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## DEVICE FOR THE ELECTRICAL PROTECTION OF POWER SUPPLY CABLES FOR PERMANENT-MAGNET MOTORS


### Abstract

A device for protecting against a short-circuit occurring on a high-voltage DC power supply line between a DC source and an active load, the device including a bypass circuit formed of a contactor K**3** and a fuse F**2** connected in series and set up parallel to the active load via a line independent of the high-voltage DC power supply line, the bypass circuit being configured such that most of the current passes through it once the fuse F**2** has melted.



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## Background/Summary

TECHNICAL FIELD

[0001] This invention relates to the field of electrical propulsion of aircraft and more specifically relates to an electrical protection device for power supply cables of permanent-magnet motors. This device also has an application in hybrid platforms where, to ensure the propulsion of the aircraft, the electrical drive system complements a thermal drive system.

PRIOR ART

[0002] All-electrical propulsion systems use an entirely electrical propulsion line composed of an electrical energy source (in general batteries) and one or more electrical loads (in general electric machines) which, to minimize the mass, are often permanent-magnet motors.

[0003] Similarly, electrical distribution systems have incorporated electrical protections to protect the electrical installation (wiring, connectors) and which are designed to react so that the electrical energy source supplying a short circuit is disconnected.

[0004] Moreover, the electrical loads must be designed to never regenerate current into the network to guarantee the stability of this network and, if they are of a kind that regenerates (permanent-magnet motor or actuator for example), the energy must be dissipated either in the motor or the actuator, or in a dedicated resistive device.

[0005] This restriction entails either an over dimensioning of the load to manage the regeneration energy (with, in the long term, a risk of destruction of the system if the aerodynamic effect of the propeller driving the motor is too high) or an additional equipment item including an energy-dissipating resistance which manifests as an increase in mass and volume, which is particularly penalizing.

[0006] FIG. **1** schematically illustrates an electrical distribution architecture in the scenario of electrical propulsion of small platforms of VTOL (vertical take-off and landing) type for example.

[0007] It consists of a battery **10** supplying power to an electric motor **20** through an electrical distribution box **30**. The battery **10** contains its own protection elements, generally with a power contactor K**1** to galvanically isolate the cells of the battery and allow maintenance operations and a power fuse F**1** which melts in the event of a short circuit being created in the electrical circuit externally to the battery **10**. The electrical distribution box **30** generally includes its own power contactor K**2**.

[0008] In the event of a short circuit on the line between the motor **20** and the electrical distribution box **30**, for example due to a damaged cable, an electric arc supplied by the current mainly provided by the battery will be created (arc current **1**), melting the fuse F**1** and, under the effect of the violence of the phenomenon, damage the cable which tends to break (see FIG. **2**).

[0009] As shown in FIG. **3** illustrating the battery and motor currents according to the state of the fuse F**1**, if, when the fuse breaks, the motor is driven by its own inertia or by the effect of the aerodynamic forces exerted on its propeller, the motor becomes generative and will supply the short circuit with the arc current (arc current **2**). Nothing in the electric circuit then makes it possible to stop the electric arc which is sustained as long as the motor is running and until the level of damage is such that there is no more metallic material to maintain the plasma of the electric arc (this period being able to last for several seconds).

[0010] Thus, in an electrical system supplying power to a rotary machine for electrical or hybrid propulsion systems, there is a requirement for a dedicated protection device which can extinguish the electric arc by eliminating the current allowing it to be sustained.

SUMMARY OF THE INVENTION

[0011] This main aim of the invention is a device protecting an electrical distribution network with an active load of permanent-magnet rotary machine type by bypassing a fault current. Another aim is to avoid overuse of the electric motor or its associated control electronics. Yet another aim is to avoid the requirement of installation of large, heavy components in the high-voltage DC (HVDC) electrical distribution network on the load side.

[0012] These aims are achieved by a device for protecting against a short-circuit occurring on a high-voltage DC power supply line between a DC source and an active load, characterized in that it consists of a bypass circuit formed of a contactor K**3** and a fuse F**2** connected in series and set up parallel to the active load via a line independent of the high-voltage DC power supply line, the bypass circuit being configured such that most of the current passes through it once the fuse F**2** has melted.

[0013] Thus, the use of an independent bypass circuit without any resistive load allows for a simple embodiment with few components and which is not very penalizing in mass and volume.

[0014] Preferably, the fuse F**2** is of low rating (less than 32 A) and the independent line is of small cross-section (less than 6 mm.sup.2).

[0015] Advantageously, the DC source is a battery and the active load a permanent-magnet electric motor.

[0016] Preferably, the contactor K**3** and the fuse F**2** are assembled in an electrical distribution box disposed between the battery and the permanent-magnet electric motor.

[0017] The invention also relates to an electrical distribution network comprising a protection device as mentioned above and an aircraft equipped with such an electrical distribution network.

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## Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0018] Other features and advantages of this invention will become apparent from the description given below, with reference to the appended drawings which illustrate an exemplary embodiment thereof devoid of any limitation and on which:

[0019] FIG. **1** schematically illustrates a circuit for supplying power to an electric motor from a battery,

[0020] FIG. **2** illustrates the circuit of FIG. **1** following an electrical fault on the power supply cables of the electric motor,

[0021] FIG. **3** shows the creation of an electric arc current between the power supply cables following the electrical fault,

[0022] FIG. **4** shows a protection device including a bypass circuit of lower impedance in accordance with the invention,

[0023] FIG. **5** shows the creation of the electric arc current and its extinction of the electric arc in the circuit,

[0024] FIG. **6** shows the gradual disappearance of the fault by opening of the bypass circuit, and

[0025] FIG. **7** illustrates the command sequence of the contactor K**3** of the bypass circuit during the creation and extinction of the electrical fault.

DESCRIPTION OF THE EMBODIMENTS

[0026] The principle of the invention is based on the addition of a bypass circuit of the electric arc current configured to limit regeneration current of a kind that supplies the short-circuit and thus to extinguish this electric arc as quickly as possible.

[0027] FIG. **4** illustrates the architecture thus obtained. The battery **10** is shown supplying power to the electric motor **20** through the electrical distribution box **30**. The battery **10** incorporates the power contactor K**1** and the power fuse F**1** and the electrical distribution box **30** includes its own protection element, the power contactor K**2**. The two high-voltage DC power supply lines (−HVDC and +HVDC) between the motor **20** and the electrical distribution box **30** bear the references **32** and **34**. In electrical propulsion, these two power supply lines have voltages typically between 270 VDC and 540 VDC or more.

[0028] In accordance with the invention, the electrical distribution box **30** further includes, an assembly formed in series of a contactor K**3** and a fuse F**2**, both of low rating (i.e. an amperage of less than 32 A), and set up in parallel with the motor **20** via an independent line consisting of two cables of small cross-section (typically less than 6 mm.sup.2) **36** and **38**, the assembly forming a bypass circuit of the electric arc current of lower impedance than the plasma of the electric arc.

[0029] By installing these cutoff elements in the electrical distribution box to bypass and control the short circuit energy with components of small size and mass, since they are dimensioned solely for this function, the increase in volume or mass is kept to a minimum.

[0030] With this configuration and as shown in FIG. **5**, when the short circuit is detected and the voltage has disappeared downstream of the contactor K**2**, the contactor K**3** is commanded to close to draw off a part of the regeneration energy of the motor. Given that the electric arc needs a certain level of energy to be sustained (air ionization energy), it is easy for those skilled in the art to dimension the contactor K**3** and the fuse F**2** to match exactly what is needed to allow the extinction of the electric arc, the bypass circuit being designed such that most of the current passes through it.

[0031] Very quickly (at the most in a few ms), the electric arc no longer has enough current to sustain itself and is naturally extinguished (arc current **3***a*). All the current passes through the bypass circuit (arc current **3***b*) of lower impedance until the melting of the fuse F**2** (see FIG. **6**). The main power supply circuit coming from the motor is then isolated; the motor can continue to be driven and to develop a voltage across its terminals, but once the electric arc has been extinguished, it will not be able to reform since this main power supply circuit is then open.

[0032] FIG. **7** shows the appearance of the different currents in the electrical circuit according to the state of the contactor K**3** in the case of a high-voltage DC power supply of 540V in a permanent-magnet electric motor of 30 kW to 4.5 MW in power.

## Claims

**1**. A device for protecting against a short-circuit occurring on a high-voltage DC power supply line between a DC source and an active load, characterized in that it consists of a bypass circuit formed of a contactor K**3** and a fuse F**2** connected in series and set up parallel to the active load via a line independent of the high-voltage DC power supply line, the bypass circuit being configured such that most of the current passes through it until the melting of the fuse F**2**.

**2**. The protection device as claimed in claim 1, wherein the fuse F**2** is of low rating and the independent line is of small cross-section.

**3**. The protection device as claimed in claim 2, wherein the low rating corresponds to an amperage of less than **32**A.

**4**. The protection device as claimed in claim 2, wherein the small cross-section corresponds to a cross-section of less than 6 mm.sup.2.

**5**. The protection device as claimed in claim 1, wherein the DC source is a battery and the active load an electric motor.

**6**. The protection device as claimed in claim 5, wherein the electric motor is a permanent-magnet electric motor of 30 kW to 4.5 MW in power.

**7**. The protection device as claimed in claim 5, wherein the contactor K**3** and the fuse F**2** are assembled in an electrical distribution box disposed between the battery and the permanent-magnet electric motor.

**8**. An electrical distribution network including a protection device as claimed in claim 1.
**9**. An aircraft including an electrical distribution network as claimed in claim 8.