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Remarks:
Amended claims in accordance with Rule 137(2) EPC.

(54) System and method for automatic and safe detection of earth faults and interwire short circuits for DC lamp circuits

(57) According to the invention, a driving circuit system (1) for driving at least two DC signal lamps (2a, 2b) comprises:
a first DC power supply (3) having a first voltage (U_1) for driving the signal lamps (2a, 2b),
a second DC power supply (4) having a second voltage (U_2) for driving only one of the signal lamps (2a, 2b), the negative poles of the first and second power supplies (3, 4) being on different potentials,
a central amperemeter (6) provided between the two power supplies (3, 4),
and driving circuits (10a, 10b) for each signal lamp (2a, 2b), each driving circuit (10a, 10b) comprising:
- a first two-way change-over switch (S_1) connected to the positive pole of either the first or second power supply (3, 4),
- a second two-way change-over switch (S_2) connected to the negative pole of either the first or second power supply (3, 4),
- a third two-way change-over switch (S_3) connecting one wire (11) of the signal lamp (2a, 2b) to either the first or the second switch (S_1, S_2),
- a fourth two-way change-over switch (S_4) connecting the other wire (11) of the signal lamp (2a, 2b) to either the first or second switch (S_1, S_2),
- two local amperemeters (13) for measuring the current (I_H, I_R) in both wires (11) of the signal lamp (2a, 2b),
- a local voltmeter (14) for measuring the voltage (U_A) applied to the signal lamp (2a, 2b), and
- a control unit (17) for controlling the four switches (S_1-S_4) and for detecting both earth faults (EF) within a driving circuit (10a, 10b) and interwire short circuits (ISC) between two driving circuits (10a, 10b), based on the measured currents and voltages.

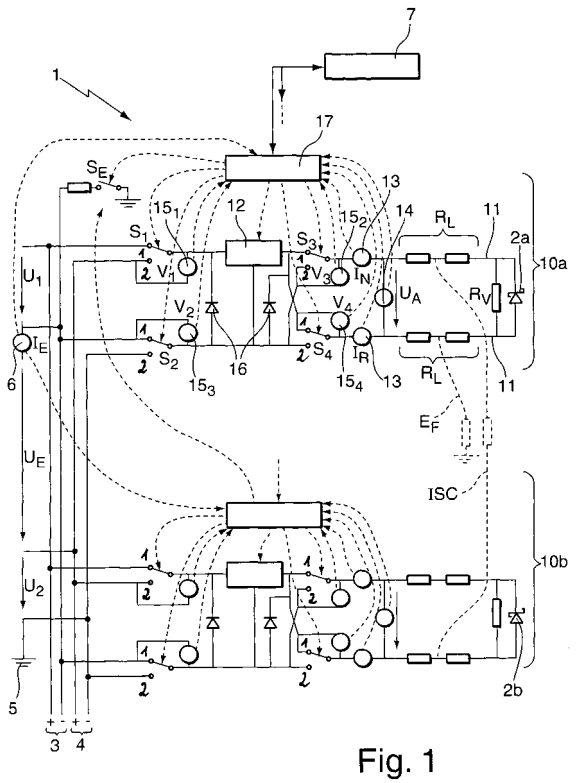

Fig. 1

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Description

Background of the invention

[0001] The invention relates to a driving circuit system for driving at least two DC signal lamps.

[0002] In electronic interlockings signal lamps are normally controlled via a two-wire circuit. For safety reasons these wires have to be supervised whether there is a short circuit to earth or between two wires to avoid the unintended lightening of a signal lamp.

[0003] Within conventional AC based lamp circuits, supervision of interwire short circuits has to be done periodically by supervision staff. Checking by staff is very expensive.

[0004] Although DC based signal lamp circuits have not been commonly used in the past, there is an increasing interest for using LEDs as signal lamps within interlocking.

Object of the invention

[0005] It is the object of the invention to further develop a system and a method for automatic and safe detection of earth faults and interwire short circuits within a driving circuit system for driving at least two DC signal lamps.

Short description of the invention

[0006] This object is achieved, in accordance with the invention, by a driving circuit system for driving at least two DC signal lamps, comprising:

a first DC power supply having a first voltage for driving the signal lamps,
a second DC power supply having a second voltage for driving only one of the signal lamps, the negative poles of the first and second power supplies being on different potentials,
a central amperemeter provided between the two power supplies,
and driving circuits for each signal lamp, each driving circuit comprising:

- a first two-way change-over switch connected to the positive pole of either the first or second power supply,
- a second two-way change-over switch connected to the negative pole of either the first or second power supply,
- a third two-way change-over switch connecting one wire of the signal lamp to either the first or the second switch,
- a fourth two-way change-over switch connecting the other wire of the signal lamp to either the first or second switch,
- two local amperemeters for measuring the current in both wires of the signal lamp,
- a local voltmeter for measuring the voltage applied to the signal lamp, and
- a control unit for controlling the four switches and for detecting both earth faults within a driving circuit and interwire short circuits between two driving circuits, based on the measured currents and voltages.

[0007] In a second aspect the above object is achieved, in accordance with the invention, by a method for detecting earth faults and interwire short circuits in the driving circuit system described above, wherein in a normal operation mode of the driving circuits, in which a signal lamp is turned on by connecting it to the positive and negative poles of the first power supply via the switches, an earth fault of a driving circuit is detected due to a leckage current measured by the central amperemeter, an interwire short circuit between wires of two driving circuits is detected due to a difference of the currents measured by the locals amperemeters of one of the two driving circuits, and an interwire short circuit between wires of one driving circuit is detected due to a comparison between the measured current and the expected current computed by both the measured voltage and the resistance of the wires and of the signal lamp.

[0008] According to the invention, a driving circuit system is provided which supports automatic supervision and detection of earth faults and interwire short circuits within safety-critical systems using DC current for switching electrical devices.

[0009] Further advantages can be extracted from the description and the enclosed drawing. The features mentioned above and below can be used in accordance with the invention either individually or collectively in any combination. The embodiments mentioned are not to be understood as an exhaustive enumeration but rather have exemplary character for the description of the invention.

Drawing

[0010] The invention is shown in the drawing, in which:

Fig. 1 shows schematically a driving circuit system for driving two DC signal lamps.

[0011] As shown in **Fig. 1**, the driving circuit system **1** for driving two DC signal lamps **2a, 2b** comprises:

- a first DC power supply **3** having a first voltage $\mathbf{U_1}$ for driving both signal lamps 2a, 2b, here formed as LEDs,
- a second DC power supply **4** having a second voltage $\mathbf{U_2}$ for driving only one of the signal lamps 2a, 2b, the negative poles of the first and second power supplies 3, 4 being on different potentials, wherein the negative pole of the second power supply 4 is connected to earth **5** and the second voltage U_2 is less than the first voltage U_1,

- a central amperemeter **6** provided between the two power supplies 3, 4, for measuring a leckage current $\mathbf{I_E}$ between the two power supplies 3,4,
- a switch $\mathbf{S_E}$ for connecting the negative pole of the first power supply 3 to the negative pole 4 of the second power supply 4, i.e. to earth 5.
- driving circuits **10a, 10b** for each signal lamp 2a, 2b, and
- a master control 7 controlling the driving circuits 10a, 10b.

[0012] First power supply 3 is powerful enough to supply all signal lamps 2a, 2b simultaneously. Second power supply 4 may to be less powerful because it has to supply one signal lamp only. Power supply $\mathbf{U_E}$ resulting from the different potentials can be very weak because it is used for earth fault detection only. The central amperemeter 6 is placed between the two power supplies 3,4 to check earth faults. Periodical testing of the central amperemeter 6 is done by closing the switch S_E. In other words, the driving circuit system 1 specifies three voltages: U_1 and U_2 for signal lamp supply and U_E for earth fault detection.

[0013] Each driving circuit 10a, 10b comprises:

- a first two-way change-over switch $\mathbf{S_1}$ connected to either the positive pole of the first or second power supply 3, 4,
- a second two-way change-over switch $\mathbf{S_2}$ connected to either the negative pole of the first or second power supply 3, 4,
- a third two-way change-over switch $\mathbf{S_3}$ connecting one supply wire **11** of the signal lamp 2a, 2b to either the first or second switch S_1, S_2,
- a fourth two-way change-over switch $\mathbf{S_4}$ connecting the other supply wire 11 of the signal lamp 2a, 2b to either the first or second switch S_1, S_2,
- a DC-DC converter or voltage regulator **12** connecting the first and third switches S_1,S_3, for generating a variable output voltage for the signal lamp 2a, 2b,
- two local amperemeters **13** for measuring the current $\mathbf{I_H}$, $\mathbf{I_R}$ in both wires 11 of the signal lamp 2a, 2b,
- a local voltmeter **14** for measuring the voltage $\mathbf{U_A}$ applied to the signal lamp 2a, 2b,
- further local voltmeters $\mathbf{15_1}$-$\mathbf{15_4}$ for measuring the voltages $\mathbf{V_1}$-$\mathbf{V_4}$ between the connections of each of the four switches S_1-5_4,
- two diodes **16** connected in parallel to the signal lamp 2a, 2b, and
- a control unit **17** for controlling the four switches S_1-S_4 and for detecting both earth faults EF within a driving circuit 10a, 10b and interwire short circuits **ISC** between two driving circuits 10a, 10b, based on the measured currents and voltages.

[0014] Each signal lamp 2a, 2b is connected with the switches S_3, S_4 by a two- wire cable, wherein the resistance of the signal lamp 2a, 2b is represented by $\mathbf{R_v}$ and the resistance of one wire 11 is represented by $\mathbf{R_L}$. The switches S_1-S_4 can be implemented by relays or any semiconductor switch. The correct working of the switches S_1-S_4 is checked by measuring the voltage $\mathbf{V_1}$-$\mathbf{V_4}$ between the connections of the switches S_1-S_4 and the occurrence of the expected current and is done by the control unit 17. All local amperemeters 13 and voltmeters 15_1-154 are provided with low-pass filters (not shown). In addition to the diodes 16, further protective components (not shown) can be provided to avoid distortion caused by inductive load switching.

[0015] Each control unit 17 of the driving circuit 10a, 10b is controlled by the master control 7 and can be realized for example by a microcontroller. Each control unit 17 supervises the voltages U_A ,V_1-V_4 and currents I_E, I_H, I_R, actuates the switches S_1-S_4 and defines the output voltage of the DC-DC converter 12. The master control 7 commands a control unit 17 to switch on or off the signal lamp 2a, 2b, determines an operation mode of a control unit 17 and organizes the process of measurement of earth faults EF and interwire short circuits ISC. Errors which have been detected by control units 17 are reported to the master control 7 immediately.

[0016] In safety critical systems the master control, the control unit, voltmeters, amperemeters have to be duplicated to accomplish the requirements of such a system (two channels supervising each other). In this case, switching on signal lamps 2a, 2b can only be executed if both channels give the command for switching on (logical multiplication).

[0017] The driving circuits 10a, 10b can be operated in a "normal operation mode" and a "test operation mode".

1. Normal operation mode:

[0018] In the normal operation mode of the driving circuits 10a, 10b, a signal lamp 2a, 2b is turned on by connecting it to the positive and negative poles of the first power supply 3 via the switches S_1-S_4. If a signal lamp 2a, 2b has to be turned on switches S_1 and S_2 are in position 1, SH is in position 1 and S_R in position 2. If a signal lamp has to be turned off switches S_{EH} and S_{ER} are in position 1, switches S_H and SR in position 2.

[0019] If an earth fault EF occurs leckage current I_E is caused and can be detected by every control units 17. If signal lamp 2a, 2b is turned on an interwire short circuit ISC between wires 11 of different driving circuits 10a, 10b may be detected due to a difference of I_H and I_R. There is no guarantee of detection however because the potential difference between the two connection points of interwire short circuit ISC may be too small depending on the position within the wires 11. Therefore a special test is necessary, which is explained hereinbelow.

[0020] Interwire short circuits ISC between the two wires 11 of one driving circuits 10a, 10b can be deduced by measurement of U_A and knowledge of I_H and Rv and R_L. The expected value of I_H can be calculated. $I_H = U_A/(R_v + 2\,R_L)$. A deviation is an evidence for the occurrence

of a short circuit or a wire breaking. R_L of wire 11 may however alter depending on temperature influences R_L can be measured in the test operation mode which is explained hereinafter. RL has to be known for the detection.

2. Test operation mode:

[0021] At any time exactly one of the driving circuits 10a, 10b can be in that operation mode. The master control 7 regulates the permission of a driving circuit 10a, 10b to switch into the test operation mode. If a driving circuit 10a, 10b has finished the test master control 7 is informed accordingly.

[0022] If, for example, driving circuit 10a is in the test operation mode the switches S_1, S_2 move into position 2 and the driving circuit 10a is connected to second power supply 4. If its signal lamp 2a was turned on it still remains turned on except for the short moment of alternating the power supply.

[0023] Now the electrical potential of the driving circuit 10a is below that of driving circuit 10b, i.e. of all other driving circuits. Any possible interwire short circuits ISC between this unit 10a and the others will lead to a leckage current I_E. The potential difference at least amounts to voltage U_E. Additionally the leakage current I_E can be detected by calculating the difference of I_H and I_R if its signal lamp 2a is turned on. If signal lamp 2a is turned off, leakage current I_E leads to values of I_H and I_R unequal to zero.

[0024] Earth fault detection is not guaranteed at all in this operation mode. This operation mode takes a short time though. If signal lamp 2a is turned off a further test step happens: The output of DC-DC converter 12 is reduced and S_4 changes into position 1 so that the signal lamp 2a is provided with reduced inverted voltage. The diode 16 with a low voltage drop (for example: Shottky diode) is connected in parallel to the signal lamp 2a. Taking into account the voltage drop, R_L can be calculated by measurement of U_A and I_H. The knowledge of value of R_L has been known for the detection of an interwire short circuit within one driving circuit 10a (see normal operation mode).

[0025] At the end a further test step is carried out: Switch S_E is closed and I_E must arise, otherwise a fault of switch SE, of amperemeter IE or ground connection must be supposed.

[0026] At the end of the test operation mode of a driving circuit 10a all switches S_1-S_4 and the voltage of DC-DC converter 12 regain the original state as defined in the normal operation mode.

Claims

1. Driving circuit system (1) for driving at least two DC signal lamps (2a, 2b), comprising:

a first DC power supply (3) having a first voltage (U_1) for driving the signal lamps (2a, 2b),
a second DC power supply (4) having a second voltage (U_2) for driving only one of the signal lamps (2a, 2b), the negative poles of the first and second
power supplies (3, 4) being on different potentials,
a central amperemeter (6) provided between the two power supplies (3, 4), and driving circuits (10a, 10b) for each signal lamp (2a, 2b), each driving circuit (10a, 10b) comprising:

- a first two-way change-over switch (S_1) connected to the positive pole of either the first or second power supply (3, 4),
- a second two-way change-over switch (S_2) connected to the negative pole of either the first or second power supply (3, 4),
- a third two-way change-over switch (S_3) connecting one wire (11) of the signal lamp (2a, 2b) to either the first or the second switch (S_1, S_2),
- a fourth two-way change-over switch (S_4) connecting the other wire (11) of the signal lamp (2a, 2b) to either the first or second switch (S_1, S_2),
- two local amperemeters (13) for measuring the current (I_H, I_R) in both wires (11) of the signal lamp (2a, 2b),
- a local voltmeter (14) for measuring the voltage (U_A) applied to the signal lamp (2a, 2b), and
- a control unit (17) for controlling the four switches (S_1-S_4) and for detecting both earth faults (EF) within a driving circuit (10a, 10b) and interwire short circuits (ISC) between two driving circuits (10a, 10b), based on the measured currents and voltages.

2. Driving circuit system according to claim 1, **characterized by** a DC-DC converter (12) connecting the first and third switches (S_1, S_3), for generating a variable output voltage for the signal lamp (2a, 2b).

3. Driving circuit system according to claim 1 or 2, **characterized by** further local voltmeters (15_1-15_4) for measuring the voltages (V_1-V_4) between the connections of each of the four switches (S_1-S_4).

4. Driving circuit system according to any one of the preceding claims, **characterized in that** each driving circuit (10a, 10b) comprises at least one diode (16) connected in parallel to the signal lamp (2a, 2b).

5. Driving circuit system according to any one of the preceding claims, **characterized in that** the negative pole of the second power supply (4) is connected

to earth (5).

6. Driving circuit system according to any one of the preceding claims, **characterized in that** the second voltage (U_2) is less than the first voltage (U_1).

7. Driving circuit system according to any one of the preceding claims, **characterized by** a master control (7) controlling the control units (17) of all driving circuits (10a, 10b).

8. Driving circuit system according to any one of the preceding claims, **characterized in that** a switch (S_E) is provided for connecting the negative pole of the first power supply (3) to the negative pole of the second power supply (4).

9. Method for detecting earth faults (EF) and interwire short circuits (ISC) in a driving circuit system (1) according to any one of the preceding claims, wherein in a normal operation mode of the driving circuits (10a, 10b), in which a signal lamp (2a, 2b) is turned on by connecting it to the positive and negative poles of the first power supply (3) via the switches (S_1-S_4), an earth fault (EF) of a driving circuit (1 a, 1 b) is detected due to a leckage current (I_E) measured by the central amperemeter (6), an interwire short circuit (ISC) between wires (11) of two driving circuits (10a, 10b) is detected due to a difference of the currents (I_H, I_R) measured by the locals amperemeters (13) of one of the two driving circuits (10a, 10b), and an interwire short circuit (ISC) between wires (11) of one driving circuit (10a, 10b) is detected due to a comparison between the measured current (I_H, I_R) and the expected current computed by both the measured voltage (U_A) and the resistance (R_L, R_V) of the wires (11) and of the signal lamp (2a, 2b).

10. Method according to claim 9, **characterized in that** in a test operation mode of one driving circuit (10a, 10b), in which only one signal lamp (2a, 2b) is connected to the second power supply (4) via the switches (S_1-S_4), an interwire short circuit (ISC) between the driving circuit (10a) and another driving circuit (10b) is detected due to a leckage current (I_E) measured by the central amperemeter (6) and, if the signal lamp (2a, 2b) is turned on, due to a difference of the currents (I_H, I_R) measured by the locals amperemeters (13) of the driving circuit (10a, 10b), and, if the signal lamp (2a, 2b) is turned off, due to currents (I_H, I_R) measured by the locals amperemeters (13) being unequal to zero.

11. Method according to claim 10, **characterized in that** in the test operation mode of one driving circuit (10a, 10b), a reduced inverted voltage is applied to the signal lamp (2a, 2b), when turned off, the resistance (R_L) of the wires (11) of the signal lamp (2a, 2b) is calculated by measuring U_A and I_H and taking into account the voltage drop at a diode (16) connected in series to the signal lamp (2a, 2b).

12. Method according to one of the claims 9 to 11, **characterized in that**, in particular at the end of the test operation mode of one driving circuit (10a, 10b), the negative pole of the first power supply (3) and the negative pole of the second power supply (4) are connected which causes the leckage current (I_E) measured by the central amperemeter (6) to arise.

Amended claims in accordance with Rule 137(2) EPC.

1. Driving circuit system (1) for driving at least two DC signal lamps (2a, 2b), comprising:

a first DC power supply (3) having a first voltage (U_1) for driving the signal lamps (2a, 2b), **characterized by**:

- a second DC power supply (4) having a second voltage (U_2) for driving only one of the signal lamps (2a, 2b), the negative poles of the first and second power supplies (3, 4) being on different potentials,
- a central amperemeter (6) provided between the two power supplies (3, 4), and driving circuits (10a, 10b) for each signal lamp (2a, 2b), each driving circuit (10a, 10b) comprising:
- a first two-way change-over switch (S_1) connected to the positive pole of either the first or second power supply (3, 4),
- a second two-way change-over switch (S_2) connected to the negative pole of either the first or second power supply (3, 4),
- a third two-way change-over switch (S_3) connecting one wire (11) of the signal lamp (2a, 2b) to either the first or the second switch (S_1, S_2),
- a fourth two-way change-over switch (S_4) connecting the other wire (11) of the signal lamp (2a, 2b) to either the first or second switch (S_1, S_2),
- two local amperemeters (13) for measuring the current (I_H, I_R) in both wires (11) of the signal lamp (2a, 2b),
- a local voltmeter (14) for measuring the voltage (U_A) applied to the signal lamp (2a, 2b), and
- a control unit (17) for controlling the four switches (S_1-S_4) and for detecting both earth faults (EF) within a driving circuit (10a, 10b) and interwire short circuits (ISC) between two driving circuits (10a, 10b), based

on the measured currents and voltages.

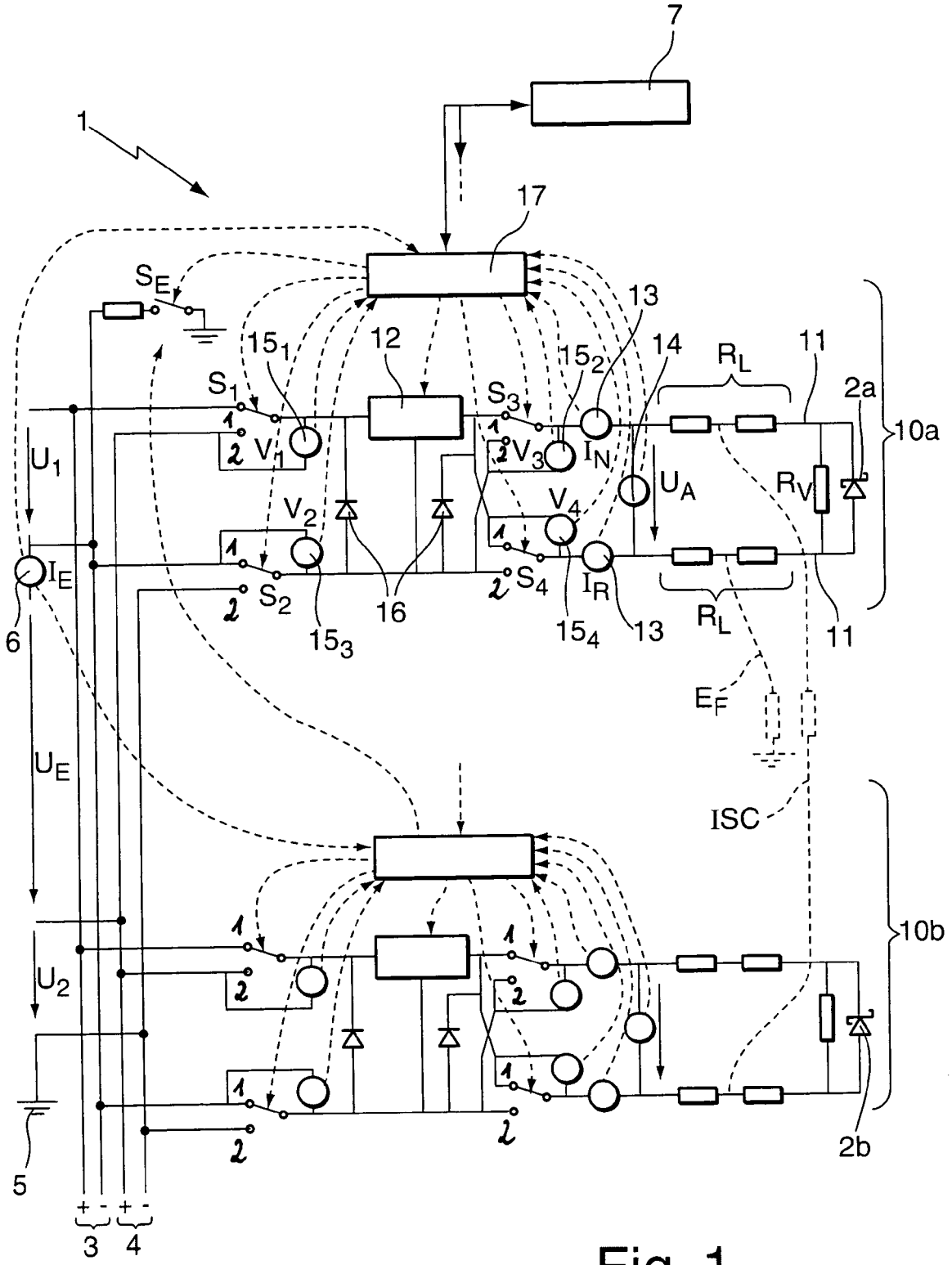
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Fig. 1

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EUROPEAN SEARCH REPORT

Application Number
EP 09 00 2228

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 2008/238344 A1 (ISOBE KOUICHI [JP] ET AL) 2 October 2008 (2008-10-02) * paragraph [0012]; figure 1 * -----	1-12	INV. H05B37/03
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			TECHNICAL FIELDS SEARCHED (IPC) H05B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	6 August 2009	Morrish, Ian

CATEGORY OF CITED DOCUMENTS

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1 EPO FORM 1503 03.82 (P04C01)

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06-08-2009

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