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(54) **BATTERY SYSTEM AND BATTERY PACK**

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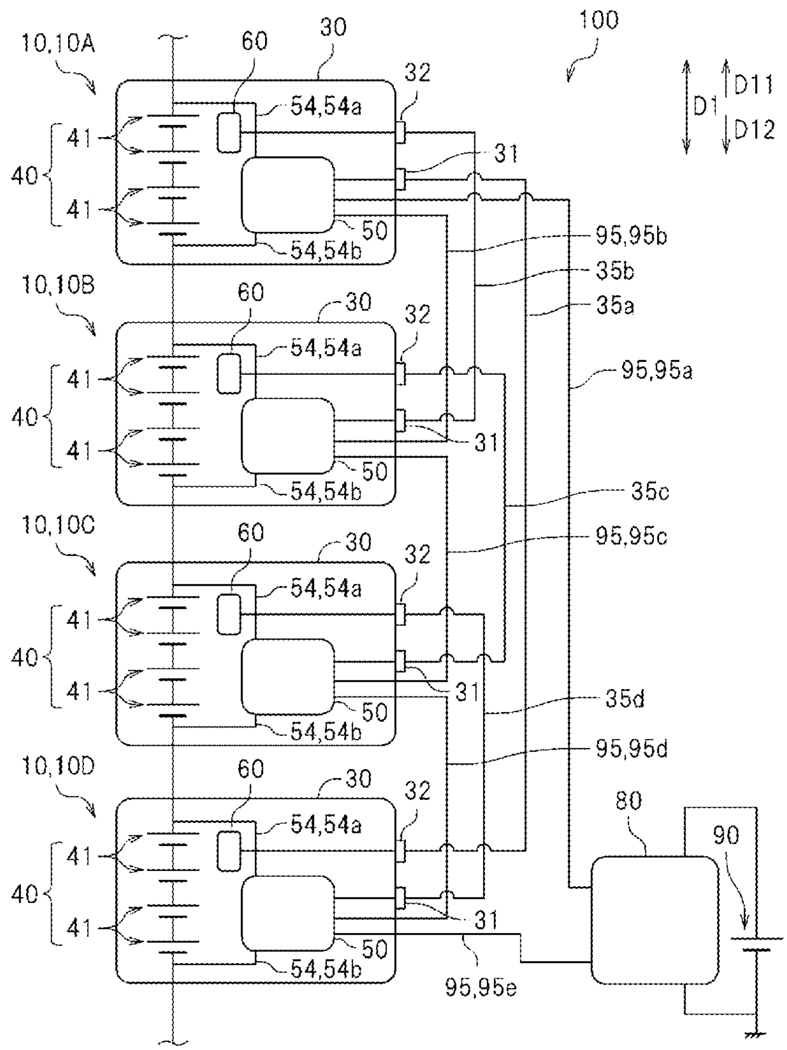
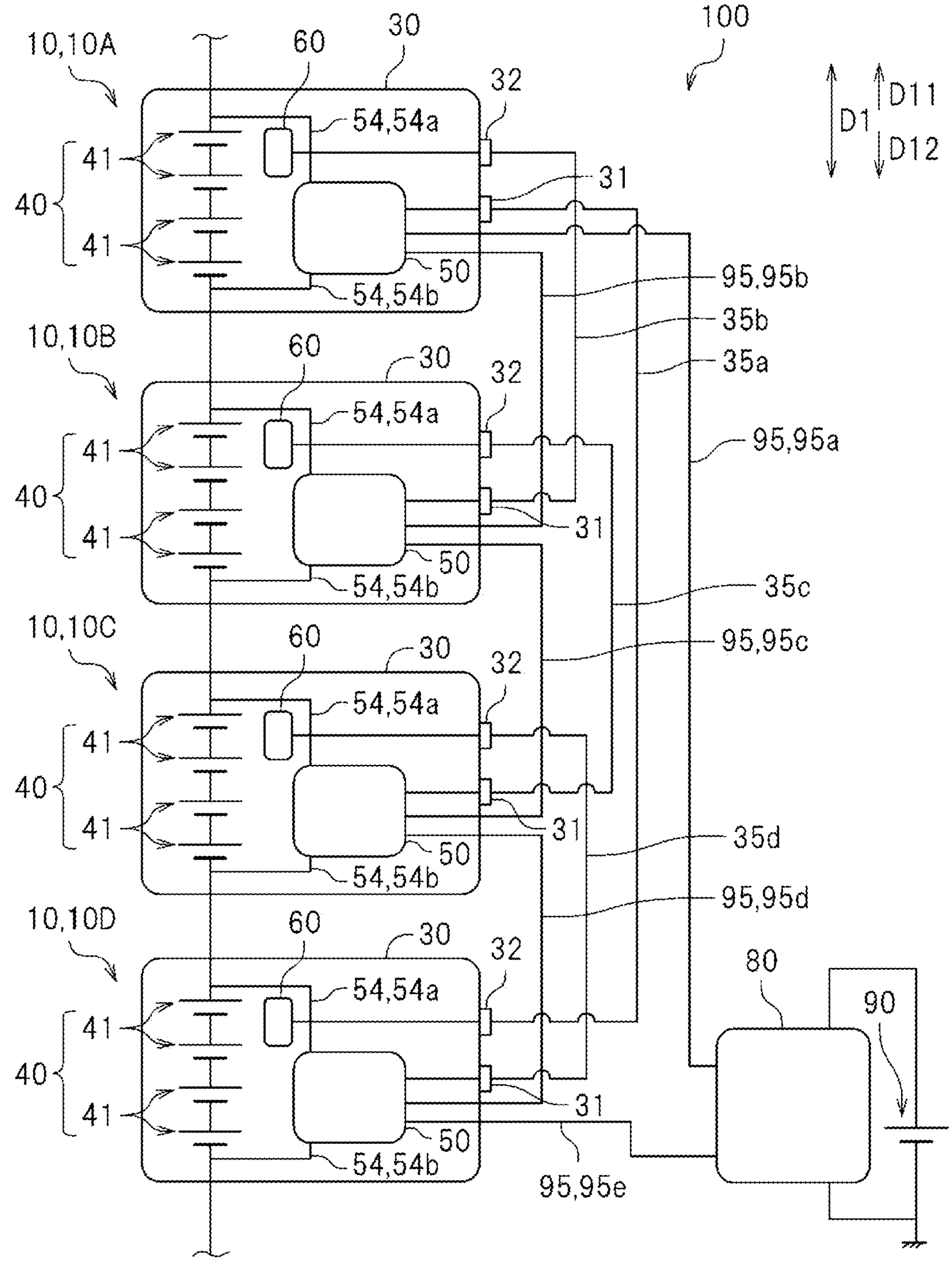
(57) **ABSTRACT**

A battery system includes a plurality of battery packs and a main controller. Each of the battery packs includes a pack case, a cell module including a plurality of battery cells disposed in the pack case, a sub-controller disposed in the pack case and electrically connected to the cell module to use the cell module as its power source, and an abnormality detection element that detects an abnormality in the entirety of the pack case. The main controller is communicably connected to each of the sub-controllers in the plurality of battery packs. The abnormality detection element of one of the plurality of battery packs is communicably connected to the sub-controller of another one of the battery packs.

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54,54b
35c
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60
30
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32
54,54a
41
40
31
41
50
35d
54,54b
95,95d
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50
54,54b
95,95e

FIG.1

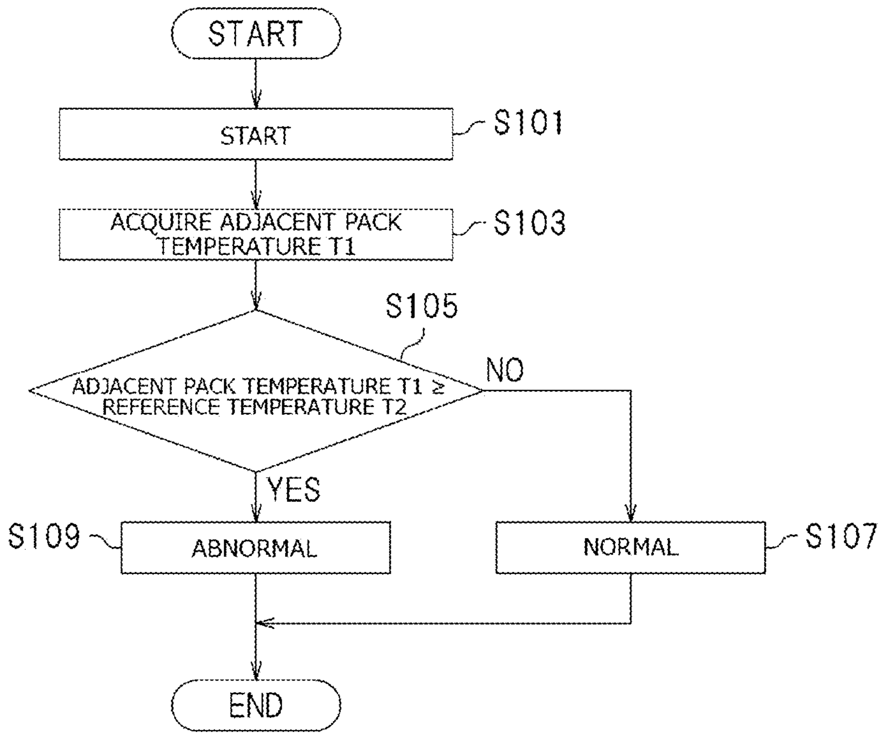

START
START
S101
ACQUIRE ADJACENT PACK TEMPERATURE T1
S103
S105
ADJACENT PACK TEMPERATURE T1 ≥ REFERENCE TEMPERATURE T2
NO
YES
S109
ABNORMAL
NORMAL
S107
END

FIG.2

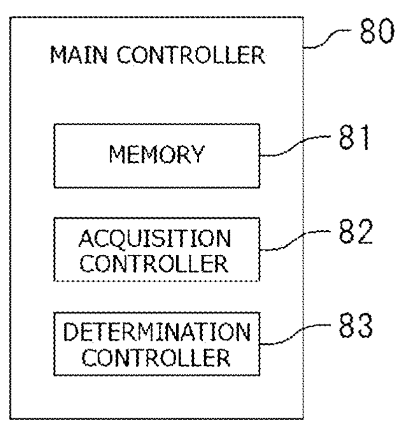
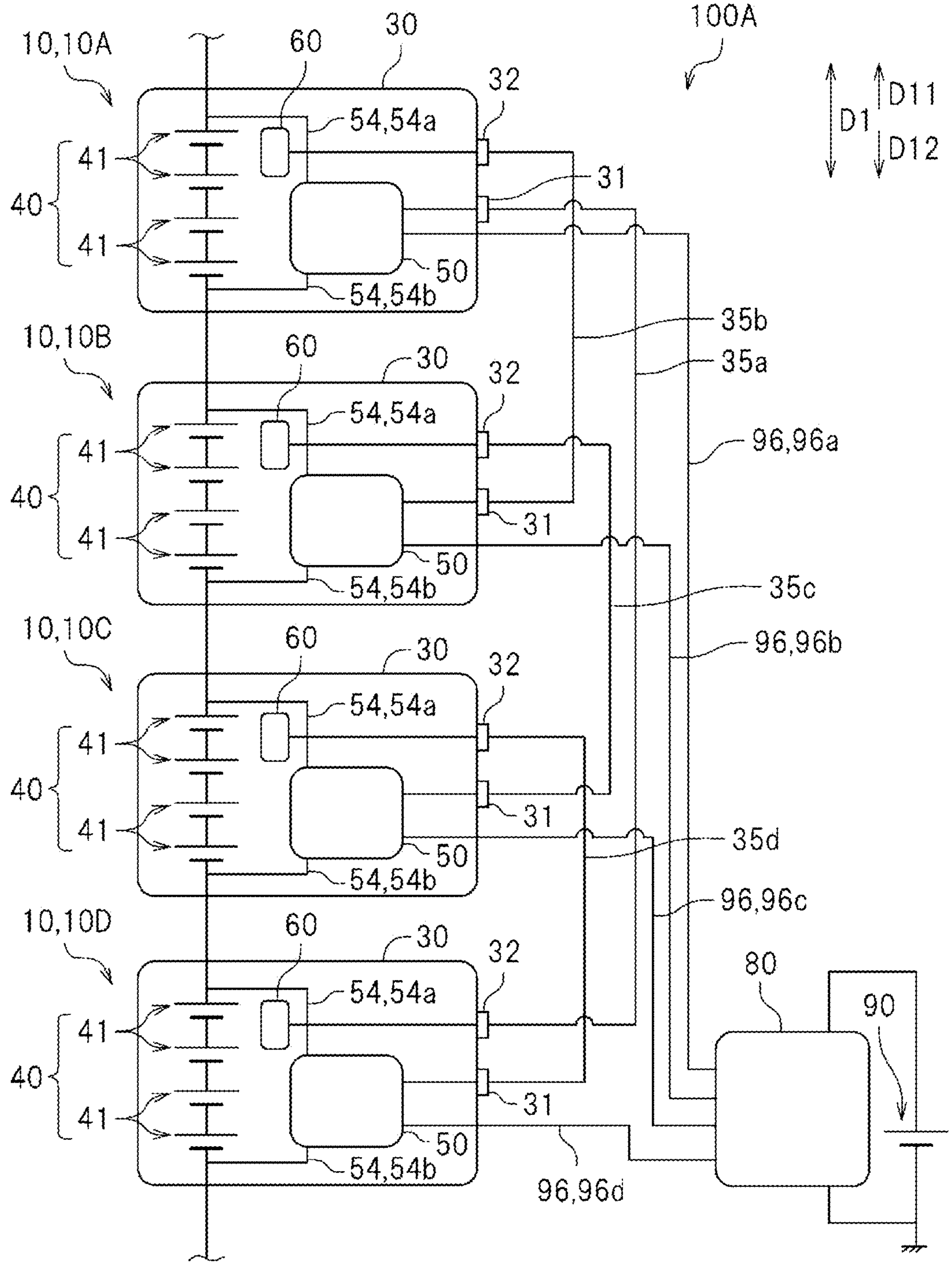

MAIN CONTROLLER
80
MEMORY
81
ACQUISITION CONTROLLER
82
DETERMINATION CONTROLLER
83

FIG.3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35a
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32
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40
31
41
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35c
10,10C
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60
30
32
54,54a
41
40
31
41
50
35d
54,54b
96,96c
10,10D
60
30
32
80
90
54,54a
41
40
31
41
50
54,54b
96,96d

FIG.4

BATTERY SYSTEM AND BATTERY PACK

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] The present application claims priority from Japanese Patent Application No. 2024-023303 filed on Feb. 20, 2024, which is incorporated by reference herein in its entirety.

BACKGROUND

[0002] The present invention relates to battery systems and battery packs.

[0003] JP 2010-080135 A, for example, discloses a battery system including a plurality of battery blocks connected in series, a battery status detection circuit, and a main control circuit. Each battery block includes a plurality of battery cells connected in series. The battery status detection circuit is connected to each of the battery cells, and includes a circuit that detects the voltage and temperature of the battery cells.

[0004] The battery status detection circuit outputs the voltage and temperature of each of the battery cells to the main control circuit. The main control circuit controls the status of each of the battery cells based on the voltage and temperature of each of the battery cells.

SUMMARY

[0005] In the battery system disclosed in JP 2010-080135 A, the battery status detection circuit is electrically connected to the battery block that is to be detected, to use the battery block as the power source. If an abnormality occurs in the battery block and power is not supplied to the battery status detection circuit, it may be possible that the electric power source for the battery status detection circuit is lost. In this case, there may be a risk that the battery status detection circuit does not start properly and is thus unable to detect the status of the battery block.

[0006] In accordance with the present disclosure, a battery system includes a plurality of battery packs and a main controller. Each of the battery packs includes a pack case, a cell module including a plurality of battery cells disposed inside the pack case, a sub-controller disposed inside the pack case and electrically connected to the cell module to use the cell module as its power source, and an abnormality detection element detecting an abnormality in an entirety of the pack case. The main controller is communicably connected to the sub-controllers of the plurality of battery packs. The abnormality detection element of one of the plurality of battery packs is communicably connected to the sub-controller of another one of the plurality of battery packs.

[0007] The battery system according to the present disclosure allows an abnormality in the entirety of the pack case of one of the battery packs to be detected by the sub-controller of another one of the battery packs through the abnormality detection element of the one of the battery packs, even when an abnormality occurs in the entirety of the pack case of the one of the battery packs and the electric power source for the sub-controller of the one of the battery packs is lost.

[0008] In accordance with the present disclosure, a battery pack includes: a pack case; a cell module including a plurality of battery cells disposed in the pack case; a sub-controller disposed in the pack case, and electrically connected to the cell module to use the cell module as its power source; an abnormality detection element detecting an abnormality in an entirety of the pack case; a first connection port connected to the sub-controller; and a second connection port connected to the abnormality detection element.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] FIG. **1** is a schematic view illustrating a battery system according to a first embodiment.

[0010] FIG. **2** is a flowchart illustrating an abnormality detection method.

[0011] FIG. **3** is a block diagram illustrating the configuration of a main controller.

[0012] FIG. **4** is a schematic view illustrating a battery system according to a second embodiment.

DETAILED DESCRIPTION

[0013] Hereinbelow, embodiments of the technology according to the present disclosure will be described with reference to the drawings. It should be noted, however, that the embodiments disclosed herein are, of course, not intended to limit the invention. The drawings are schematic illustrations, and do not necessarily reflect any actual product. The features and components that exhibit the same effects are designated by the same reference symbols as appropriate, and the description thereof will not be repeated as appropriate.

First Embodiment

[0014] FIG. **1** is a schematic view illustrating a battery system **100** according to a first embodiment. The battery system **100** according to the present embodiment is connected to a load, not shown. The load to be connected to the battery system **100** is not limited to any particular type of load. The load may be, for example, a load in a vehicle, which may include a drive device of the vehicle, such as an electric motor, or an inverter or the like. The battery system **100** is mounted in a vehicle, such as a hybrid electric vehicle and an battery electric vehicle, and is used as the power source to supply electric power to an electric motor for driving the vehicle. The battery system **100** is, however, not limited to those for use in vehicles.

[0015] As illustrated in FIG. **1**, the battery system **100** includes a plurality of battery packs **10**, a main controller **80**, and an auxiliary equipment power supply **90**. The number of battery packs **10** is not limited to any particular number, but may be 4 herein. The number of battery packs **10** may be 2, or 3, or 5 or more.

[0016] In the present embodiment, the plurality of battery packs **10** are arrayed side by side along a predetermined arrangement direction D**1**. The arrangement direction D**1** extends linearly. However, it is also possible that the arrangement direction D**1** may extend curvilinearly or may extend partially curvilinearly. Herein, a direction extending from one end (downward end in FIG. **1**) toward the other end (upward end in FIG. **1**) of the arrangement direction D**1** is referred to as a first direction D**11**. A direction extending from the other end toward the one end of the arrangement direction D**1** is referred to as a second direction D**12**. The first direction D**11** is the opposite direction to the second direction D**12**.

[0017] In the following description, the plurality of battery packs **10** are referred to as battery packs **10**A, **10**B, **10**C, and

10D, respectively in that order, along the direction extending from the other end toward the one end (i.e., the second direction D**12** herein). That is, the battery pack **10**A is disposed closest to an end of the battery pack array in the first direction D**11**. The battery pack **10**D is disposed closest to an end of the battery pack array in the second direction D**12**. The battery pack **10**B is disposed between the battery pack **10**A and the battery pack **10**C. The battery pack **10**C is disposed between the battery pack **10**B and the battery pack **10**D. Herein, the battery packs **10**A, **10**B, **10**C, and **10**D have the same configuration. Hereinafter, in the description common to the battery packs **10**A, **10**B, **10**C, and **10**D, the battery pack may be referred to as a battery pack **10**.

[0018] As illustrated in FIG. **1**, each one of the battery packs **10** includes a pack case **30**, a cell module **40**, a sub-controller **50**, and an abnormality detection element **60**. The pack case **30** is a case that contains space in the inside thereof. The pack case **30** is formed of a metal, for example. However, the material that forms the pack case **30** is not limited to any particular material.

[0019] The cell module **40** includes a plurality of battery cells **41**. The cell module **40** is disposed inside the pack case **30**. In other words, the plurality of battery cells **41** are disposed inside the pack case **30**. The battery cells **41** are ones that are capable of being charged and discharged. Each of the battery cells **41** may be, for example, a secondary battery in which repeated charging and discharging are possible by means of migration of charge carriers through an electrolyte between a pair of electrodes (for example, positive electrode and negative electrode). Each of the battery cells **41** may be a lithium-ion secondary battery, a nickel-metal hydride battery, or the like, for example. In the present embodiment, the plurality of battery cells **41** are connected in series. Herein, the plurality of battery cells **41** are connected in series via a bus bar, not shown. However, it is also possible that the plurality of battery cells **41** may be connected in parallel. The number of battery cells **41** in each one cell module **40** is not limited to any particular number and may be a predetermined number. The number of battery cells **41** in the cell module **40** in each of the battery packs **10** may be the same or different.

[0020] The sub-controller **50** is provided for each battery pack **10**, in other words, for each pack case **30**, to output detected information on an abnormality in the entirety of the pack case **30** to the main controller **80**. The sub-controller **50** is composed of an ASIC (Application Specific Integrated Circuit), for example. However, the sub-controller **50** may be composed of a microcomputer, for example. The sub-controller **50** may include a communication interface, a central processing unit (CPU) that executes control program instructions, a read only memory (ROM) that stores programs executed by the CPU, a random access memory (RAM) used as a working area for deploying the programs, and a storage device, such as a memory, that stores the foregoing programs and various data. Note that the sub-controller **50** may be composed of a single device (for example, a single CPU) or may be configured to execute control operations by a plurality of devices in cooperation with each other.

[0021] The sub-controller **50** is housed in the pack case **30**. In the present embodiment, the sub-controller **50** uses the cell module **40** (in other words, a plurality of battery cells **41**) as the power source. The sub-controller **50** is electrically connected to the cell module **40**. In the present embodiment, the sub-controller **50** is electrically connected to the cell module **40** via a power wire **54**. The power wire **54** includes a first power wire **54***a* that is electrically connected to the positive electrode side of the cell module **40** and a second power wire **54***b* that is electrically connected to the negative electrode side of the cell module **40**.

[0022] The abnormality detection element **60** detects an abnormality in the entirety of the pack case **30**. Herein, the phrase "abnormality in the entirety of pack case **30**" refers to an abnormality of a component, such as a battery cell **41** of the cell module **40**, that is housed in the pack case **30**. The abnormality of the cell module **40** (for example, a battery cell **41**) may be, for example, a high temperature abnormality that occurs due to a high temperature of the battery cell **41**. In the following description, the phrase "abnormality in the entirety of pack case **30**" may also be referred to as "abnormality inside pack case **30**".

[0023] The abnormality detection element **60** is disposed (in other words, housed) inside the pack case **30**. However, the abnormality detection element **60** may also be disposed external to the pack case **30** when it is able to detect an abnormality in the entirety of the pack case **30**. In the present embodiment, the abnormality detection element **60** detects an abnormality inside the pack case **30** in which it is housed. Note that the abnormality detection element **60** is not limited to any particular type. In the present embodiment, the abnormality detection element **60** is composed of a temperature sensor. The abnormality detection element **60** detects the temperature inside the pack case **30**. In the present embodiment, for example, when an abnormality occurs in the entirety of the pack case **30**, the temperature inside the pack case **30** may become higher. Accordingly, the abnormality detection element **60** detects that an abnormality is occurring in the entirety of the pack case **30** when the temperature inside the pack case **30** has become higher. Note that although not shown in the drawings, the abnormality detection element **60** may be electrically connected to the auxiliary equipment power supply **90**, for example, to use the auxiliary equipment power supply **90** as its power source.

[0024] In the present embodiment, as illustrated in FIG. **1**, the plurality of battery packs **10** contained in the battery system **100** (battery packs **10**A, **10**B, **10**C, and **10**D herein) are arrayed side by side along the arrangement directions D**1** and are connected in series. In other words, the cell modules **40** included in the plurality of battery packs **10** are connected in series. However, it is also possible that the plurality of cell modules **40** may be connected in parallel.

[0025] In the present embodiment, each of the battery packs **10** includes a first connection port **31** and a second connection port **32**. The first connection port **31** and the second connection port **32** are provided on the pack case **30**. The first connection port **31** is connected to the sub-controller **50** in the pack case **30**. The sub-controller **50** is communicably connected to an external component (herein, another abnormality detection element **60**) outside the pack case **30** that houses the sub-controller **50** via the first connection port **31**. The second connection port **32** is connected to the abnormality detection element **60** inside the pack case **30**. The abnormality detection element **60** is communicably connected to an external component (herein, another sub-controller **50**) outside the pack case **30** that houses the abnormality detection element **60** via the second connection port **32**.

[0026] In the present embodiment, the abnormality detection element **60** of one of the battery packs **10** is communicably connected to the sub-controller **50** of another one of the battery packs **10**. Herein, for example, the sub-controller **50** of the battery pack **10**A is communicably connected to the abnormality detection element **60** of one of the other battery packs **10**B, **10**C, and **10**D. For example, the sub-controller **50** of the battery pack **10**B is communicably connected to the abnormality detection element **60** of one of the other battery packs **10**A, **10**C, and **10**D. Herein, the sub-controller **50** is not housed in the same pack case **30** that houses the abnormality detection element **60** communicably connected to the sub-controller **50**, but is housed in another pack case **30**.

[0027] In the present embodiment, as illustrated in FIG. **1**, the sub-controller **50** of each of the battery packs **10** is communicably connected to one of the battery packs **10** that are adjacent thereto along the arrangement directions D**1**. More specifically, each of the sub-controllers **50** of the battery packs **10**B, **10**C, and **10**D, which are other than the battery pack **10**A that is disposed closest to an end of the battery pack array in the first direction D**11** among the plurality of battery packs **10**, is communicably connected to the abnormality detection element **60** of one of the battery packs **10** that are adjacent thereto along the arrangement directions D**1**. For example, the sub-controller **50** of the battery pack **10**B is communicably connected to the abnormality detection element **60** of one of the battery packs **10**A and **10**C that are adjacent thereto along the arrangement directions D**1**. For example, the sub-controller **50** of the battery pack **10**C is communicably connected to the abnormality detection element **60** of one of the battery packs **10**B and **10**D that are adjacent thereto along the arrangement directions D**1**.

[0028] More specifically, the sub-controller **50** of the battery pack **10**B is connected to the abnormality detection element **60** of the battery pack **10**A that is adjacent thereto in the first direction D**11**. The sub-controller **50** of the battery pack **10**C is connected to the abnormality detection element **60** of the battery pack **10**B that is adjacent thereto in the first direction D**11**. The sub-controller **50** of the battery pack **10**D is connected to the abnormality detection element **60** of the battery pack **10**C that is adjacent thereto in the first direction D**11**. In the present embodiment, the sub-controller **50** of the battery pack **10**A, which is disposed closest to an end of the battery pack array in the first direction D**11** among the plurality of battery packs **10**, is connected to the abnormality detection element **60** of the battery pack **10**D, which is disposed closest to an end of the battery pack array in the second direction D**12**.

[0029] In the present embodiment, the first connection port **31** of the battery pack **10**A and the second connection port **32** of the battery pack **10**D are connected to each other by a connecting wire **35***a*. The sub-controller **50** of the battery pack **10**A is connected to the abnormality detection element **60** of the battery pack **10**D via the connecting wire **35***a*. The first connection port **31** of the battery pack **10**B and the second connection port **32** of the battery pack **10**A are connected to each other by a connecting wire **35***b*. The sub-controller **50** of the battery pack **10**B is connected to the abnormality detection element **60** of the battery pack **10**A via the connecting wire **35***b*. The first connection port **31** of the battery pack **10**C and the second connection port **32** of the battery pack **10**B are connected to each other by a connecting wire **35***c*. The sub-controller **50** of the battery pack **10**C is connected to the abnormality detection element **60** of the battery pack **10**B via the connecting wire **35***c*. The first connection port **31** of the battery pack **10**D and the second connection port **32** of the battery pack **10**C are connected to each other by a connecting wire **35***d*. The sub-controller **50** of the battery pack **10**D is connected to the abnormality detection element **60** of the battery pack **10**C via the connecting wire **35***d*.

[0030] The main controller **80**, like the sub-controller **50**, may be composed of, for example, an ASIC, but may also be composed of a microcomputer. The main controller **80**, like the sub-controller **50**, may include a communication interface, a central processing unit, a ROM, a RAM, a storage device, and the like. The sub-controller **80** may be composed of a single device (for example, a single CPU) or may be configured to execute control operations by a plurality of devices in cooperation with each other. The main controller **80** is provided external to the pack case **30**.

[0031] In the present embodiment, the main controller **80** does not use the cell modules **40** of the battery packs **10** as the power source, but uses the auxiliary equipment power supply **90** as the power source. The main controller **80** is electrically connected to the auxiliary equipment power supply **90**. The type of the auxiliary equipment power supply **90** may be, but is not particularly limited to, a storage battery (a lead-acid battery herein), for example.

[0032] In the present embodiment, the main controller **80** is communicably connected to each of the sub-controllers **50** respectively included in the plurality of battery packs **10**. In the present embodiment, the main controller **80** acquires detection information on an abnormality in the entirety of the pack case **30** from the sub-controller **50** during when it executes an abnormality detection method of detecting whether or not an abnormality is occurring in the entirety of the pack case **30**. Based on the detection information, the main controller **80** is able to detect that an abnormality is occurring inside the pack case **30** of one of the plurality of battery packs **10**.

[0033] In the present embodiment, as illustrated in FIG. **1**, the main controller **80** and the plurality of sub-controllers **50** are communicably connected to each other to form a ring topology. The connection topology of the main controller **80** and the plurality of sub-controllers **50** is a ring topology. In other words, the main controller **80** and the plurality of sub-controllers **50** are connected so as to be able to communicate with each other in a loop fashion.

[0034] As illustrated in FIG. **1**, for example, the main controller **80** and the plurality of sub-controllers **50** are communicably connected via communication wires **95**. In other words, two communication wires **95** are connected to each of the main controller **80** and the plurality of sub-controllers **50**. The plurality of sub-controllers **50** are able to output information in two directions to the main controller **80**. In the present embodiment, the main controller **80** is communicably connected to the sub-controller **50** of the battery pack **10**A via a communication wire **95***a*. The sub-controller **50** of the battery pack **10**A is communicably connected to the sub-controller **50** of the battery pack **10**B via a communication wire **95***b*. The sub-controller **50** of the battery pack **10**B is communicably connected to the sub-controller **50** of the battery pack **10**C via a communication wire **95***c*. The sub-controller **50** of the battery pack **10**C is communicably connected to the sub-controller **50** of the battery pack **10**D via a communication wire **95***d*. Then, the sub-controller **50** of the battery pack **10**D is communicably connected to the main controller **80** via a communication wire **95***e*.

[0035] Hereinabove, an exemplary configuration of the battery system **100** according to the present embodiment has been described. Next, an abnormality detection method as to whether or not an abnormality has occurred in the entirety of the pack case **30** of one of the plurality of battery packs **10** included in the battery system **100** will be described with reference to the flowchart of FIG. **2**.

[0036] FIG. **3** is a block diagram illustrating the configuration of the main controller **80**. In the present embodiment, in order to sequentially execute the flowchart shown in FIG. **2**, the main controller **80** includes a memory **81**, an acquisition controller **82**, and a determination controller **83**. The memory **81**, the acquisition controller **82**, and the determination controller **83** may be implemented by a single processor or a plurality of processors, or may be implemented by circuit.

[0037] In the present embodiment, first, at step S**101** of FIG. **2**, the battery system **100** is started. Herein, the main controller **80** executes a predetermined start-up process. This start-up process starts up the sub-controller **50** and the abnormality detection element **60** of each of the battery packs **10**. Herein, the start-up process by the main controller **80** causes the sub-controller **50** of each of the battery packs **10** to be started by the power that is supplied from the cell module **40** (a plurality of battery cells **41** herein) that is electrically connected thereto. The abnormality detection element **60** of each of the battery packs **10** is started by the power supplied from the auxiliary equipment power supply **90** that is electrically connected thereto. Herein, the starting of the abnormality detection element **60** means a state in which it can detect the temperature inside the pack case **30**. The starting of the sub-controller **50** means a state in which it can acquire the temperature detected by the abnormality detection element **60** to output the temperature to the main controller **80**.

[0038] Next, at step S**103** shown in FIG. **2**, the acquisition controller **82** of the main controller **80** shown in FIG. **3** acquires an adjacent pack temperature T**1**. Herein, the acquisition controller **82** acquires the adjacent pack temperature T**1** from each of the sub-controllers **50**. Herein, the term "adjacent pack temperature T**1**" means the temperature inside the pack case **30** that houses the abnormality detection element **60** that is communicably connected to the sub-controller **50**. For example, the adjacent pack temperature T**1** that is acquired from the sub-controller **50** of the battery pack **10**B means the temperature inside the pack case **30** of the battery pack **10**A that is detected by the abnormality detection element **60** of the battery pack **10**A. For example, the adjacent pack temperature T**1** that is acquired from the sub-controller **50** of the battery pack **10**A means the temperature inside the pack case **30** of the battery pack **10**D that is detected by the abnormality detection element **60** of the battery pack **10**D.

[0039] In the present embodiment, upon receiving an instruction from the main controller **80**, each of the sub-controllers **50** acquires the adjacent pack temperature T**1** and outputs it to the main controller **80**. For example, when the acquisition controller **82** of the main controller **80** acquires the adjacent pack temperature T**1** from each of the sub-controllers **50**, the main controller **80** first transmits an acquisition signal to each of the sub-controller **50**. The sub-controller **50** that has received the acquisition signal from the main controller **80** acquires, from the abnormality detection element **60** to which it is connected, the temperature inside the pack case **30** that houses the abnormality detection element **60**. Herein, the sub-controller **50** transmits a temperature acquisition signal to the abnormality detection element **60** to which it is connected. The abnormality detection element **60** that has received the temperature acquisition signal from the sub-controller **50** to which it is connected detects (i.e., measures herein) the temperature inside the pack case **30** in which it is housed.

[0040] Thereafter, the abnormality detection element **60** transmits the detected temperature inside the pack case **30** to the sub-controller **50** to which it is connected. The sub-controller **50** acquires the temperature inside the pack case **30** that has been detected and transmitted by the abnormality detection element **60** to which it is connected as an adjacent pack temperature T**1**. Then, the sub-controller **50** transmits the acquired adjacent pack temperature T**1** to the main controller **80**. The acquisition controller **82** of the main controller **80** acquires the adjacent pack temperature T**1** that has been transmitted from the sub-controller **50**. In the above-described manner, the acquisition controller **82** is able to acquire the adjacent pack temperature T**1** from each of the sub-controllers **50**.

[0041] Next, at step S**105** shown in FIG. **2**, the determination controller **83** of the main controller **80** shown in FIG. **3** determines whether or not an abnormality is occurring inside the pack case **30**. Herein, the determination controller **83** determines whether or not the adjacent pack temperature T**1** is higher than or equal to a predetermined reference temperature T**2**. For example, when an abnormality occurs in one of the plurality of cell modules **40** housed in a pack case **30**, the temperature inside the pack case **30** rises. When an abnormality occurs inside a pack case **30**, for example, the adjacent pack temperature T**1** acquired from the sub-controller **50** connected to the abnormality detection element **60** that detects the temperature of the pack case **30** in which the abnormality has occurred, becomes higher. Therefore, the determination controller **83** determines whether or not the adjacent pack temperature T**1** is higher than or equal to a predetermined reference temperature T**2** at step S**105**. The reference temperature T**2** is stored in advance in the memory **81** (see FIG. **3**) of the main controller **80**. The reference temperature T**2** is set based on the temperature inside a pack case **30** that is expected when an abnormality occurs in the pack case **30**.

[0042] In the present embodiment, if the determination controller **83** determines that the adjacent pack temperature T**1** is lower than the reference temperature T**2** at step S**105**, the process next proceeds to step S**107** shown in FIG. **2**. At step S**107**, the main controller **80** determines that the inside of the pack case **30** in which the adjacent pack temperature T**1** has been detected is normal. On the other hand, if the determination controller **83** determines that the adjacent pack temperature T**1** is higher than or equal to the reference temperature T**2** at step S**105**, the process next proceeds to step S**109** shown in FIG. **2**. At step S**109**, the main controller **80** determines that an abnormality is occurring inside the pack case **30** in which the adjacent pack temperature T**1** has been detected. For example, if the adjacent pack temperature T**1** acquired from the sub-controller **50** of the battery pack **10**A is higher than or equal to the reference temperature T**2**, the main controller **80** determines that an abnormality is occurring inside the pack case **30** of the battery pack **10**D. For example, if the adjacent pack temperature T**1** acquired from the sub-controller **50** of the battery pack **10**C is higher than or equal to the reference temperature T**2**, the main controller **80** determines that an abnormality is occurring inside the pack case **30** of the battery pack **10**B.

[0043] In the above-described manner, the processes are executed in the sequence shown in FIG. **2** to perform the abnormality detection method. In the present embodiment, the main controller **80** transmits an acquisition signal to each of the sub-controllers **50** every predetermined detection time has elapsed. The main controller **80** executes step S**103** through step S**109** shown in FIG. **2** sequentially at the time when it transmits an acquisition signal to each of the sub-controllers **50**.

[0044] Note that the main controller **80** determines, for each of the battery packs **10**, whether or not an abnormality is occurring inside the pack case **30**. Then, if the main controller **80** determines that an abnormality is occurring inside the pack case **30** of one of the plurality of battery packs **10**, the main controller **80** determines that an abnormality is occurring in the battery system **100**. If the main controller **80** determines that an abnormality is occurring in the battery system **100**, the main controller **80** executes a predetermined abnormality process. This abnormality process may be, but is not particularly limited to, a process of stopping the battery system **100**, for example, or may be a process of sending a notification to a higher-level controller (for example, an overall controller of the vehicle in which the battery system **100** is incorporated). It should be noted that if all the battery packs **10** are normal, it means that the battery system **100** is normal, so the main controller **80** does not perform any special control operation.

[0045] In the present embodiment, as illustrated in FIG. **1**, the abnormality detection element **60** of one of the plurality of battery packs **10** is communicably connected to the sub-controller **50** of another one of the battery packs **10**, as described previously. A possible cause of an abnormality that occurs in the entirety of a pack case **30** may be, for example, an abnormality of a plurality of cell modules **40** housed in the pack case **30** (for example, a high temperature abnormality that occurs because the cell module **40** (at least one of the plurality of battery cells **41**) reaches a high temperature).

[0046] Here, it is assumed that an abnormality has occurred in the cell module **40** of the battery pack **10**B as illustrated in FIG. **1**. In this case, the inside of the pack case **30** of the battery pack **10**B shows a high temperature, so the abnormality detection element **60** of the battery pack **10**B detects an abnormality inside the pack case **30**.

[0047] For example, if an abnormality has occurred in the cell module **40** of the battery pack **10**B, it is possible that power may not be supplied to the sub-controller **50** to which power is supplied from the cell module **40** in which the abnormality has occurred. If power is not supplied, the sub-controller **50** does not start up properly. In the present embodiment, however, the abnormality detection element **60** of the battery pack **10**B is communicably connected to the sub-controller **50** of another one, the battery pack **10**C. Here, no abnormality is occurring inside the pack case **30** of the battery pack **10**C, so the sub-controller **50** of the battery pack **10**C is supplied with power and is started up properly. Thus, an abnormality inside the pack case **30** of the battery pack **10**B can be detected by the sub-controller **50** of the battery pack **10**C through the abnormality detection element **60** of the battery pack **10**B.

[0048] In the present embodiment, as illustrated in FIG. **1**, the connection topology of the main controller **80** and the plurality of sub-controllers **50** is a ring topology. The information on the adjacent pack temperature T**1** is output from the sub-controllers **50** to the main controller **80** through the communication wires **95**. As described previously, if an abnormality occurs in the cell module **40** of the battery pack **10**B and the sub-controller **50** of the battery pack **10**B is thus unusable, the communication wires **95***b* and **95***c* that are connected to the sub-controller **50** of the battery pack **10**B cannot be used. For this reason, in this case, the sub-controller **50** of the battery pack **10**C, for example, outputs the information on the adjacent pack temperature T**1** to the main controller **80** through the communication wires **95***d* and **95***e*. The sub-controller **50** of the battery pack **10**A, for example, outputs the information on the adjacent pack temperature T**1** to the main controller **80** through the communication wire **95***a*.

[0049] As described above, in the present embodiment, the battery system **100** includes a plurality of battery packs **10** and a main controller **80**, as illustrated in FIG. **1**. Each of the battery packs **10** includes a pack case **30**, a cell module **40** including a plurality of battery cells **41** disposed inside the pack case **30**, a sub-controller **50** disposed inside the pack case **30** and electrically connected to the cell module **40** to use the cell module **40** as its power source, and an abnormality detection element **60** that detects an abnormality in the entirety of the pack case **30**. The main controller **80** is communicably connected to each of the sub-controllers **50** in the plurality of battery packs **10**. The abnormality detection element **60** of one of the plurality of battery packs **10** is communicably connected to the sub-controller **50** of another one of the battery packs **10**. For example, the abnormality detection element **60** of one battery pack **10**A is communicably connected to the sub-controller **50** of another battery pack **10**B. Thus, even when an abnormality occurs in the entirety of the pack case **30** of one battery pack **10**A and the electric power source for the sub-controller **50** of the one battery pack **10**A is lost, an abnormality in the entirety of the pack case **30** of the one battery pack **10**A can be detected by the sub-controller **50** of another battery pack **10**B through the abnormality detection element **60** of the one battery pack **10**A.

[0050] In the present embodiment, each of the battery packs **10** includes a first connection port **31** connected to a sub-controller **50** and a second connection port **32** connected to an abnormality detection element **60**. For example, the second connection port **32** of the one battery pack **10**A is connected to the first connection port **31** of another battery pack **10**B by a connecting wire **35***b*. This allows the abnormality detection element **60** of one battery pack **10**A and the sub-controller **50** of another battery pack **10**B to be communicably connected to each other through the connecting wire **35***b*.

[0051] In the present embodiment, the plurality of battery packs **10** are arranged side by side along a predetermined arrangement direction D**1**. The sub-controller **50** of each of the battery packs **10** is communicably connected to one of the battery packs **10** that are adjacent thereto along the arrangement direction D**1**. For example, the sub-controller **50** of the battery pack **10**B is communicably connected to the abnormality detection element **60** of the battery pack **10**A, which is adjacent thereto along the arrangement direction D**1**. This makes it possible to shorten the distance between the sub-controller **50** and the abnormality detection element **60** that are to be connected to each other. Accordingly, it is possible to reduce the length of, for example, the connecting wire **35***b* that connects the sub-controller **50** of the battery pack **10**B and the abnormality detection element **60** of the battery pack **10**A.

[0052] In the present embodiment, a direction extending from one end (downward end in FIG. **1**) toward the other end (upward end in FIG. **1**) of the arrangement direction D**1** is defined as a first direction D**11**, and a direction extending from the other end toward the one end is defined as a second direction D**12**. Each of the sub-controllers **50** of the battery packs **10** is connected to the abnormality detection element **60** of one of the battery packs **10** that are adjacent thereto in the first direction D**11** of the arrangement direction D**1**. For example, the sub-controller **50** of the battery pack **10**B is connected to the abnormality detection element **60** of the battery pack **10**A that is adjacent thereto in the first direction D**11**. The sub-controller **50** of the battery pack **10**A, which is disposed closest to an end of the battery pack array in the first direction D**11** among the plurality of battery packs **10**, is connected to the abnormality detection element **60** of the battery pack **10**D, which is disposed closest to an end of the battery pack array in the second direction D**12**. This serves to prevent the connecting wires **35***a*, **35***b*, **35***c*, and **35***d*, which connect the sub-controllers **50** and the abnormality detection elements **60**, from being tangled complicatedly.

[0053] In the present embodiment, the abnormality detection element **60** is a temperature sensor that detects the temperature inside the pack case **30**. Herein, when an abnormality occurs inside the pack case **30**, the temperature inside the pack case **30** may become higher. Therefore, as an abnormality detection element **60** detects the temperature inside the pack case **30**, the main controller **80** is able to detect that an abnormality is occurring in the entirety of the pack case **30** of the battery pack **10** that corresponds to the abnormality detection element **60**.

[0054] In the present embodiment, the main controller **80** includes an acquisition controller **82** and a determination controller **83**, as illustrated in FIG. **3**. The acquisition controller **82** acquires, from a sub-controller **50**, the adjacent pack temperature T**1** that is detected by the abnormality detection element **60** communicably connected to the sub-controller **50**. The determination controller **83** determines whether or not the adjacent pack temperature T**1** that is acquired by the acquisition controller **82** is higher than or equal to a predetermined reference temperature T**2**. The main controller **80** is configured to detect that, if the determination controller **83** determines that the adjacent pack temperature T**1** is higher than or equal to the reference temperature T**2**, an abnormality is occurring in the entirety of the pack case **30** corresponding to the abnormality detection element **60** that has detected the adjacent pack temperature T**1**. Herein, the reference temperature T**2** may be the minimum temperature inside the pack case **30** that is expected when an abnormality occurs inside the pack case **30**. This makes it possible to detect an abnormality inside the pack case **30** by a simple control operation of determining whether or not the adjacent pack temperature T**1** is higher than or equal to the reference temperature T**2**.

[0055] In the present embodiment, the connection topology of the sub-controllers **50** of the plurality of battery packs **10** and the main controller **80** is a ring topology. Thus, by employing a ring topology for connecting the plurality of sub-controllers **50** and the main controller **80** in this way, additional battery packs **10** may be connected more easily even when the number of the battery packs **10** needs to be increased, resulting in higher scalability. For example, in the example of FIG. **1**, when one more battery pack **10** needs to be provided, the one additional battery pack **10** may be disposed between the sub-controller **50** of the battery pack **10**D and the communication wire **95***e*.

[0056] Moreover, because the above-mentioned connection topology is a ring topology in the present embodiment, the sub-controllers **50** are able to output information to the main controller **80** in two directions. For example, the sub-controller **50** of the battery pack **10**A is able to output information from two directions, the communication wire **95***a* end and the communication wire **95***b* end, to the main controller **80**. For this reason, even when the electric power source for the sub-controller **50** of the battery pack **10**B is lost, the sub-controller **50** of the battery pack **10**A is able to output information to the main controller **80** through the communication wire **95***a*.

Second Embodiment

[0057] Next, a battery system **100**A according to a second embodiment will be described. FIG. **4** is a schematic view illustrating the battery system **100**A according to the second embodiment. As illustrated in FIG. **4**, in the present embodiment, the battery system **100**A includes a plurality of battery packs **10** (battery packs **10**A, **10**B, **10**C, and **10**D herein), a main controller **80**, and an auxiliary equipment power supply **90**. Except for the connection topology of the respective sub-controllers **50** in the plurality of battery packs **10** and the main controller **80**, the configuration of the battery system **100**A is identical to that of the battery system **100** according to the first embodiment, and therefore, the description of the configuration of the battery system **100**A will be omitted as appropriate.

[0058] In the present embodiment, the connection topology of the sub-controllers **50** in the plurality of battery packs **10** (battery packs **10**A, **10**B, **10**C, and **10**D herein) and the main controller **80** is a star topology. That is, the plurality of sub-controllers **50** are communicably connected to the main controller **80** independently.

[0059] As illustrated in FIG. **4**, the plurality of sub-controllers **50** are communicably connected to the main controller **80** via communication wires **96**. Herein, the sub-controller **50** of the battery pack **10**A is communicably connected to the main controller **80** via a communication wire **96***a*. The sub-controller **50** of the battery pack **10**B is communicably connected to the main controller **80** via a communication wire **96***b*. The sub-controller **50** of the battery pack **10**C is communicably connected to the main controller **80** via a communication wire **96***c*. The sub-controller **50** of the battery pack **10**D is communicably connected to the main controller **80** via a communication wire **96***d*. Note that although one communication wire **96** connects each one of the sub-controllers **50** and the main controller **80** to each other in the present embodiment, it is also possible to use a plurality of communication wires **96** to connect them.

[0060] Thus, when the connection topology of the respective sub-controllers **50** in the plurality of battery packs **10** and the main controller **80** is a star topology, the sub-controllers **50** are likewise able to output information to the main controller **80** even if the electric power source for another sub-controller **50** is lost. Therefore, it is possible to obtain the same advantageous effects as those obtained by the first embodiment.

[0061] In the embodiments described above, the abnormality detection element **60** is a temperature sensor that detects the temperature inside the pack case **30**. However, the abnormality detection element **60** is not limited to a temperature sensor. The abnormality detection element **60** may be a thermal fuse that is housed in the pack case **30** and that blows out when the temperature inside the pack case **30** increases (for example, when the temperature reaches higher than or equal to a predetermined reference temperature). In this case, the sub-controller **50** communicably connected to the abnormality detection element **60** may detect an abnormality in the entirety of the pack case **30** that houses the abnormality detection element **60** because of blowing out of the thermal fuse, which is an example of the abnormality detection element **60**.

[0062] Various embodiments of the invention have been described hereinabove according to the present disclosure. Unless specifically stated otherwise, the embodiments described herein do not limit the scope of the present invention. It should be noted that various other modifications and alterations may be possible in the embodiments of the invention disclosed herein. In addition, the features, structures, or steps described herein may be omitted as appropriate, or may be combined in any suitable combinations, unless specifically stated otherwise.

[0063] As has been described above, the present description contains the disclosure as set forth in the following items.

Item 1:

[0064] A battery system including:
- **[0065]** a plurality of battery packs; and
- **[0066]** a main controller, wherein:
- **[0067]** each of the battery packs includes:
  - **[0068]** a pack case;
  - **[0069]** a cell module including a plurality of battery cells disposed in the pack case;
  - **[0070]** a sub-controller disposed in the pack case and electrically connected to the cell module to use the cell module as its power source; and
  - **[0071]** an abnormality detection element detecting an abnormality in an entirety of the pack case;
- **[0072]** the main controller is communicably connected to the sub-controllers of the plurality of battery packs; and
- **[0073]** the abnormality detection element of one of the plurality of battery packs is communicably connected to the sub-controller of another one of the plurality of battery packs.

Item 2:

[0074] The battery system according to item 1, wherein:
- **[0075]** the plurality of battery packs are arrayed side by side along a predetermined arrangement direction; and
- **[0076]** each of the sub-controllers of the battery packs is communicably connected to the abnormality detection element of one of the battery packs that are adjacent thereto along the arrangement direction.

Item 3:

[0077] The battery system according to item 2, wherein:
- **[0078]** when a direction extending from one end toward another end of the arrangement direction is defined as a first direction and a direction extending from the other end toward the one end is defined as a second direction;
- **[0079]** each of the sub-controllers of the battery packs is connected to the abnormality detection element of one of the battery packs that is adjacent thereto in the first direction; and
- **[0080]** the sub-controller of one of the battery packs that is disposed closest to an end of the battery pack array in the first direction among the plurality of battery packs is connected to the abnormality detection element of one of the battery packs that is disposed closest to an end of the battery pack array in the second direction.

Item 4:

[0081] The battery system according to any one of items 1 through 3, wherein the abnormality detection element is a temperature sensor detecting a temperature inside the pack case.

Item 5:

[0082] The battery system according to item 4, wherein:
- **[0083]** the main controller includes:
  - **[0084]** an acquisition controller acquiring, from the sub-controller, an adjacent pack temperature that is detected by the abnormality detection element communicably connected to the sub-controller; and
  - **[0085]** a determination controller determining whether or not the adjacent pack temperature acquired by the acquisition controller is higher than or equal to a predetermined reference temperature; and
- **[0086]** the main controller is configured to detect that, if the determination controller determines that the adjacent pack temperature is higher than or equal to the reference temperature, an abnormality is occurring in the entirety of the pack case that corresponds to the abnormality detection element that has detected the adjacent pack temperature.

Item 6:

[0087] The battery system according to any one of items 1 through 5, wherein the respective sub-controllers in the plurality of battery packs and the main controller are connected in a ring topology.

Item 7:

[0088] The battery system according to any one of items 1 through 5, wherein the respective sub-controllers in the plurality of battery packs and the main controller are connected in a star topology.

Item 8:

[0089] A battery pack including:

[0090] a pack case;

[0091] a cell module including a plurality of battery cells disposed in the pack case;

[0092] a sub-controller disposed in the pack case, and electrically connected to the cell module to use the cell module as its power source;

[0093] an abnormality detection element detecting an abnormality in an entirety of the pack case;

[0094] a first connection port connected to the sub-controller; and

[0095] a second connection port connected to the abnormality detection element.

What is claimed is:

1. A battery system comprising:

a plurality of battery packs; and

a main controller, wherein:

each of the battery packs includes:

a pack case;

a cell module including a plurality of battery cells disposed in the pack case;

a sub-controller disposed in the pack case and electrically connected to the cell module to use the cell module as its power source; and

an abnormality detection element detecting an abnormality in an entirety of the pack case;

the main controller is communicably connected to the sub-controllers of the plurality of battery packs; and

the abnormality detection element of one of the plurality of battery packs is communicably connected to the sub-controller of another one of the plurality of battery packs.

2. The battery system according to claim **1**, wherein:

the plurality of battery packs are arrayed side by side along a predetermined arrangement direction; and

each of the sub-controllers of the battery packs is communicably connected to the abnormality detection element of one of the battery packs that are adjacent thereto along the arrangement direction.

3. The battery system according to claim **2**, wherein:

when a direction extending from one end toward another end of the arrangement direction is defined as a first direction and a direction extending from the other end toward the one end is defined as a second direction;

each of the sub-controllers of the battery packs is connected to the abnormality detection element of one of the battery packs that is adjacent thereto in the first direction; and

the sub-controller of one of the battery packs that is disposed closest to an end of the battery pack array in the first direction among the plurality of battery packs is connected to the abnormality detection element of one of the battery packs that is disposed closest to an end of the battery pack array in the second direction.

4. The battery system according to claim **1**, wherein the abnormality detection element is a temperature sensor detecting a temperature inside the pack case.

5. The battery system according to claim **4**, wherein:

the main controller includes:

an acquisition controller acquiring, from the sub-controller, an adjacent pack temperature that is detected by the abnormality detection element communicably connected to the sub-controller; and

a determination controller determining whether or not the adjacent pack temperature acquired by the acquisition controller is higher than or equal to a predetermined reference temperature; and

the main controller is configured to detect that, if the determination controller determines that the adjacent pack temperature is higher than or equal to the reference temperature, an abnormality is occurring in the entirety of the pack case that corresponds to the abnormality detection element that has detected the adjacent pack temperature.

6. The battery system according to claim **1**, wherein the respective sub-controllers in the plurality of battery packs and the main controller are connected in a ring topology.

7. The battery system according to claim **1**, wherein the respective sub-controllers in the plurality of battery packs and the main controller are connected in a star topology.

8. A battery pack comprising:

a pack case;

a cell module including a plurality of battery cells disposed in the pack case;

a sub-controller disposed in the pack case, and electrically connected to the cell module to use the cell module as its power source;

an abnormality detection element detecting an abnormality in an entirety of the pack case;

a first connection port connected to the sub-controller; and

a second connection port connected to the abnormality detection element.

* * * * *