

System for supplying electrical energy to an on-board network of a submarine

5 The present invention relates to a system for supplying electrical energy to an on-board network of a submarine.

More particularly, the invention relates to such a system for supplying electrical energy that includes electrical energy storage means based on lithium batteries.

10 These electrical energy supply systems also include means for distributing this electrical energy intended for user loads, these energy distribution means including means for cutting off and isolating branches for connection of the user loads in particular in the event of a short-circuit.

Conventionally, the electrical energy storage means for these types of applications, for example for submarines, have been based on the use of lead batteries.

15 The protection equipment of the network was then dimensioned to be able to cut off short-circuit currents for example for this type of battery, these currents for example being able to reach up to 50 kA.

Yet the current trend is to use lithium batteries, and in particular lithium-ion batteries, as electrical energy storage means for the considered application type.

20 Yet the short-circuit currents of such lithium-ion batteries are much higher than the short-circuit currents of lead batteries.

Values are for example cited of 300 kA, i.e., values six times higher than the short-circuit currents of lead batteries.

The question then arises of how to cut off or interrupt such short-circuit currents with earlier designs of grid protection equipment.

25 The applicant has already proposed to reduce the short-circuit current in case of internal or external fault, by inserting the electrical energy storage system, for example a current clipper, into the power line of each branch in parallel making up the electrical energy storage system.

30 This clipper then makes it possible to limit the output current of each branch to a preconfigured value.

Thus, the short-circuit current is limited to a value compatible with the characteristics of the protection equipment of the network to which the battery is connected.

35 However, the development of this type of system with clippers is made complicated by the need for coordination between the different clippers of the different branches and knowledge of the impedance downstream from the clipper for proper operation of the solution.

Other solutions have been proposed, for example in document EP 1,641,066.

In this document, it is proposed to make the battery by branch in order to limit the short-circuit current.

The basic concept of this structure is then to limit the short-circuit current by only connecting a limited number of branches.

This document then proposes a system for managing connections and disconnections of the branches and charging the batteries.

This system requires a discharge circuit and a charge circuit uncoupled for example by diodes.

Furthermore, it requires complex management of the capacities of the different branches of the battery during the charging and discharging.

This management requires very precise knowledge of the charge states of the branches to avoid excessive exchange currents between branches during the connection and disconnection thereof.

Yet the precise knowledge of the charge state of a lithium battery is not simple.

Another solution for limiting and cutting off short-circuit currents for high-capacity lithium batteries, in particular for applications to submarines, was also presented in 2013.

This system proposes to insert, in case of fault on the network, a resistance into the power line of the branches of the batteries to attenuate the value of the current by dissipating a high heat energy.

A system of static switches, for example with semiconductor, makes it possible to deflect the current in this resistance in case of overcurrent detected at the output of the branches of the battery.

This system requires a water refrigeration device and demands a complete study of the protection and selectivity plan of the electrical network of each type of submarine where it is installed, in order to define the value of the resistance that will make it possible to limit the short-circuit current to a value allowing the operation of the electrical protection systems of the network.

Such a solution is for example described in document WO 2010/089338.

Thus, these different solutions are based on a limitation of the current at the output of the branches of the battery in order to guarantee the protection of the network and the selectivity of the network in case of fault, this limitation making it possible to ensure a current value supplied by the battery compatible with the characteristics of the protection equipment of the network.

However, it has been seen that such systems are complex and complicated to develop and implement.

The invention therefore aims to resolve these problems.

To that end, the invention relates to a system for supplying electrical energy, in particular to an on-board network of a submarine, of the type including electrical energy storage means based on lithium batteries and means for distributing this energy to user loads, these distributing means including means for cutting off and isolating branches for connection of the user loads in particular in the event of a short-circuit, characterized in that it includes:

- means for monitoring the evolution of the output current of the energy storage means in order to detect the occurrence of a short-circuit in the network,

- means for disconnecting the energy storage means from the rest of the network in the event of such a detection,

- means for connection to the network, means for generating a controlled short-circuit current, in order to trigger the operation of the cutoff and isolation means associated with the short-circuited branch, so as to isolate the latter from the rest of the network,

- means for disconnecting the short-circuit current generator from the network, and
- means for reconnecting the electrical energy storage means to the rest of the network.

According to other features of the device according to the invention, considered alone or in combination:

- the means for monitoring the evolution of the current delivered by the electrical energy storage means include means for analyzing the variation of this current over time in order to detect the appearance of a short-circuit once this variation exceeds a predetermined threshold;

- the electrical energy storage means include several branches in parallel, each of which include disconnection means;

- the disconnection means of the battery include controlled semiconductor switching members;

- the controlled semiconductor switching members comprise MOSFET transistors;

- the cutoff and isolating means of the branches for connection of the user loads comprise circuit breakers;

- the distribution means comprise at least one battery panel, at least one main panel and at least one secondary panel for distribution of electrical energy, connected between the energy storage means and the user loads;

- it further includes means for measuring isolation from the rest of the network after disconnection of the energy storage means, to avoid reconnecting these storage means to the network, if an isolation fault of the network is detected.

The invention will be better understood upon reading the following description, provided solely as an example, and in reference to the appended drawings, in which:

- figure 1 shows the general structure of a system for supplying electrical energy to an on-board network of a submarine,

5 - figures 2 to 7 illustrate the operation of such a system according to a first embodiment, and

- figures 8 to 16 illustrate the operation of such a system according to a second embodiment.

10 Figure 1 illustrates a system for supplying electrical energy to an on-board network of a submarine.

The latter includes electrical energy storage means based on lithium batteries, designated by general reference 1.

Indeed, these energy storage means include several battery branches in parallel, designated by general references 2, 3 and 4 for example in this figure 1.

15 Each of these branches is connected to a battery panel designated by general reference 5, through connection/disconnection means, respectively 6, 7 and 8.

As will be described in more detail hereinafter, these connection/disconnection means for example include controlled semiconductor switching members, for example MOSFET transistors, inserted into the branches.

20 Of course, other types of semiconductor switches may be considered.

The battery panel 5 also includes a circuit breaker designated by general reference 9.

This battery panel 5 is connected to at least one main electrical energy distribution panel, one of which is for example designated by general reference 10 in this figure 1.

25 This main electrical energy distribution panel 10 also for example includes several supply branches, each of which also includes a circuit breaker.

Thus, a branch is illustrated in this figure and it includes a circuit breaker designated by general reference 11 in this figure.

30 This supply branch makes it possible to connect this main electrical energy distribution panel 10 to at least one main electrical energy distribution panel, one of which is for example designated by general reference 12 in this figure.

35 This secondary electrical energy distribution panel 12 supplies branches for connection of user loads, for example the branch designated by general reference 13 in this figure, through branch cutoff and isolation means, also for example comprising a circuit breaker, designated by general reference 14.

A short-circuit generator, designated by general reference 15, is connected to the battery panel 5, through connecting means in switch form, designated by general reference 16 in this figure, controllable to close and open in order to connect or disconnect this generator 15 to or from the battery panel 5.

5 Such a supply structure is then relatively conventional inasmuch as the electrical energy storage means comprise lithium battery branches, connected to a battery panel, which in turn is connected through a cascade of main and secondary distribution panels, to branches for connection of user loads.

10 Each of these panels includes cutoff and isolation means for example based on circuit breakers, which are then calibrated based on their location in the supply cascade, to cut off the corresponding branch and isolate it from the rest of the network.

15 Unlike the systems of the state of the art, which proposed to limit the value of the short-circuit current at the output of the battery system, in the system according to the invention, it is proposed to disconnect the battery before it reaches its maximum short-circuit current value.

 To that end, cutoff means are then used comprising semiconductor members.

 To illustrate the problem previously mentioned regarding the value of the short-circuit current of the lithium batteries, the example may be considered of the case of placing several battery packs in parallel for applications of several hundred kilowatts/hour.

20 The short-circuit current of the system can reach extremely high values.

 For example, if one considers fifty packs of batteries in parallel, each of which can provide 4 kA, this is reflected by a short-circuit current of the system of about 20 kA.

25 Conventionally, a DC fuse according to the current technologies has a cutoff power of only 100 kA maximum and must be changed after blowout, which, in the mentioned applications, is not conceivable or at least is not acceptable, for accessibility and quick availability reasons of the energy after a fault.

 Likewise, a DC circuit breaker, which can be re-armed, also has a cutoff power of only about 100 kA maximum according to the current technologies.

30 Thus, these systems are not designed to be able to cut off short-circuit values beyond this value.

 This is why the invention proposes to act before the short-circuit current has reached its maximum value.

35 This makes it possible to limit the short-circuit current below values acceptable by the circuit breaker(s) or the fuse(s) as described, to guarantee the opening of the circuit while remaining in the zone in which the protection equipment is able to interrupt current.

Another aspect to be taken into account during the dimensioning of the protection of such a circuit, and in particular the calibration of the circuit breakers, is the selectivity of the different elements of the entire chain or cascade of circuit breakers or fuses of the electrical distribution of the system.

5 To that end, the short-circuit current must be mastered.

In particular, it must not be limited too low, failing which some circuit breakers may open too slowly, or even not open at all, which would be dangerous for the protection of the network in general and different components thereof in particular.

10 Additionally, the battery pack must not limit the short-circuit current to a level such that it does not provide a circuit breaker for the protections downstream of the electrical distribution in the network, failing which the entire installation will be faulty in the event of the slightest local fault.

To that end, in the supply system according to the invention, one uses means for monitoring the evolution of the output current of the energy storage means in order to detect
15 the occurrence of a short-circuit in the network.

In particular, these monitoring means analyze the variation of this current over time to detect the crossing of a limit trigger threshold characteristic of a short-circuit fault for example.

These monitoring means are designated by general reference 17 in figure 1.

20 These means for monitoring the current are then used to trigger the operation of the different means and members for protection of the system and the network, in order to provide the overall protection of the network, the selectivity of the triggering and the new provision of electrical energy optimally, which is important for this type of application.

Figures 2 to 7 show an example embodiment of such a system.

25 In these figures 2 to 7, one can see the various elements that have already been described in light of figure 1.

When a fault appears on one of the user load branches, for example the branch 13, as illustrated in figure 2, the means 17 for monitoring the evolution of the output current of the electrical energy storage means detect the appearance of this fault and in particular of
30 a short-circuit in the network.

This monitoring is for example an analysis of the variation of the current over time, conventionally.

In response to this detection of this short-circuit, the system triggers the disconnection of the electrical energy storage means from the rest of the network, by
35 opening the semiconductor switching members 6, 7 and 8, as illustrated in figure 3.

Once these semiconductor switching members are open, the system connects the short-circuit generating means 15 to the network and more specifically to the panel 5, as illustrated in figure 4, by closing the connecting means 16.

5 As previously indicated, these generating means are suitable for causing a controlled short-circuit current, making it possible to trigger the operation of the cutoff and isolation means associated with the short-circuited faulty branch, so as to isolate the latter from the rest of the network, as illustrated in figure 5.

Indeed, the chain or cascade of circuit breakers protecting the network, installed at different levels thereof, is designed and calibrated to make it possible to obtain the
10 aforementioned selectivity, for opening faulty branches like the branch 13.

This then makes it possible to isolate the branch and the fault relative to the rest of the supply circuit.

Once this fault is isolated, the system opens the connecting means 16 of the short-circuit generator to disconnect it from the network.

15 The circuit breaker 14 of the faulty user load branch for example 13 being open, it is then possible to reconnect the battery to the network to make the electrical energy available again, by re-closing the semiconductor switching members 6, 7 and 8, as illustrated in figure 7.

This makes it possible to reestablish the supply of the network with the exception of
20 the faulty branch 13.

One can see that such a structure has a certain number of advantages.

Indeed, by monitoring the evolution of the output current of the electrical energy storage means, in particular, by analyzing the variation of this current over time to detect the appearance of a short-circuit, once this variation exceeds a predetermined threshold, it
25 is possible to anticipate the operation of the security and protection means of the network.

In response, the system first causes the disconnection of the battery.

Then the short-circuit generating means are connected to the network to cause the triggering of the protection circuit breaker of the faulty user load branch.

This makes it possible to isolate this fault from the rest of the network.

30 The short-circuit generator is next disconnected from the network and it is possible to reconnect the battery to this network to make the electrical energy available.

In figures 8 to 16, an embodiment variant of this system is illustrated, which further incorporates means 20 for measuring isolation of the rest of the network after disconnection of the electrical energy storage means, to avoid dimensioning the means 16 so that they
35 can support the short-circuit current of the generating means 15, upon closing.

The general operation of this embodiment of the system according to the invention is very close to that which was described previously.

Indeed, during the detection of the appearance of a fault, figure 8, the system disconnects the battery from the network, figure 9.

5 Then, as illustrated in figure 10, the system opens the circuit breaker 9 of the battery panel 5, to make it possible, figure 11, for the means 20 to measure the isolation of the rest of the network and to determine whether it is possible to continue the unfolding of the process of isolating the fault as described.

10 If this is the case, in figure 12, the short-circuit generator 15 is connected to the network by the means 16 and the circuit breaker 9 of the battery panel 5 is closed, figure 13.

This then makes it possible to cause the opening of the circuit breaker associated with the faulty branch as illustrated in figure 14, to isolate the latter from the rest of the network.

15 The disconnection of the short-circuit current generator is illustrated in figure 15 and the reconnection of the battery in figure 16.

One can therefore see that in the system according to the invention, semiconductor means are used based on MOSFET transistors for example, at the output of each branch of the battery, the functionality of which is to open quickly for example in a time shorter than 20 100 microseconds, if an excessive climb of the current is detected.

This then makes it possible to disconnect the battery before the latter has established its nominal short-circuit current value.

A short-circuit current generator is then connected to the network.

25 Its function is to supply the short-circuit current sufficient to eliminate the short-circuit by opening the protection equipment of the faulty branch.

Once the fault is eliminated, the short-circuit current generator is isolated from this network and the battery is re-connected to the network.

Different short-circuit current generator technologies can be considered, for example an electromechanical technology.

30 The connecting means of the short-circuit current generator can also be based on controlled semiconductor switching technology.

Of course, still other embodiments can be considered.

CLAIMS

1.- A system for supplying electrical energy, in particular to an on-board network of a submarine, of the type including electrical energy storage means (1) based on lithium batteries and means (5, 10, 12) for distributing this energy to user loads of the network, these distributing means including one or more means (9, 11, 14) for cutting off and isolating one or more branches (13) for connection of the user loads of the network in particular in the event of a short-circuit, characterized in that it includes:

- means (17) for monitoring the evolution of output current of the energy storage means in order to detect the occurrence of a short-circuit in the network,
- means (6, 7, 8) for disconnecting the energy storage means from a part of the network in the event of such a detection,
- means (15) for generating a controlled short-circuit current, in order to trigger the operation of the cutoff and isolation means (14) associated with a short-circuited branch (13) among the one or more branches, so as to isolate the short-circuited branch from said part of the network,
- means (16) for connection to the network for the means (15) for generating a controlled short-circuit current,
- means (16) for disconnecting the means (15) for generating a controlled short-circuit current from the network, and
- means (6, 7, 8) for reconnecting the electrical energy storage means to said part of the network.

2.- The supply system according to claim 1, characterized in that the means (17) for monitoring the evolution of the current delivered by the electrical energy storage means include means for analyzing the variation of this current over time in order to detect the appearance of a short-circuit once this variation exceeds a predetermined threshold.

3.- The supply system according to claim 1 or 2, characterized in that the electrical energy storage means (1) include several branches in parallel (2, 3, 4), each of which include disconnection means (6, 7, 8).

4.- The supply system according to any one of the preceding claims, characterized in that the disconnection means (6, 7, 8) of the battery include controlled semiconductor switching members.

5.- The supply system according to claim 4, characterized in that the controlled semiconductor switching members comprise MOSFET transistors.

6.- The supply system according to any one of the preceding claims, characterized in that the cutoff and isolating means of the branches for connection of the user loads comprise circuit breakers (14).

7.- The supply system according to any one of the preceding claims, characterized in that the distribution means comprise at least one battery panel (5), at least one main panel (10) and at least one secondary panel (12) for distribution of electrical energy, connected between the energy storage means and the user loads.

8.- The supply system according to any one of the preceding claims, characterized in that it further includes means (20) for measuring isolation from said part of the network after disconnection of the energy storage means, to avoid reconnecting these storage means to the network, if an isolation fault of the network is detected.