Research on Urban Clean Energy System Evolution Model Based on Grey Theory

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Abstract. Energy is an important factor of restricting environmental problems. In order to achieve energy transformation, improve energy utilization efficiency and establish a power supply model based on clean energy, vigorously develop clean energy is an important direction of domestic energy development. This paper constructs a multi-energy load prediction model based on grey GM (1, 1) for urumqi clean energy system and calculates the urumqi as an example of the proposed model. On the one hand, this paper can verify the effectiveness of the model for this problem, on the other hand, this paper can obtain the power generation, power consumption of the whole society, typical daily wind, light output curve and typical daily load curve of urumqi during the "14th and 5th" period, so as to provide references for further local energy planning.

1. Introduction

GM (1, 1) grey prediction model is a dynamic system of quasi-differential equations. The essence of its modeling is to first accumulate the original data and generate the generated data sequence with a certain regularity. Then, by establishing the first-order differential equation model, the fitting curve is obtained to predict the system [1]. This article takes Urumqi as an example and uses the grey forecast GM (1, 1) model to predict the power generation, the whole society's power consumption, typical solar wind, light output curve, typical daily load curve, etc. The corresponding curves are obtained, which proves that the model has operability and certain reliability for similar scenario prediction, and lays a data foundation for future energy storage development and energy utilization planning issues in Urumqi.

Power load forecasting provides the basis for the work of the power system planning, dispatching, and operation departments, and ensures the scientific and safe management of the power grid and the safe and economic operation of the power system. China is a country with a large population and large power consumption. The industrialization process and the pace of urbanization have brought rapid economic growth and a large amount of energy consumption. Accurate ultra-short-term load forecasting information can help power supply companies to conduct reasonable scheduling and science Decision [2-3]. In terms of thermal load forecasting, foreign scholars have conducted in-depth research and are in a leading position. They achieved heat load prediction by considering information such as temperature and user behavior. For example, Arvastson and Erik have established a thermal load prediction model based on outdoor temperature and user behavior [4-5]. Photovoltaic forecasting According to different forecasting methods, photovoltaic output forecasting includes two types: direct forecasting and indirect forecasting. According to different prediction methods, photoelectric output prediction includes two
types: statistical method and physical method [6]. It is of great significance to use the uncertainty theory to study the prediction of photoelectric output, and the expected value or prediction interval of the output can be obtained, so as to provide more valuable reference information for the power system dispatching department [7]. In wind power forecasting, there has been a large amount of research work on wind power at home and abroad. The main research methods include neural network-based wind power prediction methods, non-parametric regression model-based wind power prediction methods, physical-based wind power prediction methods, and cloud-based Wind power prediction methods based on support vector machines [8].

2. Establishment of multi-energy load prediction model based on grey GM (1,1)
GM (1, 1) grey prediction model is a dynamic system of quasi-differential equations. The essence of its modeling is to first accumulate the original data and generate the generated data sequence with certain rules. Then, by establishing the first-order differential equation model, the fitting curve is obtained to predict the system. The advantage of grey system theory is that statistical characteristic quantities do not need to be calculated during modeling, and it can be applied to load index prediction of any nonlinear change, requiring less demand data, ignoring distribution law and change trend, convenient operation, high short-term prediction accuracy, and easy application. The application flow of grey GM (1, 1) model for multi-energy load prediction is shown below.

![Diagram of grey GM (1,1) model](attachment:greyGM_diagram.png)

**Figure 1.** The planning framework of the integrated energy microgrid

Specific steps:
Step1: Given the original sequence \( x^{(0)} = \{x^{(0)}(1), x^{(0)}(2), \ldots, x^{(0)}(n)\} \)
Step2: 1-AGO generate sequence \( x^{(1)} = \{x^{(1)}(1), x^{(1)}(2), \ldots, x^{(1)}(n)\} \)
Where, \( x^{(1)}(k) = \sum_{i=1}^{k} x^{(0)}(i), \quad k = 1, 2, \ldots, n \)
Step3: Generate sequence next to the mean \( z^{(l)} = \{z^{(l)}(2), z^{(l)}(3), \ldots, z^{(l)}(n)\} \)
Where, \( z^{(l)}(k) = \frac{1}{2}(k-1) + x^{(l)}(k)), \quad k = 2, \ldots, n \)
Step 4: Establish the gray differential equation
\[ u(k) + a x(k) = u \]

Where \( a \) and \( u \) are unknown parameters, Recorded as
\[ \hat{u} = \left( \begin{array}{c} a \\ u \end{array} \right) = \left( B' B \right)^{-1} B' y_u \]

\[ B = \left[ \begin{array}{cccc} -x(2) & 1 \\ -x(3) & 1 \\ \vdots & \vdots \\ -x(n) & 1 \end{array} \right], \quad y_u = \left( x(0), x(1), \ldots, x(n) \right) \]

Step 5: Construct the whitening equation
\[ \frac{dx(k)}{dt} + ax(k) = u \]

Step 6: The discrete form of the solution
\[ x(k+1) = \left( x(0) - \frac{u}{a} \right) e^{-ak} + \frac{u}{a}, \quad k = 1, 2, \ldots, n \]

Step 7: 1-AGO Reduction of the sequence
\[ \ddot{x}(k) = \ddot{x}(k) - \ddot{x}(k-1) \]

Step 8: Model accuracy test
\[ e(k) = x(k) - \ddot{x}(k) \]

3. Empirical analysis

3.1. Basic data
In this chapter, Urumqi is selected as an example to verify the above model and draw suggestive conclusions. This section will predict the evolution of Urumqi's urban clean energy system during the 14th Five-Year Plan period based on the constructed clean energy output prediction model and multi-energy load prediction model. The basic data used include basic data on power supply and consumption in Urumqi from 2009 to 2018, and typical daily load curve data of summer and winter in Urumqi from 2012 to 2018, as shown in Table 2-2 and Table 2-3, respectively.

| Year | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|------|------|------|------|------|------|------|------|------|------|------|
| Power generation | 99.87 | 117.79 | 163.39 | 225.11 | 197.14 | 232.32 | 279.98 | 306.14 | 348.15 | 375.65 |
| Electricity consumption of the whole society | 98.54 | 106.98 | 116.89 | 159.24 | 188.81 | 149.87 | 161.64 | 215.04 | 322.84 | 366.4 |
| The largest load | 1483 | 1870 | 2783 | 3736 | 4381 | 5081 | 5467 | 5767 | 6017 | 6300 |
| The minimum load | 826 | 943 | 1174 | 2083 | 2898 | 1709 | 2476 | 3958 | 4511 | 4650 |
| Maximum peak-valley difference | 463 | 571 | 693 | 800 | 729 | 942 | 718 | 1295 | 1131 | 1265 |

| Year | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|------|------|------|------|------|------|------|------|
| Summer | 3000 | 3131 | 3180 | 3348 | 3104 | 3437 | 3759 | 3531 | 3531 | 3391 | 3388 | 3384 | 3427 | 3468 | 3412 | 3409 | 3409 |
| Winter | 3232 | 3270 | 3167 | 3160 | 3149 | 3701 | 3128 | 3263 | 3433 | 3273 | 3239 | 3407 | 3408 | 3369 | 3394 | 3374 | 3362 | 3315 | 3312 | 3433 | 3461 | 3414 | 3437 | 3470 | 3478 | 3560 | 3569 | 3463 | 3463 |

Table 2. Basic data of typical daily load curves in summer and winter in Urumqi from 2012 to 2018
3.2. Assumptions

Based on the above data processing ideas, in order to facilitate the calculation of photovoltaic and wind power output and load in Urumqi, the following assumptions are proposed:

1) The power generation per square meter depends on the photoelectric conversion efficiency of the solar panel. At present, the mainstream photoelectric conversion efficiency level in the industry is about 20.1% for ordinary single crystals and 18.7% -19.1% for ordinary polycrystals. This article assumes that the photoelectric conversion efficiency is 20%, that is, the power generation per unit area is 200W / m².

2) The installed fan parameters are: Consider the wind speed data collection height is 70m, cut-in wind speed is 2m / s, cut-out wind speed is 24m / s, rated wind speed is 13m / s, and rated power is 1500kW.

3) It is reasonable to assume that Urumqi's target year power planning data is shown in Table 3-3.

| Table 3. Urumqi target year power planning data |
|------------------------------------------------|
| Year | Installed type | Capacity (MW) | Proportion |
|------|----------------|--------------|------------|
| 2021 | Thermal power | 12040        | 70%        |
|      | wind power    | 4300         | 25%        |
|      | Photovoltaic  | 860          | 5%         |
|      | Total         | 17200        | 100%       |
| 2023 | Thermal power | 14664        | 65%        |
|      | wind power    | 5640         | 25%        |
|      | Photovoltaic  | 2250         | 10%        |
|      | Total         | 22554        | 100%       |
| 2025 | Thermal power | 16700        | 60%        |
|      | wind power    | 7000         | 25%        |
|      | Photovoltaic  | 4100         | 15%        |
|      | Total         | 27800        | 100%       |

3.3. Forecast results and analysis

(1) Forecast of power generation and power consumption of the whole society

Using the basic data of power supply and consumption in Urumqi from 2009 to 2018 and using the load forecasting model based on gray GM (1,1), the forecast results of Urumqi's 2019-2025 power generation and the whole society's power consumption are shown in Table 2-5 and Figure 2-7.

| Table 4. Forecast results of Urumqi's power generation and the entire society's power consumption in 2019-2025 |
|----------------------------------------------------------------------------------------------------------|
| Indicator | Year | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 |
|-----------|------|------|------|------|------|------|------|------|
| Power generation | | 473.15 | 516.24 | 590.67 | 663.15 | 743.63 | 849.72 | 945.17 |
| Electricity consumption | | 390.74 | 409.58 | 440.62 | 550.14 | 620.36 | 721.64 | 820.31 |

![Figure 2. Forecast results of Urumqi's power generation and the entire society's power consumption in 2019-2025](image-url)
According to Table 2-4 and Figure 2-2, it can be known that from 2019 to 2025, the power generation and the entire society's power consumption in Urumqi will maintain a steady growth, and the power supply and demand will be basically balanced. Among them, it is expected that the power generation in 2021 will reach 596.67TWh, and the entire society's power consumption will reach 409.58TWh; it is expected that the power generation in 2023 will reach 743.63TWh, and the entire society's power consumption will reach 620.36TWh; it is expected that the power generation in 2025 will reach 945.17TWh. The electricity consumption of the whole society will reach 820.31TWh.(2) Maximum and minimum load prediction results of the entire network Using the basic data of power supply and consumption in Urumqi region from 2009 to 2018, and using the load forecasting model based on gray GM (1,1), the maximum and minimum load forecast results of the entire network in Urumqi region from 2019 to 2025 are shown in Table 3-5. Figure 3-3 and Figure 3-4.

**Table 5.** Forecast results of the maximum and minimum loads of the entire network in Urumqi from 2019 to 2025

| Year | Indicator | 2019     | 2020     | 2021     | 2022     | 2023     | 2024     | 2025     |
|------|-----------|----------|----------|----------|----------|----------|----------|----------|
|      | Maximum load | 8003.15  | 9015.17  | 10003.98 | 11236.78 | 12534.96 | 13940.61 | 15794.22 |
|      | Minimum load | 4432.64  | 5910.35  | 6395.48  | 7982.31  | 9135.47  | 10893.11 | 12307.14 |
|      | Peak-to-valley difference | 1407.84 | 1547.49  | 1700.99  | 1869.72  | 2055.18  | 2259.04  | 2483.13  |

**Figure 3.** The maximum and minimum load forecast results of the entire network in Urumqi from 2019 to 2025

**Figure 4.** Forecast results of the maximum peak-valley difference of the entire network in Urumqi from 2019 to 2025

From the above chart, it can be known that from 2019 to 2025, the maximum and minimum loads of the entire network in Urumqi will maintain a natural growth trend, and the difference between the maximum and minimum loads throughout the year will fluctuate around 3500MW. Among them, it is
expected that the maximum load of the entire network in Urumqi region will reach 10003.98MW and the minimum load will reach 6354.48MW in 2021; it is expected that the maximum load of the entire network in Urumqi region will reach 12534.96MW in 2023 and the minimum load will reach 9134.47MW; the maximum load of the entire network in 2025 is expected to reach 15794.22MW and the minimum load will reach 12307.14MW.

(3) Forecast results of clean energy output curves on typical days in winter and summer

The basic data of winter and summer typical daily wind speed and light in Urumqi were obtained using the homer pro software, and wind power and photovoltaic power output prediction models were used. The prediction results of clean energy output for typical winter and summer days in Urumqi are shown in Table 3-6 and Figure 3-5 and 3-6.

**Table 6.** Forecast results of clean energy output curves for typical winter and summer target days in Urumqi

| Year  | 2021 | 2023 | 2025 |
|-------|------|------|------|
|       | wind power | Photovoltaic | wind power | Photovoltaic | wind power | Photovoltaic |
| Time  | Summer | Winter | Summer | Winter | Summer | Winter | Summer | Winter |
| 0     | 2879   | 2937   | 0      | 0      | 3776   | 3852   | 0      | 0      | 4729   | 4825   | 0      | 0      |
| 1     | 2881   | 2940   | 0      | 0      | 3779   | 3856   | 0      | 0      | 4733   | 4829   | 0      | 0      |
| 2     | 2858   | 2942   | 0      | 0      | 3748   | 3859   | 0      | 0      | 4695   | 4832   | 0      | 0      |
| 3     | 2858   | 2942   | 0      | 0      | 3748   | 3859   | 0      | 0      | 4695   | 4832   | 0      | 0      |
| 4     | 2599   | 2935   | 0      | 0      | 3409   | 3850   | 0      | 0      | 4270   | 4821   | 0      | 0      |
| 5     | 2215   | 2916   | 0      | 0      | 2906   | 3824   | 0      | 0      | 3640   | 4789   | 0      | 0      |
| 6     | 1788   | 2465   | 0      | 0      | 2346   | 3233   | 0      | 0      | 2938   | 4049   | 0      | 0      |
| 7     | 1680   | 2356   | 0      | 0      | 2204   | 3090   | 0      | 0      | 2761   | 3869   | 1      | 0      |
| 8     | 1423   | 2090   | 44     | 0      | 1866   | 2742   | 115    | 0      | 2337   | 3434   | 216    | 0      |
| 9     | 1621   | 2290   | 109    | 0      | 2127   | 3003   | 286    | 0      | 2664   | 3762   | 539    | 0      |
| 10    | 1511   | 2180   | 273    | 6      | 1982   | 2859   | 715    | 15     | 2483   | 3581   | 1348   | 28     |
| 11    | 1433   | 2101   | 261    | 104    | 1880   | 2755   | 684    | 272    | 2354   | 3451   | 1289   | 512    |
| 12    | 1054   | 1722   | 385    | 197    | 1383   | 2259   | 1007   | 516    | 1733   | 2830   | 1900   | 974    |
| 13    | 1226   | 1887   | 409    | 334    | 1608   | 2475   | 1071   | 873    | 2013   | 3100   | 2020   | 1646   |
| 14    | 633    | 1856   | 332    | 398    | 830    | 2434   | 870    | 1042   | 1039   | 3048   | 1639   | 1964   |
| 15    | 1201   | 1869   | 645    | 475    | 1575   | 2452   | 1688   | 1242   | 1973   | 3072   | 3182   | 2341   |
| 16    | 1391   | 2058   | 742    | 373    | 1824   | 2700   | 1940   | 977    | 2284   | 3381   | 3658   | 1843   |
| 17    | 1209   | 1885   | 547    | 275    | 1585   | 2472   | 1431   | 720    | 1985   | 3096   | 2697   | 1358   |
| 18    | 1394   | 2069   | 474    | 157    | 1828   | 2713   | 1241   | 410    | 2290   | 3399   | 2340   | 774    |
| 19    | 1773   | 2448   | 432    | 41     | 2325   | 3210   | 1130   | 107    | 2912   | 4021   | 2131   | 203    |
| 20    | 2696   | 2911   | 236    | 0      | 3536   | 3818   | 617    | 0      | 4428   | 4783   | 1163   | 0      |
| 21    | 2868   | 2940   | 78     | 0      | 3762   | 3856   | 204    | 0      | 4712   | 4829   | 385    | 0      |
| 22    | 2866   | 2936   | 0      | 0      | 3758   | 3851   | 0      | 0      | 4707   | 4824   | 0      | 0      |
| 23    | 2877   | 2934   | 0      | 0      | 3773   | 3848   | 0      | 0      | 4726   | 4819   | 0      | 0      |
| 24    | 2879   | 2937   | 0      | 0      | 3776   | 3852   | 0      | 0      | 4729   | 4825   | 0      | 0      |

**Figure 5.** Forecast of typical daily wind power and photovoltaic output curves for Urumqi in the target winter
According to the above chart, it can be seen that with the increase of wind power and photovoltaic installed capacity in each year in Urumqi, the typical daily wind power and photovoltaic output curves move up simultaneously. Wind power output fluctuates in a small range in winter and a large fluctuation range in summer. Taking 2025 as an example, the output range of wind turbine output in winter is 2000MW, and it is close to 4000MW in summer. The photovoltaic power generation peak in summer is significantly higher than in winter and lasts longer. In addition, the wind power and photovoltaic power output curves exhibit obvious time complementary characteristics, and it can be expected that the superimposed curves will be smoother.

(4) Forecast results of typical daily load curves in winter and summer

Using the summer and winter typical daily load curve data from 2012-2018 in Urumqi, and using the gray GM (1,1) load forecasting model, the prediction results of typical daily load curves for winter and summer in Urumqi from 2019 to 2025 are shown in Table 3 -7 and Figures 3-7, 3-8, and 3-9.

| Year | Winter | Summertime | Minimum load | Peak-to-valley difference | Unit: MW |
|------|--------|------------|--------------|--------------------------|---------|
| 2019 |        |            |              |                          |         |
| Winter | 7079.95 | 20:00      | 6479.40      | 5:00         | 600.55 |
| Summer | 6309.39 | 12:00      | 5754.17      | 6:00         | 555.22 |
| 2020 |        |            |              |                          |         |
| Winter | 7865.97 | 16:00      | 7208.67      | 5:00         | 657.30 |
| Summer | 6815.33 | 12:00      | 6216.43      | 6:00         | 598.90 |
| 2021 |        |            |              |                          |         |
| Winter | 8807.18 | 16:00      | 8017.69      | 6:00         | 789.49 |
| Summer | 7361.85 | 12:00      | 6715.82      | 6:00         | 646.03 |
| 2022 |        |            |              |                          |         |
| Winter | 9861.01 | 16:00      | 8911.40      | 6:00         | 949.61 |
| Summer | 7952.19 | 12:00      | 7255.34      | 6:00         | 696.85 |
| 2023 |        |            |              |                          |         |
| Winter | 11040.94 | 16:00      | 9904.73      | 6:00         | 1136.21 |
| Summer | 8589.88 | 12:00      | 7838.20      | 6:00         | 751.68 |
| 2024 |        |            |              |                          |         |
| Winter | 12362.05 | 16:00      | 11008.78     | 6:00         | 1353.27 |
| Summer | 9278.69 | 12:00      | 8451.18      | 8:00         | 827.51 |
| 2025 |        |            |              |                          |         |
| Winter | 13841.23 | 16:00      | 12235.90     | 6:00         | 1605.33 |
| Summer | 10028.87 | 22:00      | 9106.79      | 8:00         | 922.08 |
Figure 7. Forecast results of typical daily load curves in winter in Urumqi from 2019 to 2025

Figure 8. Forecast results of summer typical daily load curves in Urumqi from 2019 to 2025

Figure 9. Forecast results of typical peak and valley differences in winter and summer in Urumqi from 2019 to 2025

Combining Table 3-7 and Figures 3-12, 3-13, and 3-14, from the total point of view, on the one hand, the typical daily loads of winter and summer in Urumqi from 2019 to 2025 increase year by year, and the typical daily loads of winter Overall higher than summer. It is estimated that the typical daily average loads in winter in 2021, 2023, and 2025 will be 8412.02MW, 10397.19MW, and 12851.25MW, with an average growth rate of 11.18%. The rate is 9.01%. On the other hand, the daily peak-to-valley difference in winter and summer shows a gradually increasing trend, which may be due to the continuous increase.
in the type and total amount of electrical equipment for production and living with the improvement of economic level, and the expansion of load fluctuation space.

4. Conclusion
In this paper, by using gray prediction GM (1, 1) model, generation of urumqi region during the period of "difference", the whole society power consumption, the typical Japanese style, light output curve, typical daily load curve is forecasted, and the corresponding prediction curve is obtained, on the one hand, to verify the validity of the model to predict in such questions, at the same time for the urumqi region to the future development of energy storage and energy utilization planning problem set solutions is of great guiding significance, and laid the foundation of certain data.

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