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Performance of solar resources in Saudi Arabia

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ABSTRACT

This paper presents a review for the characteristics of solar resources in 32 sites across Saudi Arabia through determining the performance of a pilot photovoltaic system based on real time solar radiation data collected during the last two years. The investigation has been done for three possible of sun tracking modes: fixed tilt angle, 1-axis and 2-axis tracking modes. The performance characteristics have been determined using three indicators: yield factor, capacity factor and performance ratio. The simulation results showed high energy productivity for all the 32 sites over Saudi Arabia. The values of performance indicators are high compared with similar systems in different countries. The main purpose of this study is to explore the relative properties for some sites in Saudi Arabia regarding solar energy production.

Contents

1. Introduction

Saudi Arabia is a major producer of oil, and in the same time is the biggest consumer of energy in the middle east [1]. Saudi Arabia plans to increase electricity generating capacity to 120 Gigawatt by 2032 to meet the country's rapidly growing demand of electricity [1]. According to the BP Statistical Review of World Energy 2014, Saudi Arabia generated 292.2 billion kilowatt-hours (kWh) of electricity in 2013 [2]. During the last decade, Saudi Arabia's consumption of electricity increased by 7.5–10% annually as shown in Fig. 1 [3]. This rapid increase in power demand is driven by population growth, a rapidly expanding industrial sector led by the development of petrochemical cities, high demand for air conditioning during the summer months, and heavily subsidized electricity rates [1]. According to the Middle East Economic Survey, Saudi Arabia has the largest expansion plan in the Middle East for energy production from renewable sources [4], for this purpose, the King Abdullah City for Atomic and Renewable Energy (K.A. CARE) has been established in 2010 in order to build a sustainable future for Saudi Arabia through the inclusion of nuclear energy and renewable energy sources within the local energy

Abbreviations and symbols: CF, Capacity Factor; *DHI*, Diffuse Horizontal Irradiance; *DNI*, Direct Normal Irradiance; Egrid, Energy injected to the grid; GSTC, Amount of irradiance at STC; *Gt*, Global solar irradiance on the plane of PV array; *GHI*, Global Horizontal Irradiance; *IEA*, International Energy Agency; *K.A.CARE*, King Abdullah City for Atomic and Renewable Energy; *KACST*, King Abdulaziz City for Science and Technology; *MPPT*, Maximum Power Point Tracking system; *NOCT*, Nominal Operating Cell Temperature; *PR*, Performance Ratio; *PV*, photovoltaic; RETScreen, Renewable energy project analysis software; *RRMM*, Renewable Resource Monitoring and Mapping network; *STC*, Standard Test Condition; *YF*, Yield Factor; ΣGt, Accumulative irradiance on the plane of PV array within certain period

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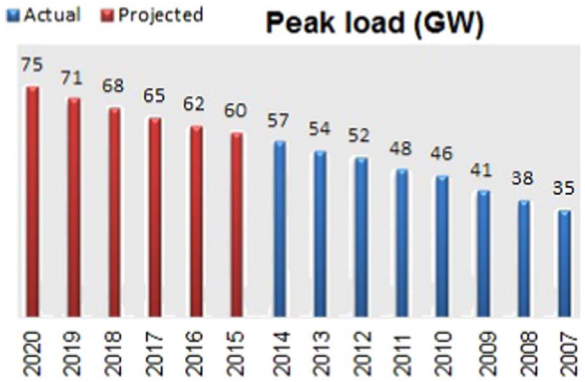

Fig. 1. Actual and projected peak load in Saudi Arabia [3].

system. Saudi Arabia plans by 2032 to add 41 GW of solar power, 18 GW of nuclear power, and 4 GW from other renewable sources to expand electricity supply in Saudi Arabia [1].

K.A.CARE as the lead Saudi Arabia government agency for renewable energy has developed the Renewable Resource Monitoring and Mapping (RRMM) Solar Measurement Network which currently consists of 32 metrological stations deployed in different sites over Saudi Arabia as shown in Fig. 2 [5]. These stations measure the Global Horizontal Irradiance (GHI), Diffuse Horizontal Irradiance (DHI), and Direct Normal Irradiance (DNI) in addition to atmospheric data. The RRMM solar network may be accessed via the interactive, web-accessible Saudi Arabia Renewable Resource Atlas [6], the details of RRMM network are summarized in [5]. Before establishing the RRMM network in 2013, there is no any extensive monitoring system in Saudi Arabia for solar radiation except one was done by King Abdulaziz City for Science and Technology in the period (1998–2000), and cover only 12 sites in Saudi Arabia [7].

Few attempts was done in the last decade to analyze and explore the solar resources in Saudi Arabia, the first one was done in 2002 by Al-Abbadi et. al., they presented a summary for metrological data recorded by KACST for 12 location across Saudi Arabia for period before 2000 [8]. In 2004 Said et.al. presented a study about current status and future potential of renewable energy in Saudi Arabia based on the data collected by KACST and other different sources such as, the Meteorology and Environment Protection administration, Saudi Aramco and King Fahd University of Petroleum and Minerals [9]. In 2007 Shafiq ulrahman et. al. presented an economic feasibility study for PV grid-connected system in 41 sites across Saudi Arabia based on the estimated metrological data provided by database of RETScreen program [10]. In 2010 El-Sebaii et. al. used the measured data of global, direct and diffuse solar radiation on horizontal surface in Jeddah city for calculating the same quantities on tilted surface [11]. In 2015, Erica et. al. summarized the first year of recorded data by 30 stations across Saudi Arabia, producing several key findings about both the solar resource characteristics and the RRMM solar network design and operations [5]. In 2016, Alyahya and Irfan presented a discussion about the new solar atlas of Saudi Arabia, they assessed selected solar resources and surface meteorological measurements provided by RRMM solar network [12].

In the present paper, the data reported by the RRMM network for the last 2 years (from March 2013 to Feb 2015) has been used to investigate the performance of photovoltaic (PV) systems in all these 32 sites. The investigation will include fixed and tracking systems. The simulation process has been done using the RETScreen software [13] for calculating the total energy yield, then the performance of PV system has been determined using three performance indicators, which are: the yield factor (YF), the capacity factor(CF) and the performance ratio (PR). These indicators were suggested by the International Energy Agency (IEA) photovoltaic power systems program [14] to help in comparison between similar PV systems to determine which one works better. In other word, this study aims to identify the best sites in Saudi Arabia as regarding the PV system performance.

2. Research methodology

The performance of PV systems is affected by set of factors such as, solar radiation, ambient temperature, wind speed, tilt and azimuth angles of PV modules, dust accumulation and technology

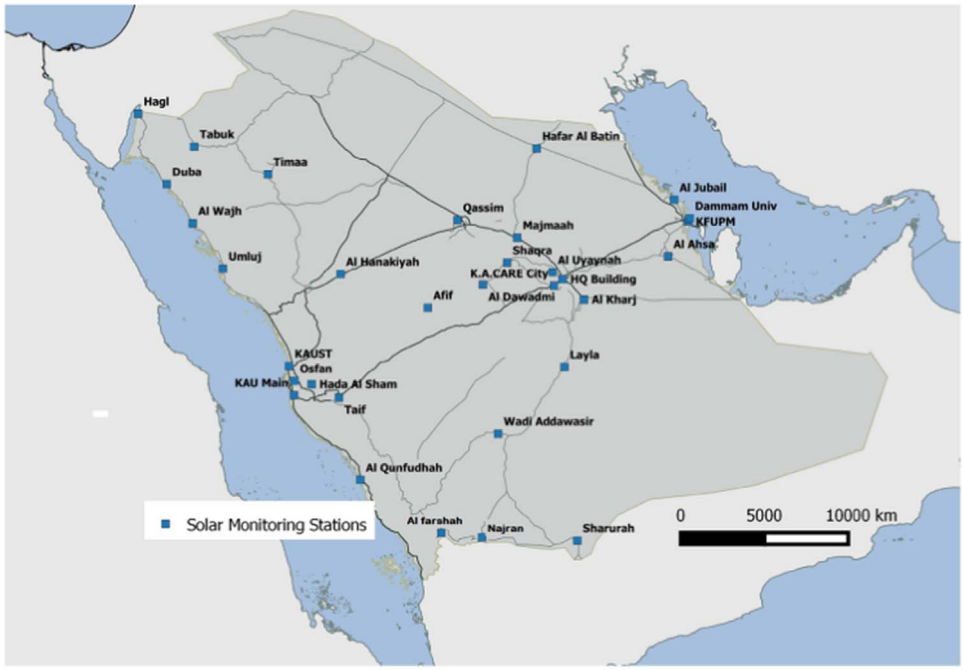

Fig. 2. Locations of solar monitoring stations of RRMM network [5].