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Using artificial neural networks to estimate solar radiation in Kuwait

Mohammed Bou-Rabee[a,*], Shaharin A. Sulaiman[b], Magdy Saad Saleh[c], Suhaila Marafi[d]

[a] PAAET Department of Electrical Engineering, College of Technological Studies, Kuwait
[b] Department of Mechanical Engineering, Universiti Teknologi Petronas, Tronoh, Malaysia
[c] PAAET, Science Department, College of Basic Education, Kuwait
[d] Department of Studies & Research, Ministry of Electricity & Water, Kuwait

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ABSTRACT

It is an aim of the Kuwaiti government to achieve more penetration levels of renewable energy sources into the national electric grid. Among the various available renewable energy alternatives, solar power generation imposes itself as the most feasible and reasonable solution for a greener Kuwait. In Kuwait, hours of sunshine range between 7 h per day in December and 11 per day in August. On average, there are about 3347 sunshine hours per year, which make it an ideal place for massive solar energy generation. This massive potential for solar energy will reduce Kuwait's dependency on oil and other fossil fuels and lead to a more secure power supply, a modernized Kuwaiti electric network, more job vacancies, and a dramatically cleaner environment. It is essential to quantify the amounts of solar radiation recorded during the past few years and to make projections for the future. In this paper, a model forecaster for the daily average solar radiation in Kuwait has been developed. The forecasting model is based on artificial neural networks that are able to cope with nonlinear data. Actual data from five different Kuwaiti sites were used as training/testing data while developing the model. The developed forecaster is intended to help country officials, prospective investors, and power system engineers choose locations for solar installation and assess the techno-economic merits of large-scale solar energy integration.

1. Introduction

Electric power systems are undergoing profound changes that have been triggered by the advent of new technologies not only in generation and storage but also in power electronics, sensing, control, computing, and communications [1]. Specifically, they are evolving toward more flexible infrastructures, termed Smart Grids, with the deployment of Distributed Generation, Intelligent Electronic Devices (IEDs), Flexible AC Transmission System Devices (FACTS), HVDC links, wide-area synchrophasor measurements, demand responses, microgrids, and virtual power producers, to cite a few. One of the main features of modern smart grids is the integration of renewable energy sources.

It is important to realize that Kuwait's expected electricity demand will significantly increase in the coming few years [2]. This imposes an imperative necessity to re-evaluate the national power grid and to investigate the feasibility of integrating renewable energy sources to maintain a clean environment [5]. Among the various renewable energy types, solar energy seems to be the most sensible for Kuwait. Ref. [4] studied the visibility and potential of solar energy on horizontal surface at Kuwait area. It concluded that Kuwait has an abundance of solar energy capability in terms of almost cloudless atmosphere for nine months and twelve hours solar time a day over the year. The daily global and monthly averaged solar intensity on horizontal surface at Kuwait area is ranging from 3 Wh/m^2 in winter to 8 kWh/m^2 in summer. Monthly averaged clear sky solar radiation on horizontal surfaces at Kuwait area is ranging from 500 W/m^2/day to 1042 W/m^2/day.

The very sunny state of Kuwait is about to become one of the world's largest solar power plants. In Kuwait and areas around it, the sun shines during approximately 140 days of each year; therefore, it is an ideal place for a massive solar facility [2,3]. Some researchers investigated issues related to the process of solar energy integration in Kuwait. For instance, AL-Enezi et al. proposed a solar model to estimate the daily global and monthly averaged solar intensity on horizontal surfaces in an area in Kuwait with clear skies using the direct radiation [4]. Ghoneim and Abdullah analyzed measured weather data to reveal hourly solar radiation on a tilted surface by assuming the ground reflection is constant for all months [5]. Al-Shehri et al. studied the feasibility of using renewable energy systems for the electrification of remote settlements in Saudi Arabia [6]. In [7], a simple methodology was developed for sizing PV water pumping systems under Kuwaiti climate conditions. Integration of a number of PV plants into an

* Corresponding author.

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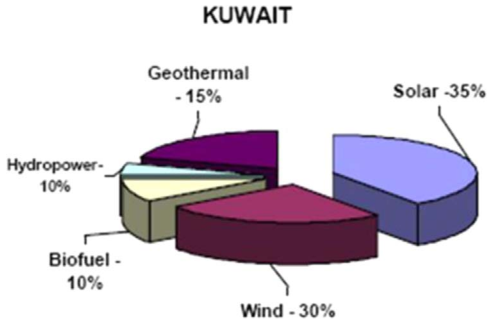

Fig. 1. Availability of RE in Kuwait.

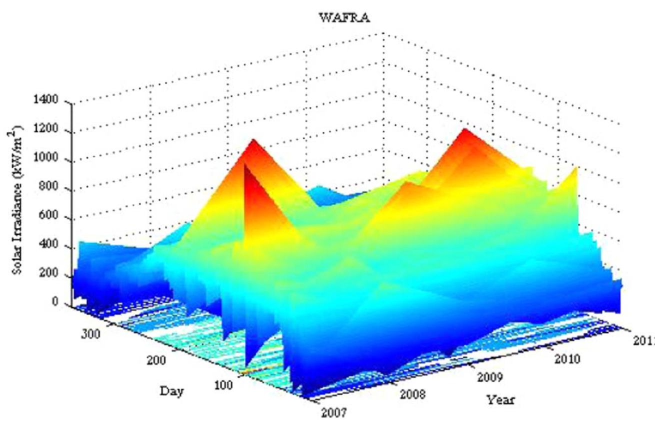

Fig. 2. Average solar radiation data for Wafra.

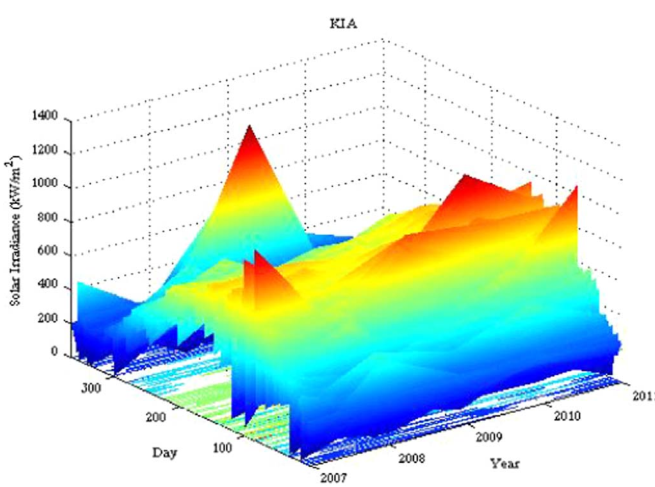

Fig. 3. Average solar radiation data for Kuwait International Airport.

electrical grid poses some technical issues due to capricious nature of the solar resource [8–10].

In Kuwait there is great awareness and very interesting attention from the state to the renewable energy sources. Many projects are under consideration in this regard. As proposed in [4] solar energy is the most promising for Kuwait, therefore, there is an increasing interest for accurate forecasting, modeling and prediction of solar irradiance. An accurate forecasting of PV production helps reducing the additional cost by proposing an appropriate strategy and accommodating the variations in electricity generation. So far, a number of physical and statistical methods have been employed to forecast PV power production [8–11]. The physical method based forecasting is principally conducted using numerical weather prediction (NWP) and cloud observations by satellite or Total Sky Imager (TSI). NWP provides

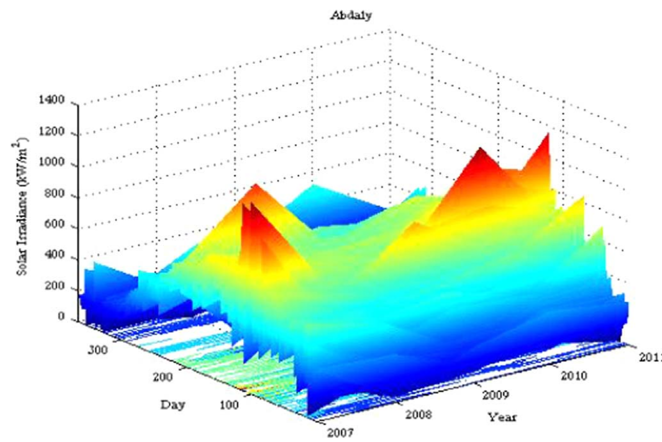

Fig. 4. Average solar radiation data for Abdaly.

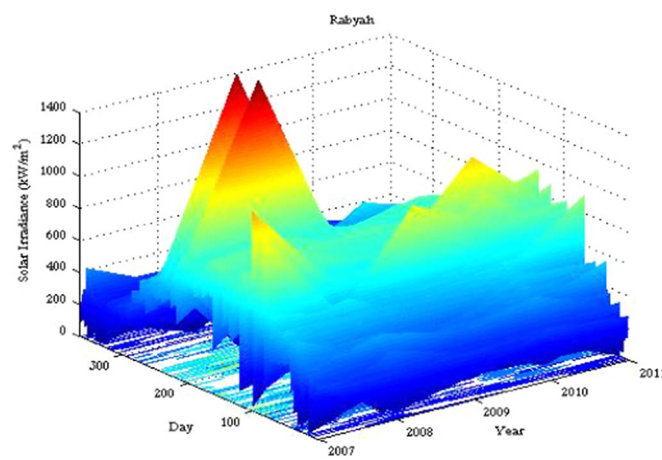

Fig. 5. Average solar radiation data for Rabyah.

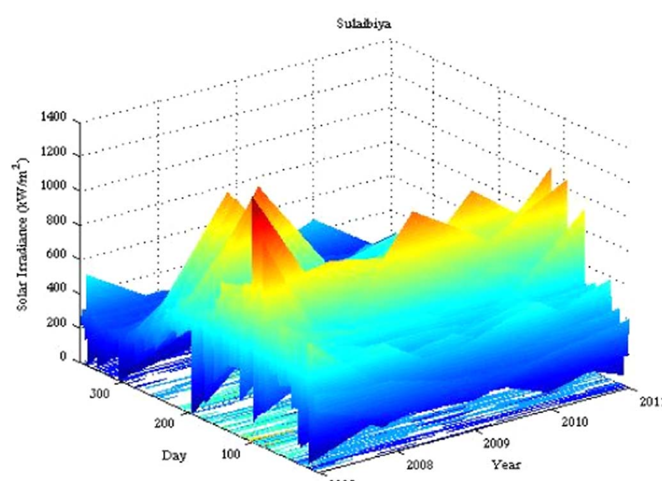

Fig. 6. Average solar radiation data for Sulaibiyah.

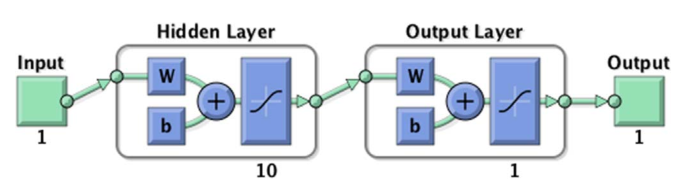

Fig. 7. Structure of ANN.