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Seasonal weather effects on wind power production in cold regions- a case study

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Abstract

This paper describes a case study of seasonal weather effects on wind park power production in cold climate region. Three years (2013-15) of analysis of a wind park SCADA data has been carried out in order to better understand the seasonal weather effects on the annual energy production (AEP) using 10 minutes averaged time series of SCADA data. Analysis of three selected wind turbines of a wind park is presented in this paper. SCADA data analysis shows a difference in the wind power production during summer- and wintertime periods, with the wind power production during winter time being considerably higher than summer time. Analysis shows that the highest wind power production is during January, whereas the lowest power production is recorded during the month of June.

Keywords; wind energy, cold climate, AEP, weather, SCADA data, wind turbine

1. Introduction

Due to increasing demand of electrical power and the efforts to protect the environment, there has been an ever increasing need of rapid expansion of renewable energy sources in order to cut the toxic emissions [3]. The cold climate regions have great potential for the wind energy sector - the estimated wind energy capacity in cold climate regions is approximately 60 GW [4]. Presently, cold regions are not the most common areas for the wind turbines installation, despite the fact of having good wind resources. Good usage of these wind resource in cold climate regions greatly depends upon the location of wind farms and weather conditions. This is primarily due to planetary boundary layer (PBL), if High Latitude Cold Climate (HLCC) regions having a significant difference when compared to low latitudes, as in the HLCC regions the thermal energy is unavailable to drive transport processes for the most time of the year.

Icing on wind turbines is recognized as a hazard, limiting the wind energy production at elevated cold climate regions, as icing has a major impact on wind turbine performance and annual wind energy production [1]. Wind energy production greatly varies during summer and wintertime periods, therefore, it is important to develop a better understanding of the seasonal effects on the wind power production and forecasting, both through real-time and with retrospective analysis. The International Energy Agency (IEA) Annex 19 '*Wind energy in cold climates'*, has also urged to find better methods of estimating the wind energy production in ice prone cold climate regions. Three years (2013-15) of SCADA data from a wind park is used for this case study.

2. Background

Icing events are defined as periods when the atmospheric temperature is below 0 ℃ and the relative humidity is above 95% [2]. There are mainly two types of icing events: *meteorological icing* (M- icing) and *instrument icing* (I- icing). Table 1 briefly describes these.

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Table 1. Meteorological and instrumental icing

Condition	Definition
Meteorological icing (M- icing)	Period during which the meteorological conditions for ice accretion are favorable.
Instrument icing (I- icing)	Period during which the ice remains at a structure and/or instrument or wind turbine is disturbed by the ice.

Similar to other renewable energy sources, seasonal weather effects also affect the wind energy [5]. Wind turbine's design and performance is linked with the meteorological weather conditions as the wind turbine power productions is calculated using following formula.

$$P_{avail} = 0.5\ \rho A v^3 C_p$$

where 'P' is the output power, 'C_p' is the power coefficient,' ρ' is the air density, 'v' is the air velocity and 'A' is the wind turbine rotor swept area, thus the air density and the wind speed are the main factors of wind power output. For high latitude regions, the air density is higher than the typical air density in warmer regions and thus the actual output of the wind turbine can be higher than the normal output. Similarly, the air density and air temperature are inversely proportional to each other, which means that with the decrease in the atmospheric temperature the air density increases, thus increasing the potential available wind power. This paper describes a case study of seasonal weather effects on annual energy production of a wind park located in a cold climate region.

3. Design of Experiment

3.1. Wind park site description

The wind park used in this study is located on complex terrain in ice prone region in Norway. Figure 1 shows the real pictures of the wind park during summer and winter periods.

Fig. 1. Wind park during summer and winter periods.

From Figure 1, one can see that during winter time, this wind park is covered with ice, which highlights the possibility of icing event on wind turbines. In addition, the significant change in atmospheric temperature during summer and winter time periods also affects the annual wind power production, which makes this particular wind park suitable for the study of seasonal effects on the wind power production.

3.2. Technical Specifications

Technical details of the wind turbines installed in the wind park in question are given in Table 2.

Table 2. Technical specifications

Turbine manufacturer	Simens
Tower height	80m
Rotor diameter	90m
Operating speed	3~25 m/s

From the preliminary SCADA data and meteorological parameters analysis, it was found that in this particular wind park, wind comes primarily from three different directions. With the wind park layout in mind, three wind turbines are selected for this case study. These three wind turbines have the best power production in each principal wind direction. Table III shows the wind direction and site of each three wind turbine used for this study.

Table 3. Turbine selection

Wind direction	Turbine	Wind Direction
1	Turbine 01	West - East
2	Turbine 11	North - South
3	Turbine 14	Southwest - Northeast

4. SCADA Data Analysis

4.1. Data sorting

Three years (*2013-2015*) of SCADA data is used for this study. This data contains meteorological, operational and production data in 10-minutes interval. The main parameters of this SCADA dataset used for this study are:

(1) Average wind velocity (m/s)

(2) Average atmospheric temperature (^{o}C)

(3) Wind power production (kW)

The SCADA data was sorted and preliminary analyzed in order to find the best data curve fit. Both horizontal and vertical interpolation techniques were used for this purpose. Polynomial curve fitting was used as it has provided the best results.

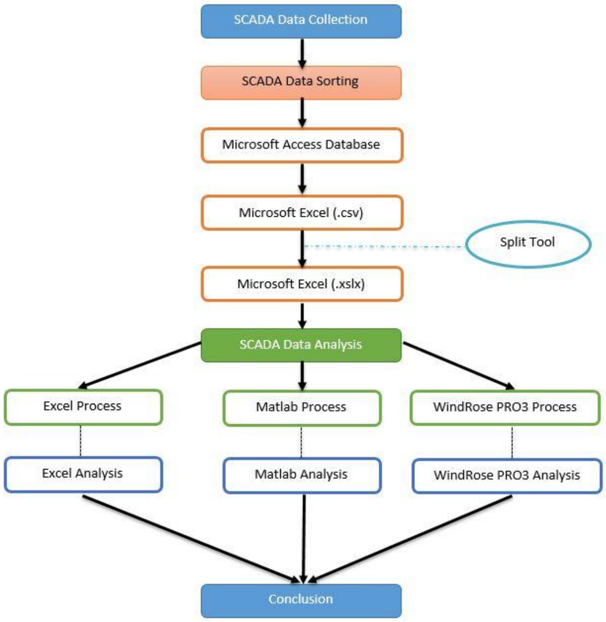


Fig.2. SCADA data analysis structure.

4.2. Data analysis

SCADA data was sorted using Microsoft Excel and Access, whereas the analytical analysis was carried out using MATLAB. Approximately half million data points were sorted and analyzed. Four interpolation methods have been used to analyze the seasonal weather effects on wind power production:

1. *Time & Average wind velocity*
2. *Time & Average temperature*
3. *Time & Wind power production*
4. *Average wind velocity & Average temperature*

Figures 3 – 5 show the three years of data analysis of each selected wind turbine. The blue curve represents 2013 dataset, the red curve represents 2014 dataset and the black curve represents 2015 dataset.

<u>Turbine 01</u>

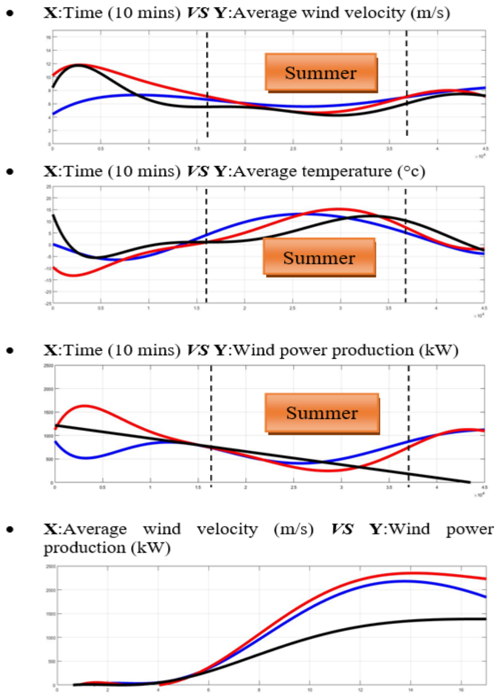


Fig.3. Seasonal effects on turbine-1.

<u>Turbine 11</u>

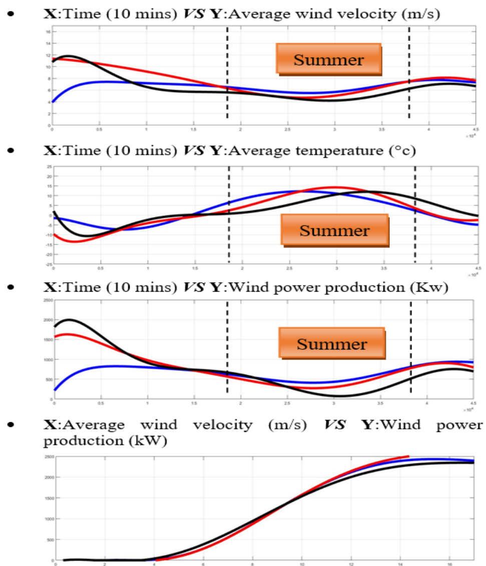
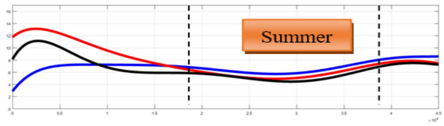


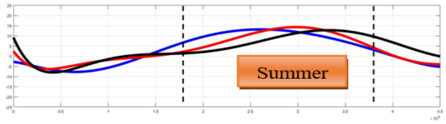
Fig.4. Seasonal effects on turbine – 11

<u>Turbine 14</u>

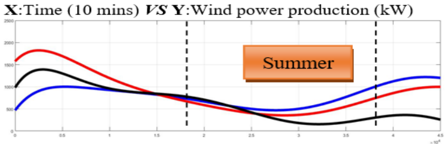
- **X**:Time (10 mins) ***VS*** **Y**:Average wind velocity (m/s)



- **X**:Time (10 mins) ***VS*** **Y**:Average temperature (°c)



- **X**:Time (10 mins) ***VS*** **Y**:Wind power production (kW)



- **X**:Average wind velocity (m/s) ***VS*** **Y**:Wind power production (kW)

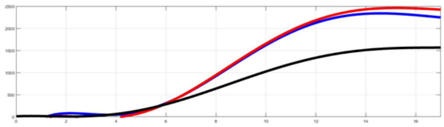
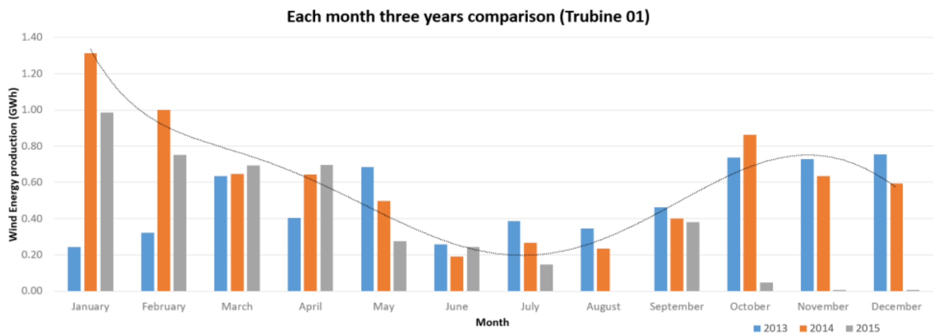
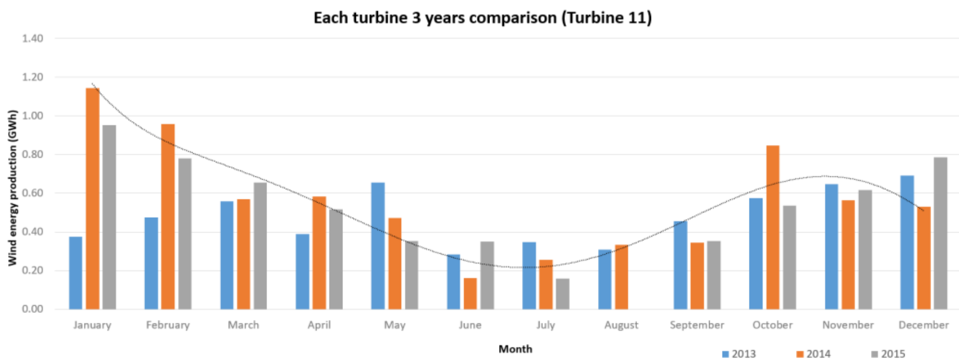


Fig.5. Seasonal effects on turbine- 14.

4.3. Annual Energy Production (AEP)

Based on the SCADA data analysis, the AEP of each wind turbine is calculated, which is needed for estimation of the seasonal effects on wind power production. Figure 6 shows the seasonal AEP of the wind turbines in this study. Unfortunately, the August 2015 data is missing due to the some issues with the technique.





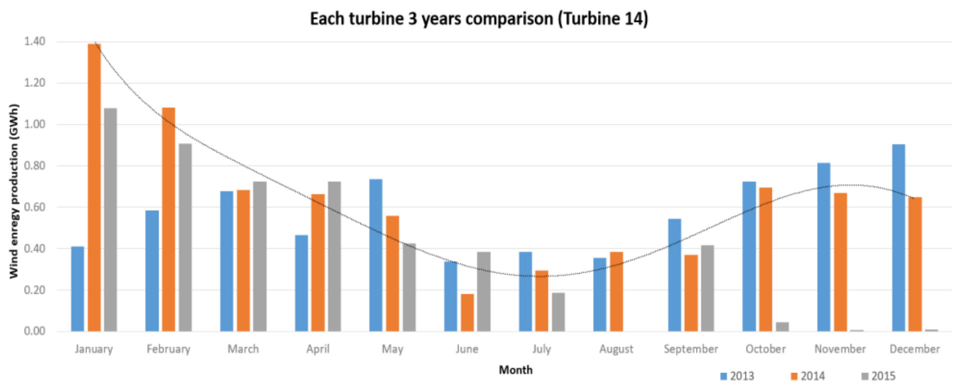


Fig.6. Annual Energy Production (AEP) of each selected wind turbine.

Figure 6 shows the AEP of the 2013-15 data separated into 12 month for each year. Results shows that there is higher wind energy production during wintertime period as compared to the summertime. From the data, the AEP is at maximum during January and at minimum during June and July. The three years total power production is 55.55 GWh with the annual and total power production of each turbine in GWh is given in Table IV.

Table 4. Wind turbine power production

	Wind Power Production (GWh)			
	2013	**2014**	**2015**	**Total**
Turbine 01	5.97	7.29	4.23	17.49
Turbine 11	5.76	6.77	6.06	18.59
Turbine 14	6.94	7.62	4.91	19.47
Total	18.67	21.68	15.20	55.55

5. Discussion

The paper provides some insights into the seasonal weather effects on wind energy power production in cold climate regions. Three years of real-time SCADA data from a wind park is sorted and analyzed. Analysis show that the average wind velocity and wind power production have the same trends (positive correlation), however, the average wind velocity and wind power production have negative correlation. Moreover, comparison of the three wind turbines AEP plots show that during wintertime the wind power production is higher than during summertime, in particular, the highest wind power production was observed in January, and smallest wind power production was observed in June. The reason for this is that the average wind velocity is lower during the summertime, in addition to the temperatures being higher at the same time, which means that average air density is lower in summertime when compared to wintertime, therefore the power production is lower in the summertime as compared to the wintertime.

6. Conclusion

This paper describes the SCADA data analysis of a wind park in a cold region. The analysis was carried out using the three years (2013-2015) of SCADA data for the three turbines of a wind park located in Norway. There are two significant correlations observed among the four main parameters - one is between average wind speed and wind power production, the other being between the average temperature and time (being almost normally distributed), which shows that the average wind velocity and the wind power production are positively correlated, but the average temperature is negatively correlated with them. These trends are linked with seasonal effects, i.e. the wind power production in wintertime is considerably higher than in summertime. Moreover, the maximum monthly wind power production is recorded in January, whereas the minimum wind power production is in June. The total power production of the three wind turbines for all three years is 55.55GWh, and, specifically, in 2014, the power production is the highest among these years, at 21.68 GWh. Results shows that higher wind speeds and lower temperatures at the wind park site during wintertime as compared to the summertime, which affects the wind power production.

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