A lamp emulating circuit for AC powered airport lighting systems may be used for emulating the failure mode of a lamp to a lamp control circuit while a PWM-driven LED lamp is used. The lamp emulating circuit has a rectifier connected to a filter for determining the voltage across the lamp transformer. This is further connected to a relay coil which opens a contact for disconnecting the LED lamp circuit from the lamp transformer, when the voltage across the lamp transformer exceeds a predetermined value. By completely disconnecting the LED lamp circuit from the lamp transformer, a failed lamp is emulated.
Filament lamp emulation for LED airport lights

Field of the invention

The present invention relates to a device and a method for detecting failures of LED airfield lighting devices.

Description of the related art

At airports, lighting systems are used for directing aircrafts during approach and taxiing. These lighting systems have a large number of lamps which have to operate reliably. Failure of a lamp must be detected immediately, so that the lamp may be repaired or replaced quickly. This is specifically important during times of low visibility. As visual light inspection bears a significant risk of an accident and produces costs, automatic lamp monitoring systems are required.

Most commonly, light sources in these lighting systems are connected into a series circuit using an isolation transformer for each lamp. Such light sources are connected with each other by using a high voltage cable and they are fed by a constant current power supply having a constant current regulator. At the time, when the constant power supply was developed and standardized, conventional lamps were the only available reliable light source.

Failure of a lamp can easily be detected, as this causes an open circuit. The US patent 3,061,828 discloses such a circuit means for detecting failure of a lamp.

When a lamp fails and causes an open circuit, the transformer by which the lamp is connected to the series circuit will go into saturation. As a consequence, instead of the low lamp resistance which is usually transformed into the series cir-
circuit by the transformer, there is a significant series inductance from the saturated transformer in the series circuit. Compared to the previous largely resistive load of the lamp, this causes a change in amplitude and phase of the voltage drop. This can be evaluated by a simple circuit for measuring phase and voltage changes.

US patent 4,675,574 discloses a method for detecting defective lamps by evaluating effects of the saturated transformer in a voltage peak shortly after zero crossing of the current.

Both systems and methods described before cannot be applied to state of the art LED lamps. An example of such lamps is disclosed in US patent 7,654,720 which uses a PWM (Pulse Width Modulator) for driving the LEDs. Such a PWM circuit has an input characteristic which is different to the load characteristic of a lamp. Therefore, lamp failure detections as disclosed in US patents 3,061,828 and 4,675,574 would not work in conjunction with such a PWM circuit. To allow for a lamp-independent failure detection, a communication over the power line may be used as disclosed in US patent application publication 2003/0160707 Al. This is a powerful but very complex and expensive solution.

Summary of the invention

The problem to be solved by the invention is to provide a device and a method for enabling state of the art constant current power supplies to detect a failure of an LED lamp.

Solutions of the problem are described in the independent claims. The dependent claims relate to further improvements of the invention.
According to the invention the behavior of a conventional lamp is emulated. A lamp emulating circuit is inserted between a state of the art lamp transformer and an LED lamp circuit. The transformer is connected with its primary winding into the series circuit with a constant current power supply and delivers a lamp current at its secondary winding. A lamp emulating circuit has means for measuring the voltage across the secondary winding of the lamp transformer and further means for switching off the LED lamp circuit from the lamp transformer, when the voltage across the secondary winding of the lamp transformer exceeds a predetermined value. When the LED lamp circuit is disconnected from the lamp transformer, the lamp transformer has no load at its secondary side and therefore goes into saturation as it would do when connected to a burned-out lamp. Therefore, lamp fault detecting means as known from the prior art reliably detect a failure. As the LED lamp circuit is disconnected from the secondary side of the transformer, nothing could draw a significant load to the transformer and therefore pull down the voltage of the secondary winding of the transformer. Accordingly, the voltage at the secondary side of the lamp transformer remains at a comparatively high level and therefore, the lamp emulating circuit keeps the LED lamp circuit switched off in a stable state.

In a preferred embodiment, the lamp emulating circuit has at least one rectifying diode, preferably a bridge rectifier connected to the secondary side of the lamp transformer. The output signal of the rectifier preferably is filtered by a capacitor. It is further preferred, if a resistor is connected between the at least one rectifier diode and the capacitor. Furthermore, a relay is connected with its coil to the capacitor to receive the voltage filtered by the capacitor. It may also be connected directly to the at least one rectifier diode, if no capacitor is used. When the voltage at the secondary winding of the lamp transformer increases, the voltage at the relay coil will also increase. When the voltage has exceeded the threshold voltage of the relay, the relay will actuate its contact. There is at least one relay contact connected between the secondary winding of the trans-
former and the LED lamp circuit. Preferably, this contact is a normally closed contact which remains in a closed state, when the relay coil has no current or at least a current below its threshold level. When the relay coil is triggered by a current exceeding its threshold level, the at least one relay contact is opened and disconnects the LED lamp circuit from the secondary winding of the lamp transformer.

In a further preferred embodiment, there is a reset switch connected in parallel to the secondary winding of the lamp transformer. Preferably, it is a spring loaded normally open switch which may manually be actuated to close its contact and therefore cause a short circuit of the secondary winding of the lamp transformer. This causes a reset of the lamp emulating circuit. For example, the voltage at the at least one rectifier diode may drop to zero, therefore causing the relay to go to its unpowered state, and therefore to close the at least one relay contact. Consequently, the LED lamp circuit is reconnected to the secondary winding of the lamp transformer. When the reset switch is released, the lamp transformer feeds a voltage to the LED lamp circuit which may resume operation.

When the circuit is operating normally, it draws current from the lamp transformer and keeps the voltage across the lamp emulating circuit below the threshold level which keeps the LED lamp circuit connected to the lamp transformer. The reset switch may also be operated remotely by means of a coil, forming a relay. It may also be any other switch like a semiconductor switch.

In a further embodiment, there may be a control circuit for triggering the relay. Preferably, this control circuit comprises at least one rectifying diode. It is further preferred, if the control circuit comprises a circuit for detecting the voltage across the secondary winding of the lamp transformer and triggers the relay if this voltage exceeds a predetermined voltage level. This control circuit may contain semiconductors like transistors or Zener-diodes or integrated circuits or even a microcontroller. This control circuit may further contain means for com-
municating its status to an external control device. Therefore, it may signal a triggered event which may be caused by a failure of the LED lamp circuit to a central control device.

In a further embodiment, the relay may have contacts for a two-pole disconnection of the LED lamp circuit from the lamp transformer.

In another embodiment, the relay may be a bistable relay which keeps its triggered state. The advantage of such a relay is the comparatively low power consumption once it has been triggered.

In a further embodiment, there may be an indicator which may be an LED (light emitting diode) which may be connected in series to the relay or which may at least be fed by current supplied by the at least one rectifier diode. Such an LED may also be triggered by the control circuit. It may indicate the status of the relay or of the lamp emulating circuit.

In a further embodiment, there may be a series capacitor between the lamp transformer and the at least one rectifier diode of the lamp emulating circuit. This capacitor provides an AC impedance and therefore limits the current flowing through the relay, as the resistor would do. The advantage of the capacitor is that it is a reactive element and therefore has no power dissipation, which the resistor would have.

In a further embodiment, instead of the relay contact, any other suitable switching device like a semiconductor switch may be used. This may be a triac, or a thyristor, IGBT MOSFET preferably in conjunction with a rectifier.

In a further embodiment, the lamp emulating circuit is contained into a connector adaptor having a first input connector which may be connected to the lamp transformer and an output connector which may be connected to the LED lamp circuit.
The embodiments shown herein relate to relay contacts which are normally closed, as this is a robust and failure-safe state. Of course, the embodiments may also be realized by at least one normally open contact.

A further aspect of the invention relates to a method for emulating a failed lamp. This method comprises the steps of measuring the voltage across a lamp transformer, and disconnecting an LED lamp circuit from the lamp transformer in the case the voltage across the lamp transformer exceeds a predetermined value.

**Description of Drawings**

In the following the invention will be described by way of example, without limitation of the general inventive concept, on examples of embodiment with reference to the drawings.

(5)

Figure 1 shows a lamp emulating circuit according to the invention.

Figure 2 shows a basic lamp circuit for airport lighting.

Figure 3 shows a simplified embodiment.

Figure 4 shows an embodiment with a dual switch.

Figure 5 shows an embodiment with a control circuit.

Figure 6 shows an embodiment with a control circuit in an all pole disconnection.

Figure 7 shows an embodiment with a series capacitor.

Figure 8 shows a basic housing for the lamp emulating circuit.
In Fig. 1, a lamp emulating circuit according to the invention is shown. Inputs 101, 102 are connected to a lamp transformer, while outputs 103, 104 are connected to an LED lamp circuit. Rectifying diodes 110, 112 are connected to input 101, while rectifying diodes 111, 113 are connected to input 102. These four rectifying diodes form a bridge rectifier which delivers a DC voltage to a series resistor 114 and a parallel capacitor 115. A relay coil 116 is connected in parallel to the capacitor 115. The relay coil actuates a relay contact 117 which is connected between input 101 and output 103. When the output voltage of the LED lamp transformer which is received by inputs 101, 102 and rectified by the rectifying diodes 110 - 113 further filtered by resistor 114 and capacitor 115, exceeds a certain threshold value, relay coil 116 is triggered and therefore opens the normally closed contact 117 for disconnecting output 103 from input 101. This causes the LED lamp circuit to be disconnected from the lamp transformer secondary winding. Reset switch 119 may be provided in parallel with inputs 101, 102. Preferably, this is a normally open spring loaded switch which can be operated manually. It may also be operated remotely by means of a coil, being a relay.

In Fig. 2, a basic lamp circuit for airport lighting is shown. A lamp transformer 20 is connected by connectors 10, 11 to an AC power line current into its primary winding 21. The primary winding 21 is coupled to a secondary winding 22 by means of transformer core 23. The current from transformer secondary windings 22 is fed to inputs 101, 102 of lamp emulating circuit 100. The outputs 103, 104 of the lamp emulating circuit are connected to an LED lamp circuit 30, which may contain a PWM controller 32 for driving at least one LED 31.

In Fig. 3, a simplified embodiment as a basic configuration is shown. It has the same components as shown in Fig. 1, but does not have a reset switch. Instead, for resetting the circuit, it must be disconnected from the lamp transformer, or the current through the lamp transformer must be disrupted, which may be done by switching off the main power supply.
In Fig. 4, an embodiment with a dual pole switch comprising two relay contacts 117, 118 is shown. This provides a full disconnection of the LED lamp circuit from the lamp transformer.

In Fig. 5, an embodiment with a control circuit for controlling the relay coil 116 is shown. A control circuit 120 is connected between inputs 101, 102 and therefore receives the voltage from the lamp transformer. This control circuit preferably comprises at least one rectifying diode, preferably a bridge rectifier. It may further comprise detecting and/or filtering elements. Most preferably, it comprises at least one of a transistor, a Zener-diode, an integrated circuit, or a microcontroller. It may have a circuit for precisely determining a threshold value and delivering a current to relay coil 116, when the voltage across inputs 101, 102 exceed that threshold value.

In Fig. 6, an embodiment similar to the previous embodiment using a control circuit 120 is disclosed. Furthermore, a second relay contact 118 is provided for an all pole disconnection of the outputs 103, 104 from inputs 101, 102.

In Fig. 7, a further embodiment with a series capacitor 130 in series to a bridge rectifier 131 is disclosed. The series capacitor provides a reactance and therefore limits the AC current through the capacitor, and therefore through the relay. This may be used in conjunction with series resistor 114. The advantage of the capacitor over the resistor is its zero power losses, therefore, keeping power dissipation of the unit small. Furthermore, a status LED 132 is provided in series with the relay coil, indicating its status and therefore the status of the relay contact. Here, LED 132 will be on, when the relay coil is activated and therefore the contact is open. Basically, the LED may also be connected in parallel to the relay coil or at any other suitable location.

In Fig. 8, a basic housing for a lamp emulating circuit is shown. The circuit may be contained in a cylindrical housing having at least one housing 150, having at least
one input connector 151, and an output connector 152. Preferably, the input connector 151 is an L-823 male connector, while output connector 152 is an L-823 female connector.
List of reference numerals

10, 11  AC power line connector
20     lamp transformer
21     primary winding
22     secondary winding
23     transformer core
100    lamp emulating circuit
101, 102 inputs
103, 104 outputs
30     LED lamp circuit
31     LED
32     PWM controller
110 - 113 rectifier diodes
114    resistor
115    capacitor
116    relay coil
117, 118 relay contacts
119    reset switch
120    control circuit
130    series capacitor
131    bridge rectifier
132    status LED
150    housing
151    input connector
152    output connector
Claims

1. Lamp emulating circuit (100) for AC powered airport lighting systems for connecting a LED lamp circuit (30) to a lamp transformer (20), comprising:
   - at least one relay contact (117, 118) for connecting the LED lamp circuit (30) to the lamp transformer (20),
   - at least one rectifying diode (110-113) connected to the lamp transformer (20),
   - at least one filtering element (114, 115) for filtering the current and/or voltage from the at least one rectifying diode (110-113), and
   - a relay coil (116) connected to the at least one filtering element (114, 115) and opening the at least one relay contact (117, 118), when the voltage at the relay coil (116) exceeds a certain threshold level.

2. Lamp emulating circuit (100) for AC powered airport lighting systems for connecting a LED lamp circuit (30) to a lamp transformer (20), comprising:
   - at least one switch (117, 118) for connecting the LED lamp circuit (30) to the lamp transformer (20),
   - a control circuit (120) for triggering the switch to disconnect the LED lamp circuit (30) from the lamp transformer (20), when the voltage at the lamp transformer (20) exceeds a predetermined level.
3. Lamp emulating circuit (100) according to claim 1,
characterized in, that
the LED lamp circuit (30) is connected to the lamp transformer (20) by two
poles and there are two relay contacts (117, 118), each relay contact con-
necting and/or disconnecting one pole.

4. Lamp emulating circuit (100) according to claim 1 or 3,
characterized in, that
the filtering element comprises at least one resistor (114) and/or at least
one capacitor (115).

5. Lamp emulating circuit (100) according to claim 2,
characterized in, that
the LED lamp circuit (30) is connected to the lamp transformer (20) by two
poles and there are two switches (117, 118), each switch connecting
and/or disconnecting one pole.

6. Lamp emulating circuit (100) according to any one of the preceding claims,
characterized in, that
a reset switch (119) is provided for short-circuiting the output of the lamp
transformer (20).

7. Lamp emulating circuit (100) according to any one of the preceding claims
characterized in, that
a status indicating LED (132) is provided for indicating the status of the
lamp emulating circuit.
8. The emulating a lamp in AC powered airport lighting systems, where at least one LED lamp circuit (30) is connected to at least one lamp transformer (20), comprising the steps of:

- protecting the voltage at the at least one lamp transformer (20),
- disconnecting the LED lamp circuit (30) from the lamp transformer (20), when the voltage at the lamp transformer (20) exceeds a predetermined level.
A. CLASSIFICATION OF SUBJECT MATTER
INV. H05B37/03 H05B33/08
ADD.

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)

H05B

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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<table>
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