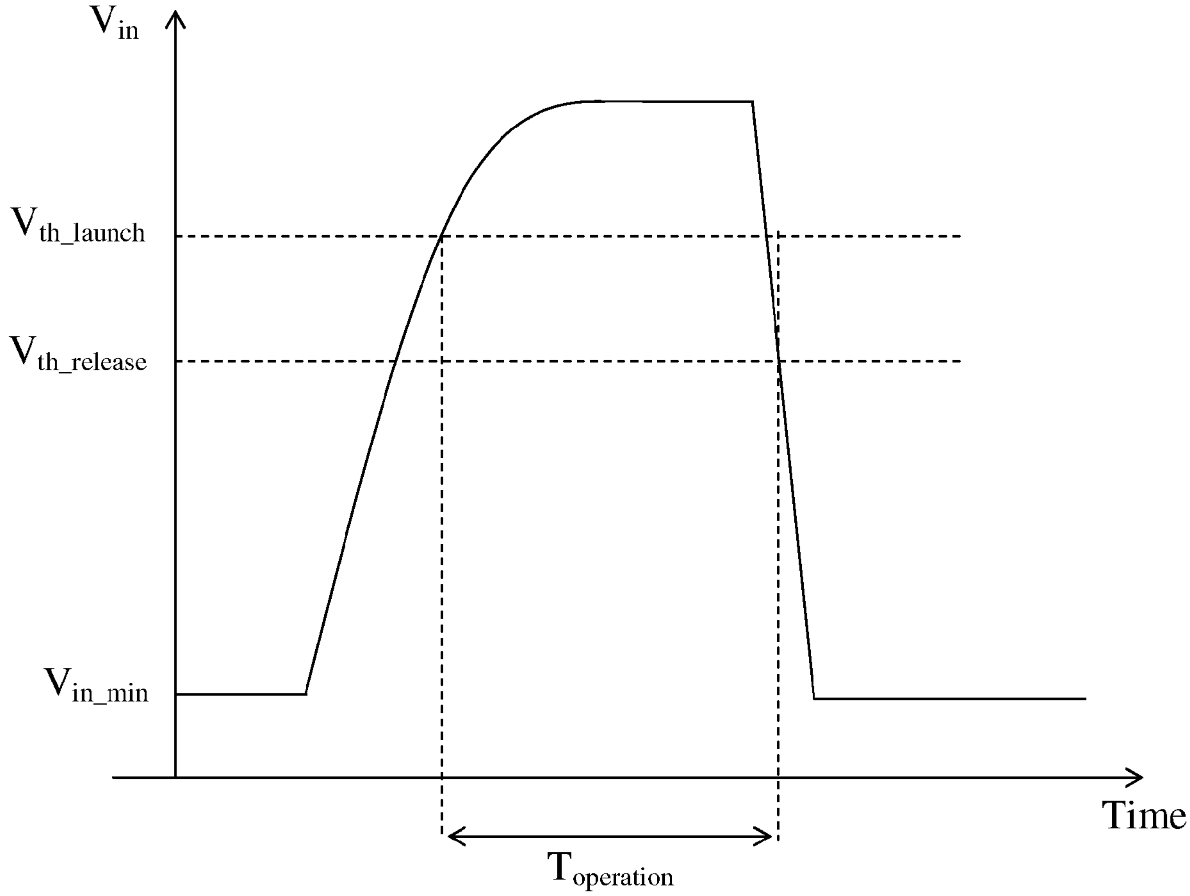


Fig. 4

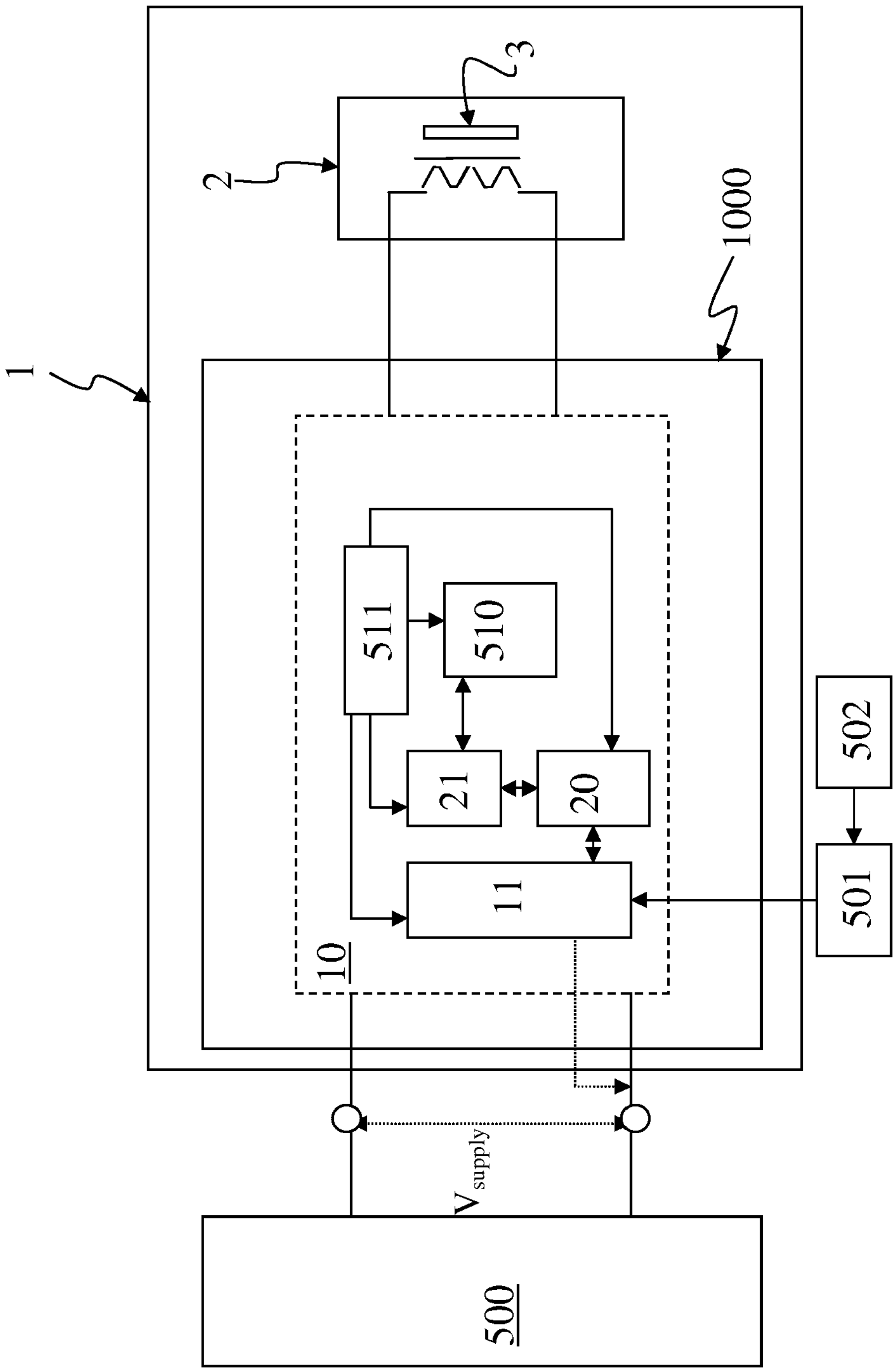
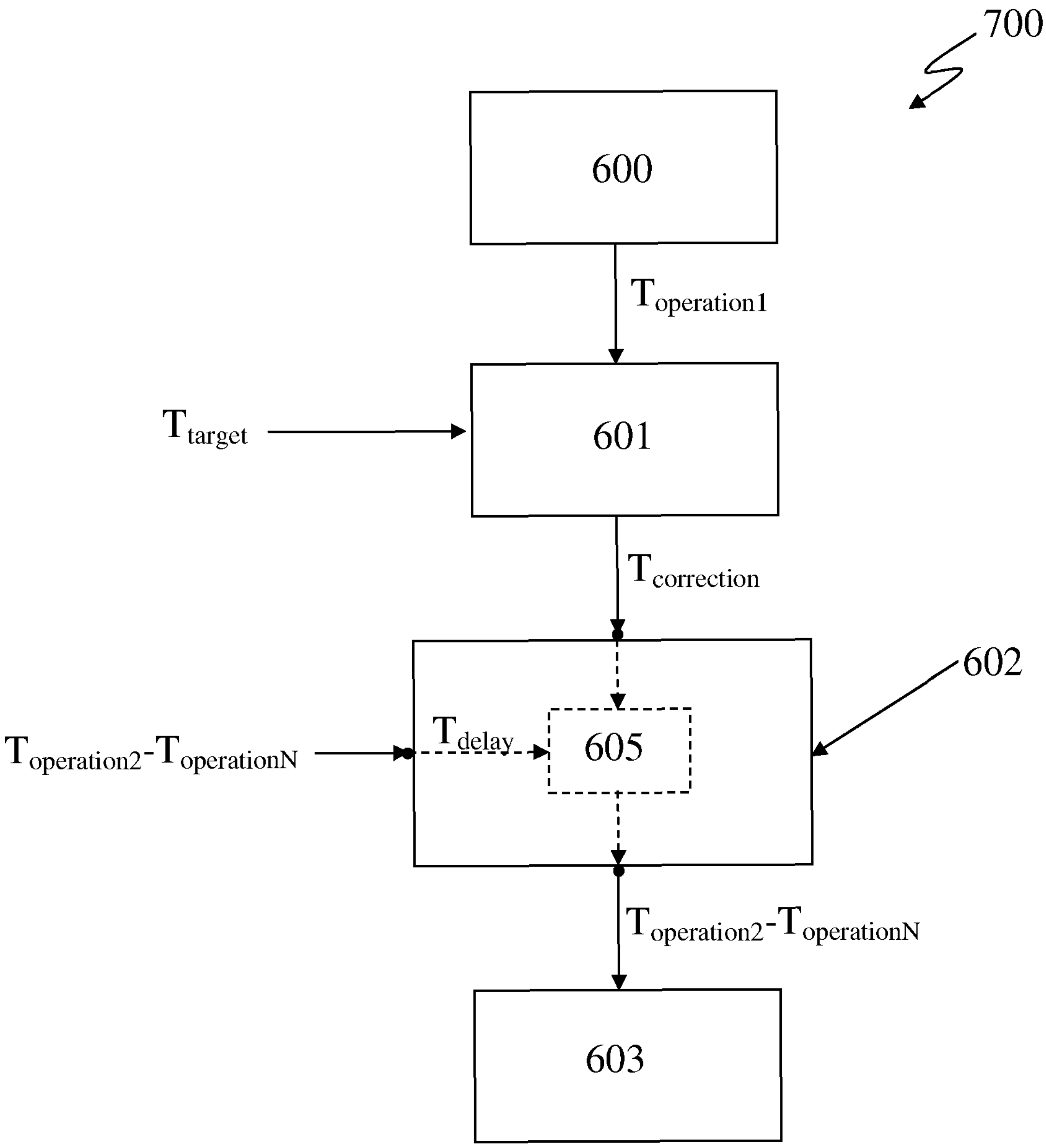


Fig. 5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600
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T_{target}
601
$T_{correction}$
602
$T_{operation2}$-$T_{operationN}$
T_{delay}
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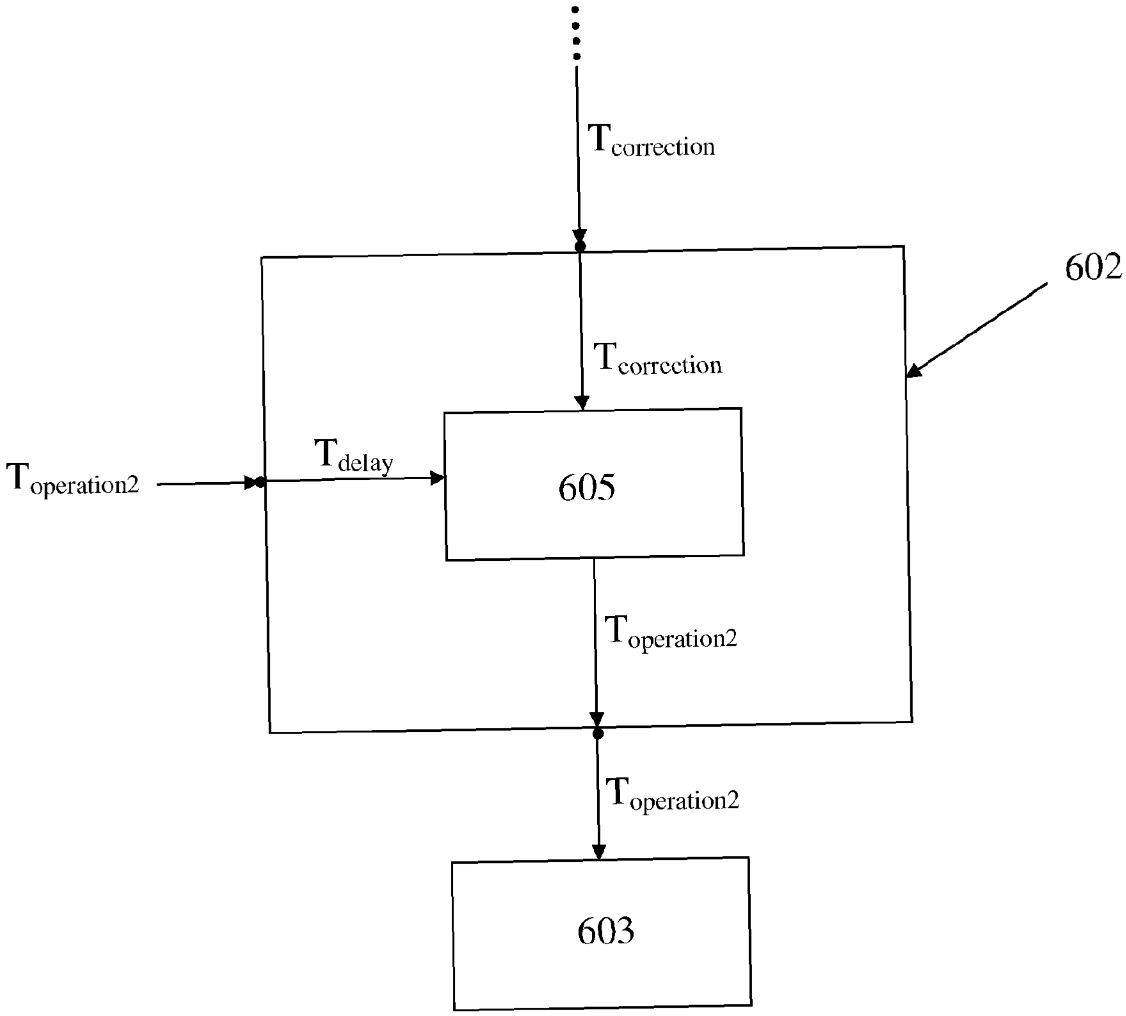
$T_{operation2}$-$T_{operationN}$
603

Fig. 6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T_{delay}
605
$T_{operation2}$
$T_{operation2}$
603

Fig. 7

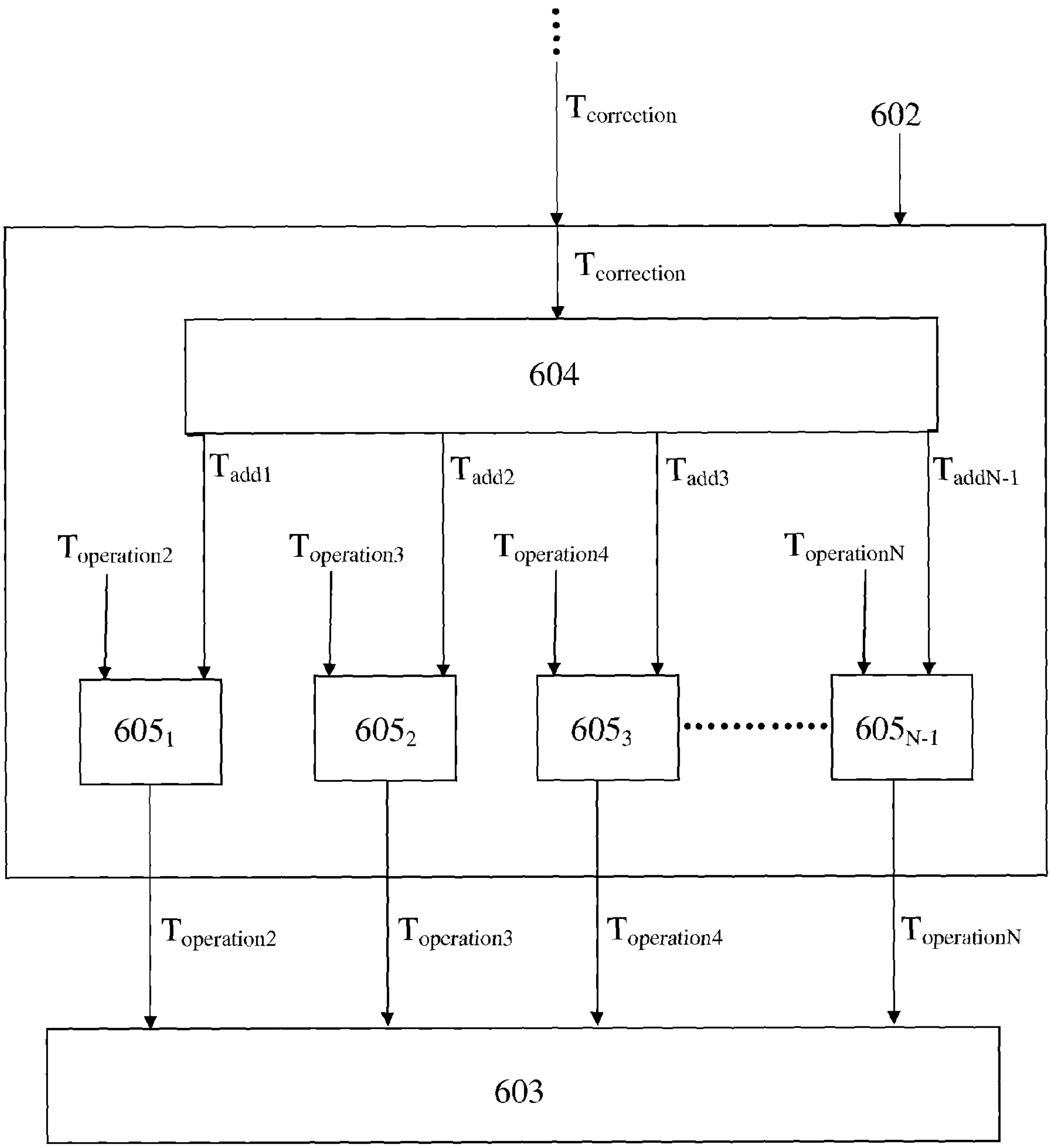
T correction
602
T correction
604
T add1
T add2
T add3
T addN-1
T operation2
T operation3
T operation4
T operationN
605 1
605 2
605 3
605 N-1
T operation2
T operation3
T operation4
T operationN
603

Fig. 8

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EUROPEAN SEARCH REPORT

Application Number
EP 12 17 8942

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	WO 2009/135519 A1 (SIEMENS AG [DE]; ERMISCH JOCHEN [DE]; HERING UWE [DE]; VOLKMAR RALF-RE) 12 November 2009 (2009-11-12) * page 10, line 33 - page 12, line 18 * -----	1-18	INV. H01H47/00

TECHNICAL FIELDS SEARCHED (IPC)
H01H

1

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	7 January 2013	Simonini, Stefano

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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