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(54) **PROTECTIVE APPARATUS, ENERGY STORAGE APPARATUS, AND METHOD FOR PROTECTING ENERGY STORAGE DEVICE**

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(58) **Field of Classification Search**
None
See application file for complete search history.

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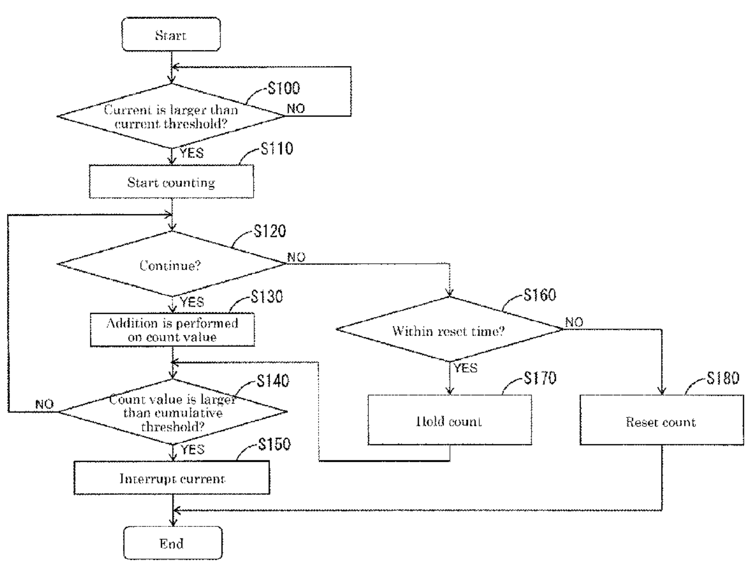
(57) **ABSTRACT**

A protective apparatus of an energy storage device includes a current breaker that interrupts the current of the energy storage device, and a control part. There are a plurality of conditions having different current thresholds and cumulative thresholds, and the control part calculates a cumulative value N of times during which the current exceeds any one of the current thresholds Is, and executes current interruption processing of interrupting the current when the calculated cumulative value N exceeds one of the cumulative thresholds Ns associated with the current threshold Is.

6 Claims, 14 Drawing Sheets



(51) **Int. Cl.**

H01M 10/48	(2006.01)
H01M 50/574	(2021.01)
H01M 50/583	(2021.01)
H02H 3/02	(2006.01)
H02H 3/08	(2006.01)
H02H 3/093	(2006.01)
H02H 7/18	(2006.01)

(52) **U.S. Cl.**
CPC ***H01M 50/583*** (2021.01); ***H02H 3/021*** (2013.01); ***H02H 3/08*** (2013.01); ***H02H 3/093*** (2013.01); ***H02H 7/18*** (2013.01); ***H02J 7/0047*** (2013.01); *H01M 2010/4278* (2013.01)

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Fig. 1

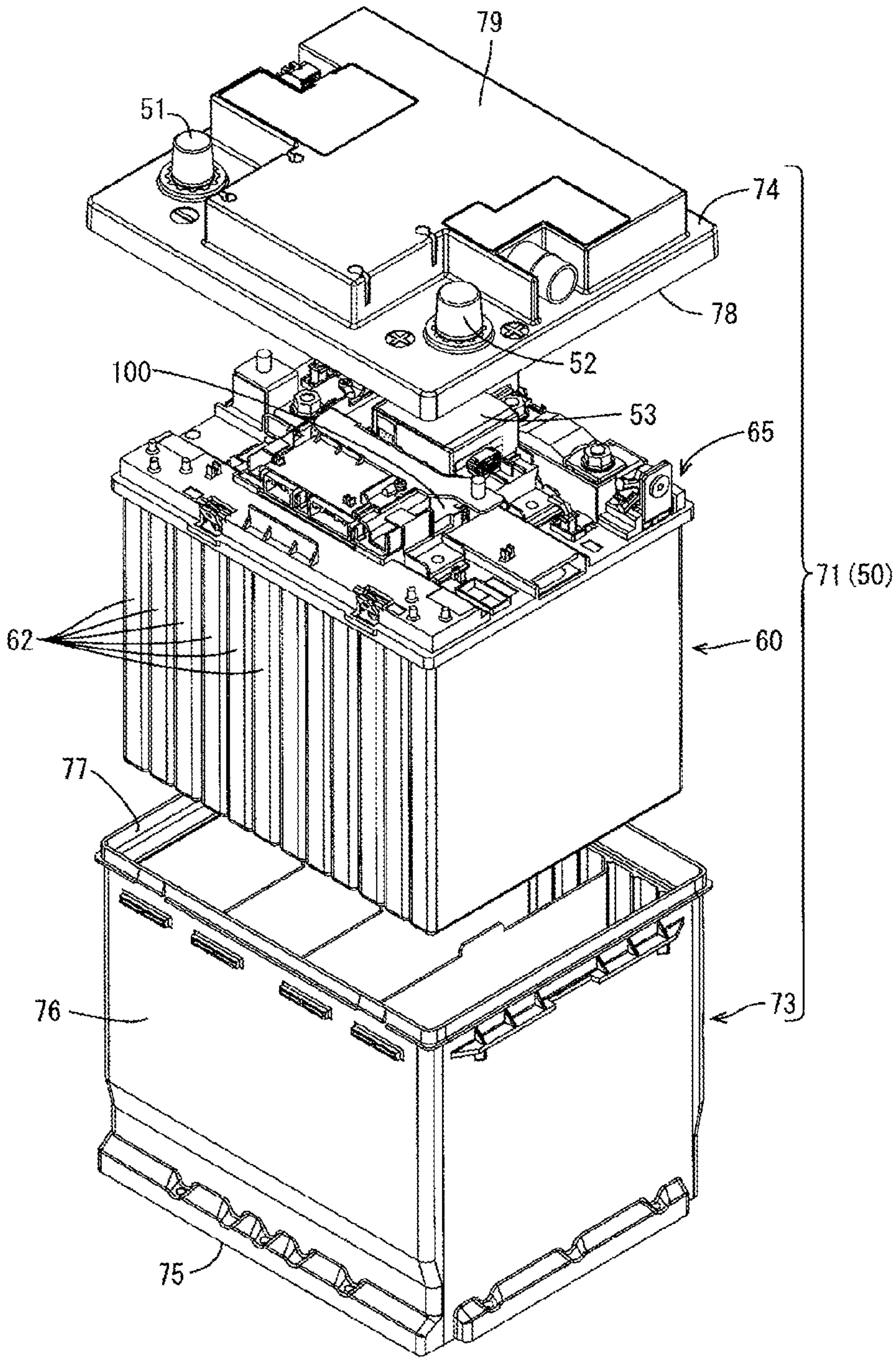


Fig. 2

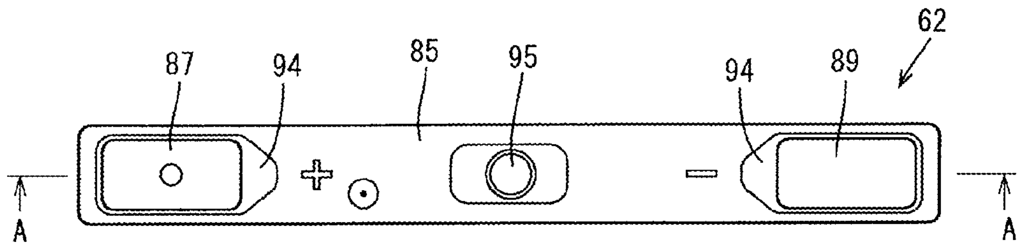

62
87
94
85
95
94
89
+
−
A
A

Fig. 3

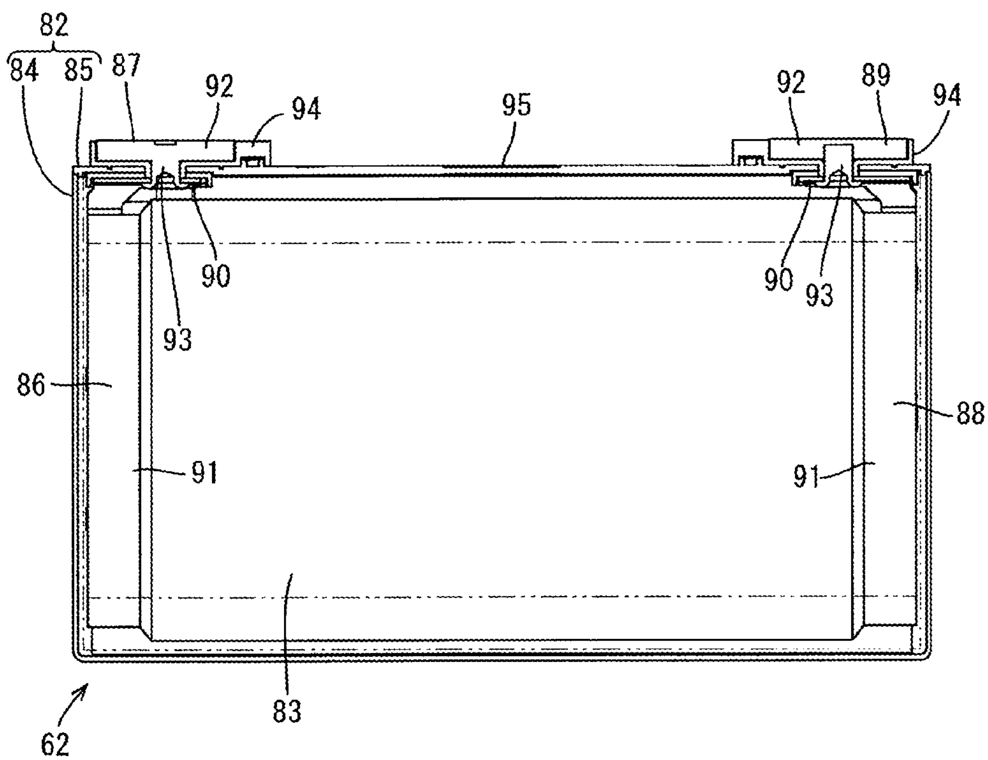
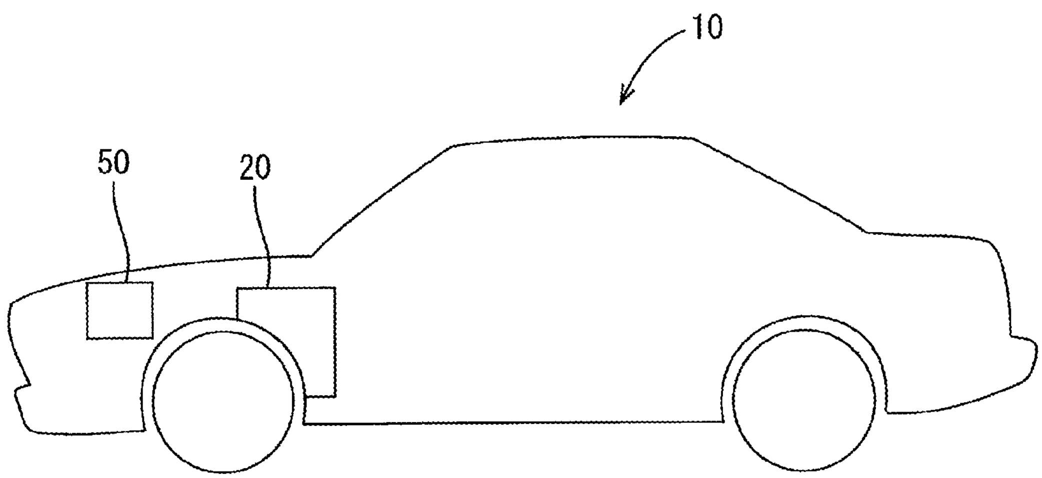

82
84
85
87
92
94
95
92
89
94
90
93
90
93
86
88
91
91
83
62

Fig. 4



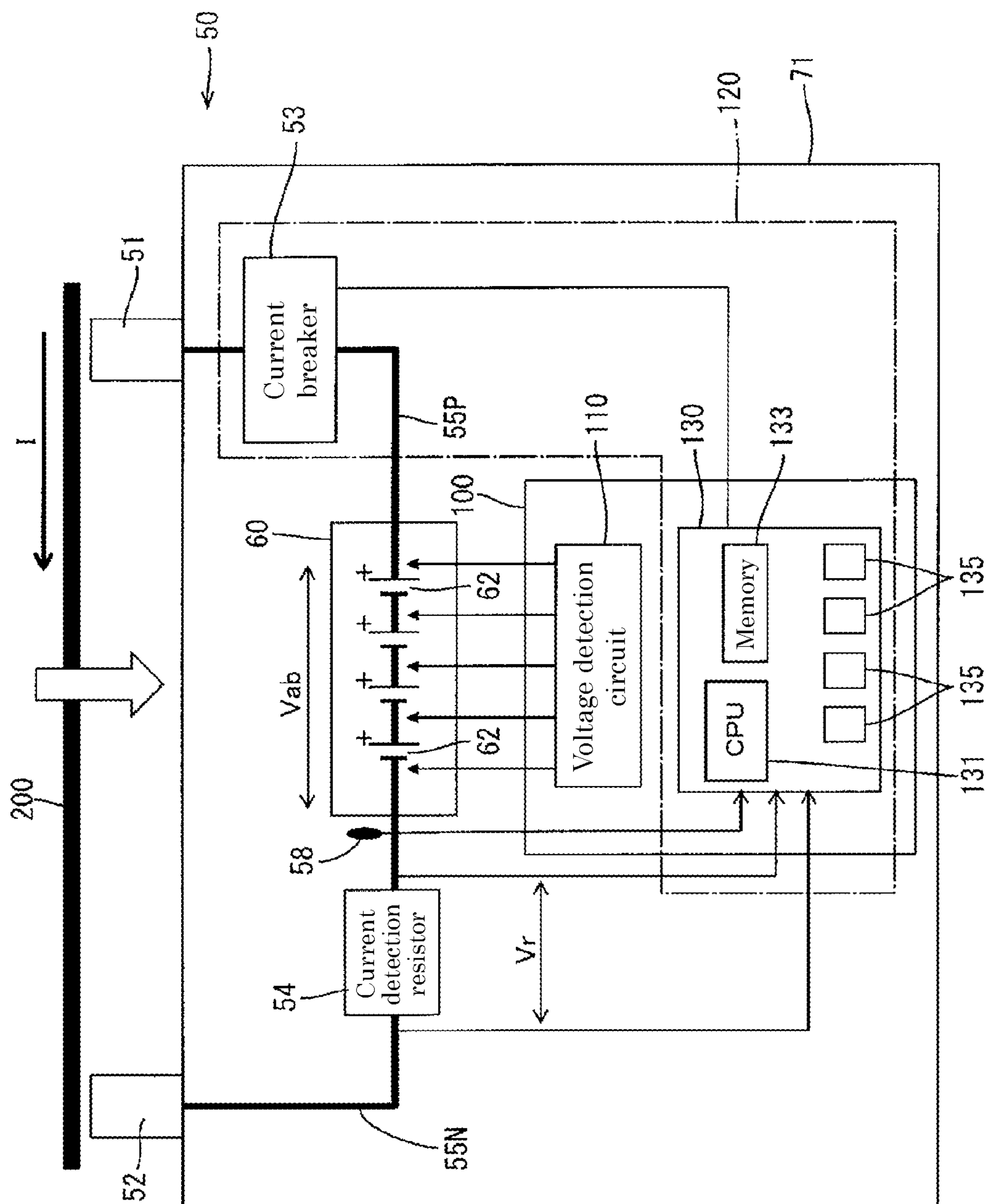
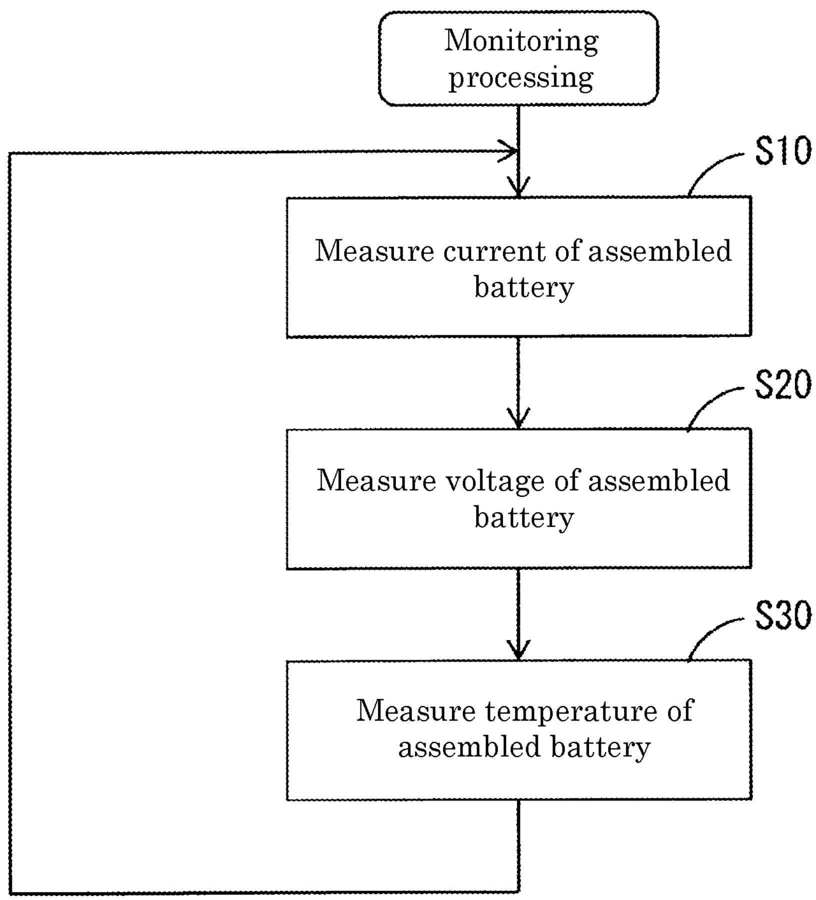

50
53
51
Current breaker
120
71
I
55P
110
130
133
100
60
Voltage detection circuit
Memory
CPU
Vab
62
62
135
135
131
200
58
54
Current detection resistor
Vr
52
55N

Fig. 5

Fig. 6


Monitoring processing
S10
Measure current of assembled battery
S20
Measure voltage of assembled battery
S30
Measure temperature of assembled battery

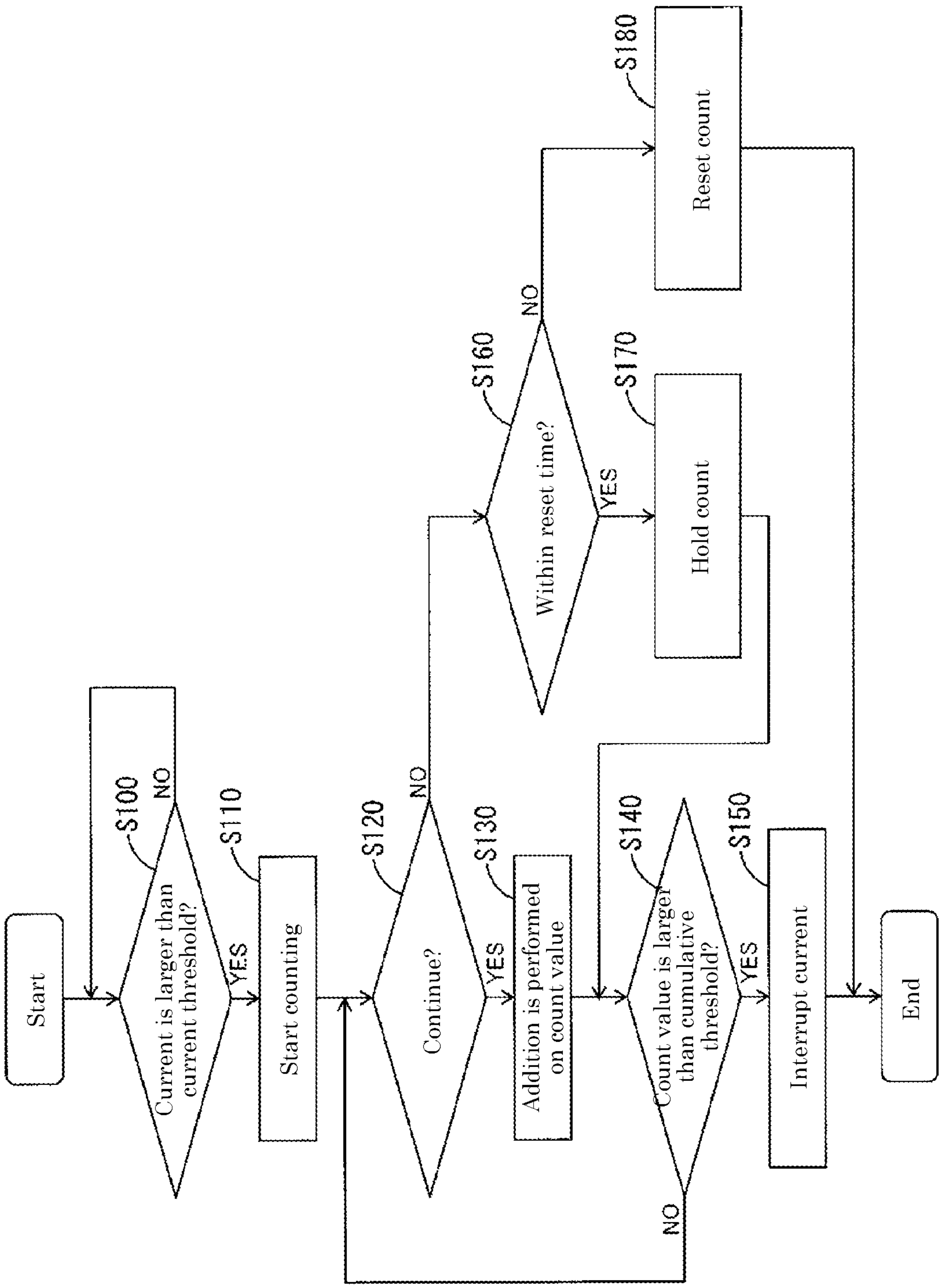

Start
S100
Current is larger than current threshold?
YES
NO
S110
Start counting
S120
Continue?
YES
NO
S130
Addition is performed on count value
S140
Count value is larger than cumulative threshold?
YES
NO
S150
Interrupt current
End
S160
Within reset time?
YES
NO
S170
Hold count
S180
Reset count

Fig. 7

Fig. 8

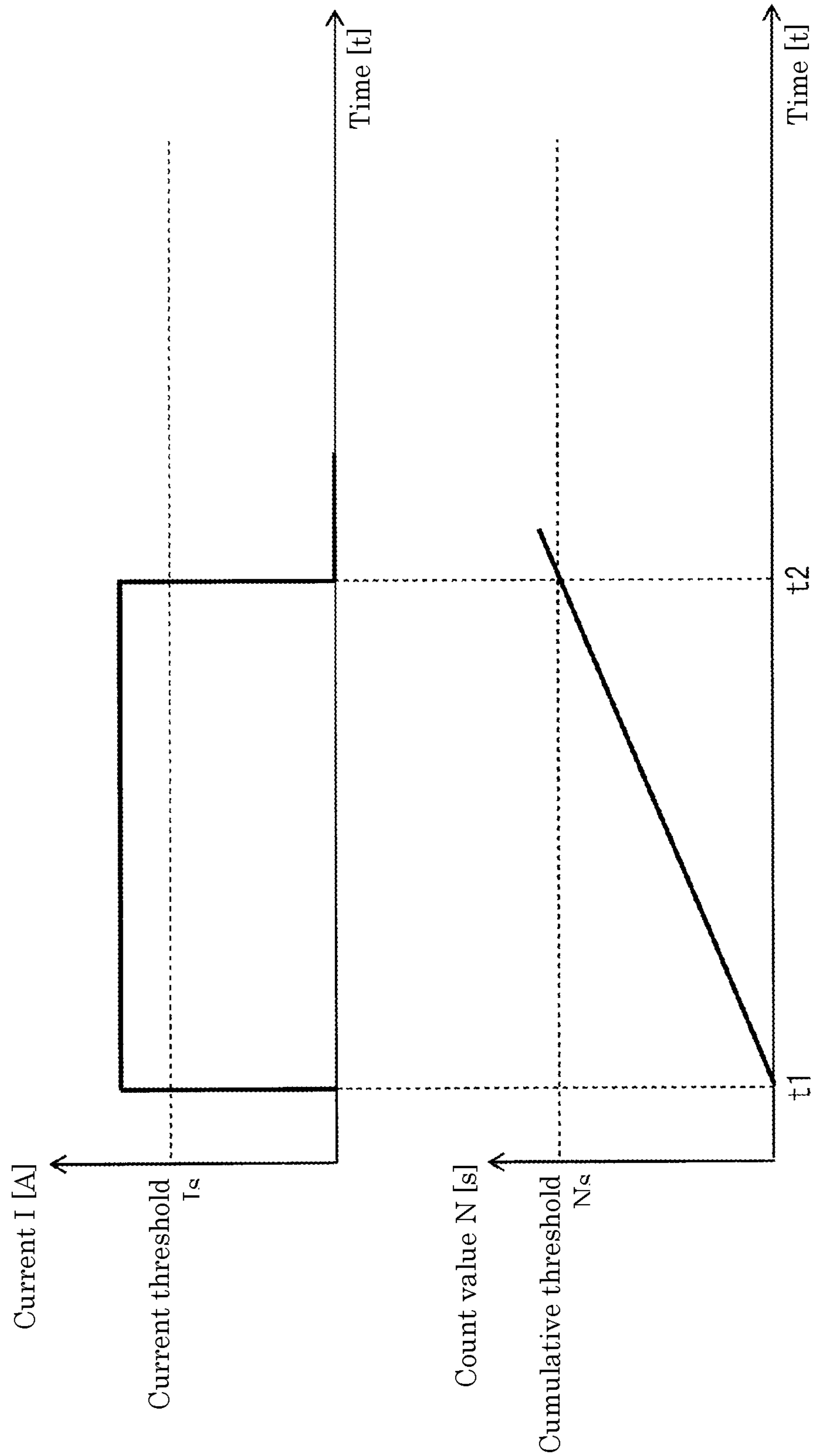

Time [t]
Current I [A]
Current threshold Is
Count value N [s]
Cumulative threshold Ns
t1
t2
Time [t]

Fig. 9

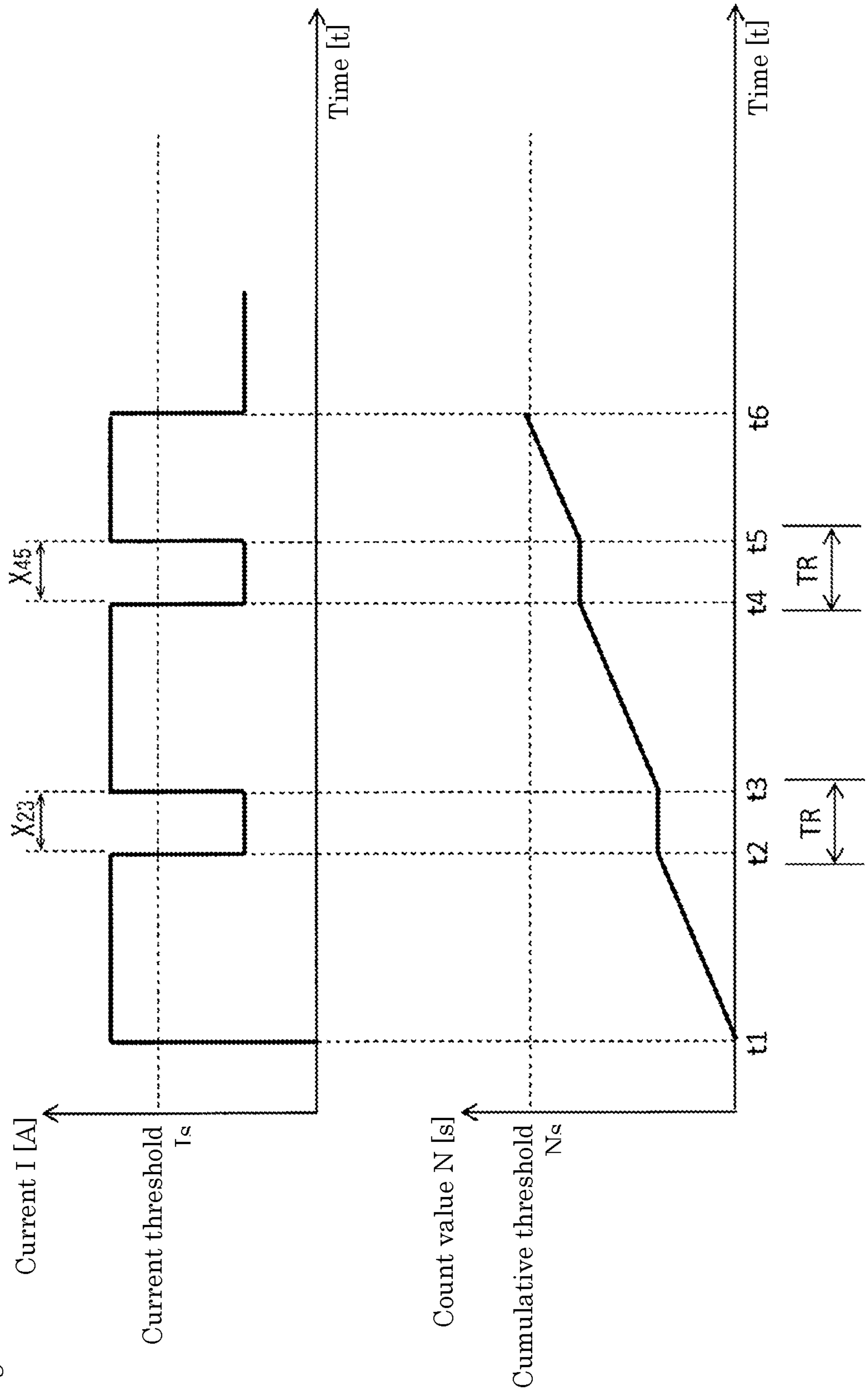

Current I [A]
Current threshold Is
Count value N [s]
Cumulative threshold Ns
Time [t]
Time [t]
X23
X45
t1
t2
t3
t4
t5
t6
TR
TR

Fig. 10

	Current threshold Is	Cumulative threshold Ns	Reset time TR
Current interruption condition 1	1450 A	10 msec	1 sec
Current interruption condition 2	900 A	2 sec	1 sec
Current interruption condition 3	700 A	40 sec	1 sec
Current interruption condition 4	300 A	60 sec	1 sec

Fig. 11

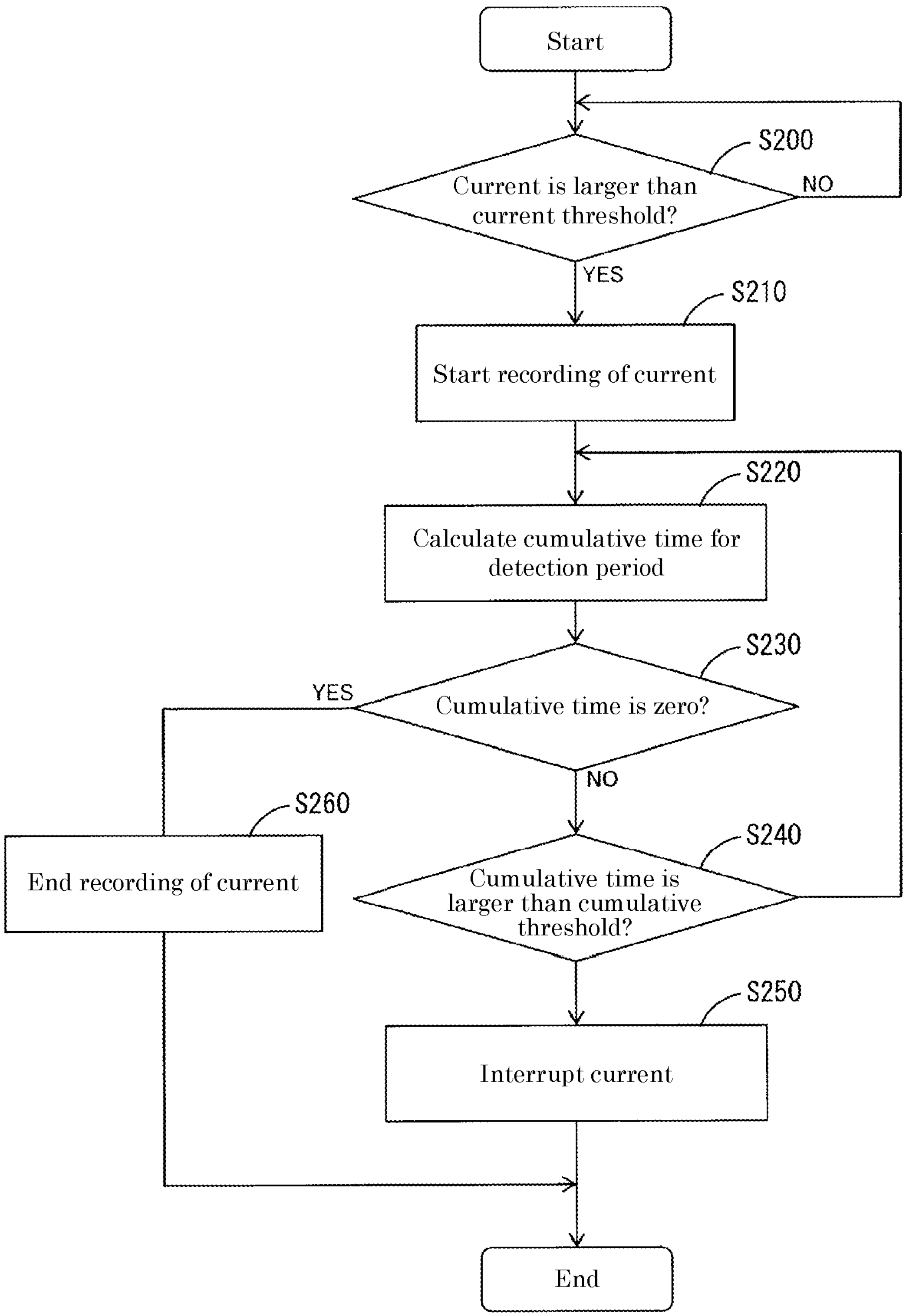

Start
S200
Current is larger than current threshold?
NO
YES
S210
Start recording of current
S220
Calculate cumulative time for detection period
S230
YES
Cumulative time is zero?
NO
S260
End recording of current
S240
Cumulative time is larger than cumulative threshold?
S250
Interrupt current
End

Fig. 12

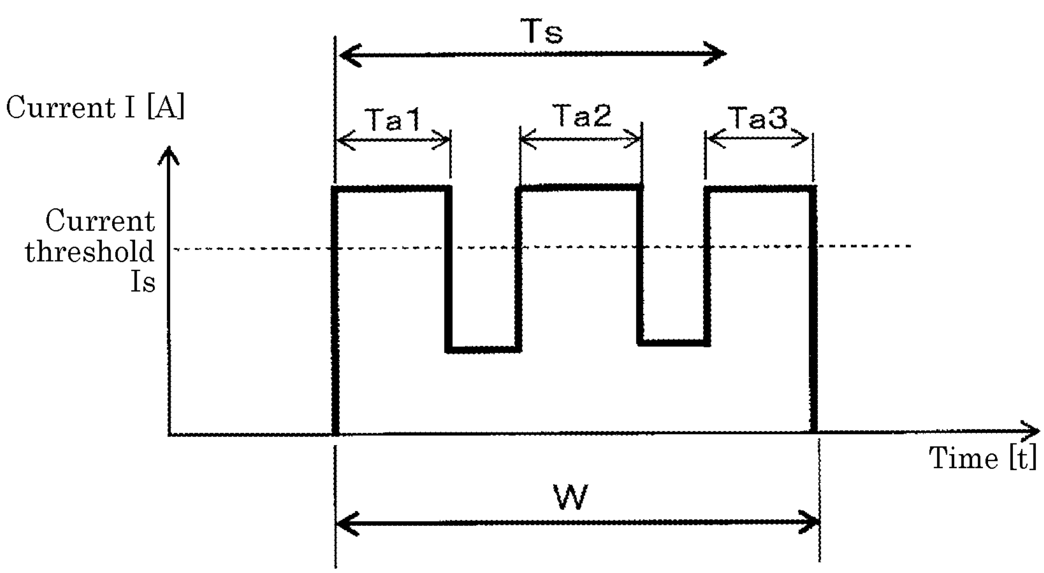


Fig. 13

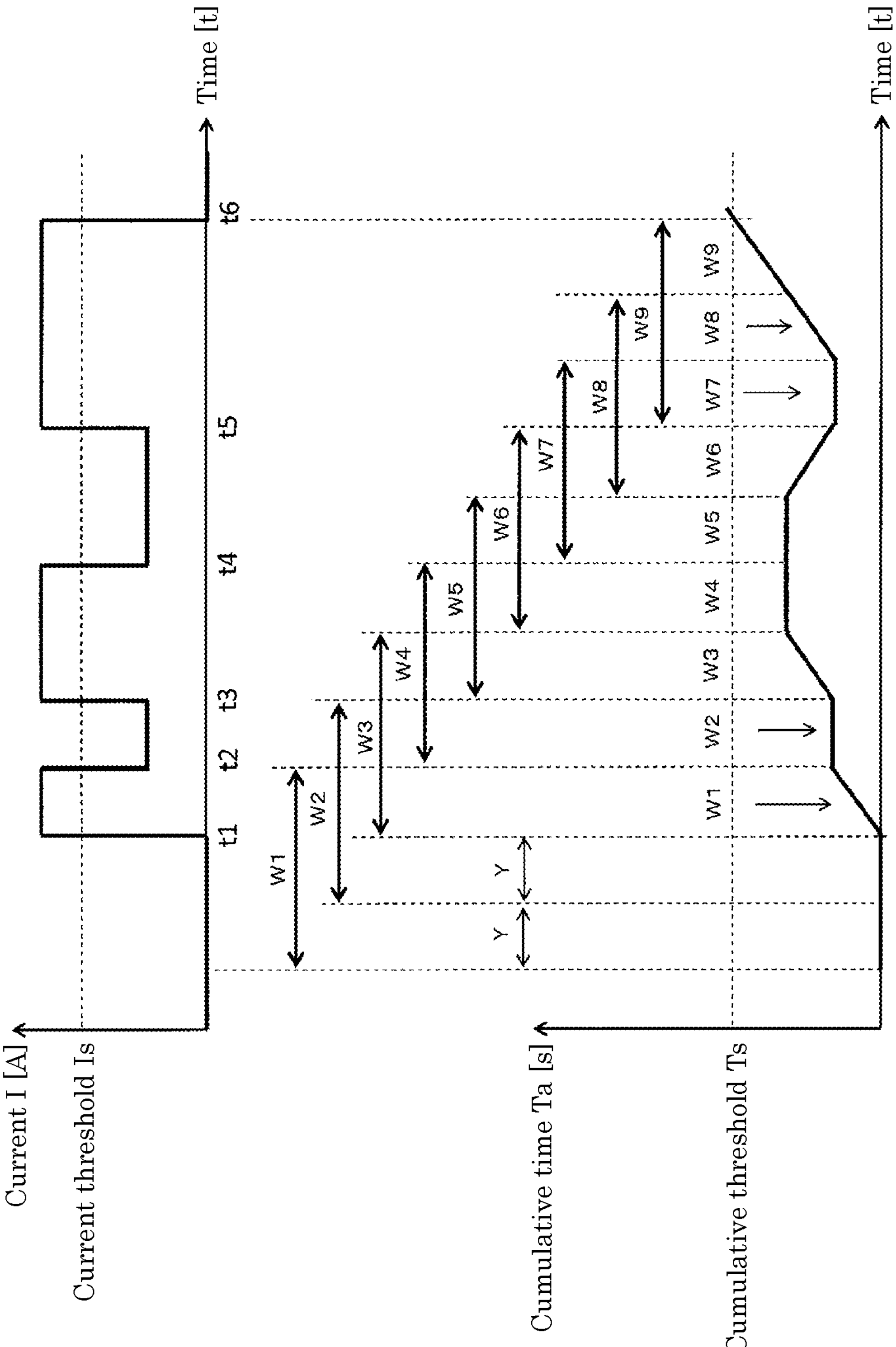
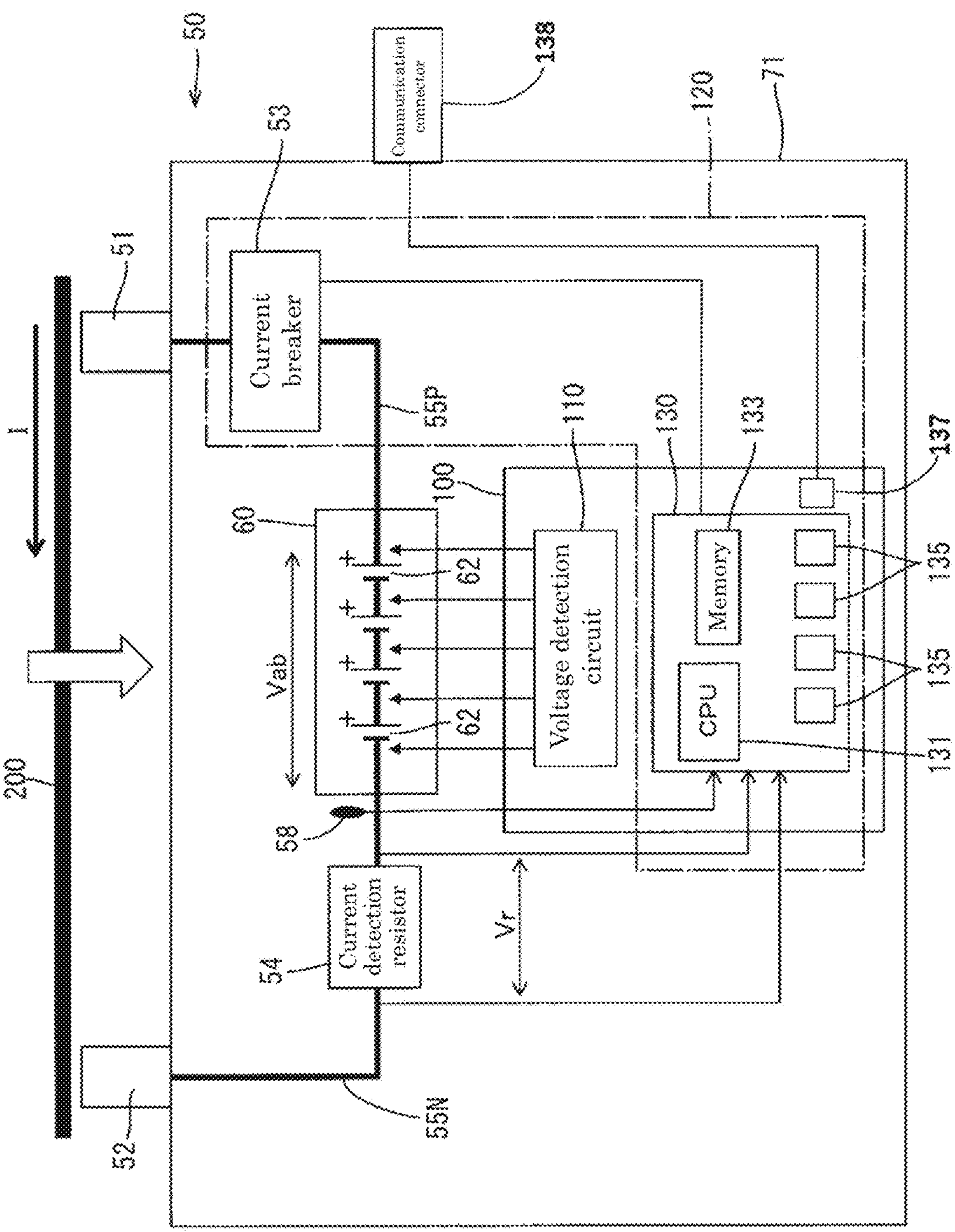

Current I [A]
Current threshold Is
Time [t]
t1
t2
t3
t4
t5
t6
W1
W2
W3
W4
W5
W6
W7
W8
W9
Y
Y
Cumulative time Ta [s]
Cumulative threshold Ts
Time [t]

Fig. 14

	Current threshold Is	Cumulative threshold Ts	Detection period W
Current interruption condition 1	1450 A	10 msec	15 msec
Current interruption condition 2	900 A	2 sec	3 sec
Current interruption condition 3	700 A	40 sec	60 sec
Current interruption condition 4	300 A	60 sec	90 sec

Fig. 15


50
138
Communication connector
120
71
53
51
Current breaker
55P
I
110
130
133
137
100
60
62
Memory
Voltage detection circuit
135
Vab
CPU
62
135
200
131
58
Current detection resistor
54
Vr
52
55N

PROTECTIVE APPARATUS, ENERGY STORAGE APPARATUS, AND METHOD FOR PROTECTING ENERGY STORAGE DEVICE

TECHNICAL FIELD

The present invention relates to a technique for protecting an energy storage device from an overcurrent.

BACKGROUND ART

The energy storage apparatus may be short-circuited between terminals by a tool at the time of assembling work or the like. The energy storage apparatus includes a current breaker such as a relay or a field-effect transistor (FET), and interrupts a current when a short circuit occurs to protect components constituting the energy storage apparatus. Patent Document 1 below describes that when a current continuously exceeds a current threshold for a time longer than a predetermined time, the current is interrupted.

PRIOR ART DOCUMENT

Patent Document

Patent Document 1: WO 2015/182515

SUMMARY OF THE INVENTION

Problems to be Solved by the Invention

In a case where the interruption of a current is determined based on a duration in which a current equal to or larger than a current threshold continuously flows, it may not be possible to interrupt a discontinuous overcurrent in which a current temporarily falls below the current threshold. When there is only one current interruption condition, the current can be interrupted only under one condition, so that the protection of the energy storage device may be insufficient.

An object of the present invention is to protect an energy storage apparatus by interrupting a current against a discontinuous overcurrent.

Means for Solving the Problems

A protective apparatus for an energy storage device according to one aspect of the present invention includes: a current breaker that interrupts a current of the energy storage device; and a control part. There are a plurality of conditions having different current thresholds and cumulative thresholds, and the control part calculates a cumulative value of times during which the current exceeds any one of the current thresholds, and executes current interruption processing of interrupting the current when the calculated cumulative value exceeds one of the cumulative thresholds associated with the current threshold.

A protective apparatus for an energy storage device according to another aspect of the present invention includes: a current breaker that interrupts a current of the energy storage device; a control part; and a communication part. There are a plurality of conditions having different current thresholds and cumulative thresholds, and the control part calculates a cumulative value of times during which the current exceeds any one of the current thresholds, and causes the communication part to transmit an alarm signal when the calculated cumulative value exceeds one of the cumulative thresholds associated with the current threshold.

The present technique can be applied to a method for protecting an energy storage device, a protection program, and a recording medium on which the protection program has been recorded.

Advantages of the Invention

According to the above aspect, a current can be interrupted to protect the energy storage device against a discontinuous overcurrent.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is an exploded perspective view of a battery.

FIG. **2** is a plan view of a secondary battery.

FIG. **3** is a cross-sectional view taken along line A-A in FIG. **2**.

FIG. **4** is a side view of a vehicle.

FIG. **5** is a block diagram illustrating the electrical configuration of the battery.

FIG. **6** is a flowchart of monitoring processing.

FIG. **7** is a flowchart of protection processing.

FIG. **8** is a diagram illustrating a waveform and a count value of an overcurrent.

FIG. **9** is a diagram illustrating a waveform and a count value of an overcurrent.

FIG. **10** is an explanatory diagram of a current interruption condition.

FIG. **11** is a flowchart of protection processing.

FIG. **12** is an explanatory diagram of a cumulative time.

FIG. **13** is a diagram illustrating a waveform of an overcurrent and a cumulative time.

FIG. **14** is an explanatory diagram of current interruption conditions.

FIG. **15** is a block diagram illustrating the electrical configuration of the battery.

MODE FOR CARRYING OUT THE INVENTION

A protective apparatus for an energy storage device includes: a current breaker that interrupts a current of the energy storage device; and a control part. There are a plurality of conditions having different current thresholds and cumulative thresholds, and the control part calculates a cumulative value of times during which the current exceeds any one of the current thresholds, and executes current interruption processing of interrupting the current when the calculated cumulative value exceeds one of the cumulative thresholds associated with the current threshold.

When the cumulative value of times when the current threshold is exceeded exceeds the cumulative threshold, the current interruption processing is executed, so that the energy storage device can be protected from a discontinuous overcurrent. By preparing a plurality of current interruption conditions having different current thresholds and cumulative thresholds, the number of combinations of the current threshold and the cumulative threshold, with which the current can be interrupted, increases as compared to when there is only one condition. Hence, the protection performance of the energy storage device against an overcurrent can be enhanced as compared to a case where there is only one condition.

The control part may calculate a cumulative value of times during which the current exceeds the current threshold for each condition, and execute current interruption processing of interrupting the current when the calculated cumulative value exceeds the cumulative threshold associated with the current threshold under any condition. The current interruption processing is executed when the cumulative threshold is exceeded under any one of the plurality of conditions, so that the energy storage device can be protected from an overcurrent with different current values and durations.

A protective apparatus for an energy storage device includes: a current breaker that interrupts a current of the energy storage device; a control part; and a communication part. There are a plurality of conditions having different current thresholds and cumulative thresholds, and the control part calculates a cumulative value of times during which the current exceeds any one of the current thresholds, and causes the communication part to transmit an alarm signal when the calculated cumulative value exceeds one of the cumulative thresholds associated with the current threshold.

For equipment to which the energy storage apparatus supplies power (e.g., electronic or electric equipment mounted on a vehicle), it is undesirable to come into a state where the current from the energy storage apparatus be interrupted to cause a power failure. In some cases, the purpose of protecting a machine that requires power of an energy storage apparatus, such as a vehicle, is prioritized over the purpose of protecting the energy storage apparatus. In such a case, instead of executing the current interruption processing at a time point when the interruption condition is satisfied, equipment outside the energy storage apparatus is notified that the interruption condition is satisfied, that is, an alarm signal is transmitted to the equipment. In this manner, the control part can determine whether or not to execute the current interruption processing based on a purpose that should be prioritized in a situation such as an emergency in cooperation with the equipment outside the energy storage apparatus. Upon reception of the alarm signal from the energy storage apparatus, the equipment outside the energy storage apparatus can proceed with preparation for the current interruption processing and other problem-solving processing.

The current breaker may be provided in a current path connecting the energy storage device and an external terminal, and the conditions may at least include a first condition for determining that a short circuit of the external terminal occurs, and a second condition for determining that a short circuit of a load connected to the external terminal occurs. The current can be interrupted to protect the energy storage device at the time of short circuit between the external terminals or at the time of load short circuit.

The control part may count, as the cumulative value, times during which the current continuously exceeds the current threshold, and in a case where the current falls from a state of exceeding the current threshold, the control part may hold the cumulative value when a time during which the current is below the current threshold is equal to or shorter than a reset time.

When the time during which the current is below the current threshold is equal to or shorter than the reset time, the cumulative value is held. That is, the cumulative value is not reset, and thereafter, when the cumulative value exceeds the cumulative threshold, the current interruption processing is executed. It is thereby possible to protect the energy storage device from the discontinuous overcurrent.

The control part may calculate the cumulative value for each detection period, and may execute the current interruption processing when the cumulative value exceeds the cumulative threshold.

When the cumulative value exceeds the cumulative threshold within the detection period, the current interruption processing is executed. It is thereby possible to protect the energy storage device from the discontinuous overcurrent.

First Embodiment

1. Description of battery **50**

As illustrated in FIG. **1**, a battery **50** includes an assembled battery **60**, a circuit board unit **65**, and a housing **71**.

The housing **71** includes a body **73** made of a synthetic resin material and a lid body **74**. The body **73** has a bottomed cylindrical shape. The body **73** includes a bottom surface portion **75** and four side surface portions **76**. An upper opening **77** is formed in an upper-end portion by the four side surface portions **76**.

The housing **71** houses the assembled battery **60** and a circuit board unit **65**. The assembled battery **60** has twelve secondary batteries **62**. The twelve secondary batteries **62** are connected with three in parallel and four in series. The circuit board unit **65** is disposed in the upper portion of the assembled battery **60**.

The lid body **74** closes the upper opening **77** of the body **73**. An outer peripheral wall **78** is provided around the lid body **74**. The lid body **74** has a protrusion **79** in a substantially T-shape in a plan view. An external terminal **51** of the positive electrode is fixed to one corner of the front portion of the lid body **74**, and an external terminal **52** of the negative electrode is fixed to the other corner.

As illustrated in FIGS. **2** and **3**, the secondary battery **62** houses an electrode assembly **83** together with a nonaqueous electrolyte in a case **82** having a rectangular parallelepiped shape. The secondary battery **62** is, for example, a lithium ion secondary battery. The case **82** has a case body **84** and a lid **85** for closing an opening at the top of the case body **84**.

Although not illustrated in detail, the electrode assembly **83** has a separator, made of a porous resin film, disposed between a negative electrode element formed by applying an active material to a substrate made of copper foil and a positive electrode element formed by applying an active material to a substrate made of aluminum foil. These are all belt-shaped, and are wound in a flat shape so as to be able to be housed in the case body **84** in a state where the negative electrode element and the positive electrode element are displaced from each other on the opposite sides in the width direction with respect to the separator.

The positive electrode element is connected to a positive electrode terminal **87** via a positive current collector **86**, and the negative electrode element is connected to a negative electrode terminal **89** via a negative current collector **88**. Each of the positive current collector **86** and the negative current collector **88** is made up of a plate-shaped base **90** and legs **91** extending from the base **90**. A through hole is formed in the base **90**. The leg **91** is connected to the positive electrode element or the negative electrode element. Each of the positive electrode terminal **87** and the negative electrode terminal **89** is made up of a terminal body portion **92** and a shaft **93** protruding downward from the center portion of the lower surface of the terminal body portion **92**. Among those, the terminal body portion **92** and the shaft **93** of the positive electrode terminal **87** are integrally formed of aluminum (single material). The negative electrode terminal **89** has the terminal body portion **92** made of aluminum and the shaft **93** made of copper and is assembled with these. The terminal body portions **92** of the positive electrode terminal **87** and the negative electrode terminal **89** are disposed at both ends of the lid **85** via gaskets **94** made of an insulating material and are exposed outward from the gaskets **94**.

The lid **85** has a pressure release valve **95**. As illustrated in FIG. **2**, the pressure release valve **95** is located between the positive electrode terminal **87** and the negative electrode terminal **89**. The pressure release valve **95** is opened when the internal pressure of the case **82** exceeds a limit value to lower the internal pressure of the case **82**.

As illustrated in FIG. **4**, the battery **50** can be used by being mounted on a vehicle **10**. The battery **50** may be for starting an engine **20** mounted on the vehicle **10**. The vehicle **10** may be an automobile or a motorcycle.

FIG. **5** is a block diagram illustrating the electrical configuration of the battery **50**. The battery **50** includes an assembled battery **60**, a current detection resistor **54**, a current breaker **53**, a voltage detection circuit **110**, a management part **130**, and a temperature sensor **58** that detects the temperature of the assembled battery **60**.

The assembled battery **60** includes a plurality of secondary batteries **62**. The twelve secondary batteries **62** are connected with three in parallel and four in series. In FIG. **5**, three secondary batteries **62** connected in parallel are represented by one battery symbol. The secondary battery **62** is an example of the "energy storage device". The battery **50** is rated at 12 V. In the battery **50** rated at 12 V, the distance between the external terminal **51** of the positive electrode and the external terminal **52** of the negative electrode tends to be narrow, and at the time of assembling the battery **50** to the vehicle or some other time, a short circuit (dead short circuit) between the terminals due to a metal material such as a tool is likely to occur as compared to a larger energy storage apparatus.

The assembled battery **60**, the current breaker **53**, and the current detection resistor **54** are connected in series via a power line **55**P and a power line **55**N. The power line **55**P and the power line **55**N are examples of current paths.

The power line **55**P is a power line for connecting the external terminal **51** of the positive electrode and the positive electrode of the assembled battery **60**. The power line **55**N is a power line for connecting the external terminal **52** of the negative electrode to the negative electrode of the assembled battery **60**.

The current breaker **53** is located on the positive electrode side of the assembled battery **60** and is provided on the power line **55**P on the positive electrode side. The current breaker **53** is a semiconductor switch such as FET or a relay. By opening the current breaker **53**, the current of the battery **50** can be interrupted. The current breaker **53** is controlled so as to be closed in a normal state.

The current detection resistor **54** is located on the negative electrode side of the assembled battery **60** and provided on the power line **55**N on the negative electrode. A current I of the assembled battery **60** can be measured by detecting a voltage Vr between both ends of the current detection resistor **54**.

The voltage detection circuit **110** can detect a voltage V of each secondary battery **62** and a total voltage Vab of the assembled battery **60**.

The management part **130** is mounted on the circuit board **100** and includes a CPU **131**, a memory **133**, and four counters **135**. The management part **130** performs monitoring processing for the battery **50** based on the outputs of the voltage detection circuit **1100**, the current detection resistor **54**, and the temperature sensor **58**.

FIG. **6** is a flowchart of the monitoring processing for the battery **50**. The monitoring processing for the battery **50** includes S**10** to S**30**. The monitoring processing for the battery **50** is always executed at a predetermined measurement cycle during the activation of the management part **130** regardless of whether or not the battery **50** is mounted on the vehicle **10**.

In S**10**, the management part **130** measures the current I of the assembled battery **60** based on the voltage Vr between both ends of the current detection resistor **54**. The management part **130** measures the voltage V of each secondary battery **62** based on the output of the voltage detection circuit **110** in S**20**, and measures the temperature of the assembled battery **60** based on the output of the temperature sensor **58** in S**30**.

The management part **130** operates using the assembled battery **60** as a power source, and constantly monitors the state of the battery **60** based on the data of the current I, the voltage V, and the temperature measured at a predetermined measurement cycle so long as there is no abnormality such as the total voltage Vab of the assembled battery **50** falling below the operating voltage.

When the abnormality of the battery **50** is detected, the management part **130** gives a command to the current breaker **53** to interrupt the current I and performs the protection operation for the battery **50**. The current breaker **53** and the management part **130** are a protective apparatus **120** of the battery **50**. The management part **130** is an example of a control part.

2. External Short Circuit and Battery Protection

When a metal material such as a tool **200** short-circuits the two external terminals **51**, **52** during assembling work or the like, an overcurrent flows through the assembled battery **60**. When the overcurrent flows, the assembled battery **60** abnormally generates heat. The value of the overcurrent at the time of discharge due to an external short circuit is much larger than the current value in the case of charge abnormality. However, at the time of starting the engine or the like, a very large current value is measured while the discharge is normal. Therefore, at the time of discharge, it is not easy to determine whether an abnormality such as an external short circuit has occurred, or the energy storage apparatus is normally operating from only the current value. The dead short circuit caused by the tool **200** or the like may occur intermittently such that the tool **200** is instantaneously separated from the external terminals **51**, **52** and comes into contact therewith again. Even when the dead short circuit is instantaneously released, the state of the battery **50** does not recover immediately, and damage remains in the battery **50** such that the state of charge (SOC) has deteriorated remarkably.

FIG. **7** is a flowchart of protection processing for the battery **50**. The protection processing for the battery **50** includes S**10** to S**180**. The protection processing for the battery **50** is always executed during the activation of the management part **130** regardless of whether or not the battery **50** is mounted on the vehicle **10**.

In step S**100**, the management part **130** compares the current I measured in the monitoring processing with a current threshold Is. When the current I is equal to or smaller than the current threshold Is (S**100**: NO), the comparison processing in S**100** is executed every time the current measurement is performed in the monitoring processing. The current threshold Is is a threshold for determining whether or not the current I is an overcurrent.

In the case of the overcurrent (S**100**: YES), the processing proceeds to S**110**. When the processing proceeds to S**110**, the management part **130** starts counting by the counter **135**. The counter **135** is for measuring a cumulative time during which the overcurrent is flowing.

After the counting is started, the processing proceeds to S**120**. When the processing proceeds to S**120**, the management part **130** compares the current I measured in the next measurement cycle of the monitoring processing with the current threshold Is and determines whether the overcurrent continues.

When the overcurrent continues (S**120**: YES), the processing proceeds to S**130**. When the processing proceeds to S**130**, the management part **130** adds "+1" to a count value N of the counter **135**.

Thereafter, in S**140**, the management part **130** compares the count value N with a cumulative threshold Ns. When the count value N is smaller than the cumulative threshold Ns (S**140**: NO), the processing returns to S**120**. The cumulative threshold Ns is a threshold for determining the accumulation of the overcurrent.

Thereafter, when the overcurrent continues to flow, the count value N is added with "+1" for each measurement cycle of the monitoring processing. The count value N is a cumulative value of times during which the current I exceeds the current threshold Is.

When the count value N reaches the cumulative threshold Ns, YES is determined in the determination processing of S**140**, and the processing proceeds to S**150**. When the processing proceeds to S**150**, the management part **130** gives a command to the current breaker **53** to interrupt the overcurrent (current interruption processing).

When the overcurrent does not continue, that is, when the current I is below the current threshold Is (S**120**: NO), the processing proceeds to S**160**.

When the processing proceeds to S**160**, the management part **130** measures a time during which the current I is below the current threshold Is, and compares the measured time with a reset time TR.

Then, when the time during which the current is below the current threshold Is is shorter than the reset time TR, the processing proceeds to S**170**. When the processing proceeds to S**170**, the management part **130** holds the count value N.

Thereafter, the processing proceeds to S**140**, and when an overcurrent is detected, the management part **130** restarts the counting by the counter **135**, and the count value N is subjected to the addition from the held value.

On the other hand, when the time during which the current is below the current threshold Is is longer than the reset time TR, the processing proceeds to S**180**. When the processing proceeds to S**180**, the management part **130** resets the count value N. Thereby, the count value N returns to zero.

FIG. **8** is a diagram illustrating a waveform of an overcurrent and transition of the count value N. The waveform of the overcurrent is a continuous waveform that always exceeds the current threshold Is. The count value N is cumulatively subjected to the addition to increase after time t**1** at which the overcurrent starts to flow, and the count value N reaches the cumulative threshold Ns at time t**2**.

When the count value N reaches the cumulative threshold Ns at time t**2**, current interruption processing (S**150**) is executed by the management part **130**, and the overcurrent is interrupted. The battery **50** can be protected by blocking the overcurrent.

FIG. **9** is a diagram illustrating a current waveform of an overcurrent and transition of the count value N. The waveform of the overcurrent is a discontinuous pulse-like waveform, and the current I is below the current threshold Is from t**2** to t**3** and from t**4** to t**5**. The lengths of period X_{23} and period X_{45} are shorter than the reset time TR.

During a period from time t**1** at which the overcurrent starts to flow to time t**2**, the current I exceeds the current threshold Is, and the count value N is subjected to the addition every time S**130** is executed, to increase with the lapse of time.

In period X_{23} from time t**2** to time t**3**, the current I is below the current threshold Is, but period X_{23} is shorter than the reset time TR, so that the count value N is held without being reset.

With the current I exceeding the current threshold Is during a period from time t**3** to time t**4**, the count value N is subjected to the addition every time S**130** is executed, to increase from the held value.

In period X_{45} from time t**4** to time t**5**, the current I is below the current threshold Is, but period X_{45} is shorter than the reset time TR, so that the count value N is held without being reset.

With the current I exceeding the current threshold Is after time t**6**, the count value N is subjected to the addition every time S**130** is executed, to increase from the held value. Then, the count value N reaches the cumulative threshold Ns at time t**6**.

When the count value N reaches the cumulative threshold Ns at time t**6**, current interruption processing (S**150**) is executed by the management part **130**, and the overcurrent is interrupted.

Even when the current I is below the current threshold Is, the count value N is not reset and is held so long as the current I falls within the reset time TR. Therefore, even in a discontinuous overcurrent in which there is a period during which the current I temporarily decreases, it is possible to prevent the count value N from being reset every time the current I falls below the current threshold Is, and it is possible to interrupt the overcurrent when the count value N reaches the cumulative threshold Ns.

FIG. **10** is a diagram illustrating current interruption conditions. The current interruption condition includes items of the current threshold Is, the cumulative threshold Ns, and the reset time TR. There are four current interruption conditions 1 to 4, and the current threshold Is and the cumulative threshold Ns are different from each other. The reset time TR is common to all the conditions 1 to 4.

The current interruption condition 1 is a condition for determining that a short circuit has occurred between the two external terminals **51**, **52** (or a condition for interrupting the external short circuit), and each of the current interruption conditions 2 to 4 is a condition for determining that a short circuit has occurred in a load connected to the external terminals **51**, **52** (or a condition for interrupting the load short circuit). In the current interruption condition 1, the current threshold Is is 1450 A, and the cumulative threshold Ns is 10 msec. The current interruption condition 1 has a larger current threshold Is and a shorter cumulative threshold Ns than those of the current interruption conditions 2 to 4.

In the current interruption conditions 2 to 4, since the magnitude of the short-circuit current varies depending on how the load is short-circuited, the current threshold Is is set in three stages, and the smaller the current threshold Is, the longer the cumulative threshold Ns.

The management part **130** simultaneously performs the protection processing (S**100** to S**150**) illustrated in FIG. **7** in parallel by using the four counters **135** for the current interruption conditions 1 to 4 and executes the current interruption processing of S**150** to interrupt the overcurrent when the count value N reaches the cumulative threshold Ns under any of the current interruption conditions 1 to 4.

By preparing a plurality of current interruption conditions, the number of combinations of the current threshold Is and the cumulative threshold Ns increases as compared to the case of one condition. Therefore, the current I can be interrupted in any event of a short circuit of the external terminal or a load short circuit.

Second Embodiment

FIG. **11** is a flowchart of the protection processing for the battery **50**. The protection processing for the battery **50** is always executed during the activation of the management part **130** regardless of whether or not the battery **50** is mounted on the vehicle **10**.

The management part **130** compares the current I measured in the monitoring processing with the current threshold Is (S**200**). The current threshold Is is a threshold for determining whether or not the current I is an overcurrent.

In the case of overcurrent (S**200**: YES), the management part **130** starts the recording of the current I (S**210**). The current I is recorded in the memory **133**.

After starting the recording, the management part **130** calculates a cumulative time Ta during which the overcurrent flowed in a detection period W (S**220**). The cumulative time Ta is a cumulative value of the times during which the current I exceeds the current threshold Is in the detection period W.

As illustrated in FIG. **12**, for example, in the detection period W, when there are three periods in which the current I exceeds the current threshold Is, the total time (Ta**1**+Ta**2**+Ta**3**) of three times is the cumulative time Ta.

Thereafter, the management part **130** determines whether the cumulative time Ta is 0 (S**230**), and when the cumulative time Ta is not 0, the management part **130** determines whether the cumulative time Ta is equal to or longer than the cumulative threshold Ts (S**240**).

When the cumulative time Ta is 0 (S**230**: YES), the management part **130** ends the recording of the current I (S**260**). When the cumulative time Ta is equal to or longer than the cumulative threshold Ts (S**240**: YES), the current interruption processing of interrupting the current I is performed by the current breaker **53** (S**250**).

When the cumulative time Ta is smaller than the cumulative threshold Ts (NO in S**240**), the processing returns to S**220**, and the management part **130** executes the processing of S**220** to S**240** for the next detection period W.

FIG. **13** is a diagram illustrating the current waveform of the overcurrent and the transition of the cumulative time Ta. The waveform of the overcurrent is a discontinuous pulse-like waveform, and the current I is below the current threshold Is from t**2** to t**3** and from t**4** to t**5**.

The recording of the current I is started from time t**1** when the current I exceeds the current threshold Is. The management part **130** calculates the cumulative time Ta for the detection period W**1** and compares the cumulative time Ta with the cumulative threshold value Ts. When the cumulative time Ta does not exceed the cumulative threshold Ts, the cumulative time Ta is calculated and compared with the cumulative threshold Ts for the next detection period W**2**.

The cumulative time Ta does not reach the cumulative threshold Ts in the detection periods W**1** to W**8** and reaches the cumulative threshold Ts in the detection period W**9**. Thus, at time t**6** when the detection period W**9** has elapsed, the current interruption processing (S**250**) is executed by the management part **130**, and the overcurrent is interrupted.

Each of the detection periods W**1** to W**9** is shifted by cycle Y and is continuous while overlapping each other. In this way, the detection interval of the cumulative time Ta can be shortened, so that the current interruption processing (S**250**) can be quickly executed when a short circuit occurs.

FIG. **14** is a diagram illustrating current interruption conditions. The current interruption condition includes items of the current threshold Is, the cumulative threshold Ts, and the detection period W. There are four types, 1 to 4, of current interruption conditions, and the current threshold Is, the cumulative threshold Ts, and the detection period W are different among the conditions.

The current interruption condition 1 is a first condition for interrupting a short circuit between the two external terminals **51**, **52**. Each of the current interruption conditions 2 to 4 is a second condition for interrupting a short circuit of a load connected to the external terminals **51**, **52**

The management part **130** simultaneously performs the protection processing (S**200** to S**260**) illustrated in FIG. **11** in parallel for the current interruption conditions 1 to 4 and performs the current interruption processing of S**250** to interrupt the overcurrent when the cumulative time Ta reaches the cumulative threshold Ts under any of the current interruption conditions.

Other Embodiments

The present invention is not restricted to the embodiments described in the above description and the drawings, but, for example, the following embodiments are included in the technical scope of the present invention.

(1) In the above embodiment, the secondary battery **62** has been exemplified as an example of the energy storage device. The energy storage device is not limited to the secondary battery **62** but may be a capacitor. The secondary battery **62** is not limited to a lithium ion secondary battery but may be another nonaqueous electrolyte secondary battery. A lead-acid battery or the like can also be used. The energy storage device is not limited to a case where a plurality of energy storage devices are connected in series but may be connected in series or may have a single cell structure.

(2) In the above embodiments, the battery **50** has been used for a vehicle. The use of the battery **50** is not limited to a specific use. The battery **50** may be used for various uses such as a use for a moving body (a vehicle, a ship, an automatic guided vehicle (AGV), etc.) and an industrial use (an energy storage apparatus for an uninterruptible power system or a photovoltaic power generating system).

(3) In the above embodiment, the management part **130** has been provided inside the battery **50**. The battery **50** only needs to include at least meters such as the current detection resistor **54** and the voltage detection circuit **110** and the current breaker **53**, and the management part **130** may be outside the apparatus of the battery **50**.

(4) In the above embodiment, the current breaker **53** has been disposed in the power line **55**P of the positive electrode, and the current detection resistor **54** has been disposed in the power line **55**N of the negative electrode. Conversely, the current detection resistor **53** may be disposed in the power line **55**P of the positive electrode, and the current detection resistor **54** may be disposed in the power line **55**N of the negative electrode.

(5) In the above embodiment, the protection processing (S**200** to S**260**) has been simultaneously performed in parallel for the current interruption conditions 1 to 4, and the current interruption processing has been executed to interrupt the overcurrent when the cumulative time Ta reaches the cumulative threshold Ts under any of the current interruption conditions. In addition, the protection processing

(S200 to S260) may be performed for any one of the four conditions of the current interruption conditions 1 to 4, and the current interruption processing may be executed to interrupt the overcurrent when the count value N reaches the cumulative threshold Ns. For example, when it is predicted that the external short circuit is likely to occur, the protection processing (S200 to S260) may be executed only for the current interruption condition 1, and the current interruption processing may be executed to interrupt the overcurrent when the count value N reaches the cumulative threshold Ns. When the current interruption condition is selected, a current interruption condition corresponding to a short circuit having a high occurrence probability may be selected. The number of current interruption conditions to be selected is not limited to one but may be two. That is, at least one or more conditions may be selected. The management part **130** may calculate a cumulative value of times during which the current I exceeds any of the current thresholds Is, and execute the current interruption processing when the calculated cumulative value exceeds one of the cumulative thresholds associated with the current threshold Is.

(6) In the above embodiment, the control part has calculated the cumulative value of the times during which the current exceeds any of the current thresholds, and executed the current interruption processing of interrupting the current when the calculated cumulative value exceeds a cumulative threshold associated with the current threshold. Alternatively, the control part may calculate a cumulative value of times during which the current exceeds any of the current thresholds, and cause the communication part to transmit an alarm signal when the calculated cumulative value exceeds a cumulative threshold associated with the current threshold.

As illustrated in FIG. **15**, the protective apparatus **120** may include a communication part **137** controlled by the management part **130**. The housing **71** may include a communication connector **138** on the lid body **74**, for example. The communication part **137** may be communicably connected to a controller of the vehicle outside the battery, such as an electronic control unit (ECU), via the communication connector **138**.

Instead of executing the current interruption processing when the interruption condition is satisfied, the management part **130** notifies the ECU outside the battery that the interruption condition has been satisfied via the communication part **137**, that is, transmits an alarm signal, and determines whether or not to execute the current interruption processing in cooperation with the ECU. Upon reception of the alarm signal, the ECU can proceed with preparation for the current interruption processing, processing for avoiding the current interruption processing such as stopping the operation of some loads, and other problem-solving processing.

(7) The present technique can be applied to a protection program for an energy storage device. The protection estimation program for the energy storage device is a program for causing a computer to execute the following processing. The protection estimation program is a program for causing the computer to execute current interruption processing in which a current interruption condition for interrupting a current of an energy storage device includes a plurality of conditions with different current thresholds and cumulative thresholds, and the control part calculates a cumulative value of times during which the current exceeds any one of the current thresholds, and interrupts the current when the calculated cumulative value exceeds one of the cumulative thresholds associated with the current threshold. The present technique can be applied to a recording medium in which the protection program for the energy storage device is recorded. The computer is, for example, the management part **130**. The energy storage device is, for example, the secondary battery **62**. The protection program can be recorded in a recording medium such as a read-only memory (ROM).

DESCRIPTION OF REFERENCE SIGNS

10: vehicle
50: battery (energy storage apparatus)
53: current breaker
54: current detection resistor
60: assembled battery
62: secondary battery (energy storage device)
120: protective apparatus
130: management part (control part)
131: CPU
133: memory
135: counter
N: count value (cumulative value)
Ns: cumulative threshold
Is: current threshold
Ta: cumulative time (cumulative value)
Ts: cumulative threshold

The invention claimed is:

1. A protective apparatus for an energy storage device, comprising:
- a current breaker that interrupts a current of the energy storage device; and
- a control part,
- wherein the control part calculates a cumulative value of times during which the current exceeds a current threshold, and executes current interruption processing of interrupting the current when the calculated cumulative value exceeds a cumulative threshold associated with the current threshold, and
- the control part counts, as the cumulative value, times during which the current continuously exceeds the current threshold, and in a case where the current falls from a state of exceeding the current threshold, the control part holds the cumulative value when a time during which the current is below the current threshold is equal to or shorter than a reset time.

2. A protective apparatus for an energy storage device, comprising:
- a current breaker that interrupts a current of the energy storage device; and
- a control part,
- wherein there are a plurality of conditions having different current thresholds and cumulative thresholds, and
- the control part calculates a cumulative value of times during which the current exceeds any one of the current thresholds, and executes current interruption processing of interrupting the current when the calculated cumulative value exceeds one of the cumulative thresholds associated with the current threshold,
- the current breaker is provided in a current path connecting the energy storage device and an external terminal, and
- the conditions at least include
- a first condition for determining that a short circuit of the external terminal occurs, and
- a second condition for determining that a short circuit of a load connected to the external terminal occurs.

3. An energy storage apparatus comprising:
an energy storage device; and
the protective apparatus according to claim 1.

4. The energy storage apparatus according to claim 3, wherein the energy storage apparatus is rated at 12 V.

5. A method for protecting an energy storage device, the method comprising:
by a control part, calculating a cumulative value of times during which the current exceeds a current threshold, and executing current interruption processing of interrupting the current when the calculated cumulative value exceeds a cumulative threshold associated with the current threshold, and
calculating, as the cumulative value, times during which the current continuously exceeds the current threshold, and in a case where the current falls from a state of exceeding the current threshold, holding the cumulative value when a time during which the current is below the current threshold is equal to or shorter than a reset time.

6. A non-transitory computer readable medium storing computer executable instructions according to the method of claim 5.

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