

# FUNCTIONALLY SAFE SWITCHING VALUE OUTPUT MODULE AND DIAGNOSTIC PROCESSING METHOD

## CROSS-REFERENCE TO RELATED APPLICATIONS

5 [0001] This application claims priority to Chinese Patent Application No. 202011587822.6, titled "FUNCTIONALLY SAFE SWITCHING VALUE OUTPUT MODULE AND DIAGNOSTIC PROCESSING METHOD", filed on December 29, 2020 with the China National Intellectual Property Administration, which is incorporated herein by reference in its entirety.

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## FIELD

[0002] The present disclosure relates to the technical field of industrial automatic control, in particular to a switching value output module having functional safety, and a method for diagnosing and processing a fault.

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## BACKGROUND

[0003] A system for controlling a switching value output on an industrial site is one of the most important input components in industrial control systems such as DCS and SIS. According to a conventional technology, a 2003 architecture is adopted in most of switch value output modules concerning about functional safety. The 2003 architecture is usually constructed by a large amount of hardware. A product designed based on such architecture generally has a high cost and a large dimension. Therefore, the product based on the 2003 architecture is limited in practical applications due to requirements for installation space and cost.

20 [0004] As the technology develops, designs of SIS products tend to achieve a smaller volume and lower cost. Architectures known as 1002D, 1002 or 1001D are adopted in more and more designs.

[0005] A design based on the 1002D architecture is as shown in Figure 1. In the design, two channels and two CPUs are disposed to control outputs and read diagnostic data of the channels independently. However, in this technical solution, necessary information interaction

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between the two channels is absent. Assuming that one of the channels fails and cannot switch off an output circuit, a CPU unit of the other one of the channels, which has no fault, is unable to obtain diagnostic information and switch off the failed circuit to lead to safety. Therefore, potential risk exists in the design in which two channels are independent from each other and lack interactions there between.

**[0006]** A design based on the 1001D architecture is as shown in Figure 2. In the design, a diagnostic unit is added on the basis that one CPU unit controls one output unit. Two switches are controlled by the diagnostic unit and the output unit, respectively, and the two switches are connected in series. The diagnostic unit can perform diagnosis on the output unit and send information to the CPU unit, and can switch off a switch controlled by the diagnostic unit when a fault occurs, so as to be safety-oriented. However, a potential risk exists in the module in a case that a fault occurs to the diagnostic unit itself and the diagnostic unit cannot provide reliable diagnostic information to the CPU unit.

## SUMMARY

**[0007]** An objective of the present disclosure is to solve a problem that, in a switching value output module, two output channels cannot interact with each other, and a diagnostic unit, when fails, cannot provide reliable diagnostic information to a CPU unit. Interactive diagnosis between two output circuits is enabled, and outputs can be switched off by interrupting communication between the CPU unit and the output circuit. Therefore, safety performance of the module is improved, the module is ensured to be safety-oriented, and development cost and a product volume are reduced while satisfying functional safety.

**[0008]** According to a first aspect of the present disclosure. A switching value output module having functional safety is provided. The switching value output module includes a CPU unit, a first output unit coupled to the CPU unit, and a second output unit coupled to the CPU unit. The CPU unit is configured to send communication data to the first output unit or the second output unit, and output fault information based on received diagnostic data fed back from the first output unit or the second output unit, to control the first output unit or the second output unit to be safety-oriented. The first output unit or the second output unit includes at least a logic circuit, a driving circuit, a check-back circuit, an output switch, which are coupled in the above-listed sequence, and a supply voltage detection circuit coupled to the

driving circuit, where an output switch SW1 of the first output unit and an output switch SW2 of the second output unit are connected in series. The logic circuit is configured to receive, through an input terminal, the communication data sent by the CPU unit, output the communication data to the driving circuit, and receive a fault signal outputted by the supply voltage detection circuit of the other one of the first output unit and the second output unit, and maintain or interrupt communication between the CPU unit and the driving circuit. The driving circuit is configured to: receive the communication data sent by the CPU unit and perform verification on the communication data, switch on or switch off the output switch based on information of the communication data after the verification succeeds, and collect an output state of the check-back circuit and line diagnose information of the output switch. The check-back circuit is configured to detect an output state of the output switch, and send the output state of the output switch to the driving circuit. The supply voltage detection circuit is configured to detect a supply voltage of the driving circuit, and send, based on the detected voltage, a control signal to the logic circuit of the other one of the first output unit and the second output unit.

**[0009]** In an embodiment, the output unit further includes a monitoring circuit coupled to the driving circuit, and the monitoring circuit is configured to receive a signal outputted by the driving circuit after the verification, and output a control signal to control the driving circuit to output an ON or OFF signal for switching on or switching off the output switch.

**[0010]** In an embodiment, the driving circuit is configured to: output no pulse signal to the monitoring circuit, in a case that the verification fails, to control the monitoring circuit to output a low level signal to the driving circuit; and send a pulse signal to the monitoring circuit, in a case that the verification succeeds, to maintain an output state of the monitoring circuit unchanged.

**[0011]** In an embodiment, the monitoring circuit includes, but not limited to, a mono-stable trigger circuit.

**[0012]** In an embodiment, the logic circuit includes at least a logic gate chip and a logic device; the logic gate chip is configured to receive, through an input terminal, the communication data sent by the CPU unit, and output the communication data converted by the logic gate chip to the driving circuit; and the logic device is configured to receive a power supply fault signal from the driving circuit of the other one of the first output unit and the

second output unit, to switch on or switch off the logic gate chip of the output unit.

**[0013]** In an embodiment, the CPU unit is further configured to send a signal indicating an internal fault of the CPU unit to the logic device, to interrupt, through the logic gate chip, communication between the CPU unit and the driving circuit.

5 **[0014]** In an embodiment, each of the output switch SW1 and the output switch SW2 has a capability of detecting a load current.

**[0015]** In an embodiment, the driving circuit includes, but not limited to, a logic chip CPLD.

10 **[0016]** According to a second aspect of the present disclosure, a method for diagnosing and processing a fault, based on the switching value output module having functionally safety is provided. The method includes at least diagnosing and processing a fault of the output switch, which includes: S1, controlling an output state of the output switch SW1 and an output of the output switch SW2 periodically based on a preset state; S2, reading back an output state detected by the check-back circuit; and S3, making a comparison between an actual  
15 check-back result read back in a single cycle and a preset check-back result, and determining, based on a result of the comparison, whether to switch off outputs of the output switch SW1 and the output switch SW2.

**[0017]** In an embodiment, the S3 includes: S31, repeating S1 to S3 to perform diagnosis on the output state of the output switch, in a case that the actual check-back result of the CPU  
20 unit is the same as the preset check-back result; and S32, controlling, by the CPU unit, both the driving circuit of the first output unit and the driving circuit of the second output unit to switch off outputs of the output switch SW1 and the output switch SW2, in a case that the actual check-back result of the CPU unit is not the same as the preset check-back result.

**[0018]** In an embodiment, the method further includes diagnosing and processing a  
25 communication fault, which includes: controlling an output of the output switch, based on the verification on the communication data between the CPU unit and the driving circuit, and based on the information of the communication data after the verification succeeds.

**[0019]** In an embodiment, the method further includes diagnosing and processing an  
30 internal fault of the CPU unit, which includes: sending, to the logic circuit, a fault signal based on an internal software or hardware fault of the CPU unit, to maintain or interrupt the

communication.

[0020] In an embodiment, the method further includes diagnosing and processing a fault of a power supply, which includes: interrupting, based on a detected fault of the power supply, communication between the CPU unit and the driving circuit of the other one of the first output unit and the second output unit, to control the output of the output switch.

[0021] In an embodiment, the method further includes diagnosing and processing a line fault, which includes: making a comparison between a load current, which is detected by the output switch and read back by the CPU unit, and a preset threshold, and controlling an output of the output switch based on a result of the comparison.

[0022] Beneficial technical effects of the present disclosure are listed below.

[0023] 1. A master control CPU unit and the two output circuits in the 1002 architecture constitute the 1001D architecture in general according to the present disclosure. A reduced dimension and a lower cost can be achieved while ensuring the functional safety. Therefore, application in confined spaces or harsh environments can be satisfied.

[0024] 2. By adding interactive diagnostic measures between the two output circuits, it is ensured that the output switch in one of the channels can be switched off in a case that the other one of the channels fails and the output switch cannot be switched off. Therefore, the safety performance of the product is further improved.

[0025] 3. A safety-oriented mechanism of interrupting communication between the CPU unit and the output unit, and then switching off an output through the monitoring circuit is added, which ensures that the output can be switched off in a case that the CPU unit is unable to control the output directly.

[0026] 4. Faults of multiple components in the module can be diagnosed and processed. The method is simple and easy to implement, and satisfies the functional safety.

## BRIEF DESCRIPTION OF THE DRAWINGS

[0027] Accompanying drawings illustrated herein are used to provide a further understanding of the present disclosure and constitute a part of the present disclosure. Schematic embodiments of the present disclosure and descriptions thereof are used to explain

the present disclosure, and do not constitute an undue limitation to the present disclosure.

[0028] Figure 1 illustrates a structural block diagram of a 1OO2D-architected digital value output circuit having functional safety.

5 [0029] Figure 2 illustrates a structural block diagram of a 1OO1D-architected switching value output module having functional safety and a high diagnostic coverage.

[0030] Figure 3 illustrates a schematic diagram of 1OO2 architecture.

[0031] Figure 4 illustrates a schematic block diagram of a switching value output module having function safety according to an embodiment of the present disclosure.

10 [0032] Figure 5 illustrates a schematic flowchart of a method for diagnosing and handling a fault of an output switch according to an embodiment of the present disclosure.

## **DETAILED DESCRIPTION OF THE EMBODIMENTS**

15 [0033] For further understanding of the present disclosure, preferred embodiments of the present disclosure are described hereinafter in conjunction with embodiments. However, it should be understood that the description is provided only to further illustrate features and advantages of the present disclosure, and is not intended to limit the claims of the present disclosure.

[0034] Before describing embodiments of the present disclosure, proper nouns are firstly explained below.

20 [0035] The 1OO2 architecture includes two channels disposed side-by-side. Each of the two channels is capable of performing a safety function. In this architecture, failure of one of the channels is allowed, without affecting execution of the safety function. The safety function fails only in a case that both the channels are in dangerous and fail. A schematic diagram of the architecture is as shown in Figure 3.

25 [0036] Based on the above explanation, the technical solutions of the present disclosure are described in detail below.

[0037] Reference is made to Figure 4. According to an embodiment of the present disclosure, a switching value output module having functional safety includes a CPU unit, a first output unit coupled to the CPU unit, and a second output unit couple to the CPU unit.

The CPU unit is configured to: send communication data to the first output unit or the second output unit; output fault information based on received diagnostic data fed back from the first output unit or the second output unit, to control the first output unit or the second output unit to be safety-oriented. The first output unit or the second output unit includes at least a logic circuit, a driving circuit, a check-back circuit, and an output switch, which are coupled in the  
5 above-listed sequence, and a supply voltage detection circuit coupled to the driving circuit. The output switch SW1 of the first output unit and the output switch SW2 of the second output unit are connected in series. The logic circuit is configured to receive, through an input terminal, the communication data sent by the CPU unit, output the communication data to the  
10 driving circuit, and receive a fault signal outputted by the supply voltage detection circuit of the other one of the first output unit and the second output unit, and maintain or interrupt communication between the CPU unit and the driving circuit. The driving circuit is configured to: receive the communication data sent by the CPU unit and perform verification on the communication data; switch on or switch off the output switch based on information of  
15 the communication data after the verification succeeds; and collect an output state of the check-back circuit and line diagnose information of the output switch. The check-back circuit is configured to detect an output state of the output switch, and send the output state of the output switch to the driving circuit. The supply voltage detection circuit is configured to detect a supply voltage of the driving circuit, and send, based on the detected voltage, a  
20 control signal to the logic circuit of the other one of the first output unit and the second output unit.

**[0038]** In the switching value output module according to an embodiment of the present disclosure, the first output unit as shown in Figure 4 is described as an example. The first output unit includes a driving circuit 1, a check-back circuit 1, a monitoring circuit 1, a supply  
25 voltage detection circuit 1, and an output switch SW1. A first terminal of the output switch SW1 is coupled to +24V, and a second terminal of the output switch SW1 is connected in series with a first terminal of the output switch SW2 of the second output unit. A second terminal of the output switch SW2 is configured to output a switching value and is coupled to a load.

**[0039]** In an embodiment of the present disclosure, the system is in a safe state in a case that an output state of the system is off, which requires that at least one of the output switch SW1 and the output switch SW2 is switched off. The CPU unit sends, to the driving circuit 1,  
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control data including a switching value. The driving circuit 1 performs communication verification on the received control data. In a case that the verification succeeds, the driving circuit 1 switches on or switches off the output switch SW1 based on the control data sent by the CPU unit. The driving circuit 1 collects an output state of the output switch SW1 through the check-back circuit 1, and reads directly a line state fed back from the output switch SW1. The output switch SW1 has a capacity of diagnosing a line fault. In a case of a fault, the output switch SW1 can send fault information to the driving circuit. The CPU unit reads check-back data from the driving circuit 1, and performs analysis collectively based on the check-back data of the first output unit and check-back data of the second output unit.

**[0040]** In a case that an overvoltage, undervoltage, or other faults occurs in a power supply VCC1 of the driving circuit 1, the supply voltage detection circuit 1 sends a fault signal VCC1\_Check to a logic device 2 of the second output unit. The logic device 2 receives the fault signal VCC1\_Check from the second output unit, and controls a logic gate chip IC2 to switch off a communication between a driving circuit 2 and the CPU unit. Therefore, the driving circuit 2 sends no pulse signal to a monitoring circuit 2. The monitoring circuit 2 outputs a low level signal to the driving circuit 2 after 1.6s due to a timeout. The driving circuit 2 switches off the output switch SW2 in response to the low level signal. Therefore, the module is safety-oriented.

**[0041]** In an embodiment of the present disclosure, the driving circuit is generally programmed by using a CPLD or other logic chips, to achieve functions of verifying data and outputting a control signal to the output switch. The monitoring circuit is generally implemented as a mono-stable trigger circuit, where trigger pulse duration is 1.6 seconds.

**[0042]** A method for diagnosing and processing a fault based on the switching value output module having functional safety is further provided according to an embodiment of the present disclosure. A schematic flow chart of the method is as shown in Figure 5. The method includes at least diagnosing and processing based on a fault of the output switch, which specifically includes steps S1 to S3.

**[0043]** In step S1, an output state of the output switch SW1 and an output state of the output switch SW2 are controlled periodically based on a preset state.

**[0044]** In step S2, an output state detected by the check-back circuit is read back.

**[0045]** In step S3, a comparison is made between an actual check-back result read back in a single cycle and a preset check-back result, and it is determined, based on a result of the comparison, whether to switch off outputs of the output switch SW1 and the output switch SW2.

5 **[0046]** Multiple implementations of the method according to embodiments are described hereinafter in conjunction with Figure 3, so that those skilled in the art can better understand the technical solutions of the present disclosure.

**[0047]** A fault of the output switch can be diagnosed and processed. In an embodiment, an open circuit, a short circuit, or other failures may occur in the output switch. The diagnosis and processing on the fault of the output switch is mainly directed to the open circuit, the  
10 short circuit, or other possible failures of the output switch SW1 and the output switch SW2.

**[0048]** The CPU unit controls states of the output switch SW1 and the output switch SW2 periodically and sequentially according to four preset states shown in a table below (from state 1 to state 4).

| Preset state | SW1 state | SW2 state | Preset check-back result |
|--------------|-----------|-----------|--------------------------|
| 1            | ON        | ON        | ON                       |
| 2            | ON        | OFF       | OFF                      |
| 3            | OFF       | ON        | OFF                      |
| 4            | OFF       | OFF       | OFF                      |

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**[0049]** In a single cycle, the CPU unit compares four actual check-back results in the cycle to the four preset results, respectively. In a case that an actual check-back result is not the same as a preset result, it is determined that the output switch SW1 or the output switch SW2 fails. In this case, the CPU unit controls the driving circuit 1 and the driving circuit 2 to  
20 switch off outputs of the output switch SW1 and the output switch SW2, so as to be safety-oriented. In order to avoid malfunction of the load, a pulse width for diagnosis is less than a response time period of the load. Typically, the pulse width is 2ms.

**[0050]** A communication fault can be diagnosed and processed. In an embodiment, a fault occurs in a communication between the CPU unit and the driving circuit. Specific steps of

diagnosis on communication data are illustrated based on communication between the CPU unit and the driving circuit 1 as shown in Figure 4. The CPU unit sends communication information, including control information, to the driving circuit 1. The driving circuit 1 receives the communication information and performs verification on internal communication data. In a case that the verification on the communication data succeeds, the driving circuit 1 sends a pulse signal to the monitoring circuit 1, to maintain an output state of the monitoring circuit 1 unchanged. Therefore, an output of the monitoring circuit 1 has no effect on a state outputted by the driving circuit 1 to the output switch SW1.

**[0051]** In a case that a fault occurs in the communication between the CPU unit and the driving circuit 1, the verification on the internal communication data in the driving circuit 1 fails, and thus the driving circuit 1 sends no pulse signal to the monitoring circuit 1. The output state of the monitoring circuit 1 is reversed after 1.6 seconds due to a timeout. Therefore, the monitoring circuit 1 outputs a low level signal to the driving circuit 1, forcing the output switch SW1 to output an OFF state, so that the module is safety-oriented.

**[0052]** An internal fault of the CPU unit can be diagnosed and processed. A fault may occur to internal software or hardware of the CPU unit. In an embodiment, an external independent circuit is required to ensure a safe state of the system, in a case that an internal fault occurs to the CPU unit. After the internal fault in the CPU unit occurs, a fault indication signal ERROR is sent to the logic device 1. The logic device 1 receives the fault indication signal ERROR and stops operation of IC1. Therefore, the communication between the CPU unit and the driving circuit 1 is interrupted.

**[0053]** In addition, since the driving circuit 1 fails to receive communication data sent by the CPU unit, the driving circuit 1 sends no pulse signal to the monitoring circuit 1. After a timeout, the monitoring circuit 1 sends a low level signal to the driving circuit 1, and thus the driving circuit controls the output switch SW1 to output an OFF state, so that the module is safety-oriented.

**[0054]** A fault of a power supply can be diagnosed and processed. In an embodiment, an overvoltage, undervoltage, or other faults may occur in a power supply of the driving circuit. Taking the first output unit shown in Figure 4 as an example, the following operations are performed to ensure a safe state of the system. In a case that an overvoltage, undervoltage, or other faults occurs in a power supply VCC1 of the driving circuit 1, the fault can be detected

by the supply voltage detection circuit 1. However, since the driving circuit 1 is under an abnormal power supply, the driving circuit 1 is not guaranteed to switch off the output. Hence, the supply voltage detection circuit 1 sends a signal to the logic device 2 for switching off IC2, so as to interrupt the communication between the CPU unit and the driving circuit 2. The driving circuit 2, which operates normally, is controlled to switch off the output switch SW2, so that the output is safety-oriented. Similarly, in a case that a fault occurs in the power supply of the driving circuit 2, the output switch SW1 can be switched off by the driving circuit 1, which operates normally. Therefore, the module is safety-oriented.

**[0055]** A line fault can be diagnosed and processed. In an embodiment, the output switch SW1 and the output switch SW2 each has a capability of detecting a load current. In a case that a load current does not satisfy threshold requirements, that is, the load current is greater than a preset threshold in a case of a short circuit, or the load current is less than a preset threshold in a case of an open circuit, a signal of an indication pin of a chip of the output switch SW1 is inverted, and the CPU unit may read back, via the driving circuit 1, line fault information indicated by the output switch SW1 and output state information of the output switch SW1.

**[0056]** The above description of the embodiments is intended merely to assist in understanding the method in the present disclosure and a core idea thereof. It should be noted that various improvements and modifications can be made to the embodiments of the present disclosure by those skilled in the art, without departing from the principles of the present disclosure. The improvements and modifications fall within the protection scope of the claims of the present disclosure.

## CLAIMS

1. A switching value output module having functional safety, comprising,  
a CPU unit;

5 a first output unit coupled to the CPU unit; and

a second output unit coupled to the CPU unit, wherein

the CPU unit is configured to send communication data to the first output unit or the second output unit, and output fault information based on received diagnostic data fed back from the first output unit or the second output unit, to control the first output unit or the second output unit to be safety-oriented;

the first output unit or the second output unit comprises at least a logic circuit, a driving circuit, a check-back circuit, an output switch, which are coupled in the above-listed sequence, and a supply voltage detection circuit coupled to the driving circuit, wherein the output switch SW1 of the first output unit and the output switch SW2 of the second output unit are connected in series;

the logic circuit is configured to receive, through an input terminal, the communication data sent by the CPU unit, output the communication data to the driving circuit, and receive a fault signal outputted by the supply voltage detection circuit of the other one of the first output unit and the second output unit, and maintain or interrupt communication between the CPU unit and the driving circuit;

the driving circuit is configured to receive the communication data sent by the CPU unit and perform verification on the communication data, switch on or switch off the output switch based on information of the communication data after the verification succeeds, and collect an output state of the check-back circuit and line diagnose information of the output switch;

25 the check-back circuit is configured to detect an output state of the output switch, and send the output state of the output switch to the driving circuit; and

the supply voltage detection circuit is configured to detect a supply voltage of the driving circuit, and send, based on the detected voltage, a control signal to the logic circuit of the other one of the first output unit and the second output unit.

2. The switching value output module according to claim 1, wherein

the output unit further comprises a monitoring circuit coupled to the driving circuit, and

the monitoring circuit is configured to receive a signal outputted by the driving circuit after the verification, and output a control signal to control the driving circuit to output an ON or OFF signal for switching on or switching off the output switch.

3. The switching value output module according to claim 2, wherein the driving circuit is configured to:

output no pulse signal to the monitoring circuit, in a case that the verification fails, to control the monitoring circuit to output a low level signal to the driving circuit; and

send a pulse signal to the monitoring circuit, in a case that the verification succeeds, to maintain an output state of the monitoring circuit unchanged.

4. The switching value output module according to claim 2, wherein the monitoring circuit comprises a mono-stable trigger circuit.

5. The switching value output module according to claim 1, wherein

the logic circuit comprises at least a logic gate chip and a logic device,

the logic gate chip is configured to receive, through an input terminal, the communication data sent by the CPU unit, and output the communication data converted by the logic gate chip to the driving circuit; and

the logic device is configured to receive a power supply fault signal from the driving circuit of the other one of the first output unit and the second output unit, to switch on or switch off the logic gate chip of the output unit.

6. The switching value output module according to claim 5, wherein the CPU unit is further configured to send a signal indicating an internal fault of the CPU unit to the logic device, to interrupt, through the logic gate chip, communication between the CPU unit and the driving circuit.

7. The switching value output module according to claim 1, wherein each of the output switch SW1 and the output switch SW2 has a capability of detecting a load current.

8. The switching value output module according to any one of claims 1 to 7, wherein the

driving circuit comprises a logic chip CPLD.

9. A method for diagnosing and processing a fault, based on the switching value output module according to any one of claims 1 to 8, wherein the method comprises at least diagnosing and processing a fault of the output switch, which comprises:

5 S1, controlling an output state of the output switch SW1 and an output state of the output switch SW2 periodically based on a preset state;

S2, reading back an output state detected by the check-back circuit; and

S3, making a comparison between an actual check-back result read back in a single cycle and a preset check-back result, and determining, based on a result of the comparison, whether  
10 to switch off outputs of the output switch SW1 and the output switch SW2.

10. The method according to claim 9, wherein the S3 comprises:

S31, repeating S1 to S3 to perform diagnosis on the output state of the output switch, in a case that the actual check-back result of the CPU unit is the same as the preset check-back result; and

15 S32, controlling, by the CPU unit, both the driving circuit of the first output unit and the driving circuit of the second output unit to switch off outputs of the output switch SW1 and the output switch SW2, in a case that the actual check-back result of the CPU unit is not the same as the preset check-back result.

11. The method according to claim 9, further comprising diagnosing and processing a  
20 communication fault, which comprises:

controlling an output of the output switch, based on verification on the communication data between the CPU unit and the driving circuit, and based on information of the communication data after the verification succeeds.

12. The method according to claim 9, further comprises diagnosing and processing an  
25 internal fault of the CPU unit, which comprises:

sending, to the logic circuit, a fault signal based on an internal software or hardware fault of the CPU unit, to maintain or interrupt the communication.

13. The method according to claim 9, further comprising diagnosing and processing a fault of a power supply, which comprises:

interrupting, based on a detected fault of the power supply, communication between the CPU unit and the driving circuit of the other one of the first output unit and the second output unit, to switch off the output of the output switch to be safety-oriented.

14. The method according to claim 9, further comprising diagnosing and processing a  
5 line fault, which comprises:

making a comparison between a load current, which is detected by the output switch and read back by the CPU unit, and a preset threshold, and

controlling an output of the output switch based on a result of the comparison.

15. The method according to any one of claims 9 to 14, wherein a time period of the  
10 single cycle is less than a response time period of a load.