Artificial Neural Network Based Grey Exponential Smoothing Approach for Forecasting Electricity Demand in Sri Lanka

D. M. K. N. Seneviratna[1#]
[1]Department of Interdisciplinary Studies, Faculty of Engineering, University of Ruhuna, Galle, Sri Lanka
[#]seneviratna@is.ruh.ac.lk

ABSTRACT The electricity supply of the country has greatly impacted the economy and the nation's standard of living; an accurate forecast of electricity demand is essential for any country to enhance industrialization, farming, and residential requirements and to make proper investment decisions. Therefore, most countries have been allocating and spending significant amounts from their annual budgets on power generation. This current study proposes an Artificial Neural Network (ANN) based approach to forecast electricity demands in Sri Lanka. For model validation, GM (1, 1), Moving Average, and Grey Exponential Smoothing models were used based on electricity gross generation data from 2000 to 2022. The empirical results suggest that the hybrid Grey Exponential Smoothing model is highly accurate under the non-stationary framework.

INDEX TERMS: Electricity Demand, ARIMA, ANN Algorithms and GM (1, 1).

I. INTRODUCTION

Electricity is one of the main essentials for various sectors of a country, such as residential, commercial, industrial, public, agricultural, and transportation to maintain services under high-quality standards [1]. Rapidly growing population and their different needs, extensive urbanization, and industrialization have directly contributed to the increase in the country's electricity demands [2]. Especially, the industrial sector has a direct effect on the country's economic development, job creation, technological advancement, increased productivity, higher incomes, and improved living standards for human beings [3].

Due to the high cost of charcoal, inadequate irregular power supply, unreliable power quality, and lack of energy efficiency, Industrial sectors in Sri Lanka have been facing some unexpected challenges since 2010[4]. For example, during year 2021-2022 period, there were prolonged power cuts across the country to manage the limited power supply [4,5]. This study aims to forecast long-term monthly electricity demand in industrial sectors in Sri Lanka using Grey System Theory (GST) and Machine Learning Approaches (ML).

Based on the literature, various researchers have conducted a range of research endeavours aimed at forecasting electricity demands; Among them, Geometric Brownian Motion [6,7], robust statistical models[8], Machine Learning (ML) [9,10], and Artificial Neural Networks (ANN) approach are significant.

Based on the Univariate Time Series Analysis and Forecasting methods such as Autoregressive Integrated Moving Average (ARIMA) approach [11, 12], Rathnayaka et.al conducted a study to forecast the electricity production and consumption in Sri Lanka [9]. By using different ANN Algorithms, Wang et.al carried out a study to estimate Short-Term Electric power demand [13]. In 2022 Hus et.al carried out a study to forecast electricity by using a self-tuned ANN-based adaptable predictor [14].

Based on the fuzzy logic approach, Xiaohuaa et.al carried out a study to predict energy demands in China[15].In the same time, based on the Grey Markov model with a rolling mechanism, Jinjin et.al carried out a study to forecast energy resources such as natural gas consumption , crude petroleum, electricity and coal in China [16]. Wang et al have done study to forecast electricity consumption of Jiangsu province, china using Dynamic grey models [17]. Liu et.al developed a neural network hybrid approach to solve energy consumption in China [18]. Yao et.al exposed a new automated monitoring control system to forecast short–term electricity power demands in Taiwan [19]. In the modern literature, Recursive Neural Networks (RNNs) based Long short-term memory (LSTM) networks with hybrid algorithms have been widely applied under three different categories to forecast power demand [20].

The current study mainly focused on forecasting Electricity demand in Industrial Sectors in Sri Lanka. The remainder of the paper is structured as follows: Section II provides a concise summary of the methodologies. Section III examines and contrasts the results of Sri Lankan electricity consumption. Finally, Section IV concludes with a discussion and outlines future research directions.

II. METHODOLOGY

In the modern world, the ability to solve complex problems under the rapidly advancing technological landscape has become increasingly dependent on computational technologies; especially, with the numerous interdependent variables and their intricate relationships, solving modern problems surpasses the analytical capabilities of traditional problem-solving methods. These technologies enable us to process vast amounts of data, identify patterns, and generate innovative and practical solutions.

By leveraging advanced tools such as artificial intelligence (AI), machine learning (ML), and optimization algorithms, these technologies enable us to process vast amounts of data, identify patterns, and generate innovative and practical solutions.

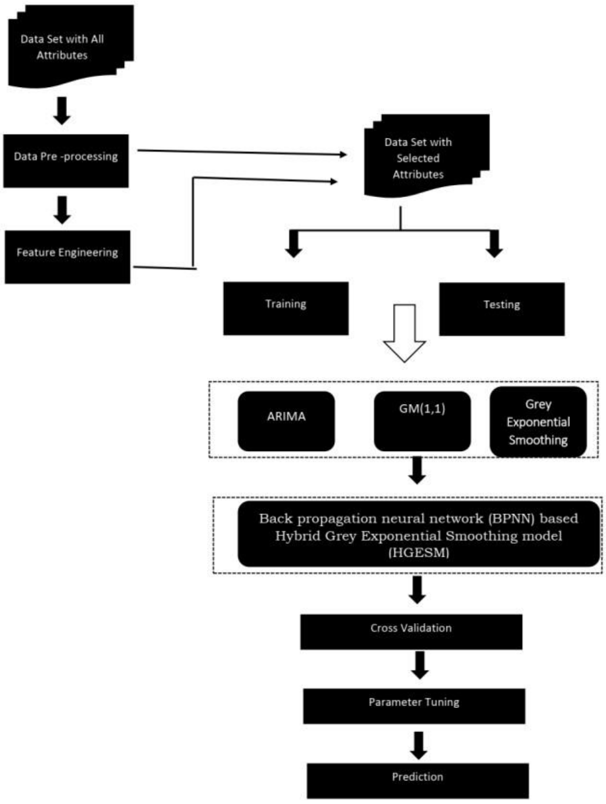

Figure 1: Implementation Methodology

The purpose of this study is to forecast electricity demand in Sri Lanka. The research process involves data extraction, pre-processing, feature extraction, feature selection, and classification stages to achieve effective sentiment analysis. Figure 1 explains the proposed methodology is processed throughout the five major steps as follows [22].

Step 1: Problem Definition and Understanding

Step 2: Data Collection, Preparation and Feature Engineering

Step 3: Algorithm Selection, Model Training and Validation

Step 4: Model Evaluation

Step 5: Documentation and Reporting.

By systematically following these steps, complex problems can be effectively tackled using computer algorithms, leading to robust and reliable solutions [23].

III. RESULT AND DISCUSSION

The electricity demand exceeding its supply is a particular problem faced by most developing countries including Sri Lanka today. Hydroelectricity has played a major role in the power-generating industry in Sri Lanka since the early 1990s [24].

Due to the various types of environmental and maintenance issues, hydropower generation in Sri Lanka has been going down seriously since the 1990s [24]. As a result, the Sri Lankan government has taken different steps. For example, electricity generation has transitioned to mixed hydro-thermal [20, 21].

As a result, the electricity generation of the country has transitioned to mixed hydro-thermal since 1998[20, 21]. In our work, annual power demand data from 2000 to 2022 is investigated. The observations were made from 2000 -2019 and are used for model fitting and 2020-2022 reserved ex-post testing.

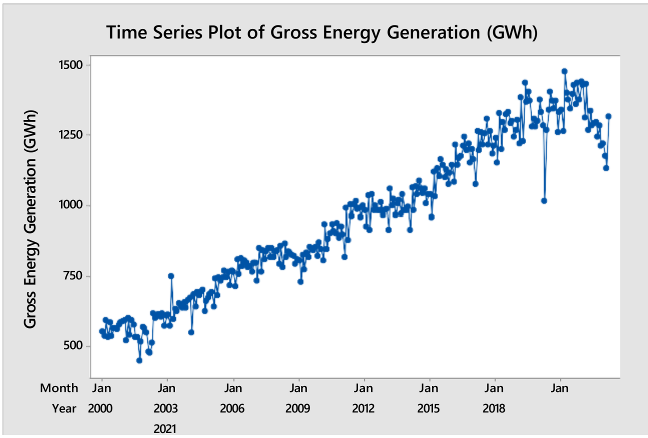

Figure 2: electricity _ Gross generation (MONTHLY)
Sources: Annual Report 2022[22]

According to figure 2, gross energy generation (GWT) of the country has increased rapidly with a significant positive trend with seasonal fluctuations.

A. Autoregressive Integrated Moving Average (ARIMA) Approach for Forecasting and Evaluation of Electricity Demand in Sri Lanka

The stationary levels were measured and summarized as Table 1[7,8].

Table 1: Unit Root Test Result _ Level Data

Method	Level data	1st difference	
	t-statistic	Prob*.	Prob.
ADF statistic	2.364504	0.999	0.0001*
Test critical	1% level	-4.057910	

values:	5% Level	-3.119910	
	10% Level	-2.701103	
PP test statistic	0.243138	0.966	0.00*
Test critical values:	1% level	-3.920350	
	5% Level	-3.065585	
	10% Level	-2.673459	
KPSS test	0.542287		0.224

Table results suggested that the first difference data stationary under the 0.05 level of significance. As a next step, the most appropriate ARIMA model was fitted.

The minimum Akaike info criterion (AIC), Schwarz criterion (SC) and Hannan-Quinn criterion (HQC) criterions suggested that, ARIMA (1, 1, 3) (AIC (0.915704), SBIC (1.104517), and HQIC (8.553372)) is a best model.

B. Hybrid Grey Exponential Smoothing Model (HGESM)

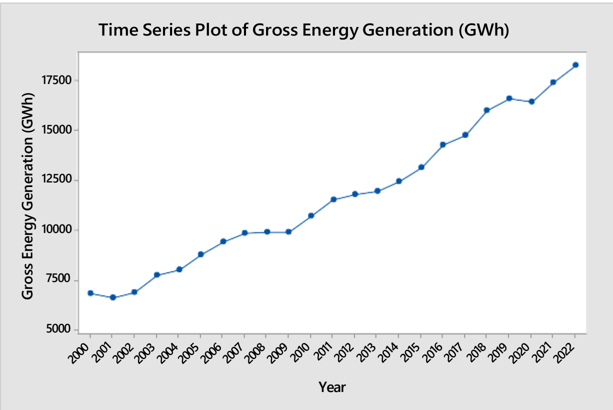

Figure 3: electricity _ Gross generation (Yearly)
Sources: Annual Report 2022[22]

According to the in Figure 3, exponential trend can be seen for electricity gross generation during 2000 -2022.

As a next step, the grey exponential smoothing model runs under the following steps.

Step I

Step I: Original row data series listed as.

$$^{(0)}(k) = [\,6802.8, 6615.2, 6892, \;\dots, \dots] \quad (1)$$

Based on the row data series, the accumulated generating sequence (AGS) is obtained as equation (2).

$$^{(1)}(k) = [\,6802.8, 13418, 20310, 28025.3, \dots] \quad (2)$$

$$^{(1)}(k) = [10110.4, 16864, 24167.65, \dots \dots .]^{T} \quad (3)$$

Step II

The GM (1,1) model can be estimated as equation (4);

$$\hat{x}^{(1)}(k+1) = (x^{(0)}(1) - 399{,}448)e^{-0.02k} + 399{,}448$$
$$k = 1,2,\dots,n \quad (4)$$

Where:Step III

$$[\hat{a}\,\hat{b}]^{T} = (B^{T} B)^{-1}B^{T}Y = [-0.045 \;\; 6626.34]^{T} \quad \text{and}$$

$$B^{T}B = \begin{bmatrix} 3612250121338.5 & -12436049.0 \\ -12436049.0 & 56.0 \end{bmatrix}$$

As a next, Grey double exponential smoothing (GDEM) model estimated as;

$$s'(k) = 1.163\, x^{(r)}(k) + 0.10562 s'(k-1) \quad (5)$$

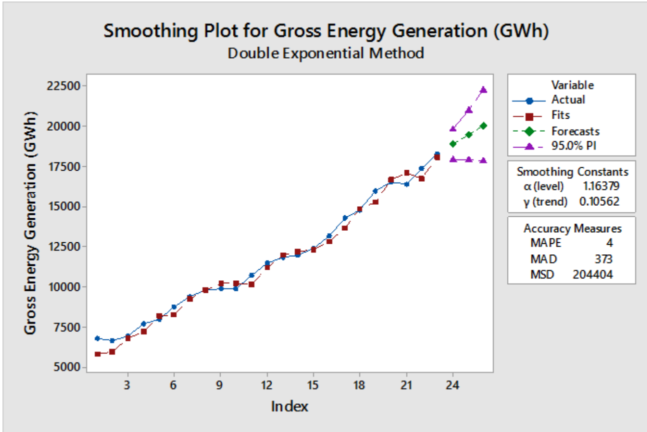

Figure 4: Double Exponential Method

Step IV

Due to the considerable error estimation, the Hybrid Grey Exponential Smoothing model (HGESM) is estimated as equation 06;

$$\hat{X}_e^{(0)}(k) = \hat{X}^{(0)}(k) + \hat{\varepsilon}^{(0)}(k) \quad (06)$$

Where; $\hat{\varepsilon}^{(0)}(k)$ is error estimation of GM(1,1) and HGESM, respectively.

B. Model Comparison

To find the best out-of-sample forecasting performance, three error accuracy measures namely MAD, MSE, and MAPE (%), are used and summarized in Table 3. Two samples from 2018 to 2020 (S_ 01) and 2020 to 2022 (S_02) were considered.

Table 2 : Model accuracy results

Model Accuracy	**Forecasting Accuracy (%)**							
	Moving Average		**Double Exp.**		**GM(1,1)**		**HGESM**	
	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2
MAD (%)	0.24	0.218	0.321	0.111	0.132	0.154	0.062	0.050
MSE (%)	8.17	5.847	12.132	2.034	2.270	3.234	0.480	0.290
RMSE	2.85	2.418	3.483	1.426	1.506	1.798	0.692	0.538
MAPE (%)	0.34	0.312	0.452	0.159	0.187	0.220	0.088	0.071

*denotes the model with the minimum error values

According to the Table 2, the newly proposed Hybrid Grey Exponential Smoothing model is highly accurate (less than 10% MAD and MAPE) than double exponential smoothing models; especially, with non-stationary patterns.

IV. CONCLUTION

Since the introduction of the Lakshapana Wimalasurendra power station in 1965, the Power sector of Sri Lanka has become heavily dependent only on hydropower. It nearly covered more than 50% of the total grid capacity in the national installed power capacity [25,26]. However, the unexpected rising demands in the industrial sector in Sri Lanka have created a serious issue with a large increase in demand for electricity [26]. Furthermore, limited generation potential availabilities of existing hydro plants due to the limited rainfall have been helping to create this problem more seriously. As a result, Sri Lanka has decided to move towards renewable and non-renewable energy sources such as Coal-fired power stations, thermal wind, and solar power for electricity generation since 2010[26].

The current study predicts and analyzes the electricity demand in Industrial Sectors in Sri Lanka. The forecasting results show that the annual demand for electricity in Sri Lanka is expected to increase by 4.9 percent over the next decade.

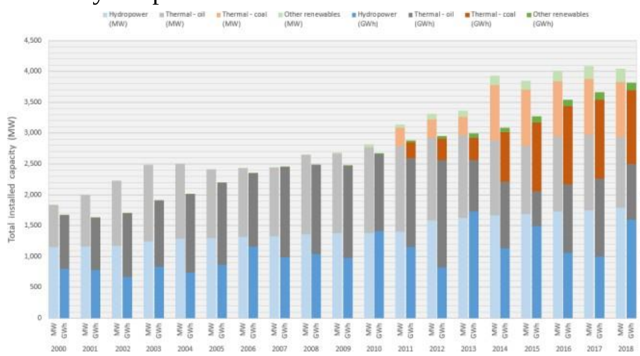

Figure 5: electrical capacity and production of Sri Lanka
Sources: Annual Report 2022[26]

The finding coincides with Ceylon Electricity Board (CEB) statistics published in 2023[26]. Hence, the government should pay urgent attention to adding additional interventions and alternative renewable and nonrenewable energy sources for the national power grid over the next 10 years as early as possible.

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ABBREVIATIONS AND SPECIFIC SYMBOLS

- ANN: Artificial Neural Network
- GESM : Grey Exponential Smoothing model
- HGES:Hybrid Grey Exponential Smoothing
- ML: Machine Learning
- GST: Grey System Theory
- RNN: Grey System Theory
- LSTM:Long short-term memory
- ARIMA: Autoregressive Integrated Moving Average

AUTHOR BIOGRAPHY/IES

D.M.K.N. Seneviratna is working as a Senior Lecturer in the Department of Interdisciplinary Studies, Faculty of Engineering, University of Ruhuna, Sri Lanka. Her research interests include the fields of Time Series Modelling, Data Mining, and Machine Learning.