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(54) METHOD AND CONTROL DEVICE FOR SWITCHING A CONTACTOR

(57) A method (30) for switching a contactor (1) is provided. The method (30) is performed by a control device (20) controlling a control voltage supplied to a coil (10) of the contactor (1), wherein the coil (10) is energized and de-energized to control the switching of the contactor (1). The method (30) comprises determining (31) a reference point of time, t1, based on a delay time, ΔT, wherein a starting point of the delay time ΔT is set in relation to a start-up of the method (30), estimating (32) a period, Tp, of the control voltage, determining (33) a duration of a measuring interval, Tm, based on the estimated period Tp of the control voltage, setting (34) starting point of a first measuring interval Tm based on the reference point of time t1, and setting starting points of subsequent measuring intervals equal to end point of an immediately preceding measuring interval, obtaining (35) measurements on the control voltage for the duration of the measuring interval Tm, and switching (36) the contactor (1) based on measurements made during the measuring interval Tm. A control device (20), computer program (23) and computer program product (22) are also provided.

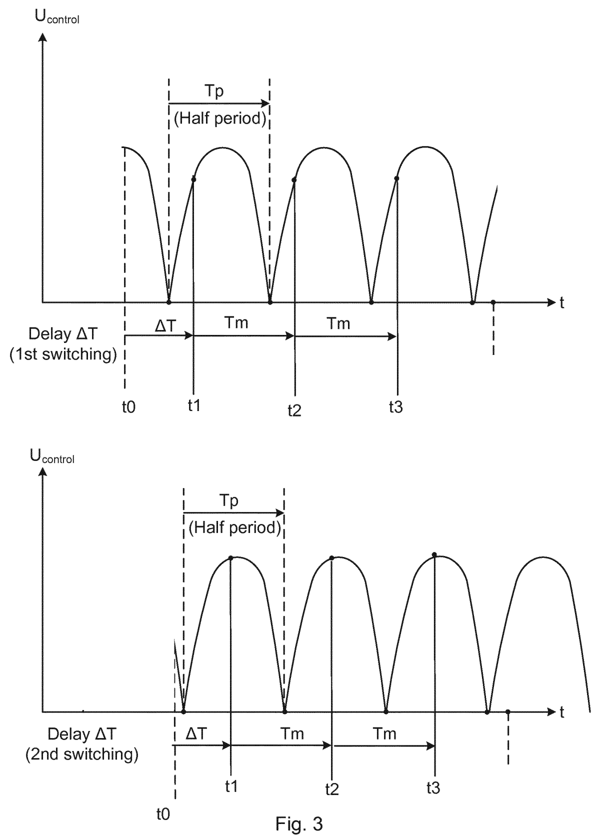

Fig. 3

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Description

Technical field

[0001] The technology disclosed herein relates generally to the field of contactors used in electrical networks, and in particular to a method for switching a contactor, a control device for controlling the contactor, computer program and computer program product.

Background

[0002] A contactor is an electrically controlled switch device that is used for switching an electrical load connected to an electric circuit. The electrical load may, for instance, be a three-phase load. In order to connect/disconnect the electrical load, the contactor comprises a contact unit, in turn comprising a number of main contacts, for instance, three main contacts. The main contacts are configured such as to connect or disconnect the electrical load to/from a main electric network. The contactor further comprises an actuating unit comprising a coil for actuating the main contacts. The electronic control circuit of the contactor is used for controlling the voltage supplied to the coil. Typically, a control voltage of the electronic control circuit is supplied by an electric circuit drawn from, for instance, one or two of three phases.

[0003] Due to synchronization effect between the main electric network and the control voltage, each of the main contacts connected to a respective one of the three phases may switch, i.e. open or close, at almost the same phase angle in many of its switching operations. The electrical load or burden on each of the main contacts will therefore differ substantially, which results in substantially different arc energies. Consequently, the main contact that is the most electrically affected one is subject to higher erosion than the other two main contacts. Therefore, the thickness of the contact material of the most affected main contact may decrease faster. This leads to different, i.e. uneven, erosion levels of different main contacts. The service time of the contactor is therefore limited by the main contact that fails first.

[0004] EP 2 856 483 B1 (ABB RESEARCH LTD) discloses a low voltage contactor and is an example on the above described contactor. The contactor is used for disconnecting a three phase load from an electric power source. The electronic control circuit controlling the voltage that is supplied to the coil implements a pre-arranged time point selection scheme and is adapted to select a time point from the pre-arranged time point selection scheme as a time delay and initiate an instant opening command based on the selected time point. Although this contactor and method for controlling it provides a well-functioning solution, it is desirable to prolong the service time of contactors even further.

Summary

[0005] An objective of the present invention is to provide improvements in switching of a contactor. It is a particular objective to ensure uniform wear of all contacts of the contactor, thereby prolonging the service time of the contactor. These objectives and others are achieved by the method, contactor, computer programs and computer program products according to the appended independent claims, and by the embodiments according to the dependent claims.

[0006] The objective is according to an aspect achieved by a method for switching a contactor. The method is performed by a control device controlling a control voltage supplied to a coil of the contactor. The coil is energized and de-energized to control the switching of contacts of the contactor. The method comprises: determining a reference point of time t1 based on a delay time ΔT wherein a starting point of the delay time ΔT is set in relation to a start-up of the method, estimating a period Tp of the control voltage, determining a duration of a measuring interval Tm based on the estimated period Tp of the control voltage, setting starting point of a first measuring interval Tm based on the reference point of time t1, and setting starting points of subsequent measuring intervals equal to end point of an immediately preceding measuring interval, obtaining measurements on the control voltage for the duration of the measuring interval Tm, and switching the contactor based on measurements made during the measuring interval Tm.

[0007] The method provides a number of advantages. For instance, erosions and heat generated by electric arcs are distributed evenly on each of the contacts in a deterministic way, which increases the service life of the contactor. The method also provides a reduced product cost by enabling a decrease of the amount of silver typically used in these contacts.

[0008] In an embodiment, the method comprises obtaining the delay time ΔT from a predetermined set of N values, by selecting from the set a delay time ΔT that is different than the preceding selected delay time ΔT. This gives non-random, i.e. deterministic, starting points, which in turn ensures switching at different points along the voltage forms, thereby ensuring to largest extent equal wear on the main contacts.

[0009] In various embodiments, is equal to the start-up of the contactor or equal to the start-up of contactor with an added off-set time. The starting point of the delay time ΔT may thus be related to, for instance, the start up-time and an off-set time, which, for instance, may comprise time for initiation of electronics etc.

[0010] In various embodiments, the estimating the period Tp of the control voltage comprises one of:

- detecting two consecutive zero crossings of the control voltage and estimating the period Tp to be equal to duration between the detected zero crossings, and
- detecting two consecutive maximum values of the control voltage and estimating the period Tp to be equal to duration between the detected maximum values.

[0011] In various embodiments, the period Tp of the control voltage is determined independently of the reference point of time t1.

[0012] In various embodiments, the obtaining measurements on the control voltage for the duration of the measuring interval Tm is de-synchronized with zero crossings of the period of the control voltage.

[0013] In various embodiments, the obtaining measurements comprise accumulating root means square, RMS, values. In other embodiments, the obtaining measurements comprise accumulating mean values.

[0014] In various embodiments, the criterion for switching the contactor is one of: the control voltage falling below a lower bound nominal voltage value for a predetermined time period, the control voltage falling below a lower bound nominal voltage value for more than 30 ms, a switch command having been stable for a predefined time period and a switch command having been stable for 4 ms.

[0015] The objective is according to an aspect achieved by a computer program for a control device for controlling a contactor. The computer program comprises computer program code, which, when run on at processing circuitry of the control device causes control device to perform the method as above.

[0016] The objective is according to an aspect achieved by a computer program product comprises a computer program as above and a computer readable means on which the computer program is stored.

[0017] The objective is according to an aspect achieved by a control device for switching a contactor. The control device controls a control voltage supplied to a coil of the contactor. The control device is configured to energize and de-energize the coil to control the switching of contacts of the contactor, the control device being further configured to obtain a time point from a time point selection scheme comprising a plurality of time points distributed in a half period of the control voltage, initiate switching of the contactor using the obtained time point as a time delay, and upon determining that a criterion for switching the contactor is met, initiate an instant switching command at same time point on the half period of the control voltage as the obtained time point.

[0018] The method comprises: determining a reference point of time t1 based on a delay time ΔT wherein a starting point of the delay time ΔT is set in relation to a start-up of the method, estimating a period Tp of the control voltage, determining a duration of a measuring interval Tm based on the estimated period Tp of the control voltage, setting starting point of a first measuring interval Tm based on the reference point of time t1, and setting starting points of subsequent measuring intervals equal to end point of an immediately preceding measuring interval, obtaining measurements on the control voltage for the duration of the measuring interval Tm, and switching the contactor based on measurements made during the measuring interval Tm.

[0019] Further features and advantages of the embodiments of the present invention will become clear upon reading the following description and the accompanying drawings.

Brief description of the drawings

[0020]

Figure 1 illustrates a contactor and a control device for controlling the contactor according to embodiments of the invention.

Figure 2 illustrates a phase voltage of a main electric network as a function of time and an aspect of the invention.

Figure 3 illustrate main aspects and different embodiments of the present invention.

Figure 4 is a flow chart over steps of an embodiment of a method for switching a contactor according to an embodiment of the invention.

Detailed description

[0021] In the following description, for purposes of explanation and not limitation, specific details are set forth such as particular architectures, interfaces, techniques, etc. in order to provide a thorough understanding. In other instances, detailed descriptions of well-known devices, circuits, and methods are omitted so as not to obscure the description with unnecessary detail. Same reference numerals refer to same or similar elements throughout the description.

[0022] Figure 1 illustrates a contactor 1 and a control device 20 for switching the contactor 1 according to embodiments of the invention. The contactor 1 is a low-voltage contactor and is used for connecting and disconnecting an electric load 2. The electric load 2 may, for instance, be a motor, but it is noted that the electric load 2 can be of any type. The electric load 2 is connected to a main electric network having one or more phases. In the particular illustrated case the main electric network has three phases L1, L2, L3, but it may, in other embodiments, have one, two, four or more phases. The contactor 1 is thus an electrically controlled switch used for switching an electrical circuit or electrical device with high current ratings. The contactor 1 is controlled by an electronic control device 20 (in the following also denoted control circuit 20) having a much lower power level than the electric circuit or device (i.e. load 2) that is being switched by the contactor 1. The control circuit 20 is configured to control a voltage, or more generally a power, that is supplied to a coil 10 of the contactor 1.

[0023] The contactor 1 comprises contacts, i.e. the current carrying part of the contactor 1, and a mechanism (for instance an electromagnet or coil) for closing and opening these contacts. The contactor 1 illustrated in figure 1 comprises three main contacts 12_1, 12_2, 12_3 (although it is noted that there could be more or fewer main contacts as well) connected to a respective one of the three phases L1, L2, L3 of the main electric network. The contactor 1 further comprises an actuating unit 3 comprising a coil 10 and a first magnet core 16 and a second magnet core 14. The first magnet core 16 is a fixed magnet core 16 and the second magnet core 14 is a movable magnet core 14. The coil 10 is typically wound around a part of the fixed magnet core 16. Each of the main contacts 12_1, 12_2, 12_3 comprises a fixed contact and a movable contact, wherein each movable contact is connected to the movable core 14. The coil 10, the fixed magnet core 16 and the movable magnet core 14 are arranged for actuating the main contacts 12_1, 12_2, 12_3 and thereby perform connection and disconnection operations. The contactor 1 may also comprise a demagnetization circuit, which speeds up the opening of the contactor 1.

[0024] When the contactor 1 is "open" it is in a non-conducting position, and when it is "closed" it is conducting, i.e. the main electric network (and hence the electric load) are in normal operation. It is noted that the contactor 1 may be "normally-open" or "normally-closed"; the "normal" state is when the coil 10 is de-energized. As long as current passes through the coil 10 a magnetic field is produced, which attracts the movable magnet core 14 to the fixed magnet core 16. When the contactor coil 10 is de-energized, gravity or a spring returns the movable magnet core 14 to its initial position and opens the main contacts 12.

[0025] In figure 1, the main electric network is used as supplier of a voltage to the control circuit 20, wherein the voltage supply is shown (in figure 1) to comprise a connection to a neutral and a connection to one of the phases L1. However, it is noted that the voltage to the electronic control circuit 20 can be provided in other ways as well, for example from two of the three phases or from a transformer (not shown) that is connected between the control circuit 20 and e.g. two of the phases of the main electric network.

[0026] Briefly, the present invention provides a method and a control device for switching the contactor 1 as described above, for operating a load 2, for instance a three-phase load. As described, the contactor 1 comprises an actuating unit 3 comprising a coil 10, wherein main contacts 12_1, 12_2, 12_3 are operated by the coil 10 and the control circuit 1 for controlling a control voltage supplied to the coil 10. The invention provides an improved way of initiating switching commands when controlling the coil 10 of the contactor 1. Low voltage is commonly defined in a range of up to about 1000V AC.

[0027] Figure 2 illustrates a phase voltage (among y-axis) of the main electric network as a function of time (x-axis). This phase voltage is the voltage that the main contacts 12_1, 12_2, 12_3 are exposed to. As mentioned earlier, the voltage used for controlling the contactor 1 (denoted control voltage) is typically derived from the main voltage U_{mains} (of the electric network).

[0028] The decision to switch the contactor 1, i.e. decision to close or open the contactor 1, is based on measurements on the control voltage. For instance, a mean value or a Root-Mean-Square (RMS) value of the main electric network instantaneous voltage or true RMS value or RMS value based on the amplitude of U_{mains} or RMS value based on the mean value can be calculated based on the measurements, so the switching command (opening/closing command) can only be given when the RMS or mean value (or other suitable value). has been calculated. According to the invention, the RMS or mean value is calculated at the end of a sliding window (shown in figure 3). Also according to the invention, an initial variable delay ΔT is used. In figure 2, this delay is illustrated as a time period ΔT. At time point P1, the contactor switching command is given by the control circuit 20.

[0029] In order to reduce the described synchronization effect, which causes more wear and erosion in one of the main contacts 12_1, 12_2, 12_3 than in the other main contacts 12_1, 12_2, 12_3, the duration of the delay ΔT should be evenly distributed within the control voltage half period. Thus, each time the contactor 1 switches the main contacts 12, the delay ΔT should have a different value than the delay ΔT used in the preceding switching.

[0030] Figure 3 illustrate main aspects and different embodiments of the present invention.

[0031] In order to determine if the contactor 1 should be switching, the control circuit 20 is arranged to keep track of the supply voltage. Therefore, the control circuit 20 continuously measures the control voltage (which, as noted, is a fraction of the voltage U_{mains}) and determines the RMS value of the voltage amplitude. As has been noted earlier, an alternative to determining the RMS value is to instead determine the mean value or some other measure, but in the following the RMS value is used as an example for describing embodiments of the invention. A first process continuously measures and filters the half period of the control voltage waveform and a second process uses the filtered period as input for calculating an updated, i.e. a current, RMS value.

[0032] In the mentioned patent publication WO 2013/178255 A1 (D1), the calculation of a new RMS voltage value is always synchronized with a zero crossing (e.g. ZX shown in figure 2). This means that when a zero crossing is detected, the voltage values are accumulated and when the next zero crossing is detected, RMS is calculated and the accumulated voltage is reset. So the measurement process of the method disclosed in D1 provides the process with a new RMS value at every zero crossing.

[0033] In contrast to the above, and in accordance with the present invention, there is no delay at all and as soon as it is decided to switch the contactor 1, a demagnetization circuit is activated. For example, it may be decided to switch the contactor 1 when the voltage has been below 55% of the lower bound nominal voltage for more than 1, 2, 3 or more measurement intervals (each of which may, for instance, be about 30 ms) or when a programmable logic controller (PLC) switch command has been stable for a defined time period, e.g. stable for 4ms. It is however noted that other criteria may be used for deciding when the contactor 1 should open the electrical circuit, and such criteria may, for instance, depend on the application at hand.

[0034] It is, as noted earlier, important to evenly distribute, over the whole control voltage half period, the activation of the demagnetization circuit, and hence distribute also the points of time when the contactor switching command is given. Thereby the erosion, wear and tear is spread evenly among the main contacts 12_1, 12_2, 12_3 in all three phases, which in turn increases the life length of the contactor 1.

[0035] When the process is started the control voltage values are accumulated during a measuring interval Tm. In order to know the time duration of the measuring interval Tm, the half period Tp of the control voltage is measured and filtered (denoted "first process" earlier). This may, for instance, be done by use of an infinite impulse response (IIR) filter. The half period Tp is simply the time that passes between, for instance, two consecutive zero crossings (or between two consecutive maximum values) and this value is fed into the IIR filter.

$$halfPeriod_{filt} = \left(\frac{1}{4}\right) \times halfPeriod_{new} + \left(\frac{3}{4}\right) \times halfPeriod_{prev} \quad \text{(Equation 1)}$$

wherein:

half $Period_{filt}$: Filtered half period
half $Period_{new}$: New calculated half period
half $Period_{prev}$: Previously calculated half period

[0036] The half period Tp is continuously calculated and is used as input in order to know for how long time the control voltage values should be accumulated during the measuring interval Tm (denoted "second process" earlier). Since the voltage waveform is either alternating current (AC) or rectified AC or direct current (DC), the voltage values accumulated during the (sliding) measuring interval Tm would be equal to voltage values accumulated between two consecutive zero crossings (or, as noted earlier, between two consecutive maximum values). The case with DC may be treated with a time-out period that is longer than an expected maximum period for possible AC voltages, and time-out value may then set equal to the period. As a particular example: the period for a 50 Hz AC voltage is 20 ms, i.e. the half period is 10 ms, and the time-out value may then be set e.g. to about 12 ms.

[0037] With reference still to figure 3, uppermost graph: at time point to, the process is started, and at the time point t1, voltage and threshold accumulators are reset. At a time point t2 a RMS value is calculated based on control voltage amplitude values that has been accumulated during a first measuring interval Tm (between t1 and t2), and using the filtered half period as input. At a time point t3 a new RMS value is again calculated based on voltage amplitude values accumulated during a second measuring interval Tm (between t2 and t3), and the filtered half period as input, and so on until a switching command is issued.

[0038] The lowermost graph of figure 3 illustrates that in a subsequent initiation of the method 30, a different delay value ΔT is obtained from the set of N such delay values. The measuring interval Tm therefore starts at a different point on the voltage waveform (later point in the illustrated example).

[0039] In figure 3, the voltage is only positive because it is rectified in, for instance, a printed circuit board (PCB) and then input to control device 20.

[0040] Some aspects of the invention may be summarized in form of method steps according to the following:

An electronic control circuit for controlling voltages supplied to the coil is provided for (e.g. configured to perform the steps):

- constructing a pre-arranged time point selection scheme including a plurality of time points distributed in a period of the control voltage of the electronic control circuit, (this step may be performed once, not necessarily each time the method is executed),

- selecting a time point to from the pre-arranged time point selection scheme,

- supplying the selected time point as a delay time ΔT as starting point of measuring interval Tm,

- initiating the closing of the contactor 1 based on the selected time point, e.g. at a time point given by to $+\Delta T$ or at a time point given by to$+\Delta T+$ n x Tm,

- later initiating an instant opening command based on the same selected time point, i.e. at the end of a measuring interval Tm.

[0041] An advantage of the method is that as soon as the measuring result is obtained and a switching command (opening or closing command) should to be issued, the command can be issued immediately.

[0042] Figure 4 is a flow chart over steps of an embodiment of a method for switching a contactor according to an embodiment of the invention.

[0043] A method 30 for switching a contactor 1 is provided. The method 30 is performed by a control device 20 arranged for controlling a control voltage supplied to a coil 10 of the contactor 1, wherein the coil 10 is energized and de-energized to control the switching of the contactor 1.

[0044] The method 30 comprises determining 31a reference point of time t1 based on a delay time ΔT wherein a starting point of the delay time ΔT is set in relation to a starting point to of the method 30. The reference point of time t1 (see e.g. figure 3) may, for instance, be set equal to the sum of the time point to at start-up of the method 30 (e.g. at initial start-up of the contactor 1 or when performing a switching operation) and the value of the delay time ΔT. The delay time ΔT can be fetched from a pre-arranged table comprising such delay time values. Adding the delay time ΔT to the starting point to will give the reference point of time t1:

$$t1 = t0 + \Delta T$$

[0045] For each start-up of the method 30, the reference point of time t1 will be at a different point along the half period graph over the control voltage. As a particular example, the delay time ΔT may have a value within the interval of 0-10 ms.

[0046] The method 30 comprises estimating 32 a period Tp of the control voltage. As has been described, the half period and hence the period can be estimated by determining time period between two consecutive zero crossings or the time period between two consecutive maximum values of the control voltage waveform. The estimation of the period Tp of the control voltage is made essentially independently of the reference point of time t1. That is, there is essentially no synchronization, which gives a more even wear of the main contacts.

[0047] The method 30 comprises determining 33 a duration of a measuring interval Tm based on the estimated period Tp of the control voltage. The duration of the measuring interval Tm, during which measurements are to be made, may be set equal to the duration of the estimated period Tp of the control voltage.

[0048] The method 30 comprises setting 34 starting point of a first measuring interval Tm based on the reference point of time t1 and setting starting points of subsequent measuring intervals equal to the end point of an immediately preceding measuring interval. At a first switching after starting the method 30, the starting point of the first measuring interval Tm is equal to t1, which in turn is equal to to + delay ΔT. The end point t2 of the first measuring interval is also the starting point of the second measuring interval, and so on.

[0049] The method 30 comprises obtaining 35 measurements on the control voltage for the duration of the measuring interval Tm.

[0050] The method 30 comprises switching 36 the contactor 1 based on measurements made during the measuring interval Tm. A decision to switch (open or close) the contactor 1 is based on the measurements on the control voltage. This decision is taken at the end of the measuring interval Tm.

[0051] In an embodiment, the delay time ΔT is obtained from a predetermined set of N values, from which set a delay time ΔT different than the preceding delay time ΔT is selected. When a switching has been made and the method 30 is to be repeated, another value from the set of values is selected. This can be made by cyclically traversing all values, or by ensuring in some other deterministic way that the same delay time ΔT is not used for consecutive switching operations.

[0052] The obtaining of the delay time ΔT may, for instance, comprise retrieving a value from a predetermined table (stored in e.g. a database or data storage accessible to the control device), and then traversing all available values in any order until all values have been used before starting to re-use the delay time ΔT values.

[0053] Owing to the fact that the method 30 according to the invention initiates the switching of the contactor 1 and instant switching commands based on a pre-arranged time point selection scheme that comprises a plurality of time points distributed in a half period of the control voltage of the control circuit 1, the instant switching commands are distributed to each of the main contacts 12. Erosions and heat generated by arcs are thereby distributed evenly on each of the one or more main contacts 12_1, 12_2, 12_3 in a deterministic way, which increases the service life of the contactor 1.

[0054] One advantage is that with a pre-arranged scheme, burdens on the contacts are shifted from one phase to the other and eventually distributed the burdens on each of the contacts, which also facilities the rated making, breaking capacity tests and operational performance tests. This is because that, typically, such tests result in the extensive heat dissipation at the main contacts. By distributing the closing of the contactor and instant opening commands on each of the main contacts, the thermal burden is distributed on each of main contacts. Thus, the risk of overheating a single main contact is significantly decreased.

[0055] The time point selection scheme for a half period of control voltage may comprise following time points corresponding to the sequence: {(0°, 60°, 120°), (10°, 70°, 130°) (20°, 80°, 140°) (30°, 90°, 150°), (40°, 100° 160°), (50°, 110°, 170°)}. Thus, the scheme comprises six groups. The pre-determined interval in this sequence in each group is 60°, while the pre-defined offset for the corresponding time points of two successive groups is 10°. Preferably, the pre-defined offset is calculated based on a phase angle in a range of 5°-15° in order to have a complete coverage of the main contacts 12_1, 12_2, 12_3 so that opening commands are initiated and distributed on each of the main contacts 12_1, 12_2, 12_3. For example, an offset calculated based on a phase angle 30° will result in only two different groups, which does not enable well-distributed opening commands on each of the main contacts 12_1, 12_2, 12_3.

[0056] With reference again to figure 1, a control device 20 is provided. The control device 20 is configured to perform the embodiments of the described method 30.

[0057] The control device 20 comprises processing circuitry 21, which may be any combination of one or more of a suitable central processing unit (CPU), multiprocessor, microcontroller, digital signal processor (DSP), etc., capable of executing software instructions stored in a computer program product 22, e.g. in the form of a storage medium 22. The processing circuitry 21 may further be provided as at least one application specific integrated circuit (ASIC), or field programmable gate array (FPGA).

[0058] The processing circuitry 21 is configured to cause the control device 20 to perform a set of operations, or steps, e.g. as described in relation to figure 4. For example, the storage medium 22 may store the set of operations, and the processing circuitry 21 may be configured to retrieve the set of operations from the storage medium 22 to cause the control device 20 to perform the set of operations. The set of operations may be provided as a set of executable instructions. The processing circuitry 21 is thereby arranged to execute the various embodiments of the method 30 as disclosed herein.

[0059] The storage medium 22 may also comprise persistent storage, which, for example, can be any single one or combination of magnetic memory, optical memory, solid state memory or even remotely mounted memory.

[0060] The control device 20 may also comprise an input/output means 24 for receiving data input and for outputting data, e.g. receiving information and/or sending commands/instructions.

[0061] The control device 20 may also comprise circuitry such as voltage and threshold accumulators.

[0062] A control device 20 is thus provided for switching a contactor 1. The control device 20 is arranged for controlling a control voltage supplied to a coil 10 of the contactor 1. The control device 20 is configured to energize and de-energize the coil 10 to control the switching of contacts 12_1, 12_2, 12_3 of the contactor 1. The control device 20 is further configured to:

- determine a reference point of time, t1, based on a delay time, ΔT, wherein a starting point of the delay time ΔT is set in relation to a start-up of the contactor 1,
- estimate a period, Tp, of the control voltage,
- determine a duration of a measuring interval, Tm, based on the estimated period Tp of the control voltage,
- set starting point of a first measuring interval Tm based on the reference point of time t1, and setting starting points of subsequent measuring intervals equal to end point of an immediately preceding measuring interval,
- obtain measurements on the control voltage for the duration of the measuring interval Tm, and
- switch the contactor 1 based on measurements made during the measuring interval Tm.

[0063] The control device 20 may be configured to perform the above steps, and implement any of the described embodiments of the method 30, e.g. by comprising one or more processors 20 (or processing circuitry) and memory 21, the memory 21 containing instructions executable by the processor 20, whereby the control device 20 is operative to perform the steps.

[0064] The invention has mainly been described herein with reference to a few embodiments. However, as is appreciated by a person skilled in the art, other embodiments than the particular ones disclosed herein are equally possible within the scope of the invention, as defined by the appended patent claims.

Claims

1. A method (30) for switching a contactor (1), the method (30) being performed by a control device (20) controlling a control voltage supplied to a coil (10) of the contactor (1), wherein the coil (10) is energized and de-energized to control the switching of contacts (12_1, 12_2, 12_3) of the contactor (1), the method (30) comprising:

   - determining (31) a reference point of time, t1, based on a delay time, ΔT, wherein a starting point, to, of the delay time ΔT is set in relation to a start-up of the method (30),
   - estimating (32) a period, Tp, of the control voltage,
   - determining (33) a duration of a measuring interval, Tm, based on the estimated period Tp of the control voltage,
   - setting (34) starting point of a first measuring interval Tm based on the reference point of time t1, and setting starting points of subsequent measuring intervals equal to the end point of an immediately preceding measuring interval,
   - obtaining (35) measurements on the control voltage for the duration of the measuring interval Tm, and
   - switching (36) the contactor (1) based on measurements made during the measuring interval Tm.

2. The method (30) as claimed in claim 1, comprising obtaining the delay time ΔT from a predetermined set of N values, by selecting from the set a delay time ΔT that is different than the preceding selected delay time ΔT.

3. The method (30) as claimed in claim 1 or 2, wherein the starting point of the delay time ΔT is equal to the start-up of the contactor or equal to the start-up of contactor (1) with an added off-set time.

4. The method (30) as claimed in any of the preceding claims, wherein the estimating (32) the period, Tp, of the control voltage comprises one of:

   - detecting two consecutive zero crossings of the control voltage and estimating the period Tp to be equal to duration between the detected zero crossings, and
   - detecting two consecutive maximum values of the control voltage and estimating the period Tp to be equal to duration between the detected maximum values.

5. The method (30) as claimed in any of the preceding claims, wherein the period, Tp, of the control voltage is determined independently of the reference point of time t1.7. The method (30) as claimed in any of the preceding claims, wherein the obtaining (35) measurements on the control voltage for the duration of the measuring interval Tm is de-synchronized with zero crossings of the period of the control voltage.

6. The method (30) as claimed in any of the preceding claims, wherein the obtaining (35) measurements comprises accumulating root means square, RMS, values.

7. The method (30) as claimed in any of the preceding claims, wherein the criterion for opening the contactor (1) is one of: the control voltage falling below a lower bound nominal voltage value for a predetermined time period, the control voltage falling below a lower bound nominal voltage value for more than 30 ms, an open command having been stable for a predefined time period and an open command having been stable for 4 ms.

8. A computer program (23) for a control device (20) for controlling a contactor (1), the computer program (23) comprising computer program code, which, when run on at processing circuitry of the control device (20) causes control device (20) to perform the method (30) according to any of claims 1-7.

9. A computer program product (22) comprising a computer program (23) as claimed in claim 8 and a computer readable means on which the computer program (23) is stored.

10. A control device (20) for switching a contactor (1), the control device (20) controlling a control voltage supplied to

a coil (10) of the contactor (1), wherein the control device (20) is configured to energize and de-energize the coil (10) to control the switching of contacts (12_1, 12_2, 12_3) of the contactor (1), the control device (20) being further configured to:

- determine a reference point of time, t1, based on a delay time, ΔT, wherein a starting point of the delay time ΔT is set in relation to a start-up of the method 30,
- estimate a period, Tp, of the control voltage,
- determine a duration of a measuring interval, Tm, based on the estimated period Tp of the control voltage,
- set starting point of a first measuring interval Tm based on the reference point of time t1, and setting starting points of subsequent measuring intervals equal to end point of an immediately preceding measuring interval,
- obtain measurements on the control voltage for the duration of the measuring interval Tm, and
- switch the contactor 1 based on measurements made during the measuring interval Tm.

11. The control device (20) as claimed in claim 10, configured to perform the method (30) as claimed in any of claims 1-10.

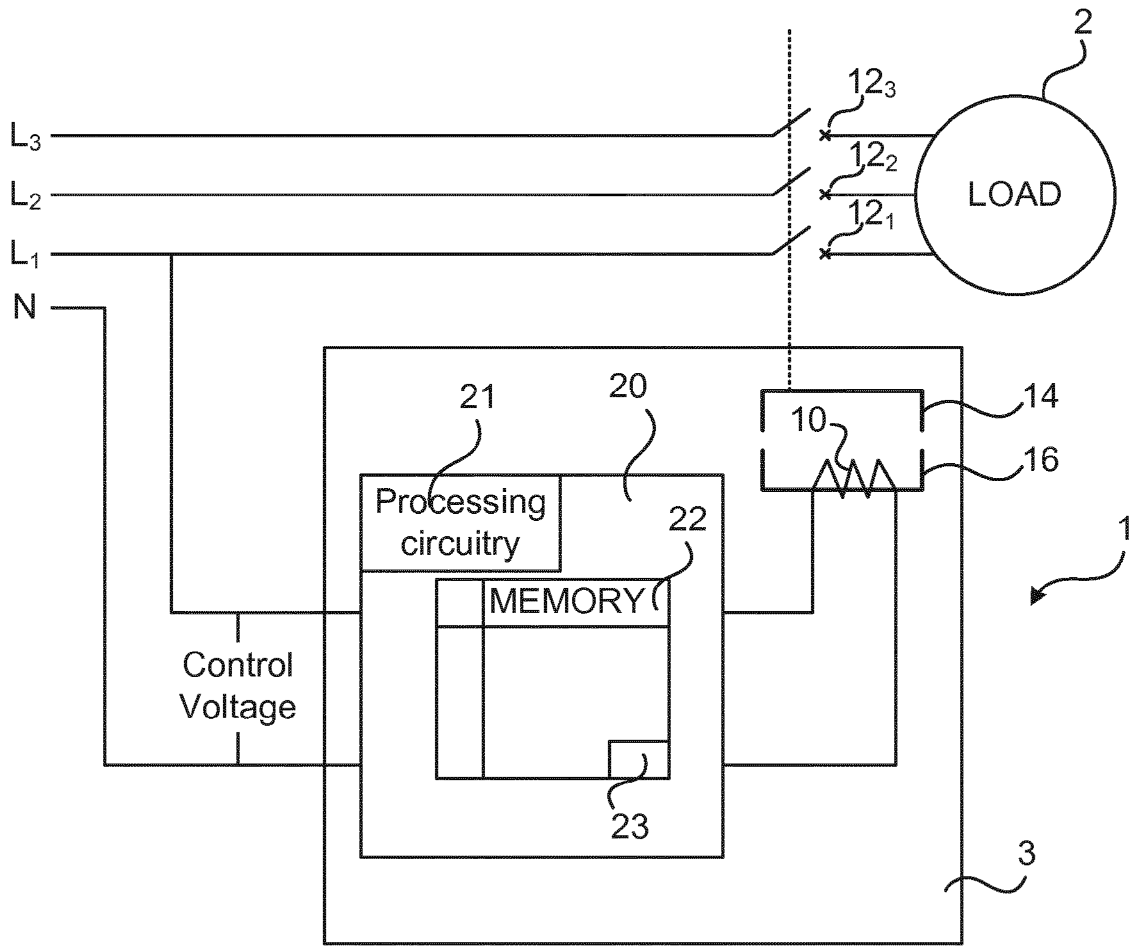

2
12_3
12_2
12_1
L_3
L_2
L_1
N
LOAD
21
20
10
14
16
Processing circuitry
22
1
MEMORY
Control Voltage
23
3

Fig. 1

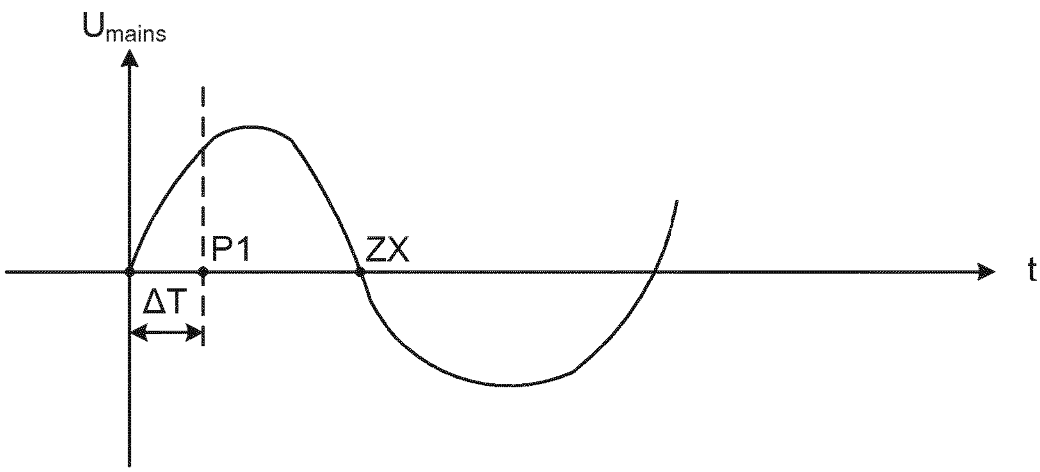
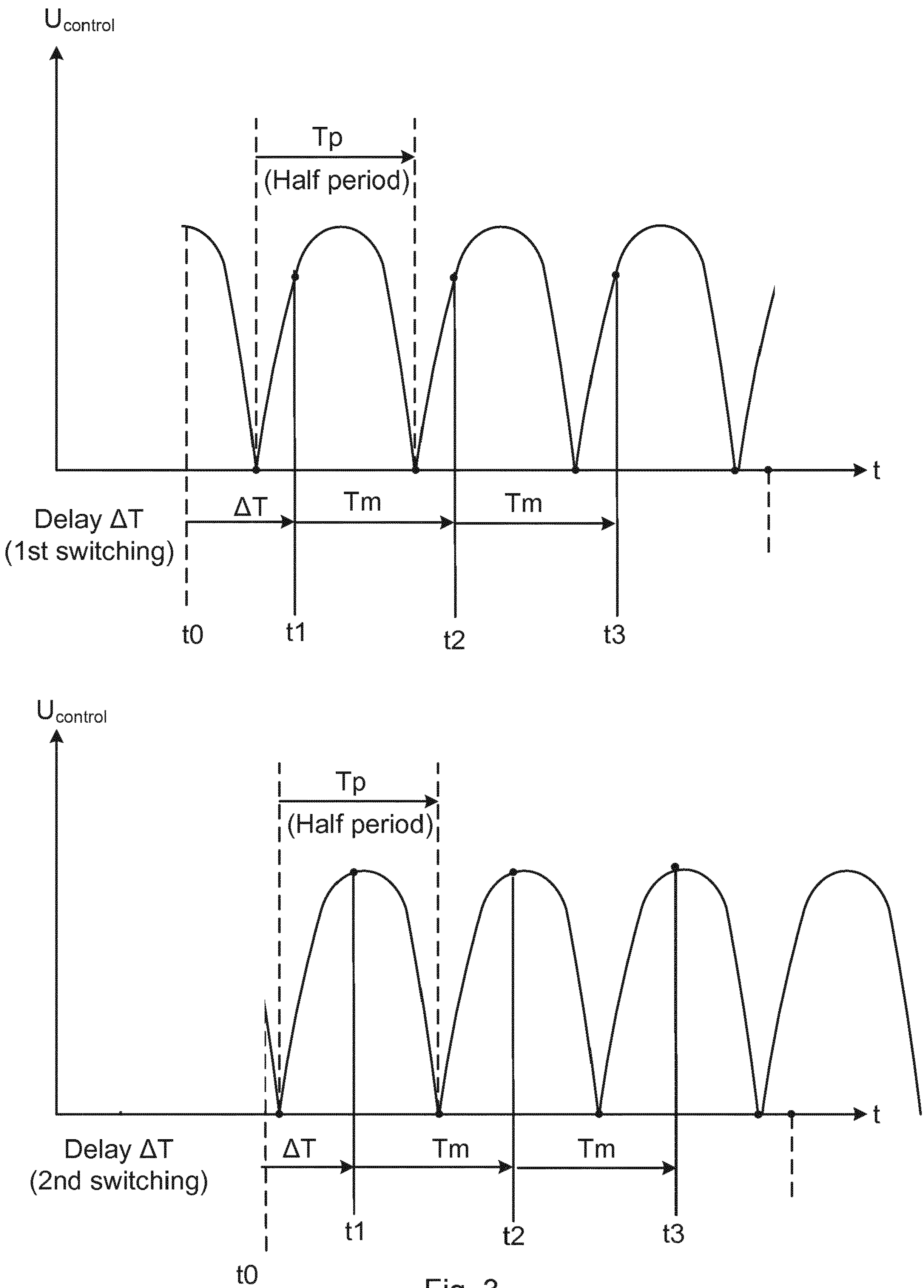

U_{mains}
P1
ZX
t
ΔT

Fig. 2



U control
Tp
(Half period)
t
Delay ΔT
(1st switching)
ΔT
Tm
Tm
t0
t1
t2
t3
U control
Tp
(Half period)
t
Delay ΔT
(2nd switching)
ΔT
Tm
Tm
t1
t2
t3
t0

Fig. 3

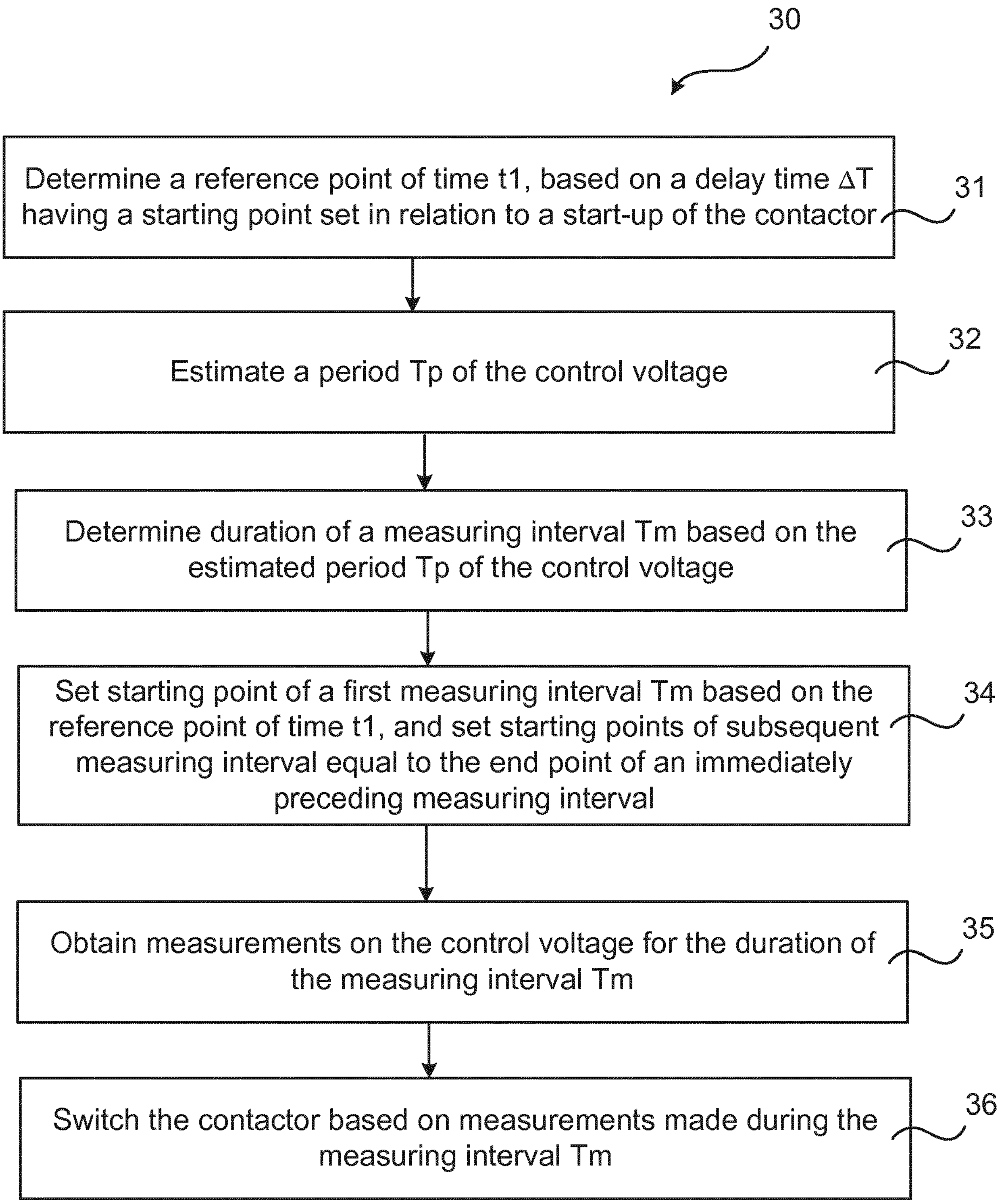

30
Determine a reference point of time t1, based on a delay time ΔT having a starting point set in relation to a start-up of the contactor
31
Estimate a period Tp of the control voltage
32
Determine duration of a measuring interval Tm based on the estimated period Tp of the control voltage
33
Set starting point of a first measuring interval Tm based on the reference point of time t1, and set starting points of subsequent measuring interval equal to the end point of an immediately preceding measuring interval
34
Obtain measurements on the control voltage for the duration of the measuring interval Tm
35
Switch the contactor based on measurements made during the measuring interval Tm
36

Fig. 4

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EUROPEAN SEARCH REPORT

Application Number
EP 17 17 8249

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The present search report has been drawn up for all claims

2

Place of search	Date of completion of the search	Examiner
Munich	14 December 2017	Bilard, Stéphane

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