

Predicting daily distribution of solar irradiation by neural networks

S. Seme, G. Štumberger and J. Pihler

University of Maribor
Faculty of Electrical Engineering and Computer Science
Smetanova 17, 2000 Maribor (Slovenia)

Phone: +386 2 220 7179, Fax number: +386 2 252 5481, e-mail: Sebastijan.Seme@uni-mb.si

Abstract. This work focuses on prediction of solar irradiation during the day. In order to predict half hourly solar irradiation during the day an artificial neural network is applied. The artificial neural network was trained using error backpropagation learning rule. Meteorological data measured during three years were used to form learning patterns. The trained artificial neural network was tested with different patterns. Some of them were new while the others were used in the training procedure. The comparison of measured and by the artificial neural network predicted daily distribution of solar irradiation shows a very good agreement for the clear days.

Key words

Daily distribution of solar irradiation; Prediction; Artificial neural networks; Meteorological parameters, Clear day

1. Introduction

Solar irradiation is a very important data for engineers who can, based on this data, define the incline and necessary number of solar modules for required power of the solar power plant. Measurement of meteorological parameters such as temperature, global irradiance, relative air pressure etc. in Slovenia is performed in the scope of Environmental Agency of the Republic of Slovenia (ARSO) in 22 point. In the cases, when the measurements of solar irradiation cannot be performed, it can be predicted by different solar models. In this way a good estimation of solar potential can be obtained.

Artificial neural network is an appropriate tool for solving real problems in the cases where classical methods are insufficient. The meteorological parameters are important parameters for indicating the amount of available solar irradiation. In this work an artificial neural network is applied to predict daily distribution of solar irradiation considering extraterrestrial irradiation and meteorological parameters.

There exist many articles where artificial neural network is applied to predict average daily solar irradiation [1]-[5]. Only a few of them, [6] and [7], are focused on solar irradiation in discrete, one hour long, time intervals during the day.

In this work five different parameters such as extraterrestrial solar irradiation on a horizontal surface, solar zenithal angle, day in the year, temperature, and relative air pressure, given in a half hour long time intervals, are used as input for artificial neural network, which is applied to predict daily distribution of solar irradiation. The results presented in the paper are given for the town Maribor in Slovenia. For training of the artificial neural network measured meteorological data for clear days between January 1st 2005 and March 31st 2008 are used. They are provided by ARSO. The comparison of measured and predicted daily distribution of solar irradiation shows a good agreement for clear days. However, some more work is needed to get acceptable agreement between measured and predicted daily distribution of solar irradiation for cloudy days.

2. Data collection

For training the artificial neural network, data like extraterrestrial solar irradiation, solar angle, temperature, relative air pressure and global irradiance are required. The first two are obtained by numerically while the last three are measured data provided by ARSO.

3. Neural networks

Neural networks are composed of simple elements operating in parallel. These elements are inspired by biological nervous systems. As in nature, the network function is determined largely by the connections between elements.

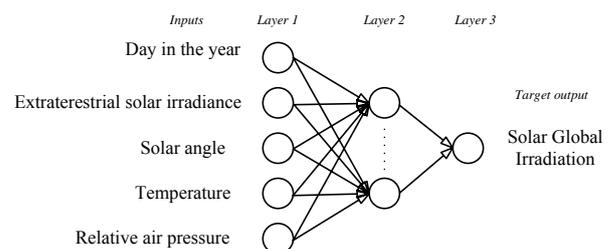


Fig. 1. Three-layer artificial neural network inputs and target.

In this study calculation and meteorological indicators have been used for distribution of solar irradiation on horizontal surface. If more indicators are used, better results in output of the model can be achieved. In this work five input parameters and one target parameter were used to train the artificial neural network. The input parameters were the day in the year, the extraterrestrial solar irradiation on a horizontal surface, the solar angle, the temperature, and the relative air pressure, while the target parameter was measured global irradiance.

4. Results

Once the artificial neural network is trained, which means that all of weights and bias are set, it can be tested. First of all it can be tested with the patterns which were used in the training procedure.

A comparison of measured and by the artificial neural network predicted global irradiance is presented point by point in Fig. 2. Better agreement of points presented in Fig. 2 with the straight line means also better agreement between measured and predicted points.

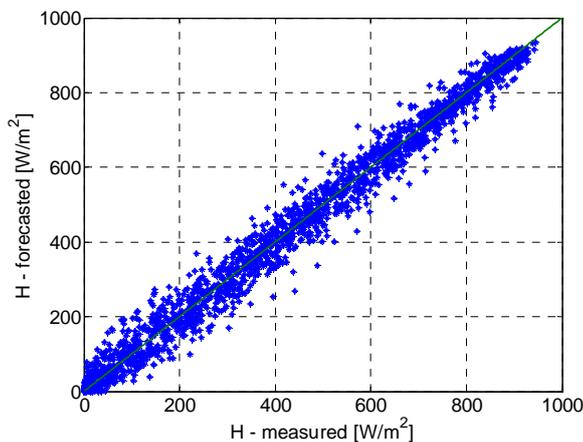


Fig. 2. Testing the trained artificial neural network with training patterns.

The comparison of the measured and predicted values shows that these values are aligned along the straight line. Quality of the trained artificial neural network can be evaluated only when it is tested also with the patterns that were not included in the training procedure. Fig. 3 shows comparison of measured and predicted global irradiance for the patterns that were not used in the training procedure.

The comparison of the measured and predicted values shows that the artificial neural network is well trained.

5. Conclusions

In this work daily distribution of global solar irradiance for clear days is predicted by the artificial neural network. The artificial neural network with 30 neurons in the first layer, 10 neurons in the second layer and 1 neuron in the third layer is used. It contains five inputs and one output. The inputs are calculated extraterrestrial solar irradiation, the day in the year, the solar angle, the temperature and the relative air pressure, while the output

parameter is the global irradiance. For training of the artificial neural network measured data acquired in three years are used. Daily distribution of the global solar irradiance predicted by the trained artificial neural network is acceptable for clear days. However, some more work is needed to improve predicted daily distribution of global solar irradiance for cloudy days.

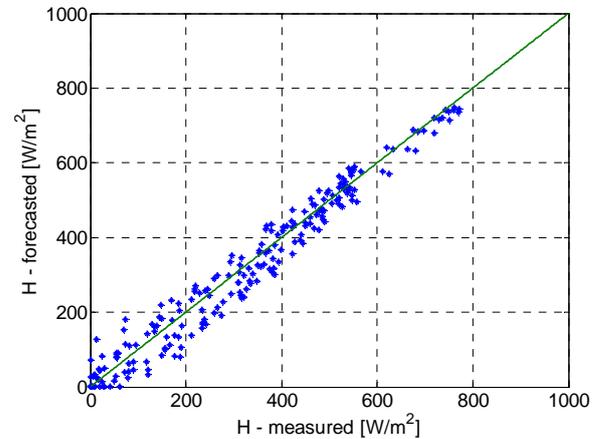


Fig. 3. Testing the trained artificial neural network with patterns which were not used in training.

References

- [1] J. L. De Souza, R. M. Nicacio, M. A. Moura, "Global Solar radiation measurements in Maceio, Brazil", *Renewable energy* 30 (2005) 1203-1220.
- [2] J. C. Cao, S. H. Cao, "Study of forecasting solar irradiance using neural networks with preprocessing sample data by wavelet analysis", *Energy* 31 (2006) 3435-3445.
- [3] S. Pattanasethanon, C. Lertsatitthanakorn, S. Atthajariyakul, S. Soponronnarit, "An accuracy assessment of empirical sine model, a novel sine model and an artificial neural network model for forecasting illuminance/irradiance on horizontal plane of all sky types at Mahasarakham, Thailand", *Energy Conversion and Management* 49 (2008) 1999-2005.
- [4] S. Cao, J. Cao, "Forecast of solar irradiance using recurrent neural networks combined with wavelet analysis", *Applied Thermal Engineering* 25 (2005) 161-172.
- [5] A. Azadeh, A. Maghsoudi, S. Sohrab Khani, "Using an Integrated Artificial Neural Networks Model for Predicting Global Radiation: The Case Study of Iran", *ICREPO*
- [6] J. Cao, X. Lin, "Study of hourly and daily solar irradiation forecast using diagonal recurrent wavelet neural networks", *Energy Conversion and Management* 49 (2008) 1396-1406.
- [7] A. Sfetsos, A. H. Coonick, "Univariate and multivariate forecasting of hourly solar radiation with artificial intelligence techniques", *Solar Energy* Vol, 68, No. 2, pp. 169-178, 2000.
- [8] *Neural Network Toolbox, Matlab User's Guide, Version 5, 2006*
- [9] J. Pihler, B. Grčar, D. Dolinar, "Improved operation of power transformer protection using artificial neural network", *IEEE Trans. On Power Delivery, Vol. 12, no. 3, pp. 1128-1136, 1997*