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Evaluating the wind energy potential for hydrogen production: A case study

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ABSTRACT

In this paper, the potential of wind energy development for the purpose of hydrogen production in the Fars province of Iran is investigated. To achieve this, wind speeds at 10 m, 30 m and 40 m heights and wind direction at 30 m and 37.5 m recorded in 10 min intervals for the period of one year for four cities of Abadeh, Juyom, Eqleed, and Marvdasht are utilized. Wind energy characteristics have been statistically analyzed to determine the potential of wind power to generate hydrogen in the examined cities. It is found that city of Abadeh has better potential for harnessing wind energy than other cities. Statistical analysis of Abadeh at 40 m height indicates the nominal wind speed of 7.47 m/s which generates maximum energy with the annual power density of 220 W/m^2. The performances of four different large-scale wind turbines for producing wind power in Abadeh are evaluated. It is found that hydrogen from wind energy in Abadeh using a small hydrogen producing unit would fuel approximately 22 cars per week if a EWT Direct wind 52/900 model wind turbine to be used.

Introduction

State of wind energy use

With the dramatically increase of industrial application in all over the world, demand for energy is increasing rapidly. Clearly, energy plays a major essential role in many countries. On the other hand, none renewable resources of energy are decreasing and 80% of global energy source is provided by fossil fuel which was consumed increasingly in recent years. Moreover, related energy problems are numerous like carbon emission, global warming, environmental hazards, and GHG

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(Green House Gas) emissions. One of the major solutions to overcome these problems is to use the wind energy as one of the renewable resources [1]. The investment on wind turbines has continued to fall in past few years if we compare it with other available technologies. Wind energy is approaching at a level which can compete with conventional methods. Renewable energy Markets as well as wind energy have evolved rapidly over the previous years. Wind is considered as an abundantly available, environmentally friendly, inexpensive, and easy to harness source of energy in many countries [2]. Fossil fuels are predicted to supply most of the required energy demands. Renewable energy is the fastest growing kind of energy with almost 10% increase in 2008 to an estimate of 14% in 2035 [3].

Fig. 1 illustrates that China was the largest single wind market in first six month of 2014 which added 7.2 GW in only six months which accounted for almost 41% of the global market for new wind turbines. Iran ranked 51 with total 100 MW capacity installed by end of 2013 [4].

Afgan et al. [5] analyzed the potential on multi-criteria assessment of hydrogen systems. They chose four criteria of performance, environment, market and social indicators. Hydrogen fuel cell systems were analyzed with three different options of natural gas turbine, photovoltaic system and wind energy. Sacramento et al. [6] proposed a plan of electrolytic hydrogen energy for the Ceará state in Brazil using photovoltaic cell panels and wind turbines. They concluded that the use of renewables to produce hydrogen would increase the energy consumption and the gross internal product per capita of the region.

Hydrogen production from wind energy

In recent years, generating hydrogen from renewable energies sources is considered as an appealing target for a gradual evolution to a clean economy and a more sustainable and smart energy mix [7,8]. Hydrogen can be generated via utilization of renewable energy such as wind energy by electrolyzing the water without emission of carbon dioxide or other hazardous gases and dependency to fossil fuels [9–11]. Hydrogen produced from different renewable energy sources like wind used as a fuel can be a good substitute to reduce greenhouse and other emissions, and reduces dependency from fossil fuels [12]. On this account, many investigations have been performed on wind-hydrogen systems in recent years.

Rodrıguez et al. [13] evaluated the potential of generating hydrogen using wind energy in the province of Cordoba, Argentina. They investigated the possibility of using hydrogen for vehicular transportation in the examined area. The achieved results indicated that the potential of wind energy in the province is high enough for providing ten times of the required hydrogen to supply the energy of whole vehicular transportation. Aiche-Hamane et al. [14] performed a study to determine the viability of hydrogen generation from wind energy in Ghardaia, Algeria. They estimated the hydrogen rate which can be generated via a 5 kW electrolyzer fed using the electricity supplied by a wind turbine with 10 kW rated power. Their results showed that 3200 m^3 hydrogen can be produced by the wind turbine with 30 m height and 4200 m^3 by the wind turbine with 60 m height.

Zhang and Wan [15] investigated a wind-hydrogen energy storage system model for massive wind energy curtailment. They investigated a model of integrating curtailed wind energy with hydrogen energy storage using 10 min interval wind speed data from the wind farm located in central north of Inner Mongolia with 66 Goldwind's GW77/1500 PMDD wind turbines. They performed economic evaluation using payback period methodology. They found that hydrogen energy storage technology using wind energy would economically be viable. Sanchez et al. [16] illustrated economic evaluation of wind park based on a hydrogen compensation system consists of combining wind energy production with a biomass gasification system and a hydrogen generation system based on these two sources. They concluded feasibility of implementing this system. Patrıcio et al. [17] investigated wind hydrogen energy system and its gradual replacement of natural gas in the State of Ceara in Brazil. They proposed the solar hydrogen energy system created by Veziroglu and Basar in the 70's. They proposed that the system would start in the year 2015 and predicted that it would have revenue US$ 730 million in the slow scenario. Sarrias-Mena et al. [18] proposed a model for hydrogen production from wind energy. They investigated the coupled operation of electrolyzer and wind turbine with four different models which were evaluated and compared under different conditions. The simulation results revealed a satisfactory operation between the wind turbine and all the models.

State of wind energy use in Iran

Recently, tendency of using wind energy to produce electricity in Iran has been significantly increased and government has placed appropriate reimbursements for renewable production of electricity. Among the Middle Eastern countries, Iran is the major country that has generated wind power. The potential of electricity generation by wind energy in Iran is about 10,000 (MW). Iranian Renewable Organization (SUNA) has done a considerable research in this regard; Iranian wind atlas was prepared by this organization [19]. The main wind power stations in Manjil and in Binalood have capacities of 70 MW and 28 MW to generate electricity, respectively [20].

Many researchers have recently studied wind power generation in Iran [21–26]. Mostafaeipour [22] has analyzed the wind energy potential for installing the wind turbine among 11 sites in Yazd Province by using wind data measured during 13 years. Harat city has been suggested by him as the best location for setting up the wind turbines. Furthermore, because of high potential of Manjil city, possibility of increasing wind power generation and the number of turbines has been suggested by Mostafaeipour and Abarghooei [20].

Also, Mirhosseini et al. [27] and Saeidi et al. [28] have studied two provinces of Semnan and Khorasan in Iran, respectively.

In this study, the wind energy potential locations in province of Fars are assessed for four cities: Abadeh, Juyom, Eqleed, and Marvdasht. No previous study on wind potentials for Fars province is reported in literature. This is part of international efforts for characterizing wind map of Iran for utilizing wind energy and other renewable energies in this region.

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