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Extreme learning machine approach for sensorless wind speed estimation

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ABSTRACT

Precise predictions of wind speed play important role in determining the feasibility of harnessing wind energy. In fact, reliable wind predictions offer secure and minimal economic risk situation to operators and investors. This paper presents a new model based upon extreme learning machine (ELM) for sensor-less estimation of wind speed based on wind turbine parameters. The inputs for estimating the wind speed are wind turbine power coefficient, blade pitch angle, and rotational speed. In order to validate authors compared prediction of ELM model with the predictions with genetic programming (GP), artificial neural network (ANN) and support vector machine with radial basis kernel function (SVM-RBF). This investigation analyzed the reliability of these computational models using the simulation results and three statistical tests. The three statistical tests includes the Pearson correlation coefficient, coefficient of determination and root-mean-square error. Finally, this study compared predicted wind speeds from each method against actual measurement data. Simulation results, clearly demonstrate that ELM can be utilized effectively in applications of sensor-less wind speed predictions. Concisely, the survey results show that the proposed ELM model is suitable and precise for sensor-less wind speed predictions and has much higher performance than the other approaches examined in this study.

1. Introduction

Wind speed plays important role in operation and management of wind energy [1]. Investigators directly measure or estimate speed of the wind. Measurement of wind speed is considered most difficult among various climatological variables [2,3]. Nevertheless, it is important for wind energy systems to accurately measure and estimate wind speed [4,5]. Report from the Intergovernmental Panel on Climate Change [51] raises concern on global warming. Therefore, various nations are looking to increase their share of energy consumption from renewable sources such as wind energy.

Many wind energy systems use generation systems with variable speed [6] as it extracts more wind power than a system that works at constant speed [7,8]. Rotation speed of turbine shaft adapts to varying wind speed to extract maximum power [9]. In other words, the main feature of variable generation system is rotation speed of turbine shaft adapts according to wind speed [9–11]. Normally, engineers deploy wind speed anemometers for measuring wind speed. However, high coast of wind anemometers discourage their usage in broad applications. For example in one wind farm one anemometer cannot be used since wind speed varies from one turbine to another [12–15]. Therefore, engineers replace anemometers with digital estimators for broad application like wind farm [16,17]. Digital wind estimator's working principal is based on the characteristics of wind turbines. For this reasons, it is desirable to replace the mechanical anemometers by the digital wind-speed estimator based on the turbine attribute [16,17]. Published literature report many wind speed estimation methods [18–23].

In addition to traditional methods, soft computing methods can be used for estimating speed of wind. Soft computing methods do not require knowledge on internal system variables. In addition, it offers advantages such as simpler solutions for multi-variable problems and factual calculation [24]. Soft computing is a novel approach for making computationally intelligent systems.

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