Transformer Order Demand Forecasting Based on Grey Forecasting Model

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Abstract. For a grey system, the known information is not enough to create an accurate physical model. But there are some rules or characteristics about time series in it. According to the grey system theory, the internal law can be found to a certain extent. According to the grey system theory, the order demand of transformer can be predicted. This prediction model overcomes the influence of the nonlinear relationship and random fluctuation of the system on the prediction accuracy. The experimental data also show that the prediction accuracy of the model is good, and the result is ideal. According to the prediction model, the transformer enterprises can adjust the production plan in time to adapt to the market changes and improve the economy of the transformer. At the same time, for the whole transformer market, timely prediction is also conducive to the state's macro-control of the power industry and promote the development of power construction.

1. Introduction
With the rapid development of China's economy, people have higher requirements for the quality of power system[1]. As an important electrical equipment in power construction, the demand of transformer will also increase[2]. In the future power construction, transformers that can adapt to various complex environments will be more popular. In the past, due to the backward production technology, domestic transformer manufacturers generally introduced foreign excellent production technology in order to improve their basic manufacturing level[3]. Based on the introduction of foreign technology, domestic manufacturers have developed converter transformers[4]. With the discovery of new materials and the progress of manufacturing technology, domestic transformer manufacturers have developed all kinds of transformers to adapt to the future market development[5].

China's power supply and demand are in surplus. In recent years, the growth rate of electricity consumption of the whole society in China has basically maintained at a low level[6]. However, the quality of foreign power consumption is difficult to guarantee, and the State Grid is also cooperating with neighboring countries, hoping to achieve a large-scale interconnection[7]. In the future, when the domestic market is relatively low and the foreign market has great potential, the domestic power enterprises are bound to seize the opportunity to break through the overseas market to obtain greater economic benefits.

Transformer is very important in power system. In the power system, the transformer can reduce the loss of power transmission in the power grid, and when the power is delivered to customers, the transformer can flexibly change the voltage to meet the needs of customers. Therefore, transformer can greatly reduce the
power loss in the power system and improve the economic benefits, which is of great significance in energy conservation, emission reduction and green environmental protection. Therefore, it is necessary to speed up the research and development of new transformers and produce more green transformers.

In the field of low-power electronics, the loss of transformer can often be ignored, and the transformer has inductance. When the voltage changes, the transformer current will also change. In this way, the impedance of the transformer changes to match the fluctuating impedance in the grid. Because the transformer has no direct connection with electricity, it achieves the purpose of voltage transformation through magnetic coupling, that is, electric energy is converted into magnetic energy and then into electric energy. Only changing alternating current can induce alternating current through magnetic field, but direct current cannot. Therefore, in the field of electronics, transformer is often used to isolate direct current and suppress common mode noise.

Domestic transformer customers usually order from fixed manufacturers, whose market structure has been solidified. With the development of economy and the improvement of manufacturing level, the output of domestic low-end transformer market exceeds the demand. In such a market situation, the domestic power industry tends to the huge potential of the foreign market. The focus of domestic transformer enterprises will change from domestic market to international market. By bidding for overseas power projects, we can open up the overseas market and digest our own excess capacity.

At the same time, although the transformers used in the construction of smart grid are more intelligent, many sensors are added and the number is gradually increasing, the underlying framework has not changed. For the transformer manufacturers in China, their innovation ability can keep up with the development of the times. The problem of overcapacity which can not be ignored restricts the development of the industry. If this problem is solved, the whole domestic industry will usher in a new era.

In short, under the domestic one-to-one production mode, its market is nearly saturated. In order to comply with the trend of the times and respond to the call of the state, enterprises will aim at the overseas market. With the construction of smart grid, the requirement of transformer becomes higher. More intelligent, efficient and environmentally friendly transformers will have more market, which challenges the innovation ability of enterprises. Fortunately, intelligent transformer is based on ordinary transformer, and its production technology has not changed greatly. If enterprises do not forge ahead, their living environment will be greatly affected and other enterprises will seize the market.

2. Method

Generally speaking, as long as we know the differential equation and initial value of a thing, we can predict the state of things at any time within the allowable error range. With the development of the times, mathematical statistics is constantly improving. Because of this, we can use fuzzy mathematics and random process to study the motion and state of things. In the field of fuzzy mathematics is to quantify the fuzzy quantity. Therefore, in the study of the variation of uncertainty, we often use the method of grey mathematics to deal with it. Using the existing information to seek the law of development and change of things, dealing with the uncertain grey system to whiten the grey system is the top priority of grey theory. To whiten the data in the grey theory, first of all, we should use the known part of the data to construct the sequence and list the differential equation, solve the parameters in the differential equation, get the time series and analyze the future value. It can deal with poor information system effectively. Grey system can be widely used in various forecasting models, mainly because it has the following advantages: (1) it does not require high samples, and does not need a lot of data. (2) There is no obvious objective law in the sample to establish an accurate physical model. (3) The demand for sample calculation is low and the amount of calculation is small. (4) It can be used for short-term, short-term and medium long-term forecasting.

When the available information is poor or insufficient, the grey prediction model has more advantages than other methods. It only needs less data to complete the prediction. The China's Transformer order data from 2011 to 2018 as follows.
Table 1. China's Transformer order data from 2011 to 2018.

| year | Transformer order (million KV) |
|------|--------------------------------|
| 2011 | 14.3                           |
| 2012 | 14.31                          |
| 2013 | 15.23                          |
| 2014 | 17.01                          |
| 2015 | 16.54                          |
| 2016 | 16.65                          |
| 2017 | 15.9                           |
| 2018 | 17                             |

We suppose there is a non negative primitive sequence.

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

One time accumulation sequence.

\[ X^{(1)} = (x^{(1)}(i), i = 1, 2, \cdots, n) \]  \hspace{1cm} (2)

Establish the following first order differential equation.

\[ \frac{dX^{(1)}}{dt} + aX^{(1)} = u \]  \hspace{1cm} (3)

It can be obtained by solving the above differential equation.

\[ \hat{X}^{(1)}(k + 1) = [X^{(0)}(1) - \frac{u}{a}]e^{-at} + \frac{u}{a}, k = 1, 2, \cdots, n \]  \hspace{1cm} (4)

The grey prediction model of the original sequence is defined as follows.

\[ \hat{X}^{(0)}(k + 1) = (1 - e^{-a}) \left[ X^{(0)}(1) - \frac{u}{a} \right] e^{-ak}, k = 1, 2, \cdots, n \]  \hspace{1cm} (5)

The grey character of the system refers to the uncertainty, randomness and fuzziness of the system. The model of grey system is called grey model, which is called GM model for short. What is hidden in the system has a certain development law and characteristics, which can be clearly revealed by GM (1,1) model, but this law must be continuous in the system.

3. Results and discussion

When transformer order data is acquired, abnormal values may appear at any stage of data generation, recording and transmission due to some reasons. It may be human error data, or it may be the fault of the recording instrument. The superposition of these accidental situations leads to some deviations in the final data. These deviations are unavoidable. There are several reasons leading to the error of prediction model.

(1) Uncertainty of prediction model.

In fact, there are many models to predict a certain sequence, but there is no unified model to predict transformer orders. Standing on the shoulders of other people's research results and using scientific
analysis methods, the model obtained in this way will have some shortcomings due to the lack of their own learning and experience. It leads to errors in the prediction results.

(2) Diversity of influence variables.

The changes of national policy, population and enterprise policy will affect the changes of transformer orders. Due to the diversity of variables, the prediction results will be biased, and the prediction will become complex. In terms of time, the long-term forecast is bound to be inaccurate. In the long-term prediction, with the passage of time, the error will become larger. The short-term prediction itself is difficult, and it is likely that it will not have any significance.

(3) Human subjectivity in prediction.

There must be errors in what people participate in. Relevant people will have subjective judgment on the data processing, selection and correction. The data generated in this way is not objective and scientific enough. In addition, everyone's knowledge and experience are limited, and it is possible to use the wrong method to process the correct data, resulting in prediction bias.

Figure 1 shows that in recent years, the output of transformers in China is increasing as a whole. Because of some factors, it may be expected to decline in a period of time, but generally speaking, it is still on the rise. Generally speaking, in the transformer industry, the ratio of profit to cost is about 1:4. Interestingly, the ratio of pure copper to copper-clad aluminum is also 1:4. This ratio of profits is not difficult for us to see the problems of some industries. Like most industries, the transformer enterprises with large output only account for a few, but have most of the market, while the small and medium-sized transformer enterprises have a large number, but their market share is very small. This pyramid structure is relatively reasonable. Although not all enterprises compete well at the same level, large enterprises can compete well, while small enterprises can also outsource large enterprises and take some small orders to survive. The overall market environment is relatively stable. Due to historical reasons, China's industrialization started later than that of developed countries, resulting in projects with independent intellectual property rights not comparable with those of developed countries. Many large transformer enterprises cooperate with foreign enterprises. After decades of development, China has completed industrialization. Due to the difficulty of production and the rapid development of China's economy, many small and medium-sized transformer enterprises have produced a large number of low-end transformers. This leads to oversupply and overcapacity.
In addition to the most basic error analysis, we also need to make error analysis on the prediction results. The residual test and relative error test are selected here. The residual is the difference between the predicted value and the actual value. If it is an ideal model, the residual is zero and the variance is normal distribution. The smaller the residual, the more accurate it is.

4 Conclusions
Since the reform and development, China's economy has developed rapidly, and China's public infrastructure has been improving. The quality of people's power consumption has been greatly improved. In the past, the phenomenon of power failure and voltage instability has been difficult to appear. At the same time, the state also vigorously supports the power industry to ensure that people enjoy low-cost and high-quality power resources. These measures greatly increase the demand for transformers. The construction of smart grid has a growing demand for new green transformers.

(1) Influence of economic aggregate level on transformer order demand.
People's increasing power demand is closely related to the continuous improvement of social and economic development level. The total economic volume of a country or region determines the scale of power demand. The higher the level of economic aggregate, the faster the growth rate, the higher the demand for power load. As an extremely important branch of total energy production, the higher the level of economic aggregate, the greater the demand for power, so the larger the transformer market space.

(2) The development of transformer industry largely depends on national policies.
The development of transformer industry needs a lot of funds, which are difficult to recover and must be solved by state-owned enterprises. At the same time, the change of power construction will also affect the demand of transformer. Nowadays, the state promotes smart grid and electric power construction, which plays a great role in promoting the development of transformer industry.

(3) Overseas market may become the focus of transformer industry in the future.
The rapid development of China's economy has also brought the problem of overcapacity, when the domestic can not digest the overcapacity, domestic manufacturers will aim at the foreign market. When assisting the infrastructure construction of the third world countries, the state can transfer the excess capacity to the third world countries. At present, domestic transformer enterprises are striving to seize the international market and layout overseas.

(4) Smart grid will also affect the transformer demand.
Smart grid will be the focus of power grid construction in the future. As an important electrical equipment in power system, transformer will also have higher requirements. Traditional transformer can not meet the requirements of smart grid, which requires enterprises to make innovation on the
basis of traditional transformer. Who can make more intelligent transformer will occupy more market.

In a word, the market of transformer industry is broad. Economic development, national policy, overseas market and smart grid construction are friendly to transformer market. In particular, the construction of smart grid is likely to become a new growth force.

In short, under the domestic one-to-one production mode, its market is nearly saturated. In order to comply with the trend of the times and respond to the call of the state, enterprises will aim at the overseas market. With the construction of smart grid, the requirement of transformer becomes higher. More intelligent, efficient and environmentally friendly transformers will have more market, which challenges the innovation ability of enterprises. Fortunately, intelligent transformer is based on ordinary transformer, and its production technology has not changed greatly. If enterprises do not forge ahead, their living environment will be greatly affected and other enterprises will seize the market. To sum up, in order to avoid subjective error caused by human, it requires high quality of relevant personnel to record and process data. This study ignores the influence of other variables on the transformer order demand, and the prediction in the future may have a large deviation due to the influence of a certain factor.

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