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(71) Applicant (for all designated States except US): **SMA SOLAR TECHNOLOGY AG** [DE/DE]; Sonnenallee 1, 34266 Niestetal (DE).

(72) Inventors; and

(75) Inventors/Applicants (for US only): **STICKELMANN, Uwe** [DE/DE]; Hinter der Schule 17, 34260 Kassel-Kaufungen (DE). **BODE, Christian** [DE/DE]; Tillystraße 13, 37434 Rollshausen (DE). **KÜNZEL, Benedikt** [DE/DE]; Klingelstraße 7, 37308 Geisleden (DE). **WOLF, Henrik** [DE/DE]; Kaufunger Str. 12, 34123 Kassel (DE).

(74) Agents: **SPECHT, Peter** et al.; Am Zwinger 2, 33602 Bielefeld (DE).

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(54) Title: WIRING TESTING DEVICE

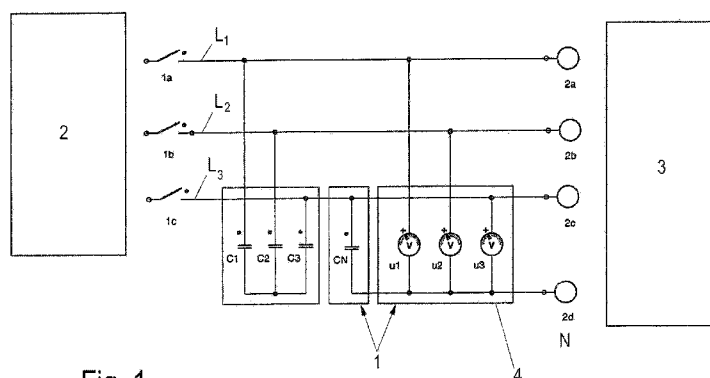


Fig. 1

(57) Abstract: A wiring testing device (1) for testing the wiring of an inverter (2), e.g. a photovoltaic inverter, used to convert direct voltage into a three-phase alternating voltage. The device is characterized by having the inverter (2) designed to be connected to a low-voltage three-phase system (3) with a neutral conductor (N) serving as the reference point for grid-side conductor voltages (u_1 , u_2 , u_3); including a test circuit (4) for measuring the conductor voltages (u_1 , u_2 , u_3); having the average value calculated from the sum of instantaneous values of the conductor voltages (u_1 , u_2 , u_3) and an error message displayed when the total voltage exceeds a threshold voltage over a defined time period; having an additional component connected between a phase (L1, L2 or L3) and the neutral conductor (N) so that a voltage unbalance is generated if the neutral conductor connection is found missing; having the voltage unbalance detected by measuring the conductor voltages (u_1 , u_2 , u_3), which means an error message will also appear if a neutral conductor connection is found missing; offering an easy way to check a grid connection for wiring errors when connecting a three-phase inverter to the power grid.

5

WIRING TESTING DEVICE

The invention relates to a device for testing the wiring, i.e. the wiring connection, of an inverter, such as a photovoltaic inverter, that serves to
10 convert direct voltage into three-phase alternating voltage in a power grid. Said inverter is designed to be connected to a low-voltage three-phase system with a neutral conductor serving as the reference point for grid-side conductor voltages.

15 Only a qualified installer is allowed to connect a three-phase inverter of this type to the power grid. It is necessary that the installer connects the various phases and the neutral conductor to the power grid in a correct and corresponding manner. However, the wiring procedure may result in wiring errors.

20

A method for automatically localizing single-phase ground faults in a medium-voltage grid has already been documented in DE 692 19 055 T2. This method involves measuring zero currents and generating vector sums. It also involves monitoring single currents and vector sums for phase shifts.

25

To detect ground faults in high-voltage grids with a resonance point grounding and an arc suppression coil, DE 10 2004 008 994 B4 proposes the use of a voltage unbalance to detect errors.

30 Documentation is also available (e.g., DD 053 803 B1) on testing devices that are used to connect, in pulses, a capacitor between a ground faulted

phase and a protective conductor and measure the current that flows through it. This allows the devices to identify ground-faulted elements in a three-phase system. Other testing devices such as those documented in DE 10 2006 009 360 B3 are used to determine the direction of a rotary
5 field. These devices also have a capacitor installed between the phase and neutral conductor.

DE 101 39 860 A1 documents a method for identifying a faulty connection in a three-phase device. Connection errors are identified by means of dq
10 transformation.

For testing missing or transposed connections in Schuko sockets, DE 32 48 008 A1 proposes the use of a test circuit for connection faults.

15 An insulation monitoring circuit with a capacitive divider has already been documented in WO 2008 152 466 A2.

The present invention provides an easy way to check a grid connection for wiring errors when connecting a three-phase inverter to the power grid. This
20 is achieved by providing a device comprising the features of claim 1 or claim 2 or claim 14. Various advantageous embodiments of the invention are comprised in the sub-claims. The invention is, however, not limited to those subclaims.

25 The invention provides an easy way to monitor the connection to a low-voltage three-phase system with a neutral conductor.

In particular, the testing device automatically detects errors during PV inverter installation and thus provides the installer with a convenient and
30 easy way to check the grid connection. The testing device can be integrated in the inverter (e.g., inside the inverter housing) or can be an

external circuit (e.g., in the form of an external testing device).

This test is performed with few measuring points and a simple test circuit and may allow to reduce the number of components to obtain a solution that is
5 both suitable for serial production and cost-effective at the same time.

When wiring the three-phase inverter, errors such as the missing connection of one or two phases, the transposition of a phase and a neutral conductor or a missing neutral conductor may occur.

10

Five error cases may arise:

- Case 1: The three-phase system is not connected to the inverter properly.
- 15 Case 2: A phase of the three-phase system is not connected to the inverter.
- Case 3: Two phases of the three-phase system are not connected to the inverter.
- Case 4: The neutral conductor of the three-phase system is not
20 connected to the inverter.
- Case 5: A phase and the neutral conductor of the three-phase system are connected to the inverter in a transposed manner.

The sum of the conductor voltages in a three-phase system equals zero in
25 case that all the conductors are properly connected. If one of the conductor voltages is missing due to improper wiring, then the voltage sum is a nonzero value.

If the variable U_{Sum} for a specific time t_{Error} exceeds a threshold of U_{Error} , an
30 error message will be displayed informing the installer that a grid connection error is present.

This principle can be used to uniquely identify error cases 2, 3, and 5 by use of a single variable for monitoring.

- 5 To identify the missing neutral conductor (error case 4), an additional component is embedded between an inverter phase and the neutral conductor terminal in the inverter in accordance with the invention. When connecting the neutral conductor of the three-phase system to the inverter, a current flows back into the power grid via said phase, the component and the
10 neutral conductor. A neutral conductor that is already connected specifies the neutral point and consequently prevents any voltage unbalance.

- If however the neutral conductor is not connected, the current cannot flow back into the power grid via the additional component and the neutral
15 conductor. In this case the embedded component generates an unbalance that can be detected by measuring the conductor voltages. This unbalance shifts the neutral point to the extent that the voltage applied to the component differs from the voltage that is present when the neutral conductor is properly wired. The difference in these voltages can be used to determine whether
20 the neutral conductor is missing. Given that all phase or conductor voltages are measured to find the total sum, no additional effort is necessary for this voltage measurement.

- The additional component is designed as a passive component. For
25 reasons of cost, potential loss and complexity, it is especially advantageous to provide a capacitor as a passive component.

- This capacitor may be dimensioned in a way that the capacitive current flowing between the phase and the neutral conductor of the three-phase
30 system should be as small as possible but high enough to generate an unbalance in the conductor voltages under rated operation with grid voltage.

In another variant the passive component may be a resistor. In a further variant the additional component, especially the capacitor, may be connected via a switch for the sole purpose of testing. This option would require an additional control unit.

5

To determine whether the inverter is connected to the three-phase system properly (case 1), capacitors are symmetrically connected to all phases, for example in a star-shaped pattern. The additional capacitor is connected in parallel to one of the capacitors.

10

In another variant two serially-connected relay contacts may be arranged between the inverter and power grid for each phase wherein for each phase a voltage measurement is performed in-between the two corresponding relay contacts. This enables a standards-compliant electrical isolation from the power grid, which is also provided when a contact is welded to one of the two relays. In this embodiment, at least one capacitor is arranged between a relay contact and a connection terminal.

15

Preferably; the inverter is configured to connect to the grid only upon absence of the alarm signal.

20

Preferably; the device further comprises a display configured to display a message upon presence of the alarm signal.

The accompanying drawings are included to provide a further understanding of the present invention and are incorporated in and constitute a part of this specification. The drawings illustrate embodiments of the present invention and together, with description serve to explain principles of the invention. In the drawings:

25

Fig. 1 shows a first embodiment of a wiring testing device;

30

Fig. 2 another embodiment of a wiring testing device; and

Fig. 3 a flow chart of a method for testing the wiring connection of an

inverter.

Figure 1 depicts a wiring testing device 1 designed for testing the wiring connection, i.e. wiring correctness of an inverter 2, for example a
 5 photovoltaic inverter.

The inverter 2 is designed to be connected to a low-voltage three-phase system 3 with grid-side conductor voltages, i.e. phase voltages, u_1 , u_2 , u_3 (phases L1, L2 and L3) and a neutral conductor N. Three phase voltages
 10 u_1 , u_2 , u_3 are present (the N conductor serving as the reference point for the phase voltages u_1 , u_2 , u_3) and measured. A test circuit 4 is provided for measuring the conductor voltages u_1 , u_2 , u_3 .

In one variant of the invention an average value is derived from the sum of
 15 instantaneous values of the conductor voltages u_1 , u_2 , u_3 . The sum is determined based on one grid cycle. An error message may appear if the total voltage exceeds a threshold voltage over a defined time period.

This variant uses the measurement of the grid-side conductor or phase
 20 voltages which are already used e.g. for a functional test of grid relays. The modulus of the sum of instantaneous values is calculated. This amount is averaged over one grid cycle.

$$U_{\text{SumHW}}(k) = |u_1(k) + u_2(k) + u_3(k)|$$

25

$$U_{\text{Sum}} = [U_{\text{SumHW}}(k) + U_{\text{SumHW}}(k-1)] / N_{\text{Grid cycle}}$$

If the variable U_{Sum} for a specific time t_{Error} exceeds a threshold of U_{Error} , an error message will be displayed informing the installer that a grid connection
 30 fault is present.

With this method, the following error cases can be identified:

- A phase of the three-phase system is not connected to the inverter.
- Two phases of the three-phase system are not connected to the inverter.
- A phase and the neutral conductor of the three-phase system are
5 connected to the inverter in a transposed manner.

Only one variable is required for monitoring.

As depicted in figure 1, an additional passive component – a capacitor CN
10 – is connected between L3 and the neutral conductor N. Said component generates a voltage unbalance if the neutral conductor connection is missing. This unbalance can be determined by measuring the conductor voltages and an error message will also appear if the neutral conductor connection is found missing. In addition, three capacitors C1, C2, and C3
15 are symmetrically connected to all phases L1, L2, L3 in a star-shaped pattern. The additional capacitor CN is connected directly or by additional components like an additional capacitor between L3 and the neutral conductor N.

20 The connecting point between the capacitors C1, C2 and C3 may additionally be connected to earth (PE, not shown) by an additional capacitor (not shown here).

Relay contacts 1a, 1b, 1c, which are serially connected to connection
25 terminals 2a, 2b, 2c for each of the phases L1-L3, are arranged between the inverter 2 and the power grid 3. Voltage measurements u_1 , u_2 , u_3 (voltage sensors of test circuit 4) are conducted between each of the phases L1, L2, L3 and the neutral conductor N.

30 The capacitors C1, C2, C3 and CN are wired to the relay contacts 1a, 1b, 1c on the grid side.

In another variant operation amplification circuits, which are not depicted in the figure, will be used to measure conductor voltages u_1 , u_2 , u_3 . A signal processor may be used to calculate the sum of conductor voltages $u_1 - u_3$.

5

As shown in fig. 2, another advantageous embodiment of a device for testing the wiring connection of an inverter 2 to a three-phase grid 3 with a neutral line may comprise the following features:

- phase voltage sensors – i.e. voltage measurement devices - for determining voltages u_1 , u_2 , u_3 between corresponding ones of each of the three phases L1, L2, L3 and the neutral line N;
- a detection unit 5 coupled to the phase voltage sensors and configured to issue an alarm signal in case the sum of the voltages of the phase voltage sensors exceeds a voltage threshold; and
- an additional component connected between one of the three phases and the neutral line; the additional component being a capacitor C_N .

This devices provides an uncomplicated and easy way of testing the wiring, i.e. the wiring correctness of the inverter 2 to the three-phase grid (system) 3. Preferably, the device comprises two capacitors connected in series between one of the three phases and ground potential, and wherein the neutral line is connected between the two capacitors. Further, the connection by the additional component is in another preferred embodiment a switchable connection.

Fig. 3 shows a flow chart of a preferred embodiment of a method for testing the wiring connection of an inverter to a three-phase grid with a neutral line, the method comprising: step 100: providing a additional component (C.C.) connected between one of the three phases L1, L2, L3 and the neutral line N; step 200: determining phase voltages u_1 , u_2 , u_3 between a corresponding

one of each of the three phases L1, L2, L3 and the neutral line N; step 300: detecting a defective wiring connection by comparing a sum of the phase voltages to a voltage threshold; and step 400: issuing an alarm signal upon detection of a defective wiring.

5

Preferably, step 300 of comparing a sum of the phase voltages to a voltage threshold comprises a step of averaging a sum of the phase voltages over a period of time. In a preferred embodiment, said period of time is an integer number of grid cycles.

10

Reference List

5	1	Wiring testing device
	2	Inverter
	3	Three-phase system
	4	Test circuit
	5	Detection unit
10		
	L1-L3	Phases
	N	Neutral conductor
	u_1 - u_3	voltages
	C1-C3	Capacitors
15	CN	Additional capacitor
	1a-1c	Relay contacts
	2a-2c	Connection terminals from inverter to low-voltage power grid

Claims

1. Wiring testing device (1) for testing the wiring correctness of an inverter (2), that serves to convert a direct voltage into a three-phase alternating current, said inverter (2) being designed to be connected to a low-voltage three-phase system (3) with a neutral conductor (N) serving as the reference point for grid-side conductor voltages (u_1 , u_2 , u_3); wherein a test circuit (4) is included for measuring the conductor voltages (u_1 , u_2 , u_3); wherein an average value is derived from the sum of the instantaneous values of the conductor voltages (u_1 , u_2 , u_3) and wherein an error message is displayed if the total voltage exceeds a threshold voltage for a defined time period; an additional component is connected between a phase (L1, L2 or L3) and the neutral conductor (N) so that, if a neutral conductor connection is found missing, a voltage unbalance is generated and can be determined by measuring the conductor voltages, which means that an error message will also appears if a neutral conductor connection is found missing, the additional component being a capacitor.
2. The device for testing the wiring connection of an inverter to a three-phase grid with a neutral line, the device comprising:
- phase voltage sensors for determining voltages between corresponding ones of each of the three phases and the neutral line;
 - a detection unit coupled to the phase voltage sensors and configured to issue an alarm signal in case the sum of the voltages of the phase voltage sensors exceeds a voltage threshold; and
 - an additional component connected between one of the three phases and the neutral line; the additional component being a capacitor.

3. The device according to claim 1 or 2, wherein capacitors (C1, C2, C3) are symmetrically connected to all phases.
- 5 4. The device according to claim 3, wherein the capacitors are connected in a star-shaped pattern.
5. The device according to one of the preceding claims, wherein the additional component is connected between one of the phases and the neutral conductor.
- 10 6. The device according to one of the preceding claims, wherein the additional component comprises two capacitors connected in series between one of the three phases and ground potential, and wherein the neutral line is connected between the two capacitors.
- 15 7. The device of one of the preceding claims, wherein the connection by the additional component is a switchable connection.
- 20 8. The device according to one of the preceding claims, wherein relay contacts are serially connected to the connection terminals between the inverter and the power grid for each phase and a voltage measurement is performed between each of the phases and the neutral conductor.
- 25 9. The device according to one of the preceding claims, characterized by having at least one capacitor arranged between a point between the relay contact and the connection terminal and the neutral conductor.
- 30 10. The device according to one of the preceding claims, characterized by the use of operation amplification circuits for measuring the conductor voltages (u_1 , u_2 , u_3).

11. The device according to one of the preceding claims, characterized by the use of a signal processor for calculating the sum of all conductor voltages (u_1 , u_2 , u_3).
- 5 12. The device of one of the preceding claims, wherein the inverter is configured to connect to the grid only upon absence of the alarm signal.
- 10 13. The device of one of the preceding claims, further comprising a display configured to display a message upon presence of the alarm signal.
- 15 14. A method for testing the wiring connection of an inverter to a three-phase grid with a neutral line, the method comprising:
- providing a additional component connected between one of the three phases and the neutral line;
 - determining phase voltages between a corresponding one of each of the three phases and the neutral line;
 - 20 - detecting a defective wiring connection by comparing a sum of the phase voltages to a voltage threshold;
 - and
 - issuing an alarm signal upon detection of a defective wiring.
- 25 15. The method of claim 14, wherein comparing a sum of the phase voltages to a voltage threshold comprises averaging a sum of the phase voltages over a period of time.
- 30 16. The method of claim 15, wherein the period of time is an integer number of grid cycles.

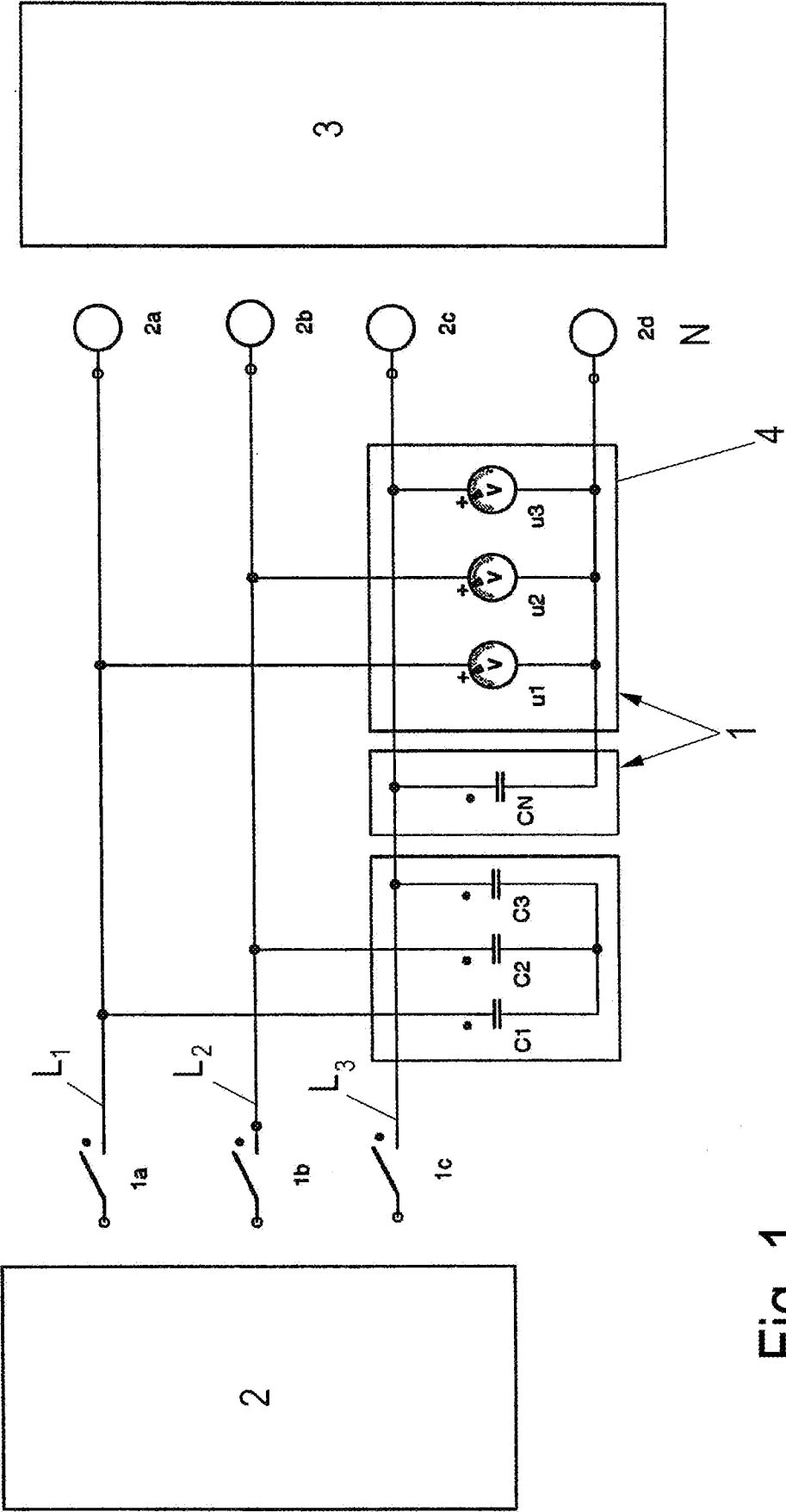


Fig. 1

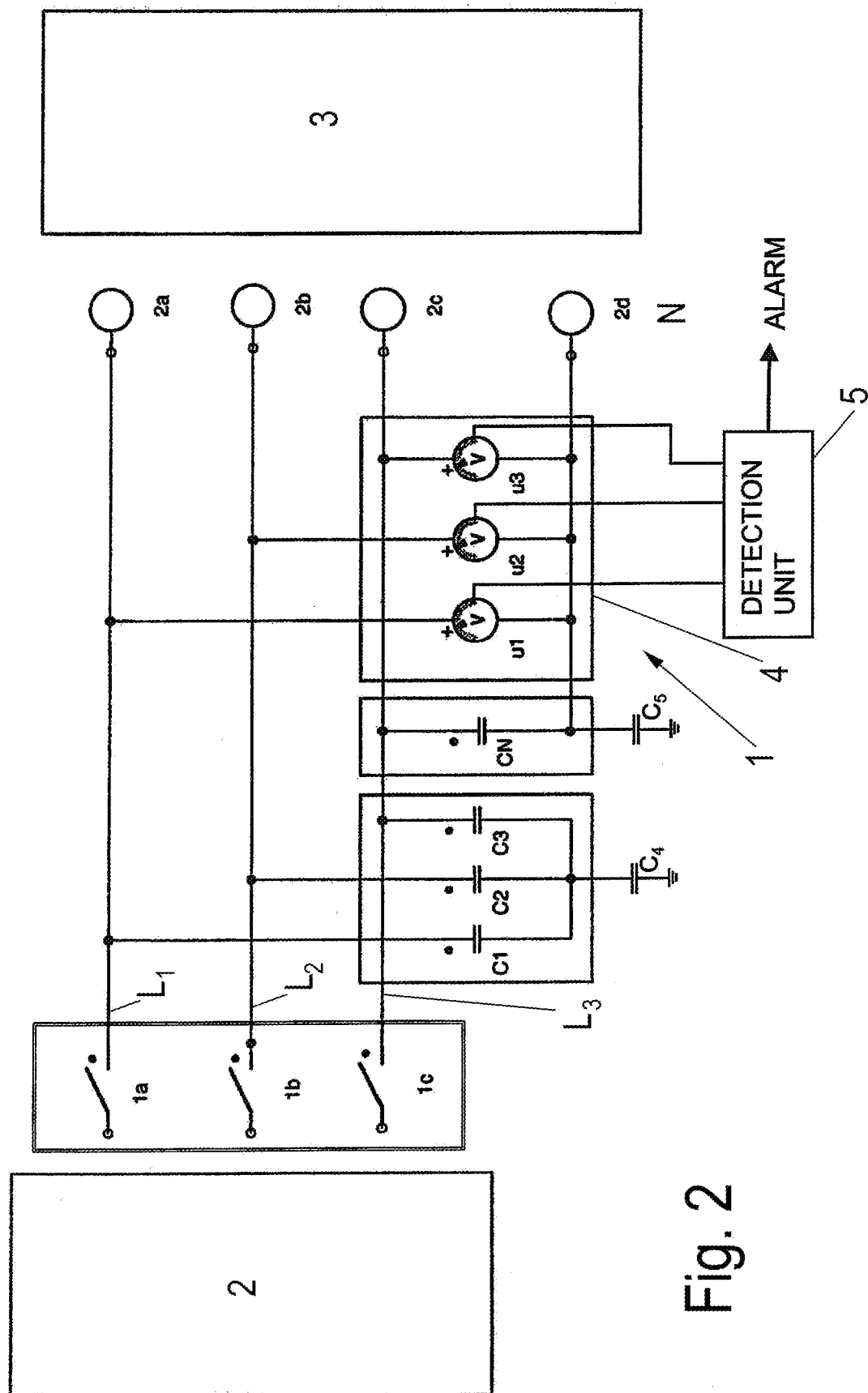


Fig. 2

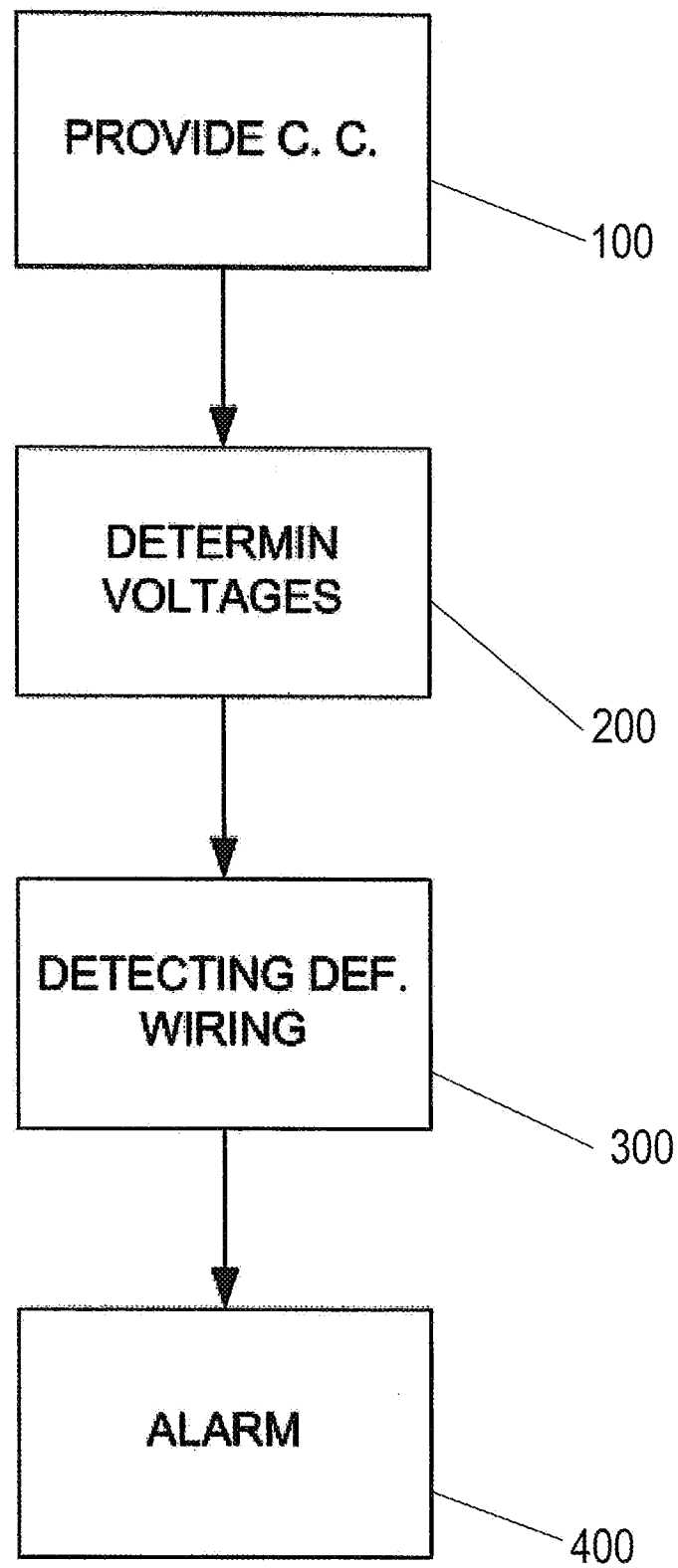


Fig. 3

INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2010/056077

A. CLASSIFICATION OF SUBJECT MATTER

INV. G01R19/165 G01R29/16 G01R31/02 G01R31/42

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)

G01R

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 practical, search terms used)

EPO-Internal, INSPEC, 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 10 2007 046921 A1 (ITF FROESCHL GMBH [DE]) 30 April 2009 (2009-04-30)	14-16
A	abstract; figure 1	1-13
X	WO 2006/126003 A1 (NEWAGE INT LTD [GB]; KOCZARA WLODZIMIERZ [PL]; ERNEST EMIL [GB]; MOSKW) 30 November 2006 (2006-11-30)	14-16
A	abstract; figure 1 paragraph [0013] - paragraph [0022]	1-13



Further documents are listed in the continuation of Box C.



See patent family annex.

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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

Böhm-Pélissier, A

INTERNATIONAL SEARCH REPORT

Information on patent family members

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PCT/EP2010/056077

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE 102007046921 A1	30-04-2009	NONE	
WO 2006126003 A1	30-11-2006	NONE	