Energy 102 (2016) 216–230

Contents lists available at ScienceDirect

Energy

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

GHGs (greenhouse gases) emission and economic analysis of a GCRES (grid-connected renewable energy system) in the arid region, Algeria

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ARTICLE INFO

Article history:
Received 6 August 2015
Received in revised form
19 January 2016
Accepted 16 February 2016
Available online xxx

Keywords:
Hybrid renewable energy system
Grid
COE (cost of energy)
Emissions
Arid region

ABSTRACT

This paper presents a method for economic evaluation and GHGs (greenhouse gases) emissions calculation from a GCRES (grid-connected renewable energy system). An investigation is made on large-scale operations of 67 MWh/day GCRES. A comparison is performed between a GCRES and a standard grid operation focusing on environmental and economic impacts. Emissions and the Renewable energy generation fraction (RF) of total energy consumption are calculated as the main environmental indicators. Costs including NPC (net present cost), COE (cost of energy) and payback period are calculated as the economic indicators. Using the hourly mean global solar irradiance, temperature and wind speed data relative to In Salah and Adrar locations characterized by an arid and hot climate according to the Koppen–Geiger climate classification, a long-term continuous implementation of hybrid renewable energy systems are simulated using HOMER software and are discussed. As results, it is observed that a GCRES reduce 30% and 35% of GHGs emission, and 81% and 76% of COE during the operation phase respectively for In Salah and Adrar.

Investments in GCRES should be considered only by planning to produce parts of the equipment locally, which leads to significantly reduce the costs and, consequently, the emissions.

1. Introduction

World energy consumption has been growing by about 2.3% per year [1]. On the other hand, the use of fossil fuels raises serious environmental concerns. The burning of fossil fuels produces around 21.3 billion tons (21.3 Gigatons) of carbon dioxide (CO_2) per year, but it is estimated that natural processes can only absorb about half of that amount, so there is a net increase of 10.65 billion tons of atmospheric carbon dioxide per year (one ton of atmospheric carbon dioxide is equivalent to 44/12 or 3.7 ton of carbon dioxide) [2]. Carbon dioxide is one of the greenhouse gases that enhances radiative forcing and contributes to global warming, causing the average Earth surface temperature to rise in response, which in the opinion of the majority of climate scientists will cause major adverse effects. A global move towards the generation of renewable energy is therefore under way to help reduce global greenhouse gas emissions. So, the application of the hybrid renewable energy system to generate electrical power has certain advantages: enables continuous supply of electrical power, it is free and available, does not pollute the environment (no emission of greenhouse gases), and counts among the renewable energy sources. It also contributes to sustainable development and growing pressure on the world's nations to reduce greenhouse gas emissions.

In this context, recently published shows the importance of the hybrid renewable energy system [3 11]. Mohammad Nezami et al. [3] have modeled a complete hybrid system including a photovoltaic array, a wind turbine, and storage batteries to determine the best approach for sizing the system to meet the electrical energy needs of a residential building in Tehran. The obtained results showed that the electrical cost of the hybrid system in Tehran is 0.62 US$/kWh, which is 78% less expensive than a wind turbine system and 34% less expensive than a photovoltaic system.

Cao, Sunliang, and Kai Sirén [4] have studied matching indices taking the dynamic hybrid electrical and thermal grids information into account for the decision-making of nZEB (Net Zero Energy Building) on-site renewable energy systems. The obtained results showed that the developed methodology could seek an optimized balance between the objectives of maximizing the matching capability and minimizing the environmental/economic load. A

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http://dx.doi.org/10.1016/j.energy.2016.02.103
0360-5442/

Nomenclature

$C_{ann,tot}$	total annualized cost [$/yr]
CRF	capital recovery factor
E_{pv}	the energy generation by photovoltaic (Wh)
E_{ToT}	the total energy generation (Wh)
E_{WG}	the energy generation by wind generator (Wh)
H	hub height of the wind turbine generator (m)
I	interest rate [%];
R_{proj}	project lifetime [yrs].
v	wind speed (m/s)
z_0	surface roughness length (m)
z	anemometer height (m)
Subscripts	
AC	alternating current
Bwh	Köppen Classification System for hot and Dry Arid (Desert) climate
CO_2	carbon dioxide
COE	cost of energy
DC	continuing current
FIT	feed in tariff (%)
G	solar irradiation (kWh m^2/day)
GCRES	grid-connected renewable energy system
GHGs	greenhouse gases
NOx	Nitrogen oxide
NPC	net present cost ($/year)
P	grid electricity price ($/kWh)
PV	photovoltaic
RF	renewable energy generation fraction (%)
S	sellback rate ($/kwh)
SO_2	Sulfur dioxide

PSO (particle swarm optimization) based on the PI controllers of a grid-connected inverter power supplied from a hybrid renewable energy system was studied by Ref. [5]. The system is composed of two renewable energy sources (wind turbine and photovoltaic – PV – solar panels) and two energy storage systems (battery and hydrogen system, integrated by fuel cell and electrolyzer). The obtained results showed that the online PSO-based PI controllers that optimize the algorithm based on the integral time absolute error index achieves the best response.

In Ref. [6] an advanced energy management strategy for a standalone hybrid energy system including a photovoltaic panel, a fuel cell, an electrolyzer, a battery bank and a super capacitor was considered. The simulation results confirmed the efficiency of the proposed control strategy, as it increases the reliability of the system and improves its energy balance.

In Ref. [7] research, an optimum design of the combined solar collector and geothermal heat pump system was studied. Their main purpose is analyzing the system from economical and technical points of view simultaneously. An optimization of two parabolic trough solar thermal power plants integrated with TES (thermal energy storage) and FBS (fuel backup system) has been performed by Boukelia, T. E., et al. [8].

The work of Stojiljkovic, Mirko M et al. [9] consists of the greenhouse gases emission assessment in residential sector through buildings simulations and operation optimization studies.

Johansson, Daniella, et al. [10] have realized a comparative study of Fischer–Tropsch production and post-combustion CO_2 capture at an oil refinery. The obtained results showed that a low charge for CO_2 economically favors FT fuel production and the CO_2 capture confirms the greatest reduction in GHG emissions.

The paper of Baghdadi et al. [11] has investigated the performance of hybrid PV–Wind–Diesel–Battery configuration based on hourly measurements related to Adrar climate (southern Algeria). Data measurements of global solar radiation, ambient dry air temperature and wind speed over a period of one year have been used.

Note that Algeria is amongst the top ten countries in the world in terms of natural gas and oil production. Indeed, Algeria relies heavily on hydrocarbons, with 94% of energy currently coming from natural gas, representing 50% of the national GDP. Recent studies suggest that about 5% of the country's electricity comes from small hydropower plants while only 0.5%–1% comes from wind and solar energy [12] and [13].

Studies estimate that electrical energy use in Algeria will rise to 83 Terawatt-hour (TWh, 1 TWh = 10^{12} Watts. hour) by 2020 and up to 150 TWh by 2030 [12] and [14]. Conversely, current projections estimate that the country's oil reserves will only cover the next 50 years while those of natural gas will only be available over the next 70 years [12] and [13]. Algeria thus faces a mounting challenge between its dependence on fossil fuels and its capacity for exploiting vast renewable sources. Some ambitious plans to develop renewable energy over the period of 2011–2030 have been put forward aspiring to generate 40% of local electricity by 2030 from solar and wind energy [3,14], with an estimated capacity of 22,000 Megawatts (MW) dedicating 12,000 MW to domestic use and 10,000 MW to exports at a cost of $60 US billion.

A recent report showed that energy usage in Algeria is split between three sectors, industrial (24%), transport (33%), and residential and services (43%) [15]. The renewable energy mix of solar and wind energy as well as effective engineering applications can potentially contribute towards energy provision for these sectors and help move the country towards a more sustainable position in terms of energy provision and consumption [12].

Algeria is very well placed to be a major actor in the lucrative market of renewable energy. However, transition to more renewable energy use will need to start immediately, at least using hybrid technologies. Genuine political will and favorable policies are essential if the renewable energy age is to be fully embraced [12].

In this respect, in Algeria, many studies on wind and solar energy systems have been accomplished [13–33] and several projects achieved:

- Construction of Algeria's first pilot wind power project, a 10 MW facility at Adrar in the southern desert, has been completed in 2011, with the installation of 12 Gamesa 850 kW turbines.

French electrical-engineering company Cegelec built the Adrar plant for the state utility board Sonelgaz. It was originally due to come online in 2012, but the political situation caused various delays.

- Achievement of The Electricity and Gas engineering Company (CEEG) and the German Group Centrotherm/Kinetics signed the contract for the manufacturing of photovoltaic modules of Rouiba éclairage [34].