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Wind Science and Engineering New Certificates of Approval and Solutions for Offshore Wind Turbine Installation Proposed

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Abstract

The most critical concerns during offshore wind turbine installation are wind conditions. Wind can cause safety issues and long periods of waiting, resulting in project delays and massive costs. The offshore wind energy industry relies on weather forecast reports, but the reports are frequently found to be inconsistent, particularly in wind speed. The decision to perform installation work is then difficult [1-15]. The current paper proposes a solution to analyse the similarity degree of the two reports, as well as predict the next opening of the weather window and its periodicity, by utilising the concept of time lag in Cross-Correlation and Pearson Correlation Coefficient. Not only must the reports be aligned, but wind types must also be precisely judged. The paper presents a new point of view .The most critical concerns during offshore wind turbine installation are wind conditions. Wind can cause safety issues and long periods of waiting, resulting in project delays and massive costs. The offshore wind energy industry relies on weather forecast reports, but the reports are frequently found to be inconsistent, particularly in wind speed. The decision to perform installation work is then difficult. The current paper proposes a solution to analyse the similarity degree of the two reports, as well as predict the next opening of the weather window and its periodicity, by utilising the concept of time lag in Cross-Correlation and Pearson Correlation Coefficient. Not only must the reports be aligned, but wind types must also be precisely judged. The paper presents a new point of view.

Introduction

The first offshore wind farm in Taiwan was completed in October 2019. Along the northwest coast of Taiwan, 20 wind turbines have been successfully installed. One critical task during the construction phase was determining the wind speed limits for offshore activities. The activities generally consist of uploading components to the vessel, sea transit, raising the vessel jack to working height, and installing wind turbine components. Wind turbine blade installation, for example, has a strict upper bound on wind speed. To minimise risk, the upper bound must be closely followed during the installation window (usually several hours). The window is based on weather forecasts. The employer, contractor, and vessel captain will then discuss the reports and decide whether or not to proceed with the installation operation. Therefore, measure the degree of similarity between reports. If the degree of similarity is high, then there is no controversy to make decisions. Contrary, if the degree of similarity is low, everything shall be discussed.

It is also important to improve one's ability to judge wind types. Unless the feature is obvious, it is often difficult to distinguish wind types simply by reading the anemometer wind speed records. The current paper presents an innovative approach and analysis that reveals significant wind characteristics across frequency bands by transferring wind speed signals from time domain to frequency domain.

The author participated in all offshore activities in Taiwan in 2019, studying weather forecast reports and vessel crane top anemometer wind data collected from June to October 2019. The author will demonstrate the idea and methods in the following sections, based on personal experience. The MATLAB software programme performs all calculations and simulations.

Offshore wind turbine installation is extremely dangerous and can be extremely harsh in many situations. Work performance is heavily reliant on professional judgments. Natural threats such as typhoons, northeast monsoons, and the Kuroshio Current occur seasonally, particularly in areas bordering the Pacific Ocean, such as Taiwan. Wind is the most important dynamic factor among the threats and should be prioritized. Wind events are divided into two types: wind phenomena and wind-driven phenomena. Wind phenomena are caused by air flow momentum impinging on a still air space or by quiescent air being drawn out to nearby regions. Wind phenomena that are frequently observed include steady wind, pick up wind, sudden/abrupt wind, and fluctuation wind. Offshore situations involving wind-driven phenomena would be sea waves fetchbreaking waves, trochoid waves, and possibly a rogue wave All of these wind events have the potential to jeopardise offshore wind turbine installation. Wind speed fluctuations, for example, can impose unsteady loads on hooks and have a negative impact on non-vertical hoist systems. As a result, wind turbine components are loaded onto the vessel and installed. Furthermore, a severe trochoid or rogue wave will weaken installation vessels with poor seafastening, make vessels impossible to position next to the Mono-Pile, jack up to working height, or even be prohibited from sailing away to the wind farm/back to the harbour.

Subjective Heading

The offshore wind energy industry has a standard procedure for operating wind turbine installation works in order to be fully prepared and minimise risk. To ensure safety and successful installation, each operation in the procedure must be approved by experts from professional engineering consultancies and insurance companies. The documents that have been approved are referred to as the Certificate

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of Approvals (CoAs). Installation vessels will normally upload wind turbine components at quays before sailing away to the construction site (the wind farm). When the installation vessels arrive, they will approach the installed Mono-Pile (MP) and Transition Piece (TP) and jack up to the working height so that the wind turbine can be installed. After the installation is finished, the vessels will jack down to zero air gap and transit.

Discussion

The Geyser in Yellowstone National Park in the United States is a well-known example of a spring that ejects water and steam intermittently. Predicting eruptions is important for both safety and tourism. Scientists have been collecting relevant data and investigating the correlations between data series in order to better predict future eruption. A similar method is used in our weather forecast reports.

Consider the two weather forecast reports A and B for wind speed. Two reports differed, resulting in debates about whether offshore wind turbines should be installed during the construction period. It becomes an important topic to understand how similar, or what the relationship is between reports A and B. To address this issue, the time lag concept "Cross-Correlation (CC)" of the reports A and B, as well as the Pearson Correlation Coefficient (PCC), are applied to wind speed data by checking the correlation degree between the reports A and B hourly and estimating what the next report will be. time to meet the similar weather profile in terms of wind speed. The term "time lag" in mathematics, is to freeze one data sequence and shift the other data sequence to the right/left by the successive time unit.

Figure 2 shows the results of CC and PCC. The report B was shifted to the right on the positive time line (+x axis), while report A was frozen. The report B was shifted to the left on the negative time line (x axis), while report A was frozen. The PCC values are displayed on the Y axis. The origin is where the reports A and B fully aligned in every hour, from 1 p.m. on August 16th to 4 p.m. on August 18th, for a total of 52 hours. The PCC values show that report A and B are correlated until the 37th hour, then there is no correlation and negative correlation until the 52nd hour. The PCC by definition is to show how similar the two between 1 and 1, and the negative PCC shows how far apart the reports A and B are from each other. In the current study, two reports have the highest correlation (PCC = 0.8) at the +2nd hour rather than the origin. The -4th hour has the second highest correlation (PCC = 0.78). Furthermore, it is discovered that PCC = 0.66 at +8th hour, PCC = 0.51 at +13th hour, and PCC = 0.41 at +20th hour: a periodic observation, a cycle of similarity every 5 to 7 h, that the reports A and B obtain relatively higher correlation around the neighbour hours. In the negative time line, the same observation can be made. If benchmark report A has an opening, the observation suggested .The decision to execute the wind turbine installation should be made at 3 o'clock (PCC = 0.8 for the +2nd hour) and 5 o'clock (PCC = 0.78 for the -4th hour) on August 16th, and the opening of the weather window is every 5 to 7 h based on the periodicity found.

To help decision makers better interpret and identify anemometer data and to improve the IEC 61400-1 standard, four wind models are introduced in Section constant, gust, ramp up, and periodic wind. The models represent deterministic signals of the most common offshore wind types and are simulated in MATLAB programming software. These four models will be compared with three anemometer data (examples) in Section identify the anemometer wind type, to reveal wind characteristics in frequency domain, because the data are random signals that are often difficult to interpret: what wind types (information) are contented

All models and examples were simulated or measured at a sampling rate of 10 Hz, with signal lengths set to 15 and 100 seconds. To convert the wind models from time domain to frequency domain, the Fast Fourier Transform (FFT) is used, and the MATLAB command used.

The constant wind model is actually the arithmetic mean of the wind speed over the 15-second time interval. This is a general wind model that represents the most accurate wind situation in nature. The measured signal length determines the constant wind speed value. The greater the length, the stronger the wind. information is taken in to the averaged data set. Therefore, constant wind speed value can be The length of the averaged time interval varies depending on the purpose of the analyzers, depicts the simulated constant wind model depicts the frequency domain characteristic of constant win. The FFT of a constant value is a Dirac Delta Function in mathematics. There is a high peak at the origin and zeros everywhere else. As a result, the constant wind characteristic can be defined as a Dirac Delta Function-like in frequency domain.

Ramp up wind is another type of natural wind. The wind speed increases uniformly over time, implying that the rate of increase is constant. In the offshore wind industry, this is referred to as a "wind speed pick up" situation. In this section, the ramp up wind speed is designed as a Line Function $y=0.0125x+5$, with a low slope value, conveying a mildly raised wind speed. The simulated ramp up wind speed in is 5 m/s to 6.8 m/s in 15 seconds.

Figure 6 depicts the frequency domain of the ramp wind using the MATLAB command "fft". The ramp up wind frequency signal has a high amplitude around the origin area and rapidly drops to an extremely low amplitude within 0.5 Hz bandwidth, continuing to drop as it approaches the x axis. After 1 Hz, the amplitude approaches zero. This fast and round smooth decay, an asymptote-like curve, can be regarded as a ramp up wind characteristic.

The ramp up event in 15 seconds should be tracked. In the event of an event with a small-medium slope of the Line Function, all CoAs must be notified. Wind speed may increase for a short period of time or for a long period of time. It will be beneficial to investigate and define when the Line Function has a deep slope, a sharp ramp up event, the association with a short-second gust wind, and to expand on the explanation in the new addition CoA.

As there are four types of wind characteristics defined in frequency domain, three anemometer measured wind data are illustrated as examples in this section and are transferred from time domain to frequency domain by FFT to analyse what information is contained in the data. Signals can be classified into two types: deterministic and random. Random signals, on the other hand, cannot be directly transferred to frequency domain by Fourier Transform. Mathematically, it is because the Fourier Transform of random signals does not exist (Dirichlet conditions). As a result, the Auto Correlation Function (ACF) is introduced to represent random signals for the purpose of the Fourier Transform. There is an ACF Fourier Transform, and its frequency domain transformation is Auto Spectral Density Function (ASDF) or Power Spectral Density Function (PSDF) (PSD). In other words, the signal's ACF and ASFD can be thought of as a Fourier Transform pair (Wiener–Khinchin theorem).

Please see Fig. 8 for an example of 100 s long, sampling rate in 10 Hz anemometer data. The wind speed fluctuates between 10 and 15 metres per second. At first glance, there are two suspicious spots at the 5th and 85th seconds where gust wind could occur, or the fluctuations could indicate a periodic wind. Nonetheless, the fluctuations are so dense and uniform that it's difficult to tell what information is in the content. First of all, the ACF is found for this data. Secondly, apply FFT (MATLAB command "fft") to the ACF and obtain its Fourier Transform pair, the ASDF. It is shown in By comparing to the frequency bandwidth similar to Sinc Function is recognized in frequency domain: several round bumpers occupying the individual frequency bandwidth about 0.3 Hz to 0.5 Hz wide. It is fair clear to see the round bumpers from origin until 3 Hz.

Conclusion

Figure 10 depicts the second example. It is difficult to tell what information this data is transporting. The only feature one can probably guess is that there appears to be something going on between the third and eighth seconds, or perhaps a message between the eighth and fourteenth seconds, or else the entire 15 s length data looks like a Sine Function concealed. As a result, it is very interesting to see what this data reveals in the frequency domain when using FFT.

Depicts the outcome of ASDF.The characteristic of a clear asymptote-like curve is discovered, and it is accompanied by several fair distinctions of round bumpers. In comparison to the two wind model characteristics, the asymptote-like curve and the round bumpers, are found but with much smaller amplitudes. In any case, the FFT operation reveals the wind types (information) of the data in the frequency domain by wind characteristics, as show. This smaller order of magnitude may imply that random signals contain less energy.

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Conflict of Interest

The authors declare that they are no conflict of interest.

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