УДК 004.8

CASCADE WARNING SYSTEM AND AUTOMATIC FIRE EXTINGUISHING DEVICE FOR THERMAL RUNAWAY OF ENERGY STORAGE BATTERY

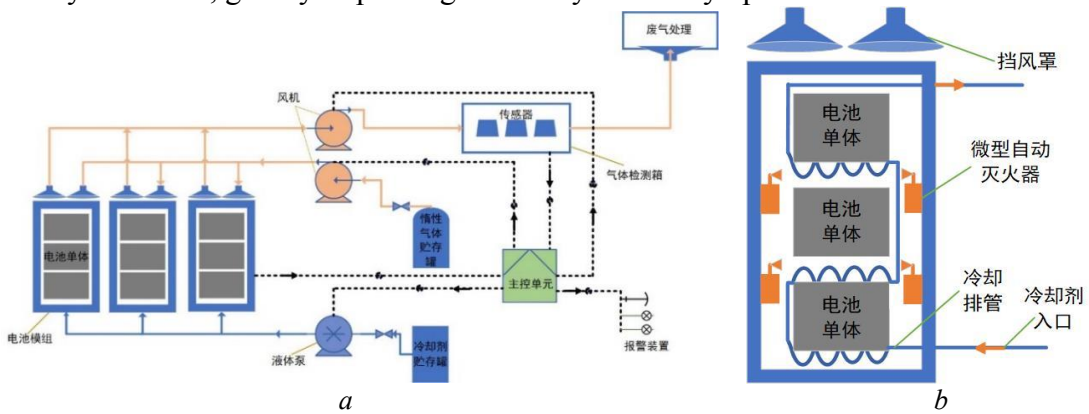
De-en Song, Liang Qiu
Northeastern University
e-mail: 20192426@stu.neu.edu.cn

Summary. *This paper combines research and analysis of the internal chemical reactions of thermal runaway of lithium-ion batteries, identifies identification features that can accurately warn of thermal runaway, adopts a stepped warning strategy, incorporates corresponding automatic firefighting measures for the salient features of three different degrees of thermal runaway stages, and designs a system that considers both warning and firefighting functions.*

In the context of today's tight fossil energy supply in the world, countries around the world are making a green energy revolution while vigorously developing the energy storage industry. However, the safety standards of today's lithium-ion energy storage batteries cannot keep up with the booming energy storage industry, and battery thermal runaway accidents occur frequently: from August 2017 to 2022 South Korea has had 34 energy storage power plant fire and explosion accidents, with direct economic losses of more than 300 million yuan.

Up to now, the national safety standards for energy storage batteries at home and abroad still have defects and loopholes that cannot be ignored, such as: traditional fire detectors are not applicable to early warning of thermal runaway of batteries, failure to warn of combustible gas explosion.

Early warning and fire fighting are independent of each other and lack of linkage, etc. To address the above defects, this paper proposes and designs an intelligent stepped warning system and automatic fire-fighting device for thermal runaway of lithium-ion battery for energy storage, adopting a graded warning strategy, designing three levels of warning and adding the best automatic fire-fighting measures corresponding to the significant characteristics of three different levels of thermal runaway stages, which can quickly and accurately identify the danger level of the battery and take timely measures, greatly improving the safety of battery operation.



a *b*

Figure 1 – System device structure diagram *a* and detailed diagram of the inside of the battery module *b*

The intelligent step warning system with automatic fire fighting device introduced in this paper is shown in fig. 1 *a*, where the black dashed line indicates the signal transmission line, the orange solid line indicates the gas transmission pipeline, and the blue solid line indicates the liquid transmission pipeline.

The system includes a feature acquisition device, a master control unit, an alarm device and a fire-fighting device. The feature acquisition device detects the battery thermal runaway feature parameters and sends them to the master control unit, which is used to process the collected battery state parameters according to a given algorithm and control the fire fighting device to take targeted fire fighting measures.

The feature collection device includes a temperature sensor set inside the battery, a gas detection box connected to the battery module through a fan, and a gas sensor set inside the gas detection box. The gas sensors include a hydrogen sensor, a carbon monoxide sensor, a carbon dioxide sensor, a methane sensor, an ethylene sensor, an ethane sensor, and a smoke sensor.

The fire-fighting device includes cooling drains distributed on the surface of the battery unit, an inert gas storage tank connected to the battery module through a fan, and a miniature fire extinguisher installed on the inner wall of the battery module, as shown in fig. 1 *b*. The cooling duct is connected to a pump through a pipe, and the pump is connected to a liquid storage tank with coolant; the outlet of the fan is connected to a wind shield set on the outside of the battery module. The inert gas is used to release inert gas to dilute the concentration of combustible gas, while the coolant is used to cool the runaway hot battery for emergency cooling. The alarm device includes an alarm indicator and a buzzer.

Table 1 – Three levels of warning mechanism and handling measures

Early warning level	**Battery thermal runaway characteristics**	**Monitoring Indicators**	**Processing measures**
First level	Increased internal battery temperature	Temperature	Input coolant to cool down
Second level	Produces large amounts of colorless and odorless dangerous gas	Characteristic gas concentration	Filled with inert gas
third level	Batteries release large amounts of smoke	Fumes	Spraying flame retardant

Energy storage industry: Energy storage power plants have a pivotal role in power peaking and distributed energy, however, the energy storage battery itself is relatively expensive. This device can be applied to energy storage power stations of various scales to effectively prevent fire and explosion accidents.

New energy vehicle field: new energy vehicles are the development trend of future vehicles. The early warning strategy and fire prevention concept proposed by this system can also be applied to new energy vehicle battery modules and charging piles.

Other industries in the energy field: Under the background of "double carbon" policy, new energy power generation, distributed energy, new energy vehicles, electric vehicles and other industries that are conducive to energy saving and carbon reduction will usher in rapid development, and there is a lack of research on their safety. Therefore, this system also provides new concepts and ideas for other research in the field.

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