

MODULE FOR PROVIDING AN INTRINSICALLY SAFE
ELECTRICAL OUTPUT POWER AND EXPLOSION-PROOF
LUMINAIRE

- 5 [0001] The invention relates to a module for providing an intrinsically safe electrical output power for at least one electrical load, in particular for one or more light-emitting diodes of a luminaire. Furthermore, the invention relates to an explosion-proof luminaire with such a module.
- 10 [0002] In environments where there is the danger of explosion all electrical operating means must be embodied so as to be explosion-proof – as described in EN/IEC 60079 Standards. For example, luminaires comprising light-emitting diodes satisfying the ignition protection type “increased safety” must be combined with additional types of ignition protection in order to achieve a
- 15 specified or required safety level (e.g., “EPL Gb”). For example, the light-emitting diodes or their control circuit may be arranged in a housing consistent with the ignition protection type “flame-proof enclosure” (Ex-d) or “encapsulation” (Ex-m). Embodiments of the housing comprising electrical operating means or electrical loads in one ignition type, for example light-
- 20 emitting diodes, are expensive and also make repair and maintenance difficult.

[0003] Publication DE 101 32 415 A1 describes a protective device for a voltage divider line to which intrinsically safe circuits are connected. The voltage on the voltage divider line is monitored and – in the event of a voltage

surge or a voltage drop above or below a threshold value - a switch is opened, said switch being connected in series relative to the voltage divider line in order to interrupt the flow of current through the voltage divider line before a spark at a dividing point can trigger an ignition of an explosive atmosphere.

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[0004] Publication WO 2015/047383 A1 describes an arc unit, in which case the branch voltage, as well as the branch current, are monitored at each parallel-connected output branch of a supply line. Furthermore, the supply voltage and the supply current are monitored on the supply line. If the supply voltage and all
10 the branch voltages are not the same and if the supply current does not correspond of the sum of the branch currents, a safety switch in the supply line is opened.

[0005] Also, various attempts have been made to simplify the expensive
15 encapsulation of electrical loads such as, e.g., light-emitting diodes. For example, publication DE 10 2013 104 240 B4 suggests to connect – preferably without tools – a carrier on which the light-emitting diodes are arranged via engagement means to a cover body, so that the light-emitting diodes are accommodated in a chamber of the cover. Between the carrier and the cover
20 body, there is formed a flame-proof gap, so that the light-emitting diodes are arranged in small-volume chambers.

[0006] Considering prior art, it may be viewed as the object of the present invention to be able to operate at least one electrical load, in particular at least

one light-emitting diode of a luminaire, in an explosion-proof manner and without expensive mechanical housing designs.

[0007] This object is achieved with a module displaying the features of Patent
5 Claim 1, as well as with a luminaire displaying the features of Patent Claim 15.

[0008] The module according to the invention is disposed to provide an intrinsically safe electrical output power (Ex-i) for at least one electrical load, for example for at least one light-emitting diode. At the inlet comprising at least
10 one first inlet connection and one second inlet connection , it is possible to provide an input power that is not an intrinsically safe current source or voltage source. The module is configured in such a manner that simple means are used to provide the not intrinsically safe input power as an intrinsically safe output power on at least one outlet of the module for respectively one electrical load.

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[0009] Each of the outlets of the module has one first outlet connection and one second outlet connection. Between the two outlet connections of an outlet, it is possible to connect an electrical load each. At the outlets that do not comprise an electrical load it is possible to connect a jumper element that short-circuits the
20 respective outlet. In one exemplary embodiment, several outlets are connected in series between the two inlet connections. In an alternative embodiment the outlets are connected in parallel, so that each outlet is connected to the inlet in parallel with the other outlets.

[0010] The module has at least one current monitoring circuit that detects the output current flowing through at least one of the loads and compares it to a current limit value. Optionally, the module may also have a voltage monitoring circuit that detects the output voltage applied to at least one outlet and compares
5 it to a voltage limit value.

[0011] At least one controllable safety switch is provided and, in one embodiment, may be arranged in the electrical connection between one of the two inlet connections and the outlets. Alternatively or additionally, one provided
10 safety switch may be arranged parallel to one or more allocated outlets of the module in order to connect the outlet or outlets in a low-resistance manner to one another or to short-circuit them and reduce a current flow through the connected load, as well as the voltage on the at least one allocated outlet. The safety switch may interrupt or block an electrical connection dependent on its
15 switch state, or create the electrical connection when it is in its conductive state. The safety switch is activated by at least one control circuit and switched either into the blocking or conductive state. The control circuit is connected to the at least one current monitoring circuit and/or to the at least one voltage monitoring circuit.

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[0012] If it is determined that either the outlet voltage exceeds the voltage limit value and/or that an outlet current exceeds the current limit value, the control circuit initiates the switching of the safety switch into its safety state. In safety state, the safety switch ensures that the electrical output voltage and the output

current are reduced, on the at least one allocated outlet, respectively, to an intrinsically safe value. For example, the current flow of the input current into one inlet connection or back out of the other inlet connection back to the current source or voltage source can be interrupted when a safety switch located in the electrical connection between one of the two inlet connections and the outlets is blocking. As a result of this, the output power is instantly reduced to zero. Capacitive components that discharge via one or more of the loads upon opening the safety switch are preferably not provided.

- 10 [0013] If the safety switch is arranged parallel to one ore more allocated outlets of the module, it is conductive in its safety stat and connects the outlet connections of the at least one allocated outlet in a low-resistance manner or short-circuits them.
- 15 [0014] A low-resistance connection by means of the safety switch is understood to mean a connection in which only a residual voltage of a few Volts or less is applied to the safety switch, i.e., preferably less than 2 to 3 V. The residual voltage is a function of the design of the safety switch. Preferably, the safety switch is a semi-conductor switch or a semi-conductor arrangement comprising
- 20 several semi-conductor components. If the safety switch is a triac or a thyristor, for example, the residual voltage may be approximately 2 V. In the event of a bipolar transistor, the residual voltage is preferably lower than 1 V. In an insulating layer field effect transistor, the residual voltage may be 0.5 V or lower, for example. The exact residual voltage depends on the type of

semiconductor that is used. The residual voltage is defined as the voltage that is still applied to the semiconductor switch that is completely saturated or fully activated.

5 [0015] By connecting the outlets in parallel the current applied to the inlet can be distributed to several outlets and is thus reduced. This is expedient in particular when the module is connected to a voltage source with known input voltage, and the input current may vary depending on a maximum input power that can be provided by the voltage source. Due to the parallel connection of the
10 outlets, the same output voltage is applied to each outlet, said voltage corresponding essentially to the input voltage. The output current is determined by all loads connected to the outlets.

[0016] In another embodiment the outlets are connected in series relative to one
15 another. This is advantageous in particular if the inlet is connected to a current source. The inlet current specified by the current source then flows through all serially connected outlets via the respectively connected load. The input voltage applied between the two inlet connections that may vary depending on a maximum input power to be provided by the current source, is distributed - in
20 accordance with the loads - to the serially connected outlets and is thus reduced.

[0017] The module is based on the idea of dividing a not intrinsically safe input power by means of a series connection and/or a parallel connection of the outlets

of the module or of several components of an electrical load connected to an outlet into intrinsically safe electrical outputs.

[0018] With the aid of the module, the at least one outlet is monitored in view of the maintenance of the intrinsically safe output power by monitoring the output current and/or the output voltage and, if a current limit value or a voltage limit value is exceeded, the output power of all outlets is switched off. As a result of this, it is possible to also restrict the optical radiation of light-emitting diodes, even if the input power becomes too high due to an error.

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[0019] According to the invention, the light-emitting diodes or electrical loads need not additionally be made explosion-proof by mechanical means, for example by a “pressure-proof encapsulation” and or an “encapsulation”. As a result of this, the embodiment of an explosion-proof electrical device such as, for example, an explosion-proof luminaire is simplified considerably. It is also possible to design the housing of such a luminaire or device in a manner that is not explosion-proof if the module and its inlet clamps are configured in an explosion-proof manner, for example as a separate component or within the housing. In all cases, at least the loads are easily accessible and can be checked, repaired or replaced at little cost.

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[0020] In one exemplary embodiment, all outlets are allocated at least one shared current monitoring circuit. This is of advantage in particular if the outlets

are connected in series. In doing so, the current monitoring circuit may be redundant.

[0021] Furthermore, it may be of advantage if each of the outlets is
5 allocated a separate voltage monitoring circuit, in which case the voltage
monitoring circuit of each outlet may be redundant. This is advantageous if the
outlets are connected in series.

[0022] When the outlets are connected in parallel, it may be advantageous if all
10 outlets are allocated a shared voltage monitoring circuit. In this embodiment it is
also preferred if each of the outlets is allocated a separate current monitoring
circuit. Also in this case, the voltage monitoring circuits, as well as the current
monitoring circuits, may be configured so as to be redundant.

15 [0023] In a preferred exemplary embodiment two serially connected separate
safety switches are provided. Preferably, each safety switch is activated by a
separate control circuit. Each control circuit is connected to respectively one
current motoring circuit or voltage monitoring circuit for each of the provided
outlets. Consequently, operational safety is further improved.

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[0024] In the exemplary embodiment, the at least one control circuit comprises
a safeguard, for example a fusible cutout. If the current exceeds the current limit
value and/or if a voltage exceeds the voltage limit value, the control circuit
causes the triggering of the fuse, so that it blocks or interrupts a current flow

through the fuse. Preferably, the fuse is connected to the control connection of the at least one safety switch and – due to the interruption of the current flow by the fuse – causes the safety switch to switch into its blocking state.

5 [0025] Preferably, the safety switch is at least one semiconductor switch or comprises at least one semiconductor switch, for example a field effect transistor, a bipolar transistor, a triac or a thyristor. The field effect transistor may be configured as a p-channel MOSFET or an n-channel MOSFET.

10 [0026] It is preferred if respectively one or more light-emitting diodes are connected to one or more of the outlets, said light-emitting diodes representing the respective electrical load on an outlet.

[0027] In one exemplary embodiment the module has an outlet, to which is
15 connected a load having several parallel branches and respectively several components, for example several light-emitting diodes. The components are connected in series in each branch so that, overall, an arrangement of the components or the light-emitting diodes in the form of a matrix is the result. In such an exemplary embodiment, for example, there is no voltage monitoring
20 arrangement of the respective outlet. Preferably, this outlet is allocated only at least one current monitoring arrangement for monitoring the respective output current. The output voltage is distributed in each branch by the serially connected components. If a branch fails, the output voltage is taken up by the at least one additionally parallel-connected branch and also distributed there over

the serially connected components or light-emitting diodes. In this embodiment, a voltage monitoring of the outlet may be omitted.

[0028] Not needed outlets can be conductively connected or short-circuited by a
5 respective jumper element, for example by a short circuit connector. This is
necessary if the outlets are connected in series. In the case of outlets that are
connected in parallel, such a jumper element is not required.

[0029] The module described hereinabove may be a component of an explosion-
10 proof luminaire. The light-emitting diodes of the luminaire that are connected to
the module may be arranged in a simple manner, without additional explosion
protection measures of the luminaire housing. In particular, an “encapsulation”
or a “pressure-proof encapsulation” or other explosion protection measures on
the light-emitting diodes may be omitted.

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[0030] Advantageous embodiments of the invention can be inferred from the
dependent patent claims, the description and the drawings. Hereinafter,
exemplary embodiments are explained in detail with reference to the appended
drawings. They show in

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[0031] Figure 1 a block diagram of a first exemplary embodiment of a
module,

[0032] Figure 2 a block diagram of a second exemplary embodiment of a module,

[0033] Figure 3 a circuit diagram of an exemplary embodiment of a
5 module,

[0034] Figure 4 a circuit diagram of a further exemplary embodiment of a module,

10 [0035] Figure 5 a perspective representation of an exemplary explosion-proof luminaire, and

[0036] Figure 6 a circuit diagram of a further exemplary embodiment of a module.

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[0037] Figure 1 shows a schematic block diagram of a first exemplary embodiment of a module 10. The module 10 has an inlet 11 with a first inlet connection 12 and a second inlet connection 13. A not intrinsically safe energy source in the form of a current source 14 or a voltage source 15 (Figure 2) can
20 be connected to the inlet 11. In the exemplary embodiment according to Figure 1, the module 10 is provided in particular to be connected to a current source 14. An inlet current I_E that is imparted, for example, by the current source 14 flows into the first inlet connection 12. An inlet voltage U_E that may vary in a load-

dependent manner at the current source 14 is located between the inlet connections 12, 13.

[0038] A controllable safety switch 16 is connected to the first inlet connection 12 or, alternatively, to the second inlet connection 13. The module 10 has at least one outlet 17. The safety switch 16 is arranged in an electrical connection between one of the inlet connections 12, 13 and one of the provided outlets 17 of the module 10 and can make possible an electrically conductive connection in its conductive state and cause an interruption in its blocking state.

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[0039] Each provided outlet 17 of the module 10 has a first outlet connection 18 and a second outlet connection 19. Between the two outlet connections 18, 19 of an outlet 17 there is applied an outlet voltage U_A . Between the two outlet connections 18, 19 of each outlet 17, it is possible to connect an electrical load 20. In the exemplary embodiments, the electrical load 20 is formed by one or more light-emitting diodes 21 that are connected in series and/or in parallel.

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[0040] The module 10 and the light-emitting diodes 21 that are connected to the outlets are a component of an explosion-proof luminaire 22, for example. One exemplary embodiment of such a luminaire 22 is illustrated by Figure 5. The luminaire 22 comprises a luminaire housing 23, in which the light-emitting diodes 21 and, in accordance with the example, also the module 10 are arranged, for example on a common carrier or a common circuit board. The luminaire housing 23 need not be designed in an explosion-proof manner if the module

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itself is designed in an appropriate explosion-proof manner or is arranged as an external explosion-proof unit outside the luminaire housing 23. By means of a connector plug 24, the inlet 11 of the module 10 can be connected to a voltage or current source. It is also possible to mechanically or electrically connect the
5 module 10 in a separate housing - as a connectable or attachable connecting module - to the luminaire 22 and be interposed between the current source or the voltage source and the light-emitting diodes 21 of the luminaire 22.

[0041] In the exemplary embodiment shown by Figure 1, there are several
10 outlets 17 that are connected in series, via a respective electrical load 20 or the at least one light-emitting diode 21 at each outlet 17. The first outlet connection 18 of the first outlet 17 is connected to the safety switch 16. The second outlet connection 19 of the first outlet 17 is connected to the first outlet connection 18 of the next serially connected outlet 17, etc. The second outlet connection 19 of
15 the last outlet 17 of the series circuit of the outlets 17 is connected to the second inlet connection 13.

[0042] The module 10 according to Figure 1 provides a specified number of outlets 17. If there should be no electrical load 20 or should there be one or more
20 light-emitting diodes 21 connected to each outlet 17, the respective outlet 17 is conductively connected or short-circuited via a jumper element 26. As a result of this, it is ensured that the series connection of the outlets 17 is not interrupted by a missing electrical load 20. If an electrical load 20 is replaced by a jumper element 26, the outlet voltage U_A at the respective outlet 17 is equal to zero.

[0043] Due to the series connection of the outlets 17, the same outlet current I_A flows through all the electrical loads 20. For example, the outlet current I_A corresponds to the inlet current I_E that is imparted when a current source 14 is connected to the module 10 or the luminaire 22.

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[0044] The module 10 comprises at least one current monitoring circuit 27. In the exemplary embodiment according to Figure 1, a single current monitoring circuit 27 is sufficient because the current through all the electrical loads 20 or through all the outlets 17 is the same. In accordance with the example, the
10 current monitoring circuit 27 is located in the electrical connection between the last outlet 17 of the series circuit of the outlets 17 and the second inlet connection 13. The current monitoring circuit 27 could also be arranged at another point between the first inlet connections 12 and the second inlet connection 13 in the module 10. The current monitoring circuit 27 generates a
15 current monitoring signal SI . The current monitoring signal SI indicates whether or not the outlet current I_A exceeds a current limit value. The current monitoring signal SI is transmitted to a control circuit 28, said control circuit activating the controllable safety switch 16 via a control signal ST .

20 [0045] Furthermore, the module 10 comprises at least one voltage monitoring circuit 29. The voltage monitoring circuit monitors respectively one outlet voltage U_A . In the exemplary embodiment according to Figure 1 each outlet 17 is allocated a separate voltage monitoring circuit 29 because the outlet voltages U_A on the outlets 17 may deviate from each other. Each voltage monitoring

circuit 29 generates a voltage monitoring signal SU, all of these being transmitted to the control circuit 28. The voltage monitoring signal SU indicates whether the outlet voltage UA monitored by the voltage monitoring circuit 29 does or does not exceed a voltage limit value.

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[0046] As long as all outlet voltages UA are below the voltage limit value and the outlet current IA is below the current limit value, the safety switch 16 remains in its conductive state, in accordance with the example.

10 [0047] As soon as one of the outlet voltages UA exceeds a specified voltage limit value or the outlet current IA exceeds the current limit value, the control circuit 28 activates the safety switch 16 via the control signal ST and moves said switch into the safety state and, in accordance with the example, into the blocking state. The outlet current IA is stopped by the electrical loads 20 as a
15 result of this, and a safe state of the module 10 or the luminaire 22 is established.

[0048] As a rule, light-emitting diodes 21 are operated by a current source 14. At the inlet 11, the current source 14 delivers a not intrinsically safe electrical
20 power that is defined by the inlet current IE and the inlet voltage UE. In particular the inlet voltage UE may become high with the current source 14, as a result of which the input power increases correspondingly. The inlet power UE is distributed – due to the series connection of the outlets 17 – proportionally distributed to the respectively connected electrical load 20 to the outlets 17. If

the same load 20 or the same light-emitting diode circuit comprising at least one light-emitting diode 21 is connected to each outlet 17, the outlet voltages U_A on the outlets 17 are substantially the same.

5 [0049] In accordance with the example, the inlet voltage U_E is distributed at least approximately uniformly over the outlets 17 if there are several outlets 17. As a result of this, the limiting of the electrical power is achieved by limiting the outlet current I_A and limiting the outlet voltage U_A at each individual outlet 17. The maximum inlet voltage U_E or input power that can be provided by the
10 current source 14 is known. Due to the plurality of outlets 17, this maximum-available inlet voltage U_E can be distributed over the outlets 17.

[0050] To provide further intrinsic safety of the module 10 or the luminaire 22, all outlets 17 or all outlet voltages U_A at the outlets 17, as well as the outlet
15 current flowing through each load 20, can be monitored. If limit values are exceeding, the current flow in the module 10 and through the respectively connected load 20 is immediately interrupted.

[0051] Figure 2 illustrate a further exemplary embodiment of the module 10 or
20 the luminaire 22. Hereinafter, only the differences with respect to the exemplary embodiment according to Figure 1 will be explained. Other than that, reference is made to the explanation hereinabove.

[0052] In the exemplary embodiment according to Figure 2, several outlets 17 are provided, these being connected in parallel to one another between the first inlet connection 12 and the second inlet connection 13. Consequently, the same outlet voltage U_A is applied to each outlet 17. However, the outlet currents I_A between the outlets 17 may be different from one another. Different from the exemplary embodiment according to Figure 1, referring to the exemplary embodiment according to Figure 2, each outlet 17 is allocated a separate current monitoring circuit 27. Each current monitoring circuit 27 of an outlet 17 transmits a current monitoring signal SI to the control circuit 28. Inasmuch as all outlet voltages U_A of the parallel-connected outlets 17 are the same, a single voltage monitoring circuit 29 is sufficient for all outlets 17. In modification of the representation according to Figure 2, the voltage monitoring circuit 29 may also be located between the safety switch 16 and the outlets 17 or any desired outlet 17. The exemplary embodiment according to Figure 2 is particularly suitable for modules 10 or luminaires 22 that are operated via a voltage source 15, so that the outlet voltage U_A in the outlet 17 corresponds to the imparted inlet voltage U_E . In one exemplary embodiment with a plurality of outlets the variable inlet current I_E splits into the corresponding number of outlets 17. The sum of all outlet currents I_A corresponds to the inlet current I_E . Analogous to the exemplary embodiment according to Figure 1, it is thus possible to limit the output power at each outlet 17 as a function of the maximum provided inlet current I_E . The number of outlets 17 may be chosen accordingly.

[0054] As in the exemplary embodiment according to Figure 1, the safety switch 16 is switched via the control circuit 28 into its safety state (for example, the blocking state), either when one of the outlet currents exceeds the current limit value or when the outlet voltage U_A or the inlet voltage U_E exceeds a voltage limit value.

[0055] Figure 3 illustrates a preferred exemplary embodiment for implementing a module 10. This module 10 may be a component of an explosion-proof luminaire 22 or it may be provided at an attachment module with separate housing. Connected to several or all outlets 17, there may be respectively one light-emitting diode circuit comprising at least one light-emitting diode 21. In the exemplary embodiment according to Figure 3 the outlets 17 are connected in series. Instead of one load at the outlet 17, it is also possible to connect a jumper element 26. The components of the module 10 that are critical in view of safety are provided in a redundant manner.

[0056] The voltage monitoring circuit 29 allocated to each outlet 17 comprises a voltage divider comprising a first voltage divider resistor 35 and a second voltage divider resistor 36 that are connected in series to one another between the first outlet connection 18 and the second outlet connection 19 of an outlet 17. The center tapping between the voltage divider resistors 35, 36 is connected to a control input of a controllable first Zener diode 37. The cathode of the first Zener diode 37 is connected – via a first resistor 38 – to the first outlet connection 18, and the anode of the first Zener diode 37 is connected to the

second outlet connection 19. Furthermore, the cathode of the first Zener diode 37 is connected – via a second resistor 39 – to the base of a first transistor 40. The first transistor 40 is embodied as a bipolar pnp transistor. The emitter connection of the first transistor 40 is connected to the first outlet connection 18, and the collector connection of the first transistor 40 is connected – via a third resistor 41 – to a control line 42 or 43.

[0057] For redundancy reasons, the same outlet 17 is allocated an additional voltage monitoring circuit 29 having the same configuration. In accordance with the example, each outlet 17 is thus allocated two voltage monitoring circuits 29, each having an identical configuration. The one voltage monitoring circuit 29 is connected to a first control line 42, and the respectively other voltage monitoring circuit 29 is connected to a second control line 43. Figure 3 shows, as examples the voltage monitoring circuits 29 for the first two outlets 27, while the remaining voltage monitoring circuits 29 have the same configuration and are symbolized only by block diagrams.

[0058] Referring to the exemplary embodiment, the first inlet connection 12 is directly connected to the first outlet connection 18 of the first outlet 17 – via a first connecting line 45. A second connecting line 46 is connected to the second inlet connection 13. The series circuit of the outlets 17 is interposed between the two connecting lines 45, 46. In the second connecting line 36, there is seated the at least one safety switch 16 that, in accordance with the example, is embodied by a transistor and – here – by a field effect transistor 47 in the form of an n-

channel MOSFET. The safety switches 16 are configured in a relatively redundant manner, so that – in the present example – two safety switches 16 are arranged in series with respect to one another in the second supply line 46.

5 [0059] The control connection of the safety switch 16 or the gate of the field effect transistor 47 is connected – via a fourth resistor 48 – to a node 49. The first node 49 is connected – via a fifth resistor 50 – to a second node 51. The second node 51 is connected – via a fuse 52 - to the first connecting line 45 or the first inlet connection 12. In accordance with the example, the fuse 52 is
10 configured as a safety fuse.

[0060] The gate of the field effect transistor 47 is connected – via a first diode 56 – to the second node 51. The emitter of a second transistor 57 that is a pnp bipolar transistor is connected to the second node 51. The collector of the
15 second transistor 57 is connected – via a sixth resistor 58 – to the second control line 42. The base of the second transistor 57 is connected to the first node 49.

[0061] The second inlet connection 13 is connected – via a resistor arrangement 59 – to a third node 60. The resistor arrangement 59 comprises one or more
20 parallel-connected resistors. The voltage applied to the resistor arrangement 59 is characteristic of the current flowing from the first inlet connection 12 to the second inlet connection 13, said current – in the present exemplary embodiment – corresponding to the inlet current I_E , as well as to the outlet current I_A , because all outlets 17 are connected in series between the two inlet connections

12, 13. Consequently, the resistor arrangement 59 forms a current-sensing resistor.

[0062] The second node 51 is connected – via a first thyristor 61 – to the third
5 node 60. The control input of the first thyristor 61 is connected to the first control line 42. A first support capacitor 62 is connected, on one side, to the cathode of the first thyristor 61 and the third node 60 and, on the other side, to the control input of the first thyristor 61.

10 [0063] A controllable second Zener diode 66 connects the second inlet connection 13 to the first node, in which case the cathode is allocated to the first node 49. A second support capacitor 67 is connected between the control connection of the second Zener diode 66 and the anode of the second Zener diode 66. The control connection of the controllable second Zener diode 66 is
15 connected – via a seventh resistor 68 – to the third node 60.

[0064] The circuit described hereinabove between the first node 49, the third node 60 and the first control line 42 forms the control circuit 28 for one of the two field effect transistors 47. The same control circuit 28 is again connected for
20 the respectively other field effect transistor 47, said control circuit 28 – different from the control circuit 28 described hereinabove - being connected to the second control line 43.

[0065] The current monitoring arrangement 27 is redundant and formed, respectively, by the resistor arrangement 59 as well as the second Zener diode 66 with the second support capacitor 67 and the seventh resistor 68.

5 [0066] As illustrated by Figure 3, a parallel circuit is provided between the first node 49 and the second inlet connection 13, said parallel circuit comprising an eighth resistor 69, a third Zener diode 70, as well as a fourth Zener diode 71. The cathodes of the Zener diodes 70, 71 are connected to the first node 49.

10 [0067] The module 10 according to Figure 3 described so far operates as follows:

[0068] As long as neither a voltage limit value nor a current limit value is exceeded, the field effect transistor 47 remains in its conductive state due to the
15 connection of its gate – via the first node 49, the second node 51 and the fuse 52 – to the first inlet connection 12. The respective first transistor 40 of each voltage monitoring circuit 29 is blocking, and the second transistor 57 of the control circuit 28 is also blocking.

20 [0069] If an outlet voltage U_S at one of the outlets 17 exceeds a voltage limit value specified by the controllable first Zener diode 37, the controllable first Zener diode 37 becomes conductive due to the voltage applied to the second voltage divider resistor 36, so that the base of the first transistor 40 is connected to the second outlet connection 19 via the respective second resistor 39. As a

result of this, the first transistor 40 becomes conductive and connects the respective control line 42 or 43 to the allocated first outlet connection 18 of the respective outlet 17. The result of this is that the first thyristor 61 is switched into its conductive state. As a result of this, a current can flow through the fuse 52, said current being high enough to trigger the fuse 52 and to interrupt the connection between the second node 51 and the first inlet connection 12. This, in turn, has the consequence that – due to the connection between the gate of the field effect transistor 47 via the first diode 56 – a fast switching of the field effect transistor 47 into the blocking state occurs. The first diode 56 accelerates this switching operation and could also be omitted in a simplified exemplary embodiment.

[0070] The controllable second Zener diode 66 is characteristic of the current limit value. If the current increases, the measuring voltage applied to the resistor arrangement 59 increases and thus also the voltage on the respective seventh resistor 68 to the control input of the controllable second Zener diode 66. If the current limit value is exceeded, the controllable second Zener diode 66 is switched into conductive state. This has the result that the base of the second transistor 57 is connected to the second inlet connection 13, as a result of which the second transistor 57 and the first thyristor 61 become conductive. The higher current through the fuse 52 caused due to this has the effect that the fuse 52 is triggered. As in the case when the voltage limit value is exceeded, this again has the result that the gate of the field effect transistor 47 is connected – via the first

diode 56 – to the third node 60 and the field effect transistor 47 is switched into its blocking state.

[0071] Figure 4 shows another exemplary embodiment of a module 10 that can be used for an explosion-proof luminaire 22. The activation of the outlets 17 with the respectively redundant voltage monitoring circuits 29 corresponds to the exemplary embodiment according to Figure 3 and is shown in Figure 4 simplified in the manner of a block diagram. Figure 4 also shows as examples only the first outlet 17 and the last outlet 17 of a series circuit. The redundant embodiment of the voltage monitoring circuit 29, as well as the control circuit 28, were omitted to avoid confusion.

[0072] In this exemplary embodiment, the field effect transistor 47 of the safety switch 16 is a p-channel MOSFET and placed in the first supply line 45. The gate of the field effect transistor 47 is connected – via a ninth resistor 78 - to a fourth node 81 and to the anode of a fifth Zener diode 82 whose cathode is connected to the first inlet connection 12. Furthermore, the first inlet connection 12 is connected to an emitter of a third transistor 83 that is configured as a pnp bipolar transistor. The collector of the third transistor 83 is connected to the fourth node 81. The base of the third transistor 83 is connected – via a tenth resistor 79 – to a fifth node 84. The fifth node 84 is connected – via a second thyristor 85 – to the second supply line 46. Furthermore, a base of a fourth transistor 84 is connected – via an eleventh resistor 80 – to the fifth node 84 that is represented by an npn bipolar transistor. The collector of this fourth transistor

86 is connected to the fourth node 81, while the emitter is connected to the second supply line 46.

[0073] The first control line 42 is connected to the control input of the second
5 thyristor 85 and to an emitter of a fifth transistor 87 that is configured as the npn
bipolar transistor. The collector of the fifth transistor 87 is connected – via a
twelfth resistor 88 – to the fifth node 84. The base of the fifth transistor 87 is
connected – via a thirteenth resistor 89 – to the collector of a sixth transistor 90.
The sixth transistor 90 is configured as the pnp transistor whose base is
10 connected – via a fourteenth resistor 91 and a fifteenth resistor 92 – to the fifth
node 84. The connection point between the fourteenth resistor 91 and the
fifteenth resistor 92 is connected to the emitter of the sixth transistor 90. The
base of the sixth transistor 90 is furthermore connected – via a controllable sixth
Zener diode 93 – to the second inlet connection 13, in which case the anode is
15 allocated to the second inlet connection 13 and the cathode is allocated to the
base of the sixth transistor 90.

[0074] The control input of the controllable sixth Zener diode 93 is connected –
via the resistor arrangement 59 – to the second inlet connection 13.
20 Consequently, the resistor arrangement 59 is interposed between the anode and
the control connection of the controllable sixth Zener diode 93.

[0075] As long as neither the voltage limit value nor a current limit value is
exceeded, the field effect transistor 47 is conductive. This is achieved in that the

fourth transistor 86 is kept in its conductive state via the connection of the fuse 52 with the first inlet connection 12, and thus the gate of the field effect transistor 47 displays a considerably lower potential than the source connection.

- 5 [0076] If a voltage limit value is exceeded, the second thyristor 85 is moved into its conductive state due to a corresponding connection of the respective outlet connection 18 to the first control line 42. The current through the fuse, in turn, has the effect that the fuse 52 disconnects the connection between the fifth node 84 and the inlet connection 12. The third transistor 83 becomes conductive,
- 10 while the fourth transistor 86 moves into its blocking state. Due to the connection of the fourth node 81 and thus the gate to the first inlet connection 12, the field effect transistor 47 is safely held in its blocking state.

- [0077] If a measuring voltage is applied to the resistor arrangement 59 resulting
- 15 from too high an outlet current I_A , said measuring voltage being higher than a current limit value, the sixth Zener diode 93 becomes conductive. This has the result that the sixth transistor 90 and, as a consequence thereof, the fifth transistor 87 are switched into their conductive state and switch the thyristor 85 into the conductive state due to a corresponding signal. Analogous to the
- 20 description hereinabove, the third transistor 83 becomes then conductive, and the fuse 52 disconnects the connection between the fifth node 84 and the first inlet connection 12. The field effect transistor 47 thus moves into its blocking state. Likewise, the fourth transistor 86 moves into blocking state as a result of this.

[0078] The control circuit 28 described in conjunction with the first control line 42, as well as the safety switch 16 that is energized as a result of this, can – as already explained – be redundant in order to increase the safety of the module 10.

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[0079] Figure 6 shows another exemplary embodiment of the module 10. This exemplary embodiment is designed in a manner similar to the exemplary embodiment of the module 10 in accordance with Figure 3. However, only a single outlet 17 exists that is not allocated a voltage monitoring device 29. The outlet voltage UA applied there is thus not monitored. The outlet 17 is allocated only at least one current monitoring circuit 27 that is redundant analogous to Figure 3, in accordance with the example.

[0080] The main difference compared to the embodiment according to Figure 3 consists in that the redundantly existing safety switches 16 are connected in parallel to the outlet 17 of the module 10. In this safety state, a current path between the first outlet connection 18 and the second outlet connection 19 is cleared, and the two outlet connections 18, 19 are connected in a low-resistance manner to each other. The low-resistance connection is understood to be a conductive connection, wherein, in the current path between the outlet connections 18, 19, there only remains a residual voltage applied to the safety switch 16. The residual voltage depends on the type of embodiment of the safety switch 16 that, preferably, is a semiconductor switch or comprises one or more semiconductor switches. In the exemplary embodiment according to Figure 6,

the safety switch 16 is the first thyristor 61. In accordance with the example, the current path between the two outlet connections 18, 19 does not contain any additional components connected in series to the safety switch 16 or the first thyristor 61.

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[0081] This embodiment of the module 10 (Figure 6) is possible because the outlet voltage U_A is made intrinsically safe by the load 20 itself. The load 20 comprises several parallel-connected branches 20a. Preferably, at least two or at least three branches 20a are connected in parallel to one another. Each of the
10 branches 20a comprises a series circuit of several components of the load 20 – several light-emitting diodes 21, in accordance with the example. The components or light-emitting diodes 21 in each branch 20a are connected in series. In this embodiment of the load 20 the outlet voltage U_A in each branch 20a is distributed over the serially connected components. Even if there should
15 occur an interruption in one branch 20a, this voltage division takes place in the at least one parallel-connected additional branch 20a, so that the outlet voltage U_S is distributed to several components or limit-emitting diodes 21, even if one of the branches 20a is interrupted.

20 [0082] Different from the embodiment according to Figure 3, the fuse 52 is connected in series between the first inlet connection 12 and the first outlet connection 18 and between the first inlet connection 12 and the branching points of the current paths containing the safety switch 16.

[0083] The emitters of the second transistor 57 of each control circuit 28 are connected to the first node 49. The fifth resistor 50 is connected in series between the first node 49 and the second node 51. The redundant current paths comprising the safety switches 16 each connect the second node 51 to the
5 second outlet connection 19, in which case, according to the example, the anode connection of the first thyristor 61 is connected to the second node 51, and the cathode connection is connected to the second outlet connection 19.

[0084] Another difference compared to the exemplary embodiment according to
10 Figure 3 consists in that, in the exemplary embodiment according to Figure 6, the bases of the two second transistors are each connected – via a sixteenth resistor 100 – to the first node 49 and – via a seventeenth resistor 101 – to respectively one allocated second Zener diode 66. A capacitor 103 is connected in parallel to the third and the fourth Zener diodes 70, 71, said capacitor being
15 connected in series between the second inlet connection 13 and the first node 49. The second inlet connection 13 is furthermore connected – via a second diode 104 and a third diode 105 – to the second node 51, in which case the cathode is connected to the second node 51, and the anode is connected to the second inlet connection 13.

20

[0085] The exemplary embodiment according to Figure 6 operates as follows:

[0086] As has already been explained, the outlet voltage U_A is not monitored. Only the exceeding of an outlet current I_A is monitored by the current

monitoring device 27. The outlet current I_A flowing through the load 20 is proportional to a measuring voltage on the resistor arrangement 59. If the outlet current I_A exceeds the current limit value as defined by the Zener voltage of the second Zener diode 66, the second Zener diode 66 is switched into conductive state. The base of the second transistor 57 of the respective control circuit 28 is connected – via the conductive second Zener diode 66 and the seventeenth resistor 101 – to the second inlet connection 13. The result of this is that the second transistor 57 becomes conductive and consequently energizes the control connection of the safety switch 16 and, in the present case, the first thyristor 61, as a result of which the first thyristor 61 is switched into its conductive state. In doing so, the current path becomes conductive and is cleared via the safety switch 16 or the first transistor 61 between the first outlet connection 18 and the second outlet connection 19, and the two outlet connections 18, 19 are connected in a low-resistance manner. Referring to this exemplary embodiment, the safety switch 16 is conductive in its safety state. Between the two outlet connections 18, 19, it is only the applied design-specific residual voltage that decreases at the safety switch 16, wherein said voltage may be approximately 2 V or less in the case of a safety switch 16 represented by the first thyristor 61. As a result of this, the outlet power on the outlet 17 is at least reduced. In the exemplary embodiment this has the effect that no outlet current I_A flows through the load 20 because the serially connected light-emitting diodes 21 at that location are in blocking state due to the low outlet voltage U_A .

[0087] Preferably, the Zener voltage of the second Zener diode 66 is selected in such a manner that the safety switch 16 is switched into its conductive safety state, before the fuse 52 triggers.

5 [0088] After the safety switch 16 has been switched into its safety state (here: conductive state), the current through the fuse 52 may increase and trigger said fuse, as a result of which a further current flow is interrupted and the outlet voltage UA is reduced to zero.

10 [0089] In the exemplary embodiment according to Figure 6 the second diode 104 and the third diode 105 are optional. They prevent an inadvertent faulty connection of the module 10 to a current or voltage source 14, 15. When the second inlet connection 13 displaying the higher potential of the energy source, a conductive connection to the first outlet connection is established via the
15 diodes 104, 105, and the fuse 52 triggers due to the thusly resulting short circuit.

[0090] The voltage on the first node can be set – analogous to the exemplary embodiment according to Figure 3 – via the third Zener diode 70, the fourth Zener diode 71 and the optionally existing capacitor 103.

20

[0091] The exemplary embodiment shown by Figure 6 can also be combined with the embodiments of the control circuit 28 and/or the additional safety switches 16, as are provided in the exemplary embodiment of Figure 3.

Therefore, it is possible to arrange – as an addition or an alternative to the safety

switches 16 arranged parallel to the outlet 17 – the safety switches 16 according to Figure 3 in series with respect to the outlet 17. For example, it is also possible to simply omit the voltage monitoring devices 29 in the exemplary embodiment according to Figure 3, when a load 20 is connected to the at least one outlet 17 –
5 as illustrated by Figure 6.

[0092] As long as not mentioned otherwise in the description hereinabove, the resistors are ohmic resistors. In a specific implementation of a circuit, it is possible to construct an ohmic resistor as shown in the circuit diagram with
10 more serially connected and/or parallel-connected resistor components. Depending on the specific dimensioning, additional ohmic resistors may be necessary to limit the currents or potential differences between two nodes.

[0093] The invention relates to a module 10 for an explosion-proof luminaire 22
15 or for another explosion-proof electrical device. The module 10 is disposed to convert a non-intrinsically safe input power on an inlet 11 into an intrinsically safe output power on one or more outlets 17. In doing so, an appropriate electrical load, for example a light-emitting diode arrangement comprising at least one light-emitting diode 21, can be or is connected to each existing outlet
20 17.

[0094] If there are several outlets 17, they can be connected in parallel or in series between a first inlet connection 12 and a second inlet connection 13 of the inlet 11. At least one current monitoring device 27 monitors the outlet current

IA. Optionally, at least one voltage monitoring device 29 can monitor an outlet voltage U_A . As soon as an outlet voltage U_A exceeds a voltage limit value and/or as soon as an outlet current I_A exceeds a current limit value, a safety switch 16 is switched into its safety state by means of a control circuit 28. The

5 safety switch 16 may be arranged in the electrical connection between the first inlet connection 12 and the second inlet connection 13 of the module 10 and can be blocking in safety state. The safety switch 16 may also be arranged parallel to one or more allocated outlets 17 and be conductive in safety state and clear a current path parallel to the at least one allocated outlet 17. Preferably, the safety

10 switch 16 comprises a field effect transistor 47, for example a MOSFET, or a thyristor 61, or is represented by a field effect transistor 47 or a thyristor 61.

List of Reference Signs:

10	Module
11	Input, inlet
12	First inlet connection
13	Second inlet connection
14	Current source
15	Voltage source
16	Safety switch
17	Outlet
18	First outlet connection
19	Second outlet connection
20	Load
21	Light-emitting diode
22	Luminaire
23	Luminaire housing
24	Connector plug
26	Jumper element
27	Current monitoring circuit
28	Control circuit
29	Voltage monitoring circuit
35	First voltage divider resistor

36	Second voltage divider resistor
37	First Zener diode
38	First resistor
39	Second resistor
40	First transistor
41	Third resistor
42	First control line
43	Second control line
45	First connecting line
46	Second connecting line
47	Field effect transistor
48	Fourth resistor
49	First node
50	Fifth resistor
51	Second node
52	Fuse
56	First diode
57	Second transistor
58	Sixth resistor
59	Resistor arrangement
60	Third node
61	First thyristor

62	First support capacitor
66	Second Zener diode
67	Second support capacitor
68	Seventh resistor
69	Eighth resistor
70	Third Zener diode
71	Fourth Zener diode
78	Ninth resistor
79	Tenth resistor
80	Eleventh resistor
81	Fourth node
82	Fifth Zener diode
83	Third transistor
84	Fifth node
85	Second thyristor
86	Fourth transistor
87	Fifth transistor
88	Twelfth resistor
89	Thirteenth resistor
90	Sixth transistor
91	Fourteenth resistor
92	Fifteenth resistor

93	Sixth Zener diode
100	Sixteenth resistor
101	Seventeenth resistor
103	Capacitor
104	Second diode
105	Third diode
IA	Outlet current
IE	Inlet current
UA	Outlet voltage
UE	Inlet voltage
SI	Current monitoring signal
SU	Voltage monitoring signal
ST	Control signal

CLAIMS

1. Module (10) for providing an intrinsically safe electrical output power for at least one electrical load (20),

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with an inlet (11) having a first inlet connection (12) and a second inlet connection (13), to which inlet a current source (14) or a voltage source (15) can be connected, said source providing an intrinsically non-safe input power at the inlet (11),

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with at least one outlet (17) that has one first outlet connection (18) and one second outlet connection (19), respectively, between which an electrical load (20) can be connected,

15

with at least one current monitoring circuit (27) that detects the outlet current (IA) flowing through at least one of the loads (20) and compares it to a current limit value,

20

with at least one controllable safety switch (16) that is arranged either in an electrical connection between one of the two inlet connections (12, 13) and the outlets (17) or is arranged parallel to the at least one outlet (17), and

- with at least one control circuit (28) that is connected to the at least one current monitoring circuit (27) and is disposed to switch the controllable safety switch (16) into a safety state when the outlet current (IA) exceeds the current limit value, wherein the safety switch (16) in safety mode
5 reduces the electrical output power on at least one outlet (17).
2. Module according to Claim 1,
characterized in that there is at least one voltage monitoring circuit (29)
that detects the outlet voltage (UA) applied to the at least one outlet (17)
10 and compares it to a voltage limit value.
3. Module according to Claim 2,
characterized in that the at least one control circuit (28) is connected to
the at least one voltage monitoring circuit (29) and is configured to
15 switch the controllable safety switch (16) into the safety state, when one
of the outlet voltages (UA) exceeds the voltage limit value.
4. Module according to Claim 2 or 3,
characterized in that each of the outlets (17) is allocated a separate
20 voltage monitoring circuit (29).
5. Module according to one of the previous claims,
characterized in that the outlets (17) are connected in series between the
two inlet connections (12, 13).

6. Module according to Claim 5,
characterized in that all outlets (17) are allocated one common current
monitoring circuit (27).
- 5 7. Module according to one of the claims 1 to 4,
characterized in that the outlets (17) are connected in parallel to one
another and are connected to the inlet connections (12, 13).
8. Module according to Claim 2 or 3 and according to Claim 7,
10 characterized in that all outlets (17) are allocated one common voltage
monitoring circuit (29).
9. Module according to Claim 7 or 8,
characterized in that each of the outlets (17) is allocated a separate
15 current monitoring circuit (27).
10. Module according to one of the previous claims,
characterized in that two safety switches (16) are connected in series or
in parallel to one another, each being energized by a separate control
20 circuit (28).
11. Module according to one of the previous claims,
characterized in that each current monitoring circuit (27) and/or each
voltage monitoring circuit (29) is present in a redundant manner.

12. Module according to Claims 10 and 11,
characterized in that each control circuit (28) is connected to one current
monitoring circuit (27), respectively, and/or to one voltage monitoring
circuit (29), respectively.
- 5
13. Module according to one of the previous claims,
characterized in that the at least one control circuit comprises a fuse (52)
arranged in such a manner that it triggers and assumes a blocking state
when the at least one current monitoring circuit (27) has determined that
10 the current limit value was exceeded and/or the at least one voltage
monitoring circuit (29) has determined that the voltage limit value was
exceeded.
14. Module according to one of the previous claims,
15 characterized in that a load (20) comprising several parallel branches
with several serially connected individual components is connected to an
outlet (17), and that this outlet (17) is not allocated a voltage monitoring
arrangement.
- 20 15. Explosion-proof luminaire (22) comprising a module (10) according to
one of the previous claims, in which case a luminaire housing (23) of the
luminaire (22) and/or the arrangement of the light-emitting diodes (21)
in the luminaire housing (23) are constructed without additional
mechanical explosion protection measures.