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Johannes Liebl *Ed.*

Grid Integration of Electric Mobility

1st International ATZ Conference 2016

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Proceedings

Today, a steadily growing store of information is called for in order to understand the increasingly complex technologies used in modern automobiles. Functions, modes of operation, components and systems are rapidly evolving, while at the same time the latest expertise is disseminated directly from conferences, congresses and symposia to the professional world in ever-faster cycles. This series of proceedings offers rapid access to this information, gathering the specific knowledge needed to keep up with cutting-edge advances in automotive technologies, employing the same systematic approach used at conferences and congresses and presenting it in print (available at Springer.com) and electronic (at SpringerLink and Springer Professional) formats.

The series addresses the needs of automotive engineers, motor design engineers and students looking for the latest expertise in connection with key questions in their field, while professors and instructors working in the areas of automotive and motor design engineering will also find summaries of industry events they weren't able to attend. The proceedings also offer valuable answers to the topical questions that concern assessors, researchers and developmental engineers in the automotive and supplier industry, as well as service providers.

Johannes Liebl
Editor

Grid Integration of Electric Mobility

1st International ATZ Conference 2016

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Editor

Dr. Johannes Liebl
Moosburg, Germany

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WELCOME

Electric mobility is one of the most outstanding industrial topics of the present time. In order to give it additional impetus, the charging infrastructure must be further expanded. Furthermore, it is in our interest that the industrial manufacturing of the numerous components of electric mobility takes place in Germany.

Particular focus must be on the development of technologies and concepts for the sensible and user-friendly integration of electric vehicles into intelligent power grids. As the proportion of regenerative energy continues to increase in the future, we will need intelligent solutions to ensure the reliability and stability of the power grid. Achieving this will require a continuous exchange of ideas and opinions between science, industry and politics. This ATZ conference will make a key contribution to this.

I wish you great success for your conference.

Matthias Machnig
State Secretary
Federal Ministry for Economic Affairs and Energy

The UN Climate Change Conference in Paris, with its key topics of global warming and deteriorating air quality, will speed up the advance of electric mobility. CO_2-neutral and zero-emission mobility require electricity to be generated from regenerative sources of energy.

Power generation from wind and solar energy, however, is dependent on the weather and is therefore not stable. The irregularities that occur in nature can result in unacceptable voltage fluctuations in the power grid. For that reason, the availability of highly flexible loads and storage systems is becoming particularly important. Electric vehicles, with their grid-relevant properties as controllable power consumers and electricity storage systems, could help to stabilize future power grids.

A true breakthrough in electric mobility will not occur until the product and the infrastructure are in perfect harmony. In order to optimize the interaction between representatives from the automotive industry, energy providers, data services and politics nationally and internationally, we are offering you this new and interdisciplinary forum in Berlin at the end of May. It will enable you to make direct contact with all interface partners to acquire comprehensive information on current issues and to exchange the very latest knowledge.

We cordially invite you to come to Berlin and we look forward to your active participation.

On behalf of the Program Advisory Board,

Your
Dr. Johannes Liebl
Editor-in-Charge ATZ | MTZ | ATZelektronik

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KEYNOTE LECTURES

Electric mobility – sustainably into the future

Dr. Marcus Bollig, BMW Group

Grid Integration of Electric Mobility, Proceedings, DOI 10.1007/978-3-658-15443-1_1

Abstract

Electric mobility has been an integral part of the BMW product strategy since the introduction of the BMW i models i3 and i8 and the expansion of the model range by various plug-in-hybrid vehicles. Customer perspectives are changing worldwide in terms of future mobility and growing importance of sustainability. Therefore, BMW has identified electric mobility as one of the key factors for the future success of the company.

Electrified powertrains provide key characteristics that perfectly fit to BMW:

- Efficiency: Electric motors are the bench mark in terms of efficiency, even having the complete chain consisting of power electronics, the battery and the charging system in mind. Braking energy can be recovered easily. Compared to internal combustion engine powertrains, the amount of energy shrinks to a quarter.
- Dynamics: With the maximum torque at already zero motor speed, electric powertrains are extremely spontaneous in response – pure fun to drive!
- Sustainability: When driving electric, no emissions are exhausted from the vehicle. This is already a great advantage to air quality in today's megacities. And – using renewable power for charging – real total emissions of almost 0 g CO_2/km can be achieved.

There are still challenges to meet on the way to the future mobility: digitalization has arrived in the car, autonomous driving is on its way. Fulfilling the demand for really sustainable mobility remains the most critical though. E-mobility will be the next step, ahead of hydrogen-mobility. Therefore, BMW welcomes efforts to support the rollout of e-mobility with incentives when buying an electric vehicle and doing further investment into the German charging infrastructure. In a third step electric vehicles can bring benefits to the electricity grid by intelligent charging, this can become an additional part in the success of e-mobility. The BMW Group has already conducted a lot of research and development in this field – this will lead to attractive products and services in the future.

The challenge of electric mobility in digitized power grids

Heiko Fastje, EWE NETZ GmbH; I. Kolmsee, EWE AG

This manuscript was not available on completion of this publication.
Thank you for your understanding.

Grid Integration of Electric Mobility, Proceedings, DOI 10.1007/978-3-658-15443-1_2

MARKETS

Marktintegration von Elektrofahrzeugen – wie SchwarmMobilität® Kaufanreize schafft und die Stromnetze stabilisiert

(The market integration of electric vehicles – how SchwarmMobilität® creates purchasing incentives and stabilizes power grids)

Gero Lücking, LichtBlick SE

Grid Integration of Electric Mobility, Proceedings, DOI 10.1007/978-3-658-15443-1_3

Abstract

Es gibt viele Gründe und Belege dafür, dass der Elektromobilität die Zukunft gehören wird. Die Experten der UBS-Bank[1] erwarteten beispielsweise schon im August 2014, dass bis 2020 mit einer Energie-Revolution zu rechnen sei, die auch zu einem Umbruch im Verkehr führen wird. Die Kosten für Lithium-Ionen-Batterien werden sich demnach bis 2020 halbieren. Nach dem Eintritt von Tesla in den Markt stationärer Batterien sind allein im Jahr 2015 die Batteriekosten um 25 Prozent gesunken. Die Reichweite der E-Autos steigt stetig, die Kosten sinken, die Fahrzeuge werden so immer attraktiver und wettbewerbsfähiger. Insbesondere auch in Kombination mit dezentraler Solarenergie, deren Kosten ebenfalls drastisch sinken, werden sie in Zeiten von Diesel-Gate zu einem unverzichtbaren Baustein der weltweiten Energiewende.

LichtBlick entwickelt mit SchwarmEnergie® Lösungen für diese dezentrale und erneuerbare Energiewelt. Produkte und Lösungen im Bereich Elektromobilität sind wesentliche Bausteine dazu.

Im „ersten Schritt“ bieten wir Kunden Produkte und Dienstleistungen an, die dazu beitragen, erneuerbare Energien in den Verkehr zu integrieren. Autofahrer sollen in Zukunft immer und überall sauberen LichtBlick-Strom tanken können. Schon heute bieten die regulatorischen Rahmenbedingungen Möglichkeiten, Elektromobilität für die Kunden und Fahrzeugnutzer mit Ökostrom noch preiswerter und damit attraktiver zu machen.

Im „zweiten Schritt“ nutzen wir die enorme Batteriekapazität von E-Fahrzeugen als SchwarmSpeicher® für sauberen Strom. Mit der IT-Plattform SchwarmDirigent® kann LichtBlick die Batterien der Elektroautos zu einer virtuellen Großbatterie bündeln und intelligent mit den Energiemärkten vernetzen. So kann bei Stromüberschuss im Netz und negativen Preisen gesteuert geladen werden. Darüber hinaus kann zur Stabilisierung der Stromnetze sogenannte Regelenergie ins Netz ein- und ausgespeist werden. Geschäftsmodelle entstehen, weil mit dieser Marktintegration von Elektrofahrzeugen ein Beitrag zur Versorgungssicherheit geleistet und Geld verdient werden kann.

[1] UBS-Studie: Global Utilities, Autos & Chemicals. Will solar, batteries and electric cars reshape the electricity system? (August 2014)

1 Intelligente Fahrstromprodukte und diskrimierungsfreier Zugang zur öffentlichen Ladeinfrastruktur

Nur Elektroautos, die mit Ökostrom betrieben werden, entlasten das Klima. Die Kosten des Ökostrombezugs können um rund 30 Prozent reduziert werden, wenn eine Regelung im Energiewirtschaftsgesetz (§ 14a EnWG) genutzt wird und Elektroautos ähnlich wie Wärmepumpen und Nachtspeicherheizungen als sogenannte „steuerbare Verbrauchseinrichtungen“ behandelt werden. Elektroautos können so an privaten oder gewerblichen Ladesäulen bspw. von abends 21 Uhr bis morgens 6 Uhr vergünstigt Strom beziehen. Für die zeitliche Einschränkung sinken die Kosten für die Netznutzung gegenüber dem üblichen Tarif um etwa 30 Prozent oder um bis zu 200 Euro pro Jahr.

Wird das Betanken am Standort „zu Hause“ nicht statisch sondern flexibel gesteuert, kann beim Tanken sogar Geld verdient werden. Am Sonntag, den 8. Mai 2016 wurden beispielsweise acht Stunden lang aufgrund geringer Nachfrage und hoher regenerativer Erzeugung negative Strompreise notiert. Werden die Fahrzeuge in dieser Zeit gesteuert geladen, erhält der Privat- oder Flottenkunde dafür, dass er Überschussstrom dem Netz entnimmt und damit sein Fahrzeug betankt, bares Geld.

Voraussetzung dafür, dass die Kunden flächendeckend von diesen intelligenten Angeboten profitieren können und sie an jeder Ladesäule auch im öffentlichen Raum den Strom des Anbieters ihrer Wahl beziehen können, ist, dass die öffentliche Ladeinfrastruktur Teil der Stromnetze wird und damit allen Stromanbietern und Vertriebsgesellschaften ein diskriminierungsfreier Zugang gewährt wird. Alle anderen Regelungen verzögern den Ausbau der Ladeinfrastruktur und sind europarechtswidrig.

2 SchwarmMobilität® für die Energiewende

Mit der Anschaffung von E-Autos und Solarbatterien bauen die Verbraucher eine gigantische Speicherkapazität auf. Bereits eine Million E-Mobile können mit einer Speicherkapazität von rund 16 Gigawattstunden mehr überschüssigen Wind- und Sonnenstrom aus dem Netz aufnehmen als alle deutschen Pumpspeicher-Kraftwerke. Da ein Auto im Schnitt 23 Stunden am Tag am Standort „zu Hause“ steht, kann ein Teil der Batteriekapazität ohne Komfortverlust für den Fahrer dem Stromnetz zur Verfügung gestellt werden. Kurzfristige Schwankungen im Stromnetz können ausgeglichen werden, die Batterien von E-Fahrzeugen können durch das Bereitstellen von sogenannter Regelenergie einen wichtigen Beitrag zur Systemstabilität der Stromnetze leisten. Im Forschungs- und Leuchtturmprojekt der Bundesregierung INEES haben die Projektpartner VW, SMA, das Fraunhofer Institut IWES und LichtBlick gezeigt, dass Elektrofahrzeuge ohne Komforteinbußen für den Nutzer zur Systemstabilisierung der Stromnetze genutzt werden können. Fahrzeugbatterien der zweiten Generation, bidirektionale Schnittstellen, tägliche Ausschreibungen zur Ermittlung der Regelenergiebedarfe, auf vier Stunden verkürzte Zeitscheiben und die Befreiung dieses Systemstroms von Netzentgelten und Umlagen führt zu jährlichen Erlösen von bis zu 1000 Euro pro Fahrzeug. Mit den aktuellen Gesetzgebungsverfahren werden alle genannten regulatorischen Voraussetzungen umgesetzt sein. Und auch die ersten Fahrzeughersteller bieten bereits serienmäßig bidirektionale Schnittstellen an.

Über SchwarmMobilität® etablieren sich so neue Geschäftsmodelle, die die Energiewende befördern und über die Nutzungsdauer der Fahrzeuge eine höhere wirtschaftliche Attraktivität entwickeln als für die Allgemeinheit teure und für die Kunden lediglich einmalig wirkende Kaufprämien.

Case Study – China's regulatory impact on electric mobility development and the effects on power generation and the distribution grid

Guiping Zhu[1], Christoph Tomoki Hein[2], Qiao Ding[2]

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Grid Integration of Electric Mobility, Proceedings, DOI 10.1007/978-3-658-15443-1_4

1 Introduction

Since the introduction of “New Energy Vehicles” (NEV) via the Ministry of Industry and Information Technology (MIIT) as a new vehicle type in 2009, several domestic car manufacturers started to offer products in that category (MIIT, 20091). Supported by restriction and subsidy policies, the sales of NEV started to increase rapidly, topping in 200,000 passenger NEV wholesale in 2015 (www.caam.com.cn, 2016). Electric Vehicles (EV) are set as key developing type of NEV in China, thus it is the focus of this paper.

In order to sustain the growth of NEV market in China and to fulfil the massive charging demand of expected 5 million NEV by 2020, more and more charging infrastructure has to be deployed in the cities as well as intercity areas such as high ways (NDRC et al., 2015).

The rapid development of EV has also brought a number of other problems including the impact of EV charging power demand on the grid. At present because of a relatively small number of electric vehicles and relatively huge capacity of power grid, the impact of electric vehicle charging on the power grid is almost negligible, and charging is available for electric vehicles at any time (so called "any-time charging" mode), thereby meeting EV charging demand to the greatest extent. Electric vehicle is a typical power-type load, that is, its charging power is great, however total required electricity is not much (China Automotive Energy Outlook 2012, 2012). Therefore, in case of a sharp increase in the number of electric vehicles and absence of control over their charging time and charging power, that is, any-time charging mode will bring a lot of negative impacts on power grid, such as new load peak and excessive power supply capacity, which is bad for coordinated development of EV industry and power grid. This paper carried out studies amid this context, which used Beijing in China as example to study EV charging impact on power grid with various charging modes.

2 NEV development in China

2.1 Electric mobility in China

Historically speaking, the origin of electric mobility (e-mobility) in China was not only related to passenger vehicles or commercial vehicles, rather to any kind of personal mobility. The ban of motorcycles out of major Chinese cities in the 90s and the lack of alternatives created a new market for personal e-mobility. Electric scooters and delivery three-wheelers were introduced as an alternative, which created a complete new market, which is shown in Figure 2-1.

In concerns of electric passenger and commercial vehicles, the market started to grow with the introduction of restrictions and incentive policies, too.

Delivery type electric three-wheeler

Private electric-scooter (e-scooter)

Figure 2-1 Electric three wheeler and electric scooter in China

Development policies to increase domestic production capabilities of NEV were introduced in 2009 with MIIT announcement (MIIT, 2009[1]). An additional policy stated that all domestic vehicle manufacturers have to certify their companies with a new NEV brand respectively product (MIIT, 2009[2]). The products can apply different technologies, such as plug-in electric hybrid vehicle (PHEV), battery electric vehicle (BEV) or fuel cell electric vehicle (FCEV), to be recognized as a "NEV" in the MIIT NEV catalogue. The first generation of NEV vehicles listed in the MIIT NEV catalogue had not achieved the mentionable sales numbers (www.chinadaily.com.cn, 2014).

2.2 NEV subsidies and restriction policies

The situation continued until governmental and local subsidies for NEV were introduced (MOF et al., 2013) which supports the targets of 5 million NEV in 2020 (SCPRC, 2012). Those targets are part of the ambitious goals of "Made in China 2025" roadmap to strengthen the key industries to become a global leader in innovation and technology. Additionally, restrictions on conventional vehicles push the industry and customer towards NEV offers respectively purchases. Cities like Beijing, Shanghai, Shenzhen restricted the release of number plates for conventional vehicles with a lottery system (BMPG, 2010) with waiting times longer than 3 years or auctions for number plates reaching prices of around 84,500RMB (approx. 11.000EUR) in 2016 for one number plate (SMPG, 2014). On the other hand, in cities like Beijing or Shanghai, number plates for NEV (in Beijing only for BEV) are not restricted and can be acquired within short time free of charge. The maximum possible subsidies and benefits for locally produced NEV and imported BEV/PHEV are respectively shown in Figure 2-2.

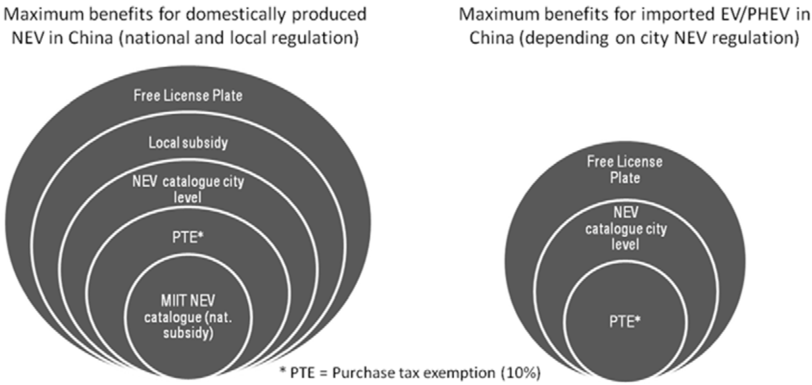

Figure 2-2 Subsidy structure for domestically produced NEV and imported EV/PHEV

The accumulated benefits for a domestically produced BEV and PHEV in Shanghai (MOF et al., 2015; SMPG, 2016) are shown below in Table 2-1 in comparison with a conventional vehicle of the same product class.

Table 2-1: Acquisition cost comparison PHEV, BEV and conventional vehicle in Shanghai 2016 (Exchange rate RMB/EUR = 0.136)

Category	BYD Qin PHEV (NEV >50km range)	BAIC EV200 BEV (NEV >150km range)	Comparable conventional vehicle (BYD F3)
Price before subsidy	209,800RMB (approx. 28,000EUR)	208,900RMB (approx. 28,000EUR)	65,900RMB (approx. 9,000EUR)
Purchase tax	0	0	3,295RMB
National Subsidy	-30,000RMB	-45,000RMB	0
Local Subsidy	-10,000RMB	-30,000RMB	0
Number plate auction	0	0	Approx. 84,500RMB
Total customer costs (after benefits)	169,800RMB (approx. 23,000EUR)	133,900RMB (approx. 18,000EUR)	153,695RMB (approx. 21,000EUR)

2.3 NEV sales increase after 2013

Considering that buyers of conventional vehicles rather need to wait for a long time for a number plate or need to purchase it with high costs, for certain customer classes a NEV is the only solution to acquire personal mobility. A mentionable sales increase can be seen from 2013 to 2016 shown in Figure 2-3. The overall registration of NEV passenger vehicle increased over 300% in 2015 compared to 2014. China is currently the biggest market for BEV and PHEV with around 200,000 wholesale of passenger vehicles in 2015 and will foster a further increase in 2016 (www.caam.com.cn, 2015).

Though governmental subsidies will be successively reduced until 2020, restrictions on conventional vehicles will remain. Those restrictions will still give buyers a certain benefit to buy a NEV comparable with the ban of motorcycles in the 90s.

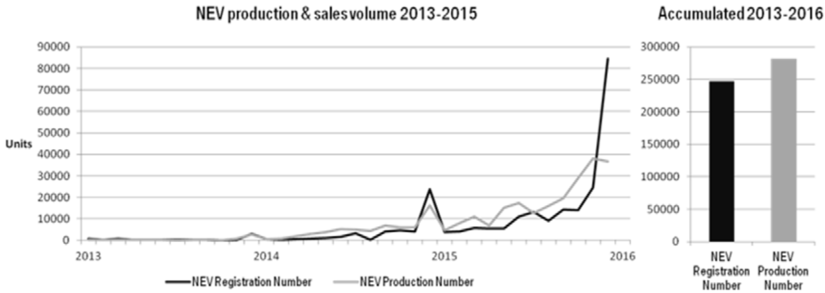

Figure 2-3 NEV production and registration volumes 2013-2015

3 Infrastructure development for NEV market in China

3.1 Overall target of infrastructure development

In order to sustain the growth of NEV market in China and to fulfil the massive charging demand of expected 5 million NEV by 2020, it is essential to enhance charging facility and charging infrastructure development in China. Overall, more than 12,000 centralized charging and swapping stations and more than 4.8 million distributed charging pillars are planned in China by 2020 (NDRC et al., 2015). Thus, the expected ratio of NEV and charging points will approximately be 1:1.

3.1.1 Development plan of centralized charging and swapping stations

Those 12,000 centralized charging and swapping stations are mainly planned in public service areas, in terms of public transportation and e-taxi services, urban sanitation and logistics industries. Meanwhile, urban public charging stations are arranged in societal parking area which could facilitate the occasional charging needs, and intercity fast charging stations are planned for intercity travel needs (NDRC et al., 2015). The expected amount of those centralized charging and swapping stations are listed in Table 3-1.

By the end of 2020, more than 1000 fast charging stations are planned to achieve a fast charging network in major provinces and cities within mainland China (NDRC et al., 2015). The fast charging network focuses to establish intercity travel by using NEV. The intercity fast charging stations as shown in Figure 3-1 are planned along highly utilized highway networks.

Table 3-1 Target amount of centralized charging and swapping stations by 2020

No.	Category of charging and swapping stations	Amount
1	Charging station for public transportation	3,850
2	Charging station for e-taxi services	2,500
3	Charging station for urban sanitation and logistics industries	2,450
4	Urban public charging station	2,400
5	Intercity fast charging station	800
	Overall	12,000

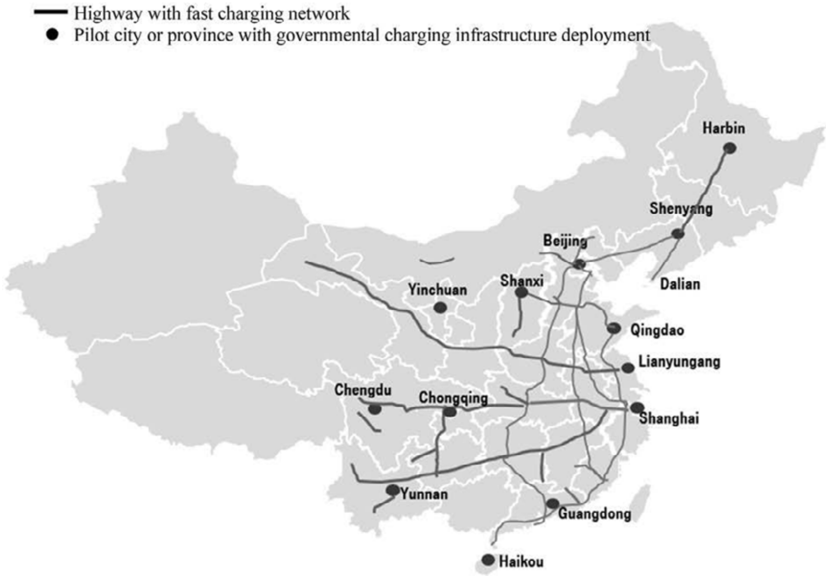

Figure 3-1 Planned intercity fast charging network in China by 2020

3.1.2 Development plan of distributed charging pillars

For passenger NEV usage, more than 2.8 million charging pillars in residential compounds and 1.5 million charging pillars for commercial areas, such as enterprises and institutions, office buildings and industrial parks are planned in China. Those charging pillars will support the essential demands and it is encouraged to share the charging pillars for public use. Besides, more than 0.5 million distributed charging pillars are planned in public parking areas, such as transportation hubs, recreational sports facilities, high rise buildings, large mansions and roadside parking, which aim to meet the occasional charging needs (NDRC et al., 2015).

3.2 Nationwide implementation of charging infrastructure

For the entire country, the Ministry of Housing and Urban-Rural Development of the People's Republic of China (MOHURD) announced that from 2016 on, 100% of parking lots in new-built residential compounds have to install charging devices. For public constructions larger than 20,000m^2 as well as shopping malls, office buildings, etc., at least 10% of the parking lots have to be equipped with charging devices (MOHURD, 2015).

To assure the electric supply to charge NEV in present residential buildings, compounds, etc. with low cost, it is recommended to co-use the power supply of illumination equipment such as street lights. For a short term solution, time-shared charging points are offered to residential compounds with limited parking spaces, meanwhile development of mechanical and multi-storey parking garages with charging facilities are considered as long term goals.

In order to effectively achieve the charging infrastructure development plan by 2020, it is suggested to define provincial targets under consideration of local NEV development levels, consisting of "acceleration", "demonstration" and "promotion" areas (GOSC, 2015). For instance, 12 cites and provinces in the acceleration area, such as Beijing, Shanghai and Guangzhou, have a target of more than 7400 charging stations and 2.5 million charging pillars by 2020 (NDRC et al., 2015).

To keep pace with the targets of the NRDC, Beijing released a set of recommendations and subsidy policies of construction land and investment for deployment of charging stations. It is encouraged to involve public-private partnerships to install charging infrastructure, subsidised with maximum 30% of the total investment (BMCDR, 2015[1]). Concerning the usage, from 2015 on, a charging service fee was introduced in Beijing which is directly related to the daily 92 octane gasoline price (BMCDR, 2015[2]).

The combination of national, provincial and city level infrastructure development targets including public as well as residential charging helps to strengthen the user satisfaction of NEV drivers and further encourages new NEV buyers.

4 Evaluation of EV charging impacts on power grid in China

As electricity demand of BEV is greatest in all kinds of NEV, following research of NEV charging impacts on power grid will only focus on BEV (EV for brief). Massive EV charging will lead to a great charging power demand on power distribution network, as well as impacts on power quality and stability of the grid, therefore EV charging impacts on local power grid should be evaluated by certain method. A model of EV charging power demand was presented firstly in this section. In this model, randomness of charging start and daily mileage of EV was considered, as well as various charging modes, to ensure simulation results close to real use-cases. Using the model, daily charging power curves of a certain number of EV with various charging modes can be obtained. By overlapping those curves with the original power load of the grid, as well as the future EV stock, charging impacts on power grid can be evaluated (Original peak load is defined as the load of the grid without EV).