

Analysis and Prospect of Key Common Technologies for Echelon Utilization of New Energy Vehicle Traction Batteries

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Abstract: Echelon utilization refers to the process of necessary detection, classification, disassembly, repair, or recombination of waste power batteries into echelon utilization battery products, so that they can be applied to other fields. Echelon utilization, as an important disposal procedure and means for retired power batteries in new energy vehicles, deserves in-depth research and exploration of its key technological development path. However, echelon utilization is still in its early stages. In order to grasp the current development status of echelon utilization technology and to further solve the existing technological bottlenecks, this article analyzes the its process and current technological development status, and puts forward targeted suggestions.

Keywords: Echelon Utilization; Waste Power Battery; Key Technology; SOH.

1. Introduction

Developing new energy vehicles is the only way for China to transition from a major automotive country to an automotive powerhouse, and is an inevitable choice for achieving green economic transformation and practicing ecological civilization construction. In recent years, under policy guidance and market promotion, China's new energy vehicle industry has achieved significant development. According to statistics from the China Association of Automobile Manufacturers, as of the end of September this year, the cumulative production and sales of new energy vehicles reached 22.56 million units, ranking first in the world for eight consecutive years; and the market share reached as high as 30% from January to September this year. With some of the new energy vehicles that were put into operation in China gradually being discontinued or scrapped after long-term use, traction batteries have begun to enter the stage of retirement and recycling. After the retirement of the traction battery, there is still a certain amount of surplus energy that can meet the application needs of other fields. After testing and restructuring, it can be used for energy storage, power backup and other fields in a cascade manner, and then disassembled to extract valuable metals such as lithium, nickel, and cobalt, achieving maximum value utilization[1-2].

With the increase in the number of retired traction batteries, China's cascade utilization industry has entered a peak period of development, and the number of cascade utilization enterprises is constantly increasing, mainly concentrated in areas such as the Yangtze River Delta and the Pearl River Delta where the number of retired batteries is high and talent, funds, and technology are concentrated. Driven by market demand, the tiered utilization market has shown a diversified development trend, and tiered products have taken the lead in achieving commercial applications in the fields of communication base station backup, power storage, and low-speed power. At present, about 90% of enterprises in the industry adopt semi-automatic production lines with automated handling and manual disassembly and

reorganization. Flexible disassembly and automated sorting and reorganization technologies with high compatibility still need to be broken through. In addition, about 95% of enterprises in the industry mainly utilize battery modules or individual units, and are accelerating the exploration of battery package utilization, promoting the improvement of multi-level cascade utilization technology level [3-4].

2. Analysis of the Current Situation of Traction Battery Echelon Utilization Process

Scrapped or retired traction batteries should not be suitable for used in electric vehicles due to factors such as reduced energy storage capacity, but they can still be used in different scenarios, such as base station backup, power grid energy storage, low-speed power. The echelon utilization process mainly includes residual energy detection, disassembly and reorganization, performance testing, coding and identification, and operation monitoring.

2.1. Residual Energy Detection

The industry currently mainly focuses on actual testing of batteries, through the test characterization of voltage, internal resistance and cycle performance, the "Residual Energy Detection of Vehicle traction battery recycling" (GB/T 34015-2017) has been developed and released. There are still breakthroughs to be made in the technical aspects of residual value assessment and non-destructive testing based on historical data.

2.2. Dismantling and Restructuring

The industry currently relies mainly on manual and semi-automatic dismantling lines to meet the disassembly needs of different types of battery packs, and the reorganization requires capacity and consistency screening and matching for the same type of batteries. After the electrical performance and safety performance test of the recovered power battery pack, if it meets the echelon utilization requirements of the

whole pack, taking the energy storage scenario as an example, after input of energy storage system parameters, it can be directly connected with PCS and monitoring units in series to form a basic energy storage unit, and then connected in parallel to form a medium to large energy storage system with varying power (Figure 1).

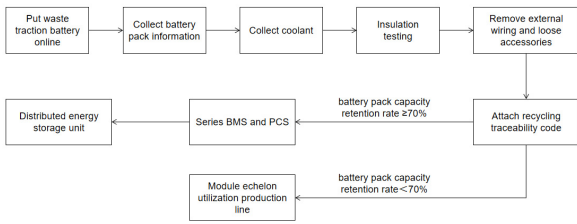


Fig 1. Process Roadmap for Whole Package Echelon Utilization

If battery pack does not meet the requirements of the echelon utilization of the entire pack, it should be disassembled into module units, and the basic module units will be tested, and the modules that meet the requirements should be stored as echelon modules, and then reassembled. Those which do not meet the requirements will enter the recycling warehouse and test each cell unit in the module (Figure 2). If the number of failed cells in the module is relatively small, the "local short circuit" method will be used to handle it and it will be stored as a hierarchical module.

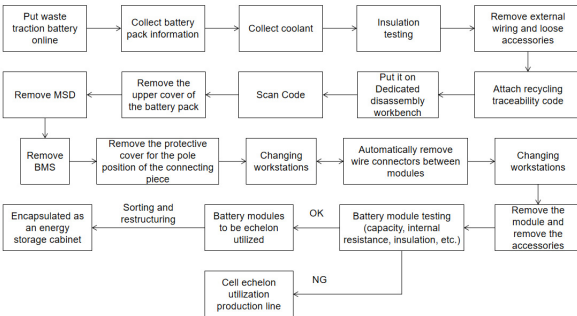


Fig 2. Process Roadmap for Module Echelon Utilization

If the number of failed cells in the module is large (Figure 3), it is disassembled into cell units, in which the failed cells are sold to the material recovery agency, and high-quality cells can be reassembled and used as products in related echelon utilization fields (such as the low-speed electric vehicle market).

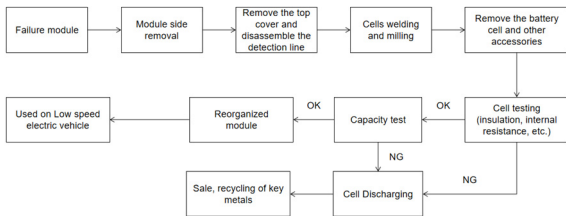


Fig 3. Process Roadmap for Cell Echelon Utilization

2.3. Operation Management

In terms of coding and identification, the "Automotive power battery Coding Rules" (GB/T 34014-2017) has been introduced to standardize, and will be improved with the industrial Internet identification analysis system in the future.

In terms of operation monitoring, similar to the traditional vehicle power battery monitoring, BMS monitoring is still the main focus. Taking into account the transformation and upgrading of the integrated industrial Internet in the future, concepts and technologies such as active identification and

trust system will be introduced to integrate the echelon battery into the ecosystem of the new energy automobile industry.

3. Progress in Key Technologies for Echelon Utilization

Before the retired traction battery be echelon utilized, the first step is to diagnose its status, evaluate whether the battery has safety hazards, evaluate the current capacity (SOH), internal resistance and other parameters, and predict the decline trend of the battery during the echelon utilization stage to determine the remaining life of the battery; On this basis, sorting and restructuring are carried out based on the state of the battery, and suitable application scenarios are selected to maximize the value of the battery in the echelon utilization stage.

3.1. Diagnosis of Battery Status

The status diagnosis of retired traction batteries includes three parts. Firstly, the current capacity, internal resistance and other parameters of the battery should be evaluated. Secondly, check whether the battery has safety hazards. Thirdly, predict the attenuation trend of the battery during the cascade utilization process. The core is to carry out the above diagnosis in an economical way.

At present, retired traction batteries can be divided into two categories based on the completeness of historical operating data. One type is which has the whole operating data when it is used in vehicle, known as the "white box". For this type of battery, for the first time, historical recycling data analysis can be used to evaluate the current state of the battery's remaining capacity, internal resistance, etc. Secondly, the safety status of the battery can be determined based on whether there is situation such as overcharging, over-discharging, overheating during its life in vehicle, and whether there is swelling when it is retired. Finally, the attenuation trend of the battery can be predicted based on the parameter changes during the charging and discharging process during the vehicle phase. This diagnostic method is fast, cost-effective, and can accurately evaluates the capacity of traction batteries. It also helps to predict the remaining life of batteries. However, its effectiveness in identifying internal safety hazards in batteries is currently low.

Another type of retired traction battery has incomplete or completely missing historical operating data, known as the "black box". There are currently two diagnostic methods to check the status of such batteries. One is to charge and discharge the battery module or battery pack several times, record the changes of battery voltage, temperature, and other parameters, and analyze the consistency among individual battery cells. Then, sample retired traction batteries to analyze their safety performance under abuse conditions and their degradation characteristics under energy storage conditions. Although this method can accurately grasp the data of capacity, internal resistance, and other states of retired traction batteries, as well as state differences among individual cells, it has a long time cycle, occupies a lot of equipment, and can cause damage to the battery, resulting in high diagnostic costs. Another method is to select several quickly measurable battery characteristic parameters (such as open circuit voltage, AC internal resistance, etc.) and diagnose the battery's status through rapid evaluation of these parameters. This diagnostic method takes shorter time and low equipment cost, but due to the unclear relationship

between the selected feature parameters and the battery state, there is usually a significant error between the diagnostic results and the actual state.

The internal safety hazards of retired traction batteries are highly hidden. Whether we use the method of analyzing historical data related to "white boxes", or the charging and discharging method for "black boxes", it is not accurately enough to assess the internal safety hazards of batteries. At the same time, due to the significant differences in the state between retired traction batteries and new batteries, it is necessary to analyze the impact of usage conditions such as the rate, the depth, the temperature of charging and discharging, and environmental temperature on battery performance, and clarify the boundary conditions for battery use in the echelon utilization stage. In the future, with the increasing improvement of historical data record and the continuous progress of data analysis technology, the "white box" data analysis method combined with sampling analysis of key performance such as battery safety and lifespan is expected to achieve accurate diagnosis of retired traction batteries at a lower cost.

3.2. Reorganization and Definition of Application Scenarios

The difference between retired traction batteries is significantly greater than that between new batteries, and effective balancing strategies should be adopted based on the differences between batteries during reassembly. Compared to new batteries, the internal resistance of retired traction batteries significantly increases, while increasing heat production under the same usage conditions, and decreasing charging and discharging performance at low temperatures. During reassembly, effective temperature control strategies should be adopted based on the environmental temperature to avoid long-term operation of the battery at high temperatures (above 40 °C) or low temperatures (below 0 °C). The safety failure risk of retired traction batteries increases, and necessary safety protection and fire protection measures should be taken in conjunction with application scenarios during restructuring.

There are multiple potential application scenarios for cascade utilization, and different application scenarios have different requirements for the state and consistency of batteries. There are also significant differences in the decline patterns of batteries in different application scenarios. Therefore, when restructuring retired traction batteries, it is necessary to select appropriate application scenarios based on the state of the batteries, consistency among batteries, and the decline trend in different scenarios.

3.3. Operation Monitoring of Cascade Products

Considering the performance monitoring, safety monitoring, and recycling management requirements of traction battery cascade utilization products, it is necessary to monitor the operation of cascade batteries. During the production process of cascade products, the coding of each product, combined with BMS, can rely on the enterprise monitoring platform to monitor the operation, maintenance, replacement, retirement and recycling of cascade products, ensuring their safe operation and efficient recycling.

Considering the great similarity between the operation monitoring of cascade products and traction batteries on the entire vehicle, while using traditional monitoring platforms is

one way, it is also possible to combine the development and promotion of secondary nodes for industrial internet identification analysis in the new energy vehicle industry. The BMS management system with unique cascade product identification codes and authentication keys can be used as an active identification carrier and be embedded inside the cascade products, carrying industrial internet identification codes and necessary security certificates, algorithms, and keys, equipped with network communication functions, capable of actively initiating connections to identification resolution service nodes or identification data application platforms, and completing product operation information monitoring. Besides, based on the identification analysis system, dynamic detection and monitoring devices such as GPS/Beidou and GPRS/4G/NB-IOT can be loaded and installed, and "the Internet plus Internet of things" technology provides services such as power inquiry and positioning, creates a smart community and smart city network, and sets sail for the smart traceability of battery cascade utilization.

4. Recommendations for the Development of Key Technologies in Traction Battery Echelon Utilization

Traction battery echelon utilization is an emerging industry, and there are still some technical bottlenecks that need to be solved urgently. Firstly, the research on key technologies such as condition assessment, sorting, and management of retired power batteries is not in-depth enough, resulting in high remanufacturing costs in the process of echelon utilization. Secondly, the continuous decrease in the cost of new batteries has reduced the low-cost advantage of echelon used batteries. Therefore, for the echelon utilization of power batteries, future work should focus on the following aspects.

4.1. Breaking Through Key Technologies Such as Identifying Safety Hazards in Retired Batteries.

Among them, the focus is on identifying battery safety hazards, analyzing the investment in state assessment, sorting and restructuring, system integration, and operation and maintenance during the echelon utilization process, and utilizing the above key technologies to reduce the cost of the whole echelon utilization process. Grasp the performance decline trend and safety state evolution law of batteries in the echelon utilization stage, and clarify the application scenarios and boundary conditions for batteries in different states.

4.2. Improve the Analysis Method based on "White Box" Historical Data

For different echelons utilization scenarios, design battery modules, establish a database, regroup according to the performance, life, capacity, internal resistance, residual energy and other data parameters of different battery modules, establish a data model and battery management system, and improve the performance of the reassembled battery. Simultaneously optimize battery status diagnosis methods based on historical data to improve the accuracy of battery status, safety hazards, and residual life assessment.

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