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Wind Speed Prediction Using Artificial Neural Networks Based on Multiple Local Measurements in Eskisehir

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Abstract

In this study, artificial neural network (ANN) based models, which differently uses multiple local meteorological measurements together such as wind speed, temperature and pressure values, are proposed and it shown ANN based multivariable model's wind speed predictions can be improved for various cases. A data monitoring system are used which can sensitively measures in milliseconds time interval and records the values of weather temperature, wind speed, wind direction and weather pressure in this study. The proposed ANN based multivariable model's root mean square error (RMSE) and mean absolute error (MAE) performances are presented and compared for various cases. The effect of using multiple local variables instead of wind speed only are analyzed and compared with persistence method for benchmark.

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Keywords: Wind energy; wind speed prediction; artificial neural network

1. Introduction

The production and the consumption of electricity has become the most important indicator of the level of development of the countries. Despite the fossil fuels are running out, the overall energy requirements in the world are met largely from fossil-based sources. At the same time, the electricity demand of the developing countries is continuously increasing [1]. Consequently, renewable clean energy sources, especially wind and solar energy

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sources have received much attention in recent years.

Wind energy is one of the most economical method of electrical power generation. Wind power plants require continuous and appropriate wind speed for sufficient power generation. For the reliability and quality of the power system, it is required to develop highly accurate wind speed prediction methods [2, 3]. For the future's optimum grid operations short term wind speed prediction is critical and a challenging problem. The prediction problem can be considered as in three categories such as; immediate short term, short term and long term based on the time horizon. In order to solve this problem, different methods have been implemented in the last decades, such as regression-based methods [4], ANN models [5-6], Markov chains [7], support vector regression [8], spatio-temporal models [9], and recently, applications of hybrid ANNs models with statistical or other intelligent [10-13], approaches have received attentions.

In this study, wind speed is predicted accurately by ANN based multiple local meteorological measurements. The proposed ANN models can differently use previous frequently recorded wind speed, temperature and pressure values together to predict the future wind speed value. Multivariable based ANN models prediction performance is tested with real data sets which are collected by using data monitoring system which can record 1 millisecond time interval sensor measurements. The effects of using multi meteorological data on wind speed prediction are clearly investigated in this study. The remaining parts of the paper are organized as follows. In Section 2, the description of the corresponding system which is constructed on a hybrid renewable smart home energy system is introduced. In Section 3, the multivariable based ANN structures for wind speed prediction is presented. Applications of the model and prediction performance results are shown in Section 4. Finally, in Section 5, the main contributions of this paper are emphasized and possible research directions are discussed.

Nomenclature

w (n)	wind speed values	*RMSE*	root mean square error
t(n)	temperature values	*MAE*	mean absolute error
p(n)	pressure values	*ANN*	artificial neural network
Δ	predicted lead time		

2. Description and representation of the data set

In this study, the data received from a data monitoring system that sensitively measures and records the values of global radiation, direct radiation, diffuse radiation, sunshine duration, weather temperature, wind speed, wind direction and weather pressure constructed on a hybrid renewable energy system consists of both 6 kW on-grid (3 kW ground mounted, 3 kW solar tracker) and 4 kW off-grid solar panels additionally 1 kW wind turbine for a smart house in Anadolu University Iki Eylül Campus of Eskisehir. All constructed renewable energy system is able to satisfy the energy needs of an average sized the house and give the big excessive produced energy to grid. The constructed hybrid renewable energy home system is shown in Fig. 1.

Fig. 1. Hybrid System Model in Anadolu University Iki Eylul Campus of Eskisehir

The measurement sensors and data logger are shown in Fig. 2 (a) and Fig. 2 (b), respectively.

Fig. 2. (a). Data Measurement System

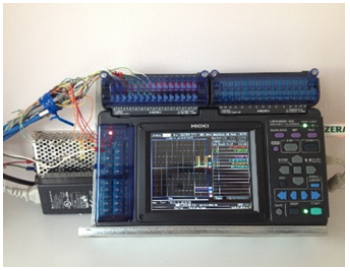

Fig. 2. (b). Data Logger

Monthly pattern of wind speed, weather pressure and weather temperature graphs are given from Fig. 3 to Fig. 5, respectively.

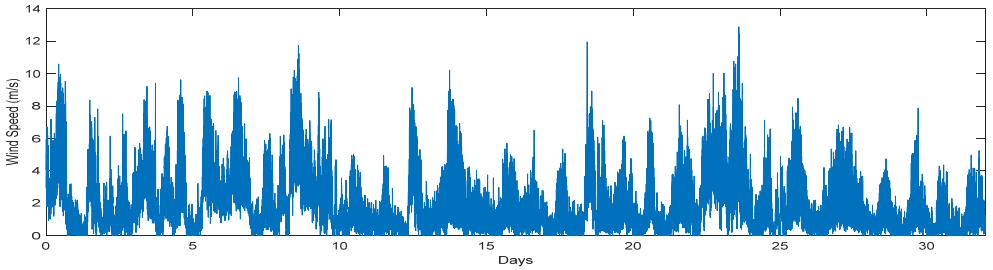

Fig. 3. Pattern of wind speed data in twenty seconds time interval in Anadolu University Iki Eylul Campus of Eskisehir

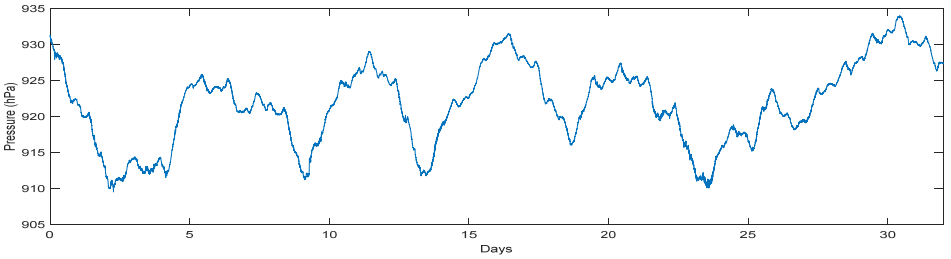

Fig. 4. Pattern of pressure data in twenty seconds time interval in Anadolu University Iki Eylul Campus of Eskisehir

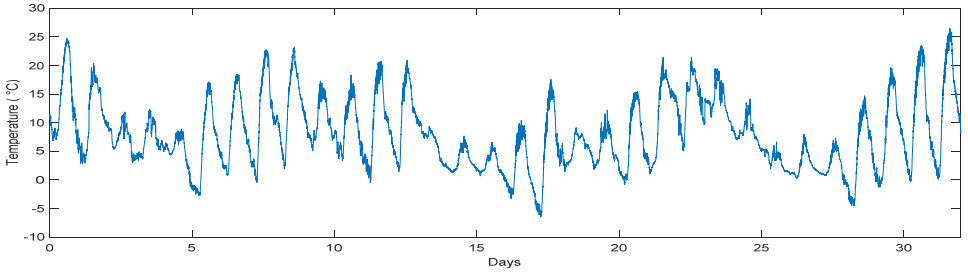

Fig. 5. Pattern of temperature data in Anadolu University Iki Eylul Campus of Eskisehir

3. The ANN structures based on multiple local meteorological data

The wind speed values are predicted using three different situations by using ANN in order to investigate multiple local meteorological data effect. For the three different cases, ANN structures are presented respectively in Fig. 6 (a), (b) and (c). In the first structure wind speed values predicted by only using wind speed data values. In the second structure, wind speed values predicted by not only wind speed values but also weather temperature values. And in the last structure, pressure values are also added the complete structure.

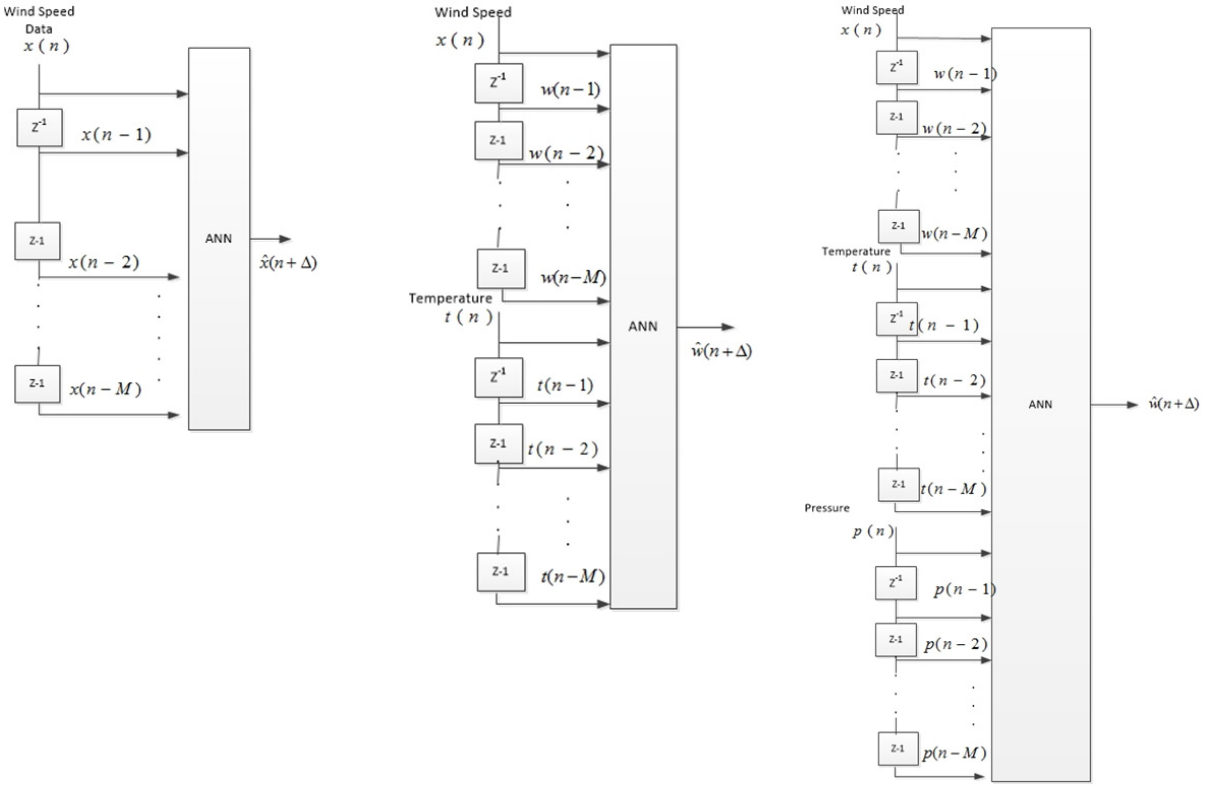

Fig. 6. (a) First structure (Only use wind speed data) (b) Second structure (use both wind speed and temperature data) (c) Third structure (use wind speed, weather temperature and weather pressure data).

4. Application and results

The above three different ANN structures are tested in part within three subsections. In first part, wind speed prediction with using only wind speed data results are presented. In the second part wind speed prediction with using weather temperature data, and lastly weather temperature data, and lastly wind speed data, weather temperature data and weather pressure data results is shown. The performances of the models are measured using RMSE and MAE values;

$$RMSE = \left[\frac{1}{N}\sum_{i=1}^{N}(x-\hat{x}_i)^2\right]^{1/2},\ MAE = \frac{1}{N}\sum_{t=1}^{n}|x-\hat{x}_i| \quad (2)$$

where N is the number of periods of time.

4.1. Wind speed prediction with using only wind speed data

The twenty seconds intervals wind speed data between 2 March and 2 April 2016 are get as the input; the last five-days are used as testing. The ANN structure has two layers is shown in Fig. 2. Feed forward back propagation is handled as a network type. Transfer function is take in a log-sigmoid. Because of the Levenberg –Marquard algorithm has fast convergence this algorithm is handled by learning process for all ANN structure. RMSE and MAE performances of according the forecast lead time (Δ) for only wind speed data results given in Table 1.

Table 1. RMSE and MAE performances of according the forecast lead time (Δ) for only wind speed data

Lead Time	RMSE	MAE
Δ =30	0.6508	0.5046
Δ =90	0.6940	0.5537

4.2. Wind speed prediction with using wind speed and temperature data

In this part, wind speed values predicted not only using wind speed values but also weather temperature values. The same structure is handled. The results are given in Table 2.

Table 2. RMSE and MAE performances of according the forecast lead time (Δ) for both wind speed and temperature data

Lead Time	RMSE	MAE
Δ =30	0.6502	0.5040
Δ =90	0.6903	0.5470

4.3. Wind speed prediction with using weather temperature data, wind speed data and weather pressure data

In this part, the weather pressure is added as an extra input data. Table 3 shows wind speed prediction with using wind speed weather pressure and weather temperature data.

Table 3. RMSE and MAE performances of according the forecast lead time (Δ) for weather temperature data, wind speed data and weather pressure data

Lead Time	RMSE	MAE
Δ =30	0.6494	0.5032
Δ =90	0.6759	0.5360

As it seen from the table results, the lowest RMSE and MAE values are obtained from third structure. For the second structure, the RMSE and MAE values has been smaller improvement according to third structure.

5. Conclusion

Wind speed prediction is extremely important for electricity market, strategy planning, commitment decision and wind farms studies for all horizon. In this study, the effects of different meteorological data for wind speed prediction are investigated using ANN. According to results, the lowest RMSE and MAE values are obtained from third structure. In the future, the analysis can be repeated for longer periods. Using different combinations of other channels, it can be investigated on the effects of wind speed prediction.

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