ELECTRIC VEHICLE DEVELOPMENT IN CHINA AND ITS POWER QUALITY CHALLENGES TO DISTRIBUTION GRID

Aiqiang PAN
State Grid Shanghai EPRI– China
dsy_panaq@126.com

Tiantian CHEN
State Grid Shanghai EPRI– China
cttinwhu@163.com

ABSTRACT

This paper firstly analyzed the current situation and development trend of electric vehicles, and illustrated the policies made by central and local government in China to promote the application of electric vehicles. And then various factors affecting the development of electric vehicle were analyzed. After that, the power quality impacts of electric vehicle were analyzed in this paper by theoretical and practical aspects. Based on the field measured data of different kinds of charging facilities, the paper analyzed power quality characteristics of charging devices from different manufacturers respectively. Two different charging modes were considered. Power quality characteristics of the different types of charging devices in different working modes are comprehensively displayed, which will provide a theoretical basis and technical support for power quality control in charging station construction.

INTRODUCTION

Energy and environment have become the problems attracting everybody's attention in the world. Human could not live without energy, and the way of using energy now is causing serious environment pollution. Especially in China, The world's biggest carbon emitters, energy consumption and environment pollution are ultimately affecting the sustained development.

With the rapid development of economy, industrialization, and urbanization, China has become the biggest automobile production and sales market for five consecutive years, followed by a growing demand for energy. According to statistics, China's automobile exhaust emissions have occupied 20% of total CO2 emissions. Therefore, to develop renewable resources and promote the use of new energy vehicles is the key solution to the national energy conservation and economic optimization.

Electric vehicles (EV), as a new round of economic growth and achieve a breakthrough in the fundamental way to transport energy transformation, has become the common strategic choice of the world's major automobile manufacturers and countries in the automotive market. And also it is the key direction of development of new energy vehicles. To develop electric vehicles, could promote fuels alternative and reduce vehicle emissions, and it is important for energy security, energy saving, pollution reduces.

EV DEVELOPMENT AND RELATED POLICIES IN CHINA

Development of electric vehicles has risen to the national strategy in China. In the past 10 years, in order to promote the development of the electric automobile industry, the government continually introduce a series of policy.

As early as 2006, by adjusting the consumption tax, the central government decide to cut down certain tax for electric vehicles (including hybrid electric vehicles, HEV).

In 2009, the policy of "energy saving and new energy vehicle demonstration financial subsidy funds management Interim Measures" was launched, the central government gave a fixed subsidy to energy-saving and new energy vehicles in pilot cities. Pure electric vehicles consumers could get 60 thousand Yuan of subsidies.

In 2013, the new EV subsidy policy was introduced, and HEV consumers could also get subsidy, which is about 35 thousand Yuan.

In 2014, the central government introduced a series of new energy vehicle support policies, including 16 policy and 78 standards. And the various local governments have issued hundreds of relevant policies. New energy vehicle consumers could get more subsidies and concessions; PVE and HVE consumers could be exempt from vehicle purchase tax.

January 2015, the Chinese government issued "the notice on 2016-2020 to promote the application of new energy automotive financial support policy", which proposed the target that new energy vehicles will reach the goal of 5 million in 2020. Local government also released lots of encouragement policies for the promotion and application of new energy vehicles, the subsidy is up to 120 thousand Yuan. High subsidies provoked the activity of the EV market. According to statistics, in 2015, EV production and sales were about 340 thousands and 33 thousands units respectively, with the year-on-year growth of 334% and 343%.

CHARGING FACILITIES DEVELOPMENT AND RELATED POLICIES IN CHINA

In recent years, with the promotion and development of electric vehicles, the inconvenient of charging made lots of worries and complaints from consumer, and even become a bottleneck in the development of new energy

vehicles. To improve the charging infrastructure is an important guarantee for the popularization.

In view of the situation that supporting policies are not perfect and coordination is difficult and the standards specification is not unified. Charging infrastructure policies and related standards had been introduced in 2015.

On 9 October 2015, General Office of China State Council released the policy of “Construction guidance of electric vehicle charging infrastructure", National Development and Reform Commission, National Energy Bureau jointly issued the “electric vehicle charging infrastructure development guidelines (2015-2020)”. It pointed out that in 2020, the advanced, intelligent and efficient charging infrastructure system should be basically built, which will meet the needs of more than 5 million electric vehicles; And the guidelines also mention that China will establish standard, perfect and open charging market and its supervision system.

On 28 December 2015, China State Administration of Quality Supervision, the National Standard Committee held a press conference, issued a new revision of the electric vehicle charging interface and communication protocol of five national standards: “Electric Vehicle conductive charging system-Part 1: General requirements”; “Connection set for conductive charging of electric vehicles- Part 1: General requirements”; “Connection set for conductive charging of electric vehicles- Part 2: AC charging coupler”; “Connection set for conductive charging of electric vehicles- Part 3:DC charging coupler”; “Communication protocols between off-board conductive charger and battery management system for electric vehicle”.

By the end of 2015, National Development and Reform Commission issued "electric vehicle charging infrastructure development guideline", the guideline shows that the charging infrastructure development goal is to build 12000 centralized charging stations, 4.8 million distributed charging pile to meet the 5 million units of electric vehicles charging requirements in 2020.

According to statistics, by the end of 2015, 3600 EV charging stations and 49000 public charging piles has been established in China, which the increase number of 18000 to last year. Private charging pile has also been rapid development. Take Pudong District at Shanghai for example, in 2015,4718 individual charging pile had been constructed, compared to 438 individual charging pile in 2014, with the growth of more than 10 times.

POWER QUALITY CHALLENGES TO DISTRIBUTION GRID

Effect of electric vehicle charging station network has two aspects instead:

Positive effects: The uses of electric power battery charging could reduce the peak valley difference, and improve the actual utilization of power distribution system facilities to expand the terminal power consumption market.

Negative effects: power batteries chargers for EV are the typical non-linear load, and will produce harmonic pollution, resulting in power factor decrease. Charging at peak time will add to the burden of the power supply system.

The power quality problems caused by electric vehicles mainly include harmonics, three-phase voltage unbalance and voltage deviation.

At the slow charging station or individual charging pile, the main power quality problems are voltage deviation and three-phase unbalanced, mainly due to the uneven distribution of the three phase load. Because the on-board charger is always equipped with APFC devices, so it could not cause much harmonic problems.

At the fast charging stations or other three-phase DC charger, because of the structure of the charger itself, the three-phase unbalance problem does not exist, and whether there is a harmonic problem is mainly based on the charger types.

There is few researches in power quality challenges of charging facilities, and also there is few electric vehicle related standards and regulations in China. The only currently standard is GB/T29316 “Power quality requirements for electric vehicle charging/battery swap with the infrastructure”, released in 2012. However this standard specifies very rough, each aspects of power quality indicators are just quote the corresponding national standard, such as the provisions of the harmonic quoted GB/T 14549 “Quality of electric energy supply Harmonics in public supply network”. In the actual applications, Many utilities refer to the standard of iec61000-3-2”Electromagnetic compatibility -limits-limits for harmonic current emissions (equipment input current is less than or equal to 16A per phase)” or IEC61000-3-4”Electromagnetic compatibility-Limits-Limitation of emission of harmonic currents in low-voltage power supply systems for equipment with rated current greater than 16A”.

POWER QUALITY OF CHARGING INFRASTRUCTURE BASED ON FIELD MEASUREMENT

We had carry out a lot of testing work on various types of EV charging facilities and we found that different manufacturers and different types of charging facilities have different performances on power quality. Two types of them are displayed as follows:

A fast charging station

The power supply structure of this fast charging station is shown in the following figure:

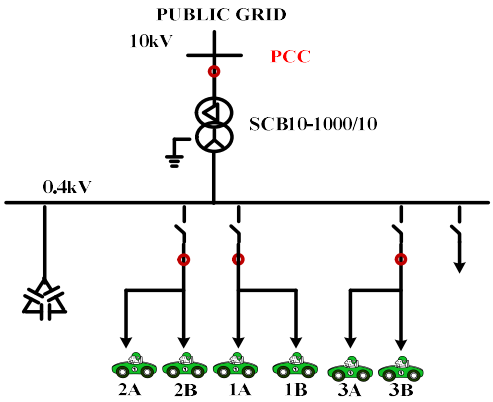

Fig.1 Structure of the charging station

The power of this charging station is supply by 10kV. After 1mva transformer, three sets of charging equipment is connected by 400V cable. Each of fast charging equipment can charge two vehicles. During the field measurement, various charging modes were arranged. The results shows that voltage deviation, frequency deviation, three-phase unbalance, voltage fluctuation and flicker meet China's national standards requirements. harmonic is our main concern.

For a single charging pile, the spectrum characteristics of the current when the battery has just started charging is studied, as shown in the following figure:

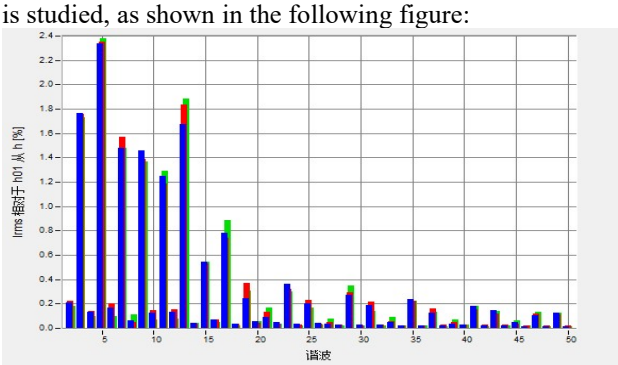

Fig.2 Spectrum of the start charging current

For a single charging pile, the study of the spectrum characteristics of the battery has been charged to 80% capacity, as shown in the following figure:

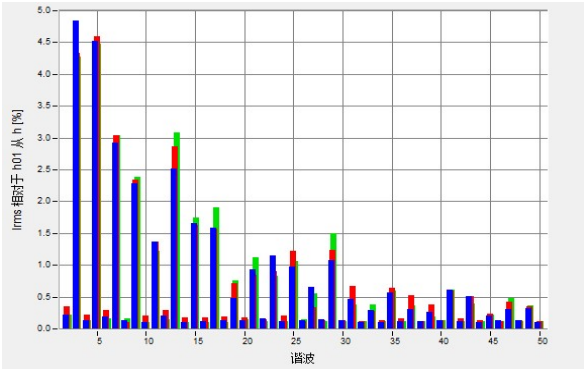

Fig.3 Spectrum of the floating charging current

And the change curve of charging current of the whole charging process of an empty vehicle battery is shown as follows. We can see that the current rise rapidly first and go down slowly.

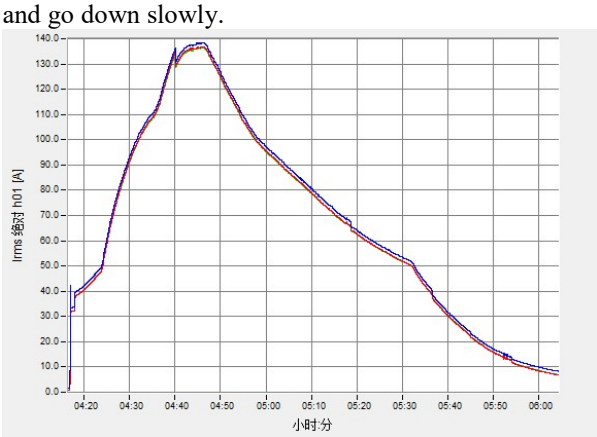

Fig.4 Curve of the charging fundamental current

And the corresponding harmonic currents are shown as follows. Taking into account the variation of the operation mode of the charging equipment, the harmonic emission is not decreased with the decrease of the fundamental current, which leads to a significant increase in the percentage of the harmonic current.

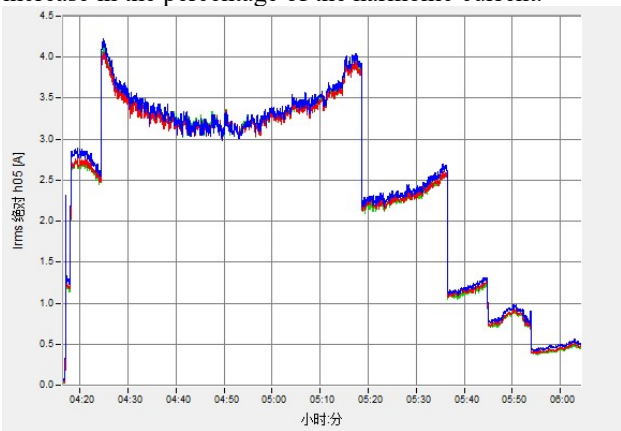

Fig.5 Curve of the 5th harmonic current

A battery swap station

This EV battery swap station is invested by the local

government, and it is the centralized battery swap station for the public transportation system. In addition to the battery charging, it also could return the unnecessary power left in batteries back to the power grid.

In the charging mode, the change curve of fundamental charging current in one day is shown as below.

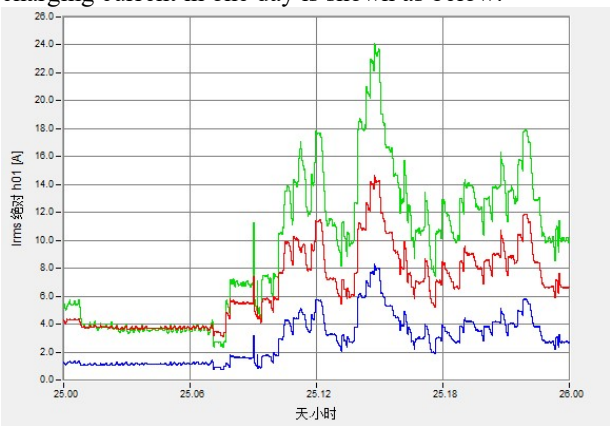

Fig.6 Curve of the charging fundamental current

And the corresponding harmonic currents (5th) are shown as follows. We can see that the harmonic currents was changing with the change of fundamental current.

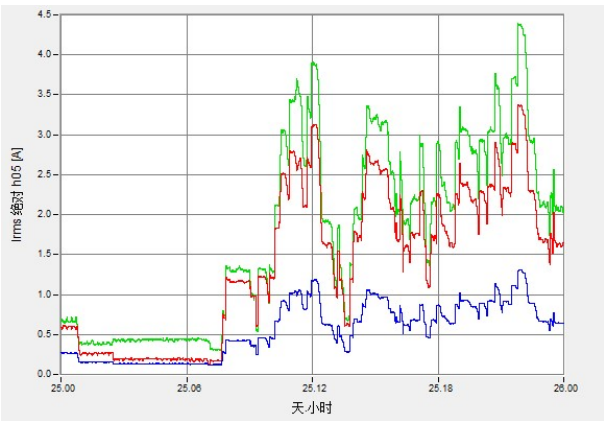

Fig.7 Curve of the 5th harmonic current

And the spectrum of the maximum charging current in this day is shown as follow:

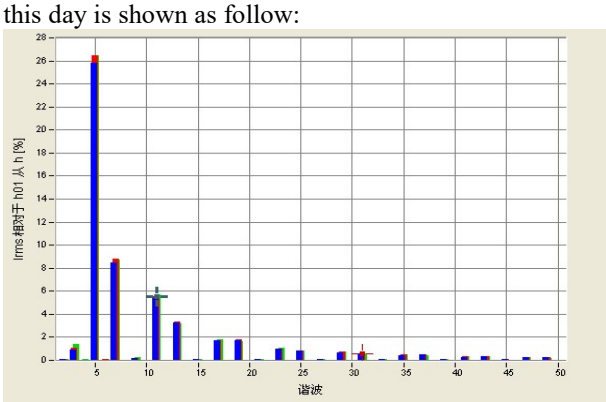

Fig.8 Spectrum of the charging current

From the above figure, it can be seen that the percentage of the harmonic current had exceeded 20%, because there is no control measures taken at this battery swap station.

By the analysis of the test results of various VE chargers, it could be proved that the overall power quality characteristics of VE chargers is generally Optimism. And voltage deviation, frequency deviation, three-phase unbalance, voltage fluctuation and flicker meet the national standard requirements. But, it is still facing some problem. Attention should be paid on harmonics pollution.

SUMMARY

At present, electric vehicles have been developed rapidly in China. One of the main reasons is that the subsidy is significant and attractive. But this way is difficult to lasting. When policy support reached a certain standard, the EV industry need market mechanism. Because people pay more and more attention on environment, the development of electric vehicles is still very optimistic, and its demand is still very strong.

More than that, lots of electric vehicle charging station have been established, which created advantage conditions for the development of electric vehicle.

Electric vehicle charger is a typical non-linear device, so a large number of electric vehicle chargers are bound to seriously affect the promotion of the grid power quality, which means that the power quality characteristics must be considered before the constructing of charging stations. While different kinds of electric vehicle charging stations have different characteristics of power quality.

This paper analyzed the power quality characteristics of the different types of charging devices in different working modes, which will provide a theoretical basis and technical support for power quality control in charging station construction.

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