SHORT TERM LOAD FORECAST USING TIME SERIES ARTIFICIAL NEURAL NETWORKS

A FINAL YEAR PROJECT PRESENTED

TO

THE DEPARTMENT OF ELECTRICAL, COMPUTER AND COMMUNICATION ENGINEERING, AHMADU BELLO UNIVERSITY, ZARIA

BY

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DECLARATION

I ABUBAKAR DAUDA (U12EE1087) hereby declare that this project work titled '**Short Term Load Forecast using Time Series ANNs**' is my original work and has not been presented for the award of any degree in any higher institution. All literature consulted are duly acknowledged and a list of reference provided.

.... 06/11/2017 ....

ABUBAKAR DAUDA DATE

ABSTRACT

The development of artificial neural network (ANN) is based on studying the relationship between input and output variables using a three or more layered networks, more commonly; input layer, output layer and hidden layer. Artificial neural networks extract information from a given data so it can be used to solve non-linear problems. The inputs are multiplied by a connection weights, and the products and biases are added and passed through an activation function to generate an output. This project work is based on forecasting load demand using time series ANN. The ability to forecast the future load based on past data is a key tool to support individual and organizational decision making. In essence, the goal of time series forecasting is to predict the behaviour of complex systems by looking only at past patterns of the same phenomenon. Traditional or classical forecasting methods suffer from serious limitations which affect the forecasting accuracy. But ANN algorithms have been found to be useful techniques for demand forecasting due to their ability to accommodate non-linear data and capture subtle functional relationships among empirical data, even where the underlying relationships are unknown or hard to describe.

CHAPTER ONE

GENERAL INTRODUCTION

1.1 Background

Power demand and sales forecasting is one of the most important functions of manufacturers, distributors and trading firms. To reduce excess and shortage of inventories and improve profitability, demand and supply must balance. When the producer aims to fulfill the overestimated demand, excess production results in extra stock keeping which ties up excess inventory. On the other hand, underestimated demand causes unfulfilled orders, lost sales foregone opportunities and reduces service levels. Both scenarios lead to inefficient supply chain. Thus, the accurate demand forecast is a real challenge for participant in supply chain (Kochak & Sharma, 2015).

The major function of a power system is to supply its customers with economical and reliable electrical energy as much as possible. For this to be achieved, the load demand of the customers or consumers (industrial, commercial and residential) must be known. The consumer load demand can be predicted using a technique termed 'Load forecasting'. Load forecasting is the projection of electrical load that will be required by a certain geographical area considering previous load usage in the said area. It helps in making vital decisions concerning the system not only from the generation side but also from a financial perspective such as scheduling of power generation, fuel purchasing and maintenance; security assessment and also provide valuable information to detect many vulnerable situations in advance. There are three approaches to load forecasting depending on the time period in which the forecast is carried out: Short term load forecast (STLF), which spans a period of an hour to one week, helps to provide a great saving potential for economic and secured operation of power system, medium term forecast, which ranges from a week to one year, concerns mainly with scheduling of fuel supply and maintenance operation and long term forecast ranging from a year upwards, which is useful for planning operations (Samuel *et al,* 2016).

Within the previous years, different methods have been developed and improved upon to forecast load demands. These methods are broadly classified into two categories. We have the classical approaches which are based on various statistical modeling methods (regression and time series) and the artificial intelligence (AI) based techniques. The AI also referred to as machine learning involves the use of artificial neural networks (ANN) in the prediction of consumer load demand (Samuel *et al*, 2016). Artificial neural network (ANN) algorithms have been found to be useful techniques for demand forecasting due to their ability to accommodate non-linear data, capture subtle functional relationships among empirical data, even where the underlying relationships are unknown or hard to describe (Kochak & Sharma, 2015).

This project work will focus on short term load forecasting using a time series ANN (MATLAB neural network toolbox) to predict power demand using historical load data at different times and different days of the week (weekday, weekend and holiday), and the percentage increase in consumption as inputs to the network. The STLF is chosen because of its usefulness in improving prompt scheduling of generator, real time control and security assessment, and determining the most economic load dispatch with operational constraints and policies, environmental and equipment limitations . The time series neural network has been found more suitable in preference to other forecasting methods due to its ability to learn with many input factors, its flexibility with noisy data, can extract patterns and detect trends that are too complex to be noticed by other techniques. It also has power of intelligence because of its adaptability and high speed of computation due to its parallel-distributed nature of processing (Shastry & Urs, 2014).

1.2 Problem Definition

In the recent days, the demand for electrical power is increasing drastically and hence has become essential to advance power generation. Load forecasting plays an important role in determining the future demand in order to meet the ever increasing demand. It is necessary to predict hourly as well as daily peak loads, while keeping accurate tracking of the load by the system generation at all times. This is a basic requirement in the operation of power systems and must be accomplished for various time intervals. Accurate prediction of load demand results in economic, reliable and secure operation of the power system which in turn saves cost (Jain & B, 2008). Since electricity cannot be stored efficiently in large quantities, the generated amount at any given time must cover all demands from consumers as well as the grid. Thus by predicting load demand using time series ANN eliminates future uncertainties.

Forecasts of the load are used to determine the need to increase or decrease the output of online generators, by committing one or more extra unit, or by interchanging the power with neighbouring systems. Forecasts are also used to determine whether the output of an ongoing unit should be increased or switched off, which is determined by generator control functions such as scheduling, unit-commitment, coordination and interchange evaluation. In addition, the electrical energy markets liberalization worldwide has led to the development of energy exchanges where consumers, traders and suppliers can interact, leading to price settings and giving a new dimension to the problem of load forecast (Espinoza *et al*, 2008).

1.3 Aim and Objectives of the Project

This project is aimed at developing a time series neural network prototype application that will predict electricity load requirement for a given historical data. The objectives of the project are:

1) To develop and train a time series artificial neural network model that can predict/forecast electric load demand using the short term load forecast approach.
2) To test the developed model using historical load data obtained from Bulk Metering Unit, Estate Department, ABU Zaria.

3) Other forecasting methods/techniques will be assessed through the literature review.

4) In addition to the above, necessary recommendations and suggestions will be made for future and further research.

1.4 Methodology

The methodology adopted is as follows:

1) The time series neural network prototype will be developed using the neural network toolbox in MATLAB R2014b software.

2) Historical load data will be collected from the school (Bulk metering unit, Estate Department, Ahmadu Bello University, Zaria) which will be used to train and test the developed network model.

3) The model will be trained using the collected load data and the performance of the network will be observed. In order to get good results, the network will be trained multiple times by varying the model parameters until a response with minimum error is obtained.

1.5 Project Outline

This project comprises of five chapters arranged in a sequential order. The first chapter contains the general introduction and a brief summary on how the project will be carried out. In chapter two previous methods used in power forecast, fundamental concepts and

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter contains a general review on the project work which will be discussed in two sub-chapters. The first section is a review of fundamental concepts while the second reviews similar works with their limitations.

2.2 Review of Fundamental Concepts

This section reviews fundamental concepts which give the theoretical background of the work. It contains an overview of load demand forecasting with its types and importance, a review on the various methods used in load forecasting and their limitations. Finally, a deeper exploration and a more detailed discussion on the method and the software that would be used in this project will be reviewed.

2.2.1 Load Demand Forecasting

Load demand forecasting is a very essential process in electric power system operation and planning. It involves the accurate prediction of electric load consumption of a given area over different periods of time. Many economic and planning activities of an electric utility company such as scheduling of generating capacity and fuel purchase, maintenance and security analysis, economic dispatch of generating units, and planning of power development are mainly operated and taken care of base on accurate load forecasting (Phuangpornpitak & Promee, 2016).

Load forecasting refers to a technique used for estimation and prediction of electric load demand for a given forecast horizon based on available information (historical data) about the state of the system. According to the period of time for which it is carried out, load forecast can be classified into three basic categories;

1) Short term load forecast which is carried out within a period of one hour to a week.

2) Medium term load forecast which spans a period of more than one week to one year.

3) Long term load forecast ranging from a year upwards.

Short term load forecast which is of interest in the project work is essentially important for scheduling functions such as generator unit commitment and coordination, short term maintenance, fuel allocation, transaction evaluation, power interchange, economic dispatch, optimal power control as well as security and network analysis functions. The basic quantity of interest in the STLF method is the historical data of the consumer load (usually taken in an hour intervals) up to 168hours (7 days). The values of the load at different times (hourly) of the day and at different days (working days and weekends) of the week are also taking into consideration. In some forecasts, weather information such as temperature and relative humidity if available are also considered. The primary application of the STLF is to predict using available data, the scheduling functions for determination of the most economic commitment of generation sources with consistency and reliability requirements, operational constraints and policies, environmental and equipment limitations, power system stability and security assessment. The STLF has being a measure field of research due to its high level of accuracy and low mean absolute percentage error (MAPE) and its numerous applications in power engineering (Kourtis *et al*, 2011).

The medium term load forecast is necessary to utility companies mainly for planning fuel procurement, scheduling of unit maintenance, energy trading and revenue assessment. It depends mainly on factors that influence demand (growth factors), such as main events, seasonal variations, additional of new loads, demand patterns of large facilities, and maintenance requirements of large consumers. In addition to the inputs used in the STLF method, the medium term load forecast also uses variables such as wind speed, rainfall, consumer type index and consumer price index. The main application of medium term load forecast is to predict the future load demand ahead several months or a year so as to make preparations for generation optimization, scheduling of fuel supply and unit maintenance operation. With the information gotten from the forecast, decisions can be made on whether to take facilities or plants for maintenance or not during a given period of time, plan major tests and commissioning events, and determine outage times of plants from one utility to another. In most utility companies, the last 25-30 years data available is used (Sheikh & Unde, 2012). Long term forecast is very crucial and plays a vital role in electric power system planning, tariff regulation, energy trading, load allocation and making decisions on future generation stations and transmission facilities. The long term forecast has not been of much interest to researchers because of its high level of inaccuracy which is related to the dependency of peak load on temperature and other weather conditions, and the unavailability of weather and economic data (Phuangpornpitak & Promee, 2016).

In general, the importance of power forecast to electric holding and utility companies can be summarized as listed below:

1) It helps in planning and developing future generation, transmission and distribution facilities.
2) It helps to provide a great saving potential for economic and secured operation of power systems.
3) It helps in making schedules for generation, fuel supply and maintenance operation.
4) It helps in ensuring system stability and generation optimization.
5) It is important for the establishment of unit commitment and real time operation.

6) It helps in making preparations so as to meet peak and base load demand of customers.

7) It also helps in making decisions on whether extra generation should be provided, the output of online generators should be increased or decreased, or the power supply of neighboring systems should be interchanged.

8) It also helps in controlling and ensuring the security of the power system.

9) Accurate load forecasts also help the utilities to operate at the highest possible efficiency.

There are various factors to consider when carrying out a forecast. These factors are mainly seen as input to the technique or method that will be used for the prediction. The factors include:

1) Time factors (day of the week, hour of the day and holidays).

2) Historical load data.

3) Weather data (temperature, humidity, etc.)

4) Consumers' classes.

5) Economic and demographic factors.

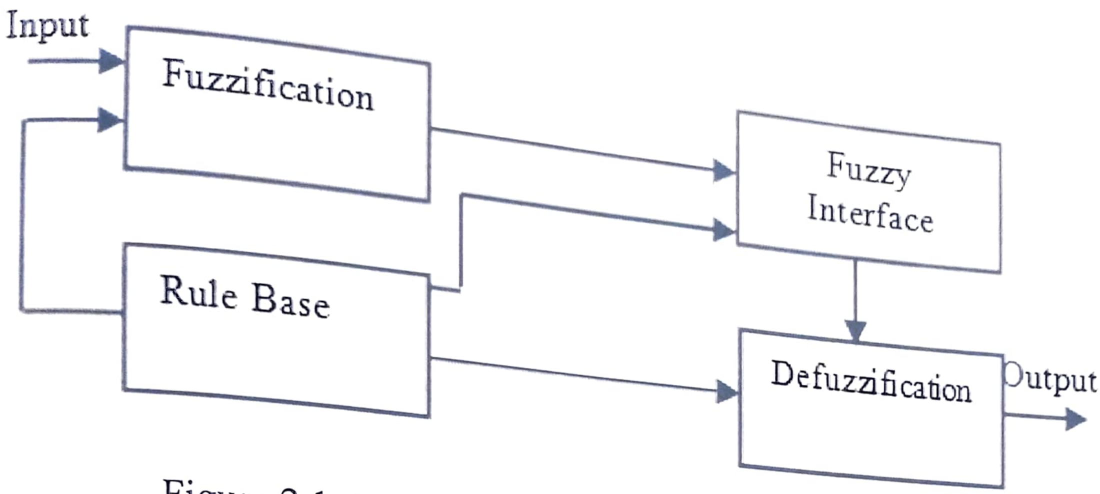

Figure 2.1: Block Diagram of a Fuzzy Logic System

2) Expert Systems: Expert systems are computer programs which have proficiency and competence in a particular field. An expert system has the ability to reason, explain and have its knowledge base expanded as new information becomes available to it. The system transform rules and procedures generated by experts in the field to automatically make forecasts about electricity demand. To develop efficient forecast software (expert system), expert forecasters will have to collaborate with software developers to include all expert information into the software. The expert system is friendly, fast and accurate because it involves the use of software applications which usually run at the click of a button (Alkhathami, 2015).

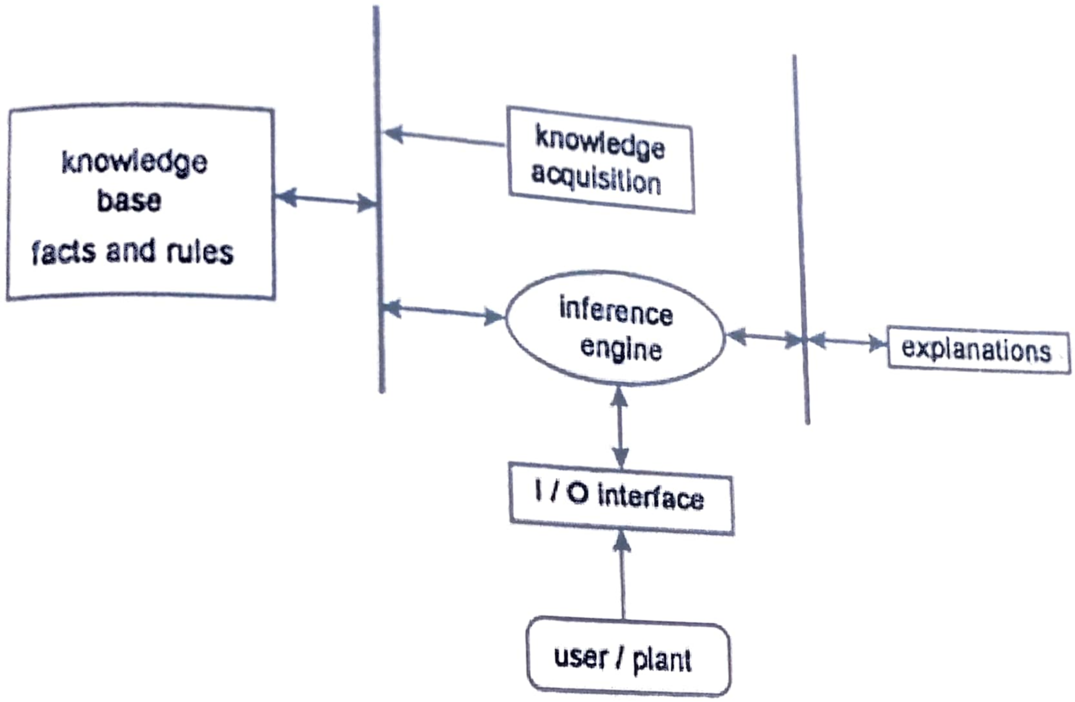

Figure 2.2: Structure of an Expert System (Nath & Balaji, 2006)

3) Support Vector Machine: The support vector machine (SVM) is a technique originated by Vapnik (1995) that is based on statistical learning theory (SLT), which analyzes data and recognizes patterns, used for classification and regression analysis (Singh *et al*, 2013). The basic idea behind SVM is to use linear model to implement nonlinear class boundaries through some nonlinear mapping of the input vector into a high-dimensional feature space. Unlike neural networks which try to define complex functions of the input feature space, SVM performs a nonlinear mapping (by using so-called kernel functions) of the data into a high dimensional (feature) space. Then SVM uses simple linear functions to create linear decision boundaries in the new space. The problem of neural

2.3 Review of Similar Work

Raza and Khosravi, (2015) presented a research titled concept of electricity demand forecasting in the area of electric power systems with the objective of surveying load demand forecasting techniques and their applications. The survey proved that use of artificial intelligence based techniques (especially neural networks) provides more accurate results for efficient energy management and better power system planning.

Wu *et al.*, (2013) proposed a technique for short term load forecasting using a combined/hybrid models. The methodology used includes the application of seasonal adjustment method and regression model in carrying out the short term load forecast. The model has a very low level of accuracy and hence need some improvements.

Kandil *et al.*, (2006) have explored the ANN capability to predict the load without necessary using the historical load trend, but only temperature instead. The study reports that using estimated load values may lead to a great degree of inaccuracy in the forecast, thus only the temperature was used as an input. Because of the ANN's input-output mapping ability, this approach could be efficient. However, the better results could be achieved by selecting other importance input variables and better network training parameters.

Xiao *et al.*, (2007) have introduced the rough set and its ability to study and remember

the

relationship between the inputs and outputs. A multi-layer back propagation neural network was used in the study and momentum method was also applied to decrease the sensitivity of local parts of error curve surface. This approach requires further development to attribute deduction threshold.

Madal *et al.*, (2006) presented a comparison of a classical load forecasting technique with an ANN-based model using actual load data. The models were used to forecast the load one-to-six hours ahead and again the MAPE showed that the ANN-based model provides reliable forecasts. Again, the optimal network structure for better forecast was never achieved.

Adepoju *et al.*, (2007) have used a supervised neural network –based model to forecast the load in the Nigerian power system. The study however did not consider the influences due to weather conditions, thus the accuracy could be improved.

From the review above, it can be seen that each research has its own limitation. Almost all the works reviewed suffer a great limitation of accuracy. In this work, the network model developed was trained multiple of times by varying the network parameters in order to achieve a high degree of accuracy.

CHAPTER THREE

PROJECT METHODOLOGY

3.1 Introduction

In this chapter, the basic procedures for developing and implementing a neural network model for STLF will be discussed. This involves the collection and processing of the historical load data to be used, construction of the neural network architecture and training of the network.

3.2 Data Collection and Processing

The historical load data used was collected from Bulk Metering Unit Estate Department of ABU Zaria for the month of April and May 2017. The data is contained in a log sheet use for recording the hourly load consumption of the school environment. A one month data could normally be used for the short term load forecast and hence for this research the load profile for May is actually used. The essence of collecting the data for two months is for pre-processing (finding replacement for missing values) of the load data which may arise either due to system collapse, earth fault, opening of a feeder for the purpose of maintenance, etc. In such situations, load information for the same hour and day can be used to fill the missing load value. Also, in a case where the load data of the same hour and day is missing for both months, extrapolation is use to fill the missing load information.

3.3 Choice of Neural Network Model

There are several network models use for developing a time series ANN. These include multi-layer perceptron network, radial basis network function, Jordan recurrent network, feed-forward back propagation neural network, Elman back propagation neural network, etc. For this project work, the feed-forward back propagation was used to implement the network model. This is because it has a special feature of combining the conventional network topology (multi-layer perceptron) with good handling of time dependencies. Moreover, it also allows smaller adjustments to the network for performance improvement without requiring changes in the general network structure.

3.3 Choice of learning principle

Four different types of learning techniques are used in designing an ANN prototype. These are; supervised learning, unsupervised learning, reinforced learning and competitive learning techniques. For this network prototype, the supervised learning technique was used to implement the neural network model. The implication is that the ANN is provided with the input as well as the target data or desired output for the prediction. The supervised learning is the most common technique used and was proven to yield meaningful results with less performance error.

3.4 Design of the Neural Network Architecture

The neural network architecture defines how the neurons are arranged or placed in relation to each other. As stated earlier, a supervised feed-forward back propagation algorithm was used for the network design. The network consists of multiple layers of computational units called perceptron which are interconnected in a feed-forward manner. The output of the network is produced by taking a linear combination of the input signal, and transforming it using an activation function. The output of the function is given by;

$$y = \varphi \sum_{i}^{n} (w_i x_i - \theta) \tag{3.1}$$

Where y represents the output, x_i the input signals, w_i is the neuron weights, θ is the bias term and φ is the activation function which can either be a linear function, step function, logistic function or a hyperbolic tangent function.

The network configuration mainly depends on the number of hidden layers, number of neurons in each hidden layer and the selected activation function. As far as neural networks are concern, there is no clear guideline on how to select the network architecture and hence the selection is basically a form of trial and error.

The neural network implemented in this project work was designed with MATLAB (R2014b) software conventionally using the 'nnstart' command. It was then provided with the processed load data as mentioned earlier that was written on Microsoft excel sheet as the training, target and test data. The training parameters were varied in order to get the best performance and response with minimum error indices. The figure below shows the neural network start window.

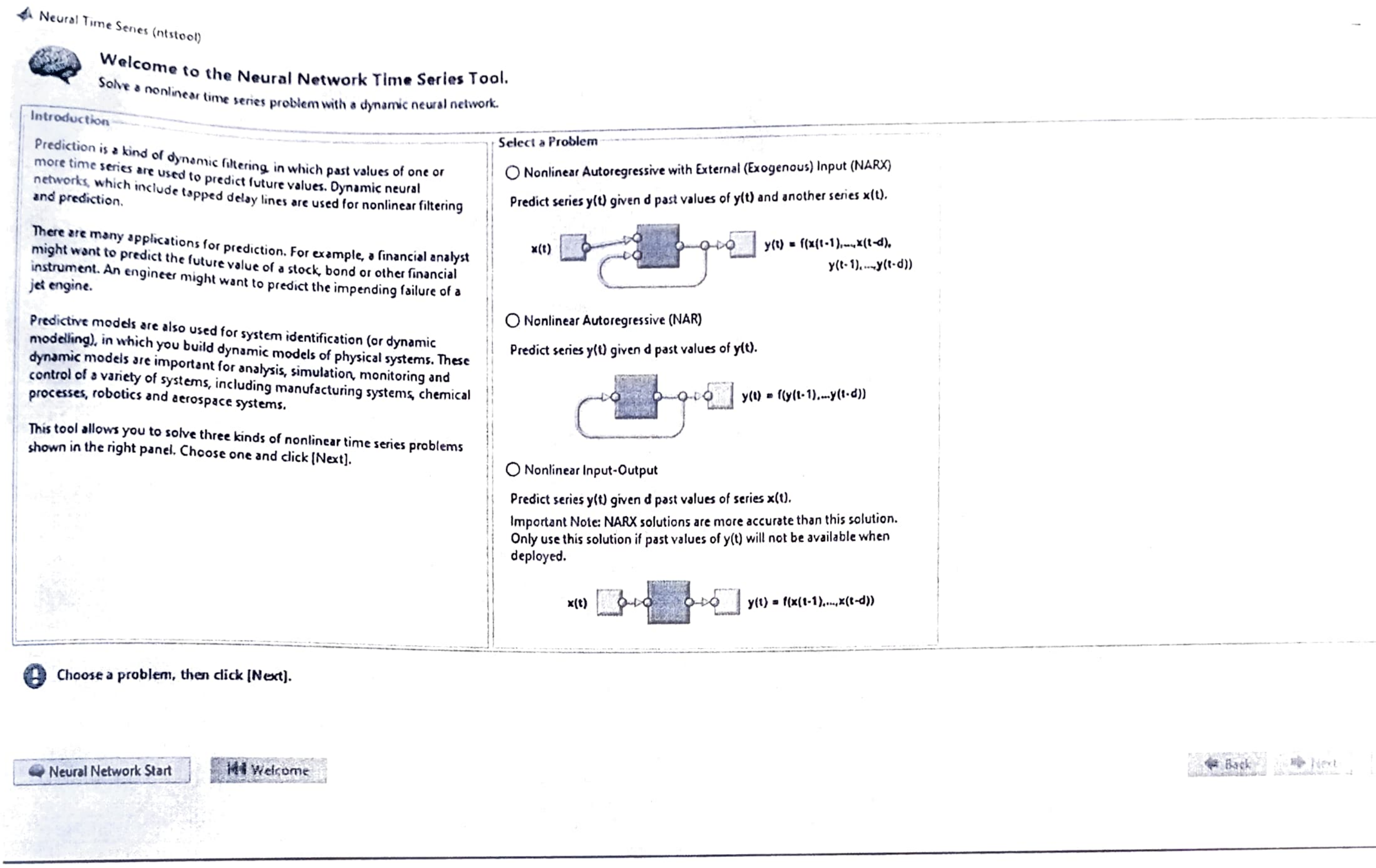

Figure 3.1: Figure Showing the 'nnstart' Command Window

The general procedure for developing the neural network model is as summarized below;

1) The data is read and loaded from an excel data file (see appendix A) using the import data function. The current week load data was taken as the target data while the previous week data was taken as the input to the neural network. MATLAB software automatically divides the data provided into three groups. The first group contains 70% of the data for training, while the remaining 30% is

divided equally for validation and testing. The figure below shows the window for data selection.

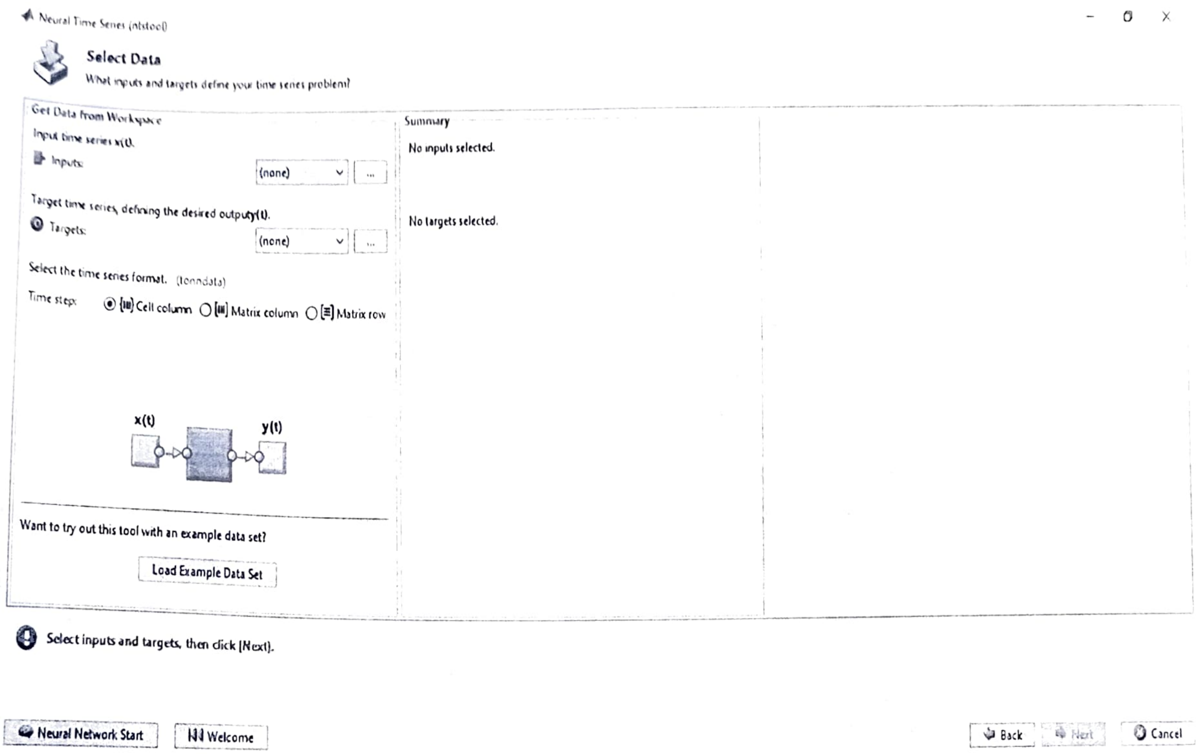

Figure 3.2: Figure Showing the Window for Data Selection

2) The network was then constructed having 168 samples of the input which produces the same number of output units. The number of neurons in the hidden layer is selected based on trial and error until a reasonable response was obtained with minimum performance error.
3) The response plot for the training session having the best possible result was then obtained. The plot provides a comparison of the actual and predicted or forecasted load and other parameters such as validation target, test target, training outputs, and so on.

4) The MATLAB code was then generated as presented in appendix A.

The network created is as shown in the figure below;

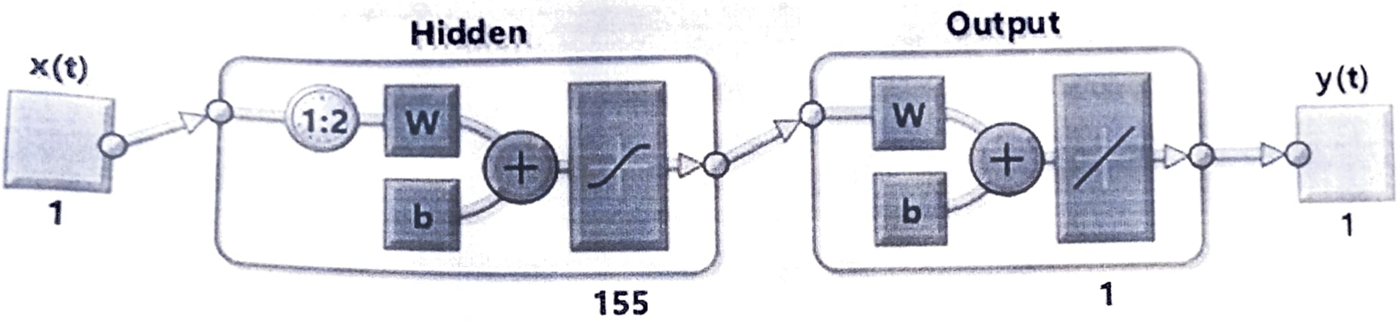

Figure 3.3: Implementation of ANN Model Using MATLAB

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter presents and discusses the forecast results and the statistical data obtained from the application of the developed ANN model for the prediction of the short term load using the data collected from Bulk Metering Unit, Estate Department, ABU Zaria.

4.2 Results

The results obtained from testing the trained neural network on new data over a one-week period and for some selected days within the week are presented below in graphical form. Each graph shows a plot of the input and output load in MW, output targets, test validation, and other parameters against time in hours. The graphs below show the response plot for 1st and 5th May 2017.

CHAPTER FIVE

CONCLUSION, LIMITATIONS AND SUGGESTIONS FOR FUTURE WORK

5.1 Conclusion

The result of the developed network model showed that the network has a good performance, and reasonable prediction accuracy was achieved. Its forecasting reliabilities were evaluated by computing the mean absolute percentage error between the exact and predicted values, and the results obtained suggest that ANN model with the developed structure can perform good prediction with least error and finally, this neural network could be an important tool for short term load forecasting. Although the network model was developed and trained using a consumer load data, the model can be slightly modified to accurately forecast the total load of a power utility company.

The developed model also has great benefit as it is experimentally easy and friendly to use, simple in design and has fast response.

5.2 Limitations

As discussed in chapter two of this project study, there are various factors that affect load forecasting and hence should be included as input to the network model so as to take into account the effect they produce, these factors include weather data such as temperature and humidity, other time factors such as holidays and special events (e.g world cup),