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FORECASTING OF TURKEY'S ELECTRICITY GENERATION AND CONSUMPTION WITH GREY PREDICTION METHOD

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Abstract

The aim of this study is forecasting of Turkey's electricity generation and consumption for the period 2017-2027. To achieve this, Turkey's electricity generation and consumption for the period 1996-2016 was modelled using Grey prediction method GM(1,1). Results showed that the small error probability (p) and posterior error ratio (C) values of GM(1,1) model for Turkey's electricity generation were obtained as 0.12 and 0.97, respectively, and 0.11 and 0.97, respectively for Turkey's electricity consumption. So, the level of established GM(1,1) models for Turkey's electricity generation and Turkey's electricity consumption is in good level. Additionally, mean absolute percentage error (MAPE) values of GM(1,1) models for Turkey's electricity generation and consumption were obtained as 3.12% and 3.08%, respectively. Results of F-test showed that p-value of GM(1,1) model for Turkey's electricity generation and consumption was 0.48. According to these results, GM(1,1) models are suitable for prediction of Turkey's electricity generation and consumption. Furthermore, the average annual grow rates of Turkey's electricity generation and consumption for the period 2017-2027 were forecasted as 5.25% and 5.58%, respectively. In addition to this, Turkey's electricity generation and consumption were forecasted as 405310GWh and 344672GWh, respectively, for 2023.

Keywords: Grey prediction method, Turkey, electricity generation, electricity consumption, forecasting

TÜRKİYE ELEKTRİK ENERJİSİ ÜRETİMİ VE TÜKETİMİNİN GRİ TAHMİN YÖNTEMİ İLE BELİRLENMESİ

Öz

Bu çalışmanın amacı, 2017-2027 yılları arasındaki Türkiye elektrik enerjisi üretimi ve tüketiminin tahmin edilmesidir. Bunu gerçekleştirmek için, 1996-2016 yılları arasındaki Türkiye elektrik enerjisi üretimi ve tüketimi verileri gri tahmin yöntemi GM(1,1) ile modellenmiştir. Sonuçlar, Türkiye elektrik enerjisi üretimi için oluşturulan GM(1,1) modeline ait küçük hata olasılığı (p) ve sonsal hata oranı (C) değerlerinin sırasıyla 0.12 ve 0.97 olduğunu, Türkiye elektrik enerjisi tüketimi için oluşturulan GM(1,1) modeline ait p ve C değerlerinin ise sırasıyla 0.11 ve 0.97 olduğunu göstermiştir. Bundan dolayı, Türkiye elektrik enerjisi üretimi ve tüketimi için oluşturulan GM(1,1) modelleri iyi seviyededir. Buna ek olarak, Türkiye elektrik enerjisi üretimi ve tüketimi için oluşturulan GM(1,1) modellerinde ortalama mutlak yüzde hata (MAPE) değerlerinin sırasıyla %3.12 ve %3.08 olduğu sonucuna ulaşılmıştır. F-testinin sonuçları, Türkiye elektrik enerjisi üretimi ve tüketimi için oluşturulan GM(1,1) modellerine ait p-değerinin 0.48 olduğunu göstermiştir. Bu sonuçlara göre, oluşturulan GM(1,1) modellerinin Türkiye elektrik enerjisi üretiminin ve tüketiminin tahmini için kullanılması uygundur. Ayrıca, 2017-2027 yılları arasında Türkiye elektrik enerjisi üretimi ve tüketiminin yıllık ortalama büyüme oranının sırasıyla %5.25 ve %5.58 olacağı tahmin edilmiştir. Buna ek olarak, 2023 yılı için Türkiye elektrik enerjisi üretimi ve tüketiminin 405310GWh ve 344672GWh olacağı tahmin edilmiştir.

Anahtar Kelimeler: Gri tahmin modeli, Türkiye, elektrik enerjisi üretimi, elektrik enerjisi tüketimi, tahminleme

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1. Introduction

According to data of Ministry of Energy and Natural Resources (ETKB), when total electricity generation of the World occurred as 24097.7TWh, Turkey was ranked in 17th place in the World with having electricity generation value was 261.8TWh at the end of 2015 [1]. According to data of Turkish Electricity Transmission Company (TEİAŞ), Turkey's electricity generation increased from 261.8TWh in 2015 to 274.4TWh in 2016 [2]. And, Turkey's electricity consumption increased from 217.3TWh in 2015 to 231.2TWh in 2016 [3].

Estimation of energy consumption and generation creates data for countries' strategic decisions for long, medium and short-term periods. Along with several estimation methods in the literature, the time series method is simple and therefore has an important place among estimation methods [4]. With this method, forecasting can be made according to a future time by

creating a correlation of past data with respect to time [5]. In the literature, there are many studies that used for estimation of time series analysis of Turkey's electricity consumption [6-10].

One of the time series methods is the Grey prediction method GM(1,1). This method is widely used in that it can be used in cases where there are few and limited data and it can perform high-order prediction [11]. In literature, there are many studies used GM(1,1) method in energy forecasting [8, 11-19].

Hamzacebi and Es (2014) predicted and forecasted Turkey's total electricity consumption. They improved basic GM(1,1) model as direct Optimized Grey Model (OGM(1,1)) and iterative Optimized Grey Model (OGM(1,1)). They tested two improved models for the period 2006-2010. Results showed that values of mean absolute error (MAE), mean absolute percentage error (MAPE) and posterior error ratio (C) were obtained as 5239.31, 3.28% and 0.18, respectively for direct OGM(1,1) and 8662.97, 5.36% and 0.81, respectively for iterative OGM(1,1). Also, they forecasted Turkey's total electricity consumption with using direct OGM(1,1) and iterative OGM(1,1) from 2011 to 2025 [8]. Şişman (2017) used ARIMA and GM(1,1) models to predict Turkey's electricity consumption for the period 1970-2005. He established models of ARIMA and GM(1,1) models to forecast Turkey's electricity consumption from 2006 to 2013. Results of the study showed that the mean absolute percentage error (MAPE) values of ARIMA and GM(1,1) models were obtained as 4.9% and 5.6%, respectively [11]. Feng et al. (2012) used GM(1,1) models to predict China's clean, coal and total energy consumption from 1998 to 2006. Results of the study showed that the accuracies of the GM(1,1) models for clean, coal and total energy consumption were obtained as 97.49%, 95.64% and 95.83%, respectively. Also, the established GM(1,1) models were used to forecast China's clean, coal and total energy consumption from 2007 to 2012 [12]. Kazemi et al. (2011) compared GM(1,1) model with Markov Chain Grey Model (MCGM) for prediction of energy demand of industry sector in Iran from 1990 to 2008. Results showed that MAPE values of GM(1,1) and MCGM model were obtained as 3.65% and 3.61%, respectively. Additionally, the established GM(1,1) and MCGM models were used for forecasting of energy demand of industry sector from 2009 to 2020 [13]. Mostafaei and Kordnoori (2014) used GM(1,1) model and MCGM to predict Iran's total energy consumption and supply from 1992 to 2006. They compared the GM(1,1) model with MCGM for the results of 2007 and 2008. Finally, total energy consumption and supply were forecasted from 2009 to 2021 by MCGM [15]. Akay and Atak (2007) used Grey prediction with rolling mechanism (GPRM) approach to predict and forecast Turkey's industrial sector and total electricity consumption. GPRM model was established for the period 1970-2004. Results showed that MAPE values were obtained as 4.36% and 3.43% for Turkey's industrial sector and total electricity consumption, respectively. Finally, they used GPRM model for forecasting of Turkey's industrial sector and total electricity consumption from 2006 to 2015 [18]. Ayvaz and Kusakci (2017) used various Grey Theory approaches, which are Discrete Grey model (DGM), Optimized Discrete Grey Model (ODGM) and Nonhomogeneous Discrete Grey Model (NDGM), to predict and forecast Turkey's electricity consumption. Established three models were tested for the data from 1970 to 2013 and NDGM was selected as the best method. The selected NDGM was used to forecast Turkey's electricity consumption from 2014 to 2030 [19].

However, studies about forecasting of both of Turkey's electricity generation and consumption with Grey prediction method are limited. The aim of this study is to forecast Turkey's electricity generation and consumption. To achieve this, Turkey's electricity generation and consumption for the period 1996-2016 was modelled using Grey prediction method GM(1,1) and with established GM(1,1) models Turkey's electricity generation and consumption were forecasted for the period 2017-2027.

2. Materials and Method

2.1. GM(1,1) Method

The Grey estimation model consists of five steps in brief [20]:

Step 1: Original numerical sequences $x^{(0)}$ are obtained by observing actual data:

$$x^{(0)} = \{x^{(0)}(1), x^{(0)}(2), x^{(0)}(3), \dots\dots, x^{(0)}(n)\} \quad (1)$$

Step 2: First-order accumulated generating operation $x^{(1)}$ is obtained:

$$x^{(1)}(k) = \{x^{(1)}(1), x^{(1)}(2), x^{(1)}(3), \dots\dots, x^{(1)}(n)\} \quad (2)$$

where,

$$x^{(1)}(k) = \sum_{i=1}^{k} x^{(0)}(i) \qquad k = 1,2,3 \dots, n \quad (3)$$

Step 3: First-order grey differential equation is obtained to establish GM(1,1) model:

$$x^{(0)}(k) + az^{(1)}(k) = b \quad (4)$$

$$\frac{dx^{(1)}}{dt} + ax^{(1)}(k) = b \quad (5)$$

Where, a is the developing coefficient, b is the grey input coefficient and $k = 2,3,4,..,n$. $z^{(1)}(k)$ is calculated by the following equations:

$$z^{(1)}(k) = \frac{x^{(1)}(k) + x^{(1)}(k-1)}{2} \;; \quad k = 2,3,4, \dots, n \quad (6)$$

Step 4: a and b coefficients are calculated by using least square method:

$$[a\ b]^T = [B^T B]^{-1} B^T Y \quad (7)$$

where,

$$B = \begin{bmatrix} -z^{(1)}(2) & 1 \\ -z^{(1)}(3) & 1 \\ -z^{(1)}(4) & 1 \\ \vdots & \vdots \\ -z^{(1)}(n) & 1 \end{bmatrix}, \; Y = \begin{bmatrix} x^{(0)}(2) \\ x^{(0)}(3) \\ x^{(0)}(4) \\ \vdots \\ x^{(0)}(n) \end{bmatrix} \text{ and } [a\ b]^T = \begin{bmatrix} a \\ b \end{bmatrix} \quad (8)$$

Step 5: Obtained a and b coefficients are put in the following equation thus GM(1,1) model is established:

$$\hat{x}^{(0)}(k+1) = (1-e^{a})\left(x^{(0)}(1) - \frac{b}{a}\right)e^{-a*k} \quad (9)$$

Where, $\hat{x}^{(0)}(1)$ equals to $x^{(0)}(1)$.

To classify the accuracy of established GM(1,1) models, small error probability (p) and posterior error ratio (C) parameters are calculated by the following equations.

$$C = \frac{S_2}{S_1} \quad (10)$$

Where, S_1 is the mean square deviation of actual data and $\bar{x}$ is the mean value of actual data which are calculated by the following equations:

$$S_1 = \sqrt{\frac{1}{n}\sum_{k=1}^{n}(x^0(k) - \bar{x})^2} \quad (11)$$

$$\bar{x} = \frac{1}{n}\sum_{k=1}^{n} x^0(k) \quad (12)$$

Where, S_2 is the mean square deviation of predicted data and $\bar{y}$ is the mean value of predicted data which are calculated by the following equations:

$$S_2 = \sqrt{\frac{1}{n}\sum_{k=1}^{n}(x^0(k) - \bar{y})^2} \quad (13)$$

$$\bar{y} = \frac{1}{n}\sum_{k=1}^{n} \hat{x}^0(k) \quad (14)$$

The small error probability (p) is calculated as:

$$p = \frac{1}{n-1}\sum_{k=2}^{n}\left(1 - \left|\varepsilon^{(0)}(k)\right|\right) \quad (15)$$

$$\varepsilon^{(0)}(k) = \left(1 - \frac{\hat{x}^0(k)}{x^0(k)}\right) \quad (16)$$

And, the accuracy of established GM(1,1) model is classified from Table 1.

Table 1. Levels of model's accuracy [12].

Accuracy level	C	p
Good	<0.35	>0.95
Qualified	0.35-0.50	0.95-0.80
Scarcely qualified	0.50-0.65	0.80-0.70
Unqualified	>0.65	<0.70

2.2. Statistical Analysis

The achievement of established GM(1,1) models on prediction Turkey's electricity generation and consumption is measured by calculation of root mean squared error (RMSE), mean absolute percentage error (MAPE) and mean absolute deviation (MAE) values. These values are calculated by the following equations:

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(u(i)-\hat{u}(i))^2}{n}} \quad (17)$$

$$MAPE\ (\%) = \sum_{i=1}^{n}\left|\frac{u(i)-\hat{u}(i)}{u(i)}\right| x\frac{100}{n} \quad (18)$$

$$MAE = \sum_{i=1}^{N}\left|\frac{u(i)-\hat{u}(i)}{n}\right| \quad (19)$$

Where, u is the actual data, $\hat{u}$ is the predicted data and n is the observation data.

Additionally, F-test statistical analysis is used to determine if the model is predictive or not. Results of F-test generate a p-value between actual data and predicted data. When the p-value is higher than 0.05 there is no significant differences between predicted data and actual data, thus the established model is predictable. Johann et al. [21] and Kant and Sangwan [22] used F-test analysis to determine predictability of the established model in their studies. In this study, F-test analysis was done by Excel with F-test Two Sample for Variances analysis tool.

3. Results and Discussions

The actual curve of Turkey's electricity consumption and generation for the period 1996-2016 is given in Figure 1. Data from Figure 1 was used to establish GM(1,1) model for Turkey's electricity generation and consumption.

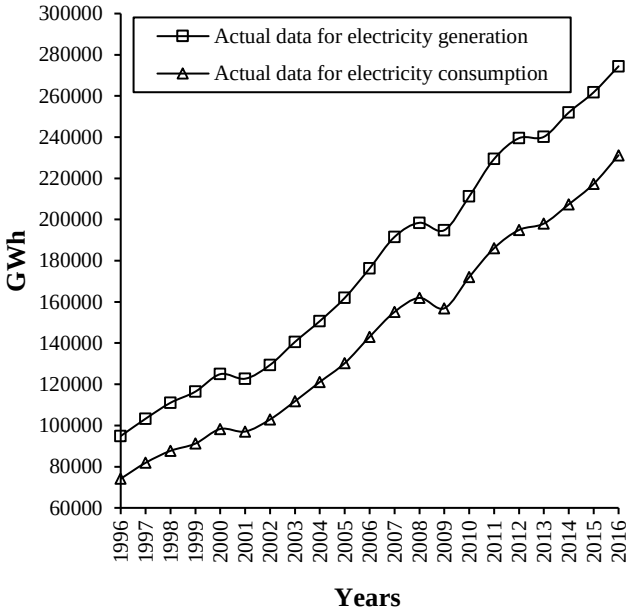

Figure 1. Turkey's electricity consumption and generation for the period 1996-2016 [2-3].

From step 4, a and b coefficients of established GM(1,1) model for Turkey's electricity generation were obtained as -0.05115 and 99647.0, respectively, when a and b coefficients of established GM(1,1) model for Turkey's electricity consumption were obtained as -0.05431 and 77692.4, respectively. Equations of GM(1,1) model for Turkey's electricity generation and consumption are given in the following equations, respectively.

$$\hat{x}^{(0)}(k+1) = (1-e^{-0.05115})\left(x^{(0)}(1) + 1948133\right)e^{0.05115*k} \quad (17)$$

$$\hat{x}^{(0)}(k+1) = (1-e^{-0.05431})\left(x^{(0)}(1) + 1430536\right)e^{0.05431*k} \quad (18)$$

Additionally, p and C values of established GM(1,1) model for Turkey's electricity generation were obtained as 0.12 and 0.97, respectively. These values were obtained as 0.11 and 0.97, respectively, for Turkey's electricity consumption. These results show that the level of established GM(1,1) models for Turkey's electricity generation and Turkey's electricity consumption are in good level according to Table 1.

The values of root mean squared error (RMSE), mean absolute percentage error (MAPE) and mean absolute deviation (MAE) of the established GM(1,1) models for Turkey electricity generation and consumption were given in Table 2. According to these results, established GM(1,1) models for Turkey's electricity generation and Turkey's electricity consumption are successful to prediction of actual data because of having low MAPE values [8, 14].

Table 2. Statistical results between actual data and established GM(1,1) model.

	Electricity generation	Electricity consumption
RMSE	6617.06	5219.54
MAPE (%)	3.12	3.08
MAE	5570.27	4396.36

Furthermore, F-test analysis between GM(1,1) models and actual data was done. Results show that p-value of GM(1,1) model for Turkey's electricity generation and consumption was obtained as 0.48. These results show that GM(1,1) models are suitable for prediction of Turkey's electricity generation and consumption from 1996 to 2016.

Figure 2 presents forecasting of established GM(1,1) models for Turkey's electricity generation and consumption from 2017 to 2027. These results show that annual grow rate of Turkey's electricity generation and consumption will be 5.25% and 5.58%, respectively. Also, Turkey's electricity generation and consumption were forecasted as 405310GWh and 344672GWh, respectively, for 2023.

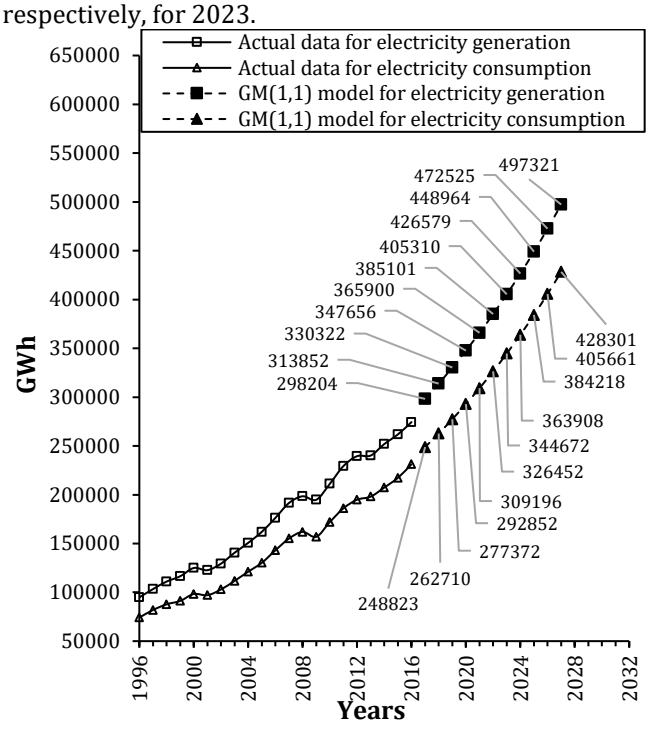

Figure 2. Forecasted data of GM(1,1) model for Turkey's electricity consumption and generation from 2017 to 2027

Figure 3 presents a comparison between the present study and other studies for forecasting of Turkey's electricity consumption. Results show that GM(1,1) model of the present study is closer to direct OGM(1,1) of Hamzacebi and Es's study [8] for Turkey's electricity consumption from 2017 to 2023. Additionally, results of the F-test analysis show that p-values between the present study and the other studies are higher than 0.05 which means that there are no significant differences among the results. So, it can be said that GM(1,1) model of the present study is consistent with the other studies [8, 19] for forecasting of Turkey's electricity consumption.

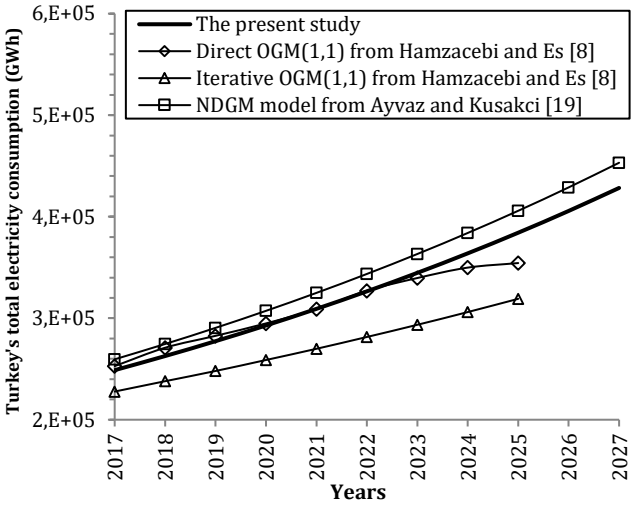

Figure 3. Comparison between the present study and other studies for forecasting of Turkey's electricity consumption

Figure 4 presents a comparison between the present study and other study for forecasting of Turkey's electricity generation from 2017 to 2027. It is obvious that the present study gives higher values than the quadratic model of Akpınar et al.'s study [23]. Also, results of the F-test analysis show that p-value between the present study and the other study [23] is higher than 0.05 which means that there are no significant differences among the results. So, it can be said that GM(1,1) model of the present study is consistent with the other study [23] for forecasting of Turkey's electricity generation from 2017 to 2027.

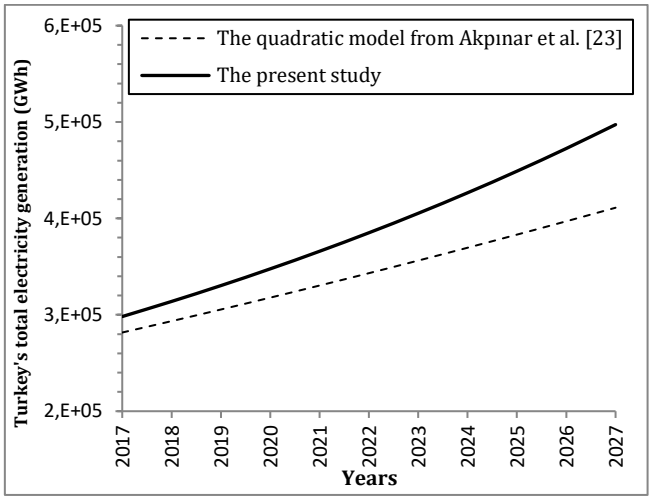

Figure 4. Comparison between the present study and other study for forecasting of Turkey's electricity generation from 2017 to 2027

4. Conclusion

This study presents prediction and forecasting of Turkey's electricity consumption and generation with Grey prediction method GM (1,1). Firstly, data of

Turkey's electricity generation and consumption for the period 1996-2016 was modelled using GM(1,1). Secondly, the established GM(1,1) models for both Turkey's electricity generation and consumption were tested with various statistical parameters. Finally, the established GM(1,1) models were used to forecast Turkey's electricity generation and consumption from 2017 to 2027. Following results were obtained as:

- The established GM(1,1) models for both Turkey's electricity generation and consumption were successful for prediction of actual data for the period 1996-2016 with having mean absolute percentage error (MAPE) value is 3.12% for Turkey's electricity generation and 3.08% for Turkey's electricity consumption.
- Turkey's electricity generation was forecasted from 298204GWh in 2017 to 497321GWh in 2027 which equals to the annual grow rate is 5.25%.
- Turkey's electricity consumption was forecasted from 248823GWh in 2017 to 428301GWh in 2027 which equals to the annual grow rate is 5.58%.

In the following studies, researchers can use GM(1,1) model for each renewable and non-renewable energy resources for Turkey's electricity generation and consumption. Also, results of this study can be compared with using other prediction methods such as Markov chain, autoregressive integrated moving average (ARIMA) or artificial neural network (ANN).

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