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Feasibility of satisfying electrical energy needs with hybrid systems for a medium-size hotel on Kish Island, Iran

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ABSTRACT

The utilization of renewable resources is growing, in part due to the environmental impacts caused by fossil fuels. The largest sources of renewable energy are wind and solar and many predict that these energy sources will be increasingly used for distributed generation. In this paper, the feasibility is examined of a grid-independent system applied for a medium-size hotel in Kish Island, Iran. Furthermore, economic optimization is included in the assessment by using the Homer software as the optimization tool. Renewable and non-renewable energy sources (fossil fuels) are considered, and the final adoption of both cases is primarily based on their associated cost and efficiency. Sensitivity analyses are performed to determine the impact on performance of several key parameters: wind speed, solar radiation and fuel costs. The target location in this study is a hotel that has 125 rooms with the total annual electrical energy consumption of 2,628,000 kWh, and a peak demand of about 620 kW. The results of a comprehensive feasibility data analysis along with its economic evaluation indicate that the wind-diesel hybrid system with battery storage is most efficient energy system for supplying the hotel's electrical energy demands.

1. Introduction

In recent years, global warming which is caused by emissions of greenhouse gases and along with other air pollutants have become significant concerns for humanity. Also, technological developments combined with continuous increases in electricity demand and shortages of fossil fuels have motivated researchers and environmental advocates to develop renewable energy sources such as wind, solar, biomass, tides and waves as alternatives to conventional fossil fuels.

Since the oil crises in the 1970s, fossil fuel prices have steadily increased; however, the costs of renewable energy technologies have declined progressively, and are projected to drop even more. These factors have fostered increased investments and research in renewable energy, especially wind and solar. The global increase in wind and solar energy utilization from 1996 to 2011 is shown in Fig. 1. Global installed capacity of wind power has increased dramatically from 6100 MW in 1996 to 238,000 MW in 2011. Global installed capacity of solar energy for electricity has grown particularly rapidly in recent years, increasing from 15,700 MW to 70,000 MW between 2008 and 2011.

Renewable energies resources tend to be widely available, more environmentally benign than fossil fuels, and sustainable over time. Some renewable energy sources are particularly useful for remote areas where other energy resources are not available or negative economic impacts [2–4]. The advantages for renewable energies are encountered by challenges. For instance, stand-alone wind or solar energy systems do not provide continuous power supply mainly due to seasonal variations and temporal intermittency [5]. One approach to address this problem is to combine these two energy resources by utilizing the strengths of one energy source to balance the weaknesses of the other. A hybrid solar-wind electrical generation system with electrical storage can provide such a reliable power supply.

In the past, solar-wind hybrid power generation systems have been applied at remote locations far away from conventional power systems, for example, to power communication satellite stations [6–9]. Presently, there is a trend to employ a common one energy source system such as wind or solar or hydro in hybrid energy systems for grid-connection applications.

In recent years, much research and many feasibility studies have been performed on hybrid energy systems around the word, leading to valuable insights. The current status of simulation, optimization,

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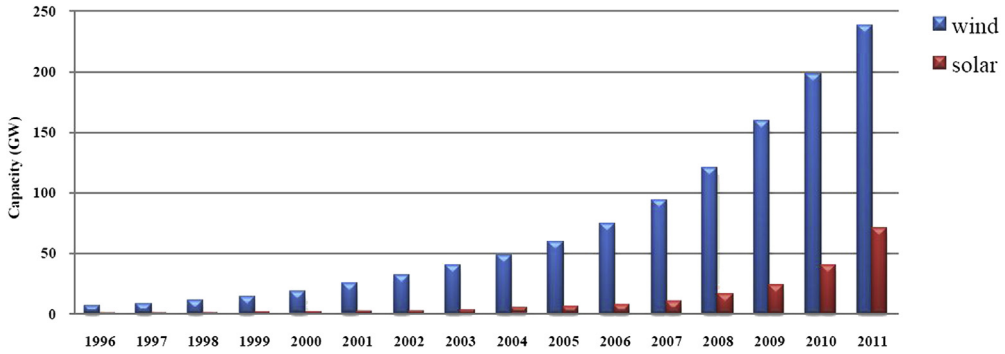

Fig. 1. Global annual installed wind and solar capacity for 1996–2011. Data source: [1].

and direct control of hybrid energy systems using solar and wind energies with battery storage have been reported by Wei Zhou et al. [10].

Some important feasibility study and application investigations have been investigated, now described, and many of them were conducted in different regions with a similar climate to Kish Island in Iran. In 2012, Essalaimeh et al. evaluated the economic feasibility of using a hybrid power system for cooling and heating in Amman, Jordan, concluding that it is feasible from technical and economic perspectives [11]. Shan Ngan and Wei Tan analyzed the implementation of hybrid systems using simulations obtained with the HOMER software in Johor Bahru, Malaysia, and showed that the economic and environmental performance of a PV/wind/diesel/battery configuration is advantageous and it is a convenient replacement for a stand-alone diesel system [12].

Cano et al. installed a PV–wind hybrid system in a tourist village in Spain, and monitored its operation over a year [13]. They observed that wind technology exhibited better performance than other energy systems. A feasibility study by Bekele and Palm assessed supplying electricity by using a solar-wind hybrid stand-alone system for a model community (200 families, consisting of 1000 people in total) located in an off-grid-power region in Ethiopia, and concluded that the hybrid system has numerous performance advantages [14]. In 2010, Yilmaz and Demiroren examined several methods for meeting electricity demands with renewable energy resources for the largest island in Turkey [15].

Research into hybrid energy systems has been expanding significantly in recent years, with the rapid progress in usage of wind turbines and photovoltaics encouraging further utilization of such systems [16–18]. Bekele et al. showed that a PV-wind-diesel hybrid system with battery storage for remote areas of Ethiopia is feasible. This study was based on analyses using the HOMER software with data from 2003 to 2005. Although the potential for wind power alone was found to be acceptable; it was found to be more advantageous to add other systems (i.e., PV, diesel generator, battery) [19]. Lal and Raturi optimized a hybrid energy system for the Fiji islands using simulations performed with the HOMER software, and indicated d that the most feasible system is a PV/wind/diesel hybrid system with 200 kW PV and 170-kW diesel generators and battery storage [20].

In 2009, feasibility studies were performed of stand-alone power sources using renewable energy sources in Australia for tourist activities at various levels of activities [21,22], and for application of hybrid energy systems to generate energy carriers in 2005 for Newfoundland, Canada [23]. The use of solar and wind energies for electricity generation to support the power grid of Jordan was evaluated in 2010, resulted in a significant electronic advances in energy conversion technologies [24].

The economics and social aspects of hybrid energy systems have also received much attention. Hybrid renewable electrical systems were shown to be economically advantageous in remote areas in Iraq and Saudi Arabia that use off-grid systems [25,26]. The results indicate that application of hybrid energy systems could significantly amplify system reliability, overcoming an important deficiency of stand-alone systems [27,28]. The amount of solar radiation incident in Iraq and Saudi Arabia are higher than that of Kish Island, but the overall quantity at Kish Island and its environment conditions are nonetheless suitable for electrical production with photovoltaic panels.

The cost of using renewable energy sources with hydrogen production systems for meeting energy demand in Turkey has been studied by Telli et al. [29]. They simulated system operation to calculate technical and economic parameters for the micro power optimization using the HOMER software. Kumar and Phuangpornpitak investigated the customer's satisfaction with PV hybrid systems and overall energy production in rural areas of Thailand [30,31], That study, similar to the research reported in this paper, is focussed towards developing reliable, economical feasible, and clean decentralized power production.

In the present investigation, we determined whether the required energy of a medium-size hotel with a capacity of 125 rooms in Kish Island, Iran, can meet economically with hybrid energy systems for which four hybrid scenarios were considered. The overall objective is to improve understanding of the usage of hybrid energy systems by incorporating renewable energies in commercial applications. In the article, the wind and solar power potential of country of Iran is investigated, and a load model of the hotel is presented along with the analysis of solar radiation and wind speed patterns of Kish. The HOMER software is used in the analyses for both technical and economic criteria.

2. Wind and solar energy status in Iran

Iran is a large country (1,648,195 square kilometers in area) located in the Middle East, with latitude of 35°41′39″ North and longitude of 51°25′17″ East. There is a diverse climate throughout the country, and more than half of it is mountainous.

Iran has begun using wind energy for electricity production since 1994. Although the country has fossil fuel resources such as oil and gas, utilization of renewable energies, especially wind power, has expanded significantly in recent years due to their numerous environmental benefits and advantages. Wind is the second source of renewable energies for power generation in Iran [32]. Wind speeds are generally high in many regions of the country, hence, making wind farm projects attractive and reliable for its power generation application. According to the country's fifth economic development plan (2010–2015), 1650 MW of wind power generation capacity long with 5000 MW of combined solar and wind power generation capacity, should be installed and in operation by 2015.