Developing an Improved Grey Prediction Model for Application to Electricity Consumption Prediction: Toward Enhanced Model Accuracy

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Abstract—In the economy, one of the crucial trends or processes that play an important role involves electricity consumption prediction. Indeed, forecasting the consumption of electricity with accuracy and precision paves the way for relevant policy makers to establish strategies for electricity supply. Despite this promising and beneficial effect of accurate forecasting, limited variables and data are unlikely to offer adequate data through which satisfactory prediction accuracy might be gained. Due to the need to address this dilemma, this study developed a novel model as an improvement of the grey forecasting model. The proposed framework combined the background value’s interpolation optimization (for the GM model) and the original data sequence’s data transformation. Also, cases studies were conducted to discern the proposed model’s prediction performance. From the findings, the proposed model outperformed most of the other grey-linked frameworks relative to the parameter of forecasting accuracy. Apart from forecasting accuracy, another parameter on which the proposed model exhibited superior results compared to grey modification frameworks and the traditional GM model involves the total electricity consumption. The implication is that the findings were informative and of practical importance whereby they would allow relevant agencies in the electricity sector to develop short-term plans or strategies (due to its electricity consumption prediction accuracy), even in situations where the source data is limited.

1. Introduction

Many factors affect the accuracy and precision of predicting the consumption of electricity [1]. Some of these factors include climatic issues, power facilities, population, and economic development [2, 3]. Hence, most of the electricity consumption’s data sequence is highly uncertain, time-changeable, stochastic, and nonlinear [4]. Given the complexity posed by these predictive factors, the need to predict the consumption of electricity has proved important and urgent for regions and countries [5, 6]. Also, there has been a growing need to develop reliable and accurate electricity consumption forecasting frameworks responsible for offering valuable data [7], lending their application to electricity system operators in terms of formulating plans and policies for electricity [8], hence effective power system management [9, 10].

2. Materials and Methods

As mentioned earlier, this study developed a combined optimized GM model to improve on some of the deficiencies with which the general GM model had been associated. To ensure that the prediction performance of the GM model was improved, hence a new version of the framework, two methods that played a crucial role involved improved calculations of the background value and the modification of the original sequence. Emerging as a novel improved grey forecasting model, the proposed framework combined the interpolation optimization of the background value and the original data sequence’s data transformation. As the modeling progressed, the original data sequence’s data transformation was made before proceeding to the phase of background value optimization. The latter objective was achieved through combination interpolation optimization. The figure below summarizes the initial stages that were used to model the proposed framework.
Figure 1: The modeling of the proposed novel improved grey forecasting framework

Given the original data sequence, data transformation was implemented. Given the logarithm, a constant $c$ was added in the data sequence’s front before acquiring the predicted value and the data sequence’s exponentials in the form:

$$\tilde{x}^{(0)}(k) = \exp(x^{(0)}(k))$$

In turn, the background value was considered and combination interpolation optimization implemented in terms of the trapezoidal formula:

$$Z^{(1)}(k + 1) = \frac{1}{3} [x^{(1)}(k + 1) + x^{(1)}(k)]$$

However, the equation above, from the previous literature, is biased in such a way that the definite integral is estimated. To counter this weakness, this study resorted to the use of the Simpson 3/8 formula in the form:

$$Z^{(1)}(k + 1) = \int_{k}^{k+1} x^{(1)}(t) dt = \frac{1}{8} [x^{(1)}(k) + 3x^{(1)}(k + \frac{1}{3}) + 3x^{(1)}(k + \frac{2}{3}) + x^{(1)}(k + 1)]$$
To estimate the indices, hence the prediction performance of the proposed model (relative to the difference between the predicted and the real values), statistical evaluation indicators that were used included the root mean squared error (RMSE) and mean absolute percentage error (MAPE). These indicators were defined using the equations:

$$\text{MAPE} = \frac{1}{n} \sum_{i=1}^{n} \left| \frac{\hat{x}^{(0)}(i) - x^{(0)}(i)}{x^{(0)}(i)} \right| \times 100\%,$$

$$\text{RMSE} = \sqrt{\frac{1}{T} \sum_{i=1}^{T} (\hat{x}^{(0)}(i) - x^{(0)}(i))^2},$$

The next procedure involved evaluating the proposed model, which was poised to emerge as an improved version of the GM model. The phase culminated into case study analyses involving short-term electricity consumption prediction. Later, the forecasting performance of the proposed framework was compared with that of other models.

3. Results and Discussion

One of the parameters that were investigated and used to determine the performance of the proposed prediction model involved the ability to forecast short-term electricity consumption at a regional level. After the MAPEs were determined, the proposed model yielded decreased prediction error. The error reduction was found to be 11.0%. Hence, the proposed framework was superior. It is also notable that the proposed model exhibited superior simulation capabilities due to its enhanced prediction accuracy. Hence, it was inferred that it, the improved version of the GM framework, is an appropriate tool through which electricity consumption could be forecasted. At this stage, it was evident that the proposed model exhibited superiority in terms of prediction and simulation performance – compared to other prediction models targeting electricity consumption at the regional level.

Given these promising outcomes, the model was applied to a real-world scenario involving data at a regional level. Similar to the previous observations documented above, the case study analysis saw the proposed model exhibit the highest prediction accuracy after being compared with the results reported for six other prediction models. With RMSE values that were obtained, the study established further that the proposed framework had the smallest RMSE, with similar results obtained in relation to MAPE values. Overall, findings demonstrate that the proposed model’s performance is superior to the LR model, as well as five other grey forecasting frameworks. From the findings established after applying the two evaluation indices, the proposed framework, which was in the form of a novel improved grey forecasting framework, exhibits superior performance and the most suitable for application in forecasting electricity consumption.

4. Conclusion and Future Directions

In summary, the GM framework assumes that given the original sequence of data, it (the data) tends to conform to exponential distribution. However, most of the practical data is characterized by approximately inhomogeneous exponential growth. It is also notable that when the background value of the GM framework is calculated, there arises bias that, in turn, alters the prediction performance of the model, hence compromised accuracy and precision of the framework. Hence, this study strived to optimize the GM framework. In particular, the experimental study combined the background value’s combination interpolation optimization with the original data sequence’s data transformation. From the findings, it was established that the proposed model’s prediction performance is superior to that of computational intelligence models and statistical analysis models. Also, the proposed framework’s performance was better than that of other grey modification models; including TGM, RGM, FGM, DGM, NNGM, GPRM, and AGM model.
Based on the observations above, the study inferred that the proposed model is better placed to predict short-term electricity consumption with precision and accuracy. Also, this state of combined optimization proved to be beneficial in such a way that it steered improvements on the GM model’s prediction performance, making it worth applying to other circumstances. However, it is important to acknowledge that if used for the long-term prediction of electricity consumption, the performance of the proposed model could be less efficient, prove superior mostly in situations involving short-term predictions of electricity consumption.

In future, there is a need to incorporate the proposed model into electricity consumption prediction systems. Also, the proposed model needs to be employed to other areas away from electricity. Some of the fields to which the model needs to be applied and implemented include natural gas consumption prediction, business forecasting, peak load forecasting, tourism demand forecasting and GDP forecasting. The latter fields have been proposed for the incorporation of the new model, an improved version of the GM model, because they experience slower changes in general and also have relatively limited source data.

In conclusion, situations, where there is aggressive growth or dramatic fluctuation in data sequence, the proposed model’s prediction accuracy could decrease rapidly. Hence, this study recommends that in the future, improvements should be made to the framework to ensure that it is better placed to accommodate these variations. In so doing, the resultant version might be robust and more efficient and also gain application to long-term prediction without encountering significant challenges or having its feasibility compromised.

5. References

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