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Load Forecasting of an Optimized Green Residential System Using Machine Learning Algorithm †

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Abstract: Load forecasting of a micro-grid system has become a challenging task due to its high volatile nature and uncertainty. Residential energy consumption is one of the most talked-about and confusing topics among different electricity loads in terms of future information and is mainly affected by irregular human activity and changing weather conditions. Therefore, techniques and algorithms are needed to reduce energy consumption and enhance the smartness of the system. Load forecasting of an optimized residential system using a machine learning (ML) algorithm is proposed for an islanded green residential system. The load profile of residential electricity consumption is developed by real-time data collected. Photovoltaic (PV) and wind energy (WE) units are considered renewable energy sources in batteries to entertain the residential loads in the proposed prototype. An efficient energy management system (EMS) is introduced to create a balance between power generation and consumption with the help of intelligent appliances under a controlled framework and to overcome peak time consumption. Prediction of load and proper energy utilization are presented to ensure the stability and durability of the system. For efficient micro-grid energy management, the residential load is forecasted using a ML algorithm named non-linear autoregressive exogenous (NARX) neural network (NN) with a minute mean absolute percentage square error of 0.226% which is far less than that of previous work performed in different forecasting scenarios. As a result, an efficient model is designed for a standalone DC micro-grid.

Keywords: load forecasting (LF); micro-grid (MG); energy management system (EMS); non-linear autoregressive exogenous (NARX); neural network (NN)

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1. Introduction

In recent years, energy management systems are one of the most investigated topics in the national and international electrical research market. There are different methods and techniques that have been used to maintain the balance between demand and supply. For an efficient energy management system, load forecasting has become an indispensable term. Load forecasting can play a comprehensive role in scheduling the generation, as well as consumption. Many approaches have been proposed regarding load forecasting and energy management system. Different neural networks are used and compared to forecast the short term load in [1]. By considering the weather conditions, short term load forecasting is completed with long-short term memory (LSTM) recurrent neural network but forecasting accuracy is far less [2]. A hybrid algorithm based on NARX neural network and particle swarm optimization (PSO) is applied to the educational buildings to predict the energy consumption [3]. NARX neural network is exercised for the prediction of solar irradiance with the outcome of 83% regression value [4] and 0.00279 mean square error (MSE) value [5]. A novel short term load forecast is proposed with minute errors using

deep learning approach in [6]. By using extreme learning, electricity price is also efficiently forecasted considering domestic energy usage in [7]. And a brief concept of energy trading is delivered to enhance energy utilization on the residential level [8]. The previous study comprises the concepts of load forecasting, energy management, and energy trading. The objective of the proposed research is to introduce a smart and joint concept of energy management, energy trading (ET) by utilizing more efficient load forecasting using NARX NN compared to its previous attempts.

2. Research Flow Diagram

Research flow diagram in Figure 1 describes different steps for the EMS and ET by collecting data (DC) from a real time source and parallelly prepared the data in data preparation (DP) block. NN model is used to analyze the incoming data from DC and DP block using different algorithms (NARX neural network). Meanwhile, the output of NN model is further fed to data forecasting block and EMS section. Where the predicted data are used to maintain the balance and provide the efficient utilization of generated energy by renewable energy sources (RES).

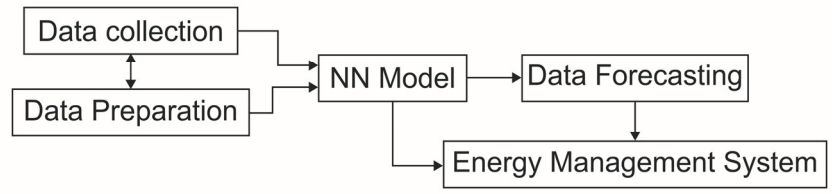


Figure 1. Research flow diagram.

3. Methodology and Design

The proposed research is based on the following steps which includes data acquisition, NN model for data forecasting and energy management system.

3.1. Data Acquisition

To evaluate the proposed model, a real time dataset of household energy consumption is used. The dataset is available on an online platform named Open Data Pakistan [9]. The prescribed dataset comprises of 42 households' energy consumption data located in Lahore and recorded at one-minute time interval. From the presented dataset, one day load profile measured in KW of house no 6 dated 14 November 2018 is used as input data for the application of the NN model as shown in Figure 2.

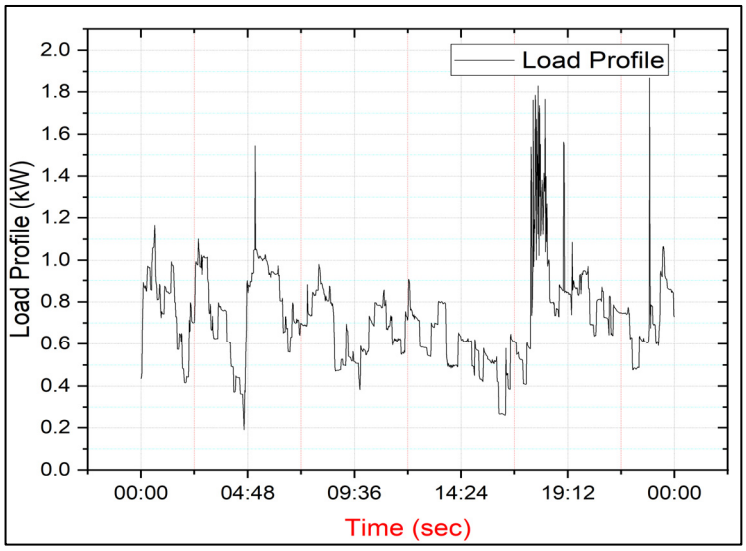


Figure 2. Real-time load profile.

3.2. Neural Network Model

NARX neural network is a recurrent dynamic neural network which is used to model different variety of non-linear systems. Series-parallel architecture of NARX network is well known for time series problems in which present and past value of $x(t)$ and the true past value of $y(t)$ are used to predict the output values as explained in Figure 3. The mathematical model is given as,

$$y(t) = f(x(t-1), \ldots, x(t-d), y(t-1), \ldots\ldots, y(t-d)) \quad (1)$$

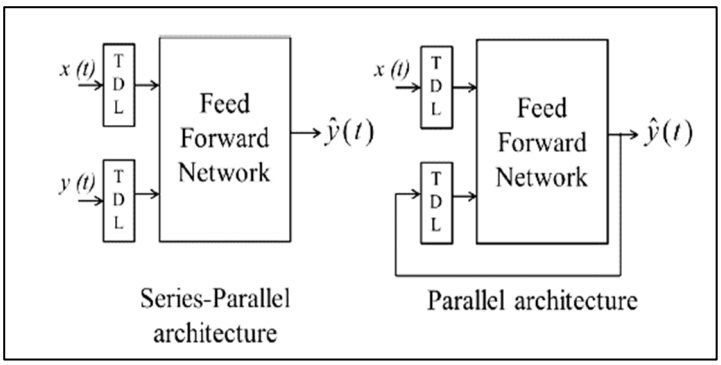


Figure 3. Series-parallel architecture of NARX.

During the application of NARX neural network, the data are prepared and loaded from workspace. Then, the data are divided into training, testing and validation datasets. The parameters of hidden layer are set by adjusting the no of neurons and time delay. Afterwards, time response, regression coefficient, and error correlation are observed. The whole process is undergone through the trial-and-error method by applying different combinations of datasets and parameters in hidden layer as shown in Figure 4. As a result, the most accurate predicted values are observed.

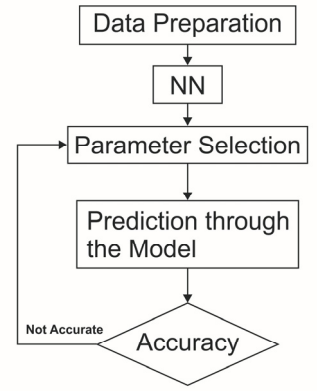


Figure 4. Workflow diagram.

3.3. Energy Management System

In Figure 5, an efficient model is presented for the energy management of a green residential system. PV and wind are acting as renewable energy source in presence of battery. Artificial intelligent monitoring and control unit (AIMC) analyze the forecasted load and make optimal decisions regarding energy trading. Baseline loads are small loads that are always connected to the supply and controllable loads are heavy and interruptible during emergency conditions. AIMC unit automatically switch off the controllable loads during cloudy days because renewable energy is not enough to entertain the heavy loads, but an energy demand request is sent to the other green homes to overcome the energy needs. With the mutual energy sharing, the overall demand can be met, and energy can be utilized in an eco-friendly environment.

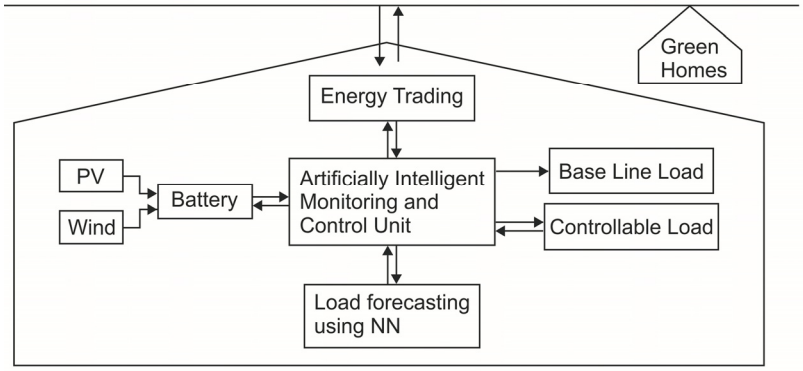


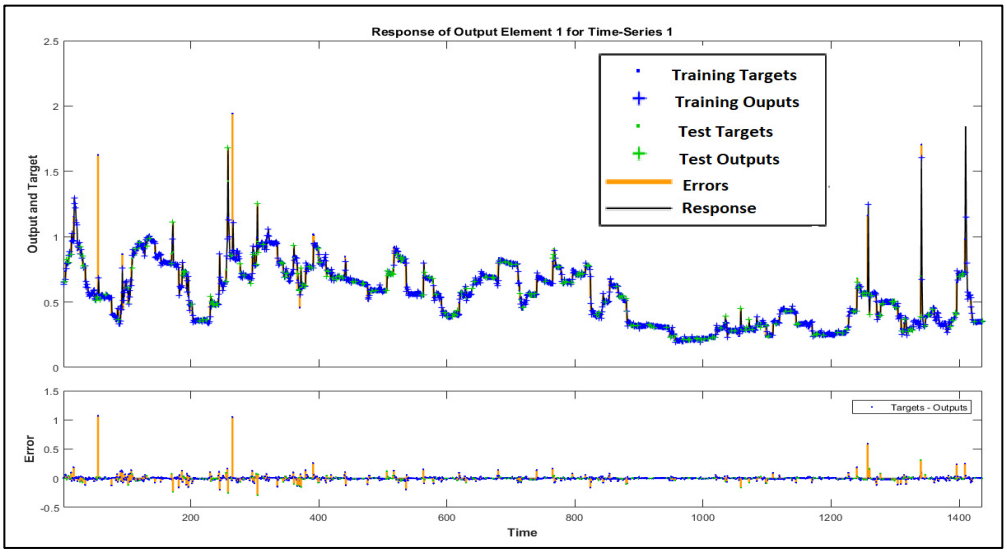
Figure 5. Green residential energy management system.

4. Results and Discussion

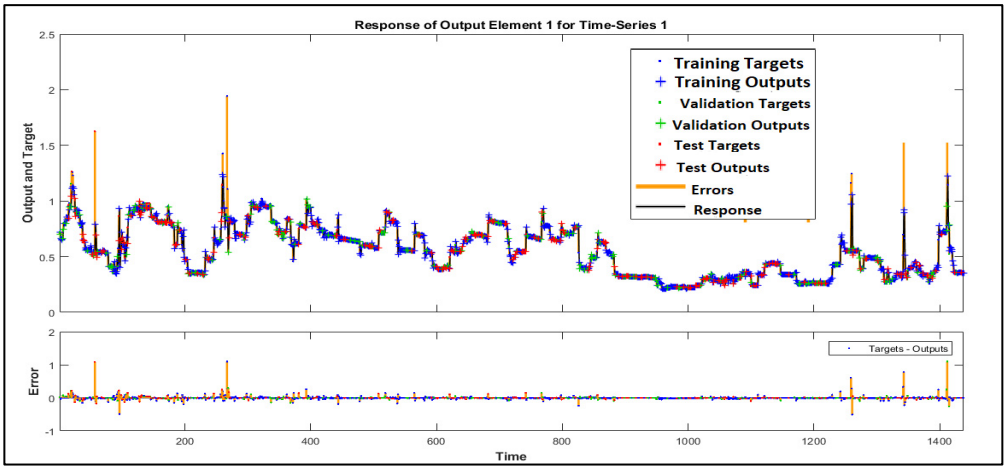
MATLAB software is used for testing and development of the NARX network. Two different types of NARX neural networks are used and their error evaluation is presented in Table 1. The first type has proven more accurate with lesser errors and better regression value. Figures 6 and 7 shows the time response and regression of NARX 1 and 2.

Table 1. Error evaluation of NARX networks.

Types of NARX	MSE	MAPE%	Regression
NARX 1	0.00323	0.226	96.93%
NARX 2	0.00545	0.293	94.86%

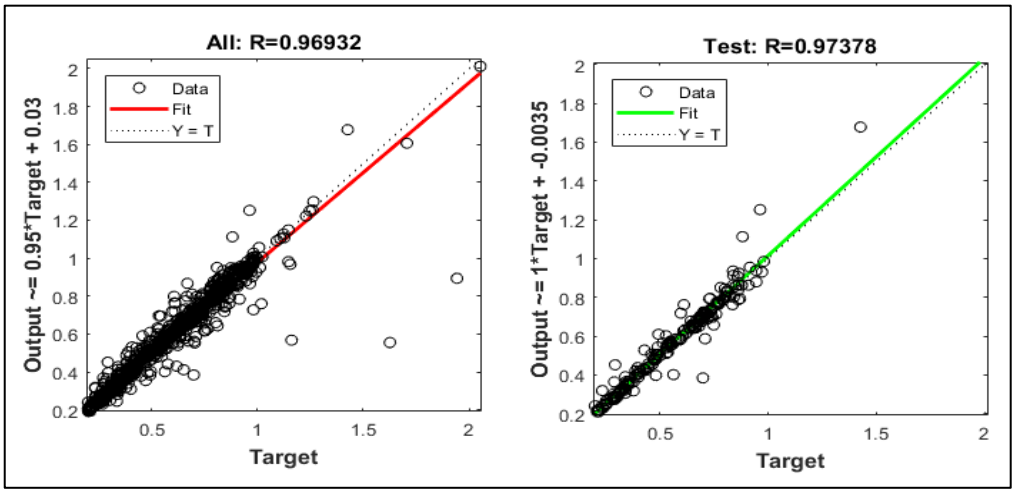


(**a**)



(**b**)

Figure 6. Time response of NN model: (**a**) NARX 1; (**b**) NARX 2.



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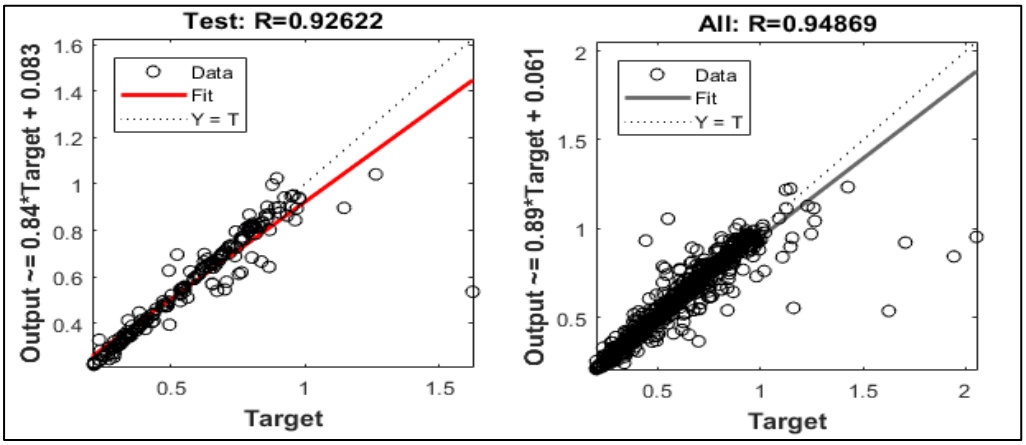

(**b**)

Figure 7. Regression value of NN model: (**a**) NARX 1; (**b**) NARX 2.

5. Conclusions

The results prove that the prescribed study is a good attempt to explore the load forecasting issue. The proposed study describes the performance of NN model in which the forecasting errors of 0.226% and 0.293% are observed and provides an initiative to build an efficient energy management system by presenting a green residential energy model. So, the overall efficiency of the proposed residential model is enhanced with an accurate forecasting and by working on the presented model it is hoped that the energy utilization may be improved in the future.

Conflicts of Interest: The authors declare no conflict of interest.

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