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Optimum estimation and forecasting of renewable energy consumption by artificial neural networks



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ABSTRACT

Increasing energy consumption has led to release of pollutants such as greenhouse gases that affects on human health, agriculture, natural ecosystems, and earth temperature. Accurate estimation and forecasting of renewable energy is vital for policy and decision-making process in energy sector. This paper presents an Artificial Neural Network (ANN) approach for optimum estimation and forecasting of renewable energy consumption by considering environmental and economical factors. The ANN trains and tests data with Multi Layer Perceptron (MLP) approach which has the lowest mean absolute percentage error (MAPE). The proposed approach is particularly useful for locations where there are no available measurement equipments. To show the applicability and superiority of the proposed ANN approach, monthly available data were collected for 11 years (1996–2006) in Iran. Complete sensitivity analysis is conducted to choose the best model for prediction of renewable energy consumption. The acquired results have shown high accuracy of about 99.9%. The results of the proposed model have been compared with conventional and fuzzy regression models to show its advantages and superiority. The outcome of this paper provides policymakers with an efficient tool for optimum prediction of renewable energy consumption. This study bypasses previous studies with respect to several distinct features.

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1. Motivations and significance

Renewable energy as the energy that is replenished naturally has a crucial role in environment protection, decreasing earth temperature, ozone layer protection and sustainable development. Additionally, fossil fuel resources with themselves bring harmful

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impacts on health and environment. Moreover, they are being replaced with new and clean sources of energy. Therefore, the need for clean and safe energy is essential in long term. Long-term planning to increase renewable energy consumption is needed to recognize the amount of renewable energy consumption in different periods and specify the important factors affecting on renewable energy demand. Thus, optimum forecasting of renewable energy consumption is vital. By exploring in the renewable energy literature we find that the measurement of renewable energy consumption has a costly procedure and also the required measurement instruments are not easily available. Thus, an accurate and efficient method for prediction of renewable energy consumption can be very helpful in this perspective. An intelligent approach is proposed to forecast and predict renewable energy consumption by an effective and efficient procedure.

2. Introduction

As populations grow, many faster than the average 2%, the need for more and more energy is exacerbated. Enhanced lifestyle and energy demand rise together and the wealthy industrialized economies which contain 25% of the world's population consume 75% of the world's energy supply [1]. Renewable energy sources are readily available in nature. Increasing atmospheric concentrations of greenhouse gasses increase the amount of heat trapped (or decrease the heat radiated from the earth's surface), thereby raising the surface temperature of the earth [2]. There are many alternative new and renewable energy sources which can be used instead of harmful fossil and conventional fuels. The energy resources have been split into three categories: fossil fuels, renewable resources, and nuclear resources [3]. The optimum decision as to what types of energy source should be utilized must, in each case, be made on the basis of economic, social, environmental and safety considerations. Exploring the literature in the field of energy consumption shows that in several countries there is a positive relationship between gross domestic production (GDP) and energy consumption. Sadorsky [4] shows that a 1% increase in real GDP per person increases per capital renewable energy consumption by 8.44% while a 1% increase in carbon dioxide emissions per person increases per capital renewable energy consumption by 5.23%. Improving some of the main features of manufacturing technology is directly related to energy consumption. The importance of energy in economic development is recognized universally and historical data verify that there is a strong relationship between the availability of energy and economic activity [2]. Increasing in greenhouse gases levels in the atmosphere will lead to warmer temperatures on the earth's surface. CO₂ is main greenhouse gas associated with global warming. At the present time, coal is responsible for 30–40% of world CO₂ emissions from fossil fuels. About 98% of carbon emissions result from fossil fuels (coal, oil, and natural gas) combustion and also currently, renewable energy resources supply 14% of the total world energy demand [5]. In addition, Demirbas [5] stated that accumulation of greenhouses in atmosphere leads to negative impacts such as air pollution and acid rains. Air pollution can cause health problems and it can also damage the environment and property. It has caused thinning of the protective ozone layer of the atmosphere, which is leading to climate change and acid rain causes extensive damage to water, forest, soil resources and even human health. It is said that it can corrode buildings and be hazardous to human health.

The limitations of energy resources and strictly increasing energy consumption trend show the need to design accurate devices for consumption of energy in manufacturing sector in particular and industrial sector in general. Hence, there is a need to focus on trend of energy consumption in the future, particularly

in manufacturing sector. The renewable energy resources (i.e., solar, wind, wave, biomass and geothermal energy) have shown undeniable benefits with regard to essential technical, environmental and political visions which can be considered as the future prospect of energy. Renewable energy is energy that comes from natural resources such as sunlight, wind, rain, tides, and geothermal heat, which are renewable (naturally replenished). Renewable energy is freely available and could be easily harnessed to reduce our reliance on hydrocarbon-based energy by both, passive and active designs. With expanding of energy consumption at worldwide, release of pollutants such as greenhouse gases makes that human health, agriculture, natural ecosystems be affected and also greenhouse gases traps the heats rising from earth and so makes increasing in earth temperature. One of the ways to decrease these harmful effects is developing of clean energies consumption such as renewable energy consumption. Using renewable energy and its impact in reducing greenhouse emission necessitates an exact estimation of renewable energy consumption. This subject is usually possible through measurement equipments of component of renewable energy (i.e., solar energy, windy energy, tidy energy and so on) while these devices are not available in some of remote or rural locations.

Using artificial neural network has proved its efficiency as an estimation tool for predicting factors through other input parameters which have no any specified relationship. Some examples of this work are provided in [6–12]. Also the capabilities of ANN methods help us to gain more reliable results. In this study we have introduced six most important effective parameters for forecasting renewable energy consumption by an integrated ANN model as follows: carbon dioxide emission, nitrogen oxide emission, carbon mono oxide emission, gas price, oil price and GDP. The output is monthly renewable energy consumption and also for post process model we considered lagged observation. Lagged variable leads to a stable ANN model. We have applied these input parameters in the framework of ANN model and data has been tested and trained by Multi Layer Perceptron (MLP). Comparing the acquired results of this study respect to well-known regression models and fuzzy regression prediction models shows a considerable improvement in the error amount and accuracy of prediction. Also the proposed model has shown higher accuracy with regard to other similar studies which use ANN methods. As an instance case study, we collected monthly data for 11 years (1996–2006) in Iran and then the best ANN model was chosen by sensitivity analysis process. In the present work, we provide a prediction with a believable amount of error which is obtained with regard to more available input parameters.

3. Studies on the advances in developing renewable energy and applied methods

The use of renewable energy offers a range of exceptional benefits, including: a decrease in external energy dependence; a boost to local and regional component manufacturing industries; promotion of regional engineering and consultancy services specializing in utilization of renewable energy; increased R&D, decrease in impact of electricity production and transformation; increase in the level of services for the rural population; creation of employment, etc. [13]. Interesting consequences can be obtained from the analysis of the trend of main world energy indicators between 1973 and 2004 [14]: (1) the rate of population growth is well below the GDP, resulting in a considerable rise of per capita personal income and global wealth, (2) primary energy consumption is growing at a higher rate than population, leading to the increase of its per capita value on 15.7% over the last 30 years, (3) CO₂ emissions have grown at a lower rate than energy

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