RNN based Energy Demand Prediction for Smart-Home in Smart-Grid Framework

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Abstract

In modern development arena, smart grid and smart home are indispensable for intelligent technology toward the sustainable expansion of green technology and social progress. Therefore, smart home appliances, automated vehicles as well as the renewable energy sources e.g. solar, wind etc. are the key components of the smart home, which guarantees the quality life and well-being. To empower those appliances, smart home needs to provide seamless energy management through the smart grid. In such case, it becomes more challenging for managing energy demand response in the smart home through the smart grid. Therefore, in this research, we have focused on solving this problem by introducing intelligent energy predictor for smart home users. More precisely, we have modeled intelligent energy predictor using recurrent neuron network for smart home IoT network. Finally, we have simulated the result of the proposed intelligent predictor model which shows higher performance gain of the proposed approach with respect to prediction accuracy and convergence.

1. Introduction

Smart home is the emblematic component of the smart grid that supports the complete IoT infrastructure consists of smart devices and renewable energy sources. Energy demand prediction is an essential task to fulfill the energy demand in a smart home. Therefore, most of the researchers have focused on service provider and suppliers point of view for forecasting the demand. However, it is more important to offer the energy demand prediction for the smart home users or other energy customers.

There are many ongoing research on energy distribution, power generation and smart grid framework development [1]. However, different types of IoT network platform are developed for smart city, smart home and other IoT applications [2]. Moreover, electrical load forecasting is one of the important challenges in which energy demand also depends on different types of weather condition [3]. On the other hand, for better manageability of the smart grid like huge infrastructure, it is necessary to forecast the accurate energy demand [4].

In this paper, we have proposed a smart device supported intelligent energy prediction model for smart home in smart grid framework. Also, we have compared our proposed method with other types of prediction model that ensure the efficiency of our proposal.

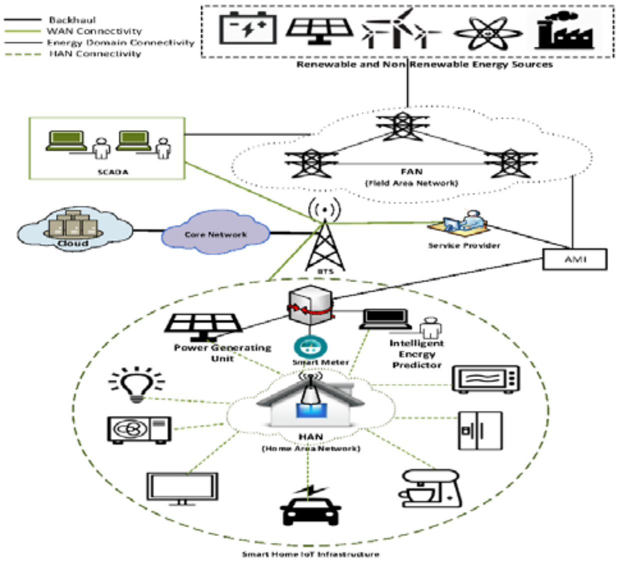

Figure 1: System Model

2. System Model

The system model of intelligent energy prediction model for smart home is depicted in Figure 1. In this system model, we have proposed a smart grid communication network with the smart device support in the home area network (HAN). However, this system model is also applicable for both residential area network (RAN) and industrial area network (IAN). Therefore, we have assumed that all the sub-station to sub-station communication, distribution and, monitoring system follows the IEC 61850-90-1 standard and supervisory control and data acquisition (SCADA) [5]. In this infrastructure, the main grid energy sources are both renewable and non-renewable energy sources. These sources are connected with field area network (FAN). Monitoring and distribution system are linked with wide area network (WAN) and FAN. Furthermore, the smart home IoT infrastructure has different types of smart home appliances, electric vehicles and also the renewable energy sources. Smart meter is the component of HAN, and gateway communicates with the advanced metering system (AMI). Additionally, there is intelligent energy predictor unit into the HAN and HAN is connected with WAN. Finally, the core network, cloud, and BTS are connected with backhaul connectivity.

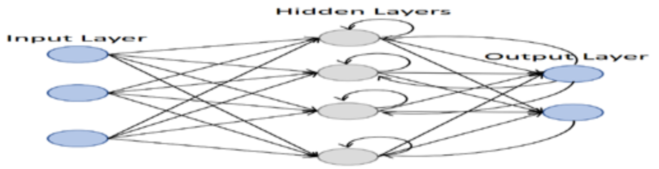

Figure 2: RNN Architecture

3. Intelligent Energy Prediction Using RNN

In Figure 2 shows the basic architecture of recurrent neuron network (RNN) [6]. There are input layer, hidden layer, and output layer. Hidden layers are fully connected. Also, the large depth of RNN able to handle the sequence data for decision making.

Table 1: Summary of Notation

Notation	Description
X_t	Input vector
h_t	Output vector of Prediction
m_t	Forget get vector
I_t	Input gate vector
O_t	Output gate vector
G_t	State gate vector
σ_o	Original sigmoid function
ϕ_E	Original hyperbolic tangent.
ϕ_h	Output hyperbolic tangent.

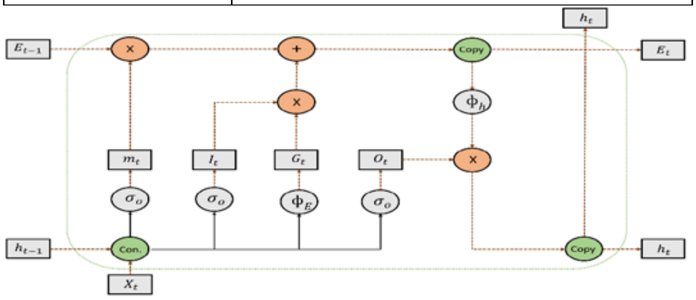

Figure 3: LSTM Architecture

The long short term memory networks (LSTMs) is the one of the optimized version of RNN and it is able to deal with the vanishing gradient problem. Figure 3 describes the basic components of stochastic gradient decent based LSTM architecture for energy demand prediction.

Following is the formulation for energy demand prediction,

$$m_t = \sigma_o(M_m X_t + V_m h_{t-1} + v_m) \quad (1)$$

$$I_t = \sigma_o(M_I X_t + V_I h_{t-1} + v_I) \quad (2)$$

$$O_t = \sigma_o(M_O X_t + V_O h_{t-1} + v_O) \quad (3)$$

$$G_t = \phi_E(M_E X_t + V_E h_{t-1} + v_E) \quad (4)$$

$$E_t = m_t \odot E_{t-1} + I_t \odot G_t \quad (5)$$

$$h_t = O_t \odot \phi_h(E_t) \quad (6)$$

In equation (1) M and V are the weight matrices and v is the bias vector that calculates the forget get vector m_t. Equation (2), (3), and (4) are responsible to finding the input gate vector I_t memory gate vector G_t and output gate vector O_t respectively. Equation (5) calculates the state vector and finally, the equation (6) gives the output vector for smart home energy demand prediction.

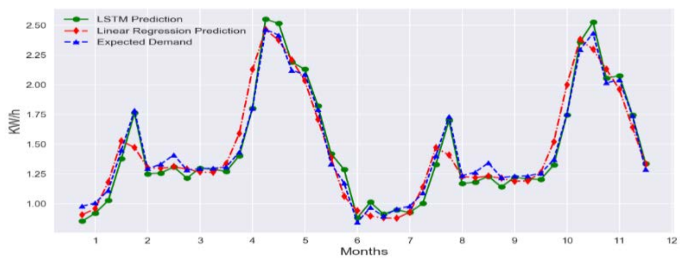

Figure 4: Prediction model comparison

Following is the intelligent energy predictor pseudo code,

***Algorithm:** Intelligent Energy Predictor*

1. Input : Vector X_t , episodes e
2. Output: Prediction vector h_t
3. **Repeat**
4. {
5. Step 1: Define and compile network:
6. Calculate m_t, I_t, O_t using eq. (1), (2) and (3)
7. Step 2: State store operation:
8. Calculate E_t using eq. (5)
9. Step 3: Update
10. $h_t = O_t \odot \sigma_h(E_t)$
11. } **Until** ∀ e

4. Performance Evaluation

In this research, we have implemented our proposed model on python platform and also, used openei residential dataset [7] for performance analysis.

Figure 4 depicts the higher prediction accuracy for RNN based LSTM (green dot) compare to linear regression (red diamond) model.

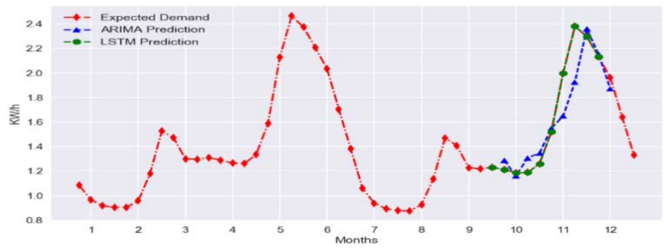

Figure 5: Energy demand forecasting

3 months energy demand forecasting represents in Figure 5 and it is observed that, the proposed model gain (green dot) higher accuracy than ARIMA model.

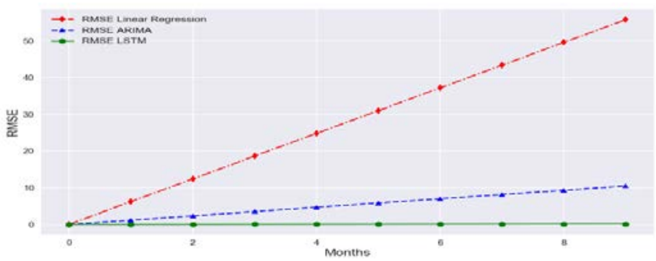

Figure 6: RMSE result

Finally, the root means square error (RMSE) is very less instead of other two methods that present in Figure 6.

5. Conclusion

RNN based smart home energy prediction model is a novel approach that enables the smart home user energy forecasting and manageability. The proposed approach substantially helps to reduce the risk to fulfill the energy demand response. Additionally, the computational and decision-making responsibilities are dispersed to smart home users instead of smart grid and service provider to facilitate the smart energy customer. This method will significantly reduce the risk of energy demand response failure in dynamic smart grid environment for smart home.

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