Forecasting Electricity Demand of Bangladesh and its relation with physical and natural variables using group method of data handling model

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A thesis submitted to the Department of Electrical and Electronic Engineering
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B.Sc in Electrical and Electronic Engineering

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Declaration

It is hereby declared that

1. The thesis submitted is my/our own original work while completing degree at Brac University.
2. The thesis does not contain material previously published or written by a third party, except where this is appropriately cited through full and accurate referencing.
3. The thesis does not contain material which has been accepted, or submitted, for any other degree or diploma at a university or other institution.
4. We have acknowledged all main sources of help.

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Abstract

The purpose of this work is to forecast the electricity demand of Bangladesh using the Group Method of Data Handling (GMDH). Electricity is one of the key variables in ensuring economic growth and a higher standard of life. For a developing country like Bangladesh, it is very important to have a near accurate forecast of electricity demand for future planning. After careful preparation of a time series data set of GDP, GNI, CO2 emission, ambient temperature, the data sheet was fed into the GMDH model and an acceptable forecast was found. GMDH Shell software is used for the application of GMDH algorithm and time series analysis.This purpose is also resolved by deep learning and ANN application.High extensive correlation among features and pre processing could make fruitful in optimal prediction.

Keywords: Data handling , GMDH, time series analysis , ANN, data pre processing.

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List of Acronyms

The following list describes all symbols and abbreviations which will be used throughout the all documents and explanations.

MPEMR - Ministry of Power Energy and Mineral - Resources

BERC - Bangladesh Energy Regulatory Commission

GNI - Gross National Income

PGCB - Power Grid Company Of Bangladesh

DESCO - Dhaka Electric Supply Company

ANN -Artificial Neural Network

GMDH - Group Method Of Data Handling

USD - United States Dollar

GDP - Gross Domestic Products

CART - Classification and Regression Tree

Table of Contents

List of Figures

List of Tables

Chapter 1

Introduction

1.1 Introduction

Bangladesh is a developing country with a large population. With the exponential growth of population, her economy is also rising. Even in the global pandemic where most countries experienced a negative GDP growth but Bangladesh has still managed to maintain a healthy growth rate of 3.8% [1]. Bangladesh has one of the most booming economies in the world. To maintain such explosive growth in the economy, the importance of electricity is undeniable.

Bangladesh has made great progress in the field of electricity generation and supply. There were only 27 active power plants and only 47% of the population had access to electricity back in 2009 [2]. However, in 2020 the number of power plants has risen to 141 and 99% of the population is under electricity coverage. This is a huge stride forward from 2009. This effect can also be observed in the growing economy of Bangladesh. Electricity is one of the key factors in becoming a middle-income country [3].

Electricity being one of the most common forms of energy has become the basic need of human civilization. After the discovery of electricity, human civilization has improved by leaps and bound. The effect of electricity is evident when we look at our current socio-economic structure. From agriculture to heavy industries, everything is dependent on electricity. Moreover, in our daily life we are dependent on electricity. This has not only improved our living standard but also ensured higher income, productivity, education, job opportunities and many more. The needs and benefits of electricity is boundless.

Electricity is one of the key factors in increasing GDP, GNI, which are key criteria of determining a country's growth. GDP as well as GNI is very important for a developing country like Bangladesh. In recent years, Bangladesh is enjoying an era of constant growth in GDP and GNI. We also know that Bangladesh has a large population. Population of Bangladesh is growing at a rate of 1.34% [4]. With such a growth rate in her population and already existing large population, the necessity of electricity is only increasing every single day. The current Government has launched a road map called "Digital Bangladesh 2030". To fulfill this goal, Bangladesh needs to not only provide constant electricity for all her inhabitants but also keep supplying uninterrupted service for her growing population. Only that way Bangladesh can fulfil her ambitious plan. By keeping up with the ever increasing demand of electricity Bangladesh will be able to increase GDP, GNI, Industrialization and that also means that the living standard and wage of general people will also increase. Therefore, we can say that electricity demand and generation are two ever increasing key variables in the development of Bangladesh.

1.2 Overview Of Bangladesh Power Sector

Bangladesh has made a huge stride in the power sector. Back in 2009 there were only 27 power plants, which was inadequate to meet the demand but in 2020 Bangladesh will boast an impressive number of 141 power plants [5]. Bangladesh has a predicted demand growth of 10-12% [6]. To keep up with the increasing demand; Bangladesh has many ongoing projects as well.

1.3 Structure Of Bangladesh Power Sector

The power division of Bangladesh is well structured. Under the Ministry of Power, Energy Mineral Resources (MPEMP), the power sector is divided into regulatory, generation, distribution and transmission sectors. Every sector has their own governing body. This layered structural system has improved efficiency by letting these subsectors

	2009	2020	12 Year edition
No. of Power Plants	27	138	(+)111
Grid capacity(MW)	4,942	24,421	(+)19,479
Highest Generation(MW)	3,268	12,892	(+)9,624
Power Import(MW)	-	1,160	(+)1,160
Total Consumers	1,08,00,000	3,91,00,000	(+)2,83,00,000
Transmission Line(ckt-km)	8,000	12,494	(+)4,494
Distribution Line(km)	2,60,000	5,94,000	(+)3,34,000
Grid Substation Capacity(MVA)	15,870	48,015	(+)32,145
Access to electricity(%)	47	97	(+)50
Per Capita Generation(KWh)	220	512	(+)292
ADP Allocation (BDT Crore)	2,677	26,546	(+)23,869
System Loss (%)	14.33	8.73	(+)23,869

Table 1.1: Power Sector At A Glance, As Of December 2020,

focus on their specific tasks and goals. While it is directly and indirectly controlled by GoB, it has increased participation from private sectors in recent years. As the apex organization, MPEMR has the overall jurisdiction in policy making, implementation, budget allocation and managing the subsectors. "Power Cell", a sub department within MPEMR was created in 1995.

This "Power Cell" acts as the focal point of all power related reformation and reconstruction processes. To help with the process, Bangladesh Energy Regulatory Commission (BERC) was created which started functioning from April 2004 [7]. The main purpose of this commission is to observe and manage the scenario for private investment in the power sector as well as to certify transparency in management, operations and billing in this sector. The goal is to create an environment beneficial for consumers and a level playing market. In the generation subsector, Bangladesh Power Development Board (BPDB) is the overseer. Although, for ease of operation and efficiency, there are four major subsidies under BPDB. They are Ashuganj Power Station Company Ltd. (APSCL), Electricity Generation Company of Bangladesh (EGCB), North West Power Generation Company Ltd. (NWPGCL) and Independent Power Producers (IPPs) [8]. They are responsible for different power zones of Bangladesh. However, responsibility of managing transmission duties is under Power Grid Company of Bangladesh Ltd. (PGCB) [8]. In the distribution sector, again BPDB is the main overseer while Dhaka Power Distribution Company (DPDC), Dhaka Electric Supply Company Ltd. (DESCO), West Zone Power Distribution Company (WZPDC), Rural Electrification Board (REB) through Rural Cooperatives are accountable for selected regions under their jurisdiction [8].

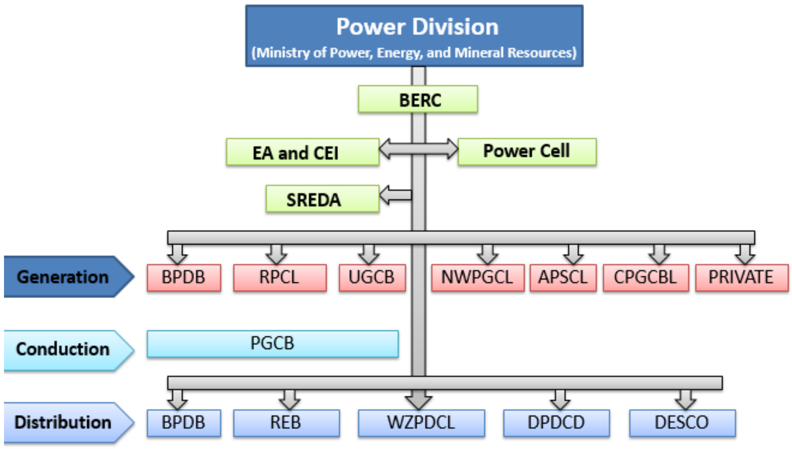

Figure 1.1: Power Structure Of Bangladesh

1.4 Present Scenario Of Bangladesh's Power Sector

A country's national economy depends on its ability to provide enough power to keep up with the demand. Without the ability to fulfill that demand a country is destined to fail. Bangladesh is no exception to that rule and with such extraordinary goals; it is even more valid for Bangladesh. Therefore, to meet the demand, many power plants are being built.In addition to that, emphasis is being given on the prospect of clean energy, namely solar power. A new division has been created to oversee the opportunities and management of solar power. Sustainable and Renewable Energy Development Authority (SREDA) is responsible for this sector. It started its journey in 2014 under Act-2012 [10]. In its short history, SREDA has already amassed many achievements under her belt. This is one of the major reformations of Bangladesh's power sector in recent years. With its goal to reduce carbon footprint and extension of renewable energy by reducing dependency on fossil fuel, it is a major change from our previous view on power energy development.

However, Bangladesh is also building many fossil fuel based power plants in addition to the grand 2,160 MW Ruppur Nuclear Power Plant. Budgets have been allocated for 22 new power plants and are in the early stage of evaluation or already started preliminary works [11]. NWPGCL alone will see its generation capability increased by 7187.6 MW by 2028 as their 6 new ongoing power plants are almost completed [12]. In addition, they have four other power plant projects in the pipeline, which will further increase generation capacity by 1275 MW [13]. Moreover, many of these ongoing and future projects are based on clean renewable energy. This is ironclad evidence of improvement and diversity in the power sector.

1.4.1 Generation and Demand

Bangladesh has been plagued by scarcity in power supply for a long period. However, in recent years supply has exceeded the net demand. The installed generation capacity as of today is 24,421 MW. This is an astounding number when compared to a meager 4,942 MW in 2009. Such numbers also represent that the generation is growing by approximately 10% per annum. This also means that per capital electricity generation has grown from 220 kWh to 512 kWh.
Moreover, in 2009 only 47% of the population had access to electricity, whereas now that percentage is as high as 97%. Furthermore, 1,160 MW is imported from India under a power trade deal. Although, this might seem like there is little scope for development in the power sector but that is not entirely true. Bangladesh is aiming to be a High Income State by 2041 with poverty being absent altogether [14]. With such a lofty goal, the challenge now is to meet the demand and keep improving. A chart is shown below on projects to be completed within 2025.

Bangladesh has decommissioned five Power generation facilities as of

Year	2020(MW)	2021(MW)	2022(MW)	2023(MW)	2024(MW)	2025(MW)	Total
Public	2456	2139	981	3621	2400	1975	13572
Private	1063	150	3109	757	590	1240	6909
Power Import	0	0	1496	0	0	0	1496
Total	3519	2289	5586	4378	2990	3215	21977

Table 1.2: Year Wise Generation Projects To Be Completed Within 2025

2020. There are other facilities, which are coming to an end of their life cycle. Decommissioning those power plants will create a void in the existing capacity of power generation. In addition, as many of the power generation units have become old, their operational capacity has also deteriorated. The installed capacity by different types are shown in below figures 1.2 and 1.3.

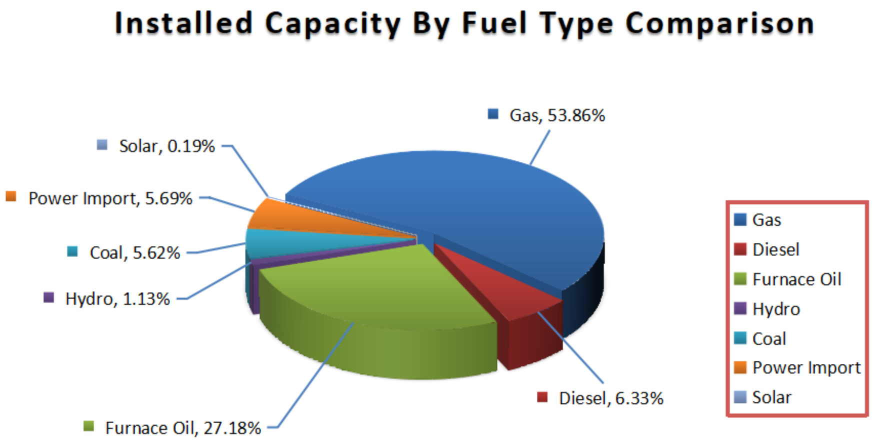

Figure 1.2: Installed Capacity By Fuel Type (FY2019-20)

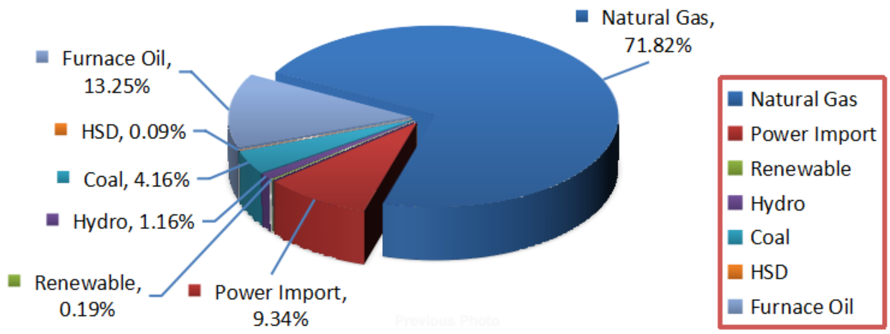

Figure 1.3: Installed Capacity By Plant Type (FY 2019-20)

1.4.2 Energy Generation

The Power Sector now enjoys public as well as private participation. As a result, a big portion of electricity generation is coming from private sectors. In FY 2018-19 a net of 70,533 MkWh was generated from public and private sectors combined. In FY 2019-20 (till January 2020) total net generation from public and private sectors including imported power is 41,848 MkWh. 52.34% of the total net generation is provided by public power plants while 37.92% came from private power plants. In addition, 9.74% of power was imported during that time [15]. Natural gas is the primary fuel type for generation portraying 71.15% of total generation, while hydro 1.46%, Coal 3.11%, Import 9.74%, Liquid fuel 14.45% and Renewable energy is accounted for 0.08%. Sector wise and Fuel net generation is FY 2019-20 (till January, 2020) is shown in Figure 1.4 and 1.5.

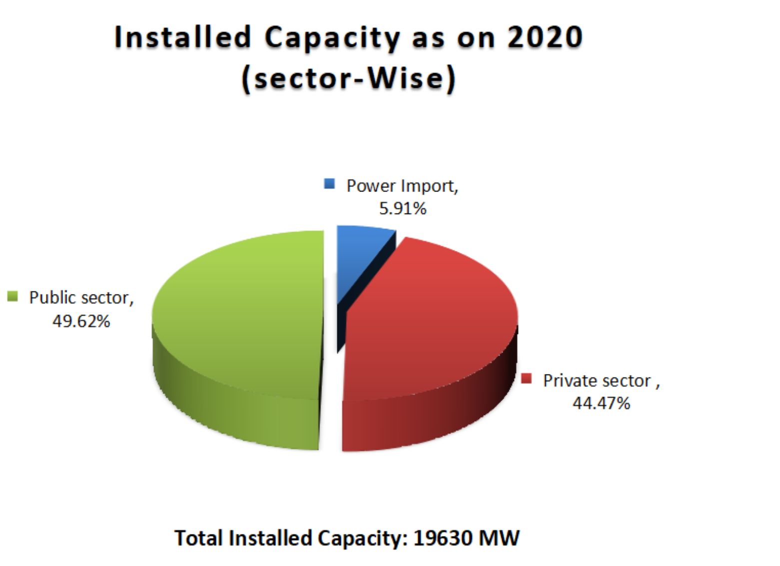

Figure 1.4: Energy Generation By Sector Wise (FY 2019-20)

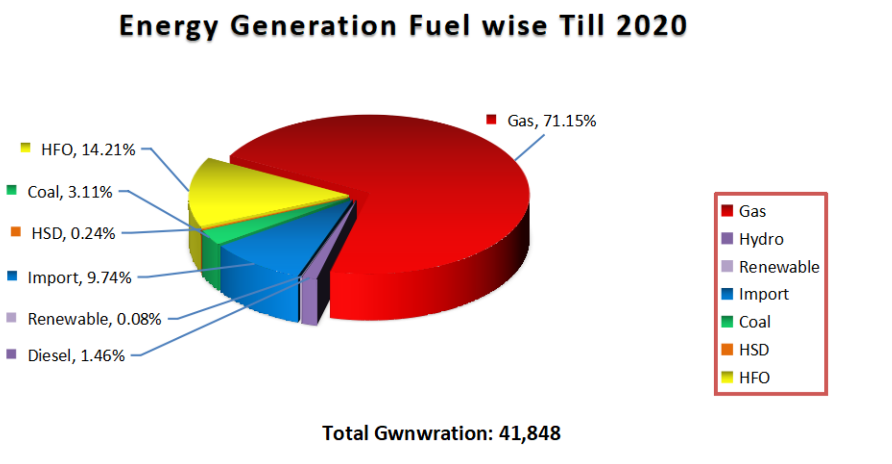

Figure 1.5: Energy Generation By Fuel Type (FY 2019-20)

1.4.3 Maximum Power Generation

Before 2009, Bangladesh was going through a severe shortage of power. However, in the last decade, the scenario has improved and now generation capacity has surpassed the net demand. Although, even after having the ability to generate sufficient power, it is difficult to supply all of it to the consumers due to distribution and transmission constraints. The table below shows the installed capacity and maximum generation by fiscal years.

Fiscal Year	Installed Capacity (Grid) (MW)	Maximum Generation (MW)
2000-2001	4,005	3,033
2001-2002	4,234	3,218
2002-2003	4,680	3,428
2003-2004	4,680	3,592
2004-2005	4,995	3,721
2005-2006	5,245	3,783
2006-2007	5,202	3,718
2007-2008	5,305	4,130
2008-2009	5,719	4,162
2009-2010	5,823	4,606
2010-2011	7,264	4,890
2011-2012	8,716	6,066
2012-2013	9,151	6,434
2013-2014	10,416	7,356
2014-2015	11,534	7,817
2015-2016	12,365	9,036
2016-2017	13,555	9,479
2017-2018	15,953	10,958
2018-2019	18,961	12,893

Table 1.3: Installed Capacity (Grid) And Maximum Generation

1.4.4 Load Shedding And System Loss

In historical years, Bangladesh suffered from significant load shedding. Although, the situation has improved but load shedding is not completely eradicated as of yet. Most of the powers generated are being supplied to the capital and the economic hubs. As a result, domestic areas are suffering from regular load shedding even today. Even after giving utmost priority, Dhaka and other major commercial and industrial zones still suffer from load shedding.
Although power generation has surpassed net demand, this is happening because of many shortcomings in transmission and distribution systems. High system loss accounts for much of the load shedding scenarios. In 2009, distribution system loss was 14.33% and in FY 2019-2020 distribution system loss was 8.73%. Although, system loss is decreasing but still inadequacy in transmission and supply, high system loss is present.

1.5 Effects Of Electricity On Economy, Nature, Population

Electricity is one of the primary indicators of a country's economic and living standard. However, blindly increasing generation capability without giving any regard for the environment will lead to a disaster. Electricity is most definitely important but we must consider all the pros and cons that comes with it.

1.5.1 Effect On Economy

Electricity is the key variable in improving socio-economic conditions and upgrading the living standard of the population. In accordance with "Vision 2041" Bangladesh needs to keep up continuous GDP growth of 7.4% till 2025 to become a higher middle earning or a high earning country [16]. Most of Bangladesh's GDP comes from RMG export. The RMG sector and other industrial sectors are completely dependent on electricity. Nowadays even agriculture is largely dependent on electricity (irrigation). Be it domestic or foreign, the effects of electricity on the economy is immeasurable.

1.5.2 Effect On Nature

Most of the power plants are fossil fuel based. Some power plants are very old as well. With the increase in power plants, carbon emissions have also increased. Carbon dioxide (CO2) is one of the main culprits behind global warming and Ozone layer depletion. As most of the power plants are fossil fuel based and more are being build; these power plants will have a diverse effect on the environment. Increased pollution from these plants will cause global warming and as a result terraform this area's atmosphere. We can see that the ambient temperature and weather has changed from what it used to be [17]. Without the adaptation of clean energy and modern technology, Bangladesh run a risk of being uninhabitable due to increased pollution.

1.5.3 Effect On Population

Human kind is dependent on electricity. The dependency has grown to such an extent that it has to be considered as the basic need of an individual. Entertainment, communication, health care, education, industries, commercial zones, and home appliances are all dependent on electricity. Bangladesh has a large population and a growth rate of 1.34% [4]. Electricity is of utmost importance for a country with such a large population. Increasing population means increasing demand and to reach the lofty goal of "Vision 2041", electricity is immensely important. It will not only upgrade the living standard but also help increase income of individuals by helping the economy.

1.6 Projection Of Future Demand

Power System Master Plan – 2016 (PSMP) has shown that the desirable average GDP growth rate of 6.4% and peak demand growth in each scenario is 7% p.a. To attain economic development and increase access development in electricity is also required. According to PSMP-2016, the net demand forecast is given below:

Year	Electricity Growth Rate	Total Demand without EE & C
2015	8.3%	8,920
2016	8.9%	9,713
2017	9.1%	10,601
2018	9.4%	11,597
2019	9.7%	12,717
2020	10.2%	14,009
2021	9.9%	15,390
2022	9.6%	16,861
2023	9.3%	18,423
2024	9.0%	20,074
2025	8.7%	21,813
2026	8.4%	23,638
2027	8.1%	25,545
2028	7.8%	27,529
2029	7.5%	29,586
2030	7.2%	31,709

Table 1.4: Peak Demand And Growth Rate Based On PSMP-2016

1.7 Objective

Electricity demand and generation is of utmost importance. It is imperative for a country to have realistic demand forecast for better administration and efficient allocation of its resources. This is even truer for a country like Bangladesh. Bangladesh has embarked on the bullet train of modernization and economic growth.
To face the challenge head on,Bangladesh need reliable demand forecast for better planning and efficient resource allocation. Through this research, we aim a new approach to develop a demand model and predict short-term demand requirement. The objectives of this research are:

- To develop a reliable model for predicting future demand of Bangladesh.
- To forecast electrical demand based on the model.
- To find out further improvement scope based on the outcome of the research.

1.8 Organization

Altogether, there are six chapters in this report. The particular organization of the contents of this report as follows:

Chapter 1 provides an overview of Bangladesh Power Sector, the organization, plans, and effects of electricity on socio-economic situation and projection of future demand. This chapter also contains the motivation and objective of this research.

Chapter 2 contains several factors that influence the demand and related work done on forecasting.

Chapter 3 provides the main ideas behind this research work. The method that was used and its theoretical background, advantages and disadvantages.

Chapter 4 says the type and source of the data, problems regarding the data and necessary modifications.
Chapter 5 is Result analysis. In this chapter, outputs of the GMDH model is provided. Different graphical representation of the output is also given. Proper error calculation also shown in this chapter.
Chapter 6 is the conclusion based on this analysis. Difficulties faced during the research, limitations, future scope are discussed in this chapter.

Chapter 2

Review Of Demand Modeling And Related Works Done In Forecasting

2.1 Introduction

Nowadays, electricity is a public commodity. There are multiple factors influencing the demand factor also due to increased demand some other related factor are influenced. Before modeling, these factors have been carefully considered and analyzed. In this chapter, the factors influencing the demand and factor influenced by demand are briefly discussed. This chapter also shows related works done in this field.

2.2 Factors Influencing Electrical Demand

2.2.1 Economic Factors

Income influences the demand by a large margin. This economic factor is one of the main driving forces behind demand. Price of electricity is also important but as electricity is a daily commodity and there is no replacement for it, increase in price will not change demand by a large margin. GDP represents the total market value of all finished goods and services provided within the country within a set period of time. This is the universally accepted indicator of a nation's economy. GNI is the total income received by a country from its resident and businesses regardless of area. Bangladesh earns a large amount of money from remittance. It is well known that one of the biggest contributor in Bangladesh's economy is its labor force in foreign countries. This is why GNI cannot be excluded while considering economic factor. It is simple enough to understand that higher income means higher purchasing power [18-23].

2.2.2 Environmental Factors

Climate and weather plays an important role in the usage of electricity. Demand of energy is largely dependent on the state of weather [24-25]. In summer, temperature is higher than normal and that increases demand. Comparatively in winter, electricity demand in homes are generally lower due to low temperature. In Bangladesh, electricity demand and bills are generally higher in summer than in winter. Warmer weather means more use of energy in operating fan, cooler, ac etc. It is safe to say that electricity demand is dependent on humidity, temperature, and wind speed, global warming and future demand will be affected by ambient temperature [26-28].

2.2.3 Population Factor

Population plays an important role in electricity demand. With the increase of population, demand is sure to increase in all sectors. However, their demographic effect on energy should be considered. The study of human population; namely their size, composition, distribution and the process of population change altogether is known as demography. Household composition, members, economic state, location, all of these factors are responsible for change in electricity demand. Although, for this research linear relation with the number of population has been considered [29-31].

2.2.4 Technology

Technology plays an important role in demand variation. Newer, more efficient, low power demanding machinery and home appliance have a direct role in the variation of demand. World is continuously researching in energy efficient electrical products. Widespread and groundbreaking advancement in this sector will mean decrease in energy demand. As, more work can be done using less energy [32-33].

2.2.5 CO_2 Emission Factor

To meet the increased demand, many power plants has to be built. Most of the power plants in Bangladesh are fossil fuel based. Fossil fuel based power plants emits a large quantity of CO2 in the atmosphere. Furthermore, increase in energy usage also means increase in carbon emission. A research done in Ghana sows that 1% increase in energy use, GDP, and population will increase carbon dioxide emissions by 0.58%, 0.73% and 1.3% [34].

2.3 Related Work Done In Forecasting

For realistic and creditable forecast, modeling depends on better understanding of data and their relation with the output. Group Method of Data Handling (GMDH) is an evolution of regression analysis and regression analysis. This is specifically prepared for forecasting using historical data. Some research has been done previously on forecasting modeling of future electrical demand.

V. Bianco, O. Manca and S. Nardini used linear regression model to forecast electricity consumption in Italy [35]. Their aim was to establish a relation between economy and demography of Italy and use that data to forecast electricity consumption in Italy.

MahediMasuduzzaman used co-integration and causality to investigate relationship between economic growth, electricity consumption and investment for Bangladesh [36]. Mustafa Yavuzdemir and Fazal-Gokgoz used time series, regression analysis and fuzzy logic technique to estimate gross annual electricity demand of Turkey [37].

Oguz KAYNARR, Halil OZEKICIOGLU Ferhan DEMIRKOPARAN used support vector regression and chaotic particle swarm algorithm forecast Turkey's Electricity Consumption [38]. Xu H., Dong Y., Wu J., Zhao W. made use of GMDH algorithm to forecast short-term load. They have compared their findings with ARIMA model and found that GMDH is a better method for forecasting [39]. Mithiya, D., Datta, L., Mandal, K. made use of ARIMA and GMDH neural network model to forecast oilseeds production in India. GMDH proved to be better at forecasting [40].Amogha A.K showed the feasibility of using GMDH Shell software for implementing GMDH algorithm for load forecasting [41].

Chapter 3

Methodology

3.1 Group Method Of Data Handling

Group method of data handling or GMDH is a modeling method developed by Prof. Alexey G. Ivakhnenko. GMDH uses a neural network type algorithm that specifically learns the relationship among the variable and develop a model. After learning the relation, GMDH can automatically select the best path for reaching desired outcome. It is more efficient and accurate than other models because GMDH can obtain explicit expression [43]. Explicit expression can tell the modeler about the most important variables in the model. GMDH is an adaptive and self-organized model. GMDH, being an adaptive method, can actually accommodate and optimize itself on the basis of data input. Furthermore, a common problem associated with ANN is overfitting, whereas, GMDH, due to its adaptive organizing nature can encounter this problem. This is one of the main reason for us to select this method. In addition, it has been observed that GMDH is better equipped to handle time series data than other existing model, namely ARIMA [40].
The relation between input-output variables can be expressed by Volterrafunctional series, which is Kolmogorov-Gabor polynomial[42]. The equation is given below:

$$y = a_0 + \sum_{i=1}^{m} a_i x_i + \sum_{i=1}^{m} \sum_{j=1}^{m} a_{ij} x_i x_j + \sum_{i=1}^{m} \sum_{j=1}^{m} \sum_{k=1}^{m} a_{ijk} x_i x_j x_k + ...$$

Here, $x = (x_1, x_2, \ldots, x_m)$ is the input variable vector and $A = (a_0, a_1, \ldots, a_m)$ is the vector of weights. Based on this polynomial Ivakgnenko developed a new algorithm by following heuristic and perception type approach by using low pair polynomial for every pair of input

[42]. He found that a second order polynomial could actually recreate Kolmogorov-Gabor polynomial through an iterative perception type polynomial [42]. Ivakhnenko polynomial is given below:

$$Y = a_0 + a_1x_i + a_2x_j + a_3x_ix_j + a_4x_i^2 + a_5x_j^2 ....(2)$$

3.2 Advantages

As GMDH self-organizing modeling method, it can somewhat counter the overfitting problem of other methods. Moreover, it is an algorithm specifically built for forecasting works. GMDH can establish relation between historical data more easily than other existing methods.

3.3 Disadvantages

A particular problem in GMDH is that, even though it is very accurate at modeling time series data and forecasting over a short period of time, its accuracy is lagging over larger period. It might even give completely unrealistic result. In addition, though GMDH can counter overfitting to some extent but increased complexity of dataset can lead to overfitting. GMDH is also highly sensitive to computation time.

Chapter 4

Data Analysis

4.1 Data analysis

This chapter introduces the data related with our research. We collected 10 types of data, which are used for time series forecasting modeling and correlated with demand. These data are collected from different reliable sources. The dataset is considered from 1995 to 2019. Finally, relevant modifications of the collected dataset briefly explained in this chapter.

4.1.1 Population

Bangladesh is the eight most populated country in the world. We collected this data from the World Bank.

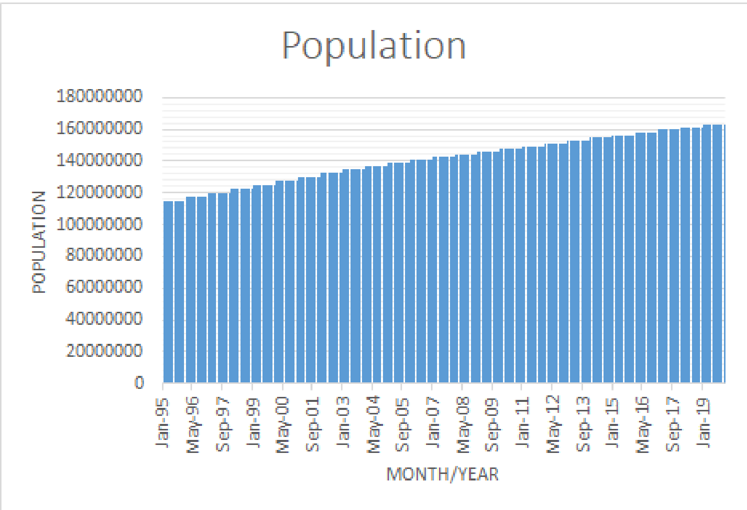

Figure 4.1: Population Of Bangladesh (1995-2019)

- Minimum value = 115169930
- Maximum value = 163046161

4.1.2 Gross Domestic Product (Bn. USD)

The Gross Domestic Product (GDP) in Bangladesh was worth 302.57 billion US dollars in 2019, according to official data from the World Bank and projections from Trading Economics. The GDP value of Bangladesh represents 0.25 percent of the world economy.

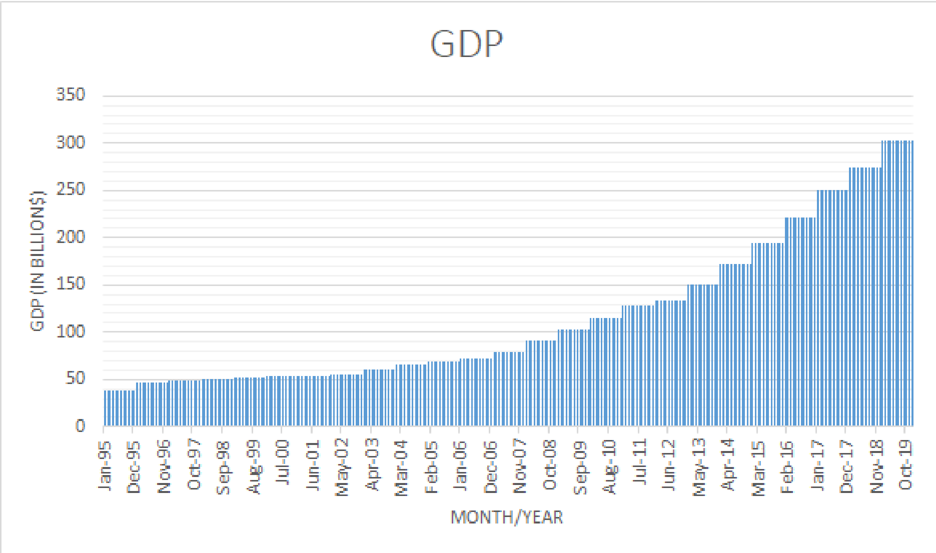

Figure 4.2: GDP Per Capita Growth Percentage Of Bangladesh (1995-2019)

- Minimum value (bn. USD) = 37.94
- Maximum value (bn. USD) = 302.571

4.1.3 GDP Growth Percentage (Per Capita)

GDP per capita growth (annual %) in Bangladesh was reported at 7.0316 % in 2019, according to the World Bank collection of development indicators, compiled from officially recognized sources. Bangladesh - GDP per capita growth (annual %) - actual values, historical data, forecasts and projections were sourced from the World Bank in January of 2020.

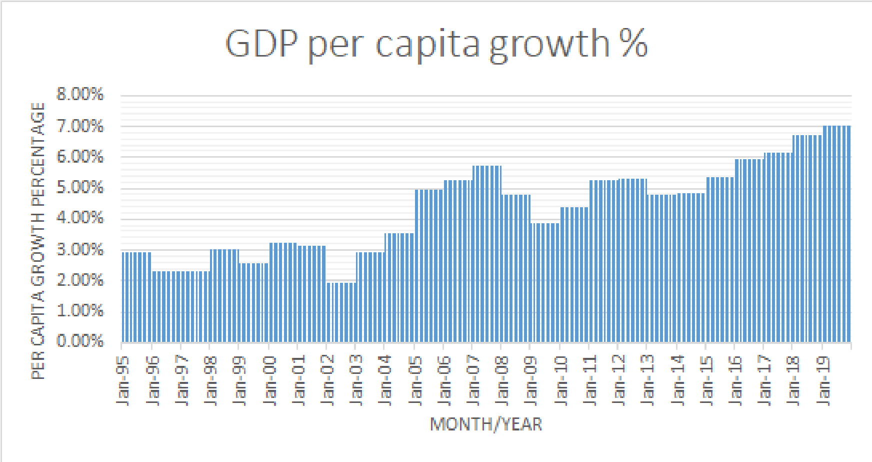

Figure 4.3: GDP Per Capita Growth Percentage Of Bangladesh (1995-2019)

- Minimum value = 02.90%
- Maximum value = 07.03%

4.1.4 GDP Total Growth Percentage

The GDP growth rate compares one year (or quarter) of a country's GDP to the previous year (or quarter) in order to measure how fast an economy is growing.

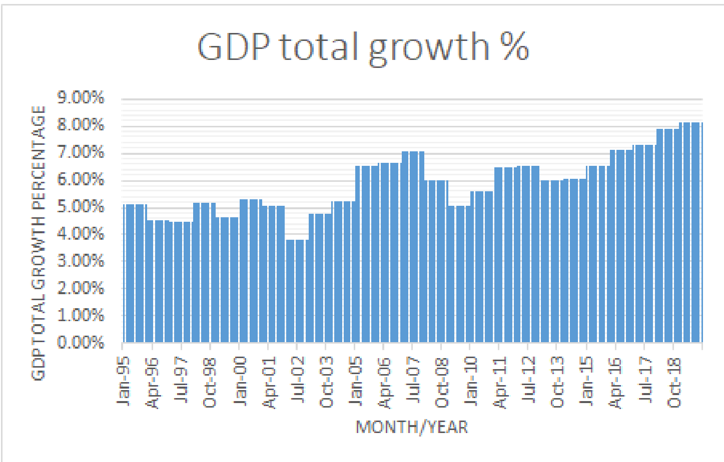

Figure 4.4: GDP Total Growth Percentage Of Bangladesh (1995-2018)

- Minimum value = 5.12%
- Maximum value = 8.15%

4.1.5 GNI Per Capita (USD)

GNI is the whole amount of money earned by a country's human beings and organizations regardless of location. It is an indicator to track a state's wealth from year to year. The wide variety includes the state's gross domestic product plus the profits it receives from foreign places resources.

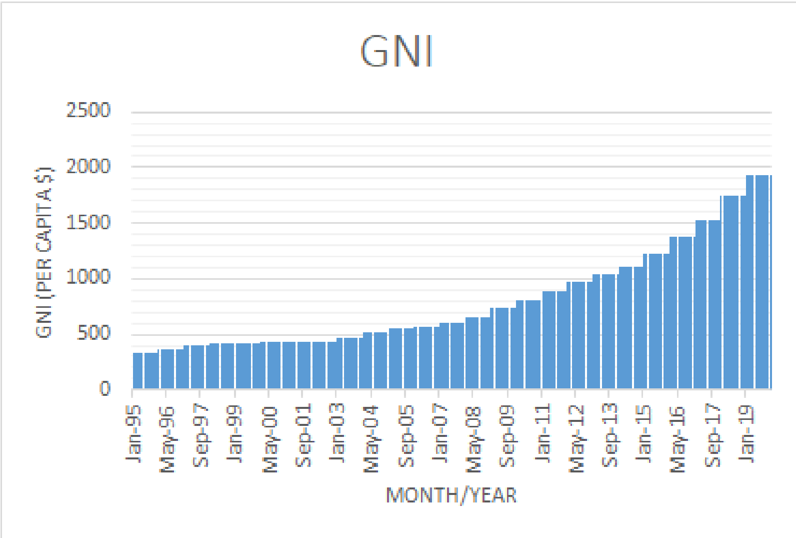

Figure 4.5: GNI (Per Capita) Of Bangladesh (1995-2019)

- Minimum value = 340 USD
- Maximum value = 1940 USD

4.1.6 GNI Growth Percentage

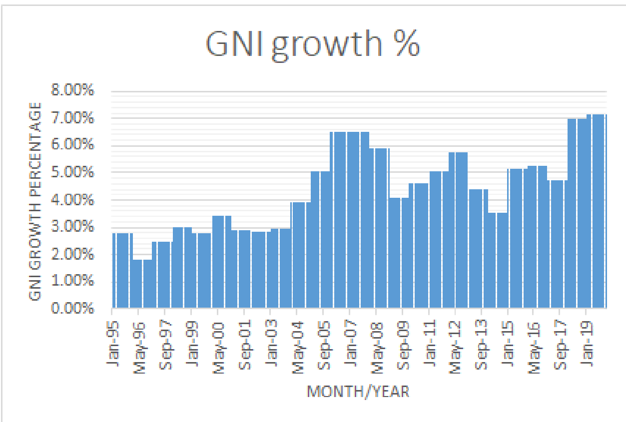

Figure 4.6: GNI (Per Capita) Of Bangladesh (1995-2019)

- Minimum value = 2.79%
- Maximum value = 7.19%

4.1.7 CO_2 emissions (metric tons per capita)

Carbon dioxide emissions (metric tons): For that indicator, we provided data for Bangladesh from 1995 to 2019.

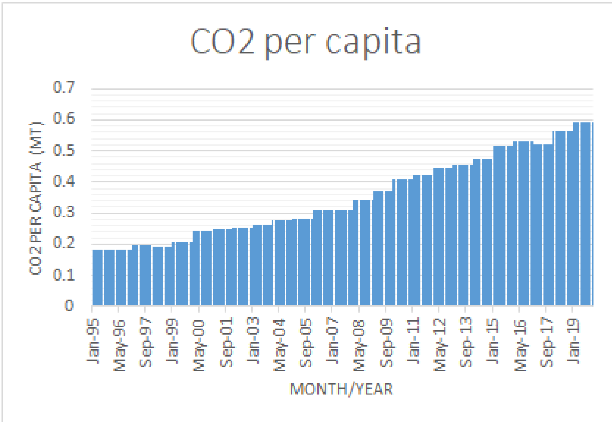

Figure 4.7: CO_2 Emission Per Capita Of Bangladesh (1995-2019)

- Minimum value = 0.183 metric ton
- Maximum value = 0.594 metric ton

4.1.8 Temperature In Celsius

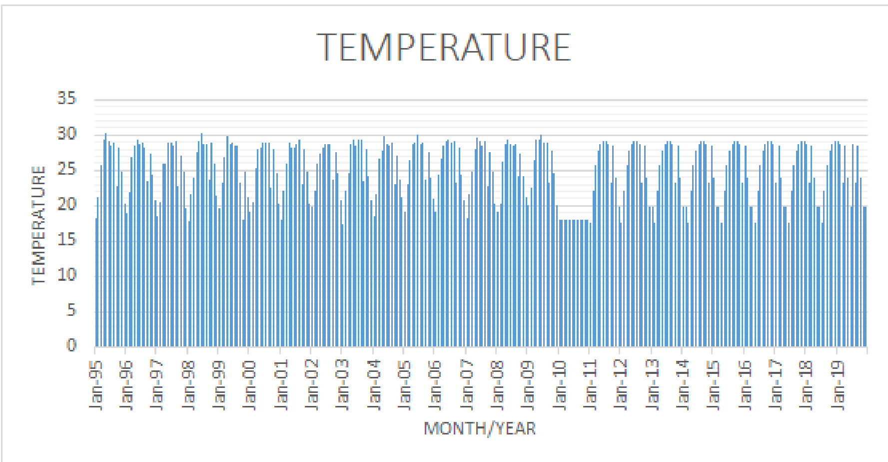

Figure 4.8: Average Ambient Temperature Of Bangladesh (1995-2019)

We collected monthly average temperature of whole nation from Bangladesh Meteorological Department

- Minimum value = 17.26 C
- Maximum value = 30.17 C

4.1.9 Electricity Consumption Per Capita

Bangladesh can offer itself absolutely with self-produced energy. The entire production of all electric powered energy producing facilities is 61 bn. kWh, additionally 113% of personal requirements. The rest of the self-produced energy is both exported into different countries and unused. Along with natural consumptions the production, imports and exports play a critical function. Accrued from World Bank.

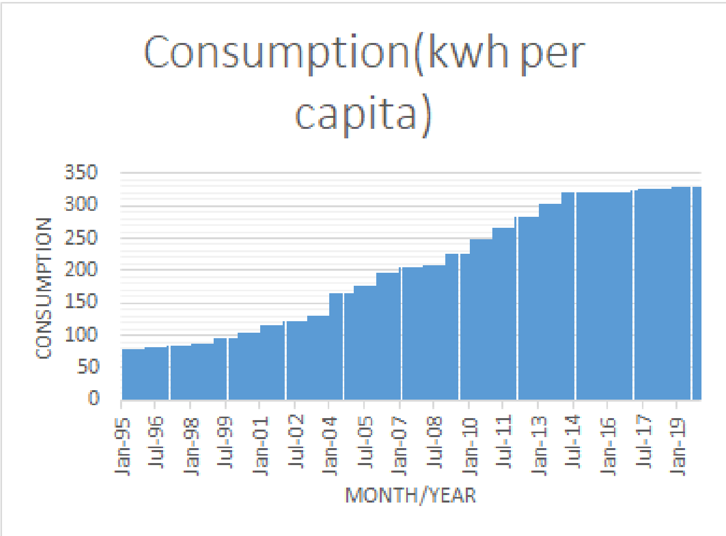

Figure 4.9: Electricity Consumption Per Capita (kWh) Of Bangladesh (1995-2019)

- Minimum value = 78.232 KWh
- Maximum value = 328 KWh

4.1.10 Electricity Average Demand

Collected from Bangladesh power development board.The utility energy area in Bangladesh has one countrywide grid with an installed capacity of 21,419 MW as of September 2019. The entire installed capacity is 20,000 MW. However, issues in Bangladesh's electric powered power area include high gadget losses.

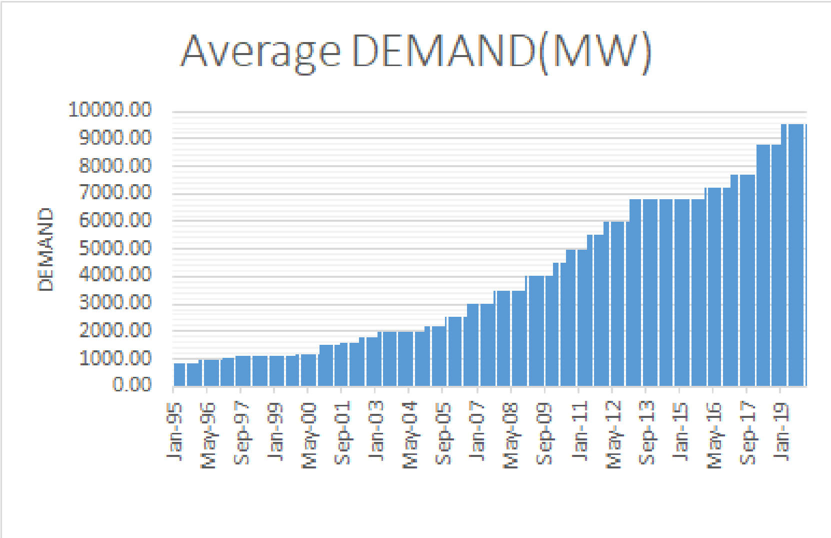

Figure 4.10: Average Electricity Demand Of Bangladesh (1995-2019)

- Minimum value = 850 MW
- Maximum value = 9523 MW

4.2 DATA Conversion

4.2.1 Correlation Matrix

A correlation matrix is without a doubt a desk, which displays the correlation coefficients for different variables. The matrix depicts the correlation between all the possible pairs of values in a table. It is far a powerful tool to summarize a massive dataset and to identify and visualize patterns in the given statistics.

In step with this correlation matrix table, we can observe that CO2 emission is strongly correlated with electricity demand, next Gross national income (GNI) and Electricity consumption per capita, GDP are related accordingly. However, temperature is lagging far behind in this case.

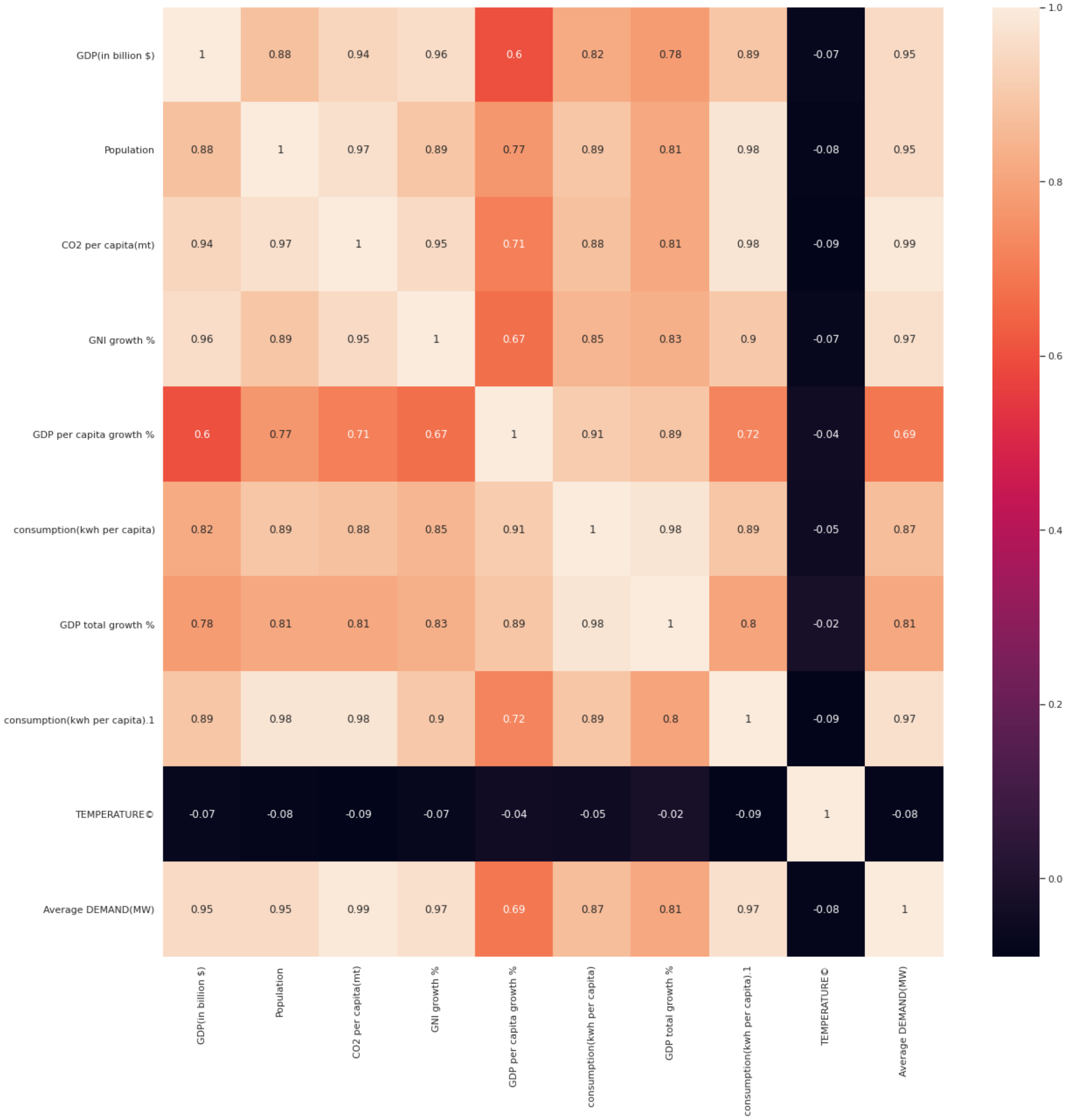

Figure 4.11: Correlation Matrix

4.2.2 Data Splitting

Data splitting is a strategy to evaluate overall performance of a model. This approach takes the dataset and divides it into two groups; training and testing. Training dataset is the subset of data used to train the model and testing dataset is the set of data used to assess the model. The aim is to estimate the functioning of the model. Here, on this examine, we have installed training dataset to 70% and testing dataset to 30%.

Chapter 5

Result Analysis

This chapter is dedicated to examine our data set through different types of prediction, error, accuracy models to achieve our final goal. In this process, we used the Group method of data handling type of neural network algorithms, which are self-organized models for complex systems. Moreover, GMDH is included with classification, clustering, curve fitting and as our main goal is to forecast electricity demand and analyze the relationship between output and input variables. For more deep analyses, we have used few supervised machine-learning algorithms such as Linear Regression, MLP Regression, K-Nearest Neighbors (KNN), gradient boosting regression.

5.1 Classification

Classification is prediction of a category of obscure occasion. GMDH incorporates an extraordinary Classification Relapse preprocessor that permits two-class and multi-class classification. GMDH requires all content information to be encoded with numbers. Target factors with more than two categories can be encoded and decayed into two fold factors or fair encoded with numbers.

As we train 70% and test 30% data from 1995 to 2019 dataset, it is visible that we predicted entire electricity demand from 1995 to 2019 to evaluate the prediction vs actual demand. Right here ash line is the actual demand, subsequent blue line is model fitted demand and red line is for predicted demand.

Classification Solver	Selected parameters
Recorder observations	Odd even
Validity strategy	K-fold
Number of folds	2
Core algorithm	GMDH neural network
Variable ranking	Correlation
Max. Number of layer	33

Table 5.1: Input parameters for classification.

Correctly classified instance	275	87.5%
Incorrectly classified instance	25	12.5%

Table 5.2: Data Correction.

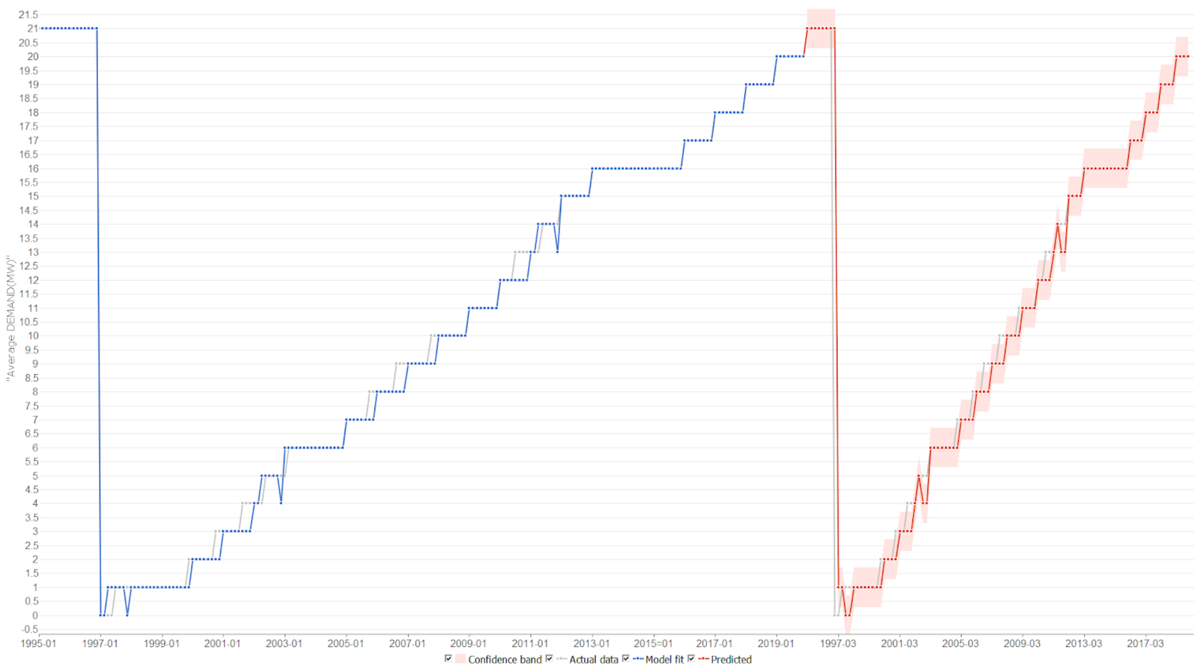

Figure 5.1: Actual Demand And Predicted Demand Classification From GMDH Model

5.2 Time Series Clustering Analysis

There are numerous exceptional categorizations of time-series clustering processes. Which includes, time-series clustering tactics may be tested in three principal sections in line with the characteristics of the facts used whether they system at once on raw statistics, circuitously with functions extracted from the raw statistics, or not directly with models constructed from the raw facts. Every other category is according to the clustering approach: shape-based, feature-based, and model-based.

However, whatever the categorization is, for any time-series clustering technique, the principal factors to be consideredare how to measure the similarity between time collection; how to compress the collection or reduce size and what algorithm to apply for the cluster. Therefore, this chapter examines time-series clustering approaches in accordance to a few most important constructing blocks: facts representation strategies, distance measurements, and clustering algorithms.

Starting with temperature, this element has no such effect in elec-

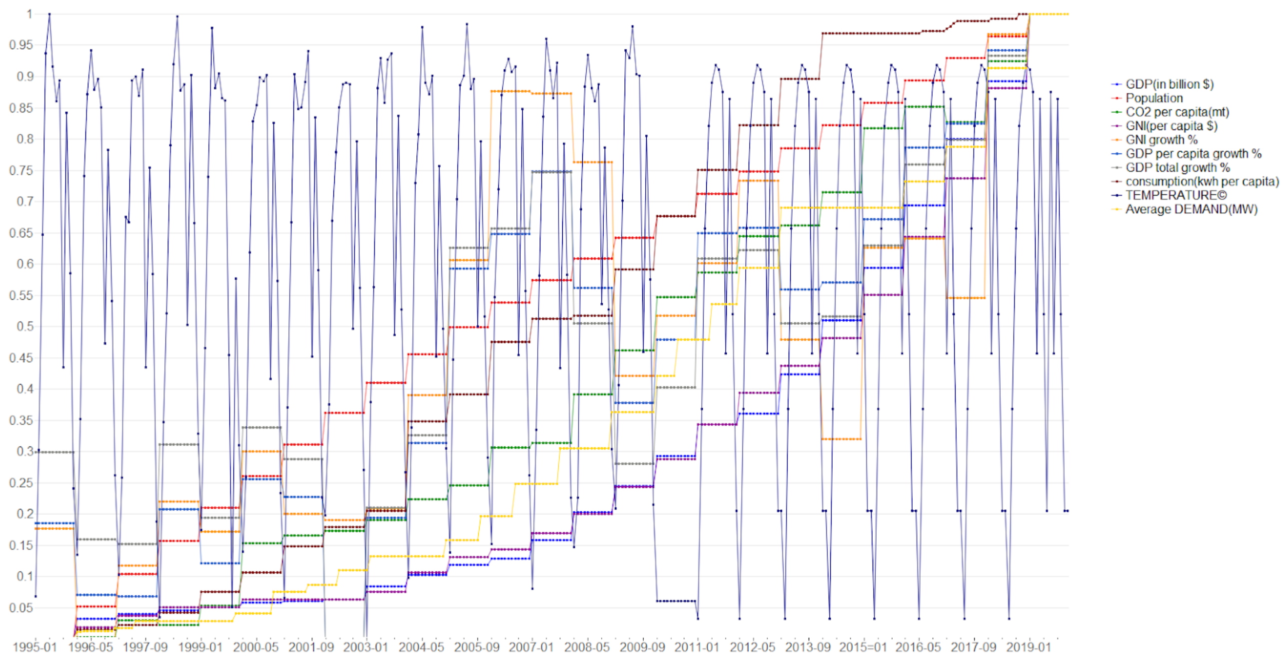

Figure 5.2: Time Series Clustering In GMDH Model

tricity demand prediction. Furthermore, temperature average value through the entire time series is seen as a constant variable. However, consumption per capita, GNI growth, population, GDP growth and CO2 emission are playing critical roles in increasing electricity demand consequently.

5.3 Time Series Forecasting

New Forecast=Last period's Forecast $+\alpha$(Last period's Actual Demand–Last period's Forecast).

$$F_t = F_{t-1} + \alpha(A_{t-1} - F_{t-1})$$

Here, F_t = New Forecast , F_{t-1} = Previous Forecast And α = Weighing. Constant ($0 \leq \alpha \leq 1$).

Year- Month	Forecasting Demand MW	Year- Month	Forecasting Demand MW	Year- Month	Forecasting Demand MW	Year- Month	Forecasting Demand MW
2020-01	9736.681	2021-01	10155.3	2022-01	10477.38	2023-01	12446.35
2020-02	9933.936	2021-02	10108.37	2022-02	10417.19	2023-02	12608.82
2020-03	9998.295	2021-03	10107.72	2022-03	10514.56	2023-03	12772.78
2020-04	10037.34	2021-04	10105.89	2022-04	10606.04	2023-04	12938.3
2020-05	10081.68	2021-05	10041.53	2022-05	10663.04	2023-05	12992.81
2020-06	10127.27	2021-06	10128.52	2022-06	10755.48	2023-06	13161.53
2020-07	10158.72	2021-07	10215.88	2022-07	12151.61	2023-07	13310.32
2020-08	10221.79	2021-08	10303.97	2022-08	12275.88	2023-0	13482.16
2020-09	10212.31	2021-09	10392.47	2022-09	12400.94	2023-09	13655.55
2020-10	10227.03	2021-10	10481.38	2022-10	12487.87	2023-10	13767.7
2020-11	10236.68	2021-11	10560.83	2022-11	12575.08	2023-11	13880.34
2020-12	10238.98	2021-12	10650.55	2022-12	12662.57	2023-12	13993.48

Year- Month	Forecasting Demand MW	Year- Month	Forecasting Demand MW	Year- Month	Forecasting Demand MW	Year- Month	Forecasting Demand MW	Year- Month	Forecasting Demand MW
2024-01	14082.71	2025-01	18175.35	2026-01	20017.69	2027-01	22619.85	2028-01	25225.28
2024-02	14196.91	2025-02	18352.34	2026-02	20286.85	2027-02	22950.97	2028-02	25740.1
2024-03	14311.6	2025-03	18530.31	2026-03	20557.98	2027-03	23284.71	2028-03	26260.54
2024-04	14426.78	2025-04	18709.28	2026-04	20831.17	2027-04	23621.17	2028-04	26786.84
2024-05	14471.42	2025-05	18889.23	2026-05	21106.41	2027-05	23960.34	2028-05	27319
2024-06	14587.66	2025-06	19070.17	2026-06	21383.71	2027-06	24302.24	2028-06	27857.01
2024-07	14704.38	2025-07	19252.11	2026-07	21644.86	2027-07	24624.63	2028-07	28352.86
2024-08	14821.61	2025-08	19435.03	2026-08	21926.27	2027-08	24971.96	2028-08	28902.59
2024-09	14939.32	2025-09	19618.93	2026-09	22209.73	2027-09	25322.02	2028-09	29458.17
2024-10	15057.53	2025-10	19803.83	2026-10	22431.04	2027-10	25592.05	2028-10	29833.26
2024-11	15176.24	2025-11	19989.72	2026-11	22653.59	2027-11	25863.68	2028-11	30210.96
2024-12	15295.44	2025-12	20176.59	2026-12	22877.37	2027-12	26136.9	2028-12	30591.29

Year- Month	Forecasting Demand MW
2029-01	30080.70
2029-02	30633.57
2029-03	31191.86
2029-04	31755.74
2029-05	32325.19
2029-06	32900.22
2029-07	33450.29
2029-08	34036.48
2029-09	34628.25
2029-10	35099.68
2029-11	35574.60
2029-12	36053.00

Table 5.3: Forecasted Average Monthly Demand Till 2029.

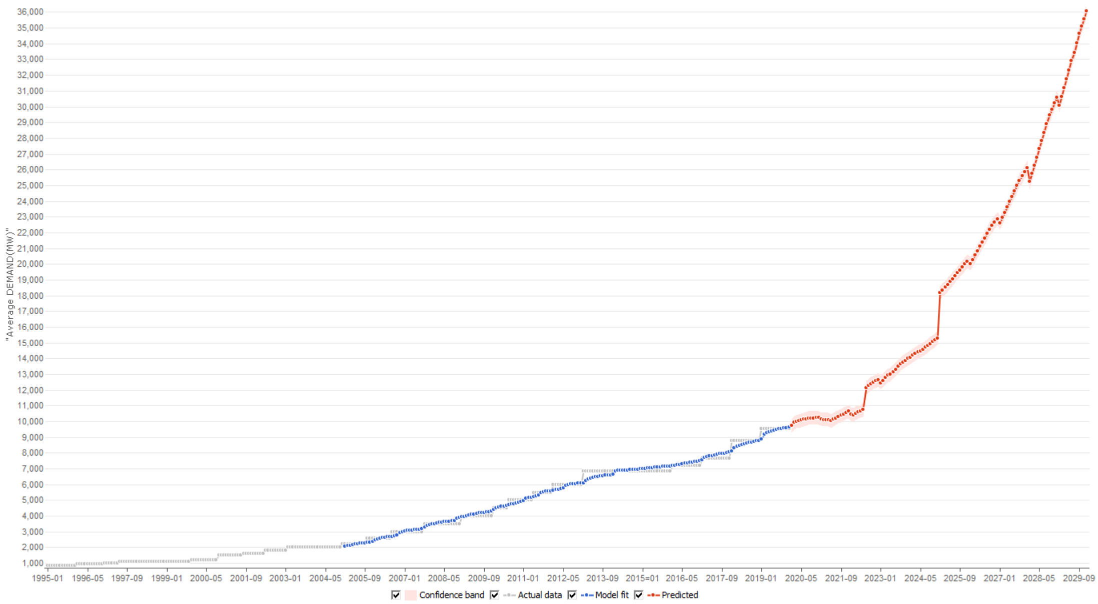

Figure 5.3: Actual Value, Fitted Value, Forecasted Value And Confidence Band In GMDH Model

5.4 Multi-Layer Perceptron Regressor

Artificial Intelligence and machine learning are often used interchangeably but the main thing is that AI provides a framework so that machines behave and compete like humans but in the real world, machines cannot be so accurate like humans. The main goal is training a machine and reaching its highest accuracy level. Joining with machine learning predictive modeling with Artificial Neural network comes about fruitfully with results. Analyzing dataset sorts, data focuses are continuous instead of discrete and target property is a real number so the entire handle goes on regressor demonstration .Multilayer Perceptron regression is a portion of ANN the common procedure is feed forward each perceptron and proceeding.

The advance goal cycle goes to the input layer as well as hidden layer with adjusting learning rate. before plunging into multilayer regressor cleaning data and planning data for algorithms was required. The reason behind it is the direct effect on accuracy and predicted result. Data type fluctuation and missing data come about interference in the entire method and to move the noise of information, data cleaning is required. Alterations for better accuracy MLP Regressor had to tune hyper parameters to maximum score. Chosen Hyper parameters are "Activation=relu" which suggests rectified linear unit and non-linear

activation function. Other than leaky relu ,relu implies all neurons in a network will get activated when the transformation is greater than 1.Otherwise, it will be deactivated over the network and relu is set by default. Since not only all neurons activate at the same time, it brought about more effective then ‘logistic’, and ‘tanh’ activation function. The respective dataset was best suited with relu activation function.
By setting activation function ’tanh’ and ’logistics’ the exactness of MLPregressor dropped into **57.29%** and **44.64%** which is not good enough to propose. As relu is computationally less expensive, it leads to better exactness than this. The logistic activation function is used when the target is a probability and it ranges 0 to 1.As our prediction is based on probability rather than real valued number. So it is the main reason of lagging result in accuracy. On the other hand ‘tanh’ is used when target class is on two class classification.Here, electricity demand prediction do not have any classification rather than it regression model because the target is a integer or floating number. Other than this hidden layer sizes=8 which signifies eight covered up layers are related with output and input layers.
’Solver=lbfgs’ and learning rate=’adaptive’ is chosen and all these adjustments the algorithm comes about into **87.56%** accuracy. Here, learning rate is selected as it starts with initial learning rate and keeps minimizing training loss in each epoch. As the dataset has continuous variables like monthly based or yearly based electricity consumption, which is more similar with inconsistent data. Furthermore, feature appearance like GDP, Temperature, Carbon emission, Population are more or less playing behind in predicting target output. Therefore, this undergoes Multivariate analysis in the machine-learning field.

5.5 Decision Tree Regressor

Decision tree lies underneath a supervised machine learning approach, which uses a tree representation to reach the final output. Decision Tree Regression, uses mean squared error is utilized to part a parent node. After that continuous splitting node in binary way, at final what instances are left in particular level that target is average value calculated. The most extreme objective is the CART calculation is limiting mean square error in dividing nodes in binary child nodes.

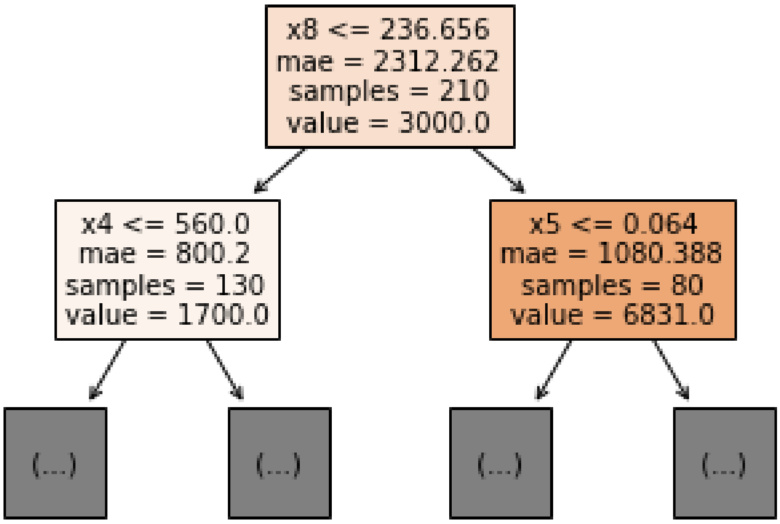

Figure 5.4: Tree Representation Of Decision

In spite of the fact that the decision tree is simple to translate and easily understandable, its accuracy may appear top to mark but usually because of failure of generalization of data which leads to more complex trees. This issue is called overfitting.

Both overfitting and underfitting is a drawback of any machine-learning algorithm. To begin with in executing decision tree regression accuracy appeared up **98.03%**, which clearly declares that model is enduring from overfitting. To deal with an overfitting model, pruning or L2 regularization is a way. Selecting "max depth=7", implies the tree will grow up to seven layers with criterion='mae'. MAE implies absolute error and which minimizes the L1 loss. L1 loss function is minimizing mean absolute error in each iteration in the tree so that the result stands in considerate state. 'Splitter=best' indicates the best splitting of each node until the last state. As our predictive model was enduring from over fitting, it has been managed with pruning technique in trees by altering hyper parameter in 'ccp alpha=0.04'. With all the adjustments, the ultimate accuracy for the decision tree model ended at **86.23%**.

5.6 Error Analysis

Error, $E = (Yt – Ft)$.
Y_t = Actual Data for Time period t.
F_t = Forecast for same time period t.
Mean Error, ME = $\frac{1}{n}\sum_{t=1}^{n}(Y_t - F_t)$
Mean Absolute Error, MAE = $\frac{1}{n}\sum_{t=1}^{n}|Y_t - F_t|$
Mean Square Error, MSE = $\frac{1}{n}\sum_{t=1}^{n}(Y_t - F_t)^2$
Root Mean Square Error, RMSE = $\sqrt{\frac{1}{n}\sum_{t=1}^{n}(Y_t - F_t)^2}$
Percentage Error, PE = $(\frac{Y_i - F_i}{Y_i}) \cdot 100$
Mean Absolute Percentage error, MAPE = $\frac{1}{n}\sum_{t=1}^{n}(|PE|)$

Sample	Actual Y	Forecasting F	Error, E=(Yt- -Ft)	Square Error,E
1	3000	3027	-27	729
2	4500	4515	-15	255
3	7204.593	7204.194	-0.399	0.159
4	8774.895	8800.808	-25.913	671.483
5	9523.208	9536.188	-12.98	168.48

Table 5.4: Sample Actual Forecasting Demand Error Test

Forecasted Percentage	Value	Target Percentage	Value
Max Negative Error	-8.43%	Max Negative Error	-10.71%
Max Positive Error	4.76%	Max Positive Error	11.81%
NMAE	1.95%	MAPE	3.20%
NRMSE	2.47%	RMSPE	3.98%

Table 5.5: GMDH Model Performance Accuracy

Chapter 6

Conclusion And Future Scope

6.1 Conclusion

To conclude, we have forecasted the future power demand of Bangladesh utilizing the group method of data handling on this research. Subsequent, correlation Matrix emphasized us toward key components at the back of increasing power demand. As a result, we have observed that each economical and natural component's connection with energy demand.

On the other hand, Deep learning and ANN algorithms each justified our result on a time series-forecasting model.Overall, we have confronted obstacles with different algorithms and have not outfitted remarkable results for our dataset. With the aim of digital Bangladesh, our prediction may additionally supervise the power generation and development of Bangladesh. Essentially, our forecasted demand comes about to reflect the actual demand reason of 2030.

6.2 Future Scope For Further Research

This research is not detailed enough to be considered as professional enterprise. There were many constraints including collection of data. As a result, we had to make some adjustment in the dataset to reach the goal.
This GMDH model is not complete yet and further refinement can be done on this. This research can work as a foundation for related and more accurate modeling of many time series forecasting. Even after all the constraints regarding dataset, this model managed to produce

a result that is similar with the forecast of PSMP-2016. With more accurate and diversified data, this model will only get more accurate. This work here has proved that group method of data handling is simpler yet more versatile and realistic and should be used in Bangladesh Power System.

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