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Research Paper

Estimation of air dew point temperature using computational intelligence schemes

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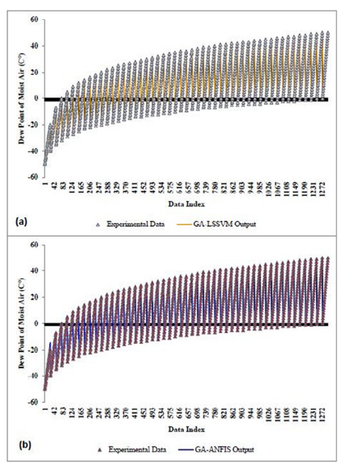
HIGHLIGHTS

- LSSVM is used to estimate the dew point of atmospheric moist air.
- The model has been developed and tested using 100 series of the data.
- ANFIS is used to estimate the dew point of atmospheric moist air.
- Genetic Algorithm (GA) was applied to optimize the corresponding parameters of these models.

GRAPHICAL ABSTRACT



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ABSTRACT

The condensation of water vapor is a crucial problem, which might have serious problems, i.e. corrosion of metals and the wash out of protective coating of apparatuses, devices and pneumatic systems. Therefore, the dew point temperature of air at atmospheric pressure should be estimated with the intention of designing and applying the suitable kind of dryer. In the current contribution, two models based on statistical learning theories, i.e. Least Square Support Vector Machine (LSSVM) and Adaptive Neuro Fuzzy Inference System (ANFIS), were developed to predict the dew point temperature of moist air at atmospheric pressure over extensive range of temperature and relative humidity. Moreover, to optimize the corresponding parameters of these models, a Genetic Algorithm (GA) was applied. In this regard, a set of accessible data containing 1300 data points of moist air dew point in the temperature range of 0–50 °C, at a relative humidity up to 100%, and atmospheric pressure has been gathered from the reference.

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Estimations are found to be in excellent agreement with the reported data. The obtained values of Mean Squared Error (MSE) and R-Square (R^2) were 0.000016, 1.0000 and 0.382402, 0.9987 for the LSSVM and ANFIS models respectively. The present tools can be of massive practical value for engineers and researchers as a quick check of the dew points of moist air.

1. Introduction

The dew point of saturated air is the amount of water vapor in the air. Water can exist in the three different states, such as liquid, solid and gas over a wide range of applications [1].

Air is a mixed gas composed of nitrogen, oxygen and water vapor. Therefore, based on Dalton's law, the total pressure of air is the summation of the partial pressures of the aforementioned gases.

The concentrations of nitrogen and oxygen are relatively constant, but the concentration of water vapor changes significantly. Owing to this problem, the amount of water vapor in air should be measured.

The significance of the dew point temperature in compressed air relies upon the application of air in any system. Its applications in portable compressors for pneumatic apparatuses, gas station tire filling systems and other cases are not problematic [2].

The main problematic effect of the dew point is in pipelines, which carry the air close to freezing temperatures. This phenomenon leads to blockage of the pipes [3]. The main application of compressed air in most present industries is to operate a variety of apparatus. The compressed air system can malfunction if condensation forms on the internal parts [4,5]. Moreover, there are special susceptible processes with water that need to have particular dryness specifications of a compressed air system.

The range of dew point temperatures in compressed air changes between 25 and –80 °C and in some special conditions, the dew point temperature decreases to lower values. Compressor systems that work without an air dryer have a tendency to produce saturated air at ambient temperature [6]. In addition, the compressed air is passed through some sort of cooled heat exchanger in systems with the capability of refrigerant drying. Therefore, in these systems, the condensed water is formed out of the air stream and the dew point temperatures are typically less than 5 °C. A desiccant dryer is a type of dryer capable of absorbing water vapor from the air stream and producing air with a dew point temperature of –40 °C [2].

Moreover, dew point temperature can be a reliable prediction of near-surface humidity. Hence the dew point temperature can change the stomatal closure in plants, where low humidity can diminish the productivity of the plants [7]. Most models in the fields of agronomic, ecologic, hydrologic, and climatologic need dew point temperature for predicting evapotranspiration [8].

The dew point temperature of a gas increases with increasing pressure. On the other hand, expanding compressed gas to atmospheric pressure leads to a decrease in the partial pressures of all the components of the gas mixture.

To prevent any problems in the air compressor systems, the design of the dew point temperature must be more than 10–12 °C under the lowest recorded outside temperatures in the line pressure for these systems [2]. Therefore, the dew point temperature of moist air should be estimated with the aim of designing and applying the appropriate type of dryer.

Since, different correlations have been developed to determine properties of moist air [1–5]. Bahadori developed a correlation based on Arrhenius-type asymptotic exponential function for estimating of saturated air dew points as a function of temperature and relative humidity at elevated pressures [9]. Another model is developed by Wexler et al. and applied in a temperature range of 0–200 °C to calculate properties of moist air. Also, a correlation based on Wexler model was developed by Hermann et al. [6] for moist air that is applied for a temperature and pressure range of 130–623.15 K and 0.01–10 MPa respectively. In this model dry air and water vapor are considered as real gases and also they used combined cross virial coefficients to achieve the accurate values of moist air properties. Another approaches based on computational intelligence paradigms can be applied for this prediction. There are four commonly used embranchments of computational intelligence paradigms, i.e. artificial neural network, fuzzy logic, adaptive neuro-fuzzy inference system and support vector machine [10–15]. Through combining the learning capability of neural networks [16–18] with the knowledge of fuzzy logic [19], a new structure is created namely, ANFIS which is abbreviate of adaptive neuro-fuzzy inference systems. Recently, support vector machines (SVMs) are a popular learning technique for classification, regression, and other learning task. Unlike traditional artificial neural network technique, the quadratic programming (QP) with linear limitations is formulated in SVM problems [14,15]. Also, simplifying the optimization processes of SVMs can be performed through a modification version of SVM namely Least Square Support Vector Machine (LSSVM) [20,21].

In this study, two models based on statistical learning theories, i.e. Least Square Support Vector Machine (LSSVM) and Adaptive Neuro Fuzzy Inference System (ANFIS), were developed to predict the dew point of atmospheric moist air over extensive range of the temperatures and relative humidities according to experimental data gathered from the reported reference [22]. The present tools can be of massive practical value for engineers and researchers as a quick check of the dew points of moist air to take safety measures for controlling the quality of atmospheric moist air and compressed air.

2. Theory

A search for the highest outputs for a mathematical problem requires a reliable method. Despite the high precision that neural networks have indicated in various areas, the non-reproducibility of the results is a critical shortcoming, which is related to the random initialization in the system. To obtain the best data from these models, it is necessary to use methods, such as the LSSVM and ANFIS [19,21,23].

When designing a mathematical model, there is a very important aspect, called the outlier diagnostics. The outliers are individual data that diverge from most of the data. The main source of the outliers is experimental error. This false data might have an undesirable effect on the model and reduce its accuracy depending on the divergence of them from the bulk of the data.

2.1. Least Square Support Vector Machine (LSSVM)

According to theory of statistical learning, support vector machine (SVM) is a ubiquitous learning approach and it was first proposed by Vapnik [24]. Furthermore, it has been mostly used to solve regression problems and the obtained result is often more accurate and better than other machine learning approaches such as multilayer perceptron artificial neural network and fuzzy logic system [25]. Based on the principle of structural risk minimization, SVM takes the fitting of training data and the complexity of the training sample into consideration [26–28]. SVM has been used recently in most engineering fields and proposed models with better accuracy than other systems [29]. This novel approach is based on the