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(54) **METHOD FOR CLOSING A MECHATRONIC CIRCUIT BREAKER**

(57) The invention provides a method for closing a circuit breaker (10) having a main branch (M), which comprises a main module with a sub-branch comprising a mechanical switch-disconnector (UFS) connected with two breaker cell constituted of a power semiconductor element with controlled duty ratio, the main branch (M) being connected with a pre-insertion module, the circuit breaker (10) and the pre-insertion module forming an assembly having a first (111) and a second (112) terminal,

respectively connected to a source (S) and the power transmission link (C), the method comprising the steps:
a) first closing the mechanical switch-disconnector (UFS) when the voltage difference between the voltages at the first and the second terminals is below a predetermined voltage;
b) closing the bypass switch (S2); and
c) closing the power semiconductor element.

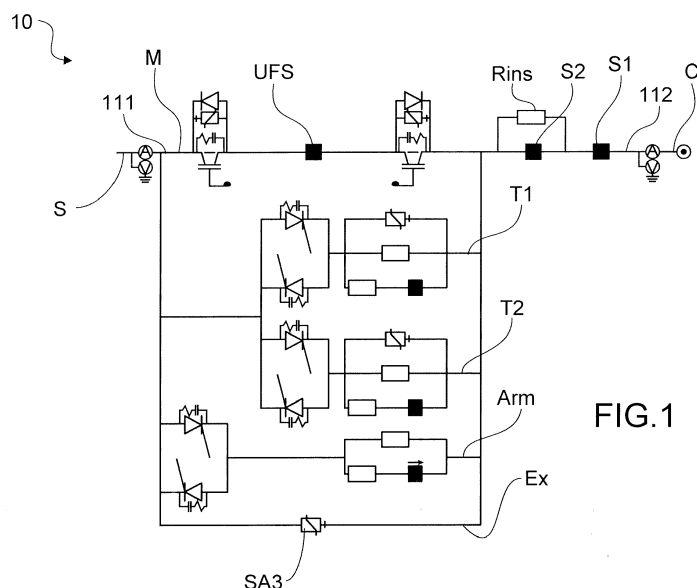


FIG.1

Description

TECHNICAL FIELD

[0001] The invention concerns the field of direct current (DC) transmission networks. Particularly, the invention relates to different possible sequencing scenarios for closing a mechatronic circuit breaker (MCB) in order to restore the power flow.

PRIOR ART

[0002] Building up and/or breaking currents in high-voltage direct current (HVDC) transmission and/or distribution networks has become of crucial importance because mastery thereof directly conditions the expansion of said networks.

[0003] As an example, the patent application [1], in the name of the applicant of the present invention, describes a Mechatronic Circuit Breaker Device ("MCB") able to break currents in a time less than a few milliseconds. To this end, the MCB comprises a main branch which comprises at least one semiconductor component breaker cell electrically in parallel with an energy absorber and with at least one mechanical switch-disconnector capable firstly of passing the steady current in its closed position with minimum insertion losses, thus avoiding high losses in the semiconductor breaker component(s), and secondly of withstanding the recovery voltage at the terminals of the device in its open position.

[0004] After current breaking, power flow restoration shall depend on the state of the power transmission link (e.g. cable, overhead line, gas insulated line) fed by the mechatronic circuit breaker, and in particular the circumstances under which the current breaking occurred, in order to avoid or limit the disturbances on the network, and to not permanently damage the mechatronic circuit breaker.

[0005] Further, in case a fault is still present on the network, it is preferable to cease the power flow restoration procedure.

[0006] However, no power flow restoration procedure involving the closing of a mechatronic circuit breaker has been disclosed so far. In particular, there is no existing closing solution for a mechatronic circuit breaker that takes into account the state of the power transmission link fed by said mechatronic circuit breaker and which limits the stress on the network and/or the mechatronic circuit breaker.

[0007] An aim of the invention is thus to define different scenarios for closing a mechatronic circuit breaker that can be employed to restore the power flow.

[0008] Another aim of the invention is also to define different scenarios for closing a mechatronic circuit breaker that can be implemented, without any modification, on an existing mechatronic circuit breaker.

[0009] Another aim of the present invention is also to define a method for charging a power transmission link

supplied by the mechatronic circuit breaker.

[0010] Another aim of the present invention is also to define a method for detecting a fault present on the power transmission link supplied by the mechatronic circuit breaker.

STATEMENT OF THE INVENTION

[0011] The aforementioned aims are, at least partly, attained by method for closing a mechatronic circuit breaker, the mechatronic circuit breaker having a main branch adapted for conducting a nominal load current to a power transmission link, the main branch comprising at least one main module with at least one sub-branch comprising at least one mechanical switch-disconnector connected in series with at least one breaker cell constituted of at least one power semiconductor element with controlled duty ratio, the main branch being connected in series with a pre-insertion module, the pre-insertion module comprising a pre-insertion resistance in parallel with a by-pass switch, the mechatronic circuit breaker and the pre-insertion module forming an assembly having a first terminal and a second terminal, respectively connected to a source and the power transmission link, the method comprising the following steps:

- a) first close the at least one mechanical switch-disconnector when the voltage difference between the voltages at the first and the second terminals is below a predetermined first threshold voltage;
- b) close the by-pass switch;
- c) close the at least one power semiconductor element with controlled duty ratio.

[0012] According to a mode of implementation, the voltage difference is repeatedly measured before triggering the step a) of closing the at least one mechanical switch-disconnector.

[0013] According to a mode of implementation, the predetermined first threshold voltage is a first withstand voltage of the at least one power semiconductor element with controlled duty ratio, the method being further characterized in that the steps a) and b) are carried out almost simultaneously, and the step c) of closing the at least one power semiconductor element with controlled duty ratio is triggered upon completion of step a).

[0014] According to a mode of implementation, the predetermined first threshold voltage is the sum of a first withstand voltage of the at least one power semiconductor element with controlled duty ratio and a second voltage corresponding to the product of an electrical resistance of the pre-insertion resistance by a making current of the at least one mechanical switch-disconnector, the method being further characterized in that step c) is triggered when the current flowing through the main branch is below a current threshold and the step b) is carried out upon completion of step c).

[0015] According to a mode of implementation, the me-

chatronic circuit breaker further comprises a first temporization branch in parallel with the main branch, the first temporization branch comprising, in series, a first thyristor and at least one first switching-assistance module with at least one first capacitor, electrically in parallel with a first discharge resistance and a first voltage surge arrester, the method being characterized in that the first temporization branch and the at least one mechanical switch-disconnector are closed simultaneously during step a), then step c) of closing the at least one power semiconductor element with controlled duty ratio before the current flowing through the first thyristor falls below a holding current of said thyristor, and successively discharge the at least one first capacitor, and perform step b).

[0016] According to a mode of implementation, the discharge of the at least one first capacitor is carried out by closing a switch in series with the first discharge resistance.

[0017] According to a mode of implementation, the predetermined first threshold voltage is a first withstand voltage of the at least one power semiconductor element with controlled duty ratio.

[0018] According to a mode of implementation, the current flowing through the first thyristor is repeatedly measured at least before carrying out the step c) of closing the at least one power semiconductor element with controlled duty ratio.

[0019] The aforementioned aims are, at least partly, attained by a method for closing a mechatronic circuit breaker, the circuit breaker having a main branch adapted for conducting a nominal load current to a power transmission link, the main branch comprising at least one main module with at least one sub-branch comprising at least one mechanical switch-disconnector connected in series with at least one breaker cell constituted of at least one power semiconductor element with controlled duty ratio, the main branch being connected in series with a first switch, the mechatronic circuit breaker and the first switch forming an assembly having a first terminal and a second terminal, respectively connected to a source and the power transmission link, the method comprising the following steps :

- a) first close the at least one mechanical switch-disconnector and the at least one power semiconductor element with controlled duty ratio;
- b) close the first switch.

[0020] According to a mode of implementation, the main branch is also connected in series with a pre-insertion module, the pre-insertion module comprising a pre-insertion resistance in parallel with a by-pass switch, the mechatronic circuit breaker, the first switch and the pre-insertion module forming an assembly having, as terminals, the first terminal and the second terminal, the method being characterized in that, after step b) completion, the method comprises the following steps:

- c) a step of fault detection on the power transmission link,
- d) if a fault is detected on the power transmission link at step c) then stop the closing, otherwise close the by-pass switch.

[0021] According to a mode of implementation, the step c) of fault detection on the power transmission link involves the repeated measurement of a voltage difference between the first and the second terminals.

[0022] According to a mode of implementation, before the closing of the mechatronic circuit breaker starts, the voltage difference between the first and the second terminals is above the sum of a first withstand voltage of the at least one power semiconductor element with controlled duty ratio and a second voltage corresponding to the product of an electrical resistance of the pre-insertion resistance by a making current of the main branch.

[0023] The aforementioned aims are, at least partly, attained by a method for closing a mechatronic circuit breaker, the circuit breaker having a main branch adapted for conducting a nominal load current to a power transmission link, the main branch comprising at least one main module with at least one sub-branch comprising at least one mechanical switch-disconnector connected in series with at least one breaker cell constituted of at least one power semiconductor element with controlled duty ratio, the at least one mechanical switch-disconnector comprises, in series, a plurality of disconnecting modules, each disconnecting module comprises, in parallel, a mechanical switch and a disconnecting surge arrester, each disconnecting module being also adapted to withstand, at its terminals, a second withstand voltage, the main branch being connected in series with at least one pre-insertion module, the pre-insertion module comprises a pre-insertion resistance in parallel with a by-pass switch, the mechatronic circuit breaker and the pre-insertion module forming an assembly having two terminals said first terminal and second terminal, respectively connected to a source and the power transmission link, the method comprising the following steps :

- a) close the at least one power semiconductor element with controlled duty ratio;
- b) close a finite number α of mechanical switches of the at least one mechanical switch-disconnector, the finite number α being defined as a positive integer so that the product of the number of unclosed mechanical switches by the second withstand voltage is greater than the voltage difference between the first and the second terminals;
- c) close one by one the remaining unclosed mechanical switches
- d) after completion of step c) close the by-pass switch.

[0024] According to a mode of implementation, the product of the number of unclosed mechanical switches

by the second withstand voltage is as close as possible to the voltage difference between the first and the second terminals.

[0025] According to a mode of implementation, the aforementioned methods for closing the mechatronic circuit breaker initially comprise a charging of the power transmission link.

[0026] According to a mode of implementation, the charging of the power transmission link involves a step a1) of closing a first temporization branch in parallel with a main branch, and which comprises, in series, a first thyristor and at least one first switching-assistance module with at least one first capacitor, electrically in parallel with a first discharge resistance and a first voltage surge arrester, the closing of the first temporization branch comprising the switching on of the first thyristor so that the at least one first capacitor charges.

[0027] According to a mode of implementation, the charging of the power transmission link further comprises a step a2) of waiting until the current flowing through the first temporization branch reaches zero, and then a step a3) of fault detection on the power transmission link.

[0028] According to a mode of implementation, the step a3) comprises the repeated measurements of the voltage difference between the first and the second terminal.

[0029] According to a mode of implementation, if a fault is detected on the power transmission link at step c) then stop the closing of the mechatronic circuit breaker, otherwise continue the closing of the mechatronic circuit breaker.

[0030] According to a mode of implementation, the mechatronic circuit breaker further comprises an arming branch in parallel with the main branch, and which comprises, in series, a third thyristor and at least one third switching-assistance module with at least one third capacitor, electrically in parallel with a third discharge resistance (DR3), the method being characterized in that the stopping of the closing of the mechatronic circuit breaker comprises the following steps:

- a4) switching on the third thyristor so that current from flowing in the first temporization branch is diverted into the arming branch;
- a5) a step of waiting until current diverted from the first temporization branch into the arming branch reaches zero;
- a6) after step a5), a step of discharging the at least one first capacitor and the at least one third capacitor into, respectively, the first discharge resistance and the third discharge resistance.

[0031] According to a mode of implementation, if no fault is detected, the charging of the power transmission link further comprises a step a7) of discharging the at least one first capacitor after the first thyristor stops conducting.

[0032] According to a mode of implementation, the

charging of the power transmission link involves a step a11) of closing an arming branch in parallel with main branch, and which comprises, in series, a third thyristor and at least one third switching-assistance module with at least one third capacitor, electrically in parallel with a third discharge resistance, the closing of the arming branch comprises the switching on of the third thyristor so that the at least one third capacitor charges.

[0033] According to a mode of implementation, the charging of the power transmission link further comprises a step a12) of waiting until the current flowing through the arming branch reaches zero, and then a step a13) of fault detection on the power transmission link at least while the arming branch is closed.

[0034] According to a mode of implementation, the step a13) comprises the repeated measurement of the voltage difference between the first and the second terminals.

[0035] According to a mode of implementation, if a fault is detected on the power transmission link at step a12) then stop the closing of the mechatronic circuit breaker, otherwise continue the closing of the mechatronic circuit breaker.

[0036] According to a mode of implementation, the charging of the power transmission link further comprises a step a14) of discharging the at least one third capacitor after the third thyristor stops conducting.

BRIEF DESCRIPTION OF THE DRAWINGS

[0037] Other characteristics and advantages of the invention will become clear from the description that follows of modes of implementing the method for closing a mechatronic circuit breaker according to the invention, given as non-limiting examples, with reference to the appended drawings in which:

- Figure 1 is an electrical circuit diagram of a mechatronic circuit breaker for an implementation of the closing method according to the invention,
- Figure 2 is an electrical circuit diagram of the main branch of a mechatronic circuit breaker for an implementation of the closing method according to the invention,
- Figure 3 is an electrical circuit diagram of the first temporization branch of a mechatronic circuit breaker for an implementation of the closing method according to the invention,
- Figure 4 is an electrical circuit diagram of the second temporization branch of a mechatronic circuit breaker for an implementation of the closing method according to the invention,
- Figure 5 is an electrical circuit diagram of the arming branch of a mechatronic circuit breaker for an implementation of the closing method according to the invention.
- Figure 6 is an electrical diagram of a mechanical switch-disconnector UFS which comprises, in se-

ries, a plurality of disconnecting modules for an implementation of the closing method according to the invention,

DETAILED DESCRIPTION OF PARTICULAR EMBODIMENTS

[0038] Although specifically described with reference to the application of building up (power restoration) high direct currents in a distribution and/or transmission line, other applications of the invention may be envisaged.

[0039] In particular, the invention proposes the closing of a Mechatronic Circuit Breaker (MCB) for restoring power flow in a power transmission link connected to a terminal of said MCB. In particular, the method for closing the MCB is implemented on a MCB having a main branch M as described in the patent application [1], in the name of the applicant of the present invention.

[0040] All along the description "connected" means "electrically connected", "in series" means "electrically connected in series", "in parallel" means "electrically connected in parallel", "closed" means rendered electrically conductive, "open" means rendered electrically nonconductive.

[0041] It is understood that, without it being necessary to specify it, the MCB has two terminals, said first terminal 111 and second terminal 112 (FIG. 1), respectively connected to a supply power transmission link S (hereafter "source S") and a fed power transmission link C (hereafter "power transmission link C").

[0042] It is understood that, when the main branch M is closed, the supply power transmission link S provides power to the power transmission link C via said main branch M. In other words, the main branch M is adapted for conducting a nominal load current to a power transmission link C.

[0043] FIG. 1 depicts an overall electrical architecture of a mechatronic circuit-breaker 10 comprising the main branch M.

[0044] The main branch M comprises at least one main module. The description is limited to a main branch M which comprises only one main module, but a plurality of identical main modules connected in parallel or in series can be considered and fall within the scope of the present invention.

[0045] The main branch M comprises at least one mechanical switch-disconnector UFS electrically in series with two breaker cells 101a, 101b (Figure 2). The breaker cells 101a and 101b are constituted, respectively, of at least one power semiconductor element with controlled duty ratio 1010a and 1010b. The breaker cells 101a, 101b may preferably be mounted at the end of the main branch M on either side of the mechanical switch-disconnector UFS.

[0046] As illustrated in figure 6, the mechanical switch-disconnector UFS may comprise at least one disconnecting module. In a preferred embodiment, the mechanical switch-disconnector comprises, in series, a plurality of

disconnecting module DM1, DM2, ..., DMn. Each disconnecting module DM1, DM2, ..., DMn of the plurality of disconnecting modules can comprise a mechanical switch MS1, MS2, ..., MSn.

[0047] As an alternative, each disconnecting module DM1, DM2, ..., DMn of the plurality of disconnecting modules can comprise, in parallel, a mechanical switch MS1, MS2, ..., MSn and a disconnecting surge arrester DSA1, DSA2, ..., DSA_n,

[0048] The mechanical switch MS1, MS2, ..., MSn can comprise a switch, typically having a breaking capacity that can reach an alternating current of a few kA. Each disconnecting module being also adapted to withstand, at its terminals, a voltage ΔU_{DM} . For example, the mechanical switch disconnecter UFS can comprise 4 to 8 disconnecting modules DM1, DM2, ..., DMn, each having a withstand voltage ΔU_{DM} in the 20 kV to 80 kV range.

[0049] The mechanical switch-disconnector UFS is depicted in figures 5, 5A and 6, and described in §[178]-[189] of the patent application [1] cited at the end of the description.

[0050] An electromagnetic actuator developed specifically for operating mechanical switch-disconnectors of the invention is described and claimed in the patent application [2] cited at the end of the description.

[0051] Each of the at least one power semiconductor element with controlled duty ratio 1010a and 1010b may comprise silicon-based insulated gate bipolar transistors (IGBT). They may equally be components based on silicon carbide, currently at the development stage, such as JFET/BJT hybrid transistors, or even GTO thyristors.

[0052] The breaker cell 101a can be constituted of an insulated gate bipolar transistor (IGBT) 1010a mounted in anti-parallel with a diode 1011b. The breaker cell 101b can be constituted of an insulated gate bipolar transistor (IGBT) 1010b mounted in antiparallel with a diode 1011a.

[0053] Each breaker cell 101a, 101b can be connected in parallel with a respective voltage surge arrester 103a, 103b designed to limit the voltage to a value less than the withstand voltage of the IGBT transistor 1010a, 1010b. For an IGBT transistor 1010a, 1010b with a withstand voltage of 4500 V, it is typical to set a maximum voltage value equal to 4000 V limited by the respective limiter 103a, 103b.

[0054] The breaker cells 101a and 101b can be connected in parallel, respectively, with snubbers 104a and 104b. For example, a snubber 104a, 104b may comprise in series a capacitor and discharge resistor. Other configurations may be contemplated and in particular the one described in §[0127] of the document [1] cited at the end of the description.

[0055] As shown by Figure 1, the main branch M may be connected in series with at least one pre-insertion module P1 so that the mechatronic circuit breaker 10 and the pre-insertion module P1 form an assembly having the two terminals said first terminal 111 and second terminal 112. The pre-insertion module P1 may comprise a pre-insertion resistance R_{ins} in parallel with a by-pass

switch S2.

[0056] If a plurality of pre-insertion modules is considered, said pre-insertion modules are in series. In that case, the user may select a specific pre-insertion module among the plurality of pre-insertion modules either for the closing or the current interruption procedure. In particular, the user may select a pre-insertion module for which the pre-insertion Rins is the most appropriate for circulating a specific current.

[0057] The main branch M may be connected in series with a first switch S1. The mechatronic circuit breaker 10 and the first switch S1 then form an assembly having the two terminals, said first terminal 111 and second terminal 112. The first terminal 111 and second terminal 112 are, respectively, connected to the source S and the power transmission link C. As exemplified in figures 1 and 2, the second terminal 112 can correspond to a terminal of the first switch S1.

[0058] Both the pre-insertion module P1 and the first switch S1 can also be considered in combination.

[0059] The mechatronic circuit breaker 10 may optionally comprise a first temporization branch T1 in parallel with the main branch M (figures 1 and 3).

[0060] The first temporization branch T1 may comprise, in series, at least a first thyristor THY1 and at least one first switching-assistance module with at least one first capacitor C1, electrically in parallel with a first discharge resistance DR1 and a first voltage surge arrester SA1. The first temporization branch T1 may further comprise a switch ST1 in series with the first discharge resistance DR1, so that the assembly comprising the switch ST1 and the first discharge resistance DR1 is in parallel with the first capacitor C1.

[0061] The mechatronic circuit breaker may further comprise a second temporization branch T2 in parallel with the first temporization branch T1 (figure 1 and 4).

[0062] The second temporization branch T2 may comprise, in series, at least a second thyristor THY2 and at least one second switching-assistance module with at least one second capacitor C2, electrically in parallel with a second discharge resistance DR2 and a second voltage surge arrester SA2. The second temporization branch T2 may further comprise a switch ST2 in series with the second discharge resistance DR2, so that the assembly comprising the switch ST2 and the second discharge resistance DR2 is in parallel with the second capacitor C2.

[0063] During an opening phase of the mechanical circuit breaker 10 (and as described in the document [1]), the first temporization branch T1 performs the diversion of the current for sufficient time for the at least one mechanical switch-disconnector UFS to begin to open and to be able to withstand a first voltage level, and to ensure a voltage drop sufficiently small not to lead to conduction in the voltage surge arresters 103a, 103b connected in parallel to the power semiconductor components 1010a, 1010b of the main branch M. The first temporization branch T1 also ensures a voltage drop sufficiently high

to facilitate the switching of the current to the second temporization branch T2 at the appropriate time, and a storing of a voltage sufficient to turn off its own power in the first thyristor THY1 when the second temporization branch T2 begins to conduct.

[0064] The mechatronic circuit breaker 10 may further comprise an arming branch Arm (figures 1 and 5) in parallel with the main branch M, and which comprises, in series, at least a third thyristor THY3 and at least one third switching-assistance module with at least one third capacitor C3, electrically in parallel with a third discharge resistance DR3. The arming temporization branch Arm may further comprise a switch ST3 in series with the third discharge resistance DR3, so that the assembly comprising the switch ST3 and the third discharge resistance DR3 is in parallel with the third capacitor C3.

[0065] The mechatronic circuit breaker may further comprise an extinction branch Ex, in parallel with the arming branch Arm, which comprises a third surge arrester SA3 (figure 1).

[0066] During an opening phase of the mechanical circuit breaker 10, the second temporization branch T2 performs the diversion of the current from the first temporization branch T1 to itself once the at least one mechanical switch-disconnector UFS has reached a first level of opening and for the time necessary for the at least one mechanical switch-disconnector UFS to acquire the dielectric strength necessary to be able to withstand the interruption voltage at the first 111 and the second 112 terminals.

[0067] The second temporization branch T2 also ensures a voltage drop sufficiently low not to lead to dielectric breakdown of the at least one mechanical switch-disconnector USF.

[0068] The second temporization branch T2 further ensures a voltage drop sufficiently high to facilitate switching of the current present in said second temporization branch T2 to the arming branch Arm at the appropriate time, and to store a sufficient voltage and energy to turn off power of the second thyristor THY2 when the arming branch Arm begins to conduct.

[0069] The arming branch Arm ensures the insertion of a variable instantaneous impedance into the circuit. The instantaneous impedance may be defined as the ratio of the instantaneous voltage at its terminals to the instantaneous current that flows through it.

[0070] Regarding the characteristics of the components of the Mechanical Circuit breaker, or the opening phase (current breaking process), the man skilled in the art can refer to the patent application [1] cited at the end of the description.

[0071] According to a first embodiment of the invention, the closing of the mechatronic circuit breaker 10 comprises a first step a) of closing the mechanical switch-disconnector UFS. The closing of the mechanical switch-disconnector is advantageously carried out when the voltage difference $\Delta U = U1 - U2$ between the first 111 and the second 112 terminals is below a predetermined first

threshold voltage ΔU_t . Furthermore, the mechatronic circuit breaker 10 comprises the pre-insertion module P1. If the switch S1 is considered, it is in a conducting state ("closed"). It is also understood that before starting the method for closing the mechatronic circuit breaker 10, the by-pass switch S2 is in a non-conducting state ("open"). The closing of the mechanical switch-disconnector UFS is triggered by a specific instruction or order of closing communicated to said mechanical switch-disconnector UFS by a controller or an electronic card or a computer or any other electronic device.

[0072] Advantageously, the voltage difference ΔU is repeatedly measured, and compared with the predetermined first threshold voltage ΔU_t before triggering step a).

[0073] The method for closing the mechatronic circuit breaker 10, further comprises the following steps:

- b) close the by-pass switch S2;
- c) close the at least one power semiconductor element with controlled duty ratio 1010a, 1010b.

[0074] Steps b) and c) are triggered by communicating a specific instruction or an order of closing to the by-pass switch S2 and to the at least one power semiconductor element with controlled duty ratio 1010a, 1010b. The specific instruction or the order of closing can be communicated by a controller or an electronic card or a computer or any other electronic device.

[0075] The predetermined first threshold voltage is a voltage for which arcing is prevented or at least limited so that no contact welding of the mechanical switches MS1, MS2, ..., MSn occur. The predetermined first threshold voltage may depend on the closing sequence, in particular on the order of the steps for closing the mechatronic circuit breaker. The determination of the predetermined first threshold voltage is within the knowledge of the man skilled in the art and is not further discussed in the present application.

[0076] In a first variant of this first embodiment, the predetermined first threshold voltage ΔU_t is a first withstand voltage ΔU_{100} of the at least one power semiconductor element with controlled duty ratio 1010a, 1010b. The first withstand voltage ΔU_{100} is less than 5%, preferably less than 1%, of the maximum withstand voltage of the mechatronic circuit breaker 10.

[0077] Furthermore, according to this variant, steps a) and b) are carried out, almost simultaneously, and the step c) of closing the at least one power semiconductor element with controlled duty ratio 1010a, 1010b is triggered upon completion of step a).

[0078] The closing time t_1 , upon reception of a closing order, of the mechanical switch-disconnector UFS is known, or may be characterized by the user before the commissioning of the mechatronic circuit breaker 10. Therefore, the triggering of the step c) can be delayed by, at least, the time t_1 with respect of step a).

[0079] In this specific first variant, there is no pre-arcing

in the mechanical switch-disconnector UFS neither does it harm any component of the main branch.

[0080] In a second variant of the first embodiment of the invention, the predetermined voltage ΔU_t is the sum of a first withstand voltage ΔU_{100} and a second voltage ΔU_{200} . The first withstand voltage ΔU_{100} is the withstand voltage of the at least one power semiconductor element with controlled duty ratio 1010a, 1010b and the second voltage ΔU_{200} is the product of an electrical resistance R_i of the pre-insertion resistance R_{ins} by a current I_{make} . The current I_{make} is a making current of the main branch M.

[0081] The making current of the main branch M is the maximum current that can be circulated through the mechatronic circuit breaker, at the moment of closing said main branch M, without triggering any welding or damages of the mechanical switches MS1, MS2, ..., MSn. Said making current is likely to be lower than the maximum current that can be circulated through the mechatronic circuit breaker after closing of the main branch M. The determination of the making current is within the technical knowledge of the man skilled in the art and is not further describe in this application.

[0082] Furthermore, according to this second variant, step c) is triggered when the current I flowing through the main branch M is below a current threshold I_t , advantageously I_t is below 90% of the making current I_{make} , and the step b) is carried out upon completion of step c).

[0083] In this specific second variant, pre-arcing can occur in the mechanical switch-disconnector UFS when ΔU_t is above a first withstand voltage ΔU_{100} , and dissipate more or less energy. As soon as the mechanical switch-disconnector USF closes, the current starts flowing through it, and in the voltage surge arresters 103a, 103b connected in parallel to the power semiconductor components 1010a, 1010b. The voltage surge arresters 103a, 103b are thus dimensioned for this energy absorption. Therefore contact welding of the mechanical switches MS1, MS2, ..., MSn or any other damage to the components of the main branch is prevented.

[0084] In a third variant of the first embodiment of the invention, the method of closing the mechatronic circuit breaker comprises the closing of the first temporization branch T1. In particular, the first temporization branch T1 and the at least one mechanical switch-disconnector UFS are closed simultaneously during step a).

[0085] Afterwards, the step c) of closing the at least one power semiconductor element with controlled duty ratio 1010a, 1010b is executed before the current I_{THY1} flowing through the first thyristor THY1 falls below a holding current of said thyristor THY1. Finally, successively discharge the at least one first capacitor C1, and perform step b). The holding current of a thyristor is the current below which said thyristor stops by itself conducting current (it is in an open state).

[0086] Advantageously, the discharge of the at least one first capacitor C1 can be carried out by closing the switch ST1 in series with the first discharge resistance

DR1.

[0087] Advantageously, the predetermined first threshold voltage ΔU_t is a first withstand voltage ΔU_{100} of the at least one power semiconductor element with controlled duty ratio 1010a, 1010b.

[0088] Advantageously, the current I_{THY1} is repeatedly measured at least before carrying out step c).

[0089] According to a second embodiment of the invention, the mechatronic circuit breaker 10 comprises the first switch S1. It is also understood that before starting the method for closing the mechatronic circuit breaker 10, the first switch S1 is in a non-conducting state ("open").

[0090] If the pre-insertion module P1 is considered, the by-pass switch S2 is in a conducting state ("closed").

[0091] In a first variant of this second embodiment, the closing of the mechatronic circuit breaker 10 comprises the following steps:

- a) first close the at least one mechanical switch-disconnector UFS and the at least one power semiconductor element with controlled duty ratio 1010a, 1010b; and
- b) close the first switch S1.

[0092] Advantageously, the at least one power semiconductor element with controlled duty ratio 1010a, 1010b comprises IGBTs that are closed during the step a).

[0093] In a second variant of this second embodiment, the mechatronic circuit breaker 10 comprises the pre-insertion module P1 and the switch S1. Before the closing of the mechatronic circuit breaker starts, both the by-pass switch S2 and the switch S1 are in a non-conducting state ("open").

[0094] The closing method of the mechatronic circuit breaker 10 comprises the following successive steps:

- a) first close the at least one mechanical switch-disconnector UFS and the at least one power semiconductor element with controlled duty ratio 1010a, 1010b; and
- b) close the first switch S1,
- c) perform fault detection on the power transmission link C,
- d) if a fault is detected on the power transmission link C at step c), then stop the closing, otherwise close the by-pass switch S2.

[0095] Performing fault detection may comprise the repeated measurements of the voltage difference $\Delta U=U1-U2$ between the first 111 and the second 112 terminals and/or the current flowing through the power transmission link C.

[0096] In the event of a fault is present on the power transmission link C, the current and voltage difference $\Delta U=U1-U2$ pattern will exhibit differences from a healthy transmission mean as:

- 1/ The reflections of current/voltage waves arrive earlier than expected;
- 2/ The power transmission link C does not charge up ;
- 3/ The current stays at a higher level than if no fault is present.

[0097] This second variant of the second embodiment is advantageously considered in case, before the closing of the mechatronic circuit breaker starts, the voltage difference $\Delta U=U1-U2$ is above the sum of the first withstand voltage ΔU_{100} of the at least one power semiconductor element with controlled duty ratio 1010a, 1010b and the second voltage ΔU_{200} , the second voltage ΔU_{200} being the product of the electrical resistance R_i of the pre-insertion resistance R_{ins} by the current I_{make} , the current I_{make} being a making current of the main branch.

[0098] According to a third embodiment of the invention, the at least one mechanical switch-disconnector UFS comprises, in series, the plurality of disconnecting modules DM1, DM2, ... DMn, each disconnecting module DM1, DM2, ... DMn comprises, the mechanical switch MS1, MS2, ..., MSn. Each disconnecting module is also adapted to withstand, at its terminals, a voltage ΔU_{DM} . The mechatronic circuit breaker 10 comprises the pre-insertion module P1, and before starting the closing of the mechanical circuit breaker 10, the by-pass switch S2 is in a non-conductive state. If the switch S1 is considered, it is in a conducting state ("closed").

[0099] According to the third embodiment, the method for closing the mechatronic circuit breaker 10 comprises the following successive steps:

- a) close the at least one power semiconductor element with controlled duty ratio 1010a, 1010b;
- b) close a finite number α of the mechanical switches MS1, MS2, ..., MSn of the at least one mechanical switch-disconnector UFS, the finite number α being defined as a positive integer so that the product of the number of unclosed mechanical switches $\times \Delta U_{DM}$ is greater than the voltage difference $\Delta U=U1-U2$ between the first and the second terminal.
- c) close one by one the remaining unclosed mechanical switches MS1, MS2, ..., MSn;
- d) after completion of step c), close the by-pass switch S2.

[0100] Advantageously, the product of the number of unclosed mechanical switches after step b) is adjusted so that the product of said number of unclosed mechanical switches $\times \Delta U_{DM}$ remains minimum and just greater the voltage difference $\Delta U=U1-U2$.

[0101] The mechanical switches MS1, MS2, ..., MSn of each disconnecting module DM1, DM2, ... DMn can be connected in parallel with a disconnecting surge arrester DSA1, DSA2, ..., DSA_n. In order to avoid uneven voltage distribution across the mechanical switch disconnecter UFS, each disconnecting surge arrester DSA1,

DSA2, ..., DSA_n is specifically dimensioned to ensure a voltage grading across the mechanical switch-disconnector UFS.

[0102] Whatever the closing method, the method for closing the mechatronic circuit breaker 10 can initially comprise a charging of the power transmission link C. "initially comprise" means the first step or first step sequence to be carry out.

[0103] Prior to closing the mechatronic circuit breaker 10, and more specifically the main branch M, it might be useful to charge the power transmission link C and to verify that the current and voltage measurement located at the first 111 and second 112 terminals correspond to an healthy link.

[0104] By healthy link, we mean that the power transmission link C is healthy.

[0105] To this end, an auxiliary branch (for example the first temporization branch T1 and/or the arming branch Arm) can be used to inject charges into the power transmission link C for raising the voltage on said power transmission link C.

[0106] In parallel, a constant monitoring of the voltage and/or the current on the power transmission link C can be carried out for detected the possible presence of a fault on the power transmission link C.

[0107] Furthermore, in case of fault detection on the power transmission link C, a rapid interruption of the charging and/or the closing can be triggered.

[0108] A fault detection may be associated with at least one of the following feature:

- 1/ the reflections of current/voltage waves arrive earlier than expected
- 2/ the power transmission link C does not charge up;
- 3/ the current stays at a higher level than if no fault is present.

[0109] The charging sequence of the power transmission link C can involve a careful raise of the voltage in order not to create disturbances in the network.

[0110] In the following, two charging method embodiments of the power transmission link C will be described.

[0111] Whatever the charging method of the power transmission link C, if the pre-insertion module P1 is considered, the by-pass switch S2 is in a non-conducting state ("open"), and if the first switch S1 is considered, it is in a conducting state ("close").

[0112] In a first embodiment, the charging of the power transmission link C involves a step a1) of closing the first temporization branch T1. The closing of the first temporization branch T1 comprises the switching "ON" ("closed") of the first thyristor THY1 so that the at least one first capacitor C1 charges.

[0113] When the first thyristor THY1 is switched "ON", a current flows through the first temporization branch T1. Therefore the first capacitor C1 charges until the voltage at its terminals reaches the withstand voltage of the first voltage surge arrester SA1, thus rendering the first volt-

age surge arrester SA1 conducting. Once the voltage difference $\Delta U = U_1 - U_2$ between the first 111 and the second 112 terminals is zero or close to zero, the current almost stops flowing through the first temporization branch T1, and the first thyristor THY1 switches in the "OFF" state ("open").

[0114] Therefore, the charging of the power transmission link C can further comprise a step a2) of fault detection on the power transmission link C while executing step a3) of waiting until the current flowing through the first temporization branch T1 reaches zero.

[0115] Step a2) can comprise repeated measurements of the voltage difference $\Delta U = U_1 - U_2$ between the first 111 and the second 112 terminals.

[0116] Furthermore, if a fault is detected on the power transmission link C at step a2), then stop the closing of the mechatronic circuit breaker 10, otherwise continue the closing of the mechatronic circuit breaker 10.

[0117] In case a fault is detected during the charging, stopping the closing of the mechatronic circuit breaker 10 comprises the following steps:

a4) switch on the third thyristor THY3 so that current flowing in the first temporization branch T1 is diverted into the arming branch Arm;

a5) wait until current diverted from the first temporization branch T1 into the arming branch Arm reaches zero;

a6) after step a5), discharge the at least one first capacitor C1 and the at least one third capacitor C3 into, respectively, the first discharge resistance DR1 and the third discharge resistance DR3.

[0118] All the steps a1) to a6) are executed via commands sent to the appropriate element of the mechatronic circuit breaker 10, and generated by a controller or an electronic card or a computer or any other electronic device, and equipped with a specific software. Monitoring tools like Voltmeters and/or current measurement systems can also be employed. It is within the knowledge of the man skilled in the art to implement and configure such tools, therefore no other details will be given in the description. This statement applies to any other step that can be considered in this charging method embodiment.

[0119] Advantageously, a step a6) starts only after deionization of the first THY1 and the third THY3 thyristors. Therefore, a specific delay can be implemented in between steps a5) and a6), said specific delay being longer the deionization time of the first THY1 and the third THY3 thyristors.

[0120] Advantageously, if no fault is detected, the charging of the power transmission link C may further comprise a step a7) of discharging the at least one first capacitor C1 after the first thyristor THY1 stops conducting.

[0121] Advantageously, a step a7) starts only after deionization of the first thyristor THY1. Therefore, a specific delay can be implemented before step a7) starts,

said specific delay being longer the deionization time of the first thyristor THY1. "after a thyristor stops conducting" means that the current flowing is below a current level, close to zero or even zero, for which said thyristor is considered as open (in a non-conducting state). The man skilled in the art is familiar with the technical features related to the thyristor which are not further detailed in the present invention.

[0122] As soon as the charging is completed, any closing of the mechatronic circuit breaker 10 described in the present invention may be considered.

[0123] Charging the power transmission link C according to the first embodiment lead a full of said power transmission link C. In other words, the voltage difference ΔU is close to zero at the end of said charging procedure.

[0124] In a second embodiment, the charging involves a step a11) of closing the arming branch Arm in parallel which comprises the switching "ON" of the third thyristor THY3 (closing of the third thyristor) so that the at least one third capacitor C3 charges.

[0125] In this second embodiment, the charging may further comprise

a step a12) of fault detection on the power transmission link (C) executed while a step a13) waiting until the current flowing through the arming branch (Arm) reaches zero.

[0126] The step a12) may comprise the repeated measurements of the voltage difference $\Delta U = U1 - U2$ between the first 111 and the second 112 terminals.

[0127] In case a fault is detected on the power transmission link C at step a12), the closing of the mechatronic circuit breaker 10 is stopped, otherwise continue the closing of the mechatronic circuit breaker 10.

[0128] The charging also comprises a step a14) of discharging the at least one third capacitor C3 after the third thyristor THY3 stops conducting.

[0129] Advantageously, a step a14) starts only after deionization of the third thyristor THY3. Therefore, a specific delay can be implemented before step a14) starts, said specific delay being longer the deionization time of the third thyristor THY3.

[0130] Steps a11) to a14) are advantageously carried out successively.

[0131] All the steps a11) to a14) are executed via commands sent to the appropriate element of the mechatronic circuit breaker 10, and generated by a controller or an electronic card or a computer or any other electronic device, and equipped with a specific software. Monitoring tools like Voltmeters and/or current measurement systems can also be employed. It is within the knowledge of the man skilled in the art to implement and configure such tools, therefore no other details will be given in the description.

[0132] The full charging of the power transmission link C can be achieved by repeating the charging according to this second embodiment until the voltage difference ΔU is close to zero. The charging method according to this second embodiment is sometimes called "multistep

charging method" whereas the charging method according to the first embodiment lead to the full charge of the power transmission link C in one step.

[0133] The first and the second charging embodiment of the power transmission link C can be combined during the closing of the mechatronic circuit breaker 10. In particular, the second embodiment can be carried out in case the charging according to the first embodiment has to be stopped, after fault detection for example.

[0134] Furthermore, the first embodiment for the charging of the power transmission link C as well as the second embodiment for the charging of the power transmission link C can be executed without considering the closing of the circuit breaker.

[0135] In other words, the invention also concerns the charging of the power transmission link C for detecting a fault on the power transmission link C.

[0136] The methods described in the present invention can be implemented for the closing of an existing mechatronic circuit breaker comprising at least the main branch M without necessary involving any modification or upgrade of said mechatronic circuit breaker.

[0137] Furthermore, the way of closing the mechatronic circuit breaker 10 may be selected among the specific embodiments presented in the description to avoid or at least limit the damaging of the power transmission link C and/or the main branch.

[0138] Contrary to known closing process of conventional circuit breaker, according to the present invention, it is possible to detect the presence of a fault before closing the mechatronic circuit breaker.

[0139] The present invention shall not be limited to the specific configuration of the mechatronic circuit breaker described, and the man skill in the art can adapt the teaching of this invention to other circuit breakers.

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[0140]

- [1] US20150002977;
- [2] US2014340182.

Claims

1. A method for closing a mechatronic circuit breaker, the mechatronic circuit breaker having a main branch (M) adapted for conducting a nominal load current to a power transmission link (C), the main branch (M) comprising at least one main module with at least one sub-branch comprising at least one mechanical switch-disconnector (UFS) connected in series with at least one breaker cell (101a, 101b) constituted of at least one power semiconductor element with controlled duty ratio, the main branch (M) being connected in series with at least one pre-insertion module (P1), the pre-insertion module (P1) comprising a pre-

insertion resistance (Rins) in parallel with a by-pass switch (S2), the mechatronic circuit breaker and the pre-insertion module (P1) forming an assembly having a first terminal (111) and a second terminal (112), respectively connected to a source (S) and the power transmission link (C), the method comprising the following steps :

- a) first closing the at least one mechanical switch-disconnector (UFS) when the voltage difference between the voltages at the first and the second terminal is below a predetermined first threshold voltage;
 - b) closing the by-pass switch (S2);
 - c) closing the at least one power semiconductor element with controlled duty ratio (1010a, 1010b).
2. A method according to claim 1, wherein the predetermined first threshold voltage is a first withstand voltage of the at least one power semiconductor element with controlled duty ratio (1010a, 1010b), the method being further **characterized in that** the steps a) and b) are carried out almost simultaneously, and the step c) of closing the at least one power semiconductor element with controlled duty ratio (1010a, 1010b) is triggered upon completion of step a).
 3. A method according to claim 1, wherein the predetermined first threshold voltage is the sum of a first withstand voltage of the at least one power semiconductor element with controlled duty ratio (1010a, 1010b) and a second voltage corresponding to the product of an electrical resistance of the pre-insertion resistance (Rins) by a making current of the at least one mechanical switch-disconnector (UFS), the method being further **characterized in that** step c) is triggered when the current flowing through the main branch (M) is below a current threshold and the step b) is carried out upon completion of step c).
 4. A method according to claim 1, wherein the mechatronic circuit breaker (10) further comprises a first temporization branch (T1) in parallel with the main branch (M), the first temporization branch (T1) comprising, in series, at least one first thyristor (THY1) and at least one first switching-assistance module, with at least one first capacitor (C1), electrically in parallel with a first discharge resistance (DR1) and a first voltage surge arrester (SA1), the method being **characterized in that** the first temporization branch (T1) and the at least one mechanical switch-disconnector (UFS) are closed simultaneously during step a), then followed by step c) of closing the at least one power semiconductor element with controlled duty ratio (1010a, 1010b) before the current flowing through the first thyristor (THY1) falls below a holding

current of said thyristor (THY1), and successively discharge the at least one first capacitor (C1), and finally performing step b).

5. A method according to claim 4, wherein the discharge of the at least one first capacitor (C1) is carried out by closing a switch (ST1) in series with the first discharge resistance (DR1).
6. A method according to claim 4 or 5, wherein the predetermined first threshold voltage is a first withstand voltage of the at least one power semiconductor element with controlled duty ratio (1010a, 1010b).
7. A method for closing a mechatronic circuit breaker (10), the circuit breaker (10) having main branch (M) adapted for conducting a nominal load current to a power transmission link (C), the main branch (M) comprising at least one main module with at least one sub-branch comprising at least one mechanical switch-disconnector (UFS) connected in series with at least one breaker cell (101a, 101b) constituted of at least one power semiconductor element with controlled duty ratio (1010a, 1010b), the main branch (M) being connected in series with a first switch (S1), the mechatronic circuit breaker (10) and the first switch (S1) forming an assembly having a first terminal (111) and a second terminal (112), respectively connected to a source (S) and the power transmission link (C), the method comprising the following steps :
 - a) first closing the at least one mechanical switch-disconnector (UFS) and the at least one power semiconductor element with controlled duty ratio (1010a, 1010b); and
 - b) closing the first switch (S1).
8. A method according to claim 7, wherein the main branch (M) is also connected in series with a pre-insertion module (P1), the pre-insertion module (P1) comprising a pre-insertion resistance (Rins) in parallel with a by-pass switch (S2), the mechatronic circuit breaker (10), the first switch (S1) and the pre-insertion module (P1) forming an assembly having, as terminals, the first terminal (111) and the second terminal (112), the method being **characterized in that**, after completion of step b), the method comprises the following steps:
 - c) detecting a fault on the power transmission link (C), and
 - d) if a fault is detected on the power transmission link (C) at step c) then terminating the closing of the mechatronic circuit breaker (10), or if no fault is detected, closing the by-pass switch (S2).
9. A method according to claim 8, wherein before the

closing of the mechatronic circuit breaker (10) starts, the voltage difference between the first (111) and the second (112) terminals is above the sum of a first withstand voltage of the at least one power semiconductor element with controlled duty ratio (1010a, 1010b) and a second voltage corresponding to the product of an electrical resistance of the pre-insertion resistance (Rins) by a making current of the main branch (M).

10. A method for closing a mechatronic circuit breaker (10), the circuit breaker having a main branch (M) adapted for conducting a nominal load current to a power transmission link (C), the main branch (M) comprising at least one main module with at least one sub-branch comprising at least one mechanical switch-disconnector (UFS) connected in series with at least one breaker cell (101a, 101b) constituted of at least one power semiconductor element with controlled duty ratio (1010a, 1010b), the at least one mechanical switch-disconnector (UFS) comprising, in series, a plurality of disconnecting modules, each disconnecting module (DM1, DM2, ... DMn) comprises, in parallel, a mechanical switch (MS1, MS2, ..., MSn) and a disconnecting surge arrester (DSA1, DSA2, ..., DSA_n), each disconnecting module being also adapted to withstand, at its terminals, a second withstand voltage, the main branch (M) being connected in series with at least one pre-insertion module (P1), the pre-insertion module (P1) comprises a pre-insertion resistance (Rins) in parallel with a by-pass switch (S2), the mechatronic circuit breaker (10) and the pre-insertion module (P1) forming an assembly having two terminals said first terminal and second terminal, respectively connected to a source (S) and the power transmission link (C), the method comprising the following steps :

- a) closing the at least one power semiconductor element with controlled duty ratio (1010a, 1010b);
- b) closing a finite number α of mechanical switches (MS1, MS2, ..., MSn) of the at least one mechanical switch-disconnector (UFS), the finite number α being defined as a positive integer so that the product of the number of unclosed mechanical switches by the second withstand voltage is greater than the voltage difference between the first (111) and the second (112) terminals;
- c) closing one by one the remaining unclosed mechanical switches (MS1, MS2, ..., MSn); and
- d) after completion of step c) closing the by-pass switch (S2).

11. A method according to claim 1 to 10, wherein the method for closing the mechatronic circuit breaker (10) comprises initially charging the power transmis-

sion link (C).

12. A method according to claim 11, wherein the charging of the power transmission link (C) involves a step a1) of closing a first temporization branch (T1) in parallel with main branch (M), and which comprises, in series, at least one first thyristor (THY1) and at least one first switching-assistance module with at least one first capacitor (C1), electrically in parallel with a first discharge resistance (DR1) and a first voltage surge arrester (SA1), the closing of the first temporization branch (T1) comprising the switching on of the at least one first thyristor (THY1) so that the at least one first capacitor (C1) charges.
13. A method according to claim 11 or 12, wherein the charging of the power transmission link (C) further comprises a further step a2) of detecting a fault on the power transmission link (C) while executing a step a3) of waiting until the current flowing through the first temporization branch (T1) reaches zero.
14. A method according to claim 13, wherein the step a2) comprises repeatedly measuring the voltage difference between the first (111) and the second (112) terminals.
15. A method according to claim 13 or 14, wherein if a fault is detected on the power transmission link (C) at step a2) then terminating the closing of the mechatronic circuit breaker (10), and if no fault is detected, continuing the closing of the mechatronic circuit breaker (10).
16. A method according to claim 15, wherein the mechatronic circuit breaker (10) further comprises an arming branch (Arm) in parallel with the main branch (M), and which comprises, in series, a third thyristor (THY3) and at least one third switching-assistance module with at least one third capacitor (C3), electrically in parallel with a third discharge resistance (DR3), the method being **characterized in that** the terminating of the closing of the mechatronic circuit breaker (10) comprises the following steps:
- a4) switching on the third thyristor (THY3) so that current flowing in the first temporization branch (T1) is diverted into the arming branch (Arm);
 - a5) waiting until current diverted from the first temporization branch (T1) into the arming branch (Arm) reaches zero;
 - a6) after step a5), discharging the at least one first capacitor (C1) and the at least one third capacitor (C3) into, respectively, the first discharge resistance (DR1) and the third discharge resistance (DR3).

17. A method according to claim 15, wherein, if no fault is detected, the charging of the power transmission link (C) further comprises a step a7) of discharging the at least one first capacitor (C1) after the first thyristor (THY1) stops conducting. 5
18. A method according to claim 11, wherein the charging of the power transmission link (C) includes a step a11) of closing an arming branch (Arm) in parallel with main branch (M), and which comprises, in series, a third thyristor (THY3) and at least one third switching-assistance module with at least one third capacitor (C3), electrically in parallel with a third discharge resistance (DR3), the closing of the arming branch (Arm) comprising the switching on of the third thyristor (THY3) so that the at least one third capacitor (C3) charges. 10 15

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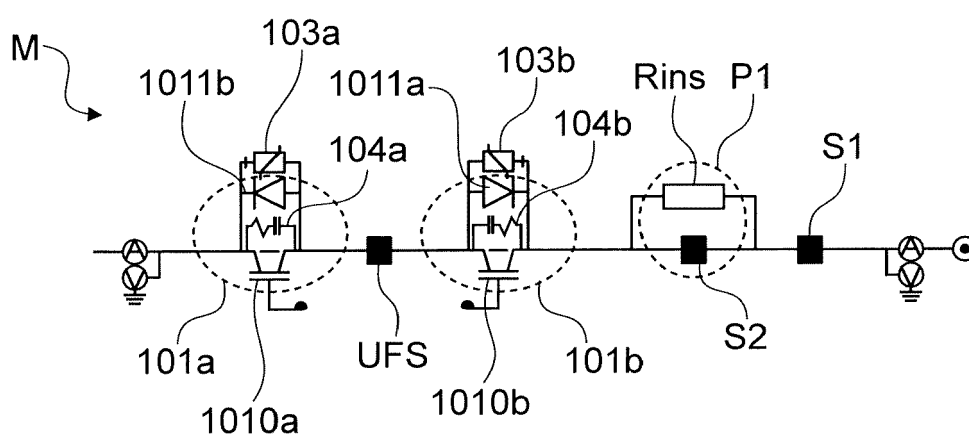
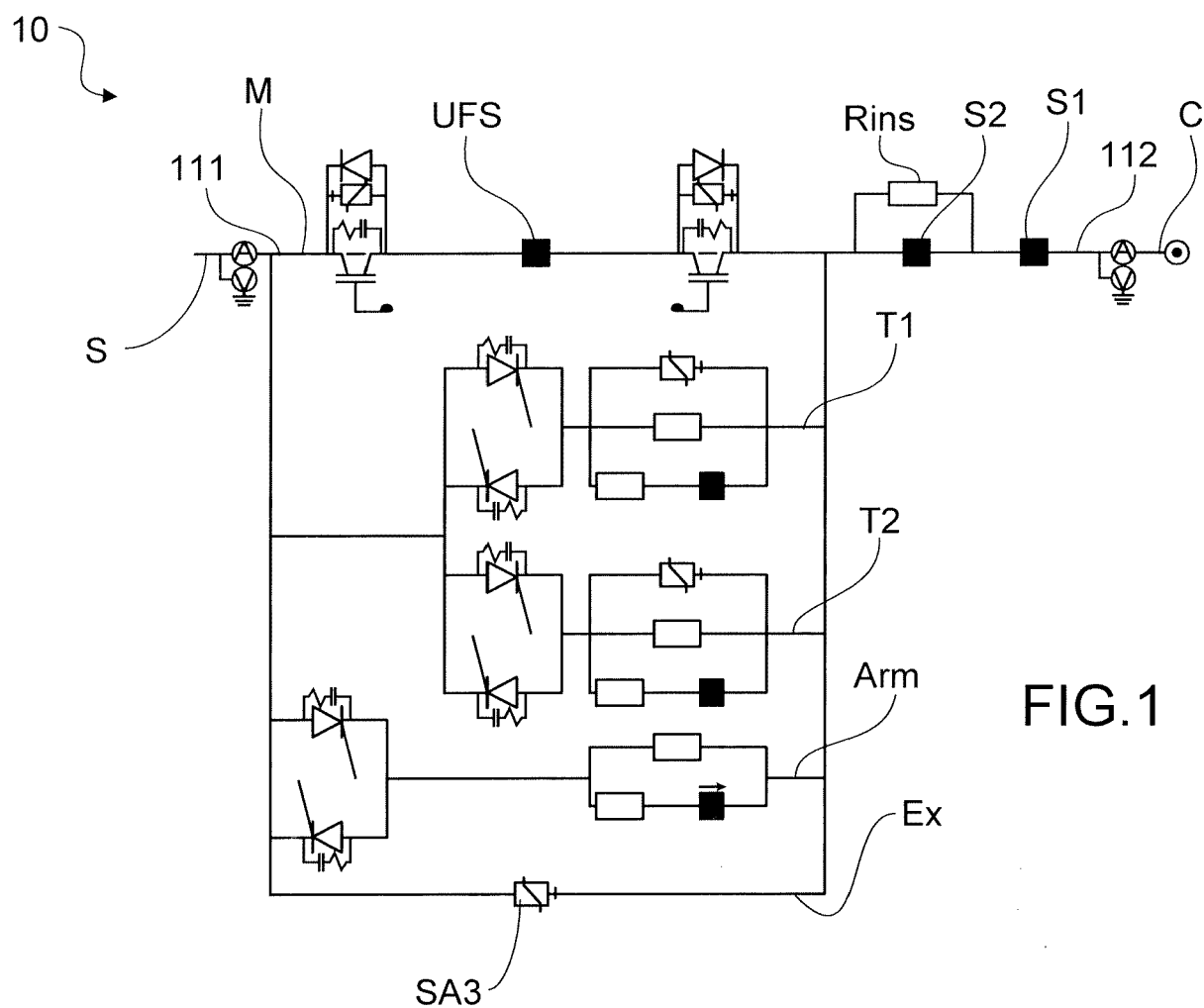
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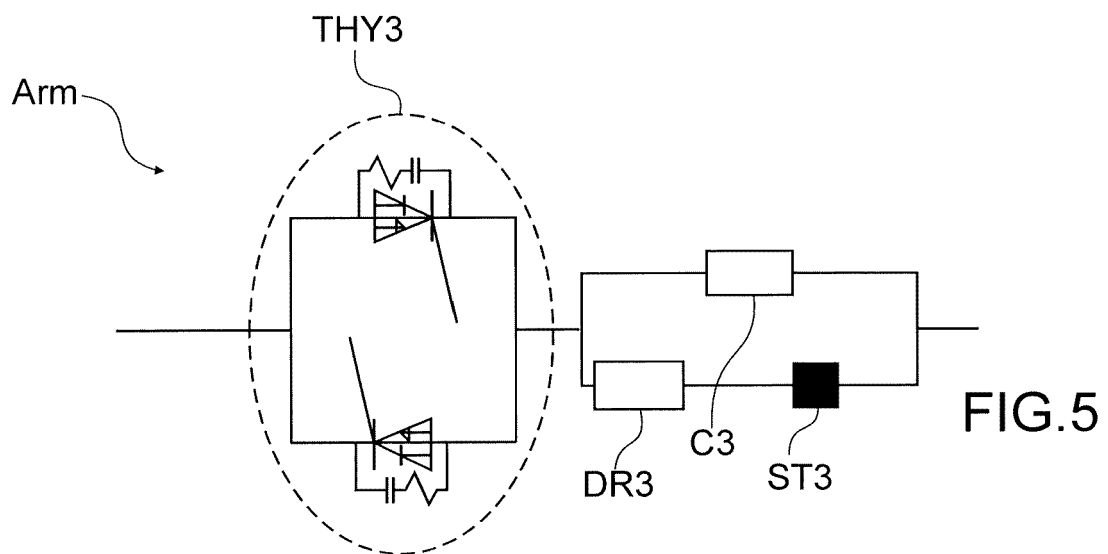
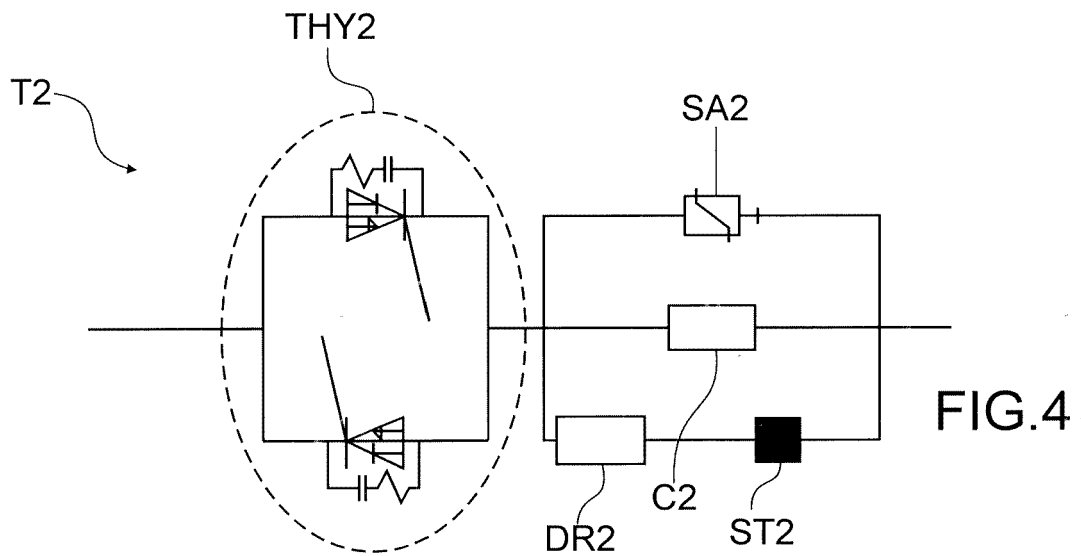
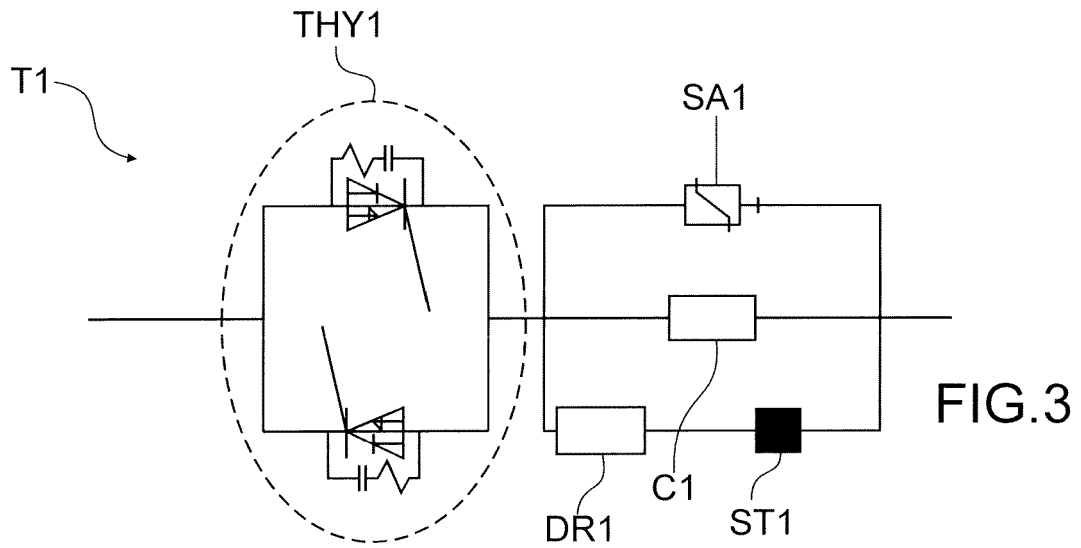
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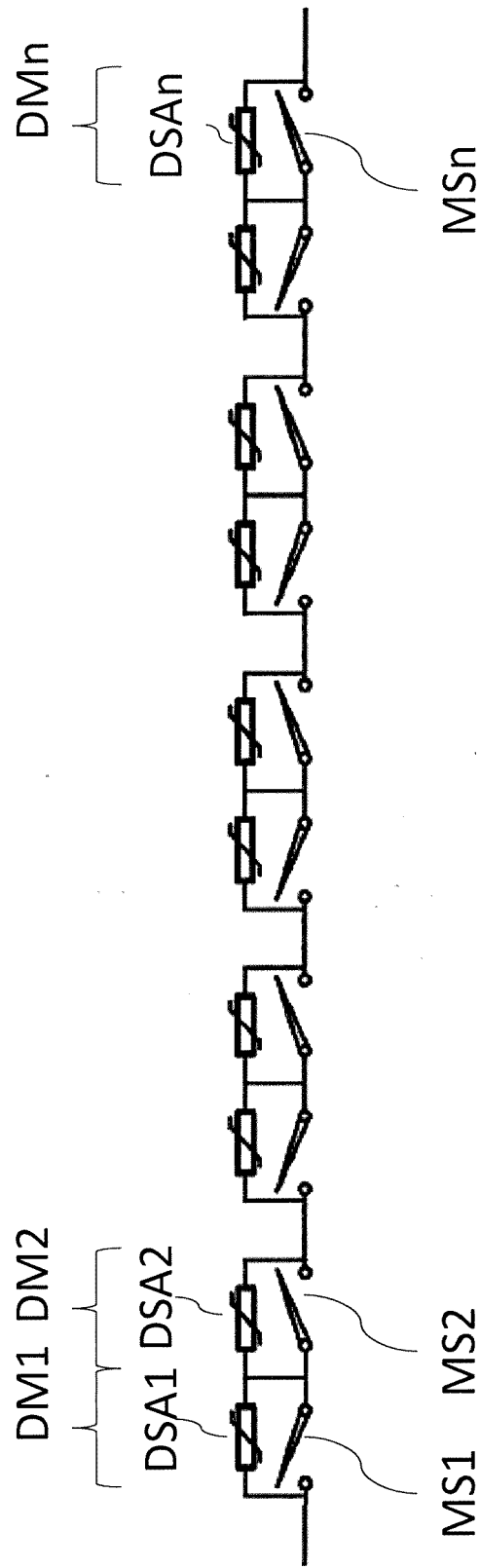


FIG.6

**PARTIAL EUROPEAN SEARCH REPORT**

Application Number

under Rule 62a and/or 63 of the European Patent Convention.
This report shall be considered, for the purposes of
subsequent proceedings, as the European search report

EP 17 29 0034

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	US 2016/300671 A1 (ERGIN DOMINIK [DE] ET AL) 13 October 2016 (2016-10-13) * abstract; figure 1 *	1-6, 11-18	INV. H01H33/666
A,D	US 2015/002977 A1 (DUPRAZ JEAN-PIERRE [FR] ET AL) 1 January 2015 (2015-01-01) * abstract; figure 1 *	1	

TECHNICAL FIELDS
SEARCHED (IPC)

H01H

INCOMPLETE SEARCH

The Search Division considers that the present application, or one or more of its claims, does/do not comply with the EPC so that only a partial search (R.62a, 63) has been carried out.

Claims searched completely :

Claims searched incompletely :

Claims not searched :

Reason for the limitation of the search:

see sheet C

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EPO FORM 1503 03.82 (P04E07)

Place of search	Date of completion of the search	Examiner
Munich	28 November 2017	Simonini, Stefano
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document		

**INCOMPLETE SEARCH
SHEET C**

Application Number

EP 17 29 0034

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Claim(s) completely searchable:
1-6, 11-18

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Claim(s) not searched:
7-10

Reason for the limitation of the search:

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Claims 1, 7 and 10 have been drafted as independent claims and have at least partly overlapping scope.

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Drafting such a plurality of independent claims with overlapping scope makes it impossible to figure out which subject matter could represent the invention for which protection is sought, so that the claims as a whole fail to comply with the clarity and conciseness requirements of Article 84 EPC.

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Note that under Article 84 in combination with Rule 43(2) EPC, an application may contain more than one independent claim in a particular category only if the subject-matter claimed falls within one or more of the exceptional situations set out in paragraph (a), (b) or (c) of Rule 43(2) EPC. This is however not the case in the present application.

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**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 17 29 0034

5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

28-11-2017

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REFERENCES CITED IN THE DESCRIPTION

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