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(54) **HIERARCHICAL DIAGNOSIS AND EARLY WARNING METHOD, SYSTEM AND APPARATUS FOR FAULTS OF ELECTROCHEMICAL ENERGY STORAGE SYSTEM.**

(57) Disclosed are hierarchical diagnosis and early warning method, system and apparatus for faults of an electrochemical energy storage system. The method includes: determining whether multidimensional detection information exceeds an information safety threshold; giving a first-level early warning signal; performing a second-level diagnosis and early warning by a big data analysis method, and recognizing a potential faulty battery cell; determining whether big data calculation information corresponding to the potential faulty battery cell exceeds a safety threshold; giving a second-level early warning signal according to the big data calculation information, and giving a serial number and position of the potential faulty battery cell; and performing a third-level diagnosis and early warning according to the multidimensional detection information corresponding to the potential faulty battery cell, determining a fault type, and giving a third-level early warning signal and a maintenance plan according to a fault diagnosis result.

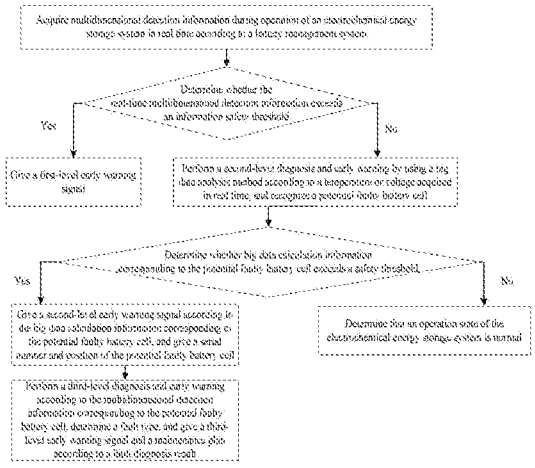

FIG. 1

HIERARCHICAL DIAGNOSIS AND EARLY WARNING METHOD, SYSTEM AND APPARATUS FOR FAULTS OF ELECTROCHEMICAL ENERGY STORAGE SYSTEM

[01] The present application claims the priority of Chinese Patent Application No. 202310649241.8, filed to the Chinese Patent Office on June 2, 2023, which is incorporated in its entirety herein by reference.

TECHNICAL FIELD

[02] The present application relates to the field of electrochemical energy storage, for example, which relates to a hierarchical diagnosis and early warning method, system and apparatus for faults of an electrochemical energy storage system.

BACKGROUND ART

[03] With development of new energy and a proposal of a smart power grid and a new power system, an electrochemical energy storage technology is playing an increasingly important role. Large-scale application of an electrochemical energy storage system puts forward new requirements for performance of the system, and especially in view of personnel and property loss and other problems that are caused by a fire and an explosion accident caused by electrochemical energy storage power station failures, safety of the electrochemical energy storage system has attracted more and more attention.

[04] In an actual operation process, since the electrochemical energy storage system includes a large number of energy storage battery cells, a power conversion system (PCS), a thermal management system, a battery management system (BMS) and other apparatuses, the number of apparatus components is large, and the amount of data in a system operation process is huge, it is difficult to effectively extract fault information, and a failure of each component will cause the system to fail to work normally. Especially when a battery failure occurs, it is likely to cause a fire and an explosion of the energy storage system, and it is difficult to achieve an early warning of an accident

only by means of current, voltage and temperature information. In addition, for potential faults that occur slowly in the battery system, if the potential faults can be recognized at an early stage and maintenance measures are taken in advance, fault hazards will be greatly reduced.

[05] However, in current laboratory research and engineering application, a hierarchical diagnosis system for faults of a large-scale electrochemical energy storage system is not comprehensive. For example, Beijing Institute of Technology has developed a battery fault diagnosis method for real-time operation data of an electric vehicle, but which can only recognize abnormal battery cells and does not further diagnose a cause of a fault. Tsinghua University has developed a method for diagnosing an internal short circuit of a battery, but this method is implemented for battery cells and can not simultaneously diagnose all battery cells of the large-scale energy storage system in real time. The current research and application do not consider a hierarchical diagnosis and early warning method for faults of a large-scale electrochemical energy storage system, and a comprehensive fault diagnosis and early warning system has not been established.

SUMMARY

[06] The present application provides a hierarchical diagnosis and early warning method, system and apparatus for faults of an electrochemical energy storage system, which can accurately and rapidly achieve a hierarchical diagnosis and early warning for the faults of the electrochemical energy storage system, thereby improving safety of the large-scale electrochemical energy storage system.

[07] The present application provides the solutions as follows:

[08] A hierarchical diagnosis and early warning method for faults of an electrochemical energy storage system includes:

[09] acquiring multidimensional detection information during operation of the electrochemical energy storage system in real time according to a battery management system, where the multidimensional detection information includes a current, a voltage, a temperature, stress, sound, hydrogen, carbon monoxide, a volatile organic compound, methane and visible light;

[10] determining whether the real-time multidimensional detection information exceeds an information safety threshold; giving a first-level early warning signal in response to the situation that the multidimensional detection information exceeds the information safety threshold; performing a second-level diagnosis and early warning by using a big data analysis method according to the temperature or voltage acquired in real time in response to the situation that the multidimensional detection information does not exceed the information safety threshold, and recognizing a potential faulty battery cell;

[11] determining whether big data calculation information corresponding to the potential faulty battery cell exceeds a safety threshold; determining that an operation state of the electrochemical energy storage system is normal in response to the situation that the big data calculation information corresponding to the potential faulty battery cell does not exceed the safety threshold; giving a second-level early warning signal according to the big data calculation information corresponding to the potential faulty battery cell in response to the situation that the big data calculation information corresponding to the potential faulty battery cell exceeds the safety threshold, and giving a serial number and position of the potential faulty battery cell; and

[12] performing a third-level diagnosis and early warning according to the multidimensional detection information corresponding to the potential faulty battery cell, determining a fault type, and giving a third-level early warning signal and a maintenance plan according to a fault diagnosis result.

[13] A hierarchical diagnosis and early warning system for faults of an electrochemical energy storage system includes:

[14] a multidimensional detection information acquisition module configured to acquire multidimensional detection information during operation of the electrochemical energy storage system in real time according to a battery management system, where the multidimensional detection information includes a current, a voltage, a temperature, stress, sound, hydrogen, carbon monoxide, a volatile organic compound, methane and visible light;

[15] a first determination module configured to determine whether the real-time multidimensional detection information exceeds an information safety threshold; give a first-level early warning signal in response to the situation that the multidimensional detection information exceeds the information safety threshold; perform a second-level diagnosis and early warning by using a big data analysis method according to the

temperature or voltage acquired in real time in response to the situation that the multidimensional detection information does not exceed the information safety threshold, and recognize a potential faulty battery cell;

[16] a second determination module configured to determine whether big data calculation information corresponding to the potential faulty battery cell exceeds a safety threshold; determine that an operation state of the electrochemical energy storage system is normal in response to the situation that the big data calculation information corresponding to the potential faulty battery cell does not exceed the safety threshold; give a second-level early warning signal according to the big data calculation information corresponding to the potential faulty battery cell in response to the situation that the big data calculation information corresponding to the potential faulty battery cell exceeds the safety threshold, and give a serial number and position of the potential faulty battery cell; and

[17] a fault diagnosis result determination module configured to perform a third-level diagnosis and early warning according to the multidimensional detection information corresponding to the potential faulty battery cell, determine a fault type, and give a third-level early warning signal and a maintenance plan according to a fault diagnosis result.

[18] A hierarchical diagnosis and early warning apparatus for faults of an electrochemical energy storage system includes at least one processor, at least one memory, and a computer program instruction stored in the memory, and when the computer program instruction is executed by the processor, the above-mentioned method is implemented.

BRIEF DESCRIPTION OF THE DRAWINGS

[19] A brief introduction to the accompanying drawings required for the examples will be provided below, the accompanying drawings in the following description are merely some examples of the present application, and those of ordinary skill in the art would also have obtained other accompanying drawings according to these accompanying drawings without involving any creative effort.

[20] FIG. 1 is a schematic flowchart of a hierarchical diagnosis and early warning method for faults of an electrochemical energy storage system provided by the present application; and

[21] FIG. 2 is a schematic diagram for grading of a hierarchical early warning in a second-level diagnosis and early warning.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[22] The following clearly and completely describes the technical solutions of the examples of the present application in conjunction with the accompanying drawings in the examples of the present application. Apparently, the examples described are merely some examples rather than all examples of the present application. Based on the examples of the present application, all other examples obtained by those of ordinary skill in the art without making creative efforts fall within the scope of protection of the present application.

[23] The present application provides a hierarchical diagnosis and early warning method, system and apparatus for faults of an electrochemical energy storage system, which can accurately and rapidly achieve a hierarchical diagnosis and early warning for the faults of the electrochemical energy storage system, thereby improving safety of the large-scale electrochemical energy storage system.

[24] The present application will be described in detail below with reference to the accompanying drawings and particular embodiments.

[25] As shown in FIG. 1, a hierarchical diagnosis and early warning method for faults of an electrochemical energy storage system provided by the present application includes:

[26] S1. Acquire multidimensional detection information during operation of the electrochemical energy storage system in real time according to a battery management system, where the multidimensional detection information includes a current, a voltage, a temperature, stress, sound, hydrogen, carbon monoxide, a volatile organic compound, methane and visible light,

[27] that is, a first-level diagnosis and early warning in S2 is performed by acquiring the multidimensional detection information including electricity, heat, force, sound, a gas, light, etc. of the electrochemical energy storage system, and a first-level early warning signal is given.

[28] Specific acquisition information is shown in Table 1:

[29] Table 1

Parameter type	Electricity	Heat	Force	Sound	Gas	Light
Parameter name	Current (I)	Temperature (T)	Stress (σ)	Sound (S)	Hydrogen (H_2)	Visible light (L)
					Carbon monoxide (CO)	
	Voltage (U)				Volatile organic compound (VOC)	
					Methane (CH_4)	

[30] S2. Determine whether the real-time multidimensional detection information exceeds an information safety threshold; give a first-level early warning signal in response to the situation that the multidimensional detection information exceeds the information safety threshold; and recognize a potential faulty battery cell by using a big data analysis method according to the current and voltage acquired in real time in response to the situation that the multidimensional detection information does not exceed the information safety threshold, and determine calculation information corresponding to the detection information of the battery cell, where the big data analysis method includes an information entropy method.

[31] Table 2

Parameter type	Electricity	Heat	Force	Sound	Gas	Light
Parameter threshold	Current (I_{max})	Temperature (T_{max}, T_{min})	Stress (σ_{max})	Sound (S_{max})	Hydrogen ($H_{2,max}$)	Visible light (L_{max})
					Carbon monoxide (CO_{max})	
	Voltage (U_{max}, U_{max})				Volatile organic compound (VOC_{max})	
					Methane ($CH_{4,max}$)	

[32] The information safety threshold is shown in Table 2:

[33] S3. Determine whether big data calculation information corresponding to the potential faulty battery cell exceeds a safety threshold; determine that an operation state of the electrochemical energy storage system is normal in response to the situation that the big data calculation information corresponding to the potential faulty battery cell does not exceed the safety threshold; and give a second-level early warning signal according to the calculation information corresponding to the potential faulty battery cell in response to the situation that the big data calculation information corresponding to the potential faulty battery cell exceeds the safety threshold, and give a serial number and position of the potential faulty battery cell.

[34] S3 specifically includes:

[35] determine a hierarchical early warning threshold;

[36] determine a hierarchical early warning of a corresponding level according to the big data calculation information of the potential faulty battery cell, the hierarchical early warning threshold, and the safety threshold; and

[37] determine a serial number and position of the potential faulty battery cell.

[38] As shown in FIG. 2, hierarchical early warnings of levels I-III are given, where TV is a parameter value of the calculation information after normalization processing of a diagnosis result of the big data analysis method, i.e., the multidimensional detection information corresponding to the potential faulty battery cell, TV1 is the safety threshold, i.e., level I early warning threshold, and TV2 and TV3 are level II and level III early warning thresholds respectively.

[39] S4. Perform a third-level diagnosis and early warning according to the multidimensional detection information corresponding to the potential faulty battery cell, determine a fault type, and give a third-level early warning signal and a maintenance plan according to a fault diagnosis result.

[40] S4 specifically includes:

[41] acquire a model library, where the model library includes normal models, fault models and corresponding algorithms of various batteries and components;

[42] determine a fault type according to the multidimensional detection information and the model library corresponding to the potential faulty battery cell; and

[43] give an early warning signal and a maintenance plan according to the fault diagnosis result.

[44] According to the present application, a multi-level fault hierarchical diagnosis and early warning from a system to a battery cell can be performed in a daily operation

process of the large-scale electrochemical energy storage system. Based on an established hierarchical diagnosis strategy, the faulty battery cell and potential faults in the large-scale electrochemical energy storage system can be recognized, and detailed diagnosis results and operation and maintenance suggestions can be given, such that safety performance of the energy storage system is greatly improved.

[45] Description is made below in combination with three examples:

[46] Example 1

[47] A large-scale electrochemical energy storage system in this example includes 10000 battery cells, an operating voltage range of the battery cells is 3.05 V to 3.55 V, and the maximum charge-discharge current is 140 A.

[48] Implementation steps of the hierarchical diagnosis and early warning method for faults of this example are as follows:

[49] (1) When the electrochemical energy storage system operates, the battery management system (BMS) acquires multidimensional detection information such as electricity, heat, force, sound, gas and light of the system in real time to monitor an operation state of the energy storage system. The information acquired at a certain time is shown in Table 3:

[50] Table 3

Parameter type	Electricity	Heat	Force	Sound	Gas	Light
Parameter name	Current (I=187.3A)	Temperature (T=27.2°C)	Stress (σ=100Pa)	Sound (S=0)	Hydrogen (H_2=0)	Visible light (L=0)
					Carbon monoxide (CO=0)	
	Voltage (U=2.3V)				Volatile organic compound (VOC=0)	
					Methane (CH_4=0)	

[51] (2) A first-level diagnosis and early warning is performed according to the acquired multidimensional detection information and each information safety threshold, and a first-level early warning signal is sent. According to the multidimensional detection information such as electricity, heat, force, sound, gas and light, and the

information safety threshold (as shown in Table 4), a current value exceeds the maximum current threshold, and a voltage value is lower than the minimum voltage threshold. The battery cell is quite likely to have a serious failure. In this case, a first-level diagnosis and early warning and an operation and maintenance strategy shall be given, and the diagnosis ends. Table 4 is shown as follows:

[52] Table 4

Parameter type	Electricity	Heat	Force	Sound	Gas	Light
Parameter name	Current (I_{max}=150A)	Temperature (T_{max}=30°C)	Stress (σ_{max}=100Pa)	Sound (S_{max}=10)	Hydrogen ($H_{2,max}$=5ppm)	Visible light (L_{max}=1)
					Carbon monoxide (CO_{max}=5ppm)	
	Voltage (U_{max}=3.65V, U_{min}=3.00V)				Volatile organic compound (VOC_{max}=5ppm)	
					Methane ($CH_{4,max}$=5ppm)	

[53] Example 2

[54] A large-scale electrochemical energy storage power station in this example includes 10000 battery cells, an operating voltage range of the battery cells is 3.05 V to 3.55 V, and the maximum charge-discharge current is 140 A.

[55] Implementation steps of the hierarchical diagnosis and early warning method for faults of this example are as follows:

[56] (1) When the electrochemical energy storage system operates, the battery management system (BMS) acquires multidimensional detection information such as electricity, heat, force, sound, gas and light of the system in real time to monitor an operation state of the energy storage system. The information acquired at a certain time is shown in Table 5:

[57] Table 5

Parameter	Electricity	Heat	Force	Sound	Gas	Light

type						
Parameter name	Current (I =70.05A)	Temperature (T =27.2℃)	Stress (σ =100Pa)	Sound (S =0)	Hydrogen (H_2=0)	Visible light (L=0)
					Carbon monoxide (CO=0)	
	Voltage (U =3.6V)				Volatile organic compound (VOC=0)	
					Methane (CH_4=0)	

[58] A first-level diagnosis and early warning is performed according to the acquired multidimensional detection information and each information safety threshold. Based on the multidimensional detection information such as electricity, heat, force, sound, gas and light, and each information safety threshold, all the battery cell signals in the energy storage system are within the safety threshold range. The information safety threshold is shown in Table 4. The system has no obvious fault and is in a normal operation state, and second-level diagnosis and early warning analysis is performed.

[59] The electricity (voltage) and heat (temperature) information acquired in real time is analyzed and normalized by using a big data analysis method (an information entropy method is used here). After recognition, calculation results of all the battery cells in the system do not exceed the safety threshold TV1, indicating that there is no potential faulty battery cell in the system and the system operates normally.

[60] Example 3

[61] A large-scale electrochemical energy storage power station in this example includes 10000 battery cells, an operating voltage range of the battery cells is 3.05 V to 3.55 V, and the maximum charge-discharge current is 140 A.

[62] Implementation steps of the hierarchical diagnosis and early warning method for faults of this example are as follows:

[63] (1) When the electrochemical energy storage system operates, the battery management system (BMS) acquires multidimensional detection information such as electricity, heat, force, sound, gas and light of the system in real time to monitor an operation state of the energy storage system. The information acquired at a certain time is shown in Table 6:

[64] Table 6

Parameter type	Electricity	Heat	Force	Sound	Gas	Light
Parameter name	Current (I =70.05A)	Temperature (T =27.2°C)	Stress (σ =100Pa)	Sound (S =0)	Hydrogen (H_2=0)	Visible light (L=0)
					Carbon monoxide (CO=0)	
	Voltage (U =3.6V)				Volatile organic compound (VOC=0)	
					Methane (CH_4=0)	

[65] (2) A first-level diagnosis and early warning is performed according to the acquired multidimensional detection information and each information safety threshold. Based on the multidimensional detection information such as electricity, heat, force, sound, gas and light, and each information safety threshold, all the battery cell signals in the energy storage system are within the safety threshold range. The information safety threshold is shown in Table 4. The system has no obvious fault and is in a normal operation state, and second-level diagnosis and early warning analysis is performed.

[66] (3) Voltage and temperature analysis and normalization processing are performed on the electricity (voltage) information acquired in real time by using a big data analysis method (an information entropy method is used here) to obtain calculation information for recognition of a potential faulty battery cell in the system. After recognition, the calculation information corresponding to the voltage large data of the battery cell numbered 3601 is: TV1≤TV3601≤TV2, indicating that there is a potential fault in the battery cell numbered 3601. In this case, a level III early warning shall be given, and a detailed fault diagnosis shall be conducted at the same time.

[67] (4) After the multidimensional detection information of the faulty battery cell in the system is obtained by means of the second-level diagnosis and early warning, it is found that an actual faulty component is a voltage sensor of the battery numbered 3601 by means of a sensor fault diagnosis model based on a first-order equivalent circuit model and an extended Kalman filter algorithm in a model library. In this case, an output fault reason is a voltage sensor fault of the battery numbered 3601, and a specific

maintenance suggestion is to replace the voltage sensor of the battery cell.

[68] In an example, a hierarchical diagnosis and early warning system for faults of an electrochemical energy storage system provided by the present application includes:

[69] a multidimensional detection information acquisition module configured to acquire multidimensional detection information during operation of the electrochemical energy storage system in real time according to a battery management system, where the multidimensional detection information includes a current, a voltage, a temperature, stress, sound, hydrogen, carbon monoxide, a volatile organic compound, methane and visible light;

[70] a first determination module configured to determine whether the real-time multidimensional detection information exceeds an information safety threshold; give a first-level early warning signal in response to the situation that the multidimensional detection information exceeds the information safety threshold; perform a second-level diagnosis and early warning by using a big data analysis method according to the temperature or voltage acquired in real time in response to the situation that the multidimensional detection information does not exceed the information safety threshold, and recognize a potential faulty battery cell;

[71] a second determination module configured to determine whether big data calculation information corresponding to the potential faulty battery cell exceeds a safety threshold; determine that an operation state of the electrochemical energy storage system is normal in response to the situation that the big data calculation information corresponding to the potential faulty battery cell does not exceed the safety threshold; give a second-level early warning signal according to the big data calculation information corresponding to the potential faulty battery cell in response to the situation that the big data calculation information corresponding to the potential faulty battery cell exceeds the safety threshold, and give a serial number and position of the potential faulty battery cell; and

[72] a fault diagnosis result determination module configured to perform a third-level diagnosis and early warning according to the multidimensional detection information corresponding to the potential faulty battery cell, determine a fault type, and give a third-level early warning signal and a maintenance plan according to a fault diagnosis result.

[73] In order to implement the above-mentioned method so as to achieve corresponding functions and technical effects, the present application further provides a

hierarchical diagnosis and early warning apparatus for faults of an electrochemical energy storage system, which includes at least one processor, at least one memory, and a computer program instruction stored in the memory, and when the computer program instruction is executed by the processor, the method is implemented.

[74] The memory is a computer-readable storage medium.

[75] According to particular examples provided by the present application, the technical effects disclosed in the present application are as follows:

[76] According to the hierarchical diagnosis and early warning method, system and apparatus for faults of an electrochemical energy storage system, the first-level diagnosis and early warning can be performed by acquiring the multidimensional detection information such as electricity (current and voltage), heat (temperature), force (stress), sound (sound), a gas (hydrogen, carbon monoxide, a volatile organic compound and methane) and light (visible light) during the operation process of the electrochemical energy storage system. If the multidimensional detection information does not exceed the threshold, big data analysis will be performed according to the electricity and heat information of all the battery cells in the system to recognize battery cells that may have potential faults in the system. Finally, detailed analysis is performed on the potential faulty battery cell by means of a battery model. According to the present application, the hierarchical early warning for faults of the energy storage system and the components is performed, such that a rapid alarm is given for the faults that have occurred, and potential faults of the system are recognized, thereby providing technical support for daily operation and maintenance of the energy storage system, and improving the safety of the large-scale electrochemical energy storage system.

[77] Based on the above description, the technical solution of the present application, in essence or from the view of part contributing to the related art, or part of the technical solution may be embodied in the form of a computer software product that is stored in a storage medium and includes a plurality of instructions configured to make one computer device (which may be a personal computer, a server or a network device, etc.) conduct all or part of the steps of the method in each of the examples of the present application. The foregoing storage medium includes various media which may store program codes, such as a universal serial bus flash drive, a mobile hard disk drive, a

read-only memory, a random access memory, a diskette and an optical disk.

[78] Various examples in the description are described in a progressive manner, differences between each example and other examples are mainly described, and the same and similar portions among various examples are seen from each other for reference. Since the system disclosed in the examples corresponds to the method disclosed in the examples, the description is simple, and reference can be made to the method description.

CLAIMS

1. A hierarchical diagnosis and early warning method for faults of an electrochemical energy storage system, comprising:

acquiring multidimensional detection information during operation of the electrochemical energy storage system in real time according to a battery management system, where the multidimensional detection information comprises a current, a voltage, a temperature, stress, sound, hydrogen, carbon monoxide, a volatile organic compound, methane and visible light;

determining whether the real-time multidimensional detection information exceeds an information safety threshold; giving a first-level early warning signal in response to the situation that the multidimensional detection information exceeds the information safety threshold; performing a second-level diagnosis and early warning by using a big data analysis method according to the temperature or voltage acquired in real time in response to the situation that the multidimensional detection information does not exceed the information safety threshold, and recognizing a potential faulty battery cell;

determining whether big data calculation information corresponding to the potential faulty battery cell exceeds a safety threshold; determining that an operation state of the electrochemical energy storage system is normal in response to the situation that the big data calculation information corresponding to the potential faulty battery cell does not exceed the safety threshold; giving a second-level early warning signal according to the big data calculation information corresponding to the potential faulty battery cell in response to the situation that the big data calculation information corresponding to the potential faulty battery cell exceeds the safety threshold, and giving a serial number and position of the potential faulty battery cell; and

performing a third-level diagnosis and early warning according to the multidimensional detection information corresponding to the potential faulty battery cell, determining a fault type, and giving a third-level early warning signal and a maintenance plan according to a fault diagnosis result.

2. The hierarchical diagnosis and early warning method for faults of an electrochemical energy storage system according to claim 1, wherein the big data analysis method comprises an information entropy method.

3. The hierarchical diagnosis and early warning method for faults of an

electrochemical energy storage system according to claim 1, wherein the giving a second-level early warning signal according to the big data calculation information corresponding to the potential faulty battery cell in response to the situation that the big data calculation information corresponding to the potential faulty battery cell exceeds the safety threshold comprises:

determining a hierarchical early warning threshold;

determining a hierarchical early warning of a corresponding level according to the big data calculation information of the potential faulty battery cell and the hierarchical early warning threshold; and

determining a serial number and position of the potential faulty battery cell.

4. The hierarchical diagnosis and early warning method for faults of an electrochemical energy storage system according to claim 1, wherein the performing third-level diagnosis and early warning according to multidimensional detection information corresponding to the potential faulty battery cell, determining a fault type, and giving a third-level early warning signal and a maintenance plan according to a fault diagnosis result comprises:

acquiring a model library, wherein the model library comprises normal models, fault models and corresponding algorithms of various batteries and components;

determining a fault type according to the multidimensional detection information and the model library corresponding to the potential faulty battery cell; and

giving a maintenance plan according to the fault diagnosis result.

5. A hierarchical diagnosis and early warning system for faults of an electrochemical energy storage system, comprising:

a multidimensional detection information acquisition module configured to acquire multidimensional detection information during operation of the electrochemical energy storage system in real time according to a battery management system, where the multidimensional detection information comprises a current, a voltage, a temperature, stress, sound, hydrogen, carbon monoxide, a volatile organic compound, methane and visible light;

a first determination module configured to determine whether the real-time multidimensional detection information exceeds an information safety threshold; give a first-level early warning signal in response to the situation that the multidimensional detection information exceeds the information safety threshold; perform a second-level diagnosis and early warning by using a big data analysis method according to the

temperature or voltage acquired in real time in response to the situation that the multidimensional detection information does not exceed the information safety threshold, and recognize a potential faulty battery cell;

a second determination module configured to determine whether big data calculation information corresponding to the potential faulty battery cell exceeds a safety threshold; determine that an operation state of the electrochemical energy storage system is normal in response to the situation that the big data calculation information corresponding to the potential faulty battery cell does not exceed the safety threshold; give a second-level early warning signal according to the big data calculation information corresponding to the potential faulty battery cell in response to the situation that the big data calculation information corresponding to the potential faulty battery cell exceeds the safety threshold, and give a serial number and position of the potential faulty battery cell; and

a fault diagnosis result determination module configured to perform a third-level diagnosis and early warning according to the multidimensional detection information corresponding to the potential faulty battery cell, determine a fault type, and give a third-level early warning signal and a maintenance plan according to a fault diagnosis result.

6. A hierarchical diagnosis and early warning apparatus for faults of an electrochemical energy storage system, comprising: at least one processor, at least one memory, and a computer program instruction stored in the memory, wherein when the computer program instruction is executed by the processor, the method according to any one of claims 1-4 is implemented.

7. The hierarchical diagnosis and early warning apparatus for faults of an electrochemical energy storage system according to claim 6, wherein the memory is a computer-readable storage medium.

REVENDICATIONS

1. Procédé de classement, de diagnostic et d'alerte anticipée des défauts d'un système de stockage d'énergie électrochimique, comprenant les étapes consistant à :

recueillir, en temps réel, des informations de détection multidimensionnelles pendant le fonctionnement du système de stockage d'énergie électrochimique selon un système de gestion de la batterie ; les informations de détection multidimensionnelles comprennent : le courant, la tension, la température, la contrainte, le son, l'hydrogène, le monoxyde de carbone, le gaz organique volatil, le méthane et la lumière visible ;

juger si les informations de détection multidimensionnelles en temps réel dépassent une valeur de seuil de sécurité de l'information ; en réponse aux informations de détection multidimensionnelle dépassant la valeur de seuil de sécurité de l'information, émettre un signal d'alerte anticipée de premier niveau ; en réponse à ladite informations de détection multidimensionnelles ne dépassant pas la valeur de seuil de sécurité de l'information, utiliser une méthode d'analyse de mégadonnées basée sur les températures ou les tensions collectées en temps réel pour effectuer un avertissement de diagnostic de deuxième niveau et identifier un monobloc de batterie potentiellement défectueux ;

déterminer si les informations de calcul de mégadonnées correspondant au monobloc de batterie potentiellement défaillant dépassent la valeur de seuil de sécurité ; en réponse aux informations de calcul de mégadonnées correspondant au monobloc de batterie potentiellement défaillant ne dépassant pas la valeur de seuil de sécurité, déterminer que l'état de fonctionnement du système de stockage d'énergie électrochimique est normal ; en réponse aux informations de calcul de mégadonnées correspondant au monobloc de batterie potentiellement défaillant dépassant la valeur de seuil de sécurité, donner un signal d'alerte de deuxième niveau sur la base des informations de calcul de mégadonnées du monobloc de batterie potentiellement défaillant. Le signal d'alerte anticipée de deuxième niveau est émis en fonction des informations de calcul de mégadonnées du monomère de batterie potentiellement défectueux, et le nombre et l'emplacement du monomère de batterie potentiellement défectueux sont indiqués ;

effectuer un diagnostic et un avertissement de troisième niveau sur la base des informations de détection multidimensionnelles correspondant au monomère de batterie potentiellement défectueux, déterminer le type de défaut et émettre un signal d'alerte anticipée de troisième niveau et un programme de maintenance sur la base des résultats du diagnostic de défaut.

2. Procédé de classement, de diagnostic et d'alerte anticipée des défauts d'un système de

stockage d'énergie électrochimique selon la revendication 1, caractérisé en ce que, le procédé d'analyse des données massives comprend un procédé d'entropie de l'information.

3. Procédé de classement, de diagnostic et d'alerte anticipée des défauts d'un système de stockage d'énergie électrochimique selon la revendication 1, caractérisé en ce que, l'émission d'un signal d'alerte de second niveau basé sur les informations de calcul du mégadonnées du monomère de batterie potentiellement défectueux en réponse aux informations de calcul du mégadonnées correspondant au monomère de batterie potentiellement défectueux dépassant une valeur de seuil de sécurité comprend les sous-étapes consistant à :

déterminer une valeur de seuil d'alerte anticipée graduel ;

déterminer un avertissement graduel du niveau correspondant sur la base des informations de calcul de mégadonnées du monomère de batterie potentiellement défectueux et du seuil d'alerte anticipée graduel ;

déterminer le nombre et l'emplacement d'un monomère de batterie potentiellement défectueux.

4. Procédé de classement, de diagnostic et d'alerte anticipée des défauts d'un système de stockage d'énergie électrochimique selon la revendication 1, caractérisé en ce que, ledit diagnostic de troisième niveau et ladite alerte précoce basés sur des informations de détection multidimensionnelles correspondant au monobloc de batterie potentiellement défectueux, déterminant le type de défaut, et donnant un signal d'alerte précoce de troisième niveau et un programme de maintenance basé sur les résultats du diagnostic de défaut, comprennent les sous-étapes consistant à :

acquérir une bibliothèque de modèles ; ladite bibliothèque de modèles comprend : un modèle normal, un modèle de défaut d'une pluralité de batteries et de composants, et un algorithme correspondant ;

déterminer un type de défaut sur la base des informations de détection multidimensionnelles correspondant à un monomère de batterie potentiellement défectueux et à la bibliothèque de modèles ;

donner un programme de maintenance basé sur les résultats du diagnostic des défauts.

5. Système de classement, de diagnostic et d'alerte anticipée des défauts d'un système de stockage d'énergie électrochimique, comprenant :

un module d'acquisition d'informations de détection multidimensionnelles, destiné à collecter des informations de détection multidimensionnelles pendant le fonctionnement du système de stockage d'énergie électrochimique en temps réel selon un système de gestion de la batterie ; lesdites informations de détection multidimensionnelles comprennent : le courant, la tension,

la température, le stress, le son, l'hydrogène, le monoxyde de carbone, le gaz organique volatil, le méthane et la lumière visible ;

un premier module de jugement, configuré pour juger si les informations de détection multidimensionnelles en temps réel dépassent une valeur de seuil de sécurité de l'information ; en réponse à ladite informations de détection multidimensionnelles dépassant la valeur de seuil de sécurité de l'information, donner un signal d'alerte anticipée de premier niveau ; en réponse à ladite informations de détection multidimensionnelles ne dépassant pas la valeur de seuil de sécurité de l'information, utiliser une méthode d'analyse de mégadonnées basée sur les températures ou les tensions collectées en temps réel pour effectuer un avertissement de diagnostic de deuxième niveau et identifier un monobloc de batterie potentiellement défectueux ;

le second module de jugement, réglé pour juger si les informations de calcul de mégadonnées correspondant au monomère de batterie potentiellement défectueux dépassent la valeur de seuil de sécurité ; en réponse aux informations de calcul de mégadonnées correspondant au monomère de batterie potentiellement défectueux ne dépassant pas la valeur de seuil de sécurité, déterminer que l'état de fonctionnement du système de stockage d'énergie électrochimique est normal ; en réponse aux informations de calcul de mégadonnées correspondant au monomère de batterie potentiellement défectueux dépassant la valeur de seuil de sécurité, donner un signal d'alerte anticipée de deuxième niveau basé sur les informations de calcul de mégadonnées du monomère de batterie potentiellement défectueux ; en réponse aux informations de calcul de mégadonnées correspondant au monomère de batterie potentiellement défectueux ne dépassant pas la valeur de seuil de sécurité, déterminer que l'état de fonctionnement du système de stockage d'énergie électrochimique est normal. un signal d'alerte anticipée de deuxième niveau, basé sur les informations de calcul de mégadonnées du monomère de batterie potentiellement défectueux, et indique le numéro et l'emplacement du monomère de batterie potentiellement défectueux ;

un module de détermination du résultat du diagnostic de défaillance réglé pour effectuer un diagnostic et un avertissement de troisième niveau sur la base des informations de détection correspondant au monomère de batterie potentiellement défectueux, déterminer un type de défaillance, et donner un signal d'alerte anticipée de troisième niveau et un programme de maintenance sur la base du résultat du diagnostic de défaillance.

6. Dispositif de classement, de diagnostic et d'alerte anticipée des défauts d'un système de stockage d'énergie électrochimique comprenant : au moins un processeur, au moins une mémoire, et des instructions de programme d'ordinateur stockées dans ladite mémoire, mettant en œuvre une méthode telle que revendiquée dans l'une quelconque des revendications 1 à 4

lorsque lesdites instructions de programme d'ordinateur sont exécutées par ledit processeur.

7. Dispositif de classement, de diagnostic et d'alerte anticipée des défauts d'un système de stockage d'énergie électrochimique selon la revendication 6, caractérisé en ce que, ladite mémoire est un support de stockage lisible par ordinateur.

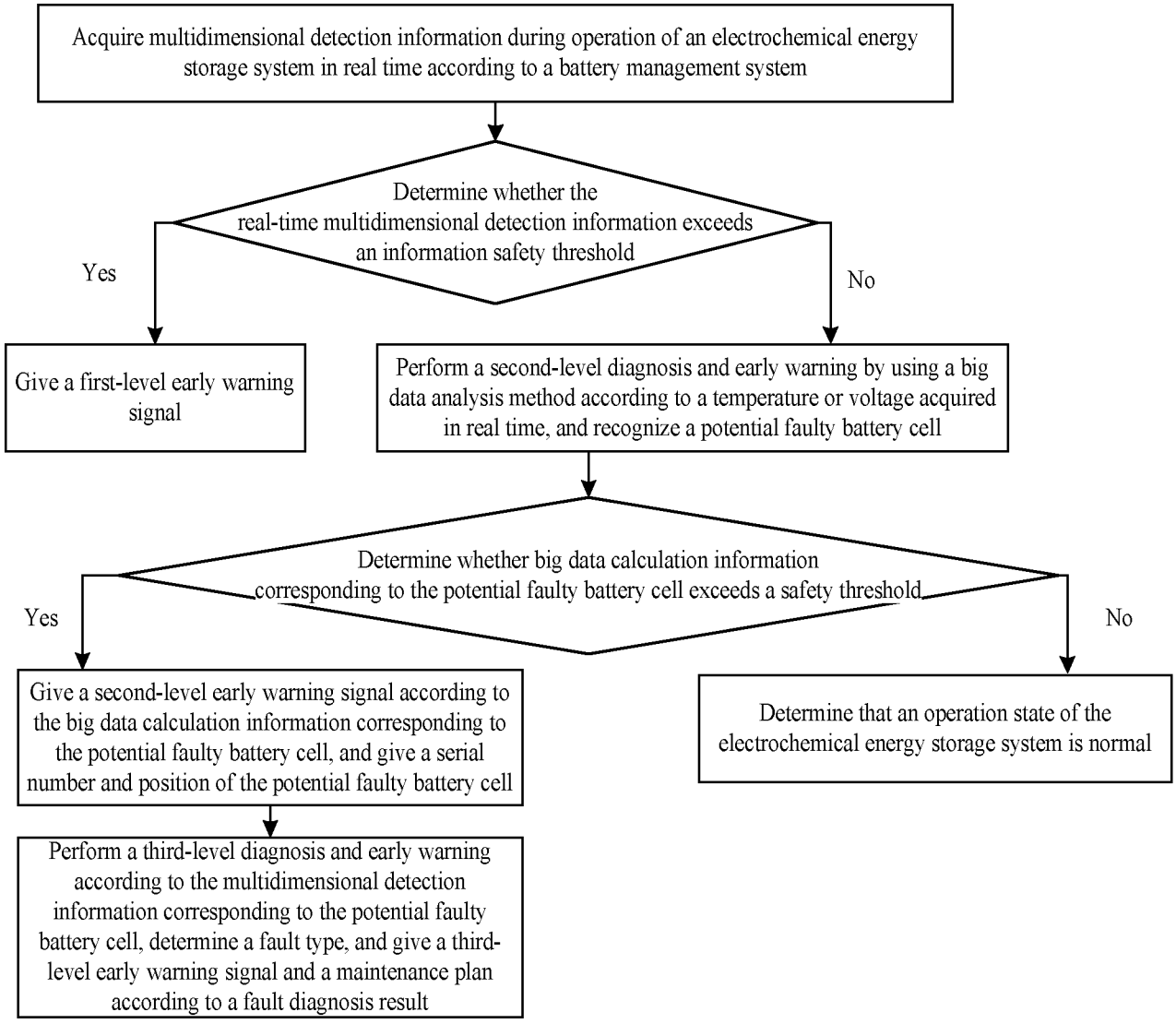
Acquire multidimensional detection information during operation of an electrochemical energy storage system in real time according to a battery management system
Determine whether the real-time multidimensional detection information exceeds an information safety threshold
Yes
No
Give a first-level early warning signal
Perform a second-level diagnosis and early warning by using a big data analysis method according to a temperature or voltage acquired in real time, and recognize a potential faulty battery cell
Determine whether big data calculation information corresponding to the potential faulty battery cell exceeds a safety threshold
Yes
No
Give a second-level early warning signal according to the big data calculation information corresponding to the potential faulty battery cell, and give a serial number and position of the potential faulty battery cell
Determine that an operation state of the electrochemical energy storage system is normal
Perform a third-level diagnosis and early warning according to the multidimensional detection information corresponding to the potential faulty battery cell, determine a fault type, and give a third-level early warning signal and a maintenance plan according to a fault diagnosis result

FIG. 1

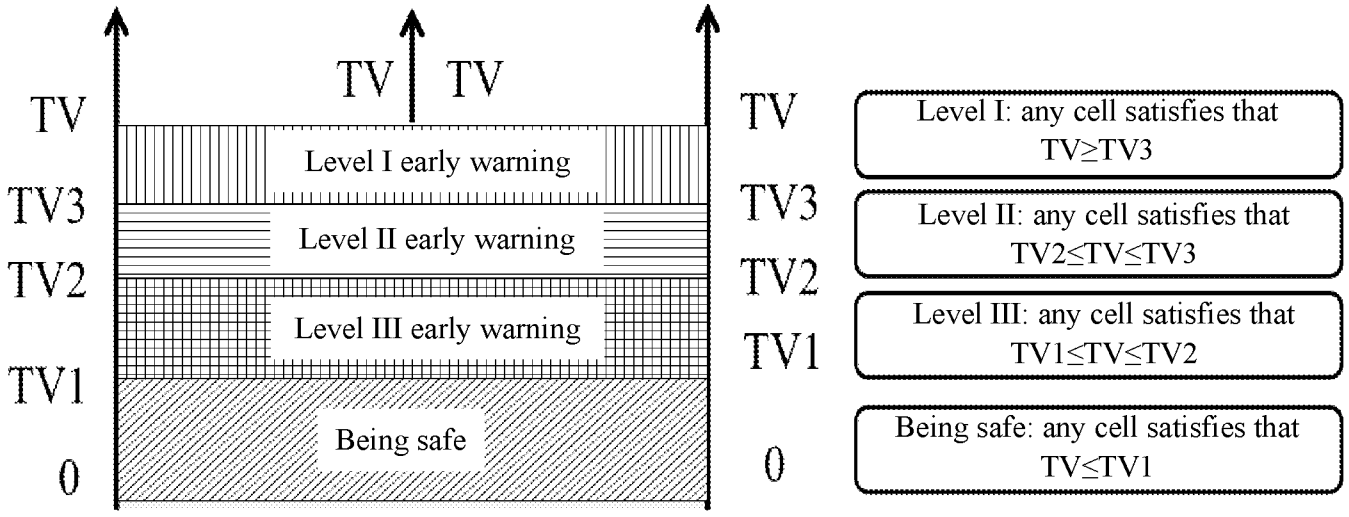
TV
TV
TV
TV3
TV2
TV1
0
Level I early warning
Level II early warning
Level III early warning
Being safe
TV
TV3
TV2
TV1
0
Level I: any cell satisfies that TV≥TV3
Level II: any cell satisfies that TV2≤TV≤TV3
Level III: any cell satisfies that TV1≤TV≤TV2
Being safe: any cell satisfies that TV≤TV1

FIG. 2