



(51) International Patent Classification:

H02H 7/26 (2006.01) *B60M* 3/00 (2006.01)
H02M 1/32 (2007.01) *H02H* 3/02 (2006.01)

(21) International Application Number:

PCT/EP2019/082276

(22) International Filing Date:

22 November 2019 (22.11.2019)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

1819433.2 29 November 2018 (29.11.2018) GB

(71) Applicant: **SIEMENS MOBILITY LIMITED** [GB/GB];
Sir William Siemens Square, Frimley, Camberley GU16
8QD (GB).

(72) Inventor: **OLLERENSHAW, Richard**; 52 Osbaldwick
Lane, York YO10 3AX (GB).

(74) Agent: **MAIER, Daniel**; Postfach 22 16 34, 80506
München (DE).

(81) Designated States (*unless otherwise indicated, for every
kind of national protection available*): 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, DJ, DK, DM, DO,

DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN,
HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP,
KR, KW, KZ, LA, LC, LK, LR, LS, 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, SA,
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.

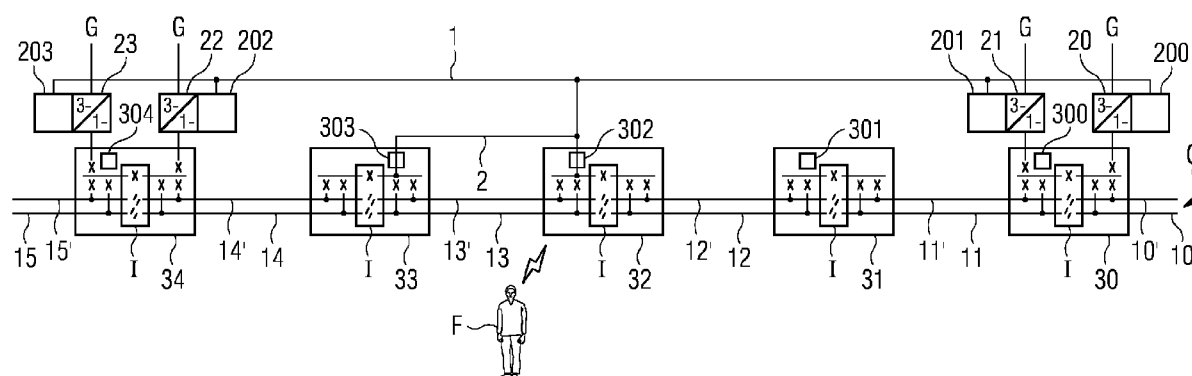
(84) Designated States (*unless otherwise indicated, for every
kind of regional protection available*): ARIPO (BW, GH,
GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ,
UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ,
TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK,
EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, 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,
KM, ML, MR, NE, SN, TD, TG).

Published:

- with international search report (Art. 21(3))
- before the expiration of the time limit for amending the
claims and to be republished in the event of receipt of
amendments (Rule 48.2(h))

(54) Title: PROTECTION SYSTEM FOR A RAILWAY ELECTRIFICATION SYSTEM AND METHOD OF OPERATING

FIG 1



(57) Abstract: Protection system for a railway electrification system, comprising: a substation controllers operable to provide fault detection functionality for the conductor sections at the substations; circuit breakers at the substations, operable to disconnect a conductor section at the substation under the control of a substation controller; a network connection between adjacent substations by which the substation controllers can distribute protection control signals from one to the next, in order to operate a circuit breaker in the adjacent substation in the response to a detected fault, characterised by, a network connection between the substations and the power converters, by which the substation controllers can distribute protection control signals to the power converters; and power converter controllers operable to perform protection functions at the power converters, in response to a protection control signal received from a substation over the network connection between the substation and the power converter.



**PROTECTION SYSTEM FOR A RAILWAY ELECTRIFICATION SYSTEM
AND METHOD OF OPERATING**

Field

5 The present disclosure relates to protection systems for railway electrification systems, and to associated methods.

Background

10 Railway electrification systems use exposed, live conducting elements which allow trains to be powered by collecting current there-from. Where these conducting elements run close to structures, vegetation or uncontrolled public areas, short circuit faults can occur. Short circuits cause intense heating that may lead to equipment damage in the electrification
15 system, as well as potentially causing serious injury. Ultimately, repair or replacement of damaged equipment caused by short circuits causes significant disruption to railway operations, and incidents involving public and railway staff result often lead to major injuries or deaths.
20

Traditional railway protection systems use distance protection devices installed at each substation to detect short circuits, and associated circuit breakers that open to enable
25 the fault to be cleared. Installing and maintaining the necessary hard-wired interconnections in this type of system is expensive, and still even with a well designed and maintained system a typical UK fault clearance duration is relatively slow, ranging from 100-350ms.

30 More recently, protection systems based on communication networks have been introduced, in which protection functions are managed using programmable logic controllers provided in intelligent electronic devices at each substation. This has
35 enabled techniques such as accelerated distance protection to be implemented. Communication between intelligent electronic devices in the protection system takes place under the IEC 61850 standard, and the protection system enables all circuit

breakers which are required to operate to clear the fault to be opened more quickly. Currently known systems have improved fault clearance duration to typically 60-100ms.

5 However, there is still a drive to achieve further reduction in fault clearance duration, as well as a drive to ensure good reliability of protection systems without increasing maintenance requirements.

10 **Summary**

According to the present disclosure there are provided systems and methods as set forth in the appended claims. Other features of the invention will be apparent from the dependent
15 claims, and the description which follows.

Accordingly there may be provided a protection system for a railway electrification system comprising a plurality of substations, a plurality of conductor sections from which power
20 can be delivered to trains, the conductor sections arranged between substations, and a plurality of power converters arranged to receive power from an electricity grid for supply to the substations and delivery to the conductor sections via the substations; wherein the protection system comprises:

25 substation controllers operable to provide fault detection functionality for the conductor sections at the substations;

circuit breakers at the substations, operable to disconnect a conductor section at the substation under the control
30 of a substation controller;

the protection system characterised by:

a network connection between the substations and the power converters, by which the substation controllers can distribute protection control signals to the power converters; and
35

power converter controllers operable to perform protection functions at the power converters, in response to a protection control signal received from a substation over the

network connection between the substation and the power converter.

By providing a network connection between the substations and the power converters, the existence of a faults detected by the substation controllers can be rapidly communicated to the power converter controllers, in order that protection functions for the railway electrification system can be performed at the power converters, for example in cooperation with protection functions performed by substations adjacent to a fault.

In one example, the substation controllers are operable to detect a fault on a conductor section next to the substation, and in response to detecting such a fault: to operate a circuit breaker to disconnect the conductor section at one end thereof; to distribute a protection control signal to the adjacent substation such that the adjacent substation can, in response, operate a circuit breaker at the adjacent substation to disconnect the conductor section at the other end thereof; and to distribute a protection control signal to the power converters. In one example, the protection system comprise a network connection between adjacent substations by which the substation controllers can distribute protection control signals from one to the next, in order to operate a circuit breaker in the adjacent substation in the response to a detected fault.

In this way, inter-trip protection is achieved between substations and protection functions can in tandem be performed by the power converters in response to the protection control signal.

In one example, the power converter controllers are operable to perform protection functions comprising: interrupting supply to the substations; and restoring supply to the substations after previously interrupting supply to the substations.

By suitable programming of the substation controllers and power converter controllers, and choice of power converter components, a rapid response time between fault detection and interruption of power to the substations is possible.

In one example, the circuit breakers at the substations are operable to disconnect and reconnect a conductor section at the substation under the control of the substation controller. In one example, the circuit breakers at the substations are operable to disconnect and reconnect a conductor at the substation under the control of the substation controller in a period while the power converter controllers have interrupted supply to the substations.

In this way, the circuit breakers at the substations may be operated off-load in response to a fault being detected, thereby increasing substation reliability.

In one example, the power converter controllers are integrated with the power converters. In one example, the power converters each comprise a power converter controller. In one example, the substation controllers are integrated with the substations. In one example, the substations each comprise a substation controller. In one example each power converter is arranged to provide power to a group of substations.

Providing controllers in the power converters in this way enables a reduction in costs compared to providing components with rapid response times and more sophisticated control functionality across the many substations on the railway electrification system.

In one example, the network connections between adjacent substations are provided as data network connections, for example as IEC 61850 network connections. In one example, the network connection between the substations and the power converters are provided as data network connections, for example

as IEC 61850 network connections. In one example the network connections between adjacent substations and between substations and power converters use the same network protocols as one another.

5

In one example, the conductor sections are sections of overhead line equipment.

In one example the power converters are AC to AC converters.

10

In one example, the power converters are static frequency converters. In one example, the power converters are three phase to single phase converters.

15

Accordingly there is provided method of operating a protection system for a railway electrification system comprising a plurality of substations; a plurality of conductor sections from which power can be delivered to trains, the conductor sections arranged between substations; and a plurality of power converters arranged to receive power from an electricity grid for supply to the substations and delivery to the conductor sections via the substations, the method comprising:

20

detecting a fault on a conductor section between substations;

25

generating a protection control signal in response to the detected fault;

delivering the protection control signal to the power converters over a network connection and in response controlling the power converters to perform a protection function;

30

and

subsequently disconnecting the conductor section on which the fault was detected at substations either side of the fault.

35

In one example, the method is performed using the protection system and/or in a railway electrification system as herein-described.

In one example, the controlling the power converters to perform a protection function comprises controlling the power converters to interrupt supply to the substations in response to the protection control signal.

5

In one example, the disconnecting the conductor section comprises comprising the steps of: operating a circuit breaker at a substation to disconnect the conductor section at one end thereof; distributing a protection control signal to an adjacent substation such that the adjacent substation operates a circuit breaker at the adjacent substation to disconnect the conductor section at the other end thereof.

10

In one example, the controlling the power converters to perform a protection function comprises step of controlling the power converters to restore supply to the substations, after the step of disconnecting the conductor section on which the fault was detected at substations either side of the fault.

15

In one example, the method comprises the further step of reconnecting the conductor section on which the fault was detected, at substations either side of the fault.

20

Brief Description of the Drawings

25

Examples of the present disclosure will now be described with reference to the accompanying drawings, in which:

Figure 1 shows an example embodiment of the protection system incorporated into a railway electrification system; and

30

Figure 2 shows an example embodiment of a method of operating a protection system for a railway electrification system.

35

Detailed Description

Referring now to Figure 1, there is shown an example embodiment of the protection system, incorporated into a railway electrification system. The railway electrification system is a high voltage AC system in which power from an electricity supply grid G is delivered to trains via overhead line equipment including overhead lines O that are formed in conductor sections 10,10'-15,15'.

Between the electricity supply grid G and the overhead lines O are power converters 20-23. The power converters 20-23 are provided as three phase to single phase static frequency converters with associated power converter controllers 200-203. The output of the power converters 20-23 is delivered to feeder substations 30,34, with further substations along the overhead lines O provided between the conductor sections 10,10'-15,15' of the overhead lines O. As shown schematically, the conductor sections 10,10'-15,15' on each of the overhead lines O are provided with suitable isolation components I between one and the next.

The protection system further comprises substation controllers 300-304. The substation controllers 300-304 operate to provide fault detection functionality for the conductor sections 10,10'-15,15' at either side of the associated substations 30-34. In the example embodiment of Figure 1, each substation 30-34 comprises its own substation controller 300-304. In this way, so that scaling the system is made easier. The substation controllers 300-304 are provided as intelligent electronic devices, which can control circuit breakers, illustrated as X, at the associated substation 30-34 as part of their functionality. By operation of the circuit breakers X at the substations 30-34, under the control of the substation controllers 300-304 it is possible to disconnect adjacent conductor sections at either side of each of the substations 30-34.

The protection system further comprises a first network connection 1, provided between the substations controllers 300-

304 and the power converter controllers 200-203. The first network connection 1 is shown between substation 32 and each of the power converters 20-23, but it is to be understood that the other substations also have a corresponding first network connection 1. The first network connection 1 is a wired connection configured for data transfer according to the IEC 61850 network protocol.

A second network connection 2, also a wired connection configured for data transfer according to the IEC 61850 network protocol, is also provided as part of the protection system. The second network connection 2 is shown only between substations 32 and 33, but is present between each substation and the next in order to enable inter-trip between substations.

Using the first network connection 1 the substation controllers 300-304 distribute protection control signals to the power converters 20-23 over the first network connection 1. In response the power converter controllers 20-23 are arranged to operate to perform protection functions.

The substation controllers each 300-304 operates to detect a fault on a conductor section next to their substation 30-34. For example, a short circuit fault F on the conductor section 13 occurs near to the substation 32. The substation controller 302 recognises the short circuit based on High Speed Overcurrent detection.

In response to detecting the short circuit fault, the substation controller 302 performs a number of functions. To isolate the short circuit by disconnecting the conductor section 13, the substation controller 302 operates a local circuit breaker X in the substation 32 to disconnect one end of the conductor section 13. The end in question is the end which connects to the substation 32. In addition, to isolate the other end of the conductor section the controller 302 sends a protection control signal over the second network connection 2 to the adjacent substation 33. The adjacent substation 33,

in response to receipt of the protection control signal by its substation controller 303, operates a circuit breaker X in the substation 33 to disconnect the conductor section at the other end thereof. Further in addition to controlling
5 the local operation of circuit breaker X in the substation 32 and sending the protection control signal over the second network connection 2, the substation controller 302 also distributes a protection control signal to the power converter controllers 200-203 of each of the power converters 20-23,
10 over the first network connection 1.

The power converters 20-23 receive the protection control signal at the power converter controllers 200-203 over the first network connection 1 and are optimised to react very
15 quickly. The power converters 20-23 comprise large, complex pieces of electrical equipment, typically provided with control systems and current limiting functionality built in, which in response to the protection control signal can be operated to reduce the current supplied to the substations 30-
20 34. That is, all the power converters 20-23 operate together in response to a protection control signal received over the first network connection 1 from any of the substations 30-34, so that supply from the power converters 20-23 is reduced and the substations are effectively disconnected at their input
25 sides.

This enables the local and inter-trip circuit breaker operations to take place on a relatively longer timescale, with the circuit breakers involved opening under no load, or at
30 least reduced load conditions.

The power converter controllers 200-203 are arranged to reconnect supply to the substations 30-34 after a predetermined period of time, the predetermined period being long enough
35 that the circuit breakers in the substations will have opened. The reconnection of supply may be arranged to take place gradually, with a ramping up of current available from the power converters 20-23 over a further predetermined peri-

od after the period during which supply is interrupted enabling the conductor sections aside from that with the fault to return to normal operation.

- 5 For example the power converter controllers may perform rapid reduction of fault current, which is then maintained for a defined period, effectively disconnecting the fault in milliseconds. The conductor section on which the fault is located can then be disconnected by circuit breakers opening off-
- 10 load. Following the predetermined period, which may for example be ~50ms, the power converter controllers are arranged to restore their normal supply voltage over a short duration, for example 100ms.
- 15 Figure 2 shows an example method of operating a protection system for a railway electrification system. The method of Figure 2 is, for example, performed in the railway electrification system of Figure 1.
- 20 At a first step, S101 a fault, for example a short circuit fault, is detected on a conductor section between substations. At step S102 a protection control signal is generated. At step S103 the protection control signal is delivered, over a network connection, to power converters of the railway
- 25 electrification system. At step S104 the power converters perform a protection function in response to the received protection control signal, interrupting supply to the substations. At step S105 the conductor section on which the fault was detected is disconnected at either side of the fault. At
- 30 step S106 the power converters restore supply to the substations.

In the example embodiment, steps S101 and S102 are performed by a substation controller local to the fault. Step S103 involves communication over the first network connection between the substation controller local to the fault and the

35 power converter controllers. Step S104 is performed by the power converter controllers. Step S105 is performed in part

by the substation controller local to the fault, and the adjacent substation controller after communication there between over the second network connection, and by the associated circuit breakers at these substations. Step S106 is
5 performed by the power converter controllers.

As will be appreciated, by communicating fault conditions over the first network connection to the power converters, a rapid response that is effective across the range of possible
10 fault locations can be made, and the associated reduction in operation of circuit breakers on load eases maintenance/increases reliability of the protection system.

Attention is directed to all papers and documents which are
15 filed concurrently with or previous to this specification in connection with this application and which are open to public inspection with this specification, and the contents of all such papers and documents are incorporated herein by reference.

20 All of the features disclosed in this specification (including any accompanying claims, abstract and drawings), and/or all of the steps of any method or process so disclosed, may be combined in any combination, except combinations where at
25 least some of such features and/or steps are mutually exclusive.

Each feature disclosed in this specification (including any accompanying claims, abstract and drawings) may be replaced
30 by alternative features serving the same, equivalent or similar purpose, unless expressly stated otherwise. Thus, unless expressly stated otherwise, each feature disclosed is one example only of a generic series of equivalent or similar features.

35 The invention is not restricted to the details of the foregoing embodiment(s). The invention extends to any novel one, or any novel combination, of the features disclosed in this

specification (including any accompanying claims, abstract and drawings), or to any novel one, or any novel combination, of the steps of any method or process so disclosed.

CLAIMS

1. A protection system for a railway electrification system comprising a plurality of substations, a plurality of conductor sections from which power can be delivered to trains, the conductor sections arranged between substations, and a plurality of power converters arranged to receive power from an electricity grid for supply to the substations and delivery to the conductor sections via the substations; wherein the protection system comprises:

substation controllers operable to provide fault detection functionality for the conductor sections at the substations;

circuit breakers at the substations, operable to disconnect a conductor section at the substation under the control of a substation controller;

the protection system characterised by:

a network connection between the substations and the power converters, by which the substation controllers can distribute protection control signals to the power converters; and

power converter controllers operable to perform protection functions at the power converters, in response to a protection control signal received from a substation over the network connection between the substation and the power converter.

2. The protection system of claim 1, wherein the substation controllers are operable to detect a fault on a conductor section next to the substation, and in response to detecting such a fault:

to operate a circuit breaker to disconnect the conductor section at one end thereof;

to distribute a protection control signal to the adjacent substation such that the adjacent substation can, in response, operate a circuit breaker at the adjacent substation to disconnect the conductor section at the other end thereof; and

to distribute a protection control signal to the power converters.

3. The protection system of claim 1 or 2, comprising a network connection between adjacent substations by which the substation controllers are operable to distribute protection control signals from one to the next, in order to operate a circuit breaker in the adjacent substation in the response to a detected fault.

4. The protection system of any preceding claim, wherein, the power converter controllers are operable to perform protection functions comprising: interrupting supply to the substations; and restoring supply to the substations after previously interrupting supply to the substations.

5. The protection system of any preceding claim, wherein the circuit breakers at the substations are operable to disconnect and reconnect a conductor section at the substation under the control of the substation controller.

6. The protection system of any preceding claim, wherein the circuit breakers at the substations are operable to disconnect and reconnect a conductor at the substation under the control of the substation controller in a period while the power converter controllers have interrupted supply to the substations.

7. The protection system of any preceding claim, wherein the power converter controllers are integrated with the power converters such that the power converters each comprises a power converter controller and the substation controllers are integrated with the substations such that the substations each comprises a substation controller.

8. The protection system of any preceding claim, wherein the network connections are provided as IEC 61850 network connections.

9. A method of operating a protection system for a railway electrification system comprising a plurality of substations; a plurality of conductor sections from which power can be delivered to trains, the conductor sections arranged between substations; and a plurality of power converters arranged to receive power from an electricity grid for supply to the substations and delivery to the conductor sections via the substations, the method comprising:

detecting a fault on a conductor section between substations;

generating a protection control signal in response to the detected fault;

delivering the protection control signal to the power converters over a network connection and in response controlling the power converters to perform a protection function; and

subsequently disconnecting the conductor section on which the fault was detected at substations either side of the fault.

10. The method of claim 9, performed using the protection system and/or in a railway electrification system as set out in any one of claims 1 to 8.

11. The method of claim 9 or 10, wherein the controlling the power converters to perform a protection function comprises controlling the power converters to interrupt supply to the substations in response to the protection control signal.

12. The method of any one of claims 9 or 11, wherein the disconnecting the conductor section comprises comprising the steps of:

operating a circuit breaker at a substation to disconnect the conductor section at one end thereof;

distributing a protection control signal to an adjacent substation such that the adjacent substation operates a cir-

cuit breaker at the adjacent substation to disconnect the conductor section at the other end thereof.

13. The method of any one of claims 9 to 12, wherein the
5 controlling the power converters to perform a protection
function comprises step of controlling the power converters
to restore supply to the substations, after the step of dis-
connecting the conductor section on which the fault was de-
tected at substations either side of the fault.

10

14. The method of any one of claims 9 to 13, comprising the
further step of reconnecting the conductor section on which
the fault was detected, at substations either side of the
fault.

15

FIG 1

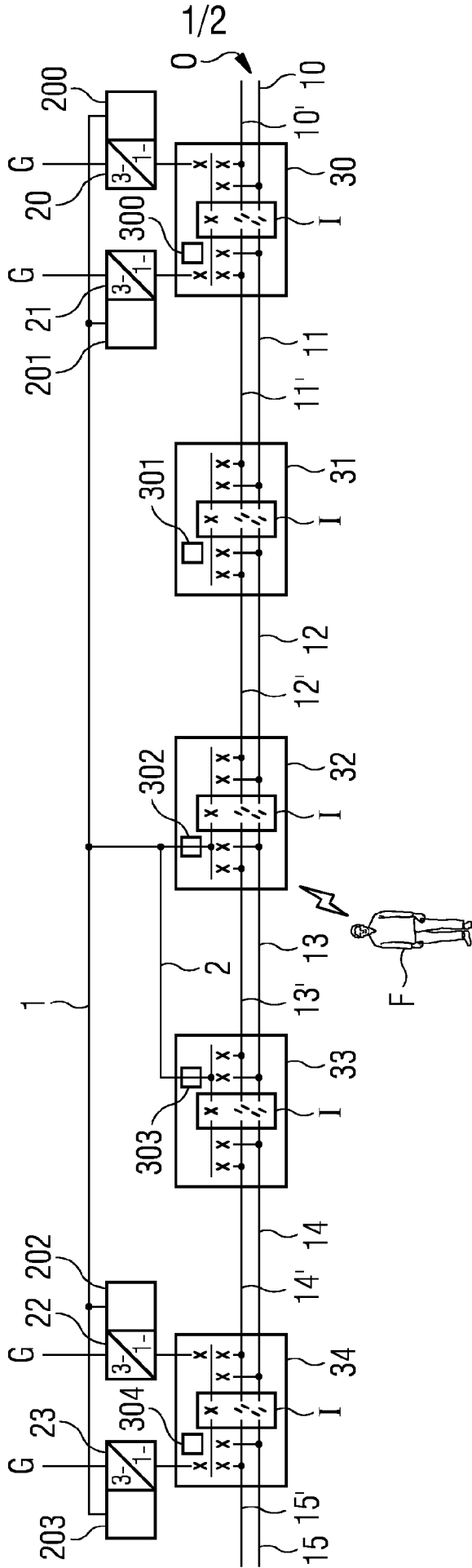
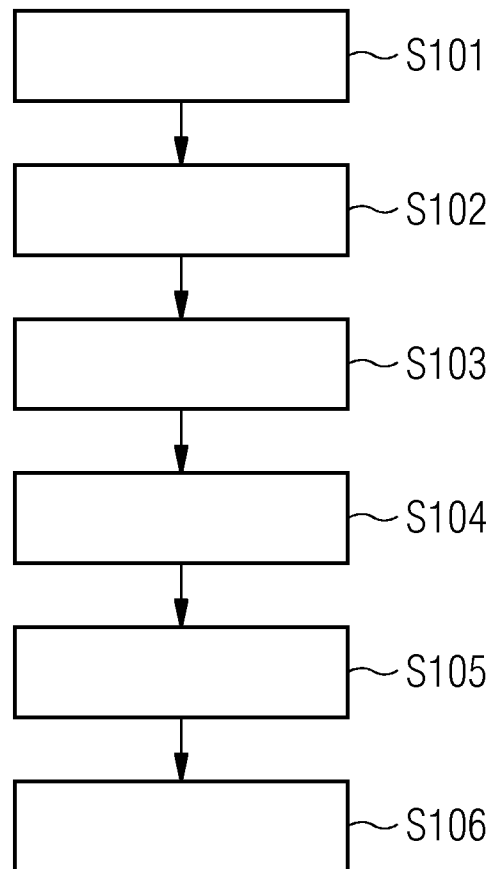


FIG 2



INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2019/082276

A. CLASSIFICATION OF SUBJECT MATTER

INV. H02H7/26 H02M1/32 B60M3/00
ADD. H02H3/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H02H H02M B60M

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE 101 39 318 A1 (SIEMENS AG [DE]) 27 February 2003 (2003-02-27)	1,4-6
Y	paragraphs [0011], [0018], [0023], [0067] figures 1, 2	2,3,7-14
Y	----- CN 108 777 475 A (TIANJIN KEYVIA ELECTRIC CO LTD ET AL.) 9 November 2018 (2018-11-09) paragraphs [0033] - [0034] figure 1	2,3,7-14
A	----- CN 203 186 126 U (UNIV JIAOTONG SOUTHWEST) 11 September 2013 (2013-09-11) figures 3, 4	1,9
	----- -/-	



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

11 March 2020

Date of mailing of the international search report

20/03/2020

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

Authorized officer

Hillmayr, Heinrich

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2019/082276

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	DE 10 2015 202243 A1 (SIEMENS AG [DE]) 11 August 2016 (2016-08-11) paragraph [0022] - paragraph [0042] figure 1 -----	1,9
A	DE 10 2015 203843 A1 (SIEMENS AG [DE]) 8 September 2016 (2016-09-08) paragraphs [0011], [0036] figures 1, 2 -----	1,9

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2019/082276

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE 10139318	A1	27-02-2003	CN 1405572 A 26-03-2003
			DE 10139318 A1 27-02-2003
			JP 3927468 B2 06-06-2007
			JP 2003153431 A 23-05-2003
			US 2004078710 A1 22-04-2004

CN 108777475	A	09-11-2018	NONE

CN 203186126	U	11-09-2013	NONE

DE 102015202243	A1	11-08-2016	BR 112017016397 A2 27-03-2018
			DE 102015202243 A1 11-08-2016
			EP 3231075 A1 18-10-2017
			RU 2669786 C1 16-10-2018
			WO 2016128162 A1 18-08-2016

DE 102015203843	A1	08-09-2016	NONE
