Study on the Matrix Model of Electricity and Electricity Price

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Abstract. Electric vehicles change the charging time of electric vehicles according to the change of electricity price, so that the electric vehicle can be transferred as a load. The solution of electricity price is different, and its essence is based on definition. The change of electricity price has changed the influence of consumers on electricity demand. It is necessary to study and formulate TOU price according to the actual situation. In this paper, the solution of the power tariff matrix is deeply analyzed, which provides a theoretical basis for the study of TOU price and has practical significance.

1. Introduction

Traditional cars are driven by internal combustion engines and powered by traditional fossil fuels. Fossil fuels take thousands of years or even tens of thousands of years to form non-renewable energy. Since the beginning of human civilization, its reserves have been decreasing day by day. Unlimited exploitation and utilization accelerated the consumption of fossil fuels. More and more people are turning to new energy electric vehicles. New energy electric vehicles have many advantages: they are driven by electric energy, no tail gas and little noise. Electric vehicles are more efficient in terms of energy efficiency than traditional cars. In particular, during the braking process that starts and stops continuously, energy conversion can be realized and some mechanical energy can be converted into electrical energy.

The development of new energy electric vehicles is a trend because of its environmental friendly characteristics. The development of new energy electric vehicles is a trend. The pure electric vehicle is the future of the automobile industry and will become the main direction of development. With the development of battery technology, the development of electric vehicles has become a worldwide consensus. Electricity can replace traditional energy, which can reduce greenhouse gas emissions and reduce excessive dependence on imported oil. In 2020, our country should compare the CO2 emissions of GDP in the unit to the target of decreasing in 2005 (40%-50%), and need to devote great efforts to road traffic.

The population base of our country is relatively large. The emission of greenhouse gases in China is mainly due to the huge increase in the number of private cars. The U. S. Department of energy official data shows that China's oil imports began to exceed the United States since 2013, ranking first in the world, and it is estimated that the proportion will rise to 57% in 2020. In the critical period of energy transformation, the comprehensive utilization efficiency should be improved, and the mode of travel of electric vehicles should be chosen to reduce the dependence of oil and reduce the effective way of environmental pollution.
Developing new energy electric vehicles has become an important strategy for automobile manufacturers. At home, a series of support policies have been introduced to become the driving force for the development of new energy electric vehicles. The national Power Grid Corp and the southern Power Grid Corp are also energizing the promotion of the electric vehicle's charging infrastructure for the promotion of the electric vehicle. By the end of 2016, the total sales volume of electric vehicles in China was 207 thousand and 300, accounting for 37.7% of the global sales of new energy electric vehicles. What is particularly noteworthy is that BYD sold 61726 cars alone, becoming the largest producer in the world over Tesla. The local government is also actively investing in attracting new energy electric vehicle industry as an important economic support industry. Through various forms of precise investment, the electric vehicle strategy will be put on the priority strategy of development.

To sum up, the electric vehicle as a new tool to improve the quality of life of the people at the same time plays an important role in energy conservation and environmental protection. The technical support of the national grid and the southern power grid, the continuous improvement of the national policy and the positive promotion of the local government have provided a good opportunity for the development of the new energy electric vehicles. It provides a new way of thinking for solving the contradiction between energy shortage and environmental pollution.

2. Electric vehicle charging and discharging characteristics
When the economic cost of the power grid is taken into account, the loss degree of each link is increased. If the control is not reasonable, it will cause the imbalance of the power flow and even the breakdown of the power grid. The electric vehicle is a random load of mobility. The behavior of access to power grid has the uncertainty of time and the uncertainty of space.

The use of control strategy to make a large number of electric vehicles in order to access the power grid has become a hot spot of research. A large number of research shows that the sequential entry of electric vehicles to the network is much smaller than the effect of disordered entry to the power system.

| Name                        | Direction of power flow                     |
|-----------------------------|---------------------------------------------|
| Charging mode (controllable load mode) | Flow into the vehicle from the power grid |
| Discharge mode (power generation mode)      | From the vehicle to the power grid         |
| Neutral Mode                      | Power free switching                       |

Table 1. Operation mode of electric vehicle.
3. Electric vehicle access to power grid technology

Document [1] networking technology is a completely new concept under the premise of continuous development of power grid. Electric vehicles have become an integral part of the smart grid. Document [2] shows the core technology of the Internet of vehicles from the principle of work and topology of the network, and explains the functions of the five major components in theory. The application scenarios of electric vehicles in the future are simulated, and the adjustment of the control strategy responding to the changes in the quantity of electric vehicles is analyzed. In the future, the electric vehicle is the node of the development of the automobile industry. The development of the intelligent power grid is the trend of the development of the modern society. The new technology V2G solves the problem of dispatching the electric vehicle into the network, and also brings some economic benefits to the users.

The [3] is connected to the micro grid in the way of electric vehicle cluster, participates in the FM of the microgrid and formulates the demand side optimization scheme. The dynamic programming simulation is carried out through the historical price data of the microgrid. The optimization of the algorithm can meet the requirements of the FM scheme of the microgrid.

![Figure 2. Typical daily load curve of electric vehicle under microgrid condition [4].](image)

Considering the effect of electric vehicle load on the distribution network, the purpose of balancing the volatility of renewable energy is to change the power station to control the operation of the microgrid and finally realize the comprehensive benefit of the society [5]. Document [6] constructs a V2G technology network system under the environment of large power grid, and studies the network scheduling architecture and establishes the information and communication system by taking the active distribution network technology into consideration. The key management scheme of hierarchical access control in elliptic curve cryptosystem is proposed. The simulation results show that it can meet the control needs of electric vehicle network.

Literature [7] electric vehicles can achieve zero emission of pollution. Taking into account the current model of peak valley electricity price, a random polynomial logit model is used to study the charging and discharging habits of electric vehicles, and the effects of the users' charging efficiency and the power grid are evaluated. Document [8] based on the gravitational model in physics, calculates the coefficient of self elasticity and mutual elasticity according to the price elasticity matrix. By establishing 4 types of vehicle charging and discharging response, the optimal TOU price is solved based on multi-objective genetic algorithm. Literature [9], based on the idea of Engineering game theory, takes into account the incentive effect of time-sharing electricity price, and simulates the problem of electric vehicle scheduling in the region, which can provide a solution for electric vehicles entering the network.
Table 2. The implementation of V2G requires two levels of technology and market analysis.

| Technical level                                      | Market level                                      |
|------------------------------------------------------|---------------------------------------------------|
| Bi-directional charging and discharging device       | The economic evaluation of V2G                    |
| communication system                                 | Operation management method                       |
| Charge and discharge control strategy                | Functional sector policy                          |
| Analysis of battery loss                             | market mechanism                                   |

Electrical energy is not easy to store. The power system itself has low efficiency, high power generation cost and easy waste. In power system, there is a serious imbalance between generating capacity and electricity consumption. System load varies with time, season and user demand. Electric vehicles can be an effective supplement to unbalanced loads. With the increase of the number of electric vehicles, the centralized deployment of electric vehicles can improve the power generation efficiency of the power system and further reduce the rotation reserve of the generator. Ensure the power supply level of the system load and slow down the pressure of the power system.

4. Electricity price model

The demand curve is a curve that shows the relationship between the price and the demand. It is the curve of the amount of goods that the buyer is willing and able to buy at the same level of each price demand curve when the other conditions are the same. The quantity of the goods is in inverse proportion to the price. When prices rise, demand decreases and prices decrease, and demand increases. Electric energy is a special commodity, and electricity needs to go through a series of processes to complete the transaction in the electricity market.

There is also a supply and demand relationship in the electricity market. The core content of the economic market is price, which can affect the direct sense of the user. At the same time, users can make feedback according to the price first time. To establish a stable electricity market, we must give full play to the regulation function of electricity price leverage.

The main problem of Power Grid Corp is the response of electric vehicle users to electricity price. Theoretically, the responsiveness of electric vehicle users to electricity price is related to price elasticity of demand. The elasticity of electric vehicle users to electricity price refers to the relative change of the demand for electric energy caused by the relative change of the electricity price, that is, the ratio of the percentage of the change of electricity consumption to the percentage of the corresponding price in a certain period of time. According to the principles of economics, the typical demand curve is shown in Figure 1. q represents electricity and p indicates electricity price. The most important factor that affects the demand is the price factor. When other factors remain unchanged, demand and price are inversely proportional. The relationship between demand q and price P is shown in the following figure:

![Figure 3](image-url)  
**Figure 3.** Diagram of typical relationship between supply and demand.
\[ \xi = \frac{\Delta q / q}{\Delta p / p} \] (1)

Formula: \( \Delta q \) and \( \Delta p \) denote the relative increment of \( q \) and \( p \) respectively.

In real life, the electricity consumption of most users at a certain time is not only related to the electricity price at that time, but also influenced by other neighboring electricity prices.

The formula for calculating the coefficient of self elasticity and the coefficient of cross elasticity:

\[ \xi_{ii} = \frac{\partial q_i / q_i}{\partial p_i / p_i} \] (2)

\[ \xi_{ij} = \frac{\partial q_i / q_i}{\partial p_j / p_j} \] (3)

In the format: \( i \) and \( j \) represent different time periods. Using the partial derivative symbol to illustrate that the \( i \) power is not only a function of the \( i \) time price, but also a function of other time price.

For the 1-n period of the day, the following formula can be obtained:

\[ \frac{\partial q_1 / q_1}{\partial q_2 / q_2} \frac{\partial q_2 / q_2}{\partial q_3 / q_3} \cdots \frac{\partial q_n / q_n}{\partial q_n / q_n} = E \begin{bmatrix} \partial p_1 / p_1 \\ \partial p_2 / p_2 \\ \vdots \\ \partial p_n / p_n \end{bmatrix} \] (4)

\[ E = \begin{bmatrix} \xi_{11} & \xi_{12} & \cdots & \xi_{1n} \\ \xi_{21} & \xi_{22} & \cdots & \xi_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \xi_{n1} & \xi_{n2} & \cdots & \xi_{nn} \end{bmatrix} \] (5)

\( E \) is the elastic matrix of \( n \times n \), and the expression of \( \xi_{ii} \) is the coefficient of elasticity, and \( \xi_{ij} \) represents the coefficient of mutual elasticity.

5. Different ways of solving the electricity price matrix

Based on the demand response rule in electricity market, the relationship between electricity price and user terminal power demand is studied. The key is to study the sensitivity of consumer demand to electricity price. Document [10-12] focuses on the power tariff matrix method and the solution process.

1) Solving method of electricity price matrix

The "BKL" model, which is jointly studied by Bell, Keeney and Little, is the discrete attractiveness model. The meaning of its research is that the decisive factor of the market share of a commodity depends on its ability to attract customers. The greater the attraction, the higher market share it has. The smaller the attractiveness, the less market share it has. Market share \( S_i \) according to the market model to express:

\[ S_i = \frac{R_{ai}}{R_i} \] (6)

In the form: \( R_{ai} \) shows the attractiveness of commodity \( a \) when time is \( i \); \( R_i \) is the total attraction of commodity \( a \) and all its similar products for time \( i \). The calculation of price elasticity coefficient of
electricity demand based on discrete attraction model [23] combined with market share concept, the formula of self elastic coefficient and cross elasticity coefficient of electricity demand price is as follows:

\[ \varepsilon_i = \frac{\partial S_{ai}}{\partial P_i} \quad \frac{1}{P_i} \]  
\[ \varepsilon_{ij} = \frac{\partial S_{ai}}{\partial P_j} \quad \frac{1}{P_j} \]  
\[ \varepsilon_{ji} = \frac{\partial S_{aj}}{\partial P_i} \quad \frac{1}{P_i} \]  

In the formula: \( P_i \) (i=1, 2, ... N) and \( P_j \) represent the price reference values of \( i \) period and \( j \) period respectively. The user adjusts the demand for electricity by responding to the electricity price.

Ignoring the influence of other factors on electricity demand, a discrete attractiveness model is established. The problem of the impact of electricity price on electricity demand is transformed into the attraction of electricity price to electricity demand. If the attractiveness is large enough, the share of total electricity demand will be higher.

Ignoring the impact of other objective factors on the demand for electricity consumption.

The greater the share of demand, the greater the demand for electricity, the greater the attraction. A discrete Attractiveness Model of demand price is established based on multiplication and competition:

\[ R_{ai} = \exp(\alpha_i) \prod_{n=1}^{m} P_n^{\beta_i} * u_i \]  

In the form: \( R_{ai} \) is the attraction of electricity price for time I to electricity demand. \( \exp() \) is a power function; The fixed coefficient of the power demand of \( I \) is the fixed demand coefficient.

The influence coefficient of \( n \) on demand attractiveness is the coefficient of time.

\( P_n \) is the electricity price of time \( n \), \( n=1, 2, ... M; \)

\( U_i \) is an error term for the electricity price of the time period of \( i \).

\[ S_{ai} = \frac{\left[ \exp(\alpha_i) \prod_{n=1}^{m} P_n^{\beta_i} * u_i \right]}{\left( \sum_{j=1}^{m} \exp(\alpha_j) \prod_{n=1}^{m} P_n^{\beta_j} * u_j \right)} \]  

\[ \xi_{ai} = \frac{\partial S_{ai}}{\partial P_i} \quad \frac{P_i}{S_{ai}} = \beta_i \sum_{j=1}^{m} P_j^{\beta_j} * u_j = \beta_i (1 - S_{ai}) \]  

\[ \xi_{aj} = \frac{\partial S_{aj}}{\partial P_j} \quad \frac{P_j}{S_{aj}} = -\beta_i \sum_{j=1}^{m} P_j^{\beta_j} * u_j = -\beta_i S_{ai} \]

In the formula: \( P_i \) (i=1, 2, ... N) and \( P_j \) represent the price reference values of \( i \) period and \( j \) period respectively. The user adjusts the demand for electricity by responding to the electricity price.
2) The solution of the electricity price matrix 2

Document [13, 14] demand refers to the demand for payment capacity. The demand relationship is influenced by many related factors. Function expressions are as follows

\[ Q = f(P, T, I, P_1, P_2, E, W, X) \]  

(15)

In the form: \( Q \) represents demand; \( P \) represents the price of a commodity; \( T \) is a consumer's preference for goods. \( I \) represents the income level of the consumer; \( P_1 \) is the price of replacement products. \( P_2 \) is the price of complementary goods. \( E \) is the supply of the product in the future. \( W \) is the resource reserve of the product. \( X \) is the other factor. Among the many factors that affect demand, price is one of the most important elements. On the premise that the other factors remain unchanged, the demand for electricity consumption is in inverse proportion to the price. Based on the understanding of user historical peak valley tariff data, document [15] presents a measurement method using elastic matrix to measure the user's response. The self elasticity coefficient \( \rho_{ii} \) of electricity price is defined as a single period response of peak to valley TOU price.

\[ \rho_{ii} = \frac{\Delta Q_i}{\Delta P_i} \]  

(16)

\[ \Delta Q_i = \int_{f_{TOU,i}(P_1, P_2, P_v)}^{f_i(P_i)} f_i(P_i) \, dt \]  

(17)

\[ \Delta P_i = P_{TOU,i} - P_i \]  

(18)

In the form: \( \Delta Q_i \) is the change of electricity price before and after I peak and valley TOU price. \( \Delta P_i \) is the change of electricity price before and after \( i \) peak and valley TOU price. \( P_{TOU,i} \) is time-sharing price of peak and valley in \( i \) period; \( P_i \) did not carry out the electricity price before the peak and valley price in the period of \( i \); \( P_p \), \( P_s \) and \( P_v \) are the electricity prices of peak Pinggu period respectively; \( f_{TOU,i} \), \( t \) \( (P_p, P_s, P_v) \) is the user load at \( t \) time after the implementation of peak valley TOU price. \( f_i(P_i) \) is the user load of \( t \) at the time when the peak valley TOU price is not implemented. It is a function of the \( t \) time price \( P_t \).

If \( \Delta P_i = 0 \) the user elasticity coefficient of \( i \) period is 0.

The \( \rho_{ij} \) is defined as the multi period response of peak to valley TOU price.

\[ \rho_{ij} = \frac{\Delta Q_j}{\Delta P_j} \]  

(19)

In the format, \( i \) and \( j \) represent different periods of time. If \( \Delta P_j = 0 \), the cross elasticity coefficient of users in \( I \) period is 0. Through the above definition, the elasticity matrix of electricity price is solved.

\[ E = \begin{bmatrix} \rho_{11} & \rho_{12} & \ldots & \rho_{1n} \\ \rho_{21} & \rho_{22} & \ldots & \rho_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \rho_{m1} & \rho_{m2} & \ldots & \rho_{mn} \end{bmatrix} \]  

(20)
The number of \( n \) is the number of periods.

The solution of electricity price 3

Literature [12, 14, 15] usually selects the average value of the electricity price and the electric quantity of the peak valley electricity price in the industry, the corresponding period is \( I \), the average electricity price \( p_i \) and the electric quantity \( q_i \) calculation formula of the peak valley time sharing price part are as follows:

\[
\begin{align*}
\frac{f_{gi} + f_{pi}}{q_{gi} + q_{pi}} & = p_{i} \\
q_{i} & = q_{gi} + q_{pi}
\end{align*}
\]

(21)

(22)

In the formula: \( P \) represents electricity sales charges; \( q \) stands for electricity sales; subscript \( f, g \) and \( p \) represent peak periods, valley time periods and peace periods.

The rate of change in electricity and electricity is calculated as follows:

\[
\frac{\hat{q}_i}{q_i} = q_{i2} / q_{i1} \quad i=1, 2, ..., n
\]

(23)

\[
\frac{\hat{p}_i}{p_i} = p_{i2} / p_{i1} \quad i=1, 2, ..., n
\]

(24)

In the form: \( P_{i2} \) is the partial price average of peak valley electricity price in \( i \) of target year. \( P_{i1} \) is the average value of peak valley electricity price in \( I \) months of the base year. \( q_{i2} \) is the average electricity value of peak valley electricity price in the target year of \( i \). \( q_{i1} \) is the partial electricity average value of peak valley electricity price in \( I \) months of the base year.

The model needs to take the historical statistics of the electric power industry for nearly two years to find the elastic coefficient. The user will adjust the electricity price change according to the actual situation. The change of the statistical data of the power industry is the macro performance of the response. This model can not only be applied to the load and tariff formulation in the current electricity market, but also has broad application prospects in the future real-time electricity market in China.

6. Summary

The main content of the power demand side management is how to formulate the peak and valley time price reasonably. For the dispatching strategy of electric vehicles, the establishment of peak valley time price is one of the key points of the research. Electric vehicles change the charging time of electric vehicles according to the change of electricity price, so that the electric vehicle can be transferred as a load. The solution of electricity price is different, and its essence is based on definition. The change of electricity price has changed the influence of consumers on electricity demand. It is necessary to study and formulate TOU price according to the actual situation. Among the many factors that affect demand, the effect of electricity price on electricity consumption will be mainly considered when other factors remain unchanged.

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