

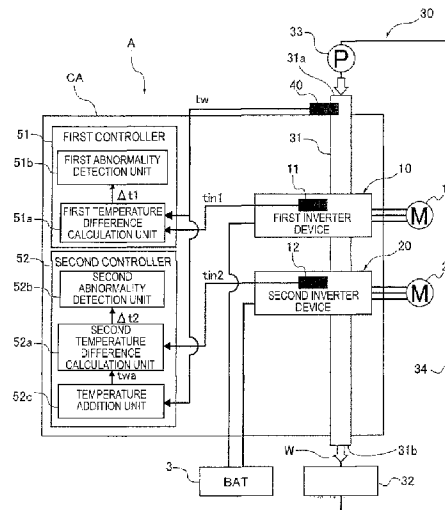


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(54) **Titre : PROCÉDE DE DETECTION D'ANOMALIE DE TEMPERATURE DANS UN APPAREIL DE CONVERSION DE PUISSANCE, ET DISPOSITIF DE DETECTION D'UNE ANOMALIE DE TEMPERATURE DANS UN APPAREIL DE CONVERSION DE PUISSANCE**

(54) **Title: TEMPERATURE ABNORMALITY DETECTION METHOD FOR POWER CONVERSION APPARATUS AND TEMPERATURE ABNORMALITY DETECTION DEVICE FOR POWER CONVERSION APPARATUS**



(57) **Abstrégé/Abstract:**

To provide an abnormality detection method for an inverter device that can improve the abnormality detection accuracy of a power module of a subsequent stage without adding a sensor for detecting the cooling fluid temperature.

An abnormality detection method for a inverter device comprises: a step (S1) for reading a first inverter temperature (tin1), a second inverter temperature (tin2), and a cooling water temperature (tw); a step (S3) for determining the presence of an abnormality in the first inverter device (10) of the preceding stage based on a first temperature difference (Δt1) between the first inverter temperature (tin1) and the cooling water temperature (tw); and a step (S6) for determining the presence of an abnormality in the second inverter device (20) in a subsequent stage based on a second temperature difference (Δt2) between a second inverter temperature (tin2) and added temperature (twa) obtained by converting a loss component of the first inverter device (10) into a temperature (addition value Tad) which is added to the cooling water temperature (tw).

ABSTRACT

To provide an abnormality detection method for an inverter device that can improve the abnormality detection accuracy of a power module of a subsequent stage without adding a sensor for detecting the cooling fluid temperature.

An abnormality detection method for a inverter device comprises: a step (S1) for reading a first inverter temperature (t_{in1}), a second inverter temperature (t_{in2}), and a cooling water temperature (t_w); a step (S3) for determining the presence of an abnormality in the first inverter device (10) of the preceding stage based on a first temperature difference (Δt_1) between the first inverter temperature (t_{in1}) and the cooling water temperature (t_w); and a step (S6) for determining the presence of an abnormality in the second inverter device (20) in a subsequent stage based on a second temperature difference (Δt_2) between a second inverter temperature (t_{in2}) and added temperature (t_{wa}) obtained by converting a loss component of the first inverter device (10) into a temperature (addition value T_{ad}) which is added to the cooling water temperature (t_w).

SPECIFICATION

Title of Invention:

TEMPERATURE ABNORMALITY DETECTION METHOD FOR POWER CONVERSION APPARATUS AND TEMPERATURE ABNORMALITY DETECTION DEVICE FOR POWER CONVERSION APPARATUS

Technical Field

[0001] The present invention relates to a temperature abnormality detection method for a power conversion apparatus and a temperature abnormality detection device for a power conversion apparatus.

Background Art

[0002] Conventionally, a technique is known in which a cooling flow path for circulating cooling water is provided in a power conversion apparatus such as an inverter device to protect the device from overheating, and temperature abnormalities are detected in the power conversion apparatus or the cooling flow path (for example, see Patent Document 1).

In this prior art the difference between the temperature of the cooling water and the temperature of the power conversion apparatus is compared with a temperature threshold value, and the fluctuation range of an indicated torque signal is compared with a torque fluctuation range threshold value. Then, if a state in which the fluctuation range of the indicated torque signal falls below the torque fluctuation range threshold value and the difference value of the temperatures exceeds the temperature threshold continues for longer than a prescribed period of time, the state is determined to be abnormal.

Prior Art Documents

Patent Documents

[0003] Patent Document 1: Japanese Laid Open Patent Application No. 2011-172406

Summary of the Invention

Problem to be Solved by the Invention

[0004] In recent years, there are case in which a plurality of power conversion apparatuses such as the inverter device described above are installed in a vehicle or the like.

However, if the prior art described above is applied to each power conversion apparatus, it becomes necessary to provide a cooling flow path in each power conversion apparatus, and to detect the temperatures of each of the power conversion apparatuses and

the cooling water to carry out temperature abnormality detection, which increases the number of temperature sensors and cooling flow paths. This leads to an increase in cost and an increase in the installation space.

[0005] In view of the problems described above, an object of the present invention is to provide a temperature abnormality detection method for a power conversion apparatus and a temperature abnormality detection device for a power conversion apparatus with which the number of cooling flow paths and temperature sensors can be reduced, thereby reducing the cost and the size.

Means to Solve the Problem

[0006] In the temperature abnormality detection method for a power conversion apparatus according to the present invention the temperatures of a plurality of power converters are detected, but with regard to the temperature of cooling fluid, only the temperature of cooling fluid that is upstream from these power converters is detected.

For the power converter in the preceding stage that is disposed on the upstream side in the cooling flow path, the presence of an abnormality is determined based on the difference between the temperature of this power converter and the temperature of the cooling fluid.

For the power converter in the subsequent stage that is disposed downstream from the cooling flow path, the presence of an abnormality is determined based on the difference between the temperature of the subsequent stage power converter and a temperature obtained by converting a loss component of the preceding stage power converter into a temperature which is added to the temperature of the cooling fluid.

According to an aspect of the present invention there is provided a temperature abnormality detection method for a power conversion apparatus provided with a plurality of power converters that convert and transmit electric power, and a cooling flow path that passes through the plurality of power converters and cools each of the power converters, the method comprising:

detecting temperatures of the power converters and detecting a temperature of a cooling fluid of the cooling flow path on an upstream side of the power converters;

determining a presence of an abnormality in a preceding stage power converter disposed upstream in the cooling flow path from among the plurality of power converters based on a difference between a temperature of the preceding stage power converter and the temperature of the cooling fluid; and

determining a presence of an abnormality in a subsequent stage power converter disposed downstream from the preceding stage power converter in the cooling flow path based on a difference between the temperature of the subsequent stage power converter and a temperature obtained by converting a loss component of the preceding stage power converter into a temperature which is added to the temperature of the cooling fluid.

According to another aspect of the present invention there is provided a temperature abnormality detection device for a power conversion apparatus, comprising:

a plurality of power converters that convert and transmit electric power;

a cooling flow path that passes through the plurality of power converters and cools each of the power converters;

power converter temperature sensors that detect temperatures of the plurality of power converters;

a cooling fluid temperature sensor that detects a temperature of a cooling fluid of the cooling flow path that is upstream from the plurality of power converters;

a preceding stage temperature difference calculation unit that calculates a difference between a cooling fluid temperature and a temperature of a preceding stage power converter disposed upstream in the cooling flow path;

a preceding stage power converter abnormality detection unit that carries out abnormality determination based on the difference calculated by the preceding stage temperature difference calculation unit;

a temperature addition unit that converts a loss component of the preceding stage power converter into a temperature and adds the same to the cooling fluid temperature;

a subsequent stage temperature difference calculation unit that calculates a difference between the temperature calculated by the temperature addition unit and a temperature of a subsequent stage power converter disposed downstream from the preceding stage power converter in the cooling flow path; and

a subsequent stage power converter abnormality detection unit that carries out abnormality determination based on the difference calculated by the subsequent stage temperature difference calculation unit.

Effects of the Invention

[0007] In the temperature abnormality detection method for a power conversion apparatus of the present invention it is not necessary to detect the temperature of the cooling fluid upstream from the power converter of the subsequent stage, and the number of necessary temperature sensors can be reduced. Therefore, it is possible to reduce the number of temperature sensors and cooling flow paths, thereby reducing costs and the size of the installation space.

Brief Description of the Drawings

[0008] [Figure 1] Figure 1 is an overall view schematically illustrating a power conversion apparatus to which the temperature abnormality detection method of a first embodiment is applied.

[Figure 2] Figure 2 is a flowchart illustrating the flow of an abnormality determination process of the power conversion apparatus.

[Figure 3] Figure 3 is an overall view schematically illustrating a power conversion apparatus to which the temperature abnormality detection method of a second embodiment is applied.

[Figure 4] Figure 4 is an overall view schematically illustrating a power conversion apparatus to which the temperature abnormality detection method of the second embodiment is applied.

[Figure 5] Figure 5 is an overall view schematically illustrating a power conversion apparatus of a third embodiment.

[Figure 6] Figure 6 is an overall view schematically illustrating a power conversion apparatus of a fourth embodiment.

Embodiments for Implementing the Invention

[0009] In the following, preferred embodiments for realizing the abnormality detection method for a power conversion apparatus of the present invention will be described based on the embodiments illustrated in the drawings.

(First Embodiment)

A temperature abnormality detection method and a power conversion apparatus for a power conversion apparatus of the first embodiment will be described below.

(Overall Configuration of a Drive System Comprising an Inverter Device)

First, the configuration of a power conversion apparatus A to which the temperature abnormality detection method according to the first embodiment is applied will be described with reference to Figure 1.

[0010] The power conversion apparatus A illustrated in Figure 1 comprises a first inverter device (a power converter) 10 for driving a first power generation machine 1, and a second inverter device (a power converter) 20 for driving a second power generation machine 2.

[0011] The first power generation machine 1 and the second power generation machine 2 are mounted in an electric vehicle, a hybrid vehicle, or the like, which is not shown.

The purposes of the two power generation machines 1, 2 are not particularly limited. For example, the two power generation machines 1, 2 can be used as drive sources

for supplying driving force to drive wheels, which are not shown. Alternatively, one of the two power generation machines 1, 2 can be used as the drive source, and the other can be used as a generator for generating power by being driven by a drive source, such as an engine, which is not shown.

[0012] The two inverter devices 10, 20 are mounted in a casing CA that houses the power conversion apparatus A.

The first inverter device 10 converts a direct current, which is the electric power from a battery 3, to an alternating current, and supplies the alternating current to the first power generation machine 1, thereby driving the first power generation machine 1, or converts the alternating current generated by the first power generation machine 1 into a direct current, and supplies the direct current to the battery 3 for charging.

[0013] Although not shown, the first inverter device 10 contains a smoothing capacitor and a power module, such as an IGBT module. Additionally, a secondary battery (lithium ion secondary battery, nickel hydrogen battery, or the like) having a voltage control range of about several hundred volts is employed as the battery 3.

[0014] As with the first inverter device 10, the second inverter device 20 also can convert a direct current from the battery 3 to an alternating current, and supply the alternating current to the second power generation machine 2, and also can convert the alternating current generated by the second power generation machine 2 into a direct current, and supply the direct current to the battery 3 for charging. Although not shown, this second inverter device 20 also contains a smoothing capacitor and a power module.

[0015] Furthermore, the first inverter device 10 and the second inverter device 20 respectively include a first inverter temperature sensor 11 and a second inverter temperature sensor 12, which detect the temperature of an internal heat-generating unit, such as a power module.

[0016] In addition, the power conversion apparatus A comprises a cooling device 30.

This cooling device 30 comprises a cooling water path 31, a radiator 32, a pump 33, and a circulation path 34, and cools the two inverter devices 10, 20 by circulating cooling water W.

[0017] The cooling water path 31 is a flow path that is formed in the casing CA, and that runs from an inflow port 31a at a first end through the first inverter device 10 (the power converter of the preceding stage) and the second inverter device 20 (the power

converter of the subsequent stage) in that order, and reaches an outflow port 31b at a second end.

[0018] A circulation path 34, which is a flow path extending from the outflow port 31b to the inflow port 31a and provided with the radiator 32 and the pump 33 in the middle thereof, is connected to the cooling water path 31. The pump 33 circulates cooling water W by sucking the cooling water W from the outflow port 31b and pumping the cooling water to the inflow port 31a. The radiator 32 radiates the heat of the cooling water W to the outside air, thereby cooling the cooling water W.

[0019] Furthermore, a water temperature sensor 40 is provided in the vicinity of the inflow port 31a, which is upstream from the first inverter device 10 in the cooling water path 31.

Detection signals from this water temperature sensor 40 and the first inverter temperature sensor 11 and the second inverter temperature sensor 12 described above are input to a first controller 51 and a second controller 52.

[0020] The first controller 51 detects a temperature abnormality of the first inverter device 10, and the second controller 52 detects a temperature abnormality of the second inverter device 20.

[0021] Next, the configurations of the first controller 51 and the second controller 52 will be described.

The first controller 51 comprises a first temperature difference calculation unit 51a and a first abnormality detection unit 51b.

The first temperature difference calculation unit 51a receives inputs of a first inverter temperature t_{in1} detected by the first inverter temperature sensor 11 and a cooling water temperature t_w detected by the water temperature sensor 40, and calculates a first temperature difference Δt_1 ($t_{in1} - t_w$), which is the difference between the two.

[0022] The first abnormality detection unit 51b determines an abnormality when the first temperature difference Δt_1 is higher than a first abnormality determination temperature t_{lim1} , and determines that there is no abnormality when the first temperature difference Δt_1 is equal to or less than the first abnormality determination temperature t_{lim1} . That is, if an abnormality occurs in the cooling device 30, or an abnormality occurs in the first inverter device 10 and abnormal heat generation occurs, the first temperature difference Δt_1 , which is the difference between the first inverter temperature t_{in1} and the cooling water temperature t_w , increases. Therefore, the first abnormality determination

temperature t_{lim1} is set to a value with which an occurrence of an abnormality can be determined, based on simulations, actual measurements at the time an abnormality occurs, and the like.

[0023] The second controller 52 comprises a second temperature difference calculation unit 52a, a second abnormality detection unit 52b and a temperature addition unit 52c.

The temperature addition unit 52c sets, as an addition value T_{ad} , a value obtained by converting the loss in the first inverter device 10 during operation into a temperature increase of the cooling water temperature t_w , and adds this value to the cooling water temperature t_w detected by the water temperature sensor 40 to obtain an added temperature t_{wa} . In the first embodiment, the temperature increase due to this loss is set to the increase in the temperature of the cooling water temperature t_w due to heat generation of the first inverter device 10 at the time of the maximum loss that is assumed in the first inverter device 10. An example of a time of maximum loss is when the first power generation machine 1 is in a locked state. For example, a locked state is when the wheels of the vehicle are hitting a wheel stop or the like, and the vehicle cannot move forward even when attempting to move forward; that is, a case in which rotation does not occur in the first power generation machine 1, even though the first power generation machine 1 is being energized and driven.

[0024] In such a locked state, the energy loss in the first power generation machine 1 becomes maximum, and is lost as thermal energy. As for the addition value T_{ad} to be added to the cooling water temperature t_w , such a locked state is actually reproduced, and the relationship between the cooling water temperature t_w , the command value to the first power generation machine 1, and the temperature increase (addition value T_{ad}) of the cooling water temperature t_w at that time is stored in the form of a map or an arithmetic expression, for example, in the first controller 51. Therefore, the temperature addition unit 52c calculates the addition value T_{ad} from the command value and the cooling water temperature t_w at the time the addition is carried out, and adds this value to the cooling water temperature t_w to obtain the added temperature t_{wa} .

[0025] The second temperature difference calculation unit 52a receives as inputs a second inverter temperature t_{in2} and the added temperature t_{wa} , and calculates a second temperature difference Δt_2 , which is the difference between the two.

The second abnormality detection unit 52b determines an abnormality when the second temperature difference $\Delta t2$ is higher than a second abnormality determination temperature $tlim2$, and determines that there is no abnormality when the second temperature difference $\Delta t2$ is equal to or less than the second abnormality determination temperature $tlim2$. This second abnormality determination temperature $tlim2$ is set in accordance with the second power generation machine 2 and the second inverter device 20, and is not necessarily the same value as the first abnormality determination temperature $tlim1$.

[0026] Next, the flow of an abnormality determination process carried out by the first controller 51 and the second controller 52 will be described based on the flowchart in Figure 2. This abnormality determination process is carried out repeatedly every control cycle, which is set in advance.

[0027] In the first Step S1, a first inverter temperature $tin1$, a second inverter temperature $tin2$, and a cooling water temperature tw , which are detected temperatures respectively from the first inverter temperature sensor 11, the second inverter temperature sensor 12, and the water temperature sensor 40, are read into the two controllers 51, 52.

[0028] In the next Step S2, the first temperature difference calculation unit 51a calculates a first temperature difference $\Delta t1$, which is the difference between the first inverter temperature $tin1$ and the cooling water temperature tw , and the process proceeds to Step S3.

[0029] In Step S3, the presence of an abnormality in either the first inverter device 10 or the cooling system is determined by the first abnormality detection unit 51b, based on whether the first temperature difference $\Delta t1$ is larger than the first abnormality determination temperature $tlim1$. If an abnormality is determined from $\Delta t1 > tlim1$ the process proceeds to Step S7, and if it is determined that there is no abnormality (normal) from $\Delta t1 \leq tlim1$ the process proceeds to Step S4.

[0030] In Step S4, to which the process proceeds when the first abnormality detection unit 51b determines that there is no abnormality (normal), the temperature addition unit 52c adds an addition value Tad corresponding to the loss component in the first inverter device 10 during operation to the cooling water temperature tw , thereby obtaining the added temperature twa , and the process proceeds to Step S5.

[0031] In Step S5, the second temperature difference calculation unit 52a calculates a second temperature difference Δt_2 , which is the difference between the second inverter temperature t_{in2} and the added temperature t_{wa} , and the process proceeds to Step S6.

[0032] In Step S6, the presence of an abnormality in either the second inverter device 20 or the cooling system is determined by the second abnormality detection unit 52b, based on whether the second temperature difference Δt_2 is larger than the second abnormality determination temperature t_{lim2} . If an abnormality is determined from $\Delta t_2 > t_{lim2}$, the process proceeds to Step S7, and if it is determined that there is no abnormality (normal) from $\Delta t_2 \leq t_{lim2}$, the first abnormality determination process is ended.

[0033] In Step S7, to which the process proceeds when an abnormality is determined in either Step S3 or Step S6, a preset fail process is executed. This fail process can be any process that suppresses heat generation in the two power generation machines 1, 2; for example, the process may be one whereby the output of one of the two power generation machines 1, 2 is suppressed by a predetermined amount or is stopped.

[0034] (Operation of the first embodiment)

Next, the operation of the first embodiment will be described.

When the inverter devices 10, 20 are driven a loss occurs in the switching element or the power module, which are not shown, heat corresponding to the loss component is generated, and the inverter temperatures t_{in1} , t_{in2} increase. In addition, each inverter device 10, 20 is cooled by the cooling device 30, and, accordingly the cooling water temperature t_w in the cooling water path 31 is increased due to the heat generation of the first inverter device 10, and this increased cooling water temperature t_w is further increased due to the heat generation of the second inverter device 20. This cooling water the temperature of which has increased is cooled by the radiation of heat by the radiator 32, and then is supplied again to the cooling water path 31.

[0035] Here, if an abnormality occurs in the cooling device 30, or if a switching element or a power module of the inverter devices 10, 20 generates abnormal heat, the temperature difference between the cooling water temperature t_w of the cooling water path 31 and each inverter temperature t_{in1} , t_{in2} increases.

[0036] Therefore, in order to detect the temperature difference between each inverter temperature t_{in1} , t_{in2} and the cooling water temperature t_w accurately it is necessary to add a water temperature sensor that detects the cooling water temperature that has increased due to the heat generation of the first inverter device 10.

[0037] However, in that case the number of water temperature sensors increases, which leads to increased costs. In addition, it is necessary to provide a water temperature sensor in a cooling water path 31 formed in the casing CA of the power conversion apparatus A, which requires labor for the installation. In particular, installation is relatively easy if this cooling water path 31 is a pipeline or the like that is independent of the casing CA, but if the cooling water path is integrally formed with the casing CA, it is difficult to carry out installation such that the cooling water temperature t_w can be accurately detected and high sealing performance can be ensured.

[0038] However, if the abnormality determination of the second inverter device 20 is carried out based on the difference between the second inverter temperature t_{in2} and the cooling water temperature t_w detected by the water temperature sensor 40, which is lower than the actual cooling water temperature of the second inverter device 20, this difference will be a value that is larger than the actual difference. Accordingly, the abnormality determination accuracy decreases, and the possibility that an abnormality will be erroneously determined and a fail process will be executed increases. That is, there is the risk that the abnormality detection accuracy will decrease, and that the operation range of the power conversion apparatus A will be reduced.

[0039] In contrast thereto, in the first embodiment an addition value T_{ad} obtained by converting the loss component of the first inverter device 10 is used with the cooling water temperature t_w detected by the water temperature sensor 40, for the abnormality determination for the second inverter device 20. Accordingly, the second temperature difference (Δt_2) between the second inverter temperature t_{in2} and the cooling water temperature in the second inverter device 20 is more accurate than when the cooling water temperature t_w detected by the water temperature sensor 40 is used as is, and the abnormality detection accuracy is improved. In addition, because the detection of the water temperature is carried out only by a water temperature sensor 40 that is on the upstream side in the cooling water path 31, it is possible to suppress the cost compared to when a water temperature sensor is separately added in the power conversion apparatus A.

[0040] Additionally, because an addition value T_{ad} that is set in advance based on actual measurement values is used in the temperature addition unit 52c, the configuration of the temperature addition unit 52c of the second controller 52 can be simplified, and the cost can be reduced. Additionally, a value set based on the temperature due to the maximum loss assumed in the first inverter device 10 is used as the addition value T_{ad} .

Accordingly, the actual temperature increase of the cooling water W due to heat generation of the first inverter device 10 will not exceed the addition value T_{ad} , so it is possible to prevent an erroneous determination in which the device is determined to be normal even though an abnormality has occurred.

[0041] (Effects of the First Embodiment)

The effects of the first embodiment are as follows.

1) The temperature abnormality detection method for a power conversion apparatus A according to the first embodiment is

a temperature abnormality detection method for a power conversion apparatus A provided with a first inverter device 10 and a second inverter device 20 as a plurality of power converters that convert and transmit electric power, and a cooling water path 31 that passes through the two inverter devices 10, 20 and cools each of the inverter devices 10, 20, comprising:

a step (S1) for detecting the temperatures (first inverter temperature t_{in1} , second inverter temperature t_{in2}) of the two inverter devices 10, 20, detecting the temperature (cooling water temperature t_w) of the cooling water in the cooling water path 31 on the upstream side of the two inverter devices 10, 20, and reading these detected temperatures;

a step (S3) for determining a presence of an abnormality in the first inverter device 10 from among the two inverter devices 10, 20, as a preceding stage power converter disposed upstream in the cooling water path 31 based on a first temperature difference Δt_1 between the first inverter temperature t_{in1} and the cooling water temperature t_w ; and

a step (S6) for determining a presence of an abnormality in the second inverter device 20 as a subsequent stage power converter disposed downstream from the first inverter device 10 by calculating an added temperature t_{wa} (Step S4) obtained by converting a loss component of the first inverter device 10 into a temperature (addition value T_{ad}) that is added to the cooling water temperature t_w , calculating a second temperature difference Δt_2 between this added temperature t_{wa} and the second inverter temperature t_{in2} (Step S5), and making the determination based on this second temperature difference Δt_2 .

Therefore, in a power conversion apparatus A equipped with first and second inverter devices 10, 20 as power converters, the number of water temperature sensors 40

can be set to "1," thereby reducing the cost, and enabling abnormality detection of the two inverter devices 10, 20 and the cooling system to be carried out with high accuracy.

[0042] 2) In the temperature abnormality detection method for a power conversion apparatus A according to the first embodiment,

the temperature (addition value T_{ad}) obtained by converting the loss component is set to a value based on a temperature that is converted from a maximum loss assumed in the first inverter device 10.

Therefore, it is possible to simplify the calculation in the temperature addition unit 52c and reduce the cost, and erroneous determinations, in which the device is determined to be normal even though an abnormality has occurred, can be prevented, thereby obtaining high detection accuracy.

[0043] 3) A temperature abnormality detection device for a power conversion apparatus A according to the first embodiment comprises:

a first inverter device 10 and a second inverter device 20 as a plurality of power converters that convert and transmit electric power;

a cooling water path 31 that passes through the two inverter devices 10, 20 and cools each of the inverter devices 10, 20;

a first inverter temperature sensor 11 and a second inverter temperature sensor 12 as power converter temperature sensors that detect the temperature of each inverter device 10, 20;

a water temperature sensor 40 that detects the temperature of cooling water of a cooling water path 31 upstream from the two inverter devices 10, 20;

a first temperature difference calculation unit 51a as a preceding stage temperature difference calculation unit that calculates a first temperature difference Δt_1 , which is the difference between a cooling water temperature t_w and a first inverter temperature t_{in1} , which is the temperature of the first inverter device 10;

a first abnormality detection unit 51b as a preceding stage power converter abnormality detection unit that carries out abnormality determination based on a first temperature difference Δt_1 calculated by the first temperature difference calculation unit 51a;

a temperature addition unit 52c that converts the loss component of the first inverter device 10 into temperature and adds the same to the cooling water temperature t_w ;

a second temperature difference calculation unit 52a as a subsequent stage temperature difference calculation unit that calculates a second temperature difference Δt_2 , which is the difference between the added temperature t_{wa} calculated by the temperature addition unit 52c and the second inverter temperature t_{in2} ; and

a second abnormality detection unit 52b as a subsequent stage power converter abnormality detection unit that carries out abnormality determination based on a second temperature difference Δt_2 calculated by the second temperature difference calculation unit 52a.

Therefore, in a power conversion apparatus A equipped with first and second inverter devices 10, 20 as power converters, the number of water temperature sensors 40 can be set to "1," thereby reducing the cost, and enabling abnormality detection of the two inverter devices 10, 20 and the cooling system to be carried out with high accuracy.

[0044] (Other Embodiments)

In the following a temperature abnormality detection method and a temperature abnormality detection device for a power conversion apparatus of another embodiment will be described.

When describing the other embodiment, configurations common to other embodiments are given the same reference symbols as those embodiments, and the descriptions thereof are omitted, with only the differences with respect to those embodiments being described.

[0045] (Second Embodiment)

The second embodiment is an example in which the method of converting the loss component of the first inverter device 10 into temperature and adding the same to the cooling water temperature t_w is different from that of the first embodiment.

That is, in the second embodiment, a value calculated based on loss calculation information that includes semiconductor characteristics, the carrier frequency, and the current supplied to the first inverter device 10, is used as the temperature obtained by converting the loss component of the first inverter device 10.

[0046] Figure 3 is an overall view schematically illustrating a power conversion apparatus B to which the temperature abnormality detection method of the second embodiment is applied.

In the temperature addition unit 252c of the second controller 252 illustrated in Figure 3, an addition value calculated by a loss calculation unit 200 provided in the first

controller 251 is used as the addition value, which is the temperature of the loss component.

[0047] In addition, the loss calculation unit 200 calculates the addition value T_{ad} based on loss calculation information that includes the semiconductor characteristics, the carrier frequency f , and the current I in the first inverter device 10.

The first inverter device 10 comprises a well-known bridge-connected insulated gate bipolar transistor (hereinafter referred to as IGBT), and a diode (Free Wheeling Diode, hereinafter referred to as FWD).

[0048] Therefore, the steady loss in the IGBT of the first inverter device 10 is calculated using the following formula (1), and the switching loss in the IGBT is calculated using the following formula (2).

In addition, the steady loss in the FWD of the first inverter device 10 is calculated using the following formula (3), and the switching loss in the FWD is calculated using the following formula (4).

The power module loss in the first inverter device 10 is then calculated from these values using the following formula (5).

[Formula 1]

$$P(I_{sat}) = \frac{1}{2\pi} \int_0^\pi (I_c \times \sin x) \times (V_{ce(sat)} \times \sin x) \times \frac{1 + D \times \sin(x + \theta)}{2} dx \quad \cdot \cdot (1)$$

[Formula 2]

$$P(I_{sw}) = E_{sw} \times f \times \frac{1}{\pi} \quad \cdot \cdot (2)$$

[Formula 3]

$$P(F_{sat}) = \frac{1}{2\pi} \int_0^\pi (-I_c \times \sin x) \times (-V_f \times \sin x) \times \frac{1 + D \times \sin(x + \theta)}{2} dx \quad \cdot \cdot (3)$$

[Formula 4]

$$P(F_{sw}) = E_{rr} \times f \times \frac{1}{2} \quad \cdot \cdot (4)$$

[Formula 5]

$$P(PM) = \{P(I_{sat}) + P(I_{sw})\} \times N(I) + \{P(F_{sat}) + P(F_{sw})\} \times N(F) \quad \cdot \cdot (5)$$

I_c ; Switching element current of IGBT (first power generation machine current)

$V_{ce(sat)}$; ON voltage of switching element of IGBT

D; PWM modulation factor

E_{sw}; Switching loss per 1 pulse of IGBT

f; PWM carrier frequency

N(I); number of IGBT chips

N(F); number of FWD chips

V_f; ON voltage of switching element of FWD

E_{rr}; Switching loss per 1 pulse of FWD

[0049] Furthermore, the loss in the first inverter device 10 obtained from the formulas above (power module loss P (PM)) is converted to temperature, and an addition value T_{ad} corresponding to the temperature increase of the cooling water is calculated.

This addition value T_{ad} is obtained by repeatedly conducting experiments in advance, and using a table or a calculation formula that is set so as to be able to obtain the value in accordance with the power module loss P (PM) and the cooling water temperature t_w.

[0050] In addition, the temperature addition unit 252c adds the addition value T_{ad} to the cooling water temperature t_w detected by the water temperature sensor 40, and the calculation itself is the same as that of the temperature addition unit 52c shown in the first embodiment.

[0051] Accordingly, in the second embodiment a value that is closer to the temperature increase of the cooling water W due to heat generation caused by actual loss in the first inverter device 10 can be set as the addition value T_{ad}, and therefore the abnormality detection accuracy is even higher.

[0052] (Effects of the Second Embodiment)

2-1) In a temperature abnormality detection method for a power conversion apparatus B according to the second embodiment,

the temperature addition unit 252c uses, as the addition value T_{ad}, which is the temperature obtained by converting the loss component to be added to the cooling water temperature t_w, a value calculated based on loss calculation information that includes the number of FWD chips N(F), the number of IGBT chips N(I), a PWM modulation factor D as a semiconductor characteristic, a carrier frequency f, a current I_c and voltage V_{ce(sat)} in the power module of the first inverter device 10.

Therefore, it is possible to obtain the optimum addition value T_{ad} corresponding to the operating state of the first inverter device 10, and to carry out a more accurate abnormality detection.

It should be noted that the addition value T_{ad} can be obtained based on any one of the current I_c , the voltage $V_{ce(sat)}$, the semiconductor characteristic (carrier frequency f , PWM modulation factor D , number of IGBT chips $N(1)$, and number of FWD chips $N(F)$).

[0053] (Third Embodiment)

The third embodiment is an example in which the method of converting the loss component of the first inverter device 10 into temperature and adding the same to the cooling water temperature t_w to obtain the addition value T_{ad} is different from those of the first and second embodiments.

[0054] That is, in the third embodiment, a value estimated based on the first temperature difference Δt_1 between the temperature of the first inverter device 10 and the cooling water temperature t_w is used as the addition value T_{ad} that is added after the loss component of the first inverter device 10 is converted to temperature.

[0055] Figure 4 is an overall view schematically illustrating a power conversion apparatus C to which the temperature abnormality detection method of the third embodiment is applied.

The second temperature difference calculation unit 352a of the second controller 352 shown in Figure 4 calculates a second temperature difference Δt_2 between the added temperature t_{wa3} , estimated by a loss estimation unit 300, and the second inverter temperature t_{in2} .

[0056] Here, the loss estimation unit 300 receives as an input the first temperature difference Δt_1 calculated by the first temperature difference calculation unit 51a, and back-calculates the loss in the first inverter device 10 from this first temperature difference Δt_1 . Furthermore, the loss estimation unit 300 estimates an addition value corresponding to the temperature increase component of the cooling water due to this loss component, and calculates an added temperature t_{wa3} obtained by adding this addition value to the cooling water temperature t_w . As for this addition value, values corresponding to the first temperature difference Δt_1 and the driving state (for example, powering, regeneration, locking, etc.) of the first power generation machine 1 at that time are stored in the first controller 51 in the form of a map.

The second temperature difference calculation unit 352a calculates a second temperature difference Δt_2 between this added temperature t_{wa3} and the second inverter temperature t_{in2} .

[0057] Thus, in the third embodiment the temperature increase of the cooling water corresponding to the estimated loss component of the first inverter device 10 is estimated based on the first temperature difference Δt_1 .

Accordingly, it is possible to obtain the actual cooling water temperature in the second inverter device 20 as the added temperature t_{wa3} , thereby increasing the abnormality detection accuracy.

[0058] (Effects of the Third Embodiment)

3-1) In a temperature abnormality detection method for a power conversion apparatus C according to the third embodiment,

a value estimated based on a first temperature difference Δt_1 , which is the difference between the first inverter temperature t_{in1} , which is the temperature of the first inverter device 10, and the cooling water temperature t_w , is used as the temperature of the loss component that is added in the second temperature difference calculation unit 352a.

That is, the heat generation state of the first inverter device 10 is estimated based on the difference between the first inverter temperature t_{in1} and the cooling water t_w , thereby enabling the addition value to be obtained with high accuracy. Therefore, the cooling water temperature in the second inverter device 20 can be estimated with high accuracy based on this highly accurate addition value, and abnormality detection can be carried out with high accuracy on that basis.

[0059] (Fourth Embodiment)

The power conversion apparatus D of the fourth embodiment is a modified example of the first embodiment and, as illustrated in Figure 5, is an example in which a third inverter device 430 for driving a third power generation machine (not shown) is added in a subsequent stage of the cooling water path 31.

[0060] A third controller 453, which carries out an abnormality determination for this third inverter device 430, comprises a third temperature difference calculation unit 453a, a third abnormality detection unit 453b, and a temperature addition unit 453c.

The temperature addition unit 453c takes, as an addition value T_{ad} , a value obtained by converting the loss in the first inverter device 10 during operation and the loss in the second inverter device 20 during operation into a temperature increase of the

cooling water temperature t_w , and adds this value to the cooling water temperature t_w detected by the water temperature sensor 40 to obtain an added temperature t_{wb} . As in the first embodiment, the temperature increase due to this loss is set to the increase in the temperature of the cooling water temperature t_w due to heat generation at the time of the maximum loss assumed in the two inverter devices 10, 20.

[0061] The third temperature difference calculation unit 453a then receives as inputs a third inverter temperature t_{in3} detected by the third inverter temperature sensor 413, and the added temperature t_{wb} , and calculates a third temperature difference Δt_3 , which is the difference between the two.

[0062] The third abnormality detection unit 453b determines an abnormality when the third temperature difference Δt_3 is higher than a third abnormality determination temperature (t_{lim3}), and determines that there is no abnormality when the third temperature difference Δt_3 is equal to or less than the third abnormality determination temperature (t_{lim3}). This third abnormality determination temperature t_{lim3} is set in accordance with a third rotary electric machine (not shown) and the third inverter device 430.

[0063] Therefore, in the fourth embodiment the effects 1) to 3) described in the first embodiment can be obtained even if the number of inverter devices increases.

[0064] (Fifth Embodiment)

The power conversion apparatus E of the fifth embodiment is a modified example of the second embodiment and, as illustrated in Figure 6, is an example in which a third inverter device 530 is added in a subsequent stage of the cooling water path 31, in the same manner as the fourth embodiment described above.

In the temperature addition unit 553c of the third controller 553 illustrated in Figure 6, an addition value T_{ad2} calculated by a loss calculation unit 500 provided in the first controller 251 is used as the addition value, which is the temperature of the loss component.

[0065] In addition, the loss calculation unit 500 calculates the addition value T_{ad} based on loss calculation information that includes the semiconductor characteristics, the carrier frequency f , and the current I in the first inverter device 10, in the same manner as the second embodiment. In addition, the loss calculation unit 500 calculates the addition value T_{ad2} based on loss calculation information that includes the semiconductor characteristics, the carrier frequency f , and the current I in the second inverter device 20.

The calculation of this addition value T_{ad2} can be carried out using a table or a calculation formula in the same manner as in the second embodiment. In addition, the addition values T_{ad} , T_{ad2} can be calculated based on any one of the current I , the carrier frequency f , and the semiconductor characteristics.

[0066] The third temperature difference calculation unit 553a then receives as inputs a third inverter temperature t_{in3} detected by the third inverter temperature sensor 513 and the added temperature t_{wb} calculated using the addition value T_{ad2} , and calculates a third temperature difference Δt_3 , which is the difference between the two.

[0067] The third abnormality detection unit 553b determines an abnormality when the third temperature difference Δt_3 is higher than a third abnormality determination temperature (t_{lim3}), and determines that there is no abnormality when the third temperature difference Δt_3 is equal to or less than the third abnormality determination temperature (t_{lim3}).

[0068] Therefore, in the fifth embodiment, the effect described in 2-1) above can be obtained even if the number of inverter devices increases.

In addition, although not shown, when the number of inverter devices thus increases, the added temperature t_{wb} can be calculated using the same method as in the third embodiment when detecting an abnormality of the third inverter device. That is, in this case a value estimated based on the second temperature difference Δt_2 in the second inverter device 20 is used as the temperature of the loss component to be added in the third temperature difference calculation unit.

[0069] The temperature abnormality detection method for a power conversion apparatus and the temperature abnormality detection device for a power conversion apparatus of the present invention were described above based on embodiments, but specific configurations thereof are not limited to these embodiments, and various modifications and additions to the design can be made without departing from the scope of the invention according to each claim in the Claims:-

[0070] For example, in the embodiments inverter devices were shown as the plurality of power converters for converting and transmitting electric power, but the power converters are not limited to inverter devices; other power converters such as converters may be used as well. Accordingly, in the embodiments a power generation machine was shown as the output target of the power converters, but the output target is not limited thereto, and other devices, such as a battery, can be used.

[0071] Additionally, cooling water was shown as the coolant that flows through the cooling flow path, but the coolant is not limited thereto; gas or fluids other than water may be used.

[0072] Furthermore, in the first embodiment the temperature increase of the water temperature at the time of maximum loss assumed in the first inverter device was set as the temperature to which the temperature of the loss component of the power converter of the preceding stage is added, but no limitation is imposed thereby. For example, it may be set as the temperature increase of the water temperature at the time of maximum loss in the driving state of the first power generation machine, in accordance with that driving state. That is, it may be set as the temperature increase at the time of maximum loss for each driving state, such a powering, regeneration, and locked.

[0073] Additionally, in the second embodiment an example was shown in which the temperature increase of the loss component is obtained based on formulas (1) to (5); however, it is not limited to the formulas (1) to (5), as long as the value is calculated based on loss calculation information that includes the semiconductor characteristics, the carrier frequency, and the current supplied to the power converter.

In addition, the number of power converters is not limited to "2" and "3" illustrated in the embodiments; four or more can be provided.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

[Claim 1] A temperature abnormality detection method for a power conversion apparatus provided with a plurality of power converters that convert and transmit electric power, and a cooling flow path that passes through the plurality of power converters and cools each of the power converters, the method comprising:

detecting temperatures of the power converters and detecting a temperature of a cooling fluid of the cooling flow path on an upstream side of the power converters;

determining a presence of an abnormality in a preceding stage power converter disposed upstream in the cooling flow path from among the plurality of power converters based on a difference between a temperature of the preceding stage power converter and the temperature of the cooling fluid; and

determining a presence of an abnormality in a subsequent stage power converter disposed downstream from the preceding stage power converter in the cooling flow path based on a difference between the temperature of the subsequent stage power converter and a temperature obtained by converting a loss component of the preceding stage power converter into a temperature which is added to the temperature of the cooling fluid.

[Claim 2] The temperature abnormality detection method for a power conversion apparatus according to claim 1, wherein

the temperature obtained by converting the loss component is set to a value based on a temperature that is converted from a maximum loss assumed in the preceding stage power converter.

[Claim 3] The temperature abnormality detection method for a power conversion apparatus according to claim 1, wherein

the temperature obtained by converting the loss component is set to a value that is calculated based on loss calculation information that includes at least one of a semiconductor characteristic, a carrier frequency or the current in the preceding stage power converter.

[Claim 4] The temperature abnormality detection method for a power conversion apparatus according to claim 1, wherein

the temperature obtained by converting the loss component is set to a value that is estimated based on the difference between the temperature of the preceding stage power converter and the temperature of the cooling fluid.

[Claim 5] A temperature abnormality detection device for a power conversion apparatus, comprising:

a plurality of power converters that convert and transmit electric power;

a cooling flow path that passes through the plurality of power converters and cools each of the power converters;

power converter temperature sensors that detect temperatures of the plurality of power converters;

a cooling fluid temperature sensor that detects a temperature of a cooling fluid of the cooling flow path that is upstream from the plurality of power converters;

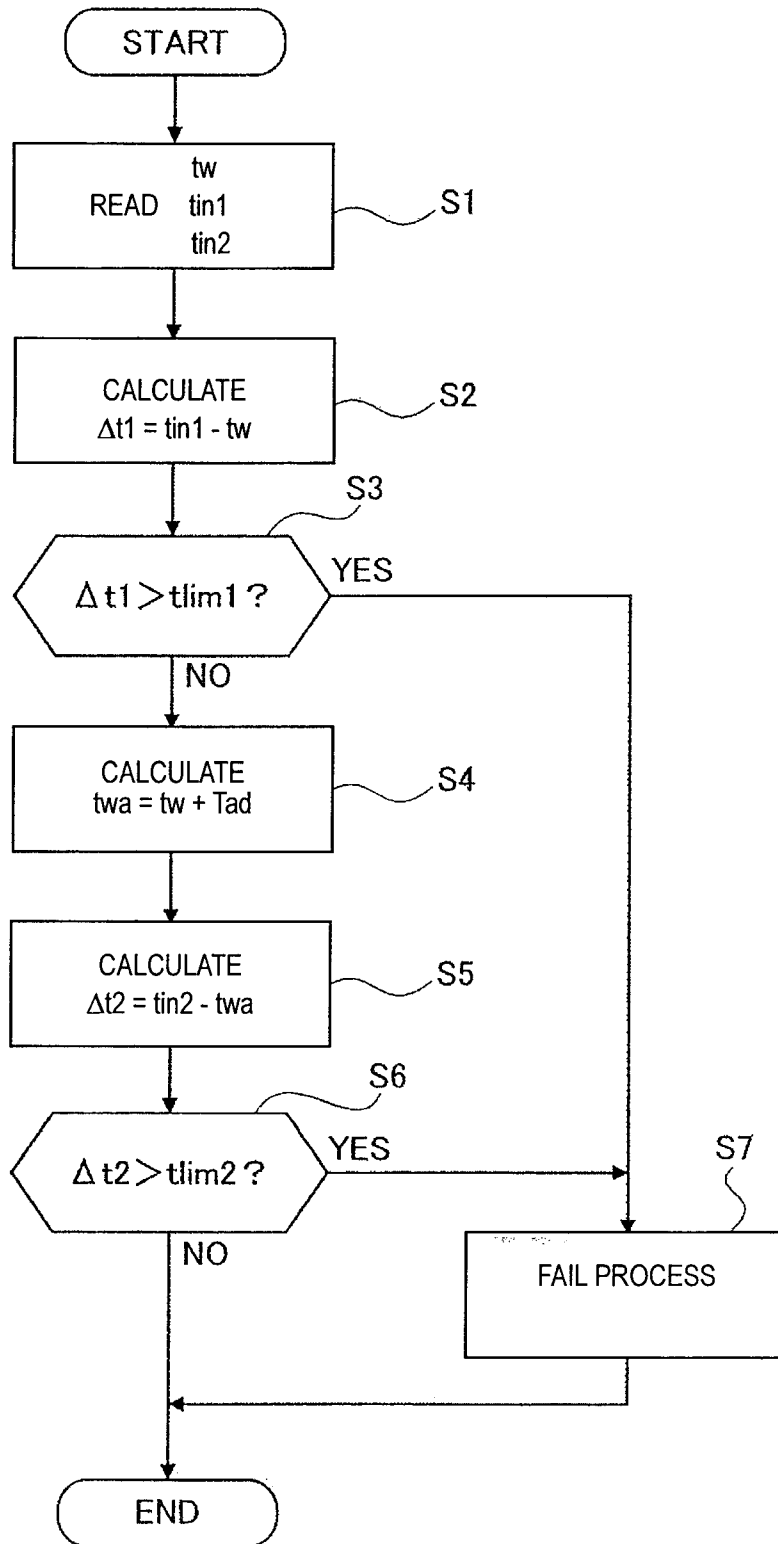
a preceding stage temperature difference calculation unit that calculates a difference between a cooling fluid temperature and a temperature of a preceding stage power converter disposed upstream in the cooling flow path;

a preceding stage power converter abnormality detection unit that carries out abnormality determination based on the difference calculated by the preceding stage temperature difference calculation unit;

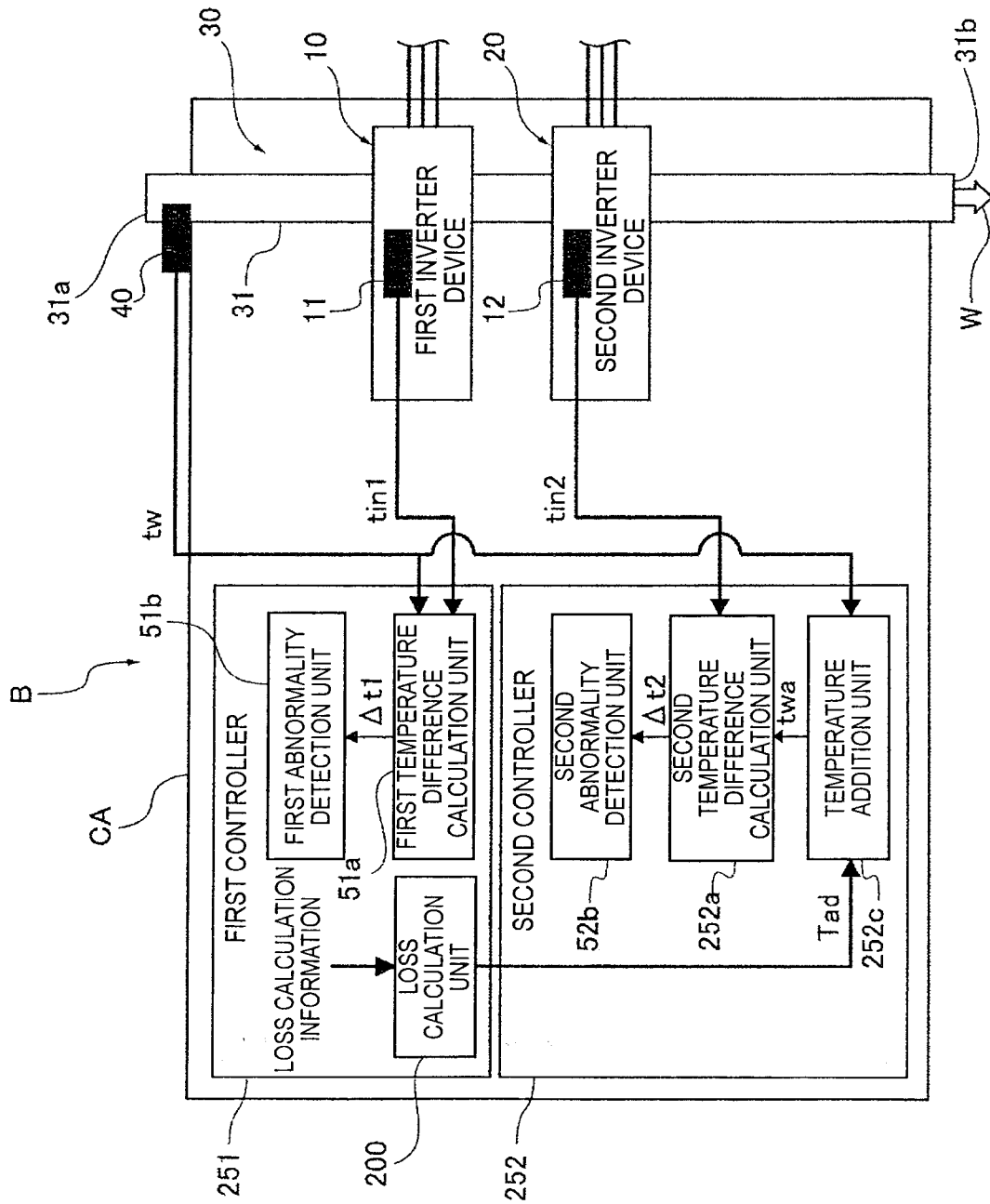
a temperature addition unit that converts a loss component of the preceding stage power converter into a temperature and adds the same to the cooling fluid temperature;

a subsequent stage temperature difference calculation unit that calculates a difference between the temperature calculated by the temperature addition unit and a temperature of a subsequent stage power converter disposed downstream from the preceding stage power converter in the cooling flow path; and

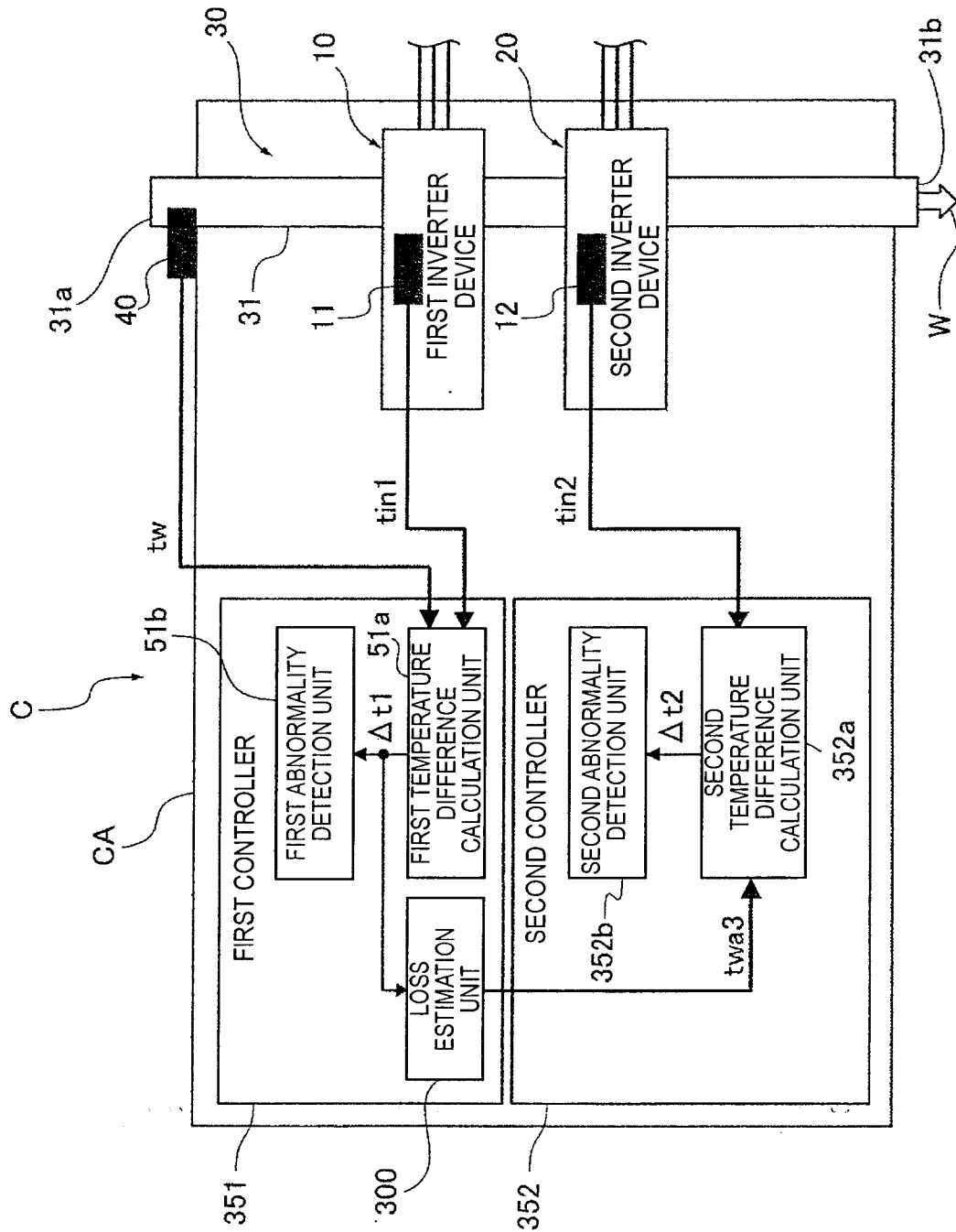
a subsequent stage power converter abnormality detection unit that carries out abnormality determination based on the difference calculated by the subsequent stage temperature difference calculation unit.

[FIG. 2]

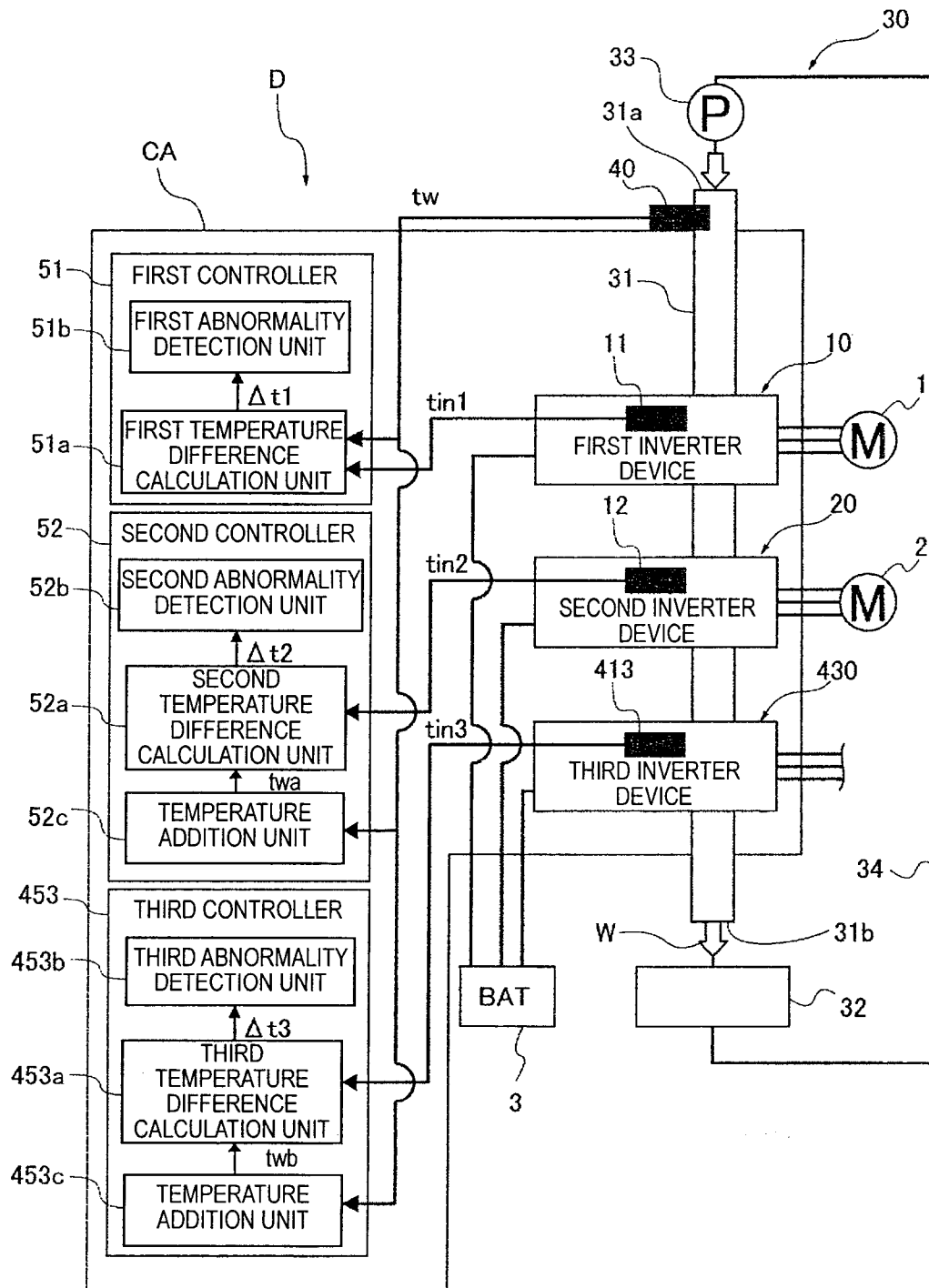
[FIG. 3]



[FIG. 4]



[FIG. 5]



[FIG. 6]

