ISSN 2616-5667 Vol.3, Issue 1: 8-13, DOI: 10.25236/AJETS.2020.030102

Prediction of Mobile Phone Charging Demand in Public Places Based on Grey Model

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ABSTRACT. *With the development of science and technology, mobile phone has become an indispensable tool. When people go out, they will use a lot of power in public places to charge their mobile phones. Therefore, it is very important to study the impact of mobile phone charging on electricity consumption in public places. In this paper, considering the effective use of mobile phones in China, the frequency of people charging in public places, and the loss of charging energy consumption, we calculated the energy consumption of mobile phone users charging in public places every year from 2012 to 2017. Then Grey Model was applied by collecting the number and capacity data of mobile phones. The results verified its reliability. After that, the model was used to predict the total energy consumption of the phone in public places in the next three years. The impact of the charging consumption of mobile phones on the energy consumption was discussed in detail. In addition, this model can also be used to study the energy consumption of electric vehicles, computers and other electrical appliances, as well as the total energy consumption in public places.*

KEYWORDS: *Mobile phone, charging demand, public places, Grey model.*

1. Introduction

Electronic devices are charged in public places more and more frequently. In the meanwhile, the demand for power outlets and charging stations for charging electronic equipment is increasing significantly. In 2018, the total number of mobile phone users in China has reached 1404 million. It is estimated that the emergency charging demand is nearly 5% [1-2]. So the daily average emergency demand will exceed 50 million times, while the daily charging demand of small city alone will reach more than 100000 times. It is of great significance to optimize the overall efficiency of mobile phones and the cost management of charging equipment [3]. At present, we need to solve the problem of forecasting the demand for mobile phone charging in public places, and further put forward the reference value for the charging of electricity in public places.

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There are many researches on mobile phone charging in public places. The research direction mainly includes charging mode, charging equipment, charging station design and charging model prediction. Some scholars constructed the charging load in two modes: conventional charging and fast charging. Monte Carlo simulation method was used to calculate the charging load curve of a certain scale mobile phone in one day under two modes [4]. In addition, in order to accurately measure the SOC of lithium-ion battery, some scholars took 2200 mA*h polymer lithium battery as the research object. Scholars used different neural network algorithms to train the training group and chose the appropriate parameters to build the neural network [5]. They finally compared the prediction effect and error of the two algorithms. Recent years, mobile Internet transformed social structure and mobile phone changed people's behavior. Moore's law promoted smart phones to become people's information standard, and the big data appeared [6]. Some scholars also found that most people have bad habits of using mobile chargers, but they did not pay attention to this problem in cognitive aspect. The improper use of mobile chargers resulted in energy loss. In the five years from the beginning of 2000 to 2005, the number of mobile phone users in China has been increasing year by year. Using linear regression model, they could predict the change and development of this number in the next five years [7].

The aim of this paper was to study the charging energy consumption of mobile phones in public places by mathematical modeling method. Besides, we planned to predict the trend of mobile phone charging in public places, so as to determine the impact of mobile phone charging on energy consumption in public places. Section 2 of the paper mainly introduces the process of building the model. The third part presents the calculation results and the prediction of charging demand. Section 4 shows the summary and discussion.

2. Mobile Phone Model

2.1 Calculation of Mobile Phone Charging

Mobile phone is an important factor in the increase of public power consumption. We consider the number of mobile phone charging and the energy consumption of each mobile phone charging process to calculate the charging energy consumption of all mobile phones. We define α as the minimum state of charge. It is assumed that when the current percentage of the battery is less than α, the mobile phone user will definitely charge the mobile phone. Therefore, we can get the relationship among the average power consumption of each mobile phone c_{phone}, the battery capacity c, charging loss β of mobile phones. It is shown as follows:

$$c_{phone} = (1-\alpha)\cdot c \,/(1\text{-}\beta)$$

Assuming that the average daily charging times of each mobile phone owner is

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T_{phone} and the average charging possibility in public is P , we can calculate that the average daily public charging times of each mobile phone owner is T_P . Finally, we calculate the average daily energy consumption of each mobile phone user $T_p \cdot c_{phone}$. Considering the number of mobile phone users N_{phone} and the number of days in a year D , we can get the energy consumption of charging mobile phones in public places in a year E_{phone} , as follows:

$$T_p = T_{phone} \cdot P$$

$$E_{phone} = D \cdot N_{phone} \cdot T_p \cdot c_{phone}$$

The growth of battery capacity has an important impact on the increase of energy consumption of mobile phones. Therefore, in the following Grey Model, we calculate the total demand of mobile phones and the total energy consumption in public places.

2.2 Grey Model

People's cognition of various systems is limited, because some of the information in the system is known and the other part is unknown. There is a certain relationship between the information in the system, which is called grey system. In this paper, the number of mobile phones and battery capacity present similar information, so it is such a system. Grey Model is a common method used to predict grey system [8]. In this paper, Grey Model GM (1,1) is used to predict the number of mobile phones and battery capacity. The basic idea of the Grey Model GM (1,1) is as follows: firstly, the original data is translated and processed in such a way that there are certain rules between the data; then according to the data formula, the correlation degree between the factors in the grey system is identified; the rules between these factors are further found, then the corresponding grey model is established, and the relevant equations are constructed; at last we predict the increase of the data in the future. The basic steps of GM (1,1) are as follows:

In the first step, in order to ensure the feasibility of GM (1,1) modeling method, it is necessary to test and process the original data. The original sequence $x^{(0)} = (x^0(1), x^0(2), ..., x^0(n))$ is treated as ratio, and the formula for calculating the level table of the sequence is as follows:

$$\lambda(k) = \frac{x^0(k-1)}{x^0(k)}, \quad k = 2,3,4\ldots,n$$

The second step is to accumulate and generate the original sequence $x^{(0)} = (x^0(1), x^0(2), ..., x^0(n))$, add and process the original sequence. The specific formula is

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$$x^{(1)}(k)=\sum_{i=1}^{k}x^{(0)}(i)$$

The sum of the new series is called $x^{(1)}(k)$

In the third step, the Grey Model GM (1,1) is established, and the specific formula of the model prediction value can be obtained as follows

$$x^{(1)}(k+1)=(x^{(0)}(1)-\frac{b}{a}e^{-ak}+\frac{b}{a}),\ k=1,2..,n-1$$

The fourth step is to test the residual of the results, and calculate the relative residual and stage ratio deviation to determine the accuracy.

3. Conclusion

3.1 Parameter Selection

The parameter α indicates the minimum charging state of the mobile phone. The user will charge the mobile phone in public, because the mobile phone cannot work normally. It is easy to stop the operation under this limit. It is assumed that people will charge the mobile phone when the state of charge reaches 15%, so as to avoid potential failure and damage. Table 1 shows the total number of mobile phones in China from 2010 to 2018 (in millions). Through data analysis, it can be found that the growth trend is obvious, but the growth rate is gradually decreasing.

Table 1 Total number of mobile phones (2010 — 2018)

	2010	2011	2012	2013	2014	2015	2016	2017	2018
Total number of mobile phones/million	62	93	122	145	172	191	209	247	258

T_{phone} indicates the daily charging frequency, about 0.5 times. $P_{phone}=0.46$ indicating the average charging possibility in public places. Then it can be calculated that the daily charging times in public places is 0.23. Table 2 shows the battery capacity of mobile phones from 2010 to 2018 (c_{phone}).

Table2. Battery capacity of mobile phone (c_{phone})

	2010	2011	2012	2013	2014	2015	2016	2017	2018
Battery capacity of mobile phone/mAh	1420	1430	1440	1570	1720	1810	1960	2710	3170

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3.2 Results of Grey Model

Based on the Grey Model, the data was translated. That is, all data minus a certain value. Then, the data matrix and data vector of the grey model were constructed by adding up the sequence in Table 1. According to the basic principle, the Grey Model was obtained:

$$X(k) = 2470e^{0.59\,(k\text{-}1)}\text{-}2451$$

The model was tested, and the predicted value was good. The precision of this model is first grade, so GM (1,1) model could be used to predict the situation of public power consumption. The prediction curve results of the original data and the actual sample curve values are shown in Figure 1.

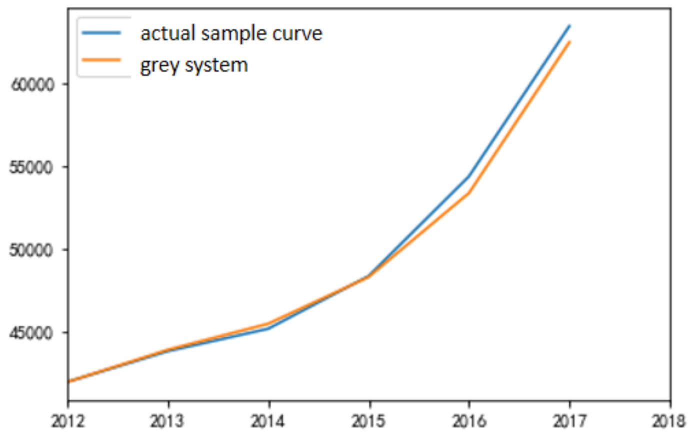

Fig. 1 Actual sample curve and grey system curve of mobile phones' charging in public places

The data from 2018 to 2020 are 78861, 108303 and 161195 respectively. In terms of data, with the rapid development of American society in the next three years, the charging demand will be higher and higher. The results also showed that the prediction model is a medium and long-term prediction method, and the theoretical reliability is relatively strong, so the prediction results are more accurate in theory. In addition, the model is easy to calculate and has strong applicability. It can use limited data to represent the internal behavior characteristics of the system. The calculation results also show that the public charging situation is about to show a rapid growth period.

4. Conclusion

Considering the number of mobile phones and their charging capacity in public

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places, this paper calculates the energy consumption of mobile phone charging in public places for all mobile phone users in one year. By using the prediction model, the charging consumption of mobile phones in public places from 2018 to 2020 is predicted. The influence of mobile phone charging on energy consumption in public places is discussed.

In this paper, the mobile phone users' charging capacity in public places also has some shortcomings. On the one hand, the energy consumption of public places may be caused by charging the portable power supply. So we lack the consideration of charging the mobile phone indirectly. On the other hand, our prediction model assumed that technology will not have a great development in recent years, without considering the possibility that the battery capacity of mobile phones will have a leap forward growth in the next few years. Then we will consider the influence of the above factors on the number of mobile phones and charging efficiency to optimize the model.

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