Hurst Index Analysis of Social Electricity Consumption Change Trend Based on R/S Analysis

Xiaodong Qi, Hu Sheng*

School of Electrical and Information Engineering, Dalian Jiaotong University, Dalian, China

*Corresponding author e-mail: hu.sheng@djtu.edu.cn

Abstract. With the rapid development of China's electricity industry, the electricity consumption is also changing with a certain trend. Therefore, it is necessary to study the trend of the power consumption statistics for the whole society in China. In this research, according to 2016-2017 electricity consumption data of China Energy journal and Zhejiang electric power journal is analyzed by R/S analysis method. Hurst indexes are estimated to study the self-similarity properties in different times. The results show that the R/S analysis method can effectively analyze the time series data of electricity consumption, and the calculated Hurst index can better reflect the self-similarity trend of the electricity consumption of the whole society in the future.

Keywords: Hurst index, R/S analysis method, electricity consumption

1. Introduction
At present, China is in the stage of rapid urbanization, which is also a necessary stage of economic development. Urbanization is also a reflection of the degree of economic civilization. With the increasing trend of China's economy, more and more data also reflect a certain trend of change. As an important basis of national economy, electric power is closely related to national economic growth. As a basic enterprise of national economy, the development and progress of electric power basically keep the same trend with the growth of national economy, and the national electricity consumption also properly describes this trend. The electricity consumption of the whole society is affected by many factors, such as the increase of social population[1,2], the change of natural conditions, urban and rural planning and development, economic and financial factors, and so on. Some suggestions are presented that the electricity consumption has self-similarity property, which can be estimated by R/S method[3-6]. By using R/S analysis method of self-affine fractal theory to describe the complexity of non-linear system, we can explain the general laws and nature of a large number of complex phenomena[7,8]. Taking the monthly electricity consumption of the whole society as an example, this paper discusses the trend and change rule of electricity consumption in China by using R/S method.
2. Rescaled range analysis

2.1 Principle of R/S analysis method

In 1965, H.E. Hurst (1900-1978) studied the relationship between water flow and storage capacity of Nile reservoir. It was found that fractal Brownian motion (FBM) can well describe the self-similarity long-term storage capacity of the reservoir. Based on this research results, a rescaled range analysis (R/S analysis) was proposed to establish Hurst index. After continuous research and improvement, most natural phenomena (such as temperature and rainfall) have been found to have self-similarity characteristic. R/S analysis can be used to analyze the fractal characteristics and self-similarity process of time series. It is a fractal statistical method of time series, which is widely used in fractal theory. Hurst index is the core parameter in this theory[6,8,9].

Time series \{x(t)\} (t = 1, 2...) are set M) for any time interval n, if \(1 \leq n \leq m\) is met, the mean value sequence is defined as:

\[
\bar{x}_n = \frac{1}{n} \sum_{i=1}^{n} x(t), 1 \leq n \leq m
\]

(1)

The cumulative deviation is:

\[
X(t,n) = \sum_{i=1}^{t} (x(i) - \bar{x}_n), 1 \leq t \leq n
\]

(2)

The range is:

\[
R(n) = \max_{1 \leq t \leq n} (X(t,n)) - \min_{1 \leq t \leq n} (X(t,n)), 1 \leq n \leq m
\]

(3)

The standard deviation is:

\[
S(n) = \left[ \frac{1}{n} \sum_{i=1}^{n} (x(i) - \bar{x}_n)^2 \right]^{1/2}, 1 \leq n \leq m
\]

(4)

According to formula (2) and formula (3), the range of rescaling is calculated as follows:

\[
\frac{R}{S} = \frac{R(n)}{S(n)}
\]

(5)

When hurst. H.E. analyzed and studied the R/S law, it was found that the average rescaling range values of different time scales were different, and most of the natural laws met the empirical formula[10,11] as follows:

\[
\frac{R}{S} = (cn)^H
\]

(6)

Where C is constant and H is Hurst index.

Take logarithm on both sides of equation (5) to get[12]:

\[
\log (R/S) = H \log c + H \log n
\]

(7)

In equation (7), \log (R/S) is used as the dependent variable and \log (R/S) is used as the independent variable to establish the double logarithmic coordinate system. The image is approximately a diagonal
line, and the slope obtained by linear fitting with the least square method is Hurst index H. H-value describes the core parameters of the long-range correlation of time series. According to the size of h-value, the correlation of time series of things is analyzed to determine whether there is a persistent trend or an anti-persistent trend.

### 2.2 Hurst index

Hurst index reflects the autocorrelation of time series, especially reflects the long-term trend of data. Hurst index has a value range between 0 and 1. According to different values, the relationship between index and trend is also different, including its memory and persistence: When \( H = 0.5 \), the time series are independent, that is to say, the time series can be described by random walk (Brownian motion). Which shows that there is no relationship between the increment of past time and the increment of future time; When \( 0 < H < 0.5 \), the time series has a negative correlation, that is, if the process represented by the past time series is an increasing trend, the future trend will be reduced; Otherwise, if the process represented by the past time series is a decreasing trend, the future will show an increasing trend, indicating the weakening of memory (anti persistence), that is, the mean recovery process. The closer the value of H is to 0, the stronger its anti-persistence is; When \( 0.5 < H < 1 \), the time series has correlation. The process represented by the past time series has the same trend as that represented by the future time series. It shows that the acute enhancement (persistence), that is to say, implies the long-term memory time series.

### 3. Analysis on the change of electricity consumption in the whole society

#### 3.1 Data statistics

According to the national electricity consumption of the whole society released by the National Energy Administration in 2016-2017, the electricity consumption of the whole society and that of some provinces and cities are statistically analyzed. This paper lists the monthly electricity consumption of the whole society in 2016 and 2017, and the electricity consumption of the whole society in Zhejiang Province and Shanghai in each month. Table 1 is the statistical data:

| sequence (n) | time       | whole country | shanghai | zhejiang |
|-------------|------------|---------------|----------|----------|
| 1           | 2016.01    | 4950          | 134.4    | 268.3    |
| 2           | 2016.02    | 3812          | 103.5    | 153.7    |
| 3           | 2016.03    | 4762          | 117.9    | 274.9    |
| 4           | 2016.04    | 4569          | 103.9    | 246.9    |
| 5           | 2016.05    | 4730          | 109.3    | 253.0    |
| 6           | 2016.06    | 4925          | 117.0    | 265.1    |
| 7           | 2016.07    | 5523          | 160.1    | 352.0    |
| 8           | 2016.08    | 5631          | 163.6    | 349.2    |
| 9           | 2016.09    | 4965          | 121.5    | 257.7    |
| 10          | 2016.10    | 4890          | 111.2    | 268.1    |
| 11          | 2016.11    | 5072          | 113.1    | 280.1    |
| 12          | 2016.12    | 5369          | 126.5    | 305.7    |
| 13          | 2017.01    | 4834          | 123.6    | 229.5    |
| 14          | 2017.02    | 4488          | 114.2    | 224.2    |
| 15          | 2017.03    | 5139          | 122.6    | 299.3    |
| 16          | 2017.04    | 4847          | 105.5    | 270.6    |
| 17          | 2017.05    | 4968          | 109.3    | 284.6    |
| 18          | 2017.06    | 5244          | 118.7    | 281.0    |

#### 3.2 Numerical analysis

Electricity consumption of three different regions of China, Zhejiang Province and Shanghai are analyzed in this section. The monthly electricity consumption data from January 2016 to December 2017 are analyzed. According to the above R/S analysis principle, the Hurst index of electricity consumption in each month region is calculated based on the formula in section 3.1. According to different regions, the data in the above table are divided into three parts to draw the image of double logarithm function. As shown in Figure 1-3:
Figure 1. National

Figure 2. Shanghai

Figure 3. Zhejiang
The values of $H$ in different regions are obtained as follows: $H_{\text{whole country}} = 0.5303$, $H_{\text{shanghai}} = 0.9297$, $H_{\text{zhejiang}} = 0.6832$. The $H$ values of the three groups of data are all greater than 0.5, indicating that the time series has self-similarity and persistence, and indicating that the change of electricity consumption in the past and the future time series are positively correlated, whether in the whole country or in different regions. Therefore, we can judge the social electricity consumption of our country has certain sustainability and growth trend according to the value of $H$. The Hurst index is 0.5303, which is close to 0.5 when analyzing the power consumption of the whole society, which shows that its sustainability is not very strong, but a slow trend. Similar to the whole country’s data, the Hurst index of Zhejiang Province is 0.6832, which is also close to 0.5. Its growth trend is relatively slow, slightly stronger than the whole country sustainability. The Hurst index of Shanghai is higher than 0.9, which shows that it has strong sustainability and obvious growth trend.

4. Conclusion
Based on the data statistics of the quantitative analysis of the electricity consumption of the whole society, the R/S analysis method is used to predict the future evolution of the electricity consumption of the whole society. The results show that the growth trend of the electricity consumption of the whole society in China is generally sustainable. Through the analysis of Hurst index, we can predict that the sustainability of electricity consumption growth in China and Zhejiang Province is not strong, while Shanghai shows a strong sustainability. Compared with the actual situation, electricity consumption in China and Zhejiang Province is affected by many factors, with different economic basis, different industrial development speed and different natural resources. As a municipality directly under the central government, Shanghai is China's economic, trade and financial center, its industry, manufacturing and many other enterprises have developed well, and the increasing influx of population and other factors are the reasons for its rapid growth. The results show that the correlation trend of time series is of great significance for future research.

Acknowledgments
The study was supported by “The Doctoral Scientific Research Foundation of Liaoning Province, China (Grant No. 20170520215)”, “Natural science research project of Liaoning Provincial Department of Education, China (Grant No. JDL2019014)”

References
[1] “Energy of China”.1003-2355
[2] “Zhejiang Electric Power”.1007-1881
[3] C. S. Tapiero. “Run length statistics and the Hurst exponent in random and birth-death random walks" Elsevierjournal, 10.1016/0960-0779(96)00032-X, 1996
[4] H. E. Hurst, Black R P.“Long-term Storage of Reservoirs” Trans.Am.Soc.Civ.Eng, 116:770-785, 1951
[5] D. T. Matteo, T. Aste, M. M. Dacorogna. “Long-term memories of developed and emerging markets:using the scaling analysis to characterize their stage of development" Journal of Banking&Finance,29(4):827-851,2005
[6] L. K. Tang.”R / S analysis of sunspot number series”Journal of Huaqiao University, 29(4):627-629, 2008
[7] H. Sheng, Y. Q. Chen, T. Qiu. “On the robustness of Hurst estimators” Signal Processing IET, 5(2):209-225,2011
[8] R. J. Buonocore, T. Aste, T. D. Matteo. Asymptotic scaling properties and estimation of the generalized Hurst exponents in financial data. Phys. rev. e,95(4):0423112017
[9] H. Sheng, H. Sun, Y. Q. Chen,et al. “Synthesis of multifractional gaussian noises based on variable-order fractional operators” Signature Processing,91(7):1645-1650,2011
[10] M. C. Alexiadis, P. S. Dokopoulos, H. S. Sahsamanoglou, et al.”Short-term forecasting of wind
speed and related electrical power” Solar Energy, 63 (1): 61-68, 1998
[11] R. Morales, D. T. Matteo, R. Gramatica, et al. “Dynamical generalized Hurst exponent as a tool to monitor unstable periods in financial time series” Physica A, 391: 3175-3184, 2012
[12] B. Mandelbrot, J. R. Wallis. “Robustness of the rescaled range R/S in the measurement of noncyclic long-run statistical dependence”. Water Resources Res: B, 5 (5): 967-988, 1969