International Conference on Applied Energy 2019
Aug 12-15, 2019, Västerås, Sweden
Paper ID: 0122

SYSTEMATIC ASSESSMENT OF USING SMALL WIND TURBINES TO POWER REMOTE OIL EXTRACTION IN CHINA

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ABSTRACT

The mix of energy supply worldwide has changed dramatically in the last few decades. In order to tackle climate change, there has been a clear movement from fossil fuels towards renewable and sustainable energy sources. Wind energy, for example, has generated 98% of Scottish electricity demand in October 2018, which has established a world-class record. On the other hand, non-renewable energies (such as oil and gas), which are not environmentally friendly, are still being recognized as the primary source of energy. This confrontation may be solved through tight integration of fossil and renewable sources. In this paper, wind sources in the Daqing oilfield of China are critically assessed to identify the potentials of using small wind turbines (SWTs) to support local oil production in remote sites. A wind power model has been built based on a one-year meteorological database. The modeling results suggested that over 80% of the original annual costs of power generation could be saved by using wind energy for oil extraction in a remote site at Daqing oilfield.

Keywords: Oil production; Small wind turbines (SWTs); Remote power supply.

1. INTRODUCTION

The oil and gas industry is not only one of the major energy suppliers, but also one of the largest customers in energy consumption. It has realized that energy used in hydrocarbon production & operation has caused the increase of greenhouse gas emission, which should be minimized where possible. The power supply in oil and gas extraction involves a wide range of activities, including driving pumps to produce fluids from subsurface and running turbines to generate electricity or heat needed for on-site operations. Mostly, the power consumed during hydrocarbon production is supplied by the main grid nearby. However, when an oilfield is mature in its later phase developments, significant finds of oil-rich areas are becoming rarer. Due to the most approachable regions are either selected clean or kept off for political reasons, oil extractions are pushing into the harsher, more remote and less promising territory. The remoteness of oil wells causes them far away from the major grid. In China, most operators choose to use diesel generator set to supply power in remote hydrocarbon developments, which has low power efficiency and creates high pollution.

The objective of this paper is to evaluate the technical and economic feasibility of harnessing wind energy to support oil production from the declining Daqing oilfield, which is the largest onshore oil fields in China. Daqing oil field has over 45,000 wells that are using beam pumping units. The annual electricity consumption of the entire field is nearly 3.6 billion kWh, where over 25% of them used in pumping operations [1].

2. WIND RESOURCE ASSESSMENT IN DAQING OILFIELD

2.1 *The oil capital in China - Daqing*

Daqing oil field, which is operated by China National Petroleum Corporation (CNPC), is one of the huge oilfields worldwide and the largest oil field in China. The field covers a geographic area of more than 6000 km^2. It was discovered in 1959 and made a tremendous contribution to the economic development of China. Daqing oilfield plays a key role in the national oil supply security. In 1976, its annual oil production is over 50

Selection and peer-review under responsibility of the scientific committee of the 11th Int. Conf. on Applied Energy (ICAE2019).

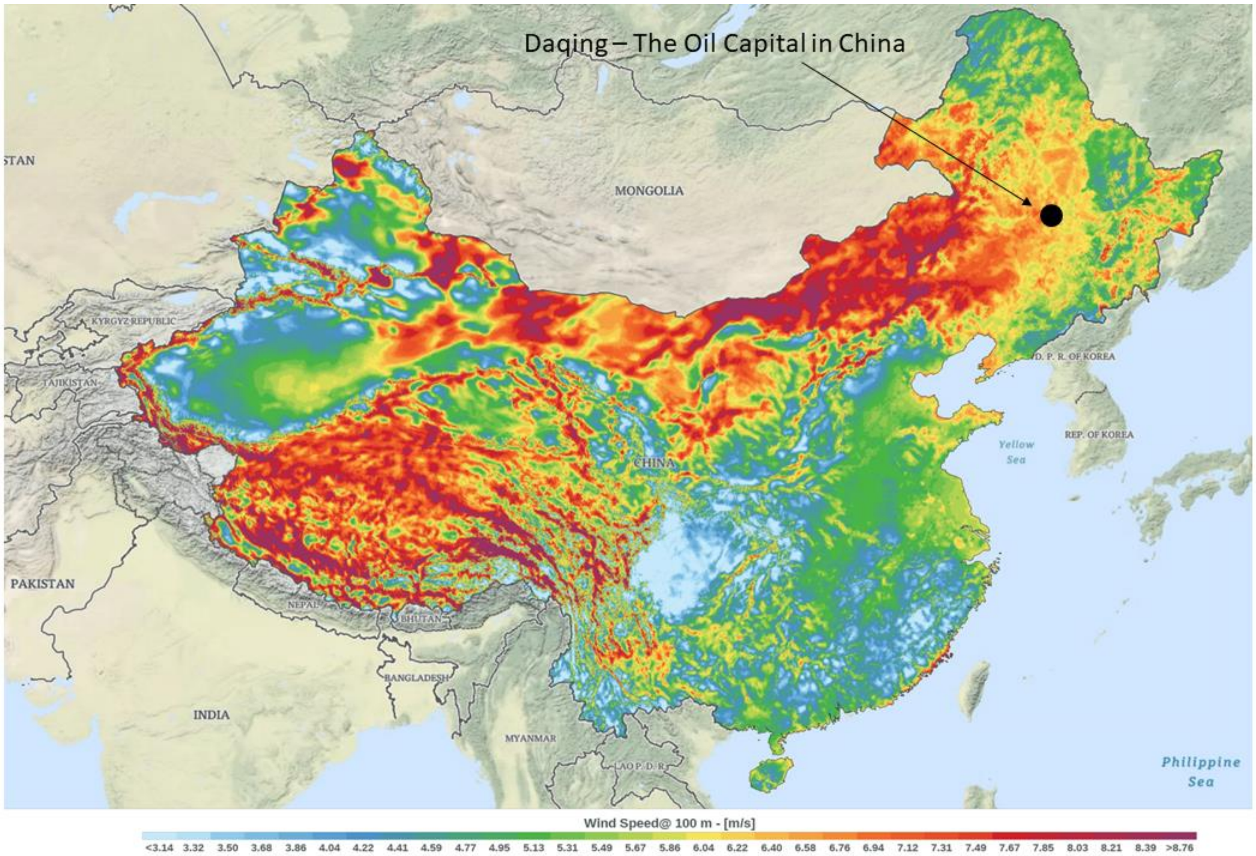

Fig 1 Wind power density map of China (this map was printed using the Global Wind Atlas online application owned by the Technical University of Denmark).

million. Since then, this annual production record was kept for 27 years.

The wind power density map of China is displayed in **Fig. 1**, where the Daqing area is highlighted by a black point. As can be seen, most of wind power density at the Daqing oilfield is higher than 300 W/m^2 at the height of 100 m, indicating considerable energy can be potentially converted at the site through wind turbines.

2.2 *Data preparation*

The one-year meteorological data (from 01/01/2018 to 31/12/2018) was extracted from a fixed weather station in Daqing, supplied by the National Oceanic and Atmospheric Administration (NOAA) [2]. The data were measured every three hours in each day, including atmospheric pressure at sea level, air temperatures, wind directions and wind speeds at a certain height.

2.3 *Wind rose*

A more succinct view of how wind direction is typically distributed at the Daqing city is presented in the form of a wind rose in **Fig. 2**. The wind direction has the most frequent occurrence of southerly winds in the WSW ~ SSW sector. The wind direction in winter and summer alternates regularly. The wind direction is stable, which is beneficial to the layout of wind turbines.

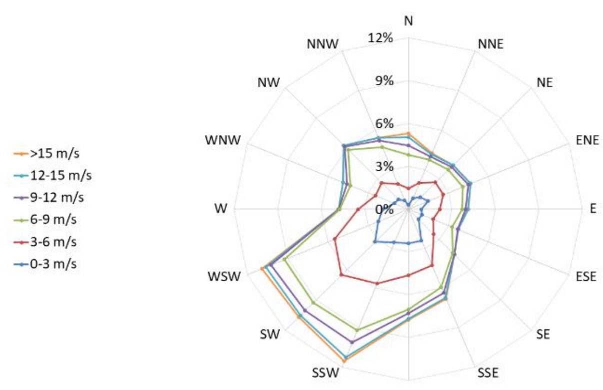

***Fig 2** Wind rose of Daqing oilfield.*

3. WIND POWER MODELING

3.1 *Modeling Methodology*

One of the most common methods to evaluate wind power outputs is to use power curves specified from commercial wind turbines. However, it is difficult to provide an accurate power curve to any locations. Air density on site is one of the impact factors that can influence the accuracy of power curves [3] and this parameter varies from one location to another. In this study, the library "windpowerlib" is applied to build a wind power model in a Python 3 environment (Python 3.7), which provides a series of classes and functions to calculate power outputs of wind turbines/farms [4]. In order to accurately predict annual wind power outputs, air density variations on site in the Daqing oilfield is involved in the simulation to correct the standard power curve from the manufacturer.

The air densities were converted by the following correlations [5]:

$$v_s = v_p \cdot (\rho_a/\rho_h)^a$$

$$a = \begin{cases} \frac{1}{3}, & v_p \leq 7.5\ m/s \\ \frac{1}{15} \cdot v_p - \frac{1}{6}, & 7.5\ m/s < v_p < 12.5\ m/s \\ \frac{2}{3}, & v_p \geq 12.5\ m/s \end{cases}$$

Where v_s is the density corrected wind speed in m/s; v_p is the standard wind speed marked in the certificated power curve from the manufacturer in m/s; ρ_a is the ambient density, which is taken as 1.225 kg/m^3 in this study; ρ_h is the air density at the hub height under site conditions in kg/m^3; a is exponential constant that is related to standard wind speeds.

3.2 *Wind turbine specification*

The commercial off-grid wind turbine H19.2-100KW was considered as an example to evaluate wind power outputs for a single SWT in the Daqing oilfield, manufactured by Anhui Hummer Dynamo Co., Ltd [6]. The specifications of the wind turbine are presented in **Table 1**.

Table 1 – Selected SWT specification [6].

Configuration	Horizontal axis; 3 Blades
Rated power	100 kW @ 12 m/s
Hub height	18 m
Rotor diameter	20.8
Cut-in wind speed	3 m/s
Cut-out wind speed	25 m/s

3.3 *Annual power outputs*

The wind power outputs are displayed in **Fig. 3** under the feed-in time series of the year 2018.

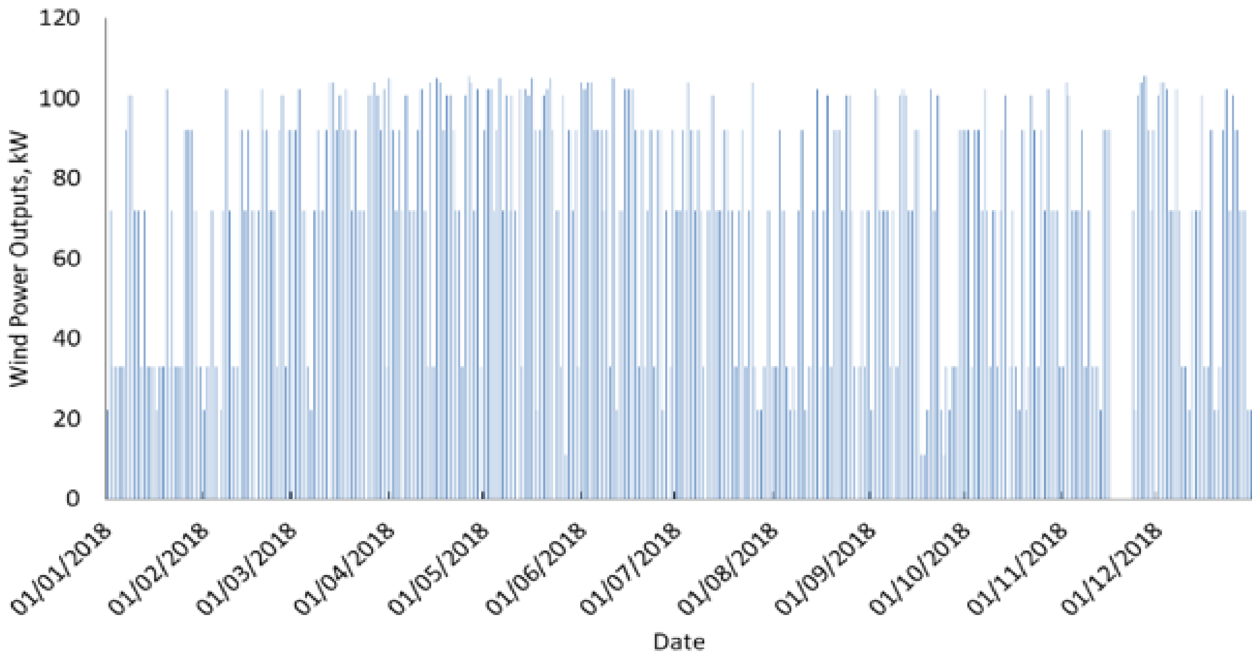

Fig. 3 – Power curve of the selected off-grid wind turbine.

The generated wind powers are corresponding to the 2480 wind speeds that were measured daily from the meteorological station. Note that, it is assumed that the wind power of wind speeds above the maximum and below the minimum values are zero in the power modeling. The annual energy output is around 323.29 MWh.

4. ECONOMIC ANALYSIS

A remote single-well oil production station in Daqing oilfield, which is far away from major grids, is selected to carry out an economic analysis. Currently, a diesel generator with an installed power of 90 kW is used for the single-well station to supply powers for operations of one beam-pumping unit and lighting & heating of one wellhead duty house. At present, the annual fuel cost of the diesel generator is about 8.11×10^4 USD.

Levelized cost of electricity (LCOE) is used to present the annual cost of the selected SWT, which can be expressed as [7]:

$$LCOE = \frac{1}{AEO}\frac{P_r C_s(1+C_v)}{n}\left(1+M\left[\frac{(1+I_c)^n-1}{I_c(1+I_c)^n}\right]\right)$$

where AEO is the annual energy output of the target wind turbine in kWh; P_r is the rated power in kW; C_s is the special cost in USD/kW; C_v is the variable capital cost; M is the variable O&M cost; n is the lifespan of the selected SWT; I_c is the interest rate of the located country. The input values of LCOE is summarized in **Table 2**.

Table 2 – LCOE inputs.

Parameters	Values
AEO	3.23×10^5 kWh
P_r	100 kW
C_s	2000/kW
C_v	0.2
M	0.035
n	20 years
I_c	0.0435

Based on this equation, the annual cost of the target SWT is 1.75×10^4 USD, which is only one-fifth of costs in the diesel generator case.

5. CONCLUSIONS

The potentials of integrating wind power and oil production have been identified for remote wells in the Daqing oilfield, China. Conventionally, powers used in remote wells' oil production were supplied through independent diesel generators, which has the disadvantages of low energy efficiency and high pollution. Alternatively, a hybrid strategy was investigated in this study, where SWT is used in power supply and the originally installed diesel generators are kept as a back-up.

Wind resource assessment of the Daqing area has released that the prevailing wind directions mainly come from the WSW - SSW sector with substantial wind speeds. Wind power modeling was carried out through using one-year (01/01/2018 ~ 31/12/2018) meteorological data. The specified SWT has a rated power of 100 kW. The simulation results show that the annual wind energy output is around 323.29 MWh, which could cover the power requirements of the remote site. The economic considerations indicated that over 80% of the original annual costs of power generation could be saved through the integration of wind energy and oil extraction.

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