

Operation Mode Analysis of Electric Vehicle Charging and Battery Swap Station

Zhao Jin-long^{1, a} Lv Xiao^{2, b} Lu Shou-yin^{2, c} Zhang Hua-dong^{1, d} Qi Hui^{1, e}

¹Shandong Electric Power Research Institute, Jinan, China

²School of Information and Electrical Engineering of Shandong Jianzhu University, Jinan, China

^azhaojl@powerrobot.org, ^blvxiao0956@163.com, ^csdznjqr@163.com, ^dzhanghd@powerrobot.org,

^eqih@powerrobot.org

Keywords: Electric Vehicle; charging and battery swap station; operation mode; billing model

Abstract. The construction and operation of the charging and battery swap station facilities is crucial to electric vehicle industry. In this article, the energy supply, operation management, billing, pricing and payment method for the station facilities are analyzed, and the advantages and disadvantages of various ways are also described in detail in order to push forward commercial operation of the electric vehicle industry in China.

Introduction

The infrastructure construction and commercial operation is the very foundations of electric vehicle (EV), and is vital to the electric vehicle industry. Currently, the charging and battery swap station have not too much in the world, and most of them are still in the demonstration of the operational phase, so it is essential to select a suitable operation mode for electric vehicle station considering China's actual conditions.

The State-of-the-art of EV Charging and Battery Swap Station

Demonstration stations which have been established at home and abroad primarily using batteries as the power source for the EV, and mostly take use of the evening sufficient power to charge battery. Some other newly-built stations (providing charging and battery swap service) use the mixed mode of charging and direct replacement of battery as the power supply.

Domestic Development Status

Up to now, China's electric vehicle charging and battery swap stations are mostly confined to the electric buses or internal group cars, which not yet built a real station network of services for different users [1].

At the year of 2006, BYD automobile Corp. built the first electric vehicle charging station in Shenzhen. In 2008, during Beijing Olympic Games the first centralized battery charging station was created, which can meet the battery charging needs of 50 pure electric buses. In July 2011, the Qingdao Xuejiadao intelligent EV charging and battery swap station [2] turned into the most fully featured, the largest and strongest service capability of smart charging in the world, which can provide charging service for 120 buses, battery swap for 540 vehicles every day, and the swapping time was not more than six minutes.

Foreign Development Status

The United States is one of the largest investment countries in electric vehicles around the world. The U.S. Solar City company has built 5 charging stations on Highway 101 in California. Each of the charging station can provide 240V, 70A quick charging service, and can be filled within 3.5h for Tesla electric cars.

Japan is the best country in the industrialization of electric vehicles. By 2012, Japan has built more than 300 charging stations. The project will be involved in the paid parking, supermarkets and restaurant chains to install a power outlet for the drivers free to use [3].

In the United Kingdom, London has 60 free car charging piles. People who drives electric vehicle can enjoy numerous timers of charging and parking services which just pay a management fee of £ 75 a year.

Better Place (BP) company plans to build a large-scale battery charging facilities network in the next three years (2011-2013); at the same time, electric vehicles will be equipped with a real-time display of remaining battery and charging station location on-board computer system [4].

With the analyses discussed above, it is not difficult to find that development and capital investment abroad for charging station infrastructure are greater than that of China, so we can learn from and draw on their experience and exploration of international cooperation to carry out the road of the key technologies developed for electric vehicles, which has positive significance for the promotion of China's electric vehicles, as well as the rapid development of infrastructure.

Three Commercial Operation Modes

At present, there are mainly three kinds of commercial operation modes for the construction and operation of the charging station facilities at domestic and abroad. The first is charging mode, the second is swap mode, and the third one is the compatible mode of charging mode and swap mode.

The Charging Mode

The charging mode is suitable for the charging pile and charging station. Charging piles are usually built in residential area parking lot, mall parking lot, or on the side of the road, as well as in private garage [5]; the charging stations are similar to the gas stations, they are usually built on the both sides of the city road or highway, and can also be built in the existing gas station. The charging mode is very popular all over the world. Fig.1 shows the charging mode in China.



Fig. 1 The charging mode

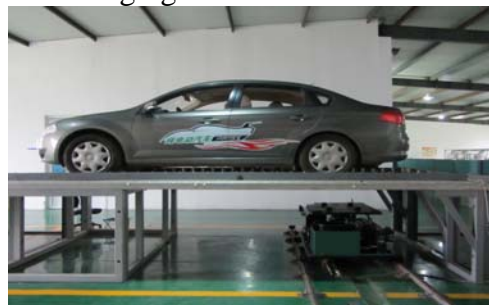


Fig. 2 The swap mode

The Swap Mode

Battery replacement mode is a more ideal commercial model in theory, a lot of enterprises and scientific researchers are doing research in this area. Shandong Electric Power Research Institute has been committed to the research of battery swap robot from the chassis for passenger vehicles, and now the robot prototype has been developed. It truly realized the automatic replacement of the battery on the electric vehicles, and just cost 4 minutes. Experiments showed that the robot has excellent performance and works stably. Fig. 2 shows the swap mode.

Compatible Mode of Charging and Swap

The compatible mode has both the advantages of charging mode and swap mode. It can not only satisfy the users charging requirements, but also provides users a battery replacement service. Table 1 has a deep comparison among these three commercial modes.

Table 1 Comparison among three commercial modes

Type	Construction project	Convenience	Controllability	User cost	Investment recovery period
Charging	Charging Station Charging pile	Limited	Difficult	Charging fees	Long
Swap	Swap station	Convenient	Easy	Charging fees	Short
Compatible mode	Charging station Charging pile Swap station	Flexible Convenient	Easier	Charging fees or Exchanging fees	Short

These three kinds of modes are both competing and complementary relationships. In the future, these three modes will be connected to a complete charging system to provide convenient, efficient service for electric vehicle users.

Operation and Management

Management Problems

To promote electric vehicles extensively, the business model must be innovated. Management right is the most important part of business model. Although the development of electric vehicles and charging equipment are still preliminary, two power grid corps and three big oil companies itch for a try, and some private enterprises are also looking for opportunities to enter this market.

The core competitiveness of power grid corps is power resources and network transmission experience^[9]. In addition, the power industry can give full play to its power production and transmission advantages to maximize price advantage and the value of environmental protection and energy saving. However, the petroleum enterprises' advantage in gas station distribution network cannot be ignored [6]. They have considerable experiences in operation and management. Especially in city center areas, gas station network of petroleum enterprises has resource advantages. Gas stations have accumulated rich experiences in marketing management in the business process.

Billing Mode

When charging stations of electric vehicles operate, operating companies need to pay energy fees to operators. Fees are paid in four ways: the swap times; the electricity usage; the trip distance; and the time quantum.

The first method is mainly for the swap-able electric vehicles. Firstly, determine charge quantities through battery-terminal; after that, calculate the mean value and mean change times; lastly, calculate the fee of each charge. This method relies on a large number of statistical data analyses. In addition, pricing for charge operation taken by robots has yet to be determined, so it is very difficult to promote it in short time.

The second kind of method is similar to the household electricity. According to the battery capacity or the swapping time, fees are paid based on the principle that more fees with more swapping. This method is popular in operating companies and charging stations now. This form can reflect the power battery charge times to some extent. It is a way to bill more precisely.

The third kind of method is similar to the existing taxi charge mode. However, since it is difficult to master vehicle driving laws in different periods and different road conditions, it is somewhat dull and stereotyped. For example, the electricity consumption of the same trip distance is different largely in peak hours from that in normal hours. so it needs a large number of actual data as charging basis. The accuracy of this method is not high, and it cannot reflect the battery usage fully.

The fourth kind of charging mode is similar to a bus pass, for monthly, quarterly or yearly. The card has a certain amount of money or charge times. With this card, users can also be provided with vehicle and battery maintenance free of charge. This way is more convenient and concessional than the other three ways.

Pricing and Payment Method

Charging pile and charging station based on charging time or charge amount. Domestic ongoing operation charging piles charge based on ordinary family electricity standard [7]. Some experts think that it is not quite reasonable. Price of slow charging may be slightly higher than general price, so profit can be obtained through price difference or providing related service. It is generally known that quick charging for battery will lead to serious consequences, concluding seriously impact on battery's circulation service life and power grid fluctuations, which finally affect the power quality. So the price should be higher than the price of slow charging. A reasonable price can be estimated through a number of test analysis [8].

The payment could be used in two ways, payment onsite and stored-value card prepaid, and payment onsite may have the cash, bank card, IC card or other forms of special charging. In the actual selection process of charging station operating mode, local charge demand should be fully considered, selecting suitable payment method under local conditions.

Summary

Embark from the development situation at home and abroad of electric vehicle charging infrastructure, this article presents a detailed analysis of three charge facilities operation modes, and difference between those is also discussed. Finally, reasonable suggestions are presented to charge services and facilities management, charging mode, pricing and payment method.

Acknowledgment

This work was supported by the R&D Project of State Grid Corporation of China (SGKJ [2012] 015).

References

- [1] Yi Zhiping. Development of the electric automobile charge exchange station. *Electronic Science and technology*. Vol. 21 (2011), p. 277
- [2] Zhang-huan. Based on the electric automobile charge for power plant construction analysis. *Power and electrical engineering*. Vol. 9 (2012), p 113
- [3] Zhou Feng-quan, Lian Zhen-wei. Mode of Electric vehicle charging station operation. *Power system protection and control*. Vol. 38 (2010), p 63-67
- [4] Yang Feng-lei. Electric vehicle commercialization pain. *China business newspaper* (2006)
- [5] Li Hui-qi. Pure electric vehicle operation mode and economic investigation. *Science and technology management research*, Vol. 7 (2007), p 238-240
- [6] Wang Ze-zhong. Electric bus charge exchange station related operation analysis. *Science technology and Industry*. Vol. 12 (2012), p 121-122
- [7] Information on <http://www.d1ev.com/>
- [8] Information on <http://www.ddqcw.com/>
- [9] Information on <http://www.chinasmartgrid.com.cn/>