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Parametric analysis for the implementation of wind power in United Arab Emirates

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ABSTRACT

In this work, the utilization of different wind turbines in a 50 MW wind park is tested, using annual hourly values of wind speeds in the Emirate of Sharjah in the United Arab Emirates. An optimization algorithm is developed in order to calculate the power output from 16 different wind turbine types with various capacities. Output data from the developed algorithm is used as input to the IPP optimization software in which the electricity unit cost is calculated. Also, parametric analyses regarding the cost of electricity production with respect to the capital costs of the wind turbines, as well as the cost of electricity production with respect to fixed costs are carried out. The power output from 5 wind parks during a stagnant and a windy day are determined. It is concluded that the utilization of fifty 1 MW wind turbines is the best option, as it presented the highest capacity factor, and the least cost of electricity production.

Contents

1. Introduction

A sound United Arab Emirates (UAE) energy policy should encourage a clean and diverse portfolio of domestic energy supplies. Such diversity helps to ensure that future generations will have access to the energy they need. Renewable energy sources for power generation (RES-E) can help provide electricity for the UAE future needs by harnessing abundant, naturally occurring sources of energy such as the sun, the wind and biomass. Effectively harnessing these renewable resources requires careful planning and advanced technology. Through improved technology, UAE can ensure that those power systems will make use of clean, natural renewable sources. RES-E technologies will not only help diversify the UAE energy portfolio, but they will do so with few adverse environmental impacts [1].

Based on the detailed literature review carried out for the purposes of this work, there has not yet been a detailed investigation of the wind potential in the UAE, and in particular for the Emirate of Sharjah. Thus the large scale integration of wind parks in the Emirate of Sharjah is examined in this work. In particular, the potential of utilizing wind power turbines and building a 50 MW wind park in the Emirate of Sharjah in UAE is studied. An optimization analysis is carried out in order to estimate the optimal wind turbine to be used within the 50 MW wind park in the Emirate of Sharjah. 16 wind turbines from 6 different manufacturers, with 13 different capacities are considered and the total annual electricity production is calculated for each case. The supplied wind data is on an hourly basis for the whole year of

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2011 in the Emirate of Sharjah, at the height of 10 m above sea level. The Weibull probability distribution function is also found to fit the hourly distribution of wind measurements. The capacity factor is calculated for each turbine, and this capacity factor is used in a cost optimization algorithm in order to calculate the cost of electricity generation for each scenario. For the simulations, the IPP optimization software [2] was used in which the electricity unit cost is calculated.

In Section 2, a literature survey of similar work carried out in the region is presented. In Section 3, the algorithm developed to calculate the capacity factor for each turbine, as well as the simulation software and data and assumptions used for the optimization analysis are presented. In Section 4, the results obtained for the optimum wind turbine to use, as well as the parametric analysis of the different scenarios in the Emirate of Sharjah are presented and discussed in detail. The conclusions are summarized in Section 5.

2. Literature review

Climate change and fossil fuel depletion are the main drivers for the recent focus on finding alternative energy resources. In [3], the UAE energy consumption situation is presented, in which the increase over the past years is due to urbanization, economic growth and population growth. This has led to an increase in demand for electricity and power, which is reflected in the overall increase in fossil fuel consumption over the years. As a result, the UAE has one of the highest energy consumptions and carbon emissions per capita in the world (exceeding the US and European countries). Thus the results emphasize that adopting RES-E in the UAE is of high importance.

RES-E is an obvious choice to reduce carbon dioxide and other pollutants contributing to global warming. However, since high cost of RES-E technologies is one of the main obstacles facing the large-scale integration of these technologies, economic and political interventions are inevitable. These interventions include the development of appropriate energy policies and strategies including demand site management, legislation, incentives to investment, energy generation targets, guidelines for energy conservation, strategies to stimulate the energy industry and taxation [4].

In [5], the policies in 61 different countries, regarding the focus on renewable energies are reviewed and compared with the current policies in the Emirate of Abu Dhabi. The main aim of the study was to come up with the best policy for the UAE government to adopt in order to reach their renewable energy targets. Since renewable energies have high initial costs they are unattractive for investors, and therefore the importance of government intervention to reduce capital costs through subsidies is again stressed upon. After studying the policies of several successful countries in the renewable energy field, such as Germany, it was concluded that it is best for the UAE to adopt a mixed policy between Feed-in-Tariffs (FiTs), which are incentives provided by the government for the renewable energy systems set up, and a quota system, which are for example limits on CO_2 emissions by conventional power producers.

In [6], the role of solar and other renewable energy solutions on energy planning in the UAE is illustrated. The government incentives and the general role of the government in utilizing renewable technologies, as well as factors such as FiTs are addressed. Presently, the UAE has negligible contribution to the world's total primary energy supply from renewables. The Emirate of Abu Dhabi is the main city in the UAE that focuses on renewable energy adaptation. An example is the Masdar initiative, which was set up in Abu Dhabi, in the aim of creating a totally green city of 40,000 residents. Abu Dhabi invested around US$15 billion on several renewable initiatives such as the green city (Masdar City), carbon capture and storage and photovoltaics production. The main renewable technology focused on is photovoltaic solar energy and concentrated solar power (CSP), such as the 100 MW CSP plant Shams 1, the 10 MW photovoltaic system. The carbon capture storage initiatives are expected to reduce Abu Dhabi's carbon footprint by a third by 2020.

The environmental implications of the power industry require power producers to come up with sustainable solutions and alternatives to the conventional fossil fuel dependent technologies. This is why many countries are adopting renewable energy sources such as solar energy and wind energy. Many studies have been carried out on the potential of harnessing solar energy in the United Arab Emirates. In [7], a study is presented which investigates the possibilities of integrating large scale PV systems and parabolic trough CSP systems in the Emirate of Sharjah through economic, technical and environmental analyses.

In [8], an optimization analysis is carried out in order to estimate the optimum renewable power generation technology for the Emirate of Sharjah, in the United Arab Emirates. The technologies studied and compared were based on solar technologies, and carbon capture and storage was also proposed as a scenario to implement. The economic analysis of these scenarios was compared with conventional power generation expansion scenarios. Even though conventional power generation, which relies solely on fossil fuels, was the least cost option, CSP option, which integrated the natural gas combined cycle, carbon capture storage and solar systems which had 24 h storage was found to be the optimum technology when considering the UAE's shift to renewable energy.

There are several optimization algorithms which can be used to calculate the cost of producing wind power in a region. For example, in [9], a new type of software is used to perform statistical calculations which help choose the best wind turbine technology for different sites within Saudi Arabia. The algorithm requires hourly wind speed data, performance curves of the wind turbines as well as the total load required in the area. The software takes into consideration the net present value (NPV), capital return factor (CRF), present and future values of the parameters within the calculations. The conclusion of the software was that as the capacity factor increases, the energy price increases.

In [2], the IPP optimization software is introduced, which is a useful tool for calculating costs of operating both conventional power generation cycles as well as renewable sources. The IPP software is used to study the cost of electricity of different technologies studied. The software uses an optimization algorithm, which takes into consideration the interest rate, inflation, capacity factor, technology at hand, maintenance costs, fixed and variable costs and years of operation.

Wind energy is a promising industry, however, not yet implemented at large scale in the Middle East region and specifically in UAE. Several studies have been carried out regarding the potential of harnessing wind power in the Middle East. According to [10], several countries from the Middle East are starting to take wind power generation into real consideration, such as Iran, Jordan and Saudi Arabia. Iran has the highest installed capacity so far of around 92 MW and plans in the future to expand to around 400 MW of wind power capacity. Studies conducted by the Iranian Renewable Energy Organization [10], showed that Iran has the potential of at least 6.5 GW wind power, which could count for a notable portion of the country's overall power consumption. Also Jordan has plans to increase the energy from renewables to 10% by 2020. Several countries within the Middle East are said to have good wind potential for wind power harnessing, such as Oman, Saudi Arabia, Iran, Syria and Jordan.