The Application of Electric Vehicle Ordered Charging Technology in Ubiquitous Power Internet of Things

Weiwei Zhang*, Chengcheng Wang*, Sa Zhang, Wanlu Zhu
NARI Group, Nanjing, Jiangsu, China

*Corresponding author e-mail: 369642550@qq.com, *1195162651@qq.com

Abstract. In recent years, the share of electric vehicles in the domestic automobile market is also increasing. When users meet the basic electricity consumption, they can use the electricity price given by the power company to reasonably allocate household energy and choose a more appropriate household energy layout, which can reduce energy consumption and save daily expenses. The purpose of this paper is to optimize the scheduling of household energy users, so as to improve the quality of power, save electricity expenditure, and obtain economic benefits. Based on the intelligent power optimization strategy and the environmental protection and energy conservation of electric vehicles, this paper analyzes the influence of V2G technology on the optimization strategy of household electricity consumption, and establishes the household electricity load model and electric vehicle model. For the whole system model, the scheduling time, power constraints and users' habit of using electric vehicles as constraints, the final scheduling scheme is obtained through dynamic planning algorithm. Finally, the simulation results verify the correctness of the model coordination control optimization method established in this paper.

1. Introduction

With the development of power grid, modern power system are experiencing the double technological revolution of power supply and load, especially the fundamental change in the load side. In the traditional power grid, the load is completely random variable, the peak value and frequency of the power grid are completed by a single side power supply terminal. However, with the demand side equipment more diversified, distributed generation, distributed energy storage, electric vehicles and other large-scale applications, the traditional passive distribution network has a two-way development trend, and there are source load nodes. At the same time, the popularity and application of intelligent instruments greatly improve the observability of the demand side. Users are no longer just the end of the load, they can interact with the scheduling organization through DSM. Demand side management, by introducing effective incentive measures, guides the users to improve the efficiency of electricity consumption, optimizes the way of electricity consumption, reduces the power consumption and demand on the premise of not affecting the normal demand of users, and realizes the management activities of environmental protection and energy conservation. Many literatures at home and abroad are concerned with how to motivate users to adjust power load adaptively through electricity price, and how to improve demand response according to different response environments [1]. Aiming at the problem of optimal scheduling of household power structure, [2] the demand response model based on real-time
electricity price, the electricity price prediction model under smart grid environment and the household energy control model under demand response environment are proposed. [3] is an optimization strategy based on the home energy storage system. By minimizing the user's electricity consumption, a low-cost electricity demand and payment system model is established, and the dynamic programming algorithm is used to solve the system, so as to minimize the energy cost of the system. Based on the background of the rapid development of smart grid and electric vehicle, this paper analyzes the market price regulation and incentive response behavior of energy Internet and home end users, and establishes the economic indicators from the perspective of users.

2. Analysis of V2G technology of electric vehicle

Electric vehicle charging and discharging technology has become an important part of intelligent power link. This paper mainly studies V2G technology, which has the characteristics of power battery energy storage. It can be used as distributed energy under certain control conditions. During the peak period of power supply, it will feed back the power to the grid to meet the needs of users. V2G technology is an intelligent two-way sequential charging and discharging technology, which reflects the two-way energy flow between power grid and electric vehicle [4]. From the point of view of grid operators, this charging and discharging mode can relieve the grid pressure, peak load, increase grid capacity and accept new energy generation capacity. From the perspective of electric vehicle owners, when the load is low, the charge is low, and when the peak load is high, the price of electricity is high, so as to ensure the demand of users for electric vehicles, so that the surplus electric energy can be sold to the grid, so as to obtain certain economic benefits. According to relevant statistics, the average use time of electric vehicle users is 2 hours / day, that is, most electric vehicles are idle for 22 hours every day. With the continuous application of electric vehicles and the large-scale construction of charging facilities, the total battery capacity of electric vehicles will be huge, which can be regarded as the variable mobile energy storage of power grid. Therefore, on the premise of meeting the daily driving needs of users, it is necessary to manage the large-scale electric vehicles. Through the research of V2G technology, guide the electric vehicles according to the normal use of users, which is helpful to coordinate the relationship between the electric vehicles and the power grid and achieve a win-win situation. Figure 1 shows the technical architecture of electric vehicle V2G.

![Figure 1. V2G electric vehicle technology](image)

3. Modeling and optimization

3.1. Household power load modeling

Nowadays, the intelligent degree of household appliances is also constantly improving. In order to optimize the dispatching of household electrical equipment, a reasonable classification of household
electrical load needs to be carried out. From the different parameters of household appliances and consumer habits of home appliances point of view, can be divided into uncontrollable household appliances and load control. Uncontrollable load mode of operation is fixed, such as lighting load daily use is relatively fixed, once the suspension of such load use will have a greater impact on life. In the optimal scheduling, the working time or working frequency of the device needs to be adjusted, so this part of the load is not included in the optimization policy scheduling.

Controllable load means that such load can be adjusted according to the actual work time of the household electricity, working frequency and so on. Such load is mainly heating equipment, such as water heaters do not need to care about the specific working time period. This type of load provides the potential for home-use optimization strategies.

For each end-user to optimize the electricity within the specified time, all of the controllable load equipment and electric vehicles will work in this time set. At times of electricity price, the price is adjusted on an hourly basis, but in real life, most of the powered devices may not be working full hours. Therefore, this paper divides an hour into several periods. We divide one hour into four equal time periods, each time period is 15 minutes, that is, 0.25h. Therefore, one day is divided into 96 time periods. If the energy consumed by the household device \( x \) in period \( t \) is expressed as \( E_{x,t} \), energy scheduling vector can be expressed as (1):

\[
E_x = [E_{x,1}, \ldots, E_{x,96}]
\]

Suppose that the power consumed by the household device \( x \) per hour is \( P_x \), power consumption is \( P_{x,t} \) at time \( t \), the period of time when the device starts to work and ends is \( t_s \) and \( t_e \), the device's runnable schedule space is \([t_s, t_e]\), the schedulable space of the equipment needs to be greater than the required working time, otherwise it does not have the scheduling conditions. Without loss of generality, the power consumption of a single device can be expressed as (2):

\[
E_0 = \sum_{t=1}^{96} P_{x,t}
\]

The price model adopted in this paper is a time-of-use model combining with practical application. In this period of time the price will not change, then in the absence of electric vehicles, can be drawn on the optimization of the total power consumption can be expressed as (3):

\[
E_f = \sum_{x=1}^{X} \sum_{t=1}^{96} C_t \cdot P_{x,t}
\]

Where \( C_t \) denotes the price of electricity grid in period \( t \).

3.2. Electric vehicle load modeling

The traditional charging methods of electric vehicles are divided into AC charging and fast DC charging. The AC charging speed is slow, the charging power is often small, and the impact on the power grid is relatively small. Generally, parking spaces are used in the long-term parking charge of electric vehicle charging piles. DC fast charging is to use the DC voltage provided by the special charging pile of electric vehicle to charge. Generally, 750V or 1000V DC voltage is used to charge, providing a large amount of electric vehicle energy in a short time.

The method of power exchange is relatively simple, which is to take out the exhausted battery from the interior of the electric vehicle through a special instrument and replace it with a fully charged battery for the electric vehicle to continue to drive. Compared with the traditional charging method, the biggest
The advantage of this method is that the charging speed of electric vehicle is very fast, and it is about as fast as the traditional vehicle. However, this method is complex in equipment, difficult in operation, high in cost, and difficult to unify the transmission technology standards. This paper does not involve the power exchange mode. [5] analyzed the two charge models separately for out-of-order charging and orderly charging under peak-valley electricity prices. [6] conducted a quantitative analysis of charging power at home, charging power in public places, battery capacity, final state of SOC, and permeability of charging pile in public places.

\[
f_c(x) = \begin{cases} 
1, & x \in [0,6] \cup [23,24] \\
0, & x \not\in [0,6] \cup [23,24] 
\end{cases} \quad (4)
\]

\[
f_d(x) = \begin{cases} 
1, & x \in [10,16] \cup [20,23] \\
0, & x \not\in [10,16] \cup [20,23] 
\end{cases} \quad (5)
\]

The probability density function of schedulable EV daily driving is shown in (6):

\[
f_m(x) = \frac{1}{\sigma_m \sqrt{2\pi}} \exp \left[ -\frac{(x - \mu_m)^2}{2\sigma_m^2} \right] \quad (6)
\]

Where \(\mu_m = 16.58\), and \(\sigma_m = 6.57\).

The EV charging model has a time scale of 24 hours, a granularity of 1 minute and a total of 1440 points throughout the day. The charging load per minute can be expressed as the following formula, where: \(P_j\) denotes the total charging power of the j minute electric vehicle, \(N\) is the scale of the electric vehicle, \(I_{n,j}\) is the charge of the nth electric vehicle at the jth minute power.

\[
P_j = \sum_{n=1}^{N} I_{n,j} \quad 1 \leq j \leq 1440 \quad (7)
\]

Assuming that electric vehicles start charging immediately after they are connected to the power grid, various types of information of electric vehicles, including the holding quantity of various types of electric vehicles, performance parameters, initial SOC (State of Charge) distribution, initial charging time distribution and charging probability, are input into the model Distribution, possible charging interval. Monte Carlo method is used to simulate and distribute the starting charging time and starting SOC of all kinds of vehicles [7-8]. Simulation flow chart is shown in Fig. 2.
Fig. 2. Monte Carlo simulation of electric vehicle charging load flow chart

The charge and discharge power characteristics of electric vehicles are realized by Monte Carlo random sampling method. For each electric vehicle, during the charging and discharging period, randomly select the charging and discharging time and daily driving distance, and assume that the electric vehicle starts to charge until the end of the state, then determine the charging duration required for the initial state of charge of the electric vehicle.

3.3. Coordination and optimization strategy

The electric vehicle charging device is a kind of electric energy storage device, which also needs a certain amount of electric energy in a certain period of time. The real-time power has little influence on the charging of electric vehicle. Therefore, the electric vehicle charging network can also be regarded as an energy load. In this paper, an energy demand oriented control program is proposed. According to the change of the total energy demand of the electric vehicle and the load curve based on the family in the time dimension, the total energy demand of the electric vehicle is allocated to the load curve, so that the total load curve of the electric vehicle after charging is relatively straight and stable, and the purpose of peak shaving and valley filling is realized.

Assuming that the total target load is $E_a$ and the basic electricity load of households is $E_f(t)$ in period $t$, the total amount of electric energy stored in the vehicle can be shown as (8):

$$E_c = \int_{t_1}^{t_2} (E_a - E_f(t)) \, dt$$  \hspace{1cm} (8)

Where: $t_1$ is the orderly charging of electric vehicles start time, and $t_2$ is the orderly charging of electric vehicles start time. The power consumption of different load in single time period is accumulated to judge whether the total power exceeds the upper limit of the total power consumption of the household and the difference between the maximum power consumption and the minimum power consumption of the time slot is obtained and the optimal result after multiple times of logic calculation is selected as the optimization value. The specific process as shown as Fig.3.
In this paper, the goal of time-of-use price simulation is to ensure that all loads can be completed within the specified time, and household electricity load is transferred to the lower price period. There is almost no work on electricity consumption during the peak period of electricity price and the optimization of the usage time of most electricity-using equipment will greatly reduce the pressure on grid peak. However, the total power consumption of all electricity- Changeless. For users, this optimization strategy reduces the user's electricity consumption to a certain extent. For the power grid, this optimization strategy could divert part of the grid peak load and smooth the load curve.

4. Conclusion
This article helps users to develop the minimum electricity consumption model under time-share electricity price, and realize the information interaction between smart grid and users. With the known time-of-use electricity price, the household electricity load model and the electric vehicle load model are established. The combination of energy Internet technology and home-based smart electricity is the future trend. With the improvement of standards and norms, the combination of smart home and electricity management will have a broader development prospect.

In the follow-up study, we will try to help residents use electricity load and electric vehicles, and even the entire smart connected home to achieve load optimization through intelligent software, helping residents to manage their energy more intelligently.

5. Acknowledgments
This work was financially supported by Science and Technology Project of State Grid Corporation “Research and Application of Key Technology of Provincial Distribution Network Operation Status Control” (No.5216A019000R)

6. References
[1] A.Motamedi, H. Zareipour, W.D.Rosehart. Electricity Price and Demand Forecasting in Smart Grids [J]. IEEE Transactions on Smart Grid, 2012, 3 (2): 664-674
[2] A.Oudalov, R. Cherkaoui, A.Beguin. Sizing and Optimal Operation of Battery Energy Storage System for Peak Shaving Application [J], Power Tech, 2007 IEEE Lausanne. IEEE, 2007:621-
625

[3] Zhou Bing. Research on Short Term Price Forecast in Smart Grid Environment [D], Zhengzhou University, 2015.

[4] Guo Xiaomin, Yang Jianwei, He Zhengyou. Probabilistic Evaluation Method of Voltage Quality for Urban Power Network Considering Vehicle to Grid [J]. Power System Technology, 2015, 39 (10): 2986-2992.

[5] Yang Bing, Wang Lifang, Liao Chenglin, et al. Distributed Coordinated Charging Control System Model for Large-scale Electric Vehicles [J], Automation of Electric Power Systems, 2015, 39(20):41-46

[6] Xu Hao, Huang Shihong, Qian Tiantian, et al. A Modeling Strategy for Charging Loads of Large-Scale Electric Vehicles Considering Multi-days Spaced Charging Mode [J], Transactions of China Electrotechnical Society, 2015, 30 (9): 130-137.

[7] Ge Qing. Electric Vehicle Charging Load Model Identification and Its Impact on Distribution Voltage [D]. Harbin Institute of Technology, 2015.

[8] Wang Yaowu. Study on Applicability and Application of Electric Vehicle Load Forecasting [D], Beijing Jiaotong University, 2015.