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(54) **A METHOD FOR DETERMINING THE LOCATION OF AN OPEN-CIRCUIT FAULT IN AN ELECTRICAL CIRCUIT AND AN ELECTRICAL CIRCUIT**

VERFAHREN ZUR BESTIMMUNG DES ORTES EINES SCHALTUNGSUNTERBRECHUNGSFEHLERS IN EINER ELEKTRISCHEN SCHALTUNG SOWIE EINE ELEKTRISCHE SCHALTUNG

PROCÉDÉ PERMETTANT DE DÉTERMINER L'EMPLACEMENT D'UN DÉFAUT DE CIRCUIT OUVERT DANS UN CIRCUIT ÉLECTRIQUE ET CIRCUIT ÉLECTRIQUE

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(73) Proprietor: **Ellego Powertec Oy**
24910 Halikko AS (FI)

(72) Inventors:
- **NURMI, Jari**
20400 Turku (FI)
- **VAINIO, Otto**
20300 Turku (FI)

(74) Representative: **Berggren Oy**
P.O. Box 16
Eteläinen Rautatiekatu 10A
00101 Helsinki (FI)

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Description

TECHNICAL FIELD OF THE INVENTION

[0001] The present invention relates to a method for determining the location of an open-circuit fault in an electrical circuit and to an electrical circuit according to the preambles of the appended independent claims.

BACKGROUND OF THE INVENTION

[0002] Aeronautical ground lighting (AGL) systems provide visual cues in runways and taxiways to help aircraft pilots during approach, landing and taxiing. A conventional AGL system comprises a constant-current regulator (CCR) that supplies electric power through series-connected transformers to luminaires, such as halogen lamps or light-emitting diodes (LEDs). The CCR is a variable voltage source, which provides an adjustable current according to luminaire brightness requirements. The series-connected transformers separate the CCR and the luminaires into primary and secondary circuits. The transformers isolate the luminaires from the high operating voltage of the primary circuit and ensure the circuit continuity in case of a luminaire failure.

[0003] An open-circuit fault may occur in an AGL system, for example, due to a break in an electrical cable that is connected between primary windings of two transformers. The locating of such a fault can be difficult and time-consuming because the electrical circuit of the AGL system is typically very long and the electrical cables are mostly buried underground. The known AGL systems do not have any built-in functionalities to determine the location of an open-circuit fault.

[0004] Document WO 01/63976 A1 describes a lamp failure alarm system for airport navigation light systems, which system comprises a device for detecting the number of failed lamps of a lamp series circuit and at least one device for detecting at least one power signal and at least one voltage signal of the lamp series circuit.

OBJECTIVES OF THE INVENTION

[0005] It is the main objective of the present invention to reduce or even eliminate the prior art problems presented above.

[0006] It is an objective of the present invention to provide a method for determining the location of an open-circuit fault in an electrical circuit. In more detail, it is an objective of the invention to provide a method for determining the location of an open-circuit fault in an electrical circuit that comprises a plurality of transformers, whose primary windings are electrically connected in series and secondary windings are electrically connected to light-emitting diodes.

[0007] It is also an objective of the present invention to provide an electrical circuit comprising a plurality of transformers, whose primary windings are electrically connected in series and secondary windings are electrically connected to light-emitting diodes, and having a built-in functionality to determine the location of an open-circuit fault in the electrical circuit.

[0008] In order to realise the above-mentioned objectives, the method and the electrical circuit according to the invention are characterised by what is presented in the characterising portions of the appended independent claims. Advantageous embodiments of the invention are described in the dependent claims.

DESCRIPTION OF THE INVENTION

[0009] A method according to the invention for determining the location of an open-circuit fault in an electrical circuit that comprises a plurality of transformers, each transformer having a primary winding and a secondary winding, the primary windings being electrically connected in series and each secondary winding being electrically connected to a light-emitting diode, comprises using a constant-current regulator to supply electric power to the primary windings, and changing the alternating voltage supplied by the constant-current regulator so that the light-emitting diodes light up, the open-circuit fault being located between the transformers that are electrically connected to the light-emitting diodes having the smallest light intensities.

[0010] The method according to the invention is used to determine the location of an open-circuit fault in an electrical circuit. The method is performed after the open-circuit fault in the electrical circuit has been detected.

[0011] The method according to the invention is applied in an electrical circuit that comprises a plurality of transformers whose primary windings are electrically connected in series and secondary windings are electrically connected to light-emitting diodes (LEDs). The series-connected primary windings of the transformers form a primary circuit to which a constant-current regulator (CCR) is electrically connected for supplying electric power (AC power) to the primary windings. The CCR is a variable voltage source, which can provide an adjustable constant current, typically over a wide voltage range. The current supplied by the CCR can be adjusted, for example, according to brightness requirements of the LEDs. The CCR can be configured to provide, for example, a plurality of discrete brightness levels for the LEDs. Each of the secondary windings of the transformers forms a secondary circuit with one of the LEDs.

[0012] During normal operation of the electrical circuit, the CCR supplies electric power through the transformers to the LEDs, which then emit light. The transformers isolate the LEDs from the high operating voltage of the primary circuit and ensure the circuit continuity in case of a LED failure. When an open-circuit fault occurs in the primary circuit, for example as a result of an electrical cable breakage, the LEDs turn off. The open-circuit fault can be detected, for example, by visually observing the LEDs or by measuring the electrical properties of the electric power supplied by the CCR. In case of the open-circuit fault, the current in the primary circuit decreases significantly and its phase shift compared to the voltage becomes positive.

[0013] The location of an open-circuit fault can be determined by using the CCR, which is electrically connected to the primary windings of the transformers, i.e. to the primary circuit. It has now been found that even in case of an open-circuit fault in the primary circuit, the LEDs can be turned on by supplying with the CCR an alternating voltage having specific characteristics, which typically differ from those used during normal operation of the CCR. The alternating voltage supplied by the CCR can be changed, for example, by adjusting one or more of the following parameters: the waveform, the amplitude (voltage level) and the frequency of the alternating voltage. In the method according to the invention, the alternating voltage supplied by the CCR is changed until the LEDs light up. The light intensities of the LEDs differ from each other in such a manner that the light intensities decrease towards the location of the open-circuit fault. The open-circuit fault is located between the transformers that are electrically connected to the LEDs having the smallest light intensities. The light intensities of the LEDs can be observed, for example, visually. The reason that the LEDs, which are closest to the open-circuit fault, have the smallest light intensities is that the current tends to pass through the capacitance of the broken electrical cable to the ground.

[0014] An advantage of the method according to the invention is that the location of an open-circuit fault in an electrical circuit can be determined in a quick and accurate manner.

[0015] According to an embodiment of the invention the step of changing the alternating voltage supplied by the constant-current regulator comprises changing at least one of the following parameters: the waveform, the amplitude and the frequency of the alternating voltage. Preferably, at least two of these parameters, such as the amplitude and the frequency, are changed during the search of the alternating voltage that can light up the LEDs.

[0016] According to an embodiment of the invention the step of changing the alternating voltage supplied by the constant-current regulator comprises changing the amplitude within a predefined amplitude range and changing the frequency within a predefined frequency range. The predefined amplitude range and the predefined frequency range define the area inside which the amplitude and the frequency of the alternating voltage can be changed when finding the alternating voltage that can light up the LEDs.

[0017] According to an embodiment of the invention the lower limit of the predefined amplitude range is larger than the sum of the threshold voltages of the light-emitting diodes. Preferably, in this case, the predefined frequency range is close to the maximum frequency of the CCR. The upper limit of the predefined amplitude range can be a value between 600 V and 1200 V, such as 800 V, 900 V or 1000 V. The lower limit of the predefined frequency range can be a value between 100 Hz and 450 Hz, such as 200 Hz, 300 Hz or 400 Hz. The upper limit of the predefined frequency range can be a value between 500 Hz and 1000 Hz, such as 600 Hz, 700 Hz or 900 Hz.

[0018] According to an embodiment of the invention the upper limit of the predefined amplitude range is smaller than the sum of the threshold voltages of the light-emitting diodes. Preferably, in this case, the predefined frequency range covers most of the frequency range of the CCR. The lower limit of the predefined amplitude range can be a value between 0 V and 50 V, such as 5 V, 10 V or 20 V. The lower limit of the predefined frequency range can be a value between 50 Hz and 100 Hz, such as 60 Hz, 70 Hz or 80 Hz. The upper limit of the predefined frequency range can be a value between 500 Hz and 1000 Hz, such as 600 Hz, 700 Hz or 900 Hz.

[0019] According to an embodiment of the invention the step of changing the alternating voltage supplied by the constant-current regulator comprises setting the frequency of the alternating voltage to a predefined frequency value and changing the amplitude within a predefined amplitude range.

[0020] According to an embodiment of the invention the predefined frequency value is close to the maximum frequency of the constant-current regulator, and the lower limit of the predefined amplitude range is larger than the sum of the threshold voltages of the light-emitting diodes. Preferably, the amplitude of the alternating voltage is changed by increasing the amplitude from the lower limit of the predefined amplitude range.

[0021] According to an embodiment of the invention the predefined frequency value is a parallel resonance frequency of the electrical circuit, and the upper limit of the predefined amplitude range is smaller than the sum of the threshold voltages of the light-emitting diodes. Preferably, the amplitude of the alternating voltage is changed by decreasing the amplitude from the upper limit of the predefined amplitude range. The parallel resonance occurs in the electrical circuit between the cable capacitance and the magnetization inductance of the transformers.

[0022] According to an embodiment of the invention the step of changing the alternating voltage supplied by the constant-current regulator comprises setting the amplitude of the alternating voltage to a predefined amplitude value and changing the frequency within a predefined frequency range. The frequency of the alternating voltage can be changed by increasing the frequency from the lower limit of the predefined frequency range, or by decreasing the frequency from the upper limit of the predefined frequency range. If the predefined amplitude value is smaller than the sum of the threshold voltages of the LEDs, the alternating voltage can light up the LEDs when its frequency corresponds to the parallel resonance frequency of the electrical circuit.

[0023] According to an embodiment of the invention the step of changing the alternating voltage supplied by the constant-current regulator comprises changing the waveform by adding harmonics to the alternating voltage. Initially, the waveform of the alternating voltage can be a sinusoidal at a specific fundamental frequency. As described above, both the amplitude and the frequency of this sinusoidal waveform can be changed during the search of such an alternating voltage that can light up the LEDs in case of an open-circuit fault. Together or separately with these, the alternating voltage can be changed by adding harmonics to the alternating voltage. The harmonic is a sinusoidal component of a periodic wave having a frequency that is an integral multiple of the fundamental frequency. Preferably, the alternating voltage can be changed by adding odd harmonics of the fundamental frequency to the alternating voltage.

[0024] The present invention also relates to an electrical circuit. The electrical circuit according to the invention comprises a plurality of transformers, each transformer having a primary winding and a secondary winding, the primary windings being electrically connected in series, a plurality of light-emitting diodes, each light-emitting diode being electrically connected to one of the secondary windings, and a constant-current regulator electrically connected to the series-connected primary windings for supplying electric power to the primary windings. In the electrical circuit according to the invention the constant-current regulator is configured, in case of an open-circuit fault in the electrical circuit, to change the alternating voltage so that the light-emitting diodes light up, the open-circuit fault being located between the transformers that are electrically connected to the light-emitting diodes having the smallest light intensities.

[0025] The electrical circuit according to the invention is a lighting circuit that has a built-in functionality to determine the location of an open-circuit fault in it. The electrical circuit can be used in an aeronautical ground lighting (AGL) system, which provides visual cues in runways and taxiways to help aircraft pilots during approach, landing and taxiing.

[0026] In the electrical circuit according to the invention, the series-connected primary windings of the transformers form a primary circuit. The CCR is electrically connected to the primary circuit for supplying electric power (AC power) to the primary windings. Each of the secondary windings of the transformers forms a secondary circuit with one of the LEDs.

[0027] During normal operation of the electrical circuit, the CCR supplies electric power through the transformers to the LEDs, which then emit light. The transformers isolate the LEDs from the high operating voltage of the primary circuit and ensure the circuit continuity in case of a LED failure. When an open-circuit fault occurs in the primary circuit, for example as a result of an electrical cable breakage, the LEDs turn off. The open-circuit fault can be detected, for example, by visually observing the LEDs or by measuring the electrical properties of the electric power supplied by the CCR.

[0028] The location of an open-circuit fault in the primary circuit can be determined by using the CCR. After the open-circuit fault has been detected, the alternating voltage supplied by the CCR is changed so that the LEDs light up. The alternating voltage can be changed, for example, by adjusting one or more of the following parameters: the waveform, the amplitude (voltage level) and the frequency of the alternating voltage. The open-circuit fault is located between the transformers that are electrically connected to the LEDs having the smallest light intensities.

[0029] An advantage of the electrical circuit according to the invention is that the location of an open-circuit fault in the electrical circuit can be determined in a quick and accurate manner.

[0030] According to an embodiment of the invention the constant-current regulator is configured, in case of an open-circuit fault in the electrical circuit, to change at least one of the following parameters: the waveform, the amplitude and the frequency of the alternating voltage. Preferably, the CCR is configured to change at least two of these parameters, such as the amplitude and the frequency, during the search of the alternating voltage that can light up the LEDs.

[0031] The exemplary embodiments presented in this text and their advantages relate by applicable parts to the method as well as the electrical circuit according to the invention, even though this is not always separately mentioned.

BRIEF DESCRIPTION OF THE DRAWINGS

[0032]

Fig. 1 illustrates an electrical circuit according to an embodiment of the invention, and

fig. 2 illustrates exemplary operating areas of the electrical circuit according to fig. 1 during normal operation and during locating of an open-circuit fault.

DETAILED DESCRIPTION OF THE DRAWINGS

[0033] Fig. 1 illustrates an electrical circuit according to an embodiment of the invention. The electrical circuit comprises a plurality of transformers 101, which each have a primary winding 102 and a secondary winding 103. The primary windings 102 are electrically connected in series so that they form a primary circuit. The electrical circuit also comprises a plurality of light-emitting diodes (LEDs) 104, each of which is electrically connected to one of the secondary windings 103. Each of the secondary windings 103 forms a secondary circuit with one of the LEDs 104. The transformers 101 isolate the LEDs 104 from the high operating voltage of the primary circuit and ensure the circuit continuity in case of the LED 104 failure.

[0034] The electrical circuit of fig. 1 comprises a constant-current regulator (CCR) 105 that is electrically connected to the primary circuit. During normal operation of the electrical circuit, the CCR 105 can supply electric power through the transformers 101 to the LEDs 104, which then emit light.

[0035] In the electrical circuit of fig. 1, an open-circuit fault has occurred due to a break in an electrical cable 106 that is electrically connected between two primary windings 102. The location of this open-circuit fault can be determined by using the CCR 105. To determine the location of the open-circuit fault in the primary circuit, the CCR 105 is configured to change the characteristics of the supplied alternating voltage so that the LEDs 104 light up. The alternating voltage supplied by the CCR 105 can be changed by adjusting one or more of the following parameters: the waveform, the amplitude (voltage level) and the frequency of the alternating voltage. The open-circuit fault is located between the transformers 101 that are electrically connected to the LEDs 104 having the smallest light intensities. The light intensities of the LEDs 104 can be observed by a person.

[0036] Fig. 2 illustrates exemplary operating areas of the electrical circuit according to fig. 1 during normal operation and during locating of an open-circuit fault. During normal operation of the electrical circuit, the amplitude and the frequency of the alternating voltage supplied by the CCR are chosen from an area 201. The area 201 defines the possible values for the amplitude and the frequency of the alternating voltage that enable the LEDs to emit light when the electrical circuit is in order.

[0037] In a case of an open-circuit fault in the primary circuit, the locating of the fault can be carried out by finding such amplitude and frequency values from an area 202 or an area 203 for the alternating voltage that enable the LEDs to light up. The open-circuit fault is located between the transformers that are electrically connected to the LEDs having the smallest light intensities. The area 202 is a so-called voltage detection area. The lower limit of the amplitude range is larger than the sum of the threshold voltages of the LEDs in the electrical circuit, and the upper limit of the amplitude range extends into the maximum amplitude of the CCR. The frequency range is close to the maximum frequency of the CCR. The area 203 is a so-called resonance detection area. The lower limit of the amplitude range is close to zero, and the upper limit of the amplitude range is smaller than the sum of the threshold voltages of the LEDs in the electrical circuit. The frequency range covers most of the frequency range of the CCR.

[0038] Only advantageous exemplary embodiments of the invention are described in the figures. It is clear to a person skilled in the art that the invention is not restricted only to the examples presented above, but the invention may vary within the limits of the claims presented hereafter. Some possible embodiments of the invention are described in the dependent claims, and they are not to be considered to restrict the scope of protection of the invention as such.

Claims

1. A method for determining the location of an open-circuit fault in an electrical circuit that comprises a plurality of transformers (101), each transformer (101) having a primary winding (102) and a secondary winding (103), the primary windings (102) being electrically connected in series and each secondary winding (103) being electrically connected to a corresponding light-emitting diode (104), the method comprising:

   - using a constant-current regulator (105) to supply electric power to the primary windings (102),

   characterised in that the method comprises:

   - after the open-circuit fault in the series-connected primary windings (102) has been detected, changing the alternating voltage supplied by the constant-current regulator (105) from the alternating voltage supplied during normal operation so that the light-emitting diodes (104) light up, the open-circuit fault being located between the transformers (101) that are electrically connected to the light-emitting diodes (104) having the smallest light intensities.

2. The method according to claim 1, **characterised in that** the step of changing the alternating voltage supplied by the constant-current regulator (105) comprises changing at least one of the following parameters: the waveform, the amplitude and the frequency of the alternating voltage.

3. The method according to claim 1 or 2, **characterised in that** the step of changing the alternating voltage supplied by the constant-current regulator (105) comprises changing the amplitude within a predefined amplitude range and changing the frequency within a predefined frequency range.

4. The method according to claim 3, **characterised in that** the lower limit of the predefined amplitude range is larger than the sum of the threshold voltages of the light-emitting diodes (104).

5. The method according to claim 3, **characterised in that** the upper limit of the predefined amplitude range is smaller than the sum of the threshold voltages of the light-emitting diodes (104).

6. The method according to claim 1 or 2, **characterised in that** the step of changing the alternating voltage supplied by the constant-current regulator (105) comprises setting the frequency of the alternating voltage to a predefined frequency value and changing the amplitude within a predefined amplitude

range.

7. The method according to claim 6, **characterised in that** the predefined frequency value is close to the maximum frequency of the constant-current regulator (105) and the lower limit of the predefined amplitude range is larger than the sum of the threshold voltages of the light-emitting diodes (104).

8. The method according to claim 6, **characterised in that** the predefined frequency value is a parallel resonance frequency of the electrical circuit and the upper limit of the predefined amplitude range is smaller than the sum of the threshold voltages of the light-emitting diodes (104).

9. The method according to claim 1 or 2, **characterised in that** the step of changing the alternating voltage supplied by the constant-current regulator (105) comprises setting the amplitude of the alternating voltage to a predefined amplitude value and changing the frequency within a predefined frequency range.

10. The method according to any of the preceding claims, **characterised in that** the step of changing the alternating voltage supplied by the constant-current regulator (105) comprises changing the waveform by adding harmonics to the alternating voltage.

11. An electrical circuit, comprising:

    - a plurality of transformers (101), each transformer (101) having a primary winding (102) and a secondary winding (103), the primary windings (102) being electrically connected in series,
    - a plurality of light-emitting diodes (104), each light-emitting diode (104) being electrically connected to one of the secondary windings (103), and
    - a constant-current regulator (105) electrically connected to the series-connected primary windings (102) for supplying electric power to the primary windings (102),

    characterised in that the constant-current regulator (105) is configured, in case of an open-circuit fault in the series-connected primary windings (102), to change the alternating voltage supplied by the constant-current regulator (105) from the alternating voltage supplied during normal operation so that the light-emitting diodes (104) light up, the open-circuit fault being located between the transformers (101) that are electrically connected to the light-emitting diodes (104) having the smallest light intensities.

12. The electrical circuit according to claim 11, **characterised in that** the constant-current regulator (105) is configured, in case of an open-circuit fault in the series-connected primary windings (102), to change at least one of the following parameters: the waveform, the amplitude and the frequency of the alternating voltage.

Patentansprüche

1. Verfahren zum Bestimmen des Ortes eines Leerlauffehlers in einer elektrischen Schaltung, die eine Vielzahl von Transformatoren (101) umfasst, wobei jeder Transformator (101) eine Primärwicklung (102) und eine Sekundärwicklung (103) aufweist, wobei die Primärwicklungen (102) elektrisch in Reihe geschaltet sind und jede Sekundärwicklung (103) elektrisch mit einer entsprechenden Leuchtdiode (104) verbunden ist, wobei das Verfahren Folgendes umfasst:

    - Verwendung eines Konstantstromreglers (105) zur Versorgung der Primärwicklungen (102) mit elektrischer Energie,

    dadurch gekennzeichnet, dass das Verfahren Folgendes umfasst:

    - nach dem Erkennen des Leerlauffehlers in den in Reihe geschalteten Primärwicklungen (102) die von dem Konstantstromregler (105) gelieferte Wechselspannung gegenüber der im Normalbetrieb gelieferten Wechselspannung zu ändern, so dass die Leuchtdioden (104) aufleuchten, wobei der Leerlauffehler zwischen den Transformatoren (101) liegt, die mit den Leuchtdioden (104) mit den geringsten Lichtstärken elektrisch verbunden sind.

2. Verfahren nach Anspruch 1, **dadurch gekennzeichnet, dass** der Schritt des Änderns der von dem Konstantstromregler (105) gelieferten Wechselspannung das Ändern mindestens eines der folgenden Parameter umfasst: die Wellenform, die Amplitude und die Frequenz der Wechselspannung.

3. Verfahren nach Anspruch 1 oder 2, **dadurch gekennzeichnet, dass** der Schritt des Änderns der von dem Konstantstromregler (105) gelieferten Wechselspannung das Ändern der Amplitude innerhalb eines vordefinierten Amplitudenbereichs und das Ändern der Frequenz innerhalb eines vordefinierten Frequenzbereichs umfasst.

4. Verfahren nach Anspruch 3, **dadurch gekennzeichnet, dass** die untere Grenze des vordefinierten Amplitudenbereichs größer ist als die Summe der Schwellenspannungen der Leuchtdioden (104).

5. Verfahren nach Anspruch 3, **dadurch gekennzeichnet, dass** die obere Grenze des vordefinierten Amplitudenbereichs kleiner ist als die Summe der Schwellenspannungen der Leuchtdioden (104).

6. Verfahren nach Anspruch 1 oder 2, **dadurch gekennzeichnet, dass** der Schritt des Änderns der von dem Konstantstromregler (105) gelieferten Wechselspannung das Einstellen der Frequenz der Wechselspannung auf einen vordefinierten Frequenzwert und das Ändern der Amplitude innerhalb eines vordefinierten Amplitudenbereichs umfasst.

7. Verfahren nach Anspruch 6, **dadurch gekennzeichnet, dass** der vordefinierte Frequenzwert nahe der maximalen Frequenz des Konstantstromreglers (105) liegt und die untere Grenze des vordefinierten Amplitudenbereichs größer ist als die Summe der Schwellenspannungen der Leuchtdioden (104).

8. Verfahren nach Anspruch 6, **dadurch gekennzeichnet, dass** der vorgegebene Frequenzwert eine Parallelresonanzfrequenz des Stromkreises ist und die obere Grenze des vorgegebenen Amplitudenbereichs kleiner als die Summe der Schwellenspannungen der Leuchtdioden (104) ist.

9. Verfahren nach Anspruch 1 oder 2, **dadurch gekennzeichnet, dass** der Schritt des Änderns der von dem Konstantstromregler (105) gelieferten Wechselspannung das Einstellen der Amplitude der Wechselspannung auf einen vordefinierten Amplitudenwert und das Ändern der Frequenz innerhalb eines vordefinierten Frequenzbereichs umfasst.

10. Verfahren nach einem der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** der Schritt des Änderns der von dem Konstantstromregler (105) gelieferten Wechselspannung das Ändern der Wellenform durch Hinzufügen von Oberwellen zu der Wechselspannung umfasst.

11. Eine elektrische Schaltung, die Folgendes umfasst:

- eine Vielzahl von Transformatoren (101), wobei jeder Transformator (101) eine Primärwicklung (102) und eine Sekundärwicklung (103) aufweist, wobei die Primärwicklungen (102) elektrisch in Reihe geschaltet sind,
- eine Vielzahl von Leuchtdioden (104), wobei jede Leuchtdiode (104) elektrisch mit einer der Sekundärwicklungen (103) verbunden ist, und
- einen Konstantstromregler (105), der elektrisch mit den in Reihe geschalteten Primärwicklungen (102) verbunden ist, um den Primärwicklungen (102) elektrische Energie zuzuführen,

dadurch gekennzeichnet, dass der Konstantstromregler (105) so konfiguriert ist, dass er im Falle eines Unterbrechungsfehlers in den in Reihe geschalteten Primärwicklungen (102) die von dem Konstantstromregler (105) gelieferte Wechselspannung gegenüber der im Normalbetrieb gelieferten Wechselspannung ändert, so dass die Leuchtdioden (104) aufleuchten, wobei der Unterbrechungsfehler zwischen den Transformatoren (101) liegt, die elektrisch mit den Leuchtdioden (104) mit den geringsten Lichtstärken verbunden sind.

12. Elektrische Schaltung nach Anspruch 11, **dadurch gekennzeichnet, dass** der Konstantstromregler (105) so konfiguriert ist, dass er im Falle eines Leerlauffehlers in den in Reihe geschalteten Primärwicklungen (102) mindestens einen der folgenden Parameter ändert: die Wellenform, die Amplitude und die Frequenz der Wechselspannung.

Revendications

1. Procédé pour déterminer l'emplacement d'un défaut de circuit ouvert dans un circuit électrique qui comprend une pluralité de transformateurs (101), chaque transformateur (101) ayant un enroulement primaire (102) et un enroulement secondaire (103), les enroulements primaires (102) étant connectés électriquement en série et chaque enroulement secondaire (103) étant connecté électriquement à une diode électroluminescente (104) correspondante, le procédé comprenant :

- l'utilisation d'un régulateur de courant constant (105) pour fournir de l'énergie électrique aux enroulements primaires (102),

caractérisé en ce que le procédé comprend :

- après détection du défaut de circuit ouvert dans les enroulements primaires connectés en série (102), la modification de la tension alternative fournie par le régulateur de courant constant (105) à partir de la tension alternative fournie en fonctionnement normal de sorte que les diodes électroluminescentes (104) s'allument, le défaut de circuit ouvert étant situé entre les transformateurs (101) qui sont connectés électriquement aux diodes électroluminescentes (104) ayant les plus faibles intensités lumineuses.

2. Procédé selon la revendication 1, **caractérisé en ce que** l'étape de modification de la tension alternative fournie par le régulateur de courant constant (105) comprend la modification d'au moins un des paramètres suivants : la forme d'onde, l'amplitude et la fréquence de la tension alternative.

3. Procédé selon la revendication 1 ou 2, **caractérisé en ce que** l'étape de modification de la tension alternative fournie par le régulateur de courant constant (105) comprend la modification de l'amplitude dans une plage d'amplitude prédéfinie et la modification de la fréquence dans une plage de fréquence prédéfinie.

4. Procédé selon la revendication 3, **caractérisé en ce que** la limite inférieure de la plage d'amplitude prédéfinie est supérieure à la somme des tensions de seuil des diodes électroluminescentes (104).

5. Procédé selon la revendication 3, **caractérisé en ce que** la limite supérieure de la plage d'amplitude prédéfinie est inférieure à la somme des tensions de seuil des diodes électroluminescentes (104).

6. Procédé selon la revendication 1 ou 2, **caractérisé en ce que** l'étape de modification de la tension alternative fournie par le régulateur de courant constant (105) comprend le réglage de la fréquence de la tension alternative à une valeur de fréquence prédéfinie et la modification de l'amplitude à l'intérieur d'une plage d'amplitude prédéfinie.

7. Procédé selon la revendication 6, **caractérisé en ce que** la valeur de fréquence prédéfinie est proche de la fréquence maximale du régulateur de courant constant (105) et la limite inférieure de la plage d'amplitude prédéfinie est supérieure à la somme des tensions de seuil des diodes électroluminescentes (104).

8. Procédé selon la revendication 6, **caractérisé en ce que** la valeur de fréquence prédéfinie est une fréquence de résonance parallèle du circuit électrique et la limite supérieure de la plage d'amplitude prédéfinie est inférieure à la somme des tensions de seuil des diodes électroluminescentes (104).

9. Procédé selon la revendication 1 ou 2, **caractérisé en ce que** l'étape de modification de la tension alternative fournie par le régulateur de courant constant (105) comprend le réglage de l'amplitude de la tension alternative à une valeur d'amplitude prédéfinie et la modification de la fréquence dans une plage de fréquence prédéfinie.

10. Procédé selon l'une quelconque des revendications précédentes, **caractérisé en ce que** l'étape de modification de la tension alternative fournie par le régulateur de courant constant (105) comprend la modification de la forme d'onde en ajoutant des harmoniques à la tension alternative.

11. Circuit électrique, comprenant :

- une pluralité de transformateurs (101), chaque transformateur (101) ayant un enroulement primaire (102) et un enroulement secondaire (103), les enroulements primaires (102) étant connectés électriquement en série,
- une pluralité de diodes électroluminescentes (104), chaque diode électroluminescente (104) étant connectée électriquement à un des enroulements secondaires (103), et
- un régulateur de courant constant (105) connecté électriquement aux enroulements primaires connectés en série (102) pour fournir de l'énergie électrique aux enroulements primaires (102),

caractérisé en ce que le régulateur de courant constant (105) est configuré, en cas de défaut de circuit ouvert dans les enroulements primaires connectés en série (102), pour modifier la tension alternative fournie par le régulateur de courant constant (105) de la tension alternative fournie en fonctionnement normal de sorte que les diodes électroluminescentes (104) s'allument, le défaut de circuit ouvert étant situé entre les transformateurs (101) qui sont connectés électriquement aux diodes électroluminescentes (104) ayant les intensités lumineuses les plus faibles.

12. Circuit électrique selon la revendication 11, **caractérisé en ce que** le régulateur de courant constant (105) est configuré, en cas de défaut de circuit ouvert dans les enroulements primaires connectés en série (102), pour modifier au moins un des paramètres suivants : la forme d'onde, l'amplitude et la fréquence de la tension alternative.

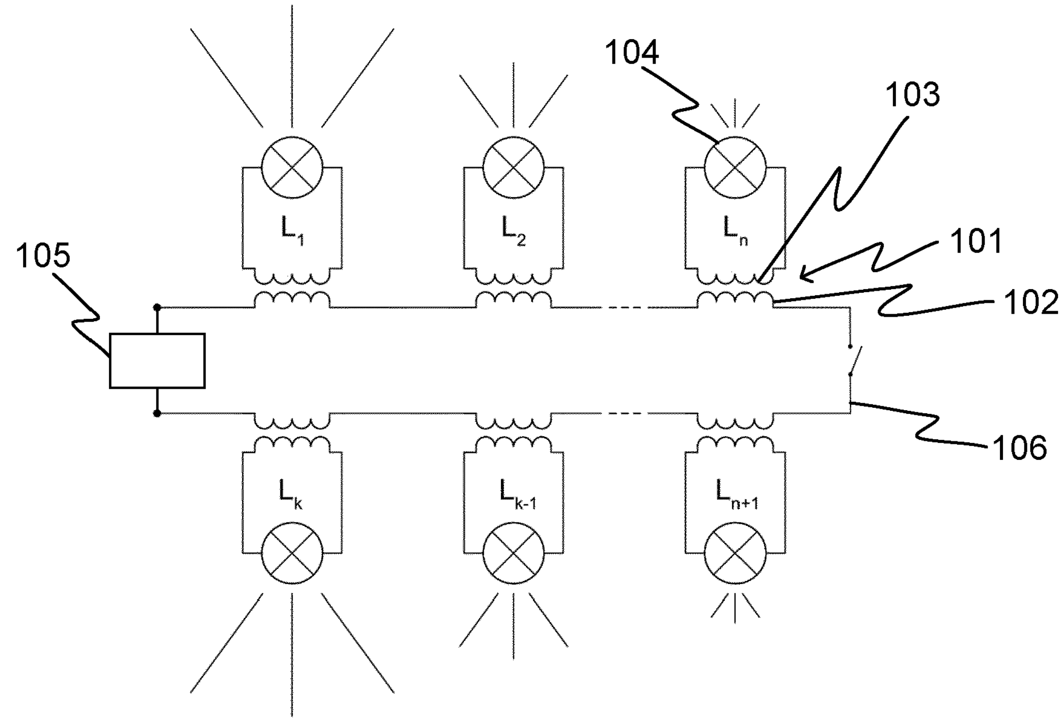
104
103
101
102
105
106
L1
L2
Ln
Lk
Lk-1
Ln+1

Fig. 1

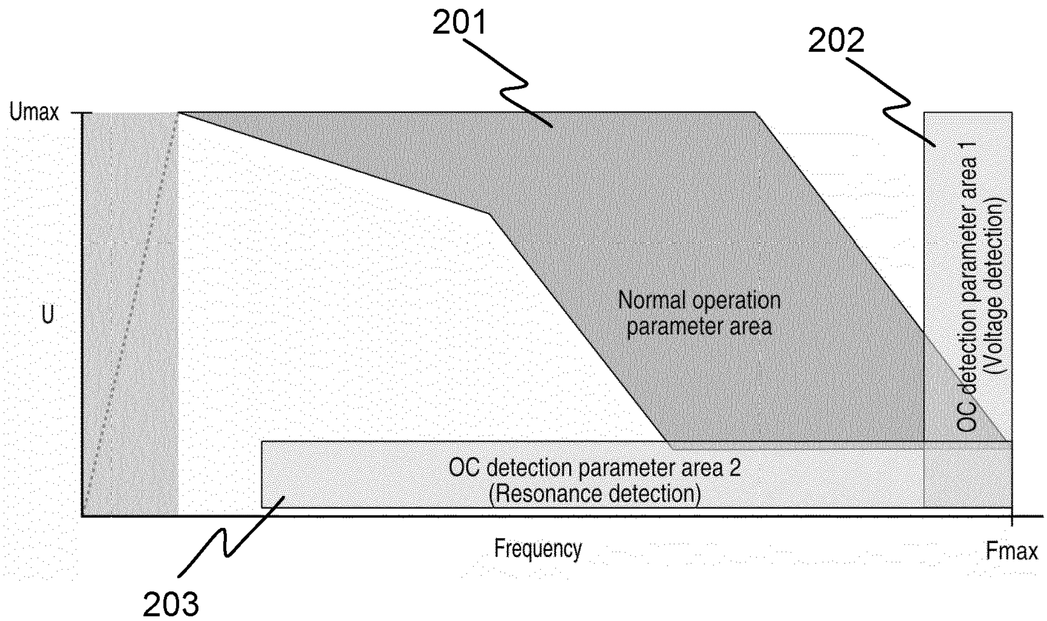
201
202
Umax
U
Normal operation parameter area
OC detection parameter area 1 (Voltage detection)
OC detection parameter area 2 (Resonance detection)
Frequency
Fmax
203

Fig. 2

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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