Available Online at http://www.recentscientific.com

CODEN: IJRSFP (USA)

International Journal of Recent Scientific Research
Vol. 10, Issue, 06(C), pp. 32842-32848, Jun, 2019

ISSN: 0976-3031

International Journal of Recent Scientific Research

DOI: 10.24327/IJRSR

Research Article

OPTIMIZATION OF CHARGING AND DISCHARGING BEHAVIOR OF ELECTRIC VEHICLES IN DISTRIBUTION NETWORK

[1,2]*Dong, H., [3,2]Liu, Y., [4]Huang, J., [1]Lian, W., [1,2]Wu, L., [1]Wang, T., [1]Ma, T., [1]Huang, Y. and [1]Zhong, J

[1]School of Electrical Engineering, Jinan University, Zhuhai 519070, PR China
[2]Mathematical modeling base, Jinan University, Zhuhai 519070, PR China
[3]School of International Business, Jinan University, Zhuhai 519070, PR China
[4]School of Intelligent Systems Science and Engineering, Jinan University, Zhuhai 519070, PR China

DOI: http://dx.doi.org/10.24327/ijrsr.2019.1006.3554

ARTICLE INFO

Article History:
Received 6th March, 2019
Received in revised form 15th April, 2019
Accepted 12th May, 2019
Published online 28th Jun, 2019

Key Words:
Electrical Vehicle, Distribution Network, Multi-objective Mathematical Programming and Newton-Raphson Method.

ABSTRACT

Based on the received one-week charging record of 100 electric vehicles, we propose a simple electric vehicle charging and discharging optimization management model for the impact of the large-scale change of power flow in the behavior of electric vehicles and distribution networks. We firstly use the charging record and data statistics theory to analyze the distribution law of charging and discharging behavior characteristics of electric vehicles such as charging probability, charging start time, connection duration and charging power. Then we explore the influence of the disordered charging of electric vehicles, considering the influencing factors of electric vehicle charging and uses the multi-objective mathematical programming idea to reduce the equipment investment and the optimal ratio of different charging power levels of peak-to-valley difference of disordered charging load of electric vehicles. Finally, based on the Newton-Raphson method, the classical method of power flow calculation, we optimize the charging and discharging behavior of electric vehicles in the distribution network, and minimizes the total active cost of the grid active power loss and electric vehicle owners. Aiming at the goal, the multi-objective mathematical programming idea is used to obtain the optimal charging and discharging scheme. We use a simpler scheme to provide a reference for the optimal management problem of electric vehicle charging and discharging, which has great social significance.

INTRODUCTION

The transportation sector consumes about half of China's oil resources and produces huge amounts of greenhouse gases. In response to increasingly serious resource and environmental problems, governments around the world are actively promoting electric vehicles (EV). In addition to adopting a series of economic subsidy policies for its production and sales, the formulation of the timetable for the ban on fuel vehicles has also been put on the agenda by many countries including China. The energy of electric vehicles mainly comes from the power grid, and its large-scale development is inseparable from the support of the power system. As a mobile energy storage, electric vehicles have broad application prospects in peak shaving and load leveling, providing auxiliary power system services and cooperating to absorb new energy. Vehicle to Grid (V2G) refers to the optimal management of the charging and discharging behavior of electric vehicles through reasonable strategies and advanced communication means. In the process of interaction, there are three interests of the grid, the operator (charging station) and the EV user. The EV user can exchange energy directly with the grid or the operator's charge and discharge agent service. This is the charging and discharging behavior of electric vehicles. The disordered charging behavior of electric vehicles has the characteristics of strong randomness and high simultaneity factor, which will bring challenges such as increased peak-to-valley difference, voltage drop and increasing loss to the distribution network(Sungwoo *et al*, 2012; Shilei *et al*, 2017). Therefore, it is more demanding for reasonable energy management(Jingjia *et al*, 2018). Effective scheduling and control methods are key to reducing its negative impact and fully utilizing its energy storage(Junhua *et al*, 2011). At present, researches on the charging and discharging scheduling of electric vehicles at home and abroad have

Corresponding author:* **Dong, H
School of Electrical Engineering, Jinan University, Zhuhai 519070, PR China

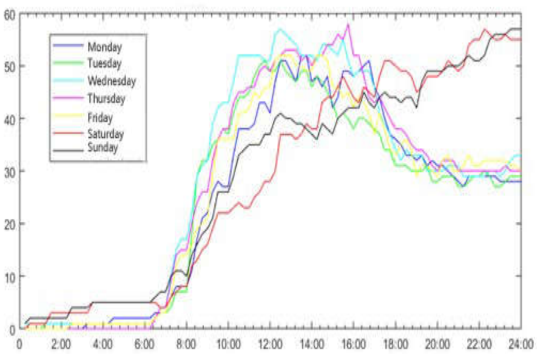
achieved certain results. Juanjuan(Juanjuan *et al*, 2016) obtained the daily load curve of the electric vehicle charging load through Monte Carlo simulation, based on which an optimization model aiming at the minimum peak-to-valley difference was established. At the same time, the orderly management of electric vehicle charging was realized through the optimization of peak and valley electricity price period. However, this method does not take into account the factor that the electric vehicle also discharges to the grid, which may lead to poor applicability of the optimization results (Shan Xu, 2018). Izadkhast(Izadkhast *et al*, 2015) studied the impact of large-scale entry of electric vehicles on different stakeholders from the perspective of grid operation safety. But they did not consider user satisfaction and its impact on the charging and discharging model. Guihong(Guihong *et al*, 2015) proposed a two-layer optimization model for charging and discharging strategies considering operator interests and user satisfaction, which used the satisfaction matrix to give due consideration to user satisfaction. However, this method only analyzed the overall user satisfaction from the macro level, ignoring the satisfaction of individual users(Yang *et al*, 2019).

Based on the above analyses, we study the charging and discharging records of electric vehicles, comprehensively consider the factors affecting their charging and user needs, and want to design a simple charging and discharging optimization management model for electric vehicles, which realizes reasonable scheduling between electric vehicles and distribution networks. It may have certain economic and social benefits.

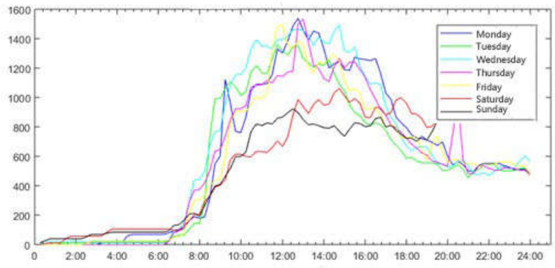
MATERIALS AND METHODS

Characteristics and Distribution of Electric Vehicle Charging Behavior

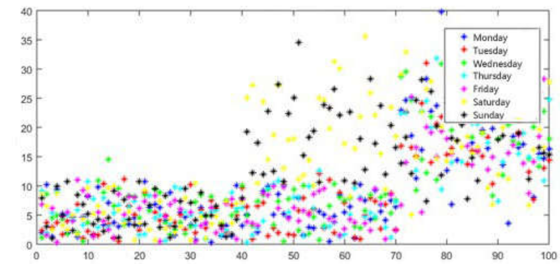
Knowing the charging records of 100 electric vehicles, we divide the day into 96 time periods and each time period is 15 minutes (0:00-0:15, 0:15-0:30, … ,23: 45-24:00). We count the number of connections of 100 vehicles with charging piles in each time period, charging start time, charging connection duration and charging power. After that, we get the average charging power per vehicle per week and the average charging time of each day of each time period. The charging status of each day of each time period is shown in Figure 1, Figure 2 and Figure 3.



Graph 1 Distribution of number of charging vehicles at various times of each day of the week



Graph 2 Distribution of charge power at various times of the day during the week



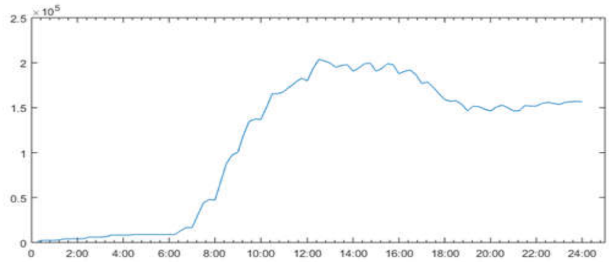
Graph 3 Distribution time of charging connection of 100 vehicles

In Figure 1, the vehicles are charged from 7:00 to 18:00 on Monday to Friday (working hours); on weekends, charging starts at around 7:00 in the morning until 12 o'clock in the evening. In Figure 2, the charging power from Monday to Friday is mostly distributed from 7:00 to 18:00 (working hours); the charging power on weekends starts from around 7:00 am to 12:00 pm. In Figure 3, the charging connection time of about 70 vehicles on weekdays is concentrated within 10 hours, and about 30 vehicles are connected between 10-40 hours; on weekends, about 40 vehicles are connected within 10 hours and about 60 vehicles are connected between 10-40 hours.

The distribution of the three characteristics of electric vehicle charging behavior can verify the common sense that people working in the daytime during weekdays and go on trips at weekends.

The impact of Disordered Charging of Electric Vehicles

Charging load curve of 10,000 Electric Vehicles in 24 hours



Graph 4 Charging load curve

It can be seen from Figure 4 that the charging load distribution also conforms to the distribution law of the charging behavior of the electric vehicles.

Proportional Optimization model for Different Charging Power Levels of Electric Vehicles

Table 1 Electric vehicle charging power level.

	AC level 1	AC level 2	DC
Power (kW)	1.4-1.9	7.7-25.6	40-100
Cost per device (CNY)	3000	15000	500000

There are different charging power levels for electric vehicles. We try to find out a plan that we can meet the needs of users (to obtain the expected charging power within the charging connection time), and also reduce equipment investment and the optimal ratio of peak-to-valley difference of the disordered charging load of electric vehicles.

Taking 100 vehicles as an example, a proportional optimization model for different charging power levels of electric vehicles is established. The peak-to-valley difference of the disordered charging load of electric vehicles is "ΔQ"("kw"), the equipment investment is T (CNY).

$$U = u_1 \Delta Q + u_2 T \quad (1)$$

Where:

ΔQ(kw) = the electric vehicle disordered charging load peak-to-valley difference;

T （CNY） = the equipment investment;
U = the comprehensive optimization of ΔQ(kw), T.

Considering that the equipment investment is equivalent to the peak-to-valley difference of the disordered charging load of electric vehicles, the weight-to-weight ratio u_1, u_2 is 0.5 and 0.5 respectively.

$u_1 = 0.5, u_2 = 0.5$

The average charging power of the AC primary mode is 1.65kw and of the AC secondary mode is 16.65kw. The charging power of the DC mode is 70kw.

We believe that the peak-to-valley difference of the disordered charging load of electric vehicles should be divided into two parts, which are the peak-to-valley difference of the disordered charging load of electric vehicles ΔQ_1 in time and $\overline{\Delta Q_2}$ in the way. Considering that the peak-to-valley difference between the two types of electric vehicles' disordered charging load should be equally valued, we set the weight ratio equally.

$$\Delta Q = 0.5\Delta Q_1 + 0.5\overline{\Delta Q_2}$$

Among them, the peak-to-valley difference of the disordered charging load of the electric vehicle in time are:

$$\Delta Q_1 = P_{1max} - P_{1min} \quad (2)$$

$$P_{1max} = N_{1max}\left[\frac{(1.4+1.9)}{2}x + \frac{(7.7+25.6)}{2}y + \frac{(40+100)}{2}z\right] \quad (3)$$

$$P_{1min} = N_{1min}\left[\frac{(1.4+1.9)}{2}x + \frac{(7.7+25.6)}{2}y + \frac{(40+100)}{2}z\right] \quad (4)$$

Where:

N_{1min} = the minimum number of accesses that 100 electric vehicles are charged per week at each time interval;

N_{1max} = the maximum number of accesses that 100 electric vehicles are charged at each time of the week.

In addition, we choose to use the variance of the charging power of each charging method to calculate the peak-to-valley difference of the disordered charging load of electric vehicles in each time and each way, which can better reflect the load difference of each device.

The average value of the peak-to-valley difference of the disordered charging load of the electric vehicle in each charging mode is as follows:

$$\overline{\Delta Q_2} = \frac{\sum_{i=1}^{12} \Delta Q_2(i)}{12} (i = 1,2,3\ldots 96) \quad (5)$$

The peak-to-valley difference of the disordered charging load of the electric vehicle in each period of charging mode is

$$\Delta Q_2(i) = \frac{(CP_1(i) - \overline{CP(i)})^2 + (CP_2(i) - \overline{CP(i)})^2 + (CP_3(i) - \overline{CP(i)})^2}{3} \quad (6)$$

The charging load corresponding to the three devices at each time are

$$CP_1(i) = N(i)\left[\frac{(1.4+1.9)}{2}x\right] (i = 1,2,3\ldots 96) \quad (7)$$

$$CP_2(i) = N(i)\left[\frac{(7.7+25.6)}{2}y\right] (i = 1,2,3\ldots 96) \quad (8)$$

$$CP_3(i) = N(i)\left[\frac{(40+100)}{2}z\right] (i = 1,2,3\ldots 96) \quad (9)$$

Where

$N(i)$ = the number of accesses that 100 electric vehicles are charged on average during each week.

The average charging load of the three in each period of time is

$$\overline{CP(i)} = \frac{CP_1(i) + CP_2(i) + CP_3(i)}{3} (i = 1,2,3\ldots 96) \quad (10)$$

The amount of investment to be made for the three types of equipment is

$$T = 3000*x + 15000*y + 5000000*z \quad (11)$$

We also need to meet the needs of users when selecting various devices for charging (that is, the vehicle needs to obtain the expected charging power during the charging connection), and the AC primary mode has a charging capacity of $\frac{(1.4+1.9)}{2}N(i)t(i)x$ in the Period i. In the AC secondary mode, the amount of charge in the Period i is $\frac{(7.7+25.6)}{2}N(i)t(i)y$, and the amount of charge in the DC mode is $\frac{(100+40)}{2}N(i)t(i)z$ in the Period i.

Then the constraints to meet the user's electricity demand are

$$\min U = u_1 \Delta Q + u_2 T$$
$$s.t.\begin{cases} \frac{(1.4+1.9)}{2}N(i)t(i)x + \frac{(7.7+25.6)}{2}N(i)t(i)y + \frac{(100+40)}{2}N(i)t(i)z \geq G(i) \\ x + y + z = 1 \\ x, y, z \geq 0 \end{cases} \quad (12)$$

Where:

$t(i)$ = the connection length of 100 electric vehicles that are charged on average during each time period.

$G(i)$ = the average amount of electricity that 100 electric vehicles need to be charged during each time period;

MATLAB is used to solve the minimum function fmincon of nonlinear constrained multivariate functions, results are as follows:

$$\begin{cases} x = 0.8378 \\ y = 0.1622 \\ z = 0 \end{cases}$$

The proportion of the first-level AC is 83.78% and the ratio of the second-level AC is 16.22%. The DC charging is not used. The preliminary analysis should be that the DC charging equipment is expensive, which leads to high cost. If users overuse DC equipment, the load difference between the devices will be too large, which may lead to loss.

Optimization of charging and discharging behavior of electric vehicles in distribution network

When the EV is parked in a residential area, it is often exchanged directly with the distribution network through the charging pile, which may cause a dramatic change in the distribution of currents.

Power flow calculation, the power science term, refers to the calculation of the distribution of active power, reactive power and voltage in the power network under given power system network topology, component parameters and power generation and load parameters. The goal is to calculate the power system for a given operating state, which means the node voltage and power distribution are used to check whether the components of the system are overloaded, whether the voltage at each point meets the requirements and whether the distribution and distribution of power are reasonable and power loss. The power flow calculation results can be used for power system steady state research, safety estimation or optimal power flow and other aspects that have direct influence on the models and methods of power flow calculation. The current power system's tidal technology mainly uses the Newton-Raphson method.

We make the Following Assumptions

Assumption A: It is assumed that the normal distribution of the remaining electric quantity of the electric vehicle with electric power is evenly scattered between (10, 50)**.**
Assumption B: The power flow is uniform when a single electric vehicle is physically connected to the power grid through a charging pile and there is electrical energy flowing.
Assumption C: The length of the charging connection refers to the length of time that the electric vehicle is physically connected to the power grid through the charging pile, but does not ensure that there is a certain amount of electric energy flowing in the physical connection.
Assumption D: The electric vehicle will consume all the electricity charged, that is, the electric vehicle's charge amount is equal to the electricity consumption.
Assumption E: At the beginning of the energy flow of electric vehicle the battery power is normally distributed between the minimum and maximum values (average value is 30, variance is 5). After the car sells electricity to the operator or the grid, the battery power is at a minimum. After purchasing power from the operator or the grid, the battery power is at a maximum.
Group F: Charging piles can provide sufficient electricity to electric vehicles.
Group G: The electricity produced by photovoltaic power generation is used directly and does not accumulate.
Group H: Electric vehicles have electricity refers to the remaining power of electric vehicles in the range of 10 to 50kwh, and no electricity refers to the remaining power of electric vehicles is 10kwh.
Group I: Considering the actual situation, the EV can only be connected to the electric car for charging during the time period of 0:00-6:00 and 18:00-24:00. No access is given for the rest of the time.

Calculation of user spending

Obviously, the user's cost per time period $H(i)$ includes three parts, one is the cost of charging $H_1(i)$, the other is the cost of the equipment $H_2(i)$ and the third is the cost of selling electricity $H_3(i)$.

$$H(i) = H_1(i) + H_2(i) - H_3(i)(i = 1,2,3,\ldots,12) \tag{13}$$

Where

i = 12 time periods in which one day is divided;
K = the maximum number of vehicles connected to node 8, $K = 5000$.

In fact, the battery limit of an electric car is $O_{max} = 50kwh$. When the electric battery of the electric vehicle is lower than or equal to $10kWh$, the battery should be charged, that is, the minimum battery level of the electric vehicle is $O_{min} = SOC * O_{max} = 0.2 * 50kwh = 10kwh$. Under normal circumstances, the battery power of the electric car is between $(10,50)(kWh)$. An electric vehicle with a battery capacity lower than $10kWh$ can be selected for charging or not charging. It is assumed that the probability of electing an electric vehicle with a power lower than $10kWh$ is X; an electric vehicle with an electric quantity higher than $10kWh$ can be optionally charged. We can assume that a charging probability is $Z$and a discharge probability is Y. Next, the three-part solution will be deduced separately.

Calculate the cost of charging $H_1(i)$

The charging cost $H_1(i)$ for each period of time consists of two parts, one is the charging cost $H_{11}(i)$ of the electric vehicle with the electric quantity lower than $10kWh$, and the other is the charging cost $H_{12}(i)$ of the electric vehicle with the electric quantity higher than $10kWh$. The electricity fee is determined by the unit price and the total charge.

The Formulas are as follows

$$\begin{gathered} H_1(i) = H_{11}(i) + H_{12}(i) \\ H_{11}(i) = K * C(i) * X * (O_{max} - O_{min}) * J'(i) \\ H_{12}(i) = K * [1 - C(i)] * Z * [O_{max} - S(i)] * J'(i) \end{gathered} \tag{14}$$

Where

$C(i)$ = the probability of existence of an electric vehicle with a charge below $10kWh$ in each time period;

$S(i)$ = the amount of electricity when the battery with power is connected to the node 8;

Z = the probability of charging the vehicle with electricity;
$J'(i)$ indicates the price of electricity charged by the electric vehicle during the period i.

Compute equipment costs $H_2(i)$

Obviously, the installation, operation and maintenance of charging equipment require cost. The cost of equipment $H_2(i)$ is determined by the cost of a single device and the number of electric vehicles that are selected for charging. The number of electric vehicles selected for charging is the sum of the number of electric vehicles selected to charge less or more than $10kWh$ electric power. In addition, the cost of a single device is determined by the choice of charging method, that is, the cost of a single device is the sum of the cost of using the AC level 1 and AC level 2 charging method.

Based on the Above Ideas, the Formula is as Follows

$$H_2(i) = [K * C(i) * X + K * (1 - C_i) * Z] * (B_1 * T_1 + B_2 * T_2) \quad (15)$$

Where:
B_1 = the ratio of the AC level 1 charging mode used in the electric car connected to the node 8, $B_1 = 0.1$;
B_2 = the ratio of the alternating current level 2 charging mode in the electric car connected to the node 8, $B_2 = 0.9$;
T_1 = the single cost of the alternating level one mode;
T_2 = the cost of a single exchange for the secondary mode.

Calculate the profit of selling electricity $H_3(i)$

When the electric vehicle's power is higher than , the owner can choose to sell electricity to the grid to make profits.

$$H_3(i) = K * [1 - C(i)] * Y * [S(i) - O_{min}] * J''(i) \quad (16)$$

Where

Y is the probability of selective discharge of a car with electricity;

$J''(i)$ is the price of electricity discharged by the electric vehicle during time period i.

In summary, the formula is available, and the average user cost per time period is as follows

$$\overline{H} = \frac{\sum_{i=1}^{12} H(i)}{12} \quad (17)$$

Power flow calculation

Power change

The access power P(i) of the node 8 electric vehicle in each time period is

$$P(i) = P_1(i) - P_2(i) \quad (18)$$

The charging power $P_1(i)$ of electric vehicles is determined by the number of electric vehicles that are selected for charging and the power of a single device.

$$P_1(i) = \frac{\{K * C(i) * X + K[1 - C(i)] * Z\}[B1 * \frac{1.4 + 1.9}{2} + B2 * \frac{7.7 + 25.6}{2}]}{100000} \quad (19)$$

For the electric vehicle's discharge power $P_2(i)$, the discharge power is determined by the number of electric vehicles that are selected to sell electricity and the unit discharge power.

$$P_2(i) = \frac{5K * [1 - C(i)] * Y}{100000} \quad (20)$$

Calculation of network loss

The calculation of the network loss is solved by the Newton-Raphson method in the form of Cartesian coordinates(Jian *et al*, 2013). This method transforms the solution process of the nonlinear equation into a process of repeatedly solving the corresponding linear equation with a fast convergence speed. If a good initial value is chosen, the algorithm will have a square convergence characteristic. Moreover, the number of iterations is basically independent of the size of the network being calculated. Newton's method also has good convergence reliability which depends on having a good initial value for start-up. If not, the algorithm may not converge or converge on a node that cannot run at all.

When using Cartesian coordinates, the amount of power flow problem to be determined is the real and imaginary components of the voltage of each node $e_1, f_1, e_2, f_2, \ldots, e_m, f_m$.

Since the voltage vector of the balance node is given, a total of 2*(n-1) equations are required for the amount to be determined. In fact, in addition to the power equation of the equilibrium node, there is no constraint in the iterative process, and each of the other nodes can list two equations.

For node PQ, P_{is} and Q_{is} are given, so they can be written

$$\begin{cases} \Delta P_i = P_{is} - e_i \sum_{je_i}(G_{ij}e_j - B_{ij}f_j) - f_j \sum_{je_i}(G_{ij}f_j + B_{ij}e_j) = 0 \\ \Delta Q_i = Q_{is} - f_i \sum_{je_i}(G_{ij}e_j - B_{ij}f_j) + e_j \sum_{je_i}(G_{ij}f_j + B_{ij}e_j) = 0 \end{cases} \quad (21)$$

For node PV, P_{is} and V_{is} are given, so they can be written

$$\begin{cases} \Delta P_i = P_{is} - e_i \sum_{je_i}(G_{ij}e_j - B_{ij}f_j) - f_j \sum_{je_i}(G_{ij}f_j + B_{ij}e_j) = 0 \\ \Delta V_i^2 = V_{is}^2 - (e_i^2 + f_i^2) = 0 \end{cases} \quad (21)$$

Iterative calculation

When using Cartesian coordinates, the node voltage phasor and complex admittance can be expressed as:

$$\begin{cases} \dot{V}_i = e_i + jf_i \\ Y_{ij} = G_{ij} + jB_{ij} \end{cases} \quad (22)$$

Substitute the above two relations. Expand and separate the real part and the imaginary part; Assume that the first, second, ..., m numbers in the system are P-Q nodes, m+1, m+2, ..., n-1 are P-

V nodes. According to the nature of the nodes, the following iterative formulas are obtained:

At the PQ node:

$$\begin{cases} \Delta P_i = P_i - e_i \sum_{j=1}^{m} (G_{ij} e_j - B_{ij} f_j) - f_i \sum_{j=1}^{m} (G_{ij} f_j + B_{ij} e_j) \\ \Delta Q_i = Q_i - f_i \sum_{j=1}^{m} (G_{ij} e_j - B_{ij} f_j) + e_i \sum_{j=1}^{m} (G_{ij} f_j + B_{ij} e_j) \end{cases} (i = 1,2,3,\ldots,m)$$

At the PV node:

$$\begin{cases} \Delta P_i = P_i - e_i \sum_{j=1}^{m} (G_{ij} e_j - B_{ij} f_j) - f_i \sum_{j=1}^{m} (G_{ij} f_j + B_{ij} e_j) \\ \Delta V_i^2 = V_i^2 - (e_i^2 + f_i^2) \end{cases} (i = m-1, m-2, \ldots, n-1)$$

Only one balance node is set and the voltage is known which will not participate in iteration, and its voltage is:

$$V_n = e_n + jf_n \qquad (23)$$

Modified equation iteration

The modified equation iteration includes a total of 2*(n-1) equations. The initial value of the voltage and the symbol of the variable correction amount are selected, substituted into the equation and expanded according to the Taylor series, and the quadratic equation e_i, f_i and subsequent items are omitted to obtain a set of linear equations or linearized equations, often called the modified equations:

$$\Delta W = -J \Delta U \qquad (24)$$

$$\Delta W = \begin{bmatrix} \Delta P_1 \\ \Delta Q_1 \\ \vdots \\ \Delta P_m \\ \Delta Q_m \\ \Delta P_{m+1} \\ \Delta U^2{}_{m+1} \\ \vdots \\ \Delta P_{n-1} \\ \Delta U^2{}_{n-1} \end{bmatrix} \Delta U = \begin{bmatrix} \Delta e_1 \\ \Delta f_1 \\ \vdots \\ \Delta e_m \\ \Delta f_m \\ \Delta e_{m+1} \\ \Delta f_{m+1} \\ \vdots \\ \Delta e_{n-1} \\ \Delta f_{n-1} \end{bmatrix}$$

$$J = \begin{bmatrix}
\frac{\partial \Delta P_1}{\partial e_1} & \frac{\partial \Delta P_1}{\partial f_1} & \cdots & \frac{\partial \Delta P_1}{\partial e_m} & \frac{\partial \Delta P_1}{\partial f_m} & \frac{\partial \Delta P_1}{\partial e_{m+1}} & \frac{\partial \Delta P_1}{\partial f_{m+1}} & \cdots & \frac{\partial \Delta P_1}{\partial e_{n-1}} & \frac{\partial \Delta P_1}{\partial f_{n-1}} \\
\frac{\partial \Delta Q_1}{\partial e_1} & \frac{\partial \Delta Q_1}{\partial f_1} & \cdots & \frac{\partial \Delta Q_1}{\partial e_m} & \frac{\partial \Delta Q_1}{\partial f_m} & \frac{\partial \Delta Q_1}{\partial e_{m+1}} & \frac{\partial \Delta Q_1}{\partial f_{m+1}} & \cdots & \frac{\partial \Delta Q_1}{\partial e_{n-1}} & \frac{\partial \Delta Q_1}{\partial f_{n-1}} \\
\vdots & \vdots & \cdots & \vdots & \vdots & \vdots & \vdots & \cdots & \vdots & \vdots \\
\frac{\partial \Delta P_m}{\partial e_1} & \frac{\partial \Delta P_m}{\partial f_1} & \cdots & \frac{\partial \Delta P_m}{\partial e_m} & \frac{\partial \Delta P_m}{\partial f_m} & \frac{\partial \Delta P_m}{\partial e_{m+1}} & \frac{\partial \Delta P_m}{\partial f_{m+1}} & \cdots & \frac{\partial \Delta P_m}{\partial e_{n-1}} & \frac{\partial \Delta P_m}{\partial f_{n-1}} \\
\frac{\partial \Delta Q_m}{\partial e_1} & \frac{\partial \Delta Q_m}{\partial f_1} & \cdots & \frac{\partial \Delta Q_m}{\partial e_m} & \frac{\partial \Delta Q_m}{\partial f_m} & \frac{\partial \Delta Q_m}{\partial e_{m+1}} & \frac{\partial \Delta Q_m}{\partial f_{m+1}} & \cdots & \frac{\partial \Delta Q_m}{\partial e_{n-1}} & \frac{\partial \Delta Q_m}{\partial f_{n-1}} \\
\frac{\partial \Delta P_{m+1}}{\partial e_1} & \frac{\partial \Delta P_{m+1}}{\partial f_1} & \cdots & \frac{\partial \Delta P_{m+1}}{\partial e_m} & \frac{\partial \Delta P_{m+1}}{\partial f_m} & \frac{\partial \Delta P_{m+1}}{\partial e_{m+1}} & \frac{\partial \Delta P_{m+1}}{\partial f_{m+1}} & \cdots & \frac{\partial \Delta P_{m+1}}{\partial e_{n-1}} & \frac{\partial \Delta P_{m+1}}{\partial f_{n-1}} \\
\frac{\partial \Delta U^2{}_{m+1}}{\partial e_1} & \frac{\partial \Delta U^2{}_{m+1}}{\partial f_1} & \cdots & \frac{\partial \Delta U^2{}_{m+1}}{\partial e_m} & \frac{\partial \Delta U^2{}_{m+1}}{\partial f_m} & \frac{\partial \Delta U^2{}_{m+1}}{\partial e_{m+1}} & \frac{\partial \Delta U^2{}_{m+1}}{\partial f_{m+1}} & \cdots & \frac{\partial \Delta U^2{}_{m+1}}{\partial e_{n-1}} & \frac{\partial \Delta U^2{}_{m+1}}{\partial f_{n-1}} \\
\vdots & \vdots & \cdots & \vdots & \vdots & \vdots & \vdots & \cdots & \vdots & \vdots \\
\frac{\partial \Delta P_{n-1}}{\partial e_1} & \frac{\partial \Delta P_{n-1}}{\partial f_1} & \cdots & \frac{\partial \Delta P_{n-1}}{\partial e_m} & \frac{\partial \Delta P_{n-1}}{\partial f_m} & \frac{\partial \Delta P_{n-1}}{\partial e_{m+1}} & \frac{\partial \Delta P_{n-1}}{\partial f_{m+1}} & \cdots & \frac{\partial \Delta P_{n-1}}{\partial e_{n-1}} & \frac{\partial \Delta P_{n-1}}{\partial f_{n-1}} \\
\frac{\partial \Delta U^2{}_{n-1}}{\partial e_1} & \frac{\partial \Delta U^2{}_{n-1}}{\partial f_1} & \cdots & \frac{\partial \Delta U^2{}_{n-1}}{\partial e_m} & \frac{\partial \Delta U^2{}_{n-1}}{\partial f_m} & \frac{\partial \Delta U^2{}_{n-1}}{\partial e_{m+1}} & \frac{\partial \Delta U^2{}_{n-1}}{\partial f_{m+1}} & \cdots & \frac{\partial \Delta U^2{}_{n-1}}{\partial e_{n-1}} & \frac{\partial \Delta U^2{}_{n-1}}{\partial f_{n-1}}
\end{bmatrix}$$

Taking the access power range with less active loss as the constraint condition that the active loss is as small as possible to achieve the purpose of optimizing the two objective functions, the minimum and maximum constraints of the access power of the node 8 in each time period can be obtained.

List the objective function, which are user costs. The active grid loss has been listed by the iterative method and calculated as a constraint.

$$\min \bar{H}$$

$$s.t. \begin{cases} P_{min}(i) \le P(i) \le P_{max}(i) \\ 0.9 \le X \le 1 \\ 0 \le Y + Z \le 1 \\ 0 \le Y \le 1 \\ 0 \le Z \le 1 \end{cases} \qquad (25)$$

Obviously, when the electric vehicle's power is lower than 10kWh, the owner will go to charge with a high probability. At this time, X may take 90% or more to meet the actual situation. The results are:

$$\begin{cases} X = 0.9 \\ Y = 0.1542 \\ Z = 0 \end{cases} \qquad (26)$$

90% of the vehicles that have no electricity will be charged, 15.42% of the vehicles with electricity will be discharged to make profits, and the cars with electricity will not be recharged, so that the user and the grid will have the least loss of active power.

CONCLUSION

The grid is the source of energy for charging and discharging electric vehicles. How to connect the electric vehicle and the power grid, which means that the design and installation of the "interface" to meet the conditions of convenience, safety and high efficiency, has become the key to the current promotion of electric vehicles.

This model considers two sub-goals (both reduce equipment investment and the peak-to-valley difference of electric vehicle's disordered charging load) and meets the user's demand. Therefore, a total optimization degree U is determined and a linear programming model is established. While the assignment of weights is more subjective, so this model can be improved by listing several weight distribution schemes and effects.

This model satisfies two conditions (grid active network loss and total cost of electric vehicle owners) at the same time. It adopts the idea of “exhaustion method”, so that the range of loss is small enough to meet the target, and then reverse the range of the number to obtain the optimal solution. It can obtain a more accurate optimal charging and discharging scheme while it is impossible to get the precise objective function for optimization.

References

Bae S, Kwasinski A. (2012). Spatial and temporal model of electric vehicle charging demand[J]. IEEE Transactions on Smart Grid, 3(1):394-403. https://ieeexplore.ieee.org/abstract/document/5959242

Cai, S., Sun, L. J. (2017). Design of mobile payment charging pile based on ZigBee and Web[J]. Electronic Science and Technology, 30(2):126-129. http://www.cnki.com.cn/Article/CJFDTotal-DZKK201702033.htm

Shi, J. J., Yuan, T. J., Saeed A. K., Qin, W. P., Han, X. Q., Duan, G. Z. (2018). Wind/vehicle cooperative participation in unit combination strategy considering the configurability of electric vehicles [J]. High Voltage Technology, 44(10): 3433-3440.

http://hve.epri.sgcc.com.cn/CN/abstract/abstract2458.shtml

Zhao, J. H., Wen, F. Z., Yang, A. M. (2011). The Influence of Electric Vehicles on Power System and Its Scheduling and Control Problems[J]. Automation of Electric Power Systems, 35(14):2-10. https://wenku.baidu.com/view/21415d53b5daa58da0116c175f0e7cd18425188f.html

Xia, J. J., Zhou, M. J., Yuan, S. (2016). Optimization Model of Electric Vehicle Peak-Valley Time-Sharing Electricity Price Period[J]. Power Technology, 40(9): 1848-1850. http://xueshu.baidu.com/usercenter/paper/show?paperid=ba152aeaba0ba74db9ae677bab424326&site=xueshu_se

Xu, S., Li, Y. (2018). Optimization model of peak-valley electricity price period for guiding electric vehicle orderly charge and discharge[J]. Power Demand Side Management, 20(05):11-15. http://xueshu.baidu.com/usercenter/paper/show?paperid=1v700af03v5d0860r80n0ed06p353596&site=xueshu_se

Izadkhast S., Garcia-Gonzalez P., Frias P. (2015). An Aggregate Model of Plug-in Electric Vehicles for Primary Frequency Control [J]. IEEE Transactions on Power Systems, 30 (3): 1475-1482. https://ieeexplore.ieee.org/abstract/document/6871408/

Huang, G. H., Lei, X., Yang, Y. (2015). Electric vehicle two-layersmart charge-discharge tactics considering wind generation and user's satisfaction[J]. Transactions of China Electrotechnical Society, 30(5): 85-97. https://wenku.baidu.com/view/46c60a6153ea551810a6f524ccbff121dc36c519.html

An, Y., Li, H. Q., Yu L. F., Yu X. Y., & Meng Z. L. (2019). Optimization of charging and discharging strategies for electric vehicles in residential areas considering user satisfaction[J]. Electrical Measurement & Instrumentation, 56(06):7-13. http://www.cnki.com.cn/Article/CJFDTotal-DCYQ201906003.htm

Hu, J., Yang, X. W., Chen, F. (2013). An Improved Algorithm Based on Power Flow Calculation of Newton-Raphson Power System[J]. Computing Technology and Automation, 32(04):41-44. http://xueshu.baidu.com/usercenter/paper/show?paperid=a604562c6eda66fccf9f415760aa2fa3&site=xueshu_se

How to cite this article:

Dong, H *et al*., 2019, Optimization of Charging and Discharging Behavior of Electric Vehicles in Distribution Network. *Int J Recent Sci Res.* 10(06), pp. 32842-32848. DOI: http://dx.doi.org/10.24327/ijrsr.2019.1006.3554

****