(12) STANDARD PATENT (11) Application No. **AU 2012348683 B2**
(19) AUSTRALIAN PATENT OFFICE

(54) Title
Method for eliminating an electric arc driven by at least one voltage source of an inverter circuit

(51) International Patent Classification(s)
H02M 7/162 (2006.01) ***H02M 7/48*** (2007.01)
H02M 1/32 (2007.01)

(21) Application No: **2012348683** (22) Date of Filing: **2012.11.22**

(87) WIPO No: **WO13/083414**

(30) Priority Data

(31) Number	(32) Date	(33) Country
11191935.3	**2011.12.05**	**EP**

(43) Publication Date: **2013.06.13**
(44) Accepted Journal Date: **2017.02.02**

(71) Applicant(s)
ABB Technology AG

(72) Inventor(s)
Guggisberg, Adrian;Eckerle, John;Wahlstroem, Jonas

(74) Agent / Attorney
FB Rice, Level 23 44 Market Street, Sydney, NSW, 2000

(56) Related Art
WO 2010/127699 A1
US 2010/0066174 A1

(12) NACH DEM VERTRAG ÜBER DIE INTERNATIONALE ZUSAMMENARBEIT AUF DEM GEBIET DES PATENTWESENS (PCT) VERÖFFENTLICHTE INTERNATIONALE ANMELDUNG

(19) Weltorganisation für geistiges Eigentum
Internationales Büro

(43) Internationales Veröffentlichungsdatum
13. Juni 2013 (13.06.2013)

WIPO | PCT

(10) Internationale Veröffentlichungsnummer
WO 2013/083414 A3

(51) Internationale Patentklassifikation:
H02M 7/162 (2006.01) *H02M 1/32* (2007.01)
H02M 7/48 (2007.01)

(21) Internationales Aktenzeichen: PCT/EP2012/073360

(22) Internationales Anmeldedatum:
22. November 2012 (22.11.2012)

(25) Einreichungssprache: Deutsch

(26) Veröffentlichungssprache: Deutsch

(30) Angaben zur Priorität:
11191935.3 5. Dezember 2011 (05.12.2011) EP

(71) Anmelder: **ABB TECHNOLOGY AG** [CH/CH]; Affolternstrasse 44, CH-8050 Zürich (CH).

(72) Erfinder: **GUGGISBERG, Adrian**; Nelkenweg 12, CH-5303 Würenlingen (CH). **ECKERLE, John**; Käferholzstrasse 119, CH-4058 Basel (CH). **WAHLSTROEM, Jonas**; Förbenweg 1, CH-5213 Villnachern (CH).

(74) Anwalt: **BERNER, Thomas**; ABB Patent Attorneys, c/o ABB Schweiz AG, Intellectual Property CH-IP, Brown Boveri Strasse 6, CH-5400 Baden (CH).

(81) Bestimmungsstaaten *(soweit nicht anders angegeben, für jede verfügbare nationale Schutzrechtsart)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Bestimmungsstaaten *(soweit nicht anders angegeben, für jede verfügbare regionale Schutzrechtsart)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), eurasisches (AM, AZ, BY, KG, KZ, RU, TJ, TM), europäisches (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT,

[Fortsetzung auf der nächsten Seite]

(54) Title: METHOD FOR ELIMINATING AN ELECTRIC ARC DRIVEN BY AT LEAST ONE VOLTAGE SOURCE OF AN INVERTER CIRCUIT

(54) Bezeichnung : VERFAHREN ZUR ELIMINATION EINES MITTELS MINDESTENS EINER PHASENSPANNUNGSQUELLE EINER UMRICHTERSCHALTUNG GETRIEBENEN LICHTBOGENS

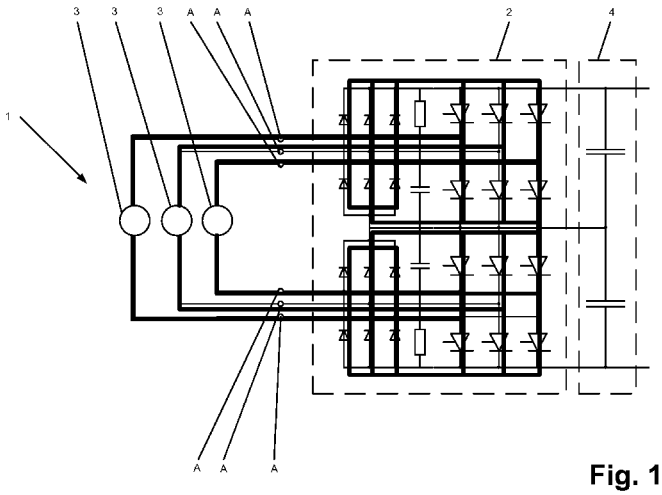

Fig. 1

(57) Abstract: The invention relates to a method for eliminating an electric arc that is driven by at least one phase voltage source (3) of an inverter circuit (1), said inverter circuit having an inverter unit (2) and an energy storage circuit (4). The at least one phase voltage source (3) is connected to the inverter unit (2) on the alternating voltage side, the inverter unit (2) having a plurality of controllable power semiconductor switches. According to said method, an electric arc produced during operation of the inverter circuit (1) is detected and the at least one phase voltage source (3) is short-circuited. In order to detect the electric arc, either a state variable of the inverter circuit (1) is monitored for a definable threshold value or alternatively the surroundings of the inverter circuit is optically monitored for the occurrence of an electric arc. If an electric arc is detected, at least part of the controllable power semiconductor switches of the inverter unit (2) is controlled such that at least one short circuit path across the inverter unit (2) is produced to short-circuit the at least one phase voltage source (3).

(57) Zusammenfassung:

[Fortsetzung auf der nächsten Seite]

WO 2013/083414 A3

LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Veröffentlicht:

— *mit internationalem Recherchenbericht (Artikel 21 Absatz 3)*

— *vor Ablauf der für Änderungen der Ansprüche geltenden Frist; Veröffentlichung wird wiederholt, falls Änderungen eingehen (Regel 48 Absatz 2 Buchstabe h)*

(88) Veröffentlichungsdatum des internationalen Recherchenberichts:

5. Dezember 2013

Es wird ein Verfahren zur Elimination eines mittels mindestens einer Phasenspannungsquelle (3) einer Umrichterschaltung (1) getriebenen Lichtbogens angegeben, bei dem die Umrichterschaltung eine Umrichtereinheit (2) und einen Energiespeicherkreis (4) aufweist, wobei auf der Wechselspannungsseite der Umrichtereinheit (2) die mindestens eine Phasenspannungsquelle (3) angeschlossen ist, und wobei die Umrichtereinheit (2) eine Vielzahl an ansteuerbaren Leistungshalbleiterschaltern aufweist, und bei dem während des Betriebes der Umrichterschaltung (1) ein auftretender Lichtbogen detektiert wird und daraufhin die mindestens eine Phasenspannungsquelle (3) kurzgeschlossen wird. Zur Detektion des Lichtbogens wird entweder eine Zustandsgrösse der Umrichterschaltung (1) auf einen vorgebbaren Schwellwert der Zustandsgrösse hin überwacht oder es wird alternativ die Umgebung der Umrichterschaltung optisch auf das Auftreten eines Lichtbogenlichtes hin überwacht. Wird dann ein Lichtbogen detektiert, wird zumindest ein Teil der ansteuerbaren Leistungshalbleiterschalter der Umrichtereinheit (2) derart angesteuert, dass mindestens ein Kurzschlusspfad über die Umrichtereinheit (2) zum Kurzschluss der mindestens einen Phasenspannungsquelle (3) gebildet wird.

2012348683 08 Dec 2016

Method for eliminating an arc driven by means of at least one phase voltage source of a converter circuit

DESCRIPTION

Technical field

The invention relates to the field of power electronics. It is based on a method for eliminating an arc driven by means of at least one phase voltage source of a converter circuit in accordance with the preamble of the independent claim.

Background

Converter circuits nowadays typically have a converter unit, with at least two phase connections being provided on the AC voltage side of said converter unit, with it then being possible to connect phase voltage sources for providing a corresponding AC voltage to said phase connections. On the DC voltage side of the converter unit, the converter circuit typically comprises an energy storage circuit, which is formed by one or more capacitive energy stores, for example.

During operation of the converter circuit, i.e. if electrical energy is flowing from the AC voltage side of the converter unit to the DC voltage side of the converter unit and the AC voltage is being rectified in the process, or if electrical energy is flowing from the DC voltage side of the converter unit to the AC voltage side of the converter unit and the DC voltage is being inverted in the process, as a result of a fault it may arise that an arc driven, in terms of current, by means of the phase voltage source occurs, for example, on the AC voltage side of the converter unit or else on the DC voltage side of the converter unit. Such an arc is

extremely undesirable since it can damage or even destroy the converter unit, but also the entire converter circuit.

Generally, mechanical switches are used at the phase connections in order to short-circuit the phase voltage source or phase voltage sources. If an arc which occurs is detected in a converter circuit, the mechanical switches are closed in order to short-circuit the phase voltage source or phase voltage sources in order to eliminate the arc driven, in terms of current, by the phase voltage source or the phase voltage sources. However, such mechanical switches have a slow response time, an enormous physical size, require a high degree of maintenance and increase the complexity of the design of the converter circuit.

As disclosed in DE 10 2009 002 684 A1, undesired arcs can also occur in a converter circuit for feeding a plasma load, wherein the arc is generated by MF coils L1, L2 of the converter circuit, as described in DE 10 2009 002 684 A1 in paragraphs [0006] and [0007] in conjunction with Figure 1a. In order to eliminate an arc generated by the MF coils L1, L2 of the converter circuit, the polarity of the voltage at the output connections 13, 14 is reversed, wherein, prior to this, the voltage is set to a value in the region of 0V and the current across the output connections 13, 14 is set to a value in the region of 0A, i.e. the connected plasma load is disconnected from the supply and deenergized, as described in DE 10 2009 002 684 A1, paragraph [0045].

Any discussion of documents, acts, materials, devices, articles or the like which has been included in the present specification is not to be taken as an admission that any or all of these matters form part of the prior art base or were common general knowledge in the field relevant to the present disclosure as it existed before the priority date of each claim of this application.

Summary

Throughout this specification the word "comprise", or variations such as "comprises" or "comprising", will be understood to imply the inclusion of a stated element, integer or step, or group of elements, integers or steps, but not the exclusion of any other element, integer or step, or group of elements, integers or steps.

2012348683 08 Dec 2016

According to a first aspect, there is provided a method for eliminating an arc driven by means of at least one phase voltage source of a converter circuit, in which method the converter circuit has a converter unit and an energy storage circuit, wherein the at least one phase voltage source is connected on the AC voltage side of the converter unit, and wherein the converter unit has a multiplicity of actuable power semiconductor switches, wherein, during operation of the converter circuit, an arc which occurs is detected and, thereupon, the at least one phase voltage source is short-circuited, wherein, in order to detect the arc, a state variable of the converter circuit is monitored for a predeterminable threshold value of the state variable, and wherein, in the event of a discrepancy between the state variable and the predeterminable threshold value, at least some of the actuable power semiconductor switches of the converter unit are actuated such that at least one short-circuiting path is formed via the converter unit in order to short-circuit the at least one phase voltage source.

According to a second aspect, there is provided a method for eliminating an arc driven by means of at least one phase voltage source of a converter circuit, in which method the converter circuit has a converter unit and an energy storage circuit, wherein the at least one phase voltage source is connected on the AC voltage side of the converter unit, and the energy storage circuit is connected on the DC voltage side of the converter unit, and wherein the converter unit has a multiplicity of actuable power semiconductor switches, wherein, during operation of the converter circuit, an arc which occurs is detected and, thereupon, the at least one phase voltage source is short-circuited, wherein, in order to detect the arc, the surrounding environment of the converter circuit is monitored visually for the occurrence of an arc light, and wherein, in the event of the occurrence of the arc light, at least some of the actuable power semiconductor switches of the converter unit are actuated such that at least one short-circuiting path is formed via the converter unit in order to short-circuit the at least one phase voltage source.

Some embodiments of the present disclosure aim to provide a method for eliminating an arc driven by means of at least one phase voltage source of a converter circuit, by means of which method an arc which occurs in a converter circuit can be eliminated particularly easily and quickly.

In some embodiments, the converter circuit has a converter unit, at least one phase voltage source and an energy storage circuit, wherein the at least one phase voltage source is connected on the AC voltage side of the converter unit. In addition, the converter unit

comprises a multiplicity of actuable power semiconductor switches. In accordance with the method, during operation the converter circuit detects an arc which occurs and, thereupon, the at least one phase voltage source is then short-circuited. In accordance with the present disclosure, in order to detect the arc, a state variable of the converter circuit is now monitored for a predeterminable threshold value of the state variable. In the event of a discrepancy between the state variable and the predeterminable threshold value, at least some of the actuable power semiconductor switches of the converter unit are then actuated such that at least one short-circuiting path is formed via the converter unit in order to short-circuit the at least one phase voltage source. By means of the abovementioned detection of an arc occurring and of the formation of at least one short-circuiting path via the converter unit, the arc which occurs can advantageously be quenched particularly easily and quickly and thus eliminated. Additional short-circuiting devices, such as mechanical switches known from the prior art for short-circuiting the at least one phase voltage source, are not required.

As an alternative to the abovementioned detection via a state variable of the converter circuit, in order to detect the arc, the surrounding environment of the converter circuit is monitored visually for the occurrence of an arc light, wherein, in the event of the occurrence of the arc light, at least some of the actuable power semiconductor switches of the converter unit are likewise actuated in such a way that at least one short-circuiting path is formed via the converter unit in order to short-circuit the at least one phase voltage source. By means of this alternative detection of an arc occurring and of the formation of at least one short-circuiting path via the converter unit, as well, the arc occurring can advantageously be quenched particularly easily and quickly and therefore eliminated. Additional short-circuiting devices are not required in this case either.

These and further objects, advantages and features of the present invention will become obvious from the detailed description below relating to preferred embodiments of the invention in conjunction with the drawing.

Brief description of the drawings

Figure 1 shows a first embodiment of a converter circuit with illustrated short-circuiting current paths in accordance with the method according to the invention,

Figure 2 shows a second embodiment of a converter circuit with illustrated short-circuiting current paths in accordance with the method according to the invention,

Figure 3 shows a third embodiment of a converter circuit with illustrated short-circuiting current paths in accordance with the method according to the invention, and

Figure 4 shows a fourth embodiment of a converter circuit with illustrated short-circuiting paths in accordance with the method according to the invention.

The reference symbols used in the drawing and the significance thereof are listed by way of summary in the list of reference symbols. In principle, identical parts have been provided with the same reference symbols in the figures. The described embodiments represent, by way of example, the subject matter of the invention and do not have any restrictive effect.

Description of embodiments

Figure 1 shows a first embodiment of a converter circuit with illustrated short-circuiting current paths in accordance with the method according to the invention. Figure 2 to Figure 4 show a second, third and fourth embodiment, respectively, of a converter circuit, wherein, in each of these converter circuits, possible short-circuiting paths in accordance with the method according to the invention are illustrated. The respectively possible short-circuiting paths of the converter circuits shown in Figure 1 to Figure 4 are illustrated as bold lines. In general, the converter circuit 1 has a converter unit 2, at least one phase voltage source 3 and an energy storage circuit 4, wherein the at least one phase voltage source 3 is connected on the AC voltage side of the converter unit 2. The connection of the phase voltage source 3 is performed at a phase connection A on the AC voltage side of the converter unit 2. Since the converter circuits shown in Figure 1 to Figure 4 all have a three-phase design, in each case three phase voltage sources 3 are also provided, wherein, in general, as already mentioned, at least one phase voltage source 3 is provided. In addition, the converter unit 2 generally has a multiplicity of actuable power semiconductor switches, wherein, according to Figure 1, thyristors are used as actuable power semiconductor switches and, according to Figure 2, integrated gate-commutated thyristors (IGCTs) are used. In contrast, in the case of the converter circuit shown in Figure 3, preferably insulated-

gate bipolar transistors (IGBTs) and thyristors are used as actuable power semiconductor switches, wherein the possible short-circuiting paths then run via the thyristors, as illustrated in Figure 3. Preferably, in the case of the converter circuit shown in Figure 4 as well, IGCTs can be used as actuable power semiconductor switches, via which possible short-circuiting paths then run.

In accordance with the method, if an arc occurs during operation, this arc is detected and, thereupon, the at least one phase voltage source 3 is then short-circuited. Such an arc can occur as a result of a fault, wherein the arc is typically driven, in terms of current, by the at least one phase voltage source 3. In accordance with the invention, in order to detect the arc, a state variable of the converter circuit 1 is now monitored for a predeterminable threshold value of the state variable. In the event of a discrepancy between the state variable and the predeterminable threshold value, at least some of the actuable power semiconductor switches of the converter unit 2 are then actuated such that at least one short-circuiting path is formed via the converter unit 2 in order to short-circuit the at least one phase voltage source 3. By means of the abovementioned detection of an arc occurring and of the formation of at least one short-circuiting path via the converter unit 2, the arc occurring can advantageously be quenched particularly easily and quickly and therefore eliminated. Additional short-circuiting devices can advantageously be dispensed with.

As an alternative to the abovementioned detection via a state variable of the converter circuit 1, in order to detect the arc, the surrounding environment of the converter circuit 1 is monitored visually for the occurrence of an arc light, wherein, in the event of the occurrence of the arc light, at least some of the actuable power semiconductor switches of the converter unit 2 are likewise actuated such that, again, at least one short-circuiting path is formed via the converter unit 2 in order to short-circuit the at least one phase voltage source 3. For the visual monitoring, a photodiode or another light-sensitive electronic component or else a camera can be used, for example. By means of this alternative detection of an arc occurring and of the formation of at least one short-circuiting path via the converter unit 2 as well, the arc occurring can advantageously be quenched particularly easily and quickly and therefore eliminated. In the case of this alternative too, no additional short-circuiting devices are required.

If an energy storage circuit 4 is connected on the DC voltage side of the converter unit, in relation to the converter circuit 1, as illustrated by way of example in Figure 1 to Figure 4, the

2012348683 08 Dec 2016

state variable is preferably the voltage across the energy storage circuit 4 and the predeterminable threshold value of the state variable is a predeterminable threshold value of the voltage across the energy storage circuit 4. The energy storage circuit comprises one or more capacitive energy stores, such as capacitors, for example. In the event that the predeterminable threshold value of the voltage across the energy storage circuit 4 is undershot, at least some of the actuable power semiconductor switches of the converter unit 2 are then actuated such that at least one short-circuiting path is formed via the converter unit 2 in order to short-circuit the at least one phase voltage source 3.

As an alternative to the voltage across the energy storage circuit 4 as the state variable, it is also conceivable for the state variable to be the voltage at a phase connection A on the AC voltage side of the converter unit 2 and for the predeterminable threshold value of the state variable then to be a predeterminable threshold value of the voltage at a phase connection A on the AC voltage side of the converter unit 2. In the event that the predeterminable threshold value of the voltage at a phase connection A on the AC voltage side of the converter unit 2 is undershot, at least some of the actuable power semiconductor switches of the converter unit 2 are actuated such that at least one short-circuiting path is formed via the converter unit 2 in order to short-circuit the at least one phase voltage source 3.

In the case of a converter circuit as shown in Figure 3 and Figure 4, as an alternative to the voltage across the energy storage circuit 4 as state variable or as an alternative to the voltage at a phase connection A on the AC voltage side of the converter unit 2 as state variable, it is also conceivable for the state variable to be the voltage across a converter circuit element 5, as is illustrated in Figure 3 and Figure 4, of the converter unit 2 and for the predeterminable threshold value of the state variable then to be a predeterminable threshold value of the voltage across a converter circuit element 5. In the event of a discrepancy, in particular in the event that the predeterminable threshold value of the voltage across a converter circuit element 5 is undershot, at least some of the actuable power semiconductor switches of the converter unit 2 are actuated such that at least one short-circuiting path is formed via the converter unit 2 in order to short-circuit the at least one phase voltage source 3.

2012348683 08 Dec 2016

List of reference symbols

1	converter circuit
2	converter unit
3	phase voltage source
4	energy storage circuit
5	converter circuit element
A	phase connection

2012348683 08 Dec 2016

CLAIMS

1. A method for eliminating an arc driven by means of at least one phase voltage source of a converter circuit, in which method the converter circuit has a converter unit and an energy storage circuit, wherein the at least one phase voltage source is connected on the AC voltage side of the converter unit, and wherein the converter unit has a multiplicity of actuable power semiconductor switches,
wherein, during operation of the converter circuit, an arc which occurs is detected and, thereupon, the at least one phase voltage source is short-circuited,
wherein, in order to detect the arc, a state variable of the converter circuit is monitored for a predeterminable threshold value of the state variable, and
wherein, in the event of a discrepancy between the state variable and the predeterminable threshold value, at least some of the actuable power semiconductor switches of the converter unit are actuated such that at least one short-circuiting path is formed via the converter unit in order to short-circuit the at least one phase voltage source.

2. The method as claimed in claim 1, wherein the energy storage circuit is connected on the DC voltage side of the converter unit, and the state variable is the voltage across the energy storage circuit, the predeterminable threshold value of the state variable is a predeterminable threshold value of the voltage across the energy storage circuit and, in the event that the predeterminable threshold value of the voltage across the energy storage circuit is undershot, at least some of the actuable power semiconductor switches of the converter unit are actuated such that at least one short-circuiting path is formed via the converter unit in order to short-circuit the at least one phase voltage source.

3. The method as claimed in claim 1, wherein the state variable is the voltage at a phase connection on the AC voltage side of the converter unit, the predeterminable threshold value of the state variable is a predeterminable threshold value of the voltage at a phase connection on the AC voltage side of the converter unit, and, in the event that the predeterminable threshold value of the voltage at a phase connection on the AC voltage side of the converter unit is undershot, at least some of the actuable power semiconductor switches of the converter unit are actuated such that at least one short-circuiting path is formed via the converter unit in order to short-circuit the at least one phase voltage source.

2012348683 08 Dec 2016

4. A method for eliminating an arc driven by means of at least one phase voltage source of a converter circuit, in which method the converter circuit has a converter unit and an energy storage circuit, wherein the at least one phase voltage source is connected on the AC voltage side of the converter unit, and the energy storage circuit is connected on the DC voltage side of the converter unit, and wherein the converter unit has a multiplicity of actuable power semiconductor switches,
wherein, during operation of the converter circuit, an arc which occurs is detected and, thereupon, the at least one phase voltage source is short-circuited,
wherein, in order to detect the arc, the surrounding environment of the converter circuit is monitored visually for the occurrence of an arc light, and
wherein, in the event of the occurrence of the arc light, at least some of the actuable power semiconductor switches of the converter unit are actuated such that at least one short-circuiting path is formed via the converter unit in order to short-circuit the at least one phase voltage source.

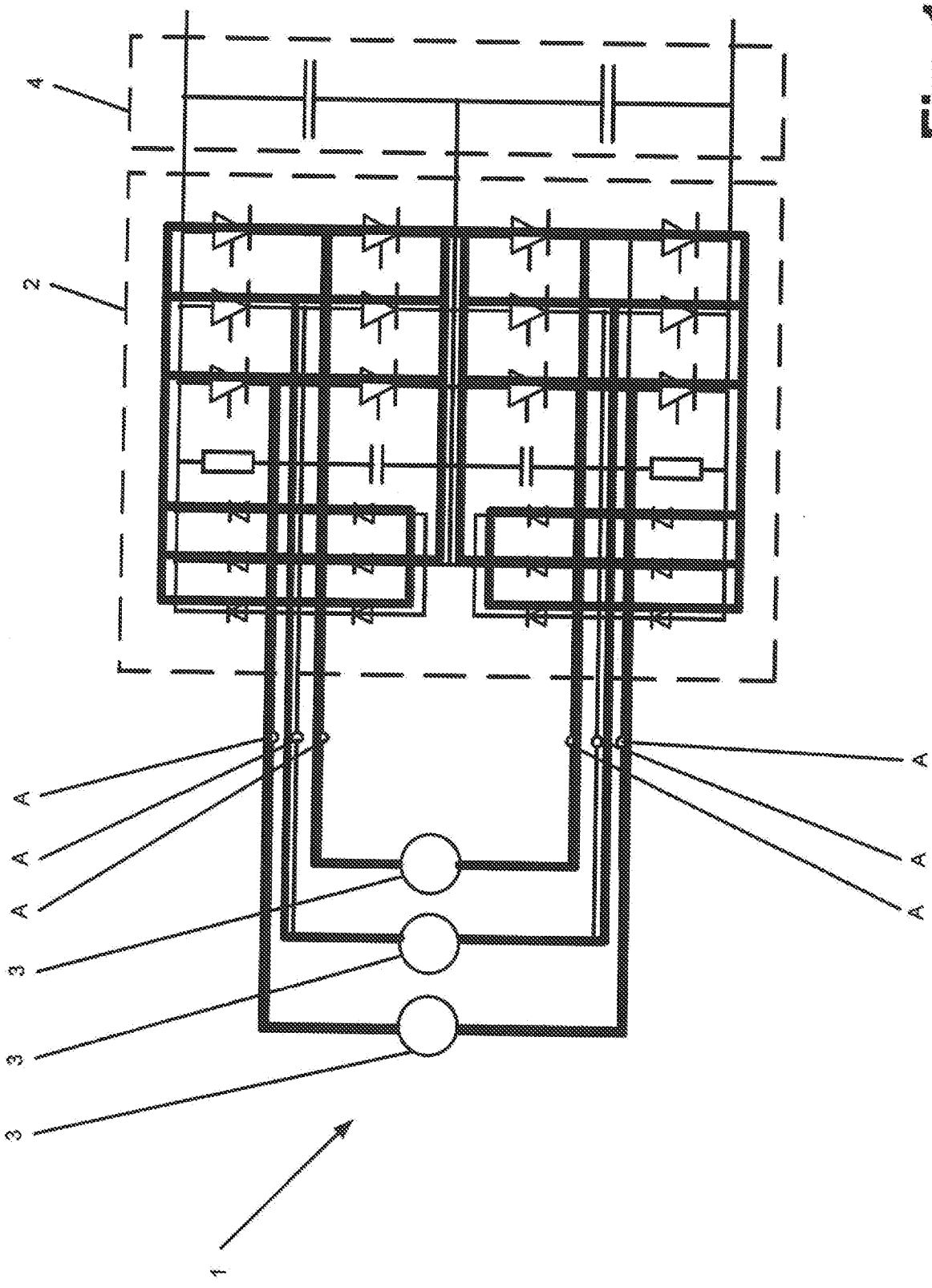

Fig. 1

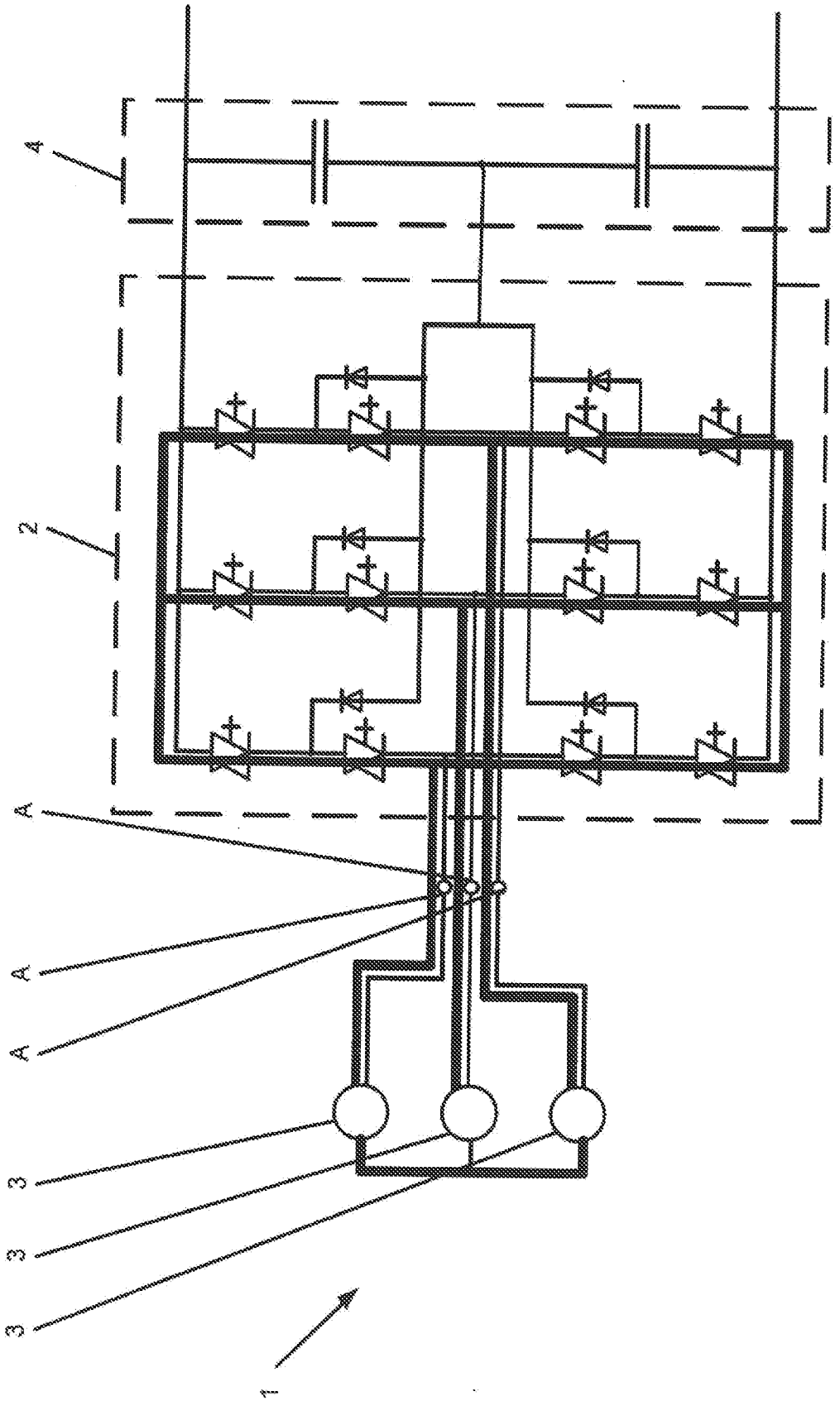

Fig. 2

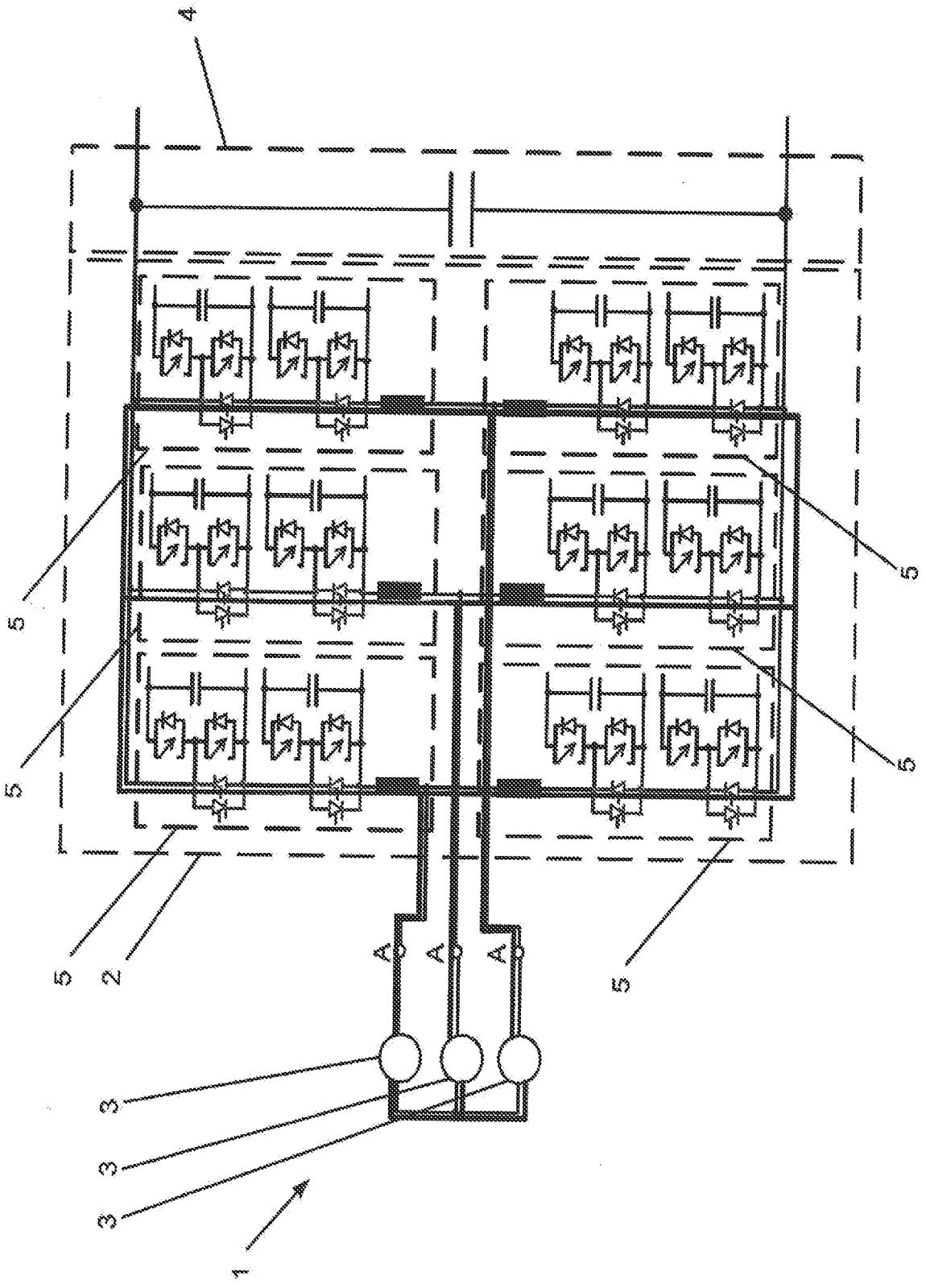

Fig. 3

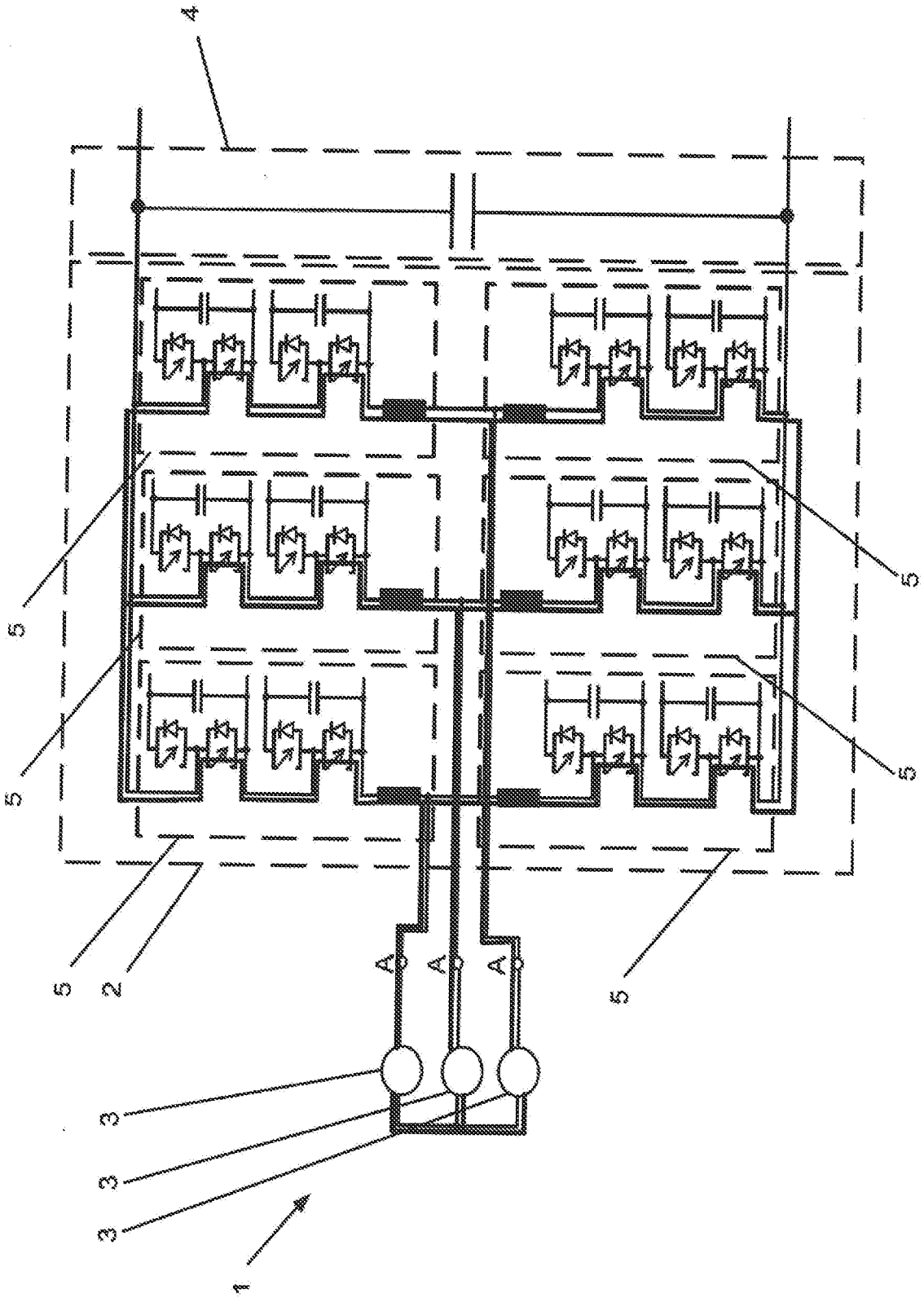

Fig. 4