

Safety static relay cell and associated assembly of static relay cells

5 The present invention relates to a safety static relay cell of the type comprising an input terminal and an output terminal, at least one main switch in series with the input terminal and the output terminal, and a control unit configured to control the or each main switch independently.

The invention applies to the field of electronic safety systems, in particular to electronic safety systems for railway signaling.

10 Static relays are used in electronic safety systems as output switches. These are switching devices made in particular with semiconductor-based electronic components. These relays are said to be static because they do not include mechanical or electromechanical components. They make it possible to control the passage of a high-intensity current with a low-power control signal.

15 The advantage of such static relays is the durability of the components used, the latter being able to support a large number of switches and electromechanical safety relays. These also generate less heat and their opening speed is more easily controllable.

20 Typically, these static relays comprise switches, such as transistor-based switches, for example insulated-gate field-effect transistors (MOSFET).

Document CN 105946902 discloses an output using dynamic control signals to control switches, such as transistors, via two control units.

25 However, by using such components, the transistors subject to a high voltage can, even in the off state, allow a weak current to pass, due to the wear or malfunctions of the semiconductor components. Beyond a certain value, a charge could be wrongly controlled, causing a safety problem.

30 The invention aims to propose a safety static relay cell and an associated assembly of static relay cells making it possible to detect wear or a failure of its component switches. The safety static relay cells and the associated assembly of static relay cells must be able to continue to perform their cutoff function, even in case of failure of a component.

To that end, the invention relates to a device of the aforementioned type, characterized in that it comprises a leakage current detector, able to detect a leakage current in the or each main switch.

35 Such a static relay cell makes it possible to detect the presence of a leakage current through its component switches.

According to certain embodiments, the safety static relay cell includes one or several of the following features:

- the leakage current detector comprises a module for measuring the leakage voltage, the leakage voltage representing the leakage current, a periodic voltage signal generator, able to generate a comparison signal, a comparator able to compare the value of the leakage voltage and the value of the comparison signal, and to give, as output, a leakage current detection signal having a duty factor representative of the leakage current,

- the control unit comprises a reception module coupled at its output to the comparator in order to receive the leakage current detection signal, and a computing module able to compute the duty factor of the leakage current detection signal,

- the periodic signal generator is a sawtooth signal generator, the generated comparison signal being a sawtooth signal,

- the periodic signal generator comprises a DC current source, a capacitor and a secondary switch, the DC current source being able to charge the capacitor, the secondary switch being able to short-circuit the capacitor when it is in the closed position in order to cause the discharge of the capacitor, and being controlled by a discharge control signal transmitted by the control unit,

- the module for measuring the leakage voltage comprises a voltage divider bridge, the measuring module being connected to the terminals of the main switch or of the assembly of the main switches,

- the cell comprises at least two main switches in series, and

- each main switch includes a transistor and a diode connected in antiparallel with the transistor, and wherein at least one transistor is a field-effect transistor, preferably an insulated-gate field-effect transistor.

The invention also relates to an assembly of static relay cells of the type comprising a first static relay cell and a second static relay cell in series, each cell being of the aforementioned type, wherein the output terminal of the first cell is connected to the input terminal of the second cell, the control units of each cell being able to communicate with one another.

According to certain embodiments, the assembly of static relay cells further comprises a third static relay cell, a fourth static relay cell and a fifth static relay cell, each cell being of the aforementioned type and wherein the input terminal of the first cell is connected to the input terminals of the third cell and the fifth cell, the output terminal of the third cell is connected to the output terminal of the fifth cell and the

input terminal of the fourth cell, and the output terminal of the second cell is connected to the output terminal of the fourth cell, the control units of each cell being able to communicate with one another.

These features and advantages of the invention will appear more clearly upon reading the following description, provided solely as a non-limiting example, and done in reference to the appended drawings, in which:

- [Fig 1] figure 1 is a schematic illustration of an assembly of static relay cells according to the invention, comprising two safety static relay cells in series,

- [Fig 2] figure 2 is a schematic illustration of a safety static relay cell of figure 1, in particular comprising two main switches in series between an input terminal and an output terminal, a leakage current detector, and for each switch, a control module,

- [Fig 3] figure 3 is a graph showing an exemplary evolution over time of the values of a comparison signal and leakage current detection signals, according to different operating cases of the cell of figure 2, and

- [Fig 4] figure 4 is a schematic illustration of a variant of the assembly of static relay cells of figure 1.

Figure 1 shows an assembly 5 of static relay cells comprising a first safety static relay cell 6 and a second safety static relay cell 7, which are preferably identical, in series. Each of the cells 6 and 7 comprises an input terminal 16 and an output terminal 18, the output terminal 18 of the cell 6 being connected to the input terminal 16 of the cell 7. Each cell 6, 7 comprises two main switches 12 connected in series between its input terminal 16 and its output terminal 18.

In a variant, each cell 6, 7 comprises a single switch 12 connected between the input terminal 16 and the output terminal 18.

The architecture of a safety static relay cell 6 or 7 is disclosed hereinafter, in light of figure 2.

The cell 6 is able to circulate a current I from the input terminal 16 toward the output terminal 18, when the switches 12 are in the closed position.

Hereinafter, all of the voltages are considered in reference to the potential of the output terminal 18.

The switches 12 are each controlled independently by a control unit (command and read) 20 also advantageously able to recover the state of the switch among a closed state and an open state. More specifically, for each switch 12, the control unit (command and read) 20 comprises a control module 22 configured to

generate and send the corresponding switch 12 a control signal for the switching of the switch 12. Advantageously, each control signal is a dynamic signal.

Each switch 12 advantageously comprises a transistor 26 and a diode 28 that are connected in antiparallel with the transistor 26. The transistors 26 are for example field-effect transistors, preferably insulated-gate field-effect transistors. In this case, the drain of a first transistor 26 is connected to the input terminal 16, its source is connected to the drain of the second transistor 26, and the source of the second transistor 26 is connected to the output terminal 18. For each transistor 26, the corresponding control module 22 is connected to the transistor 26 by its gate.

Furthermore, the cell 6 comprises a leakage current detector 30 including two inputs 31 and 32 connected to the terminals of the assembly of the two switches 12 and an output 33 connected to the control unit (command and read) 20. The detector 30 is able to detect a leakage current potential circulating in the switches 12, in particular when at least one of the switches 12 is in the open position.

The detector 30 includes a measuring module 34 comprising two inputs connected to the inputs 31 and 32 of the detector 30 and an output. It is able to supply a leakage voltage V_+ as output, the leakage voltage V_+ being representative of the leakage current.

The detector 30 further includes a comparator 38 comprising two inputs and an output. It is connected by one of its inputs to the output of the measuring module 34 and by its output to the output 33 of the detector 30.

The detector 30 further includes a periodic comparison voltage signal generator 42 connected to the other input of the comparator 38. The generator 42 is controlled by the control unit (command and read) 20. It is able to generate and supply, through an output, to the comparator 38, a comparison signal V_- , the comparison signal V_- being a periodic voltage signal.

In the example of figure 2, the detector 30 includes an insulated power supply 46 connected to the measuring module 34 and the generator 42 and able to supply electricity to the latter.

In a variant that is not shown, the detector 30 includes two insulated power supplies, one being connected to the measuring module 34, the other being connected to the generator 42.

For example, the measuring module 34 is a voltage divider bridge comprising two resistances 50 and 52 connected in series between one of the inputs of the measuring module 34 and a DC voltage source 56, and a diode 60 connected between a node 62 between the resistances 50 and 52, and the other input of the

measuring module 34. The node 62 is connected to the output of the measuring module 34.

The DC voltage source 56 is supplied by the power supply 46 and is able to supply a reference voltage V_{REF} .

5 The diode 60 is oriented such that it is an off state when the switches 12 are closed and the current I has a positive intensity.

10 The generator 42 is for example a sawtooth signal generator, the generated comparison signal V_- being a sawtooth signal. It comprises a capacitor 66 connected to a DC current source 70, and a secondary switch 74 connected in parallel to the capacitor.

The DC current source 70 is supplied by the power supply 46 and is able to charge the capacitor 66 with a DC voltage. The terminal of the positively charged capacitor 66 is connected to the output of the generator 42.

15 The control unit (command and read) 20 is configured to control the switching of the switch 74. More specifically, the control unit (command and read) 20 comprises a control module 78 for controlling the generator 42, configured to generate and send the switch 74 a discharge control signal V_{DC} .

20 The switch 74 for example comprises a field-effect transistor 82, preferably an insulated-gate field-effect transistor. In this case, the drain and the source of the transistor 82 are placed so as to short-circuit the capacitor 66 in order to cause the discharge of the capacitor 66, when the transistor 82 is on, and the gate of the transistor 82 is connected to the module 78.

25 The comparator 38 is able to compare the value of the leakage voltage V_+ and the value of the comparison signal V_- , and to give, as output, a leakage current detection signal V_{OUT} having a duty factor α representative of the leakage current.

The control unit 20 is able to recover the leakage current detection signal V_{OUT} at the output 33 of the detector 30. More specifically, the control unit (command and read) 20 comprises a reception module 88 connected to the output 33 of the detector 30 and able to recover the leakage current detection signal V_{OUT} .

30 Additionally, the module 78 is connected to the output 33 of the detector 30 and is able to recover the leakage current detection signal V_{OUT} .

The reception module 88 is connected to the module 78 and is able to recover the discharge control signal V_{DC} .

35 The control unit (command and read) 20 further comprises a calculating module 92 connected to the reception module 88 and configured to calculate the duty factor α of the leakage current detection signal V_{OUT} , the value of the duty factor

α being representative of the leakage current, as well as the duty factor of the discharge control signal V_{DC} . It is further able to store the calculated duty factors, and to vote on different calculated duty factor values.

A duty factor refers to the ratio between the time where the signal is in the high state over a period and the total time of a period.

The operation of the cell 6 will now be disclosed using figure 3, showing an exemplary evolution over time of the discharge control signal V_{DC} on the graph 200, of the comparison signal V_{-} on the graph 202, and of the leakage current detection signal V_{OUT} for three operating cases respectively on the graphs 204, 206 and 208.

The cell 6 typically comprises two operating states: a closed state when the two switches 12 are closed and the current I circulates from the input terminal 16 to the input terminal 18, and an open state when at least one of the switches 12 is open.

The graph 200 shows the evolution over time of the discharge control signal V_{DC} generated by the module 78. When it is in the high state, it controls the closing of the switch 74 and the discharge of the capacitor 66. The discharge control signal V_{DC} is a periodic signal with a period $t_3 - t_0$. Over the first period, it is in the high state between two instants t_2 and t_3 .

Hereinafter, the behavior of the cell 6 is examined over the first period, that is to say, between an initial instant t_0 and the instant t_3 , the behavior being identical of the other periods.

The graph 202 shows the evolution over time of the comparison signal V_{-} generated by the generator 42. At the initial instant t_0 , the capacitor is discharged and the value of the comparison signal V_{-} is nil. Until the instant t_2 , the current source 70 charges the capacitor 66 with a current of constant intensity and the value of the comparison signal V_{-} increases linearly with a slope that is a function of the intensity of the current generated by the current source 70 and the electrical capacitance of the capacitor 66, until reaching a value V_{-max} at the instant t_2 . At the instant t_2 , the module 78 controls the closing of the switch 74, which primes the discharge of the capacitor 66, and the value of the comparison signal V_{-} is then nil between the instants t_2 and t_3 .

The graph 202 also shows, in dotted lines, values of the leakage voltage V_{+} for different operating scenarios. The leakage voltage V_{+} assumes a value V_{+a} in a case a where the two switches 12 are open and no leakage current is observed. It assumes a value V_{+c} in a case c where the two switches 12 are closed. It assumes a value V_{+b} in a case b where one of the switches 12 is closed and the other is open

and observes a leakage current, or where both switches 12 are open and both observe a leakage current.

The graphs 204, 206 and 208 show the evolution over time of respective signals V_{OUTa} , V_{OUTb} and V_{OUTc} corresponding to the leakage current detection signal V_{OUT} for the respective cases a, b and c. The signal V_{OUTa} , or respectively V_{OUTb} or V_{OUTc} , is in the high state when the leakage voltage V_+ is greater than the comparison signal V_- , that is to say, between the instant t_0 and an instant t_{1a} , or respectively t_{1b} or t_{1c} , as well as between the instant t_2 and the instant t_3 , and in the low state otherwise, that is to say, between the instants t_{1a} , or respectively t_{1b} or t_{1c} , and t_2 .

In order to detect that a switch 12 is defective and allowing a leakage current to pass, the control unit (command and read) 20 switches one of the switches 12 to the open state and the other to the closed state, the switch 12 in the open state being that which is tested. The reception module 88 then recovers the leakage current detection signal V_{OUT} and calculates its duty factor α_b . It performs the same operation to test the other switch 12.

The calculating module 92 then calculates the duty factors α_b corresponding to these two tests. The duty factors α_b calculated for each of the tested switches 12 are compared to duty factors calculated and stored by the calculating module 92 when the two switches 12 are open α_a and closed α_c and the duty factor of the discharge control signal V_{DC} , in order to detect a leakage current potential, in particular when one of the duty factors α_b is weaker than α_a .

Advantageously, the reception module 88 recovers the discharge control signal V_{DC} , so as to verify that the signal is generated correctly.

In case of failure of one of the switches 12 of a cell 6, the latter is left not controlled by the control unit (command and read) 20 and in particular closed, and the state change of the cell 6 is ensured only by the other switch 12.

It will then be understood that a cell 6 comprising two switches 12 makes it possible to have a higher operating safety than a cell 6 comprising a single switch 12.

In case of failure of one of the two switches 12, the cell 6 is considered to have failed.

The assembly 5 is in a closed state when the cells 6 and 7 are in the closed state, and in an open state when at least one of the cells 6 and 7 is in the open state.

When one of the cells of the assembly 5 has failed, it is left in the closed state and the opening and closing of the composite architecture 5 is ensured by the other cell of the assembly 5. A maintenance operation on the faulty cell will then be launched.

5 Figure 4 shows another embodiment of the assembly 105 of static relay cells comprising a first cell 106, a second cell 107, a third cell 108, a fourth cell 109 and a fifth cell 110, all of which are safety static relay cells.

10 Each of the cells 106 to 110 comprises an input terminal and an output terminal. The first and second cells 106 and 107 are connected in the same way as the first and second cells 6 and 7 of the assembly 5. The input terminal of the first cell 106 is further connected to the input terminals of the third cell 108 and the fifth cell 110, the output terminal of the third cell 108 is connected to the output terminal of the fifth cell 110 and the input terminal of the fourth cell 109, and the output terminal of the second cell 107 is connected to the output terminal of the fourth cell 109.

15 The assembly 105 is in a closed state when the cells 106 and 107 are closed, or when the cell 109 and at least one of the cells 108 and 110 are closed. It is in an open state when at least one of the cells 106 and 107 is open, and the cell 109 or the cells 108 and 110 are open.

20 Thus, in case of failure of one of the cells 106 to 110, it is left in the closed state, and the opening and closing of the assembly 105 can be ensured by the other cells.

25 It will then be understood that the embodiment of the assembly 105 makes it possible to have a greater availability than the embodiment of the composite architecture 5. Indeed, the assembly 105 can make it possible to ensure the operating safety even in case of failure of 2, or even 3 cells, as long as 2 cells in series do not fail simultaneously.

CLAIMS

1. A safety static relay cell (6) comprising:
 - an input terminal (16) and an output terminal (18),
 - at least one main switch (12) in series with the input terminal (16) and the output terminal (18), and
 - a control unit (20) configured to control the at least one main switch independently (12), characterized in that it comprises a leakage current detector (30), which configured to detect a leakage current in the at least one main switch (12), the leakage current detector (30) comprising:
 - a measuring module (34) configured to measure a leakage voltage (V_+), the leakage voltage (V_+) being representative of the leakage current,
 - a periodic voltage signal generator (42), which configured to generate a comparison signal (V_-), and
 - a comparator (38) which can compare the value of the leakage voltage (V_+) and the value of the comparison signal (V_-), and to give, as output, a leakage current detection signal (V_{OUT}) having a duty factor (α) representative of the leakage current.
2. The cell (6) according to claim 1, wherein the control unit (20) comprises a reception module (88) coupled at its output to the comparator (38) in order to receive the leakage current detection signal (V_{OUT}), and a computing module (92) which configured to compute the duty factor (α) of the leakage current detection signal (V_{OUT}).
3. The cell (6) according to claim 1 or 2, wherein the periodic signal generator (42) is a sawtooth signal generator, the generated comparison signal (V_-) being a sawtooth signal.
4. The cell (6) according to claim 3, wherein the periodic signal generator (42) comprises a DC current source (70), a capacitor (66) and a secondary switch (74), the DC current source (70) being able to charge the capacitor (66), the secondary switch (74) being able to short-circuit the capacitor (66) when it is in the closed position in order to cause the discharge of the capacitor (66), and being controlled by a discharge control signal (V_{DC}) transmitted by the control unit (20).
5. The cell (6) according to any one of claims 1 to 4, wherein the module (34) for measuring the leakage voltage (V_+) comprises a voltage divider bridge (50, 52), the measuring module being connected to the terminals of the main switch or of the assembly of the main switches.

6. The cell (6) according to any one of the preceding claims, wherein the cell (6) comprises at least two main switches (12) in series.

7. The cell (6) according to any one of the preceding claims, wherein each main switch (12) includes a transistor (26) and a diode (28) connected in antiparallel with the transistor (26), and wherein at least one transistor (26) is a field-effect transistor, preferably an insulated-gate field-effect transistor.

8. An assembly (5, 105) of static relay cells, characterized in that it comprises a first static relay cell (6, 106) and a second static relay cell (7, 107) in series, each cell being according to any one of the preceding claims, wherein the output terminal (18) of the first cell (6, 106) is connected to the input terminal (16) of the second cell (7, 107), the control units (20) of each cell being able to communicate with one another.

9. The assembly (5, 105) of static relay cells according to claim 8, further comprising a third static relay cell (108), a fourth static relay cell (109) and a fifth static relay cell (110), each cell being according to any one of claims 1 to 7, wherein:

- the input terminal (16) of the first cell (6, 106) is connected to the input terminals (16) of the third cell (108) and the fifth cell (110),

- the output terminal (18) of the third cell (108) is connected to the output terminal (18) of the fifth cell (110) and the input terminal (16) of the fourth cell (109), and

- the output terminal (18) of the second cell (7, 107) is connected to the output terminal (18) of the fourth cell (109),

the control units (20) of each cell being able to communicate with one another.