Analysis of Charging Demand of Electric Vehicles in Residential Area

Tsai-Hsiang Chen
Department of Electrical Engineering
National Taiwan University of Science and Technology
Taipei, Taiwan, R.O.C.
thchen@mail.ntust.edu.tw

Rih-Neng Liao
Department of Electrical Engineering
National Taiwan Universityof Science and Technology
Taipei, Taiwan, R.O.C.
D9807104@mail.ntust.edu.tw

***Abstract*—Electric vehicle (EV) in Taiwan may have the opportunity to popularity, the grid will recharge large number of vehicles, the planning and design of the power generation, transmission, and distribution capacity will also propose new specifications and requirements. EV charging on the grid are caused by the issues such as power supply demand, difference of peak and off-peak and power quality. A basis for the above problems is required through the EV charging demand analysis. We consider characteristics of both vehicle and user driving, and adopt the Monte Carlo method to simulate the daily charging demand of different places and penetration and calculate the distribution system design parameters. The simulation results can be provided to T.P.C. and various circles as the planning grid and EV charging system a reference.**

***Index Terms*—Electric Vehicle(EV); Charging Demand; Load Curve.**

I. Introduction

With excessive greenhouse gas emissions, which will leads to the problem of climate change, warming and deterioration. In the world countries actively involved in the new carbon reduction policies in order to the control of greenhouse gas emissions. Development of EVs can reduce the greenhouse gas emissions, reduce people's dependence on fossil fuels and reduce noise, as well as improve air pollution and upgrade the quality of the living of the city.

Europe, America and Japan, China and South Korea and Australia countries are actively promoting the development of EVs. With the development of vehicle battery technology advancement must be building the charging equipment, which makes the development of EVs scale gradually increase [1]. EVs charge direct to impact the power supply on the grid and vehicle occur cluster charging that we could have made face a new challenges and opportunities- on the grid. In the planning and design of the power generation, transmission, and distribution capacity also will propose new specification and requirement. Random characteristic of EVs is more than normal load in the spatial distribution and charging time. This is not only caused by many uncertainties on the grid [2], but is also difficult to accurately predict. On the other hand, vehicle cluster-charging will increase peak to valley gap, increase system load, equipment overload, voltage drop and fluctuation [3], harmonic [4], three-phase imbalance [5], loss [6], distribution transformer life [7] and other issues. For all of the above issues, we should establish EV charging demand model as a basis in the first phase.

The current literatures related to impact of EV charging demand factors including:

1) Vehicle characteristics: such as the type and size of the EVs, state-of-charge (SOC), scale of vehicles and recharging power level. In [8], it is assumed that the scale of development of the EVs and the initial SOC are constant. In [9], consider different type of EVs and charging power level. In [10], it is assumed that the charging power is constant. In [11], it is assumed that the type of EVs battery capacity is constant, and analyze electricity demand, and consider both different scale of EVs and initial SOC distribution. In [12], consider different types of EVs, such as small, medium and large SUV to correspond different battery capacity and different charging power.

2) *Driving characteristics:* such as traveling time, distance, parking locations, as well as charging sites, time, cycles and moment. In [19], it is assumed that the EV charging behavior is the randomness in a fixed period of time. In [9], it is assumed that the EV charging time is constant. In [11], analyze distribution of the EV charge time based on user driving statistical data. In [13], consider vehicle charging mostly in the evening after work or in the evening, and assume a fixed charging sites.

On the other hand, bass model is proposed [14], and adopt Monte Carlo charging method and used queuing theory to predict charging demand of EV, but charging sites only consider the residential area. [15] calculate the charging demand at different typical charging sites such as residential areas, workplaces, commercial and parking. So far, true charging demand model of the EV has not yet been proposed. In summary, model of EV charging demand will involve related problems on the grid such as planning, design, operation, safeguard, and emergency response. With the development of EVs promote policies such as demonstration runs of project and preferential policy, we are urgent development of EVs energy supply strategy used layout and planning charging facilities (charging system) as a reference. It will be possible to rid the gas station layout way of thinking.

This article aims to analyze the charging demand of the regional EVs. The related impact factors includes type and scale of vehicles, state-of-charge, scale of vehicles and recharging power level, as well as traveling time, distance, parking locations, charging sites, charging time, charging cycles and charging moment. We adopt Monte Carlo method to simulate the daily load curve in different places and different scale of vehicles, and analyze the required parameters on the distribution design.

II. Impact Factors and Set Parameter

A. Distribution of vehicles parking location

In [16], survey vehicle parking percentage of per hour in different location. Vehicles parked at home in the percentage of up to 85% or more at night and early morning. About 50% to 65% of the vehicle from home drive to locations is parked during a day, and most of parking in the workplace is about 25 to 35%. From work and evening (17:00 to 22:00) between vehicle activities may be distributed to other places and return home. We will through analysis of survey results to get daily average percentage of vehicles, and it is assumed that vehicle distributed of places.

B. Distribution of the vehicle traveling mileage

Distribution of daily mileage of vehicles mainly depends on vehicle usage such as commute to work, visiting or pick up their relatives and children, leisure, business use, and shopping. In 2009, Taiwan Department of Transportation survey of the national private vehicle that the average drive daily mileage is about 37.86 km, which about 45.9% vehicles is below mileage of 20 km and about 82.7% vehicles is below mileage of 60 km. After processing this statistical data, vehicle daily mileage is approximately exponential normal distribution and result shown in Figure 1.

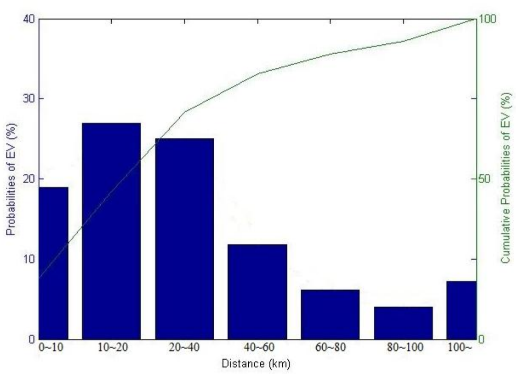

Fig. 1. Home of vehicles the average drive daily mileage

C. Distribution of the vehicle arrived time in various places

In 2009, U.S. Department of Transportation survey of the national household vehicles shown in [17]. Survey results can be seen that the time of most of the vehicles arrive at workplace is at 7:30 to 9:30. Most of the vehicles go home or go to shopping malls, and go home at 17:00 to 20:00. Noon, some vehicles maybe recharge at the mall lead to another wave of power demand. The vehicle is arrived during 7:00 to 22:00 with a higher percentage at charging station. The above of the result of survey with the most of vehicle arrived time match. Therefore, we are assumed in this paper that shown in Figure 2.

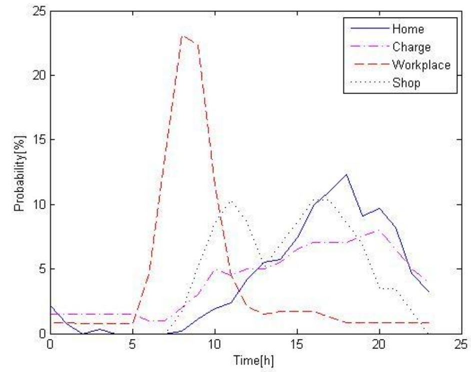

Fig. 2. Distribution of the vehicle arrived time per hour in places

D. Control technology and charging mode

The chargers are nonlinear devices mainly by composed of power electronic components, and convert the power of AC to DC and store in the batteries. It will produce the harmonic injecting into the grid when charging leads to reduce life of other equipment and monitoring instrumentation measurement of errors. At present charger usually contains pulse width modulation and power factor correction technology will make total harmonic distortion of the charge current less than 3% and power factor up to 99% or more [18]. In addition, some of charging methods have been proposed [19], while two-stage rechargeable control is the most generally technology.

E. State of charge

The vehicle power battery at market includes lead-acid, nickel metal hydride and lithium-ion. However, the lithium-ion battery of energy density, efficiency and life have the better performance than other batteries, only have a little worse in terms of price and security status [20]. Due to the state-of-charge of the battery charge and discharge are vulnerable to surrounding environment effects such as charging power and temperature, as well as the battery material characteristics such as cycle life and the discharge of depth. Therefore, the battery model is not easy to establish. We assume that the vehicles arrived each of initial charge state is a uniform random distribution.

F. Type and scale of EVs

In Taiwan, development of a series policies support EVs. Main types of vehicles are for private, public transportation, rental, government and corporate. However, private vehicles will account for the majority, and location distribution and charging time have strong randomness. Therefore, it is necessary to analyze the influence on the grid. We assumes that private vehicles in 2015, 2020, 2025 and 2030 corresponds to total vehicle penetration rate of 7.5%, 16%, 24.5% and 33% in Taipei city, Taiwan.

G. Level of charging power

The EVs replenishment energy can be divided into the conductive charging and battery swapping. The conduction charging can be divided into types of on-board and off-board. AC and DC charging interface harmonization of standards of the vehicles for power demand of simulation analysis is very important. Interface specification of EV charging formulates by international IEC 62196 and SAE J1772 as a reference, IEC 62196 standard illustrates four charging mode. In [21], illustrated four charging mode of IEC 62196 standard. Charging power is mainly affected by service object, setting place and requirement charging time. This article assumes that private vehicles in different places (such as charging stations, commercial, shopping mall and home) corresponds charging power level as shown in Table 1.

TABLE I. DIFFERENT PLACES CORRESPONDS CHARGING POWER LEVEL

Charging level		Specification	Requirement charging time	Applicable places
AC	Type 1	1Φ, 220V 15A,3.3 kW	6-8h	home
	Type 2	1Φ, 220V 30A,6.6 kW	1-3h	commercial shopping
DC	Type 3	480V 168A,80 kW	<0.1h	charging

III. SIMULATE RESULT AND DISCUSSION

We consider that total vehicle number are 600,000. The use the model of probability and use the Monte Carlo method, through 50,000 of iterative simulate to get vehicle charging average daily load curve with different scale of vehicles and different places. The results are shown in Figure 3 to 7, and related load parameters are shown in Table 2. The results can provide to serve charging system in the early planning and layout as reference. The results are described as follows: (1) Vehicles penetration rates in different places are proportional to the power demand. (2) It is difficult to establish a strict mathematical model between charging demand and factors. However, daily load curve can be found with vehicle parking places of profile similar. Therefore, we will also propose another simplified model to solve complex mathematical problems of nonlinear and probability statistics and can significantly shorten the simulation time. (3) EVs charging will cause load and peak load growth, through intelligent control methods to help grid operation and can be achieved such as demand-side management, coordinated control and vehicle-to-grid. However, the load shifting effect of the EVs in V2G technology of intelligent with related to vehicles scale and electricity supply. It is assumed that 20% of the vehicles join in the grid, and will expect to produce 7.3 to 31MWh energy in the grid as regulation and control. (4) EVs charging may be focused on commercial feeders, and maximum demand is 8.9 MW in 2015. After work, they may be concentrated or dispersed in commercial or residential feeders, and maximum demand is 0.74 MW and 22.4 MW in 2015. To make on the grid may greatly occur power supply, overload and voltage fluctuation in norms related problems during load peak. The maximum demand is 12.3 MW at charging station in 2015, and it should not be connected to the past feeder, and should built dedicated feeder. We face initial layout and planning of charging facilities, through the feeder allowable maximum charging demand and analysis of uncertain vehicle position on the grid can grasp the influence of EV charging system. And further take into account the specific area of localized distribution system of EV charging.

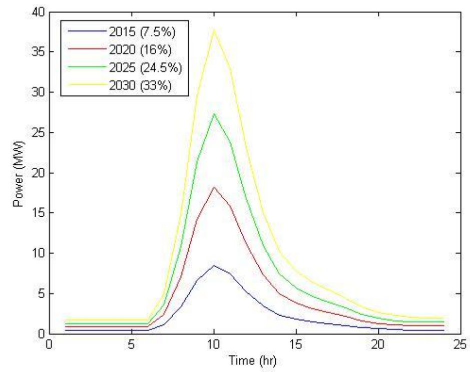

Fig. 3. Daily load curve of EV charging at workplace

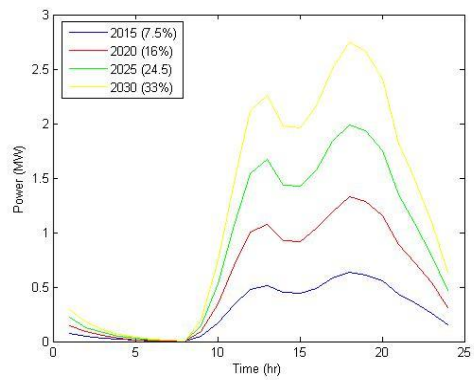

Fig. 4. Daily load curve of EV charging at shopping mall

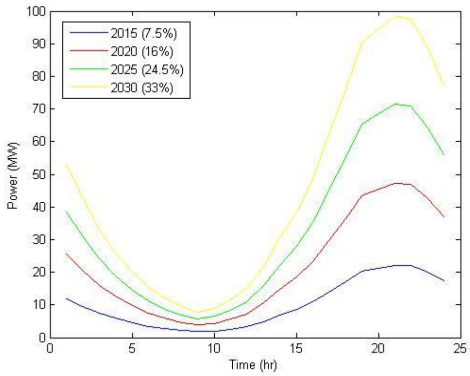

Fig. 5. Daily load curve of EV charging at home

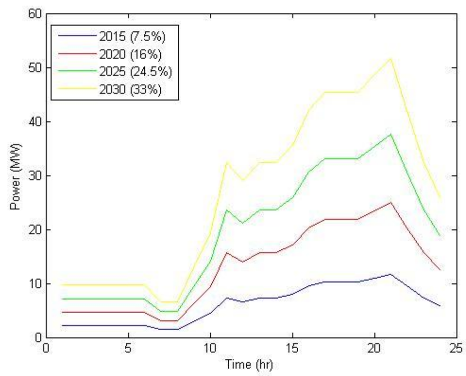

Fig. 6. Daily load curve of EV charging at charging station

IV. Conclusions

The development of EVs in the future will maybe bring enormous effect on the grid. Planning and design of the grid will face both opportunities and challenges. We results of simulation can be used to assess the impact of grid transformer capacity and power quality in a region. The main factor of charging demand is arrived time. Large-scale cluster of EVs connect to the power grid at peak period, and will cause the system load peak and valley increases. If users can recharge less than the average load demand, or through control methods such as coordination charge and intelligent charging, as well as by EVs energy storage characteristics can cause load shifting and improve operation of grid. We consider the type and the capacity, initial SOC, scale of vehicles, charging control mode, charging power level, driving time and mileage, distribution of parking time, charging sites and charging times, using Monte Carlo method establish daily load curve. In practice, EV charging demand model is constructed on a lot of statistical data as basis. Hence we need to development of a lot of detailed works. EV charging system builds process, in addition to considerable practical experience also need available of the design parameters as a reference.

Acknowledgements

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