Insight: Wind Turbines

Recognizing the Risk

Using wind to generate energy is projected to grow to approximately 30% of the renewable energy production in 2050. Enabling this growth is the adoption of new technologies enabling larger turbines with higher electrical output for use in offshore wind farm installations. Wind turbines with an output of 16MW have been placed into service in 2023 and larger turbines are already in the design stage. This document covers risks associated with both onshore and offshore horizontal axis wind turbines.

Risks associated with wind turbines include extreme weather, electrical and mechanical failure, and fire.

One of the most common hazards is from lightning - either a direct strike or an electric surge caused by a nearby strike. The intense energy that is released by lightning can damage the key components of a wind turbine including the blades, nacelle, and any portion of the electrical system. This may also lead to fire within the nacelle and a catastrophic failure. A lightning strike does not have to be a direct strike as any nearby strike could cause an electrical surge and damage electrical equipment.

Hurricanes, tornadoes, and other extreme weather events have been known to cause an overspeed of the rotor resulting in damage to the turbine e.g. damage and detachment of the blades. This type of damage can lead to structural instability and collapse of the entire unit.

Hail can also damage the blades and ice buildup can cause an imbalance of the rotor, also damaging the blades. Falling ice can be severe enough to damage ground-level equipment.

Offshore wind turbines have additional risks due to the complexity of the installations, access challenges, higher wind speeds, ocean waves, changing currents to name a few. Structural failure and submarine cable failure are a major concern for these types of installations. Out of the scope of this document, are the risks associated with the customized offshore substations and the time associated with repairs should a failure occur.

Structural damage caused by earthquakes is a risk that is similar for any type of structure and wind turbines are no exception. Electrical failures can occur at any location within the electrical system. An electrical failure in the nacelle would leave the wind turbine inoperable at best or if a fire is caused it could lead to a catastrophic failure of the entire wind turbine. Any electrical failure of the connection cable or within the onshore or offshore substation would most likely lead to the wind turbine, sections of the wind farm, or the entire wind farm being electrically disconnected from the electrical grid.

A fire in the nacelle is an extremely hazardous event as this can spread quickly in this confined area resulting in a catastrophic loss. Oil fill transformers located in the nacelle or at the base of the structure present a great risk due to the flammability of the oil.

Mechanical failures such as blade failure or overspeed events have been known to happen. Aside from the natural weather causes these can be caused by improper installation, manufacturing defects, transportation damage, or poor design.

Corrosion of structures or any other equipment associated with a wind turbine is a concern especially in locations subject to higher corrosion due to salt water.

Controlling the Hazard

Extreme weather has become increasingly common throughout the world with changing weather patterns. Taking all the information available when designing a wind farm is of the utmost importance.

Design standards such as IEC 61400-1 for onshore and IEC 61400-3 for offshore wind turbine installations should be referenced when designing wind farms. These standards help to provide an appropriate level of protection against damage from all hazards throughout the design life of the installation.

Electrical systems should be designed in a way to minimize the impact of a single wind turbine failure. Cable routes that connect wind turbines to the connection substation should be limited to a select number of turbines or possibly installed in a looped configuration to reduce downtime. This becomes even more important for offshore installations since the repair time and costs can be very high for submarine cables. Access to specialized seagoing vessels will also increase the repair time which is why a contract with a repair company may be necessary. Electrical substations that contain redundant parallel transformers is recommended so that in the event of a transformer failure the electrical load may still be connected to the electrical grid even if it is at a limited capacity.

Fire detection within the nacelle is recommended in the form of smoke detectors. If smoke detectors are deemed to be ineffective then heat detectors should be used.

Lightning protection should be installed on each wind turbine and in accordance with IEC61400-24 to verify there is appropriate protection against a lightning strike.

One issue that is sometimes overlooked is the access to onshore wind turbines. During construction access roads are constructed so that materials can be delivered to each location, but as time goes by these roads may not be maintained to the same standards. If a failure occurs and large equipment is needed to perform a repair it may be difficult or even impossible to access these sites which will lead to additional downtime.

Having an adequate inspections, testing, and maintenance program is critical to help identify deficiencies that can be corrected before a failure occurs.

Conclusion

Wind generation is a growing industry with no signs of slowing down. Wind will play a large role in the effort to move away from fossil fuels and understanding the risks involved can help minimize the number of failures and business interruption.

For more information, contact your local AIG Risk Engineer.

Resources / Standards

IEC 61400-1 Wind energy generation systems – Part 1: Design requirements

IEC 61400-3 Wind energy generation systems – Part 3: Design requirements for fixed offshore wind turbines

IEC 61400-24 Wind energy generation systems – Part 24: Lightning protection

https://www.eia.gov/todayinenergy/detail.php?id=51698