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# Improving Solar Energy Prediction in Complex Topography Using Artificial Neural Networks: Case Study Peninsular Malaysia

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*This research assesses the feasibility of using artificial neural networks (ANN) to predict and improve the spatial distribution of solar radiation data, using Peninsular Malaysia as a case study. This peninsula has seas to the east and west that control cloud formation and rain throughout the year. A rugged mountain range bisects the length of the peninsula creating a complex topography. These features make it difficult to develop effective empirical solar radiation models to cover large areas in Peninsular Malaysia. In this article, several different solar radiation prediction models were designed using the ANN tool in MATLAB. Geographical and meteorological data from 24 solar energy stations were used to predict the solar radiation in 341 cities. Standard multilayer, feed-forward, and back-propagation neural networks were used for the 12 solar radiation models with different numbers of neurons, training functions and activation functions. Predicted solar radiation results were actively used to develop monthly solar radiation maps. The results show that the mean absolute percentage error is less than 6.07% for both the training and testing datasets. This shows that the models are highly reliable predictors of solar radiation values, even in the selected locations that have deficient or unavailable solar radiation databases. The maps show that Peninsular Malaysia receives a monthly average daily solar radiation of between 3.82 and 5.23 kWh/m$^2$-day, and that the extreme northern region in Peninsular Malaysia has the highest solar radiation intensity throughout the year.* © 2015 American Institute of Chemical Engineers Environ Prog, 00: 000–000, 2015

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## INTRODUCTION

In many regions of the world it is difficult to acquire and compile solar radiation data due to the complex topography of the land mass. Quantitative and qualitative measurements require long periods of time (normally several years) in order to be of practical use for evaluation. Rugged terrains and hostile climatic conditions make it very difficult to obtain distributed data over many regions, due to problems with installation, maintenance, quality control, and cost [1]. Therefore, currently available data (with acceptable accuracy) must be judiciously exploited and extrapolated [2]. Different attempts have been made to extrapolate extensive field results by creating solar radiation models based on satellite and meteorological station databases. Two types of such models have been critically reviewed in many studies [3–6]. The first type is an empirical entity based on the meteorological parameters employed. The second type includes data mining models such as Artificial Neural Networks (ANNs) or Fuzzy Logic, whereby each model is defined by its intrinsic characteristic accuracy.

Peninsular Malaysia has 24 meteorological stations that measure solar radiation, each operated by the Meteorological Department of Malaysia. Several different empirical models have been built to predict solar radiation in different locations throughout Peninsular Malaysia [7–13]. Since these empirical models are generally tied to a single location, as well as being limited in scope and application, they are not suitable for creating a solar radiation map of the entire peninsula. The rugged terrain of the peninsula severely hinders the accuracy of extrapolating such models [12].

This research article focuses on two objectives. The first is to evaluate the advantages of using artificial neural network (ANN) techniques to predict solar radiation in a region with complex weather patterns and topographical geography. The second is to show how the topography impacts the solar radiation distribution over Peninsular Malaysia. It is hoped that the procedures employed in this study will provide a prediction method that will be useful for stakeholders seeking to exploit solar energy as an alternative energy source.

## METEOROLOGICAL STATION DATA

Peninsular Malaysia is characterized by an extensive coastal plain in the east and west. It has 9 states extending from 1°20' to 6°40' latitude north and 99°35' to 103°20' longitude east. The central parts are rugged, mountainous