HYBRID WIND-SOLAR ENERGY SYSTEM FOR REMOTE LOCATIONS IN NORTHERN ALBERTA

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DOI: 10.56007/arrivet.v1i1.14

ABSTRACT:

Using renewable energy resources as alternatives to fossil fuel systems is encouraged globally by government and other agencies to achieve greenhouse gas emission reduction targets. Solar and Wind energies are the two widely common renewable energy resources and have reached a mature technological phase for various applications in rural and urban settings. However, these energy resources are prone to intermittency with temporal and seasonal availability. In a cold climate region like northern Alberta, the winter conditions limit solar energy availability significantly. On the other hand, wind energy in the region has consistent availability most of the time. In this work, to develop a standalone all-season sustainable energy system at remote locations, such as rural areas and agricultural applications, a hybrid wind-solar system configuration is modeled, simulated, and analyzed to achieve 200 watts of uninterrupted power in Alberta weather conditions. The results show that wind energy production compliments solar energy production during the wintertime. The hybrid configuration can meet a consistent load demand that is difficult to implement in northern Alberta conditions.

Keywords: renewable energy; solar; wind

1. INTRODUCTION

With current efforts on reducing greenhouse gas emissions from individual, community, corporate, and government levels, renewable energy resources are prioritized over fossil fuel systems wherever feasible (Jahangiri, 2016). Renewable energy resources, in general, are widely accessible over the globe. However, challenges towards renewable energy system implementations are the initial cost of deployments and the intermittency in energy availability (Suberu, 2014). These factors are greatly affected by geographical locations. Battery-driven large energy storage capacity and renewable systems may solve the power intermittency issue. Still, in many cases, the energy availability, storage cost, and overall system footprint are prohibitive to such system implementations. Intermittency levels in renewable energy systems can be significantly improved if the combination of renewable energy sources, that can complement each other, be implemented (Dhunny, 2019). The hybrid renewable energy system configuration can be a cost-effective and environmentally friendly solution for remote locations where a sustainable energy supply is needed on standalone configurations (Huang, 2015).

Alberta has excellent potential for wind and solar energy resources (Green Alberta Energy, n.d.; Solbak et al., 2016; Canada Energy Regulator, 2018). However, due to snow depositions and the geographic location at higher latitudes, the northern part of Alberta experiences a significantly lower amount of solar energy in wintertime (Jamil and Pearce, 2022). On the other hand, wind power remains consistent throughout the year in most of the region (Barrington-Leigh and Ouliaris, 2017; Rahmanifard and Plaksina, 2019). In general, wind shows a consistent pattern compared to solar energy.

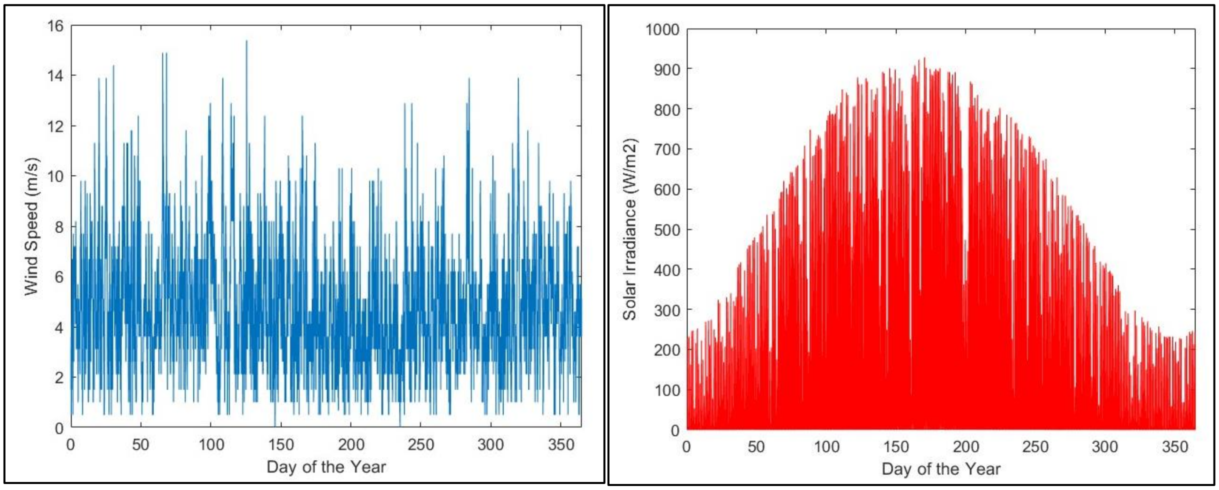
Due to harsh weather conditions in northern Alberta, these areas are sparsely populated, and so is the utility infrastructure. However, there is a need for sustainable energy in many of these remote locations. The nature of these sites can vary from a remote pipeline or environmental monitoring stations, agricultural applications, small communities, where connectivity to the power grid network is cost prohibitive.

This paper analyzes the prospects of hybrid wind and solar energy renewable energy for standalone year-round sustainable operations in the northern Alberta region. While the system evaluated may have several applications, the current model is designed to provide power supply to support a remote sensing system to remotely monitor bison farming in feedlot settings. Wintertime scenario where solar energy availabilities can be significantly lower than that in summertime conditions has been discussed. Weather data sources, corresponding simulation models, and system characteristics are discussed in section 2. Energy availabilities from individual sources and the combined output are calculated in section 3. We show that wind and solar photovoltaic (PV) systems (as a combination) can provide feasible options as an energy source for out-of-grid remote locations in northern Alberta.

2. METHODOLOGY

2.1 Data on Wind and Solar Energy Availabilities

Typical availabilities of solar and wind energy at a location in northern Alberta are shown in Fig. 1. The wind velocity data at 10m height was taken from the monitoring station located at Lloydminster, Alberta, as available from the online database of Agriculture and Irrigation, Alberta Environment and Parks, and Environment Canada (Government of Alberta, n.d.). The three components of solar radiation (direct, horizontal, and diffuse irradiance), as available from the National Solar Radiation Database (NSRDB) (The National Renewable Energy Laboratory, n.d.) were used for solar energy data. From Fig. 1, a pattern in solar energy availability with four-fold energy reductions during wintertime, as expected, can be seen. On the other hand, the wind pattern shows consistent behavior with slightly stronger frequency of higher wind-speed occurrences during wintertime than that in the summer. More details on the production analysis and how both systems can complement each other will be discussed later in the results and discussion section.



(a) (b)

Figure 1: Wind (a) and solar energy (b) potential near Lloydminster, Alberta region for 2021. The day of the year represents the day number starting from January 1.

2.2 Photovoltaic System

For the photovoltaic (PV) system performance, three main models are needed to simulate the production of the system. The first two are the weather data model, in terms of solar radiations including ambient temperature, and the PV performance model with the availability of characteristic parameters of the PV Panel. However, the third component/model required is the solar geometry model, which is needed to determine the angle of incident of solar radiation on the PV panel at any time of a day, month, and year depending upon the orientation of the PV panel. A brief description of these three models considered in the study is provided elsewhere (Burhan and Huda, 2023).

Characteristic parameters of the PV module considered in this analysis are given in Table 1.

Table 1: Characteristic parameters of the PV module

Parameters	At STC*	At NOCT**
Open circuit Voltage	40.9V (T_C = 0.048 %/°C)	38.3V
Short Circuit Current	11.52A (T_C = -0.27 %/°C)	9.32A
Voltage at Maximum Power	34.4V	32.0V
Current at Maximum Power	10.76A	8.63A
Maximum Power	370W (T_C = -0.35 %/°C)	276.3W

*STC (Standard Testing Conditions): irradiance l000 W/m2, Cell Temperature 25oC, Spectra at AM1.5

**NOCT (Nominal Operating Cell Temperature): irradiance 800W/m2, Ambient Temperature 20oC, Spectra at AM1.5, Wind at 1m/S

2.3 Wind Energy System

A commercially available low-footprint vertical axis wind turbine generator system was chosen for our analysis. As per specifications, the system (Aeolos-V 600W) has a lower start-up speed and capacity to operate at high wind speeds, occasionally observed in northern Alberta (see Figure 1). The power vs. wind speed characteristics is shown in Fig. 2.

3. RESULTS AND DISCUSSION

We used the solar radiation and weather data obtained from NSRDB (National Solar Radiation Database) for a remote location at northern Alberta near Lloydminster. The windspeed data was taken from the Lloydminster weather station.

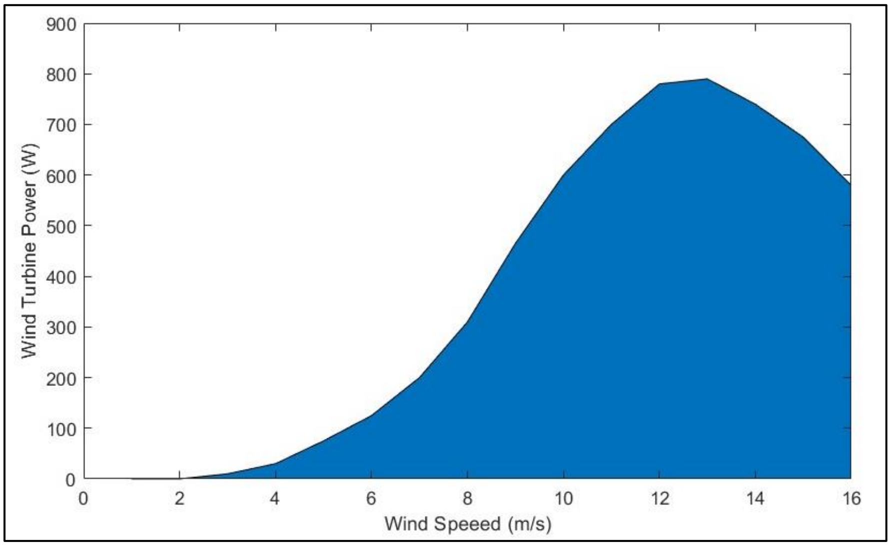
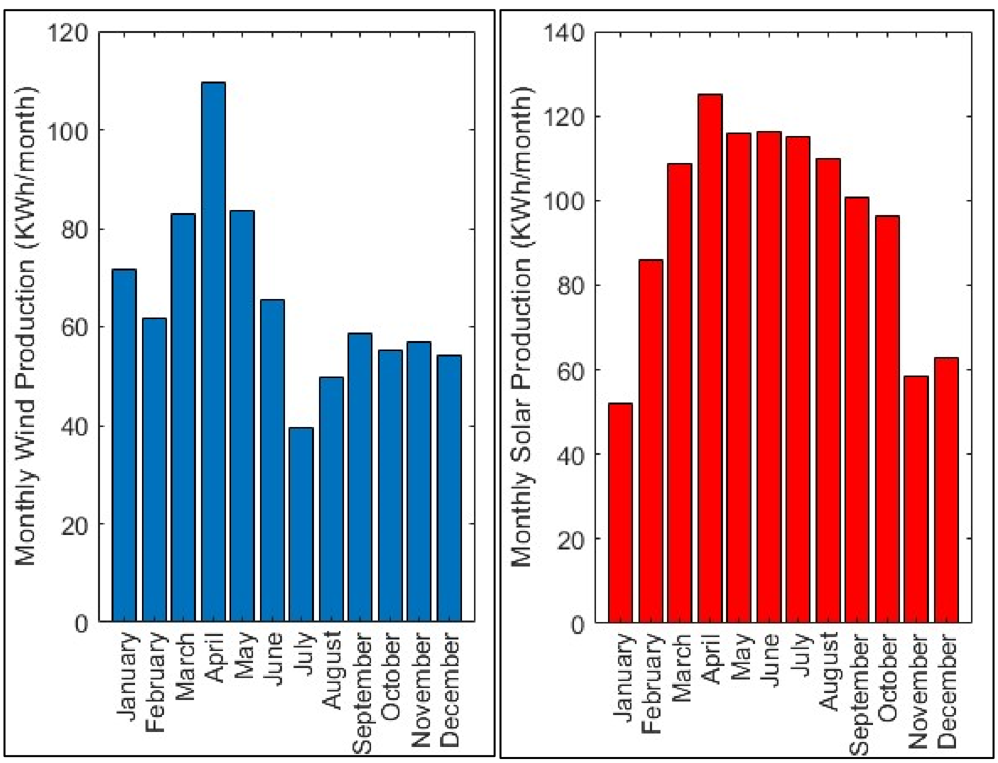


Figure 2: Power curve of vertical axis wind turbine (Aeolos-V 600W)



(a) (b)

Figure 3: Monthly average production of wind (a) and solar (b) systems

Figure 3 shows the monthly average energy production with a similar deployment capacity of 800W and 740W for wind turbine and solar PV (2 panels). These system capacities were selected to run a continuous total electrical load of 200W for a remote monitoring station. A significant seasonal variation can be seen in the production of both systems. Overall, the solar system has more output, especially from spring till early winter, which reduces drastically during the winter months of November, December, and January. On the other hand, wind turbine generator shows consistent productions during wintertime that are similar to or higher than productions in the summertime. The strongest wind power output is during springtime, and the lowest monthly production is recorded during July.

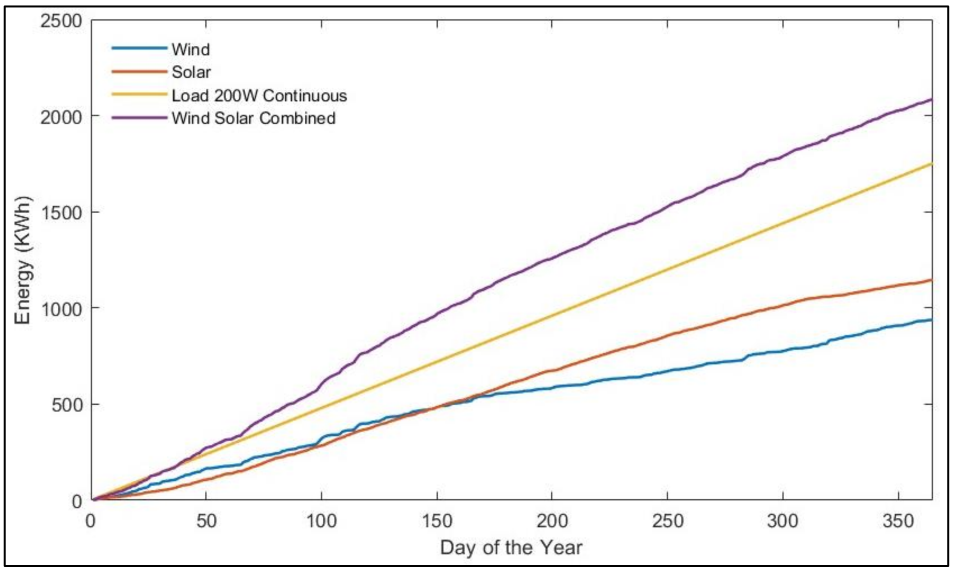


Figure 4: Cumulated energy production and demand

It is apparent from the plots in Figure 3 that wind and solar energies can complement each other in designing a sustainable standalone energy system at remote locations. To analyze the potential and capacity of the proposed hybrid wind-solar configuration to meet the electrical load requirements of the remote monitoring station, cumulated energy production and demand over one year were calculated and shown in Figure 4. The day of the year in the Figure is calculated from the beginning of the calendar year (i.e., January 01). It is seen that energy generation from wind power contributes to a larger fraction for the first few months of the year (wintertime) until solar energy becomes the dominant power source from late spring to onward. The combined wind-solar system, in this case, is seen to generate sufficient power with some degree of redundancy on the assumption of a steady consumption rate throughout the year. Having a combined renewable energy system thus can be a viable approach to achieve sustainable energy throughout the year in a cold climate scenario. Depending on the particular geographic location and the nature of meteorological conditions, a hybrid renewable energy system involving wind and solar energies can be designed with stronger or less reliance on one particular system over the other. However, reliance on only one type of renewable source can lead to significant interruptions in power availability, even in the presence of sizable storage capacities.

4. CONCLUSION

Performance simulation and analysis of a hybrid wind-solar energy system is presented and discussed as a standalone energy supply unit for a remote location in the northern Alberta region. The hybrid wind-solar configuration proved to be a feasible and sustainable energy solution for such remote locations. Availability of solar energy significantly reduces during the peak winter months in northern Alberta. Wind energy, on the other hand, remains consistent throughout the year. A hybrid wind-solar system can complement each other, resulting in a sustainable standalone energy system. A hybrid system was designed for a year-round sustainable load capacity of 200 watts in a standalone configuration. The power supply over a year will be adequate to fulfill the needs of a remotely located bison monitoring system, which includes cameras, a weather station, an automated scale, a computer, and laser sensors.

5. ACKNOWLEDGMENTS

The authors acknowledge fundings from Alberta Innovates and Go Productivity.

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