Research on all-electric vehicles in the U.S. based on equal dimensions grey forecasting method

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Abstract. Due to the influence of environment factors, the world is committed to curbing the use of fossil fuels. Electric vehicles become more and more popular because it uses renewable energy. This essay uses equal dimension grey foresting method to predict whether the trend of all-electric vehicles development can achieve or not. This essay also uses the theory depending on reality to predict the number and the proportion. Finally, we conclude that the U.S. may switch to all-electric vehicles and give advice on how to build electric charging stations.

1. Introduction
Currently, poor energy shortage is becoming increasingly severe in environment and economic with the progress and development of the world. Some problems such as high oil price, high exhaust emissions and unreasonable energy-consumption pattern have limited a healthy development of national economy in countries.

In order to solve the above problems, many consumers begin to buy electric vehicles and some countries propose policies. But the fact whether that electric cars can substitute for gasoline is unknown in the future. Consequently, building a model to forecast the penetration of electric cars is meaningful. The situation in the world is complicated, so wo choose America to make predictions.

2. Notations and assumptions

2.1. Notations

| Symbol | Definition |
|--------|------------|
| a      | Development factor |
| b      | Gray amount of action |
| $t_1$  | The time when the vehicle is fully charged. |

2.2. Assumption
Due to the complexity of the actual condition, we make the following assumptions to make our problems easy.

1. The policy do not have a great impact on the number of the electric vehicles and the electric charging stations.
2. All electric cars which travel at the same distance consume the same amount of electricity. We do not consider different types of electric cars.

3. Equal dimension grey forecasting method

We utilize equal dimension grey forecasting method to make predictions which are the total number of the U.S. electric vehicles. This model uses partially known information to predict the increasing data.

Firstly, the model makes a level test. Let the original data be:

\[ x^{(0)} = [x^{(0)}(1), x^{(0)}(2), \ldots, x^{(0)}(n)] \]  \hspace{1cm} (1)

Calculate the level test:

\[ \lambda(k) = \frac{x^{(0)}(k-1)}{x^{(0)}(k)}, (k = 2, 3, \ldots, n) \]

if \( \lambda(k) \in (e^{-\frac{2}{n+1}}, e^{-\frac{3}{n+1}}) \), it can be predicted.

Secondly, accumulate the original data as:

\[ x^{(1)}(n) = \sum_{k=1}^{n} x^{(0)}(k), n = 1, 2, 3 \ldots t \] \hspace{1cm} (2)

Among them:

\[ x^{(1)}(n) = \sum_{k=1}^{n} x^{(0)}(k), n = 1, 2, 3 \ldots t \] \hspace{1cm} (3)

The establish equations:

\[ \frac{dx^{(1)}}{dt} + ax^{(1)} = b \] \hspace{1cm} (4)

Thirdly, construct a matrix B and vector Z:

\[
B = \begin{bmatrix}
-0.5(x^{(0)}(1) + x^{(0)}(2)) & 1 \\
-0.5(x^{(0)}(2) + x^{(0)}(3)) & 1 \\
\ldots & \ldots \\
-0.5(x^{(0)}(t-1) + x^{(0)}(t)) & 1
\end{bmatrix}
\]

\[
Z = \begin{bmatrix}
x^{(0)}(2) \\
x^{(0)}(3) \\
\ldots \\
x^{(0)}(2)
\end{bmatrix}
\]

Fourthly, solve coefficients using least square method:

\[ x^{(0)}(t+1) = x^{(1)}(t+1) - x^{(1)}(t), t = 0, 1, 2 \ldots, \] \hspace{1cm} (5)

\[ x^{(0)}(1) = x^{(0)}(1) \] \hspace{1cm} (6)

Then we use the prediction formula can easily know the total number of the U.S. electric vehicles is exponential growth.

**Table 1.** The total number of the U.S. electric vehicles

| Year | 2014   | 2015   | 2016   | 2017   |
|------|--------|--------|--------|--------|
| Number | 289000 | 401000 | 550000 | 740000 |
4. Curing Fitting
To further illustrate the U.S. electric cars can be all covered, we curve to fit the total number of cars in the United States.

According to the above two models, we make figure 1. From the figure, the cars overall trend in the U.S. has been declining. The electric cars overall trend in the U.S. has been rapidly increasing. So the U.S. will switch to all-electric vehicles.

| Year | Number($10^8$) |
|------|----------------|
| 2005 | 1.32909        |
| 2006 | 1.35047        |
| 2007 | 1.35222        |
| 2008 | 1.35882        |
| 2009 | 1.32500        |
| 2010 | 1.29053        |
| 2011 | 1.27577        |
| 2012 | 1.20902        |
| 2013 | 1.20984        |
| 2014 | 1.22322        |

Figure 1. The vehicles prediction in the U.S.

5. The distribution of electric charging stations
When the U.S. switch to all-electric vehicles, the country need to build charging stations. However, urban, suburb and rural face complex environments. For example, the population, the number of cars, the area of road and so on. So we need to find the distribution of electric charging stations.

The output efficiency formula of charging pile is clarified:

\[ P_{out} = P_{in} \times \eta \times \cos \phi \]  (7)

Charging station daily can be charged:
\[ num = k \times n \times \frac{16}{t_1} \]  

(8)

\( t_1 \) is the time when the vehicle is fully charged.

5.1. For suburb

The charging piles used in the suburbs are super. By daily reckoning, a fully charged electric car has a range of 450KM. The average daily driving distance of an electric vehicle is 60KM, so the driving time is \( T = 7.5 \) days (one charge per 7.5 days). Online data can be used to determine the time required for full power. The number of rechargeable vehicles per charging pile per day is \( N = \frac{16}{t_1} \).

5.2. For urban and rural

In order to simplify the problem, we only consider the proportion between urban and rural. The proportion of urban and rural population is 21:4, so the proportion of charging stations in urban and rural areas is 21:4.

6. Conclusion

Through equal dimension grey forecasting method, we know that the number of the U.S. electric vehicles is exponential growth. So the electric verticals will replace fossil fuel cars in the future. From an environmental point of view, the whole world will become better and have a wonderful homeland.

References

[1] Information on http://www.tesla
[2] Huanqing Bian, Letian Xia. Population forecast based on the grey maerkefu chain model[J]. The practise and understanding of mathatics, 2012, 42(07): 127-132.
[3] Baoling Duan, Qiang Feng, Dejun Liu, Yushan Bu. Forecast of urban population size based on GM(1,1) model: a case study of Datong. [J]. Journal of Shanxi agricultural university (natural science edition).
[4] Rong X. Reaserch on site selection of electric vehicle chargng station[D]. Capital University. of economics and trade, 2017.3:5.
[5] Qingquan Chen. Current status and trends of electric vehicles[J]. Mechanical manufacturing and automation, 2003(01):1-4+19.
[6] Zhang L. Study on data acquisition and processing system of electric vehicle charging pile based on ARM9[D], North China Electric Power University, 2012.4:10