

(19)



**Octrooiencentrum
Nederland**

(11)

2035666

(12) A OCTROOIAANVRAAG

(21)

Aanvraagnummer: **2035666**

(51)

Int. Cl.:
H01M 50/00 (2023.01)

(22)

Aanvraag ingediend: **23 augustus 2023**

(62)

(30)

Voorrang:

(41)

Aanvraag ingeschreven:
11 september 2023

(43)

Aanvraag gepubliceerd:
11 september 2023

(71)

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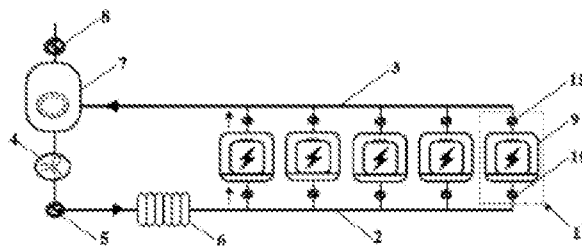
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LITHIUM BATTERY ENERGY STORAGE POWER STATION INTEGRATING TEMPERATURE CONTROL AND FIRE AND EXPLOSION PROTECTION

(57)

The present invention belongs to the new technical field of electric energy storage, and provides a lithium battery energy storage power station integrating temperature control and fire and explosion protection. A sealed circulation system using fireproof, explosion-proof and electrically insulated inert gas as a working medium is established, and a plurality of lithium battery energy storage units are placed in sealed explosion-proof cabinets separately and connected to the circulation system. Temperature of a lithium battery is adjusted by controlling temperature and flow rate of gas flowing through each sealed cabinet. When an explosion and combustion accident occurs in the lithium battery, the system function is quickly switched by controlling a valve, and flue gas of the lithium battery is sealed and collected under protection of the inert gas to prevent the combustible flue gas from continuing to explode and combust.



**LITHIUM BATTERY ENERGY STORAGE POWER STATION INTEGRATING
TEMPERATURE CONTROL AND FIRE AND EXPLOSION PROTECTION**

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TECHNICAL FIELD

The present invention belongs to the new technical field of electric energy storage, and relates to a lithium battery energy storage power station integrating temperature control and fire and explosion protection and a control method therefor.

BACKGROUND ART

Energy storage is an important link in energy reform and the construction of multiple clean energy supply systems. As an electrochemical energy storage method, lithium-ion battery energy storage is developing rapidly all over the world. By the end of 2020, the installed capacity of lithium-ion battery energy storage in the world has reached 13.1 GW, and the installed capacity of lithium-ion battery energy storage in China has reached 2902 MW. With the large-scale application of lithium-ion power stations, the safety risks of lithium-ion battery energy storage power stations are prominent. External overheating, collision, extrusion, overcharge, internal short circuit caused by dendrites and other conditions can cause thermal runaway of lithium-ion batteries. In the process of thermal runaway, the temperature reaches a certain threshold, which leads to an exothermic reaction. The released heat accumulates inside the batteries and causes the temperature to rise, which leads to more exothermic reactions, eventually leads to the fire and explosion of the batteries, and even the fire and explosion of the whole battery pack and energy storage power stations. For lithium-ion batteries used in energy storage power stations, even if the external conditions such as overheating, collision and extrusion are strictly restricted, the thermal runaway of the batteries can still be triggered. For example, the inevitable inconsistency in the production process of lithium-ion batteries leads to inconsistent aging, which is extremely likely to lead to overcharge of some batteries, and then trigger thermal

runaway. Metal lithium dendrites produced by aging, low-temperature fast charging, internal inconsistency and other problems in lithium-ion batteries can pierce the diaphragm, causing internal short circuit of the batteries and causing thermal runaway. Therefore, the safety problems such as fire and explosion caused by thermal runaway of lithium-ion batteries are the main bottlenecks restricting the development of lithium-ion battery energy storage power stations, such that the fire-proof and explosion-proof technology of lithium-ion battery energy storage power stations needs further development.

In order to prevent the thermal runaway of lithium-ion batteries, people have taken many technical measures. Firstly, the quality and consistency of lithium-ion batteries are improved, which can reduce the risk of serious lithium dendrites in lithium-ion batteries. Secondly, better control is given to lithium-ion batteries, including voltage, current and temperature control, so as to avoid problems such as overcharge, supercooling and overheating. Thirdly, the development of thermal runaway of lithium-ion batteries in a single battery and the spread in battery packs and energy storage battery cabinets are limited. Some of the main measures include the use of lithium battery safety valves to deflate during the process of thermal runaway of the batteries. Heat insulation and flame retardant materials are added in battery packs or between battery packs to limit the uncontrolled spread of heat caused by fire spread. Early warning is used for thermal runaway of lithium-ion batteries, and then fire-fighting measures are used in time.

However, there are still many defects in the existing technical means to control the thermal runaway of lithium batteries. The first is to improve the quality and consistency of the batteries, which contradicts the demand for large-scale production and application of lithium-ion batteries. For industrial products, the qualified rate cannot reach 100%. The greater the total production and application scale, the more the absolute number of batteries will be. Further, the larger the application scale, the more difficult it is to ensure the control accuracy of voltage, current and temperature of each lithium battery, which also increases the

possibility of accidents. The fire and explosion of a single lithium ion battery is extremely likely to cause the fire and explosion of the whole energy storage power station. In addition, in the design of safety valve for lithium ion batteries, the vaporized electrolyte is discharged from the batteries, which can improve the safety of single battery to a large extent. However, the flammable electrolyte vapor mixed with air is extremely likely to reach the flash point or explosion limit, which causes more serious combustion or explosion on the scale of stack and power station at extremely fast speed. When the lithium-ion batteries in the energy storage power stations are not well separated from one another, that is, when flame and explosion propagation are effectively prevented, even if early warning is successful, it is still extremely difficult to prevent explosion and extinguish fire because a large number of lithium-ion batteries are on fire.

Inert gas such as carbon dioxide, nitrogen, argon, heptafluoropropane, trifluoromethane, hexafluoropropane, and mixed gas IG 541 (mixed gas having 52% nitrogen, 40% argon and 8% carbon dioxide) are often used for fire fighting in electrical systems. Up to now, there is no design of energy storage power station that uses inert gas to regulate and control the working temperature of lithium-ion batteries and further prevent fire and explosion.

SUMMARY

An objective of the present invention is to provide a lithium battery energy storage power station integrating temperature control and fire and explosion protection and a control method solution thereof, which protects and cools a lithium battery with inert gas, and further solves the safety problem and temperature control problem of the lithium battery energy storage power station.

The technical solution of the present invention:

According to the lithium battery energy storage power station integrating temperature control and fire and explosion protection, a sealed circulation system using fireproof, explosion-proof and electrically insulated inert gas as a working medium is established, and a plurality of lithium battery energy storage units

are placed in explosion-proof storage cabinets separately and connected to the circulation system. Temperature of the lithium battery is adjusted by controlling temperature and flow rate of gas flowing through each explosion-proof storage cabinet. When an explosion and combustion accident occurs in the lithium battery, the system function is quickly switched by controlling a valve, and flue gas of the lithium battery is sealed and collected under protection of the inert gas to prevent combustible flue gas from continuing to explode and combust.

10 According to an exhaust gas flow rate of thermal runaway of a lithium battery energy storage unit, the sealed explosion-proof storage cabinet is designed; the lithium battery energy storage unit is placed in the sealed explosion-proof storage cabinet, and connected to a gas inlet valve and an exhaust valve to form a
15 sealed lithium battery storage cabinet unit;

a plurality of sealed lithium battery storage cabinet units are connected in parallel between a gas inlet pipe and an exhaust pipe;

a main pipeline is connected to a circulating fan for driving
20 gas to run, a main pipeline valve, a temperature controller for adjusting gas temperature and a gas buffer tank, and an overload exhaust valve is mounted on the gas buffer tank to form a sealed closed gas circulation system; and the closed gas circulation system is internally provided with flame retardant gas;

25 the closed gas circulation system is filled with fire-proof and explosion-proof inert gas and mixed gas thereof, which is the lithium battery energy storage power station integrating temperature control and fire and explosion protection; and

a temperature sensor and a controller are further provided in
30 the lithium battery energy storage power station integrating temperature control and fire and explosion protection; the temperature sensor is connected to the controller; the controller is further connected to the circulating fan, the main pipeline valve, the temperature controller, the overload exhaust valve and the gas
35 inlet valve; and the controller is configured to control the circulating fan, the main pipeline valve, the temperature controller, the overload exhaust valve and the gas inlet valve according to

temperature collected by the temperature sensor.

The present invention has the effects and beneficial effects as follows:

(1) gas circulation is controlled, control of each lithium
5 battery energy storage unit in the energy storage power station is realized, such that working thereof is uniformly in the best state.

(2) The closed system is filled with the fire-proof and explosion-proof inert gas, which isolates the combustible flue gas
10 which is subjected to thermal runaway of the lithium battery from contact with the atmosphere, and prevents the combustible flue gas cloud from igniting and exploding and the pollution of the flue gas to an environment.

(3) Compared with a conventional design, a complete automatic
15 control system is formed by providing the temperature sensor, a smoke sensor and the controller.

(4) The closed design of the sealing avoids influence of atmospheric humidity, condensation and other problems on electrical apparatuses, and therefore the closed design is more suitable for
20 application in wet and rainy areas.

(5) The sealed closed system may also reduce the risk of accidental leakage of battery electrolyte, prevent the electrolyte from polluting the environment, and further improve the power station's ability to resist natural disasters such as earthquakes,
25 floods and lightning strikes.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a systematic schematic diagram of a lithium battery energy storage power station.

30 In the figure: 1. sealed storage cabinet unit; 2 gas inlet pipe; 3 exhaust pipe; 4 circulating fan; 5 main pipeline valve; 6 temperature controller; 7 gas buffer tank; 8 overload exhaust valve; 9 explosion-proof storage cabinet; 10 gas inlet valve; 11 exhaust valve.

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DETAILED DESCRIPTION OF THE EMBODIMENTS

The specific implementation of the present invention is de-

scribed in detail below with reference to the technical solution and the accompanying drawings.

Example 1:

As shown in FIG. 1, a ternary lithium-ion battery with a voltage of 3.7 V and a capacity of 180 Ah is used, after a lithium-ion battery thermal runaway test is used, a gas product is collected to obtain a gas production rate of 0.332 m³. An energy storage unit is composed of five ternary lithium-ion batteries. The energy storage unit has a capacity of 900 Ah, 3.33 kWh, a weight of 15.2 kg, a volume of about 7 L(425 × 154 × 107 mm), and a thermal runaway gas production rate of $V_g = 6 \times 0.332 \text{ m}^3 = 1.660 \text{ m}^3$. A gas buffer tank 7 is designed as cuboid $V_c = 2.3 \text{ m} \times 2.3 \text{ m} \times 2.0 \text{ m} = 10.58 \text{ m}^3$. Volume of an exhaust pipe 3 and a sealed storage cabinet 11 is ignored, and according to initial system pressure $P_0 = 0.1 \text{ MPa}$, when a lithium battery energy storage unit is combusted completely, maximum static pressure in a closed system is calculated as follows:

$$P = P_0(V_g + V_c)/V_c = 0.1 \times (1.660 + 10.58)/10.58 = 0.116 \text{ MPa}$$

The above pressure is the maximum static pressure of the buffer tank 7, the exhaust pipe 3, a main pipeline valve 5 and an exhaust valve 11. When a safety factor of 1.26 is taken, the components may be designed according to bearing pressure of 0.15 MPa. A designed pressure safety threshold for opening an overload exhaust valve 8 is 0.14 MPa.

When the lithium battery combusts and explodes, an explosion-proof storage cabinet 9 has to be baked at high temperature, such that the explosion-proof storage cabinet 9 and a gas inlet valve 10 are designed according to bearing pressure of 0.2 MPa, and a safety factor is about 1.68. The explosion-proof storage cabinet 9 is designed as steel cuboid (volume of 33.88 L) with an inner cavity depth of 550 mm, a width of 280 mm and a height of 220 mm, a sealed door is designed in width and height directions, and size is small, which facilitates pressure bearing. The diameter of the exhaust valve 11 is DN60, the diameter of the gas inlet valve 10 is DN40, the gas inlet and exhaust branch pipes are made of ordinary steel pipes (bearing pressure of 2.5 MPa) and welded to the explosion-proof storage cabinet 9.

40 sealed lithium battery storage cabinet units 1 are connected in parallel to a main pipeline, the diameter of the main pipeline is DN200 (including a gas inlet pipe 2 and the exhaust pipe 3), and the main pipeline is made of an ordinary steel pipe.

5 A circulating fan 4 is an explosion-proof medium-pressure blower with a flow rate of 70 m³/min (power of 11 kW), considering process resistance, a static flow rate is not less than 60 m³/min = 1 m³/s, and the flow rate q allocated to each sealed lithium battery storage cabinet unit 1 is 2.5×10^{-2} m³/s. If carbon dioxide is used as

10 working medium in the system, density of carbon dioxide $\rho = 1.754$ kg/m³, specific heat of constant pressure $C_p = 855.5$ kJ/kg/K, and a temperature difference between inlet and outlet $\Delta t = 5$ K, gas flow heat dissipation power in each sealed lithium battery storage cabinet unit 1 may be calculated as follows:

$$15 \quad N = \rho q C_p \Delta T = 1.754 \times 2.5 \times 10^{-2} \times 855.5 \times 5 = 187.6 \text{ W}$$

The gas flow heat dissipation power N is divided by power N_E of the energy storage unit ($= 900 \text{ A} \times 3.7 \text{ V} = 3330 \text{ W}$), and a heat dissipation power ratio may be obtained as follows:

$$n = N/N_E = 187.6/3330 = 5.63\%$$

20 Usually, internal resistance of the lithium battery consumes about 5% of the total power, and it may be seen therefrom that the gas flow heat dissipation power completely satisfies heat dissipation requirements.

Finally, a temperature controller 6 is configured with heat

25 dissipation capacity of $40 \times 187.6 = 7504 \text{ W}$, diameters of the overload exhaust valve 8 and the main pipeline valve 5 are configured according to DN200, a lithium battery energy storage power station consisting of 200 lithium battery cells and 40 lithium battery energy storage units is established, and total storage capacity of electric energy is 133.2 kWh.

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$P_0 = 0.7 \text{ MPa}$, $T_0 = 303 \text{ K}$; a specific heat ratio of carbon dioxide is taken as $\gamma = 1.30$, inlet temperature $T_1 = 193 \text{ K}$ after expansion to normal pressure $P_1 = 0.1 \text{ MPa}$ is calculated. Outlet temperature is $T_3 = 303 \text{ K}$, and a temperature difference $\Delta T = 303 - 193 =$

35 110 K.

$$N = \rho q C_p \Delta T = 1.754 \times 2.5 \times 10^{-2} \times 855.5 \times 5 = 187.6 \text{ W}$$

$$q = 1.2 * N / (\rho C_p \Delta T) = 200 / (1.754 \times 855.5 \times 110) = 1.212 \times$$

$$10^{-3}\text{m}^3/\text{s} = 4.36 \text{ m}^3/\text{hr}.$$

$$\frac{T_1}{T_0} = \left(\frac{P_1}{P_0} \right)^{\frac{\gamma-1}{\gamma}}.$$

The temperature sensor and the controller (the temperature sensor and the controller are not shown in FIG. 1) are further provided in the lithium battery energy storage power station integrating temperature control and fire and explosion protection of the present invention; the temperature sensor is connected to the controller; the controller is further connected to the circulating fan, the main pipeline valve, the temperature controller, the overload exhaust valve and the gas inlet valve; and the controller is configured to control the circulating fan, the main pipeline valve, the temperature controller, the overload exhaust valve and the gas inlet valve according to temperature collected by the temperature sensor.

A control method for the energy storage power station of the present invention aims at controlling four states of normal operation of the lithium battery power station, overheating of a certain lithium battery energy storage unit, explosive combustion of a certain lithium battery energy storage unit and massive explosive combustion of lithium battery energy storage units separately, and a specific process is as follows:

(1) In a normal working state, the main pipeline valve 5 of the closed gas circulation system and the exhaust valve 11 of each sealed lithium battery storage cabinet unit 1 are in a normally open state, the circulating fan 4 drives gas in the system to flow, and a gas flow rate in each sealed lithium battery storage cabinet unit 1 is adjusted by the gas inlet valve 10; when the temperature collected by the temperature sensor indicates that the working temperature of the battery in the whole power station is too low or too high, the temperature is adjusted by changing the flow rate of the circulating fan 4 and heating and cooling by the temperature controller 6; when the temperature collected by the temperature sensor indicates that the working temperature of a

certain lithium battery energy storage unit is too low or too high, the gas flow rate of the sealed lithium battery storage cabinet unit 1 is adjusted through the gas inlet valve 10; and the working temperature of all lithium batteries are controlled evenly
5 in the best state.

2) When the lithium battery of a certain lithium battery energy storage unit is overheated and exceeds pre-warning temperature, the gas inlet valve 10 on the sealed lithium battery storage cabinet unit 1 is fully opened, load of the adjacent sealed lithium
10 um battery storage cabinet unit 1 is cut off, and the gas inlet valve 10 and the exhaust valve 11 of the adjacent sealed lithium battery storage cabinet unit 1 are closed to enter a fire-fighting preparation state; and further, the flow rate of the circulating fan 4 is increased, the gas in the system is led to the thermal
15 runaway explosion-proof storage cabinet 9 in quantity, and the thermal runaway of the batteries is prevented by increasing air-flow cooling.

(3) Once gas cooling is difficult to prevent the thermal runaway of the lithium batteries, when a certain lithium battery energy storage unit is combusted and exploded, only the exhaust
20 valve 11 of the combusted and exploded sealed lithium battery storage cabinet unit 1 is always open, and the load of the system and the main pipeline valve 5, the gas inlet valve 10 and the exhaust valve 11 are closed; and combustible flue gas generated by
25 the combustion and explosion of the lithium batteries is introduced into the gas buffer tank 7 by means of the exhaust pipe 3, and harmless treatment is performed after the combustion and explosion of the lithium batteries completely stop.

(4) Once lithium batteries in more sealed lithium battery
30 storage cabinet unit 1 are combusted and exploded, and the exhaust valve 11 of the combusted and exploded lithium sealed lithium battery storage cabinet unit 1 is continuously opened to introduce the combustible flue gas into the gas buffer tank 7; and when the pressure in the gas buffer tank 7 exceeds a safety threshold, the
35 overload exhaust valve 8 is immediately opened to prevent the pressure from opening the explosion-proof storage cabinet 9 and causing combustible smoke leakage.

A flame retardant gas working medium in the closed gas circulation system in a filling manner is one of carbon dioxide, nitrogen, argon, perfluoroalkane, perchloroalkane, chlorofluoroalkane and bromofluoroalkane and mixed gas thereof, with carbon dioxide
5 being the best.

C O N C L U S I E S

1. Lithiumbatterijenergie opslagkrachtstation die een temperatuur-
regeling en brand- en explosiebescherming integreert, omvattende
de volgende componenten:
in overeenstemming met het uitlaatgasdebiet van thermische weglo-
5 per van een lithiumbatterijenergie-opslagseenheid is een afgesloten
explosiebestendige opslagkast ontworpen; de opslagseenheid van de
lithiumbatterijenergie wordt in de afgesloten explosiebestendige
opslagkast geplaatst en aangesloten op een gasinlaatklep en een
uitlaatklep om een afgesloten lithiumbatterij opslagkasteenheid te
10 vormen;
een aantal afgesloten lithiumbatterij -opslagkasteenheden zijn pa-
rallel aangesloten tussen een gasinlaatpijp en een uitlaatpijp;
een hoofdpijpleiding is verbonden met een circulerende ventilator
voor het laten stromen van gas, een hoofdpijpleidingventiel, een
15 temperatuurregelaar voor het aanpassen van de gastemperatuur en
een gasbuffertank, en een uitlaatklep van de overbelasting wordt
gemonteerd op de gasbuffertank om een afgesloten gesloten gascir-
culatiesysteem te vormen; en het gesloten gascirculatiesysteem is
intern voorzien van vlamvertragend gas;
20 het gesloten gascirculatiesysteem is gevuld met vuurbestendig en
explosiebestendig inert gas en gemengd gas daarvan, wat de lithi-
umbatterijenergie opslagkrachtstation is die temperatuurregeling
en brand- en explosiebescherming integreert; en
een temperatuursensor en een controller zijn verder voorzien in de
25 opslagstation van het lithiumbatterijenergie opslagkrachtstation
die temperatuurregeling en brand- en explosiebescherming inte-
greert; de temperatuursensor is verbonden met de controller; de
controller is verder verbonden met de circulerende ventilator, de
hoofdpijpleidingsklep, de temperatuurregelaar, de uitlaatklep van
30 de overbelasting en de gasinlaatklep; en de controller is geconfi-
gureerd om de circulerende ventilator, de hoofdpijpleidingsklep,
de temperatuurregelaar, de uitlaatklep van de overbelasting en de
gasinlaatklep te regelen in overeenstemming met de temperatuur die
is gemeten door de temperatuursensor.

2. Lithiumbatterijenergie opslagkrachtstation die een temperatuur-
regeling en brand- en explosiebescherming integreert volgens con-
clusie 1, waarbij een vlamvertragend gaswerkmedium in het gesloten
5 gascirculatiesysteem op een vullende manier een van koolstofdioxi-
de, stikstof, argon, perfluoralkaan, perchloroalkaan, chloroflu-
oralkaan en bromofluoralkaan en gemengd gas daarvan is .

3. Lithiumbatterijenergie opslagkrachtstation die een temperatuur-
10 regeling en brand- en explosiebescherming integreert volgens con-
clusie 1 of 2, waarbij het vlamvertragende gaswerkmedium in het
gesloten gascirculatiesysteem op een vullende manier koolstofdi-
oxide is.

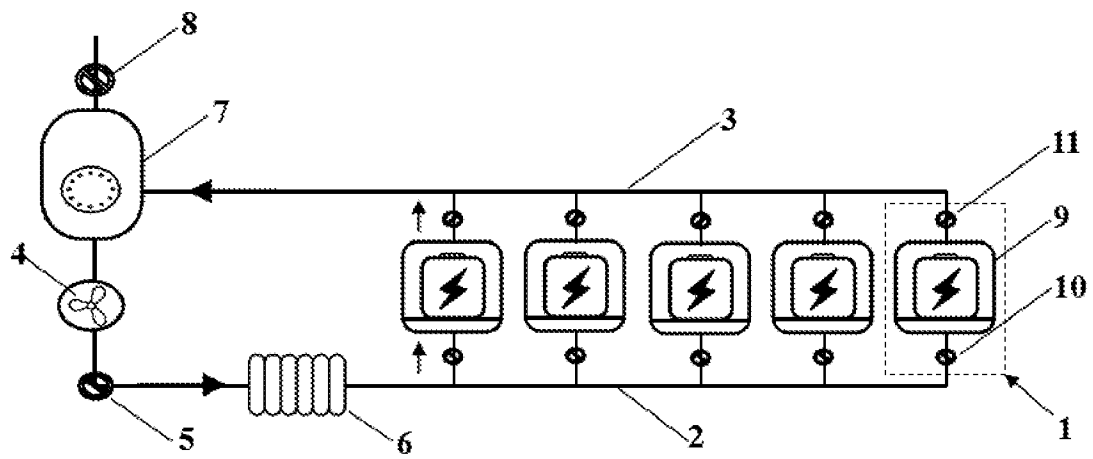


FIG. 1