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Study on Operation System of Pure Electric Bus

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Abstract

The operation system of pure electric bus was established, which was based on priority of charging security, mainly sub-box charging, power batteries leasing system and replacing the battery. The multi-stage application theory of the power battery was put forward in order to extend battery life and reduce the use costs. The related theories were successfully applied in the Olympic electric bus system, and good results were obtained.

Keywords: pure electric bus; sub-box charging; leasing system; fast charge

1 Introduction

Short range and long charging period of the battery are the main bottleneck problems for the popularization and application of the pure electric vehicle. In addition, EVs infrastructure mainly with charge stations is inadequate and incomplete, as results that the social promotion of electric vehicle is subject to certain limitations. Firstly, the electric vehicles should make a breakthrough in the application field of fixed station, fixed route and regularly using, and then gradually promote various applications. Public bus accords with the characteristics well. The electric bus technology meets the status of requests, such as carrying capacity and adaptability of urban public transport buses; and it make application in the central area of the major cities. So they can alleviate the pollution in the city, and develop EVs' advantage of zero-emissions. [1, 2]

2 The application system of pure electric bus

A complete application system of pure electric bus includes the following function modules or sub-systems.

a) Electric vehicle: ensuring the operation of the mass transit system;
b) Charge station: rendering service of charging or battery replacement;
c) Dispatching centre: managing the operation and using of the electric bus;
d) Parking lots: providing area for parking the buses temporarily;
e) Maintenance station: repairing the vehicles and daily maintenance.

The main difference of the function modules, between the operation system of pure electric bus and application service system of traditional vehicle, is that pure electric passenger car is in the

need for charging or battery replacement service, in other words, there is charge station instead of gas station. In the operation management systems and operations scheduling system of vehicle, because of hardware changes, it also increase consideration in the station management positions and the time to replace the battery or battery charge in the scheduling of vehicles, as well as the ability of vehicles' continued mileage [3].

During the Beijing Olympic Games 2008, a relatively complete operation system (Fig.1) is established for the first time in the international arena. There are 50 pure electric power buses running in the Olympic central area, which service the athletes, the media and reporters and Olympic officials with transportation. Ensuring to supply energy for the electric bus running, an electric bus charge station of 5,000 square meters was built in the Olympic central area. It is the largest of its kind and the most of chargers' number, and also provides 24-hour charging, battery replacement service for the electric bus during the Olympic. The charge station also includes an entire vehicle maintenance station and a power battery maintenance station for the daily maintenance and repair.

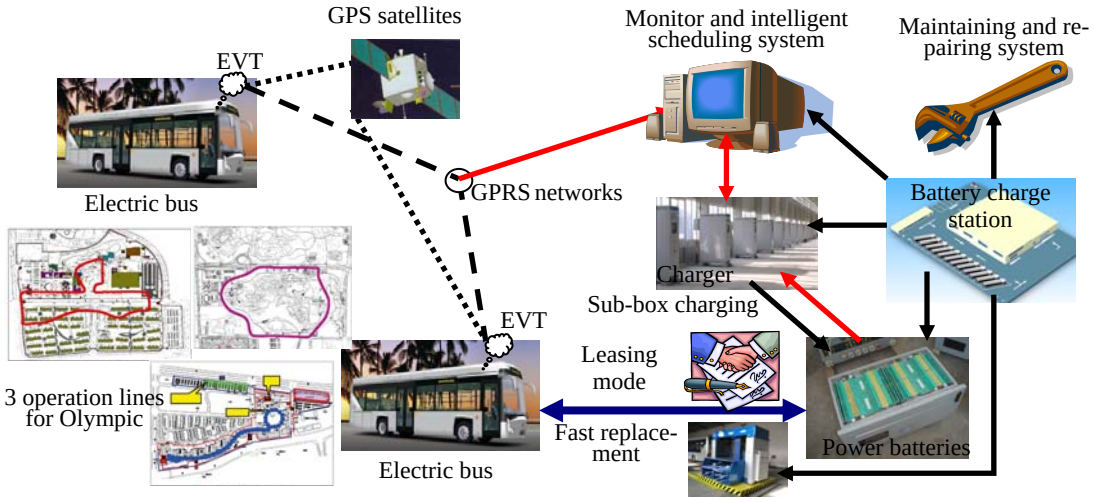

Figure 1: Operation system of pure electric bus in the Olympics

Power battery is charged under the mode of leasing system and sub-box charging system. In the power battery leasing system, the cost of vehicle divides into an entire vehicle cost and a power battery cost. In the other words, the bus company buys the buses without power battery, which was supplied by the battery makers or suppliers. They also supply the services of battery charging and replacing, and specialized managements. The bus company only pays for the battery leasing or the energy cost. To improve the reliability of equipment and to ensure security of battery charging are the aims of sub-box charging system, in which the power battery of entire vehicle is divided into several independent units by group and then charge the units.

With 240 battery chargers of 9 KW, the electric bus charge station carries out the sub-box charging for the battery units and its monomeric voltage and temperature are monitored. The charging dates are transmitted and recorded by charging station monitoring system. And the electric buses operate with the battery fast replacing system. In order to ensure the electric bus efficient and orderly operation in different lines, many technologies are integrated, such as communications, computer networks, GPS, GIS. According to the characteristics of the electric bus and the operating conditions need of Olympic, the electric bus remote monitoring and scheduling system are estab-

lished. Meanwhile the electric bus scheduling control center is set up in order to carry out all-state running control and management.

3 Charging operating mechanism of the electric bus

According to the difference of using characteristics of power battery pack, there are three views in its charging operating mechanism: 1) Increase the travel distance of one time charge as long as possible in order to meet day traveling demand. And charge the battery at outage time or night. 2) With modest vehicle rang, fast charge in the vehicle running gap to meet demand; 3) Separate vehicle and battery charging, and replace the battery in time. [4]

3.1 One time charge to meet day traveling demand

In order to meet the needs of operation, vehicles need to load more batteries or use the high energy density battery. In this way, the batteries must have large depth of discharge and high performance. Based on energy consumption (about 1 kW.H/km) and daily operation mileage requirements (about 250 km a day) of a type of electric buses in Beijing bus line, and considering appropriate depth of discharge, the electric bus needs 2.5 tons of lithium ion batteries，which are about 20%~25% of the complete vehicle kerb mass, although the specific energy can be reached more than 130 Wh/kg by now. If using lead acid batteries with the specific energy about 35Wh/kg, the electric bus needs 8~9 tons batteries, which are about 70%~80% of the complete vehicle kerb mass. And it is not suitable for application in practice. So far, according to the advanced cell technology, one time charge to meet day traveling demand is feasible. If using scheme of multiple charging, the weight of the batteries will be reduced significantly, and using more types of battery will become possible.

3.2 Fast charging

In the existing charging battery technology and manufacturing level, charging the power battery efficiently can be realized in theory and in practice, especially when the battery power is between 30% and 80%. Generally, the capacity of power batteries in the electric bus is above 200 Ah. Implementing fast charging by 0.5 ~ 1.5 C charge rate, namely charging electric current in 100 ~ 300 A, is also can be realized in charging equipment. For a 10 ~ 20 km electric passenger line, the energy consumption of an operating cycle can get added after 10 ~ 20 minutes charge. If a bus round-trip time is 50 minutes, in this kind of charging mechanism, the bus occupating coefficient will decline about 20%. It will be less than 20% if consider the vehicle fleet departure intervals and other factors. In the actual operation, increasing appropriately the number of buses satisfy the need of charging. Based on 50 minutes round-trip time and 5 minutes departure intervals, theoretically 11 cars will meet the requirements without considering charging time; however, it should have 13 cars if consider charging time (15min).

3.3 Fast replacement of the batteries

Fast replacement of the batteries means that a bus must have more than one group of battery pack averagely. The keys to the problem are storage space of backup batteries and how to realize fast replacement of the batteries. In this case, the battery replacement, charging and maintenance can be finished by professionals, who can find the problems of the single battery in the battery pack and maintain it in time. It is of positive significance for the reasonable use. The depth of the battery discharge will be reduced, as is helpful to improve the battery life. At the same time, charge the power batteries without occupancy vehicles but out of the bus, so the vehicle usage is improved. This mechanism has been successfully used in the Beijing Olympics.

3.4 Combining several methods

Achieve organic combination of the above three schemes in order to meet the requirements every day. Design a vehicle with appropriate range to meet needs of technology, economy and operation. In the actual operation, the bus continues to work until the battery pack doesn't meet the next round trip with some practical benchmark on depth of discharge. While battery capacity fails to meet demand, if there is enough time to charge batteries, do it; otherwise, perform the fast replacement of the batteries. As improves the vehicle usage and reduces the batteries load. Because of the immature measurement technology of the battery remaining power, the driving and use archives should be built in the operation scheme in order to estimate the battery remaining power. It is of certain difficulties to organize and manage the operation with the combining several methods.

4 Charging modes of the electric bus

With the operation mechanism of electric car, in according to whether the batteries are separated form vehicles, there are two modes in charging. One is charging the whole batteries with occupancy vehicle; another is charging the battery pack in rechargeable battery storage platforms based on the fast replacement mechanism. According to whether charge the batteries as a whole battery pack, there are two modes as well, such as the sub-box charging model and the power battery group charging model. [5]

4.1 Charging with occupancy vehicle:

In this mechanism, the battery charging device is connected with interfaces in the bus, and then directly charges the whole batteries with occupancy vehicle when the voltages is below the standard voltages according to the operation mechanism. However, the bus can not be used during the charging time in this way. At present, even though charge the batteries with the rapid charging technology it is more than 1 hour to make the bus full of electric power. In addition, the power battery life will be influenced by using large current to charge for a long time. So it is revealed that the main fault of this mechanism is the low utilization of the buses.

4.2 Charging the battery pack based on the fast replacement mechanism

The buses can be operated without the restriction of charging time, because the batteries are separated from the buses. In this case, it is easy to monitor the charging process and to observe the status, and it can make charging efficiently and ensure security.

4.3 Power battery group charging model

The vehicle power battery, as a whole, will be charged by a high-powered battery charger. It is simple to control and the mechanical and electrical connection is the same as charging with occupancy vehicle. According to need and mechanism, the charging time can be adjusted by most economical and reliable methods.

4.4 The sub-box charging model

The vehicle power battery system is divided into several subsystems to be charged. So a large battery voltage will be decomposed into safety voltages, and then use multiple small power chargers simultaneously to charge the subsystems. More monomer battery parameters can be considered, which is useful to ensure the charging security. In addition, the small power charger guarantees the reliability of the vehicle operation because of its mature technology, relatively low cost and high reliability. To charge a battery system with more subsystem chargers, it requires high control accuracy and the coordination of chargers. And it is a highly demanding job to management the battery

because the batteries should be used together with others in a same system but not mixed loading.

Combined with vehicles operating mechanism, Electric bus running in the Olympics take full account of the operation security, charging security and mainly adopt the model of sub-box charging. Power battery system, which is 360 Ah and 384 V, is divided into 10 cases assembled on both sides. They will be placed on the storing and charging platform and be charged separately by 9 kW power battery chargers. Single charging device has the independent control system, which controls a case of battery's charging. Battery state parameters will be monitored by cooperative control system and unified monitoring system during battery charging. Meanwhile, the vehicle was equipped with interface for power battery group charging to meet needs of charging with occupancy vehicle in special conditions.

5 Power battery charge control strategy

In centralized application of large-scale power battery, in addition to consider power battery own chemical and physical properties, it is necessary to consider many factors, such as battery storage model, the storage environment, charger conditions, centralized storage, charging safety and the influence to power grid. In the factors, it is firstly considered to ensuring battery charging safety. According to the different types of power battery, formulate a personalized priority sequence of control parameters to monitor and control in charging process. In existing battery management system and charging technology level, it is possible to detect monomer battery parameters in charging process. So to ensure the battery charging safety, it is important to monitor the monomer battery parameters as far as possible.

For lead-acid battery and lithium ion battery, voltage is the most sensitive parameters of over-charging. Over-voltage is the most dangerous condition. Therefore in priority set, monomer battery voltage is defined as the highest and charging system will stop when the voltage is beyond the limit value. For NI-MH battery, a large number of experiments show that specific temperature rise is the most sensitive parameters in the charging process especially later period of charging.

Based on the large number of experiments and tests for the power battery centralized charging, considering the differences in the physical and chemical properties of different power batteries, the control strategy should be based on the extreme parameters of monomer battery to ensure the safety of power battery charging.

6 Power battery leasing system

In pure electric vehicle application and promotion, the cost of vehicles is the most sensitive problem which is also the most difficult to solve with the current technical conditions. And the most important reason for high use cost is the high purchasing cost and short life of power batteries. On one hand, battery life is limited by power battery technology, and obviously lower than the vehicle life. On the other hand, the unreasonable charging or discharging cause rapid attenuation of battery life.

Therefore, the solution to this problem relies on improvement of power battery technology and the reasonable use of battery power. For the use of power battery, especially the battery charging and the maintenance work are professional and demanding works. It is impossible to use power battery professionally for a consumer. So there was a contradiction between demand of popularization and application of specialization. To solve this problem, the best method is to separate the power battery management and the use of vehicles. Vehicle users are concerned only about the use of vehicles. Power battery is managed and charged by specialized enterprises, and the battery will be only regarded as the power energy. As a traditional car should be supplied with the fuel to continue to use when it has not enough fuel to combust, the

power battery electric vehicle could go to the charge station for the professional services for electric power battery charging or replacement when it needs to supplement. The operation organizations only pay the cost of electricity charge and leasing. The biggest advantage of the way is to solve the customer's worries. At the same time, 'only buy a car without batteries' also greatly saves the initial investment for the customer and improve the social enthusiasm of using electric vehicle.

7 The multi-stage application theory of the power battery

Zero-emission electric vehicles will be used extensively in many aspects, such as city buses, special purpose vehicles for Municipal Affairs or sanitation, short-haul passenger vehicles and the sight-seeing buses in the scenic area. Each vehicle has different requirements for battery performance. Combined with actual situation of EVs' application and promotion, the multi-stage application theory of the power battery accords with the needs to the industrialization of electric vehicle and is operational under power battery leasing system.

In terms of existing storage batteries, lithium ion battery is superior to other storage batteries in the comprehensive efficiency and energy density. It can be used as the ideal traction power and has a good prospect. But, due to the existing technical conditions and raw material costs, it is of certain difficulty to significantly reduce cost in the short term. The leasing mechanism reduces the cost of buying electric vehicle, but also significantly increases the cost of battery manufacturer, who should spend the huge investment to set up the battery replacement system and undertake all the problems of batteries but recoups their costs more slowly. However, the multi-stage application theory solves the problem in a certain extent, and reduces the costs and the investment cycle. The multi-stage application means that the batteries, which are used for a period of time and can not meet the level of the last echelon's demand, could be used as energy of the smaller electric vehicle according to a certain judgment basis. The devices using power energy from high to low level are large buses and municipal transports, medium-sized and small buses and electric cars, sightseeing trolley buses and storage power station, etc.

8 Conclusion

(1). The operation system of pure electric bus was put forward, which was based on priority of charging safety, mainly sub-box charging, power batteries leasing system and replacing the battery;

(2). Considering the application economic of the power battery, the multi-stage application theory of the power battery was put forward ;

(3). Operation system of pure electric bus was successfully applied in the Olympic electric bus system, as proved the rationality of the system.

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