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Hydrogen production by hybrid system and its conversion by fuel cell in Algeria; Djanet

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ABSTRACT

In this work we present a scenario of wind and solar energy production and seasonal energy storage producing Hydrogen in Djanet (East-South of Algeria). In addition we suppose assume the use of a set of fuel cells which are connected to the grid to provide a supply of energy when needed afterwards. The aim of this primary study is giving an alternative solution for the electric production in Djanet, which is mainly based on diesel generator. For that we made an investigation to highlight the potential of renewable energy production in this region. To ascertain feasibility of one hybrid system, we made energetic assessment considering the real climatic conditions of Djanet.

Introduction

Nowadays, the worldwide energy consumption is about 20 000 TWh. The world energy demand increased by 5% in the developing countries and by 1% in the developed countries. In Algeria, in the recent years, the increase of the energy demand reached more than 10% [1].

On the one hand this increase is due to population growth with 1.18% in 2016 [2] and human development of modern societies. On the other hand the permanent industrial development and the global economic growth (3.1% in 2016) [3]. About 80% of total energy issued from conventional sources and produced by burning fossil fuels [4].

Unfortunately fossil fuels of a non-renewable nature are polluting and in full depletion [5]. The generalization of the utilization of fossil fuels is rapidly resulting in critical environmental problems throughout the world and a negative impact on economies [6–8]. Indeed as the demand for fuels is steadily increasing, concern about the depleting energy sources is increasing. Moreover, the use of fossil fuels responsible for environment degradation as a result of pollutants emission [9]. This represents a great threat not only for fauna and flora but also for human life and the political stability of countries around the world. Therefore, there is an urgent need to conserve these resources and explore the wider use of alternative energy resources [10] for example — solar, wind, hydro, biomass, etc.

Due to the oil crisis in 1973, and the constraints caused by the use of the fossil sources, considerable progress has been made in the search for alternative energy sources. Since that, there was a great recognition of the importance of integrating REs in the energy sector of countries that aim to achieve sustainable development [11,12]. In Algeria, after the damages

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Nomenclature

F	Faraday constant (C/mol)
G_h	Solar irradiance (W/m^2)
I_0	Exchange current density (A/cm^2)
I	Current density (A/cm^2)
i	Current density (A/m^2)
N_c	Number of cells
n	Number of electrons
P_{wmax}	The rated power of the wind turbine (850 kW)
P_0	Atmospheric pressure (bar)
Q	Hydrogen flow rate Slpm
R	Gaz constant 8314 1 J mol^{-1} K^{-1}
T	Temperature of the electrolyser (K)
T_a	Ambient temperature (K)
T_c	Photovoltaic cell temperature (K)
U_c	Thermal loss factor (W/m^2.K)
U_W	Proportionality constant of wind velocity
V_1	Wind velocity at altitude Z_1
V_2	Wind velocity at altitude Z_2(m/s)
V_W	Wind velocity (m/s)
Z_1	The altitude of the site (m)
Z_2	Z_1+ hub height (m)
PEMFC	proton exchange membrane fuel cells
eff	PV module efficiency (0.12 in our case)
act	activation
ohm	ohmique
conc	concentration
rev	reversible

Greek letters

α	Coefficient relating to the nature of the ground (0.12012 for Djanet)
ρ	Air density (kg/m^3)
λ	Absorption coefficient of solar irradiation
ξ_F	Represents the current efficiency

induced by the use of the fossil fuels, and the drastic rising of their cost, the Algerian government engaged itself to develop renewable sources to cover 20% of the national electricity needs by 2030 with renewable energy and 35% in 2040 [13]. However, as we know, due to the dependence of renewable energies on the climatic conditions and its intermittence, they do not provide a constant power. However, the combination of several types of renewable sources, such as wind and solar power, leads to significant output power.

Therefore, once the load demand satisfied by the different hybridized sources, it is necessary to store the excess energy, which be injected into the grid when needed afterwards. At present, Hydrogen proves to be the better energy carrier from its clean and renewable nature and its great calorific value, and its considerable applications in the energy field [14,15].

For the hydrogen production, different methods exit [16–19]. However, the sustainability can be reached particularly using renewable energy in hydrogen production as like in the hybrid systems [20–22]. The HES power system are a combination of one or more RE sources with conventional generator fueled by fossil fuels to provide back-up power [23]. The main reason of integrating renewable energy sources in a hybrid system is primarily to save fossil fuels, furthermore reduce their environmental impact [24]. In the conventional hybrid systems, diesel generators and batteries are traditionally used [25], but these are expensive to operate and maintain especially in remote areas. In addition, they have a detrimental impact on the environment [26] unlike the renewable energy hybrid power systems which are more environmentally friendly and more sustainable [27]. This is the main reason why hybrid power systems using renewable energy sources in recent years, have received considerable attentions worldwide [28–33].

For Algeria, this represents a great opportunity to both increase and diversify its energy resources. Indeed, Algeria has a great potential in renewable energy such as solar and wind energy [34], mainly in the Sahara which represents more than 80% of its area. Unfortunately most of its production is provided by fossil sources [35]. To estimate the potential of RE sources in Algeria, a few studies have been done [36–39]. Likewise for the Hydrogen production by electrolysis fueled by renewable energy sources, studies are infrequent [40–42].

Our work focuses on the study of local Hydrogen production in the province of Djanet, longitude 6.755 and latitude 28.116. (South East of Algeria). The renewable hybrid energy system (RHES) studied is a scenario of a combination of two RE sources; the PV source and a wind turbine generator working in parallel with diesel generator as primary source, and electrolyser for Hydrogen production and a fuel cell power system.

The main aim of the study is to bring out the RE potential in Djanet by estimating the amount of Hydrogen production, and at the same time reduce the diesel consumption and maintain a continuous supply of power generated from REs sources to the grid and finally, carried out the viability of such hybrid system.

The production of Hydrogen takes place from 1st October to 30th May, corresponding to the weak electricity load period characterized by an average temperature of 18.2 °C. The period from 1st June to 30th September characterized by a highest average temperature (29.7 °C) corresponds to the high load season. This leads to a considerable need for energy, in particular for the air conditioning, ventilation and cooling systems. In this period, the fuel cell power system converts the stored hydrogen to electricity, that will be injected into the grid.

For such work weather data are an important factor for pre-feasibility study of renewable hybrid energy system for any particular site. Here the Wind resources data are taken from (*AWS Truepower and AW Power*). The Solar energy resources data are taken from (*Solar Med Atlas*).

The choice of the province of Djanet based more on data availability schedule of the region; Power consumption (SKTM/SONELGAZ), temperature and solar radiation data (Solar Med Atlas) and wind speed. Moreover, its geo climatic conditions, such as surface area 57460 km^2, the average maximum temperature in months summer (29.7 °C) and a sky mostly clear during the year. Other social and especially economic factors should be took into account. However, our first primary study is an energetic assessment of the potential of renewable energy in the region and the analysis of feasibility

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