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The Research Status and Development Trend of Electric Vehicle Power Supply Technology

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Abstract

Electric vehicle (EV) power supply infrastructure construction and the related technologies are the prerequisite and core of the EV industry development respectively. This paper introduces the technology research and application situation of charging, battery swapping and smart charging/battery swap service network operation management in China, and meanwhile introduces the EV energy supply infrastructure construction and some typical pilot projects in China. And the EV energy supply technologies development trend is discussed at last.

Keywords: *electric vehicle, energy supply technology, charging/changing equipment*

1. Introduction

EV has been a kind of new technology that will realize the sustainable development of the whole world. In China, EV industry has been listed as one of the 7 strategic emerging industries. Based on <the "12th five-year plan" of EV technology development> launched by ministry of science and technology, the production and sales of pure EVs (PEV) and plug hybrid EVs (PHEV) will be 500,000 till 2015, and will get to 2 million till 2020, the total amount will be up to 5 million [1-2].

EV energy supply technologies and infrastructure construction ensure the EV industry develops fast and healthily. Nowadays, State Grid Corporation of China (SGCC), China Southern Grid (CSG) and some related institutes have launched a lot of work on EV energy supply key technologies like charging, battery swapping and smart charging/battery swap service network, facilities and system, standard system, smart charging/battery swap service network pilot projects construction and operation modes discovery, and have had some achievements [3-7]. This paper mainly introduces Chinese EV energy supply technologies research situation, typical application and pilot projects, and discusses the EV energy supply technologies development trend.

2. EV Charging Technology Research

Based on the characteristics of charging technologies and related charging facilities, the charging technologies can be classified into AC charging, DC charging, AC/DC hybrid charging and wireless charging.

2.1. AC Charging

AC charging spot is an important EV charging facility, mainly supply power for PEVs and PHEVs. It can be classified into vertical type and wall mount by installation method and into single-socket and double-sockets by number of outlets on one single spot. Fig.1 gives the structure of typical AC charging spot.

2.2. DC Charging

The special facility of DC charging is DC charger, it mainly supplies DC fast (or slow) charging styles for commercial vehicles, passenger vehicles, special vehicles, etc. DC charger can be classified into integrated type and split type by different structures. Currently, the DC charging machine key technology have been mastered, include DC charger efficient energy

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conversion, power factor correction and harmonic suppression, intelligent charging, etc. more high frequency switching DC charger are researched and applied, whose structure is given priority to with split type charging machine, mainly used in EV charging stations. Figure 2 gives the typical structure of split off-board charger.

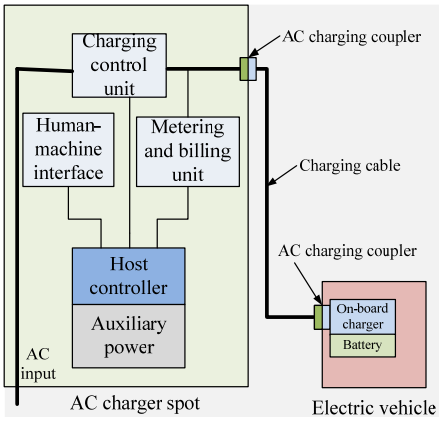

Figure 1. The Typical Structure of AC Charging

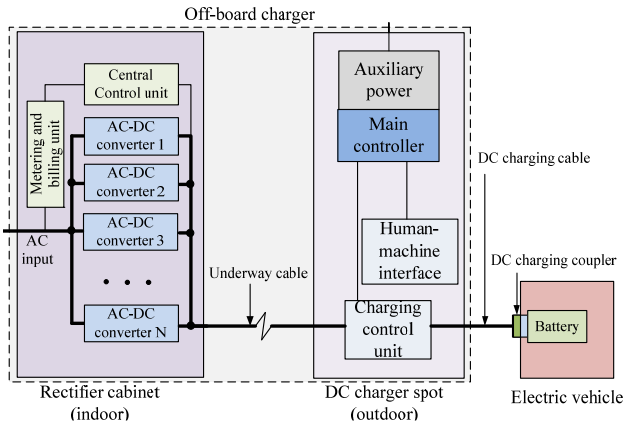

Figure 2. The Typical Structure of Split Spot Off-board Charger

2.3. AC/DC Hybrid Charging

To combine with the advantages of the above two charging types, some vehicle enterprises design their EVs equipped AC and DC charging couplers together. Considering about the convenience of installation and usage, the couplers of AC and DC are integrated. The EV circuit can identify these two charging types automatically: use DC charging to speed up charging, shorten the time and improve the efficiency, use AC charging to satisfy the customers' demands of slow charging as long time parking.

2.4. Wireless Charging

Wireless charging technology (also called non-contact technology) is a new technology which has been treasured and researched recent years. It can be classified into three types of electromagnetic induction, magnetic resonance and radio waves. Today, the electromagnetic induction is relatively mature while the magnetic resonance is one of the important research fields of EV wireless charging technology.

Nowadays, an amount of universities and institutes has developed the wireless charging research. The Chinese Academy of Sciences designed a wireless charging system which based on electromagnetic induction in 2004. This system can charge battery with 12Ah/36V. The Nanjing University of Aeronautics and Astronautics, Chongqing University and other local universities and institutes are researching the non–contact power transfer technology which based on electromagnetic induction. The Southeast University has launched the research of wireless power transfer technology by resonance coupling for many years, realized the kilowatt wireless power transfer within 0.4m, and their achievement can be used on the EV wireless charging.

3. EV Battery Swap Technology Research

EV battery swap technology means serving electricity for EVs by swapping traction batteries, with the advantages of short time, battery maintenance convenience, less influence for grid. Based on suitable vehicle types, the battery swap technology can be classified into commercial vehicle battery swapping and passenger vehicle battery swapping.

3.1. Commercial Vehicles Battery Swap Technology

3.1.1. One-step Battery Swap Technology

This technology applies a battery swap facility to pick the battery out of EV, and then the facility is rotated 180 degree to transfer battery to charging rack. Figure 3 gives a diagram of one-step battery swapping system.

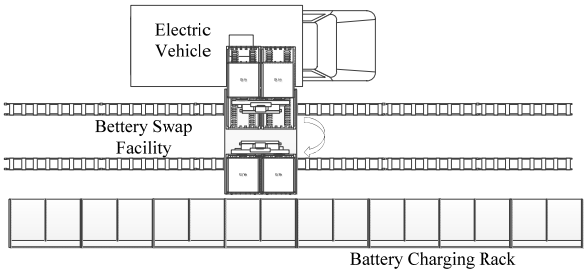

Figure 3. The One-step Battery Swapping System

The advantage of one-step battery swap technology is the relatively simple structure, and the disadvantage is that the temperature of charging environment and battery swapping efficiency are limited by system scale.

3.1.2. Circular Orbit (improved one-step type) Battery Swap Technology

Because of the existing problems of one-step battery swapping, the improved one-step battery swap technology has been designed. This system applies RGV (Rail Guide Vehicle) technology, through circular rail and two separate battery swapping robots to solve existing problems of one-step type. Because the two battery swapping robots are in charge of transferring empty batteries from vehicle and transferring full batteries to vehicle respectively and at the same time, the efficiency is improved. And the heating and ventilation system can be installed at the bottom of charging rack, which can avoid the efficiency lost when charging in cold environment.

3.1.3. Standard Two-steps Battery Swap Technology

The switching area using standard two-step battery swap technology includes battery management system, battery transfer system and battery swap system. The battery swap system applies the special battery swapping facilities, to load and dump the batteries. The battery management system is standard logistics system, to management battery charging and dispatch. The battery transfer system as an interaction operation platform between battery swap system and battery management system is in charge of battery transferring.

With the split design of battery management system and battery transfer system, the standard two-steps battery swap technology effectively improves the one-step battery swapping system and the operation service level. The advantages are like: system operation efficiency optimized, strong applicability of battery swapping facilities, controlled charging environment temperature, battery life-cycle extended, etc. The disadvantages are like: the system structure relatively complex, covering an area of large.

3.1.4. Intensive Two-steps Battery Swap Technology

Intensive two step type in electric system is developed through the transit zone being embedded in battery management. On the basis of standard two-steps type, intensive two-steps battery swap technology further reduces occupied area, and optimizes swapping process.

3.2. Passenger Vehicle Battery Swap Technology

Passenger EV battery swap technology mainly includes the trunk battery swapping and the chassis battery swapping.

3.2.1. Trunk Battery Swap Technology

This technology is suitable for the passenger EV whose batteries are placed in the trunk. Its main advantages include lower vehicle modification cost and multiple kinds of operation like full-automation, half-automation and manual operation. Its main disadvantages include poor safety of vehicle collision and turn in high speed, because of the heavy batteries all placed on the back of vehicle, and inconvenience for customer because the trunk occupied by batteries.

3.2.2. Chassis Battery Swap Technology

This technology is mainly focus on the passenger EV whose batteries placed on the chassis. The whole battery swapping process normally takes 3 minutes. The technology advantage is the EV's safety and comfort basic are consistent with the same type fuel car. The defect is that the demand is high for battery safety protection and temperature control and switch electrical equipment.

4. Smart Charging/Battery Swap Service Network Operation Management System Research

Under the large-scale application of EV, the charging/battery swap service network inevitably from the demonstration run to commercial operation, which needs to adopt information technology management to monitor the service network, support the service management and operation, and set up service network operation management system to support EV large-scale charge or battery swapping demand. At present, SGCC has established the company headquarters, provinces, cities, station level four business applications such as charge for electricity service network operation management system. Figure 4 gives the structure of EV smart charging/battery swap service network operation management system.

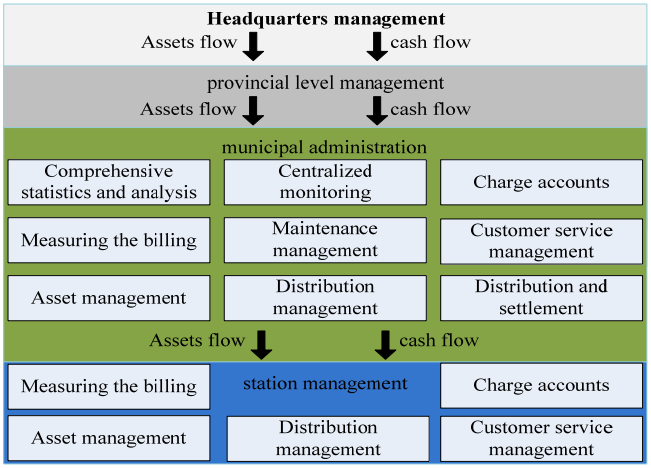

Figure 4. Intelligent Service Network Operation Management System's Overall Architecture

On the basis of the J2EE framework platform for the support of information technology, information security protection technology, based on RFID/power battery electric cars identity recognition technology, and information sharing and asset management technology based on Internet of things, the service network operation management system has been successfully developed. It effectively supports EV intelligent charger for service network of the comprehensive operation management, implements the function of customer service, billing, charge measurement accounting, distribution and settlement, asset management, cell distribution and maintenance operation, the application of centralized monitoring, etc. The service network operation business requirements are satisfied, and the intelligent service network operation management is implemented, which provides information technology support

for EV intelligent charger for service, ensures the charge for service network is efficient, reliable and safe operation.

5. Chinese EV Demonstration Projects in Charging/Battery Swap Service Network Construction

5.1. The Basic Situation

The mainly construction units of EV charging/battery swap service network include the State Grid Corporation of China, Southern Power Grid Company, and China Putian group. By the end of 2012, the State Grid Corporation has built 14 703 charging spots and 353 charging/battery swap stations (including 162 charging stations and 191 charging/battery swap stations), and built zhejiang province and Suzhou-Shanghai-Hangzhou inter-city two intelligent charger for service network pilot projects. Southern Power Grid has built 2901 AC charging spots and 15 charging/battery swap stations, and the Pearl River Delta intelligent charger for service network is under construction. China Putian Corporation has carried out filling in service network construction in Shenzhen, and has completed 63 charging/battery swap stations. In addition, Sinopec, PetroChina, CNOOC, etc. relying on the existing gas stations to build charging test station, such as, Sinopec has built two gas charging stations in Beijing.

At present, Chinese EV energy supply infrastructure construction has entered a rapid development period, has become the largest number country in charging/battery swap stations and charging spots.

5.2. Pilot Projects

5.2.1. Qingdao Xuejiadao Charging/Battery Swap Station

This station is the first charging/battery swap station integrating bus charging/battery swapping, passenger car battery concentrated charging, energy storage application at home.

In charging, bus charging/battery swap station can charge for 120 buses at the same time, and filled charging station can charge for 360 passenger cars at the same time. In battery swap, the bus every time batteries swap need 6 to 8 minutes, one day 540 cars batteries can be replaced, and 280 buses charging demand can be satisfied, which is over 50% of the total Huangdao district bus. In storage function, bus charging/battery swap station power is 700kW, filled charging station maximum power is 4320kW, and Battery pilot use of storage and discharge power is 2000kW. Reducing peak and filling valley is realized, the load of peak to valley adjust is 7020kW, and can up to 10520kW. On the distribution function, filled charging station configured 1440 groups batteries, can satisfy10 distribution stations battery needs in Huangdao district. As of December 2012, the station has been accumulated for electric buses in 75679, vehicles traveling 10.05km, the battery power consumption of 10.08 million kWh.

5.2.2. Beijing Gaoantun Charging/Battery Swap Station

The station is located in Gaoantun circular economy industrial park in Beijing Chaoyang district, covers an area of about 9800 square meters, has set up 4 electric lines, 1 distribution line, can service eight EVs swapping batteries at the same time. Its daily service capacity is 400 cars, each sanitation car can completed swapping batteries in 6-8 minutes, and the battery swapping time of each passenger car is less than 5 minutes. This station is a circulation industry demonstration effect of the EV in plant, highlighted the core values of energy conservation and environmental protection.

5.2.3. Zhejiang Province Intelligent Charging/Battery Swap Service Network Pilot Project

The project total constructed 500 communication charging spots and 13 charging/battery swap stations, could support EV across the inter-city traffic in Hangzhou, Jiaxing, Huzhou, Jinhua and Shaoxing. Zhejiang demonstration project has realized the construction and operation innovation technology and application, is the first intercity interconnected intelligent charger for service network, can provide experience for the electric network construction operations building in nationwide. As of September 2012, Hangzhou used in electric mode of electric car mileage is more than 10 million km.

5.2.4. Suzhou-Shanghai-Hangzhou Interconnection Service Network Initial Pilot Project

The project involved 9 intelligent charging/battery swap stations in 5 service area on Suzhou, Shanghai, Hangzhou three expressways, including Jiangsu Baiyang lake 2 service areas and Yangcheng lake 1 service area, Shanghai fengjing 2 service areas, and Zhejiang Jiaxing 2 service areas and Xinteng 2 service areas. It implements EV charging/battery swap service among Suzhou, Shanghai and Hangzhou.

6. Chinese EV Energy Supply Technology Development Trend

Combining with the development of China smart grid and new energy vehicles plan, we think the EV energy supply technology and facilities will deepen the research and application in the following areas:

Intelligence: In addition to operating services intelligent level continues to improve, vehicle-to-grid (V2G) level will be the focus of the intelligent. On the one hand, with EV rapid development, energy supply facilities can achieve orderly charging under the management of operating system, load balance charge, reduce the charging infrastructure investment and the cost of EV use. On the other hand, The EV can be used as a mobile energy storage unit, combining with the advanced smart grid technologies, effectively participate load management and system peak shaving, and realize good interaction with the power distribution system, thereby improve the efficiency of the power system as a whole, and make the power supply is stable and reliable.

Network: EV large-scale development needs cannot be satisfied by simple setting up charging piles and charging/battery swap stations, the cross-regional operation electric service network must be built, and diversified business model is implemented based on the electric service network. The future development direction of electricity service network is nationwide interconnection. Under the direction of smart grid unified planning and unified construction, the EV service network will be from charging pile, charging stations, small scale expands unceasingly, eventually develop to wide range of charging/battery swap network, and realize the unified management.

Standardization: EV energy supply infrastructure needs to implement the standardization of construction and operation. By speeding up developing the commercial charging device and EV related technical standards and interface specifications, the service system should be built. At the same time, based on electrical facilities and gradually establish a communication network hardware platform, using various information technology means and through the overall management of the operating system, constructs a reasonable allocation of resources, unified service standards and information sharing energy supply service network, promotes the standardization of the electric car energy supply facilities service level. At present, under the puss of SGCC and other research institutions, China has preliminarily set up the EV energy supply facilities standards system, and is leading the international standard IEC 62840 electric cars in electric facilities safety requirements, the preparation work is going well.

7. Conclusion

EV obtains the government and relevant enterprises attention and support in China, has been all-round developing developed EV charger facilities research and trial operation. In charge, battery swapping, and operation management has obtained core technology breakthrough. At the same time, combining with the construction of smart grid, China has established the electric car energy supply technology system, as the interaction between EV and smart grid V2G technology is also open in the research.

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