Renewable and Sustainable Energy Reviews 20 (2013) 155–168

Contents lists available at SciVerse ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Experimental assessment of the solar energy potential in the gulf of Tunis, Tunisia

Ahmed Ridha El Ouderni, Taher Maatallah, Souheil El Alimi *, Sassi Ben Nassrallah

Energy and Thermal Systems Laboratory, National Engineering School of Monastir, University of Monastir, Avenue Ibn, El Jazzar 5019, Tunisia

A R T I C L E I N F O

Article history:
Received 15 November 2011
Received in revised form
3 November 2012
Accepted 5 November 2012
Available online 31 December 2012

Keywords:
Gulf of Tunis
Global solar Radiation
Model comparison
Solar energy potential

A B S T R A C T

This work carries out the availability of the global solar radiation over the site of Borj-Cedria in the gulf of Tunis (36°43′04″N latitude and 10°25′41″E longitude), Tunisia. Global solar radiation variability was assessed on hourly, daily, monthly and seasonal scales. Solar potential in the gulf of Tunis was evaluated using the solar radiation data collected by the meteorological NRG weather station installed in the Center of Research and Technologies of Energy (CRTEn) in the Borj-Cedria area. The collected measurements during the last three years (2008, 2009 and 2010) were based on 10 min time step. These data have allowed us to evaluate the global solar flux, the sun duration, the yearly and the seasonal frequency distribution of the global solar radiation. Moreover, a conventional model has been used to estimate the hourly solar radiation on a horizontal plane and it has been validated by experimental measurements in specific days. The results show that the global solar radiation predicted by the conventional model has a good agreement with the experimental data during the clear sky conditions with a mean absolute percentage error (MAPE) of 4.1%. However, the limitation of the conventional model appears under the cloudy sky weather which is proved by the highest value of relative error percentage reaching 14.26% occurred during the autumnal equinox day.

Contents

* Corresponding author. Tel.: +216 98452098; fax: +216 73501597.
E-mail address: souheil.elalimi@gmail.com (S. El Alimi).

1364-0321/$ - see front matter
http://dx.doi.org/10.1016/j.rser.2012.11.016

1. Introduction

No doubt that all kind of energies took origin from the sun. This huge furnace, with a diameter of 1.39×10^9 m, emits a total energy output of 3.8×10^{20} MW, however only a tiny fraction of 1.7×10^{14} kW is intercepted by the earth. So that since the prehistoric times, man has realized that a good use of solar energy is in his benefit. Therefore, solar energy has been harnessed by mankind [1]. Indeed, the Greek physician Archimedes (212 BC) burned the Roman fleet by means of concave metallic mirror in the form of hundreds of polished shields; all reflecting on the same ship [1,2]. Then, Kircher (1601–1680) worked out some experiments to validate the story of Archimedes. Yet, no report of his findings survived [3].

Despite of the serious difficulties to apply the solar energy concentration, the use of concentrating collectors was the first application developed in this field. The construction of the first solar furnaces, capable of melting iron, copper and other metals, was recorded from the French scientist Lavoisier during the 18th century [1].

The furnaces were in use throughout Europe and the Middle East and attained the remarkable temperature of 1750 °C. The 19th century was marked by two important events; the first one was the discovery of the photovoltaic effect by Becquerel as a new form of solar energy exploitation. The second was related to the several attempts to convert solar energy into other forms based upon the generation of low pressure steam to operate steam engines. In fact, Monchot has built several solar-powered steam engines between the years 1864 and 1878 [3].

As the lack of water was always a problem to humanity, researchers attempted to harness solar energy by developing new equipment suitable for the desalination of sea-water. Consequently, solar distillation has been in practice for a long time. At the same period, the first water distillation plant was built at Las Salinas, Chile in 1874 [3,4], using solar stills that evaporate salty water. Besides, in Algeria Mouchot designed and set a truncated cone reflector in1875. Another furnace was set up in Algeria.

After that, Eneas installed a focusing collector to operate a water pumping apparatus at California farm in 1901 by concentrating the sun's rays at a focal point where the boiler was located. In 1904, a Portuguese priest, constructed a large solar furnace which appeared quite modern in structure, being a large, off-axis, parabolic horn collector [3].

In 1913, the world's largest pumping plant was implemented in Meadi, Egypt by Shuman, in collaboration with Boys using long parabolic cylinders to focal point sunlight into a long absorbing tube. In 1928, Pasteur has reported a novel way to use solar concentrators in solar distillation by focusing solar rays into a copper boiler containing water. The steam generated from the boiler was piped to a conventional water cooled condenser in which distilled water was accumulated [4].

Otherwise, the house heating and hot water appeared in the mid 1930s and recognized a real expansion in the last half of the 40s all over the world. The main solar water heaters were manufactured in many countries, for instance, the thermosyphon types which consist to a two flat-plate solar collectors having an absorber and storage tank.

On the other hand, the first practical application of solar cells was in space in the 1960s when scientists discovered other photovoltaic materials such as gallium arsenide (GaAS) which increased the cost of PV installation.

The global installed capacity of photovoltaics at the end of 2002 was near 2 GWp [5] Photovoltaic (PV) cells are made of various semiconductors, basically the silicon (Si), compounds of cadmium sulfide (Cds), cuprous sulfide (Cu2S), and GaAs which are materials that are only moderately good conductors of electricity. Thirty years ago, PV modules began to be for large-scale commercial applications with an efficiency below 10%. Nowadays, their efficiency is about 20% and estimated to reach 25% in 2020.

2. Recent studies

Knowledge of the availability of the global solar flux at the earth's surface has a great importance in solving many scientific problems and harnessing the practical utilization of solar energy. This available quantity of energy changes within geographic place because it depends on climatic and atmospheric conditions.

It is known that global solar radiation is poorly sampled in weather station networks. For this reason, we find in the literature, recently, many authors who attempted to develop several models to estimate the global solar radiation and asses their corresponding solar potential [6–23]. We can find also software packages allowing the solar flux density estimation of several sites.

Coskum et al. [24] have modified the concept of the probability density frequency usually used to analyze the wind and the outdoor temperature distributions in order to estimate the solar radiation distribution and therefore to investigate and design better the solar energy systems. They have also conducted their study with global solar irradiation data of many years recorded by the Turkish State Meteorological Service.

Ryder et al. [25] have used the solar irradiance measurements from a new high density urban network in London. They have measured annual averages and demonstrated that central London receives 30 ± 10 W m^{-2} less solar irradiance than outer London at midday, equivalent to 9 ± 3% less than the London average. They have obtained these measurements basing on a new technique referred to the 'Langley flux gradients' that infer aerosol column concentrations over a clear periods of 3 h and this technique has been developed and applied to three case studies.

The survey of Ramachandra et al. [26] has focused on the assessment of the Indian potential resource with variability derived from high resolution satellite data. They have also presented a techno-economic analysis of the solar power technologies and a prospective for a minimal utilization of the available land.

Sorapipatana [27] has adopted a satellite technique to assess solar energy potential in Kampuchea. In his work, he has estimated