Wind

Wind Turbine & Radar Interactions and Solutions

The Department of War (DoW), Federal Aviation Administration (FAA), and other federal entities that operate or utilize radars, along with the wind energy and radar industries, have understood for 20 years that wind turbines may impact radars if not properly analyzed, sited, and/or mitigated.

Fortunately, through two decades of collaboration, federal agencies, the radar industry, and the wind industry have developed and deployed assessment tools; a rigorous site-specific, mission-specific, technical and scientific evaluation process; adjustments to wind farm plans, such as turbine layout; software solutions; hardware upgrades that help avoid or minimize potential impacts from wind turbines on radars. In the case of offshore wind, DoW plays a major role in assessing potential areas for leasing, with the Bureau of Ocean Energy Management (BOEM) only leasing areas where resolution of any DoW concerns is possible.

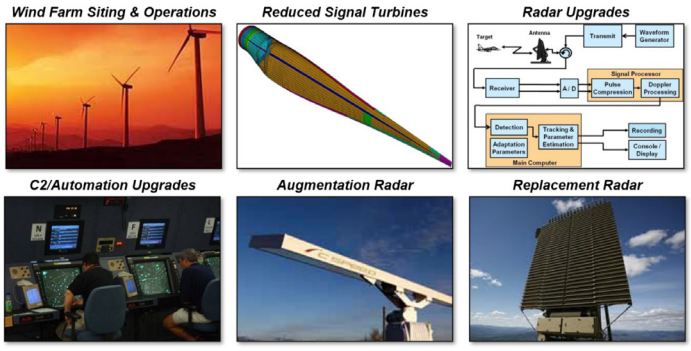
As the Department of Energy wrote in a 2024 report to Congress, "...the development and use of radar interference mitigation techniques, and collaboration both among federal agencies and between the federal government and the wind industry have enabled federal radar agencies to continue to perform their missions without significant impacts..."

If a project developer and DoW reach agreement on solutions to address DoW concerns about a proposed project, including concerns related to potential radar impacts, the agreement is memorialized in writing with the developer obligated to follow through on specific commitments, including potentially funding radar hardware and/or software upgrades. Further, for offshore wind, BOEM imposes terms and conditions on project permit approvals that require implementation of measures to address military concerns.

In General

At a basic level, radar sends out pulses of energy to detect moving targets, such as aircraft, vessels, and weather. If wind turbines are located in areas where radars can "see" (known as "radar line-of-sight" or RLOS), then these large structures with three rotating blades can contribute to the unwanted returns received by radar (known as "clutter"), which can make it more difficult to track intended targets. Though unlike aircraft, vessels, or weather, wind turbines are stationary, that is, do not change location. So, a trained operator can generally distinguish between moving and stationary targets on the radar screen.

Wind turbine radar interference mitigation technology categories



Source: U.S. Department of Energy

Review Process Protect Against Harmful Impacts

Because of the potential impacts, the wind energy industry evaluates the potential for projects to impact radar even before filing with federal agencies for review. This allows industry to anticipate any federal agency concerns and take steps to minimize impacts even before talking with federal agencies.

The FAA, DoW, and other agencies have robust review processes for proposed wind turbines. The reviews include technical analysis based on the specific turbine locations, the layout and height of the turbines, the type of radar(s) in the vicinity, the range of the radar(s), and the mission the radar(s) support. If the turbines are not within RLOS, then there is no concern. However, given the hundreds of radars of various types around the country, it is increasingly difficult to completely avoid being in RLOS of all radars when developing a wind farm.

Overview of Specific Radars and Solutions to Avoid or Minimize Impacts

If a concern about a proposed project is identified during the assessment, the agency talks with the developer about potential ways to avoid or minimize the impact. As summarized below, the technical solutions vary by radar type.

Air navigation/air defense radars

- The potential impacts to air navigation and air defense radars from the spinning blades are well understood as are several available mitigation methods detailed in a 2024 report from the DOE. Solutions to address impacts may include adjustments to wind farm layout, radar hardware and software upgrades and adjustments, deployment of additional radars that are then fused with an existing radar to present a complete picture, and combining data streams from multiple existing radars, among other measures. The DOE report identifies a number of additional technical solutions that show promise and just need additional field testing to validate their effectiveness.

Marine radars

- A 2022 National Academy of Sciences (NAS) report reinforces what the offshore wind industry and regulators have understood based on a decade plus of experience with offshore wind deployment in Europe: wind turbines may be visible on marine radar returns, but there are proven mitigation options already available, with additional options potentially worth developing.
- Mitigation options can include properly trained radar operators, properly installed and adjusted equipment (radars, antenna, etc.), appropriately marked wind turbines, and the use of automatic identification systems (AIS).

Weather radars

- Weather radar interference can come from many sources, including the ground, buildings, swaying trees during heavy winds, and migrating birds. Accurately interpreting weather radar readings while accounting for clutter is an everyday part of the job for meteorologists.
- The potential of wind turbines to impact weather radar has been well understood for nearly 20 years. The National Weather Service (NWS) has published guidelines that help developers assess whether the NWS may have a concern about a proposed project location.
- Developers have agreed to reduce the number of turbines, revise layouts, remove some proposed turbines of concern, and even shut down turbines during potential severe weather events to resolve NWS and some DOW concerns.
- Mitigation options may also include properly trained operators, adjustments to planned wind turbine heights, and combining data streams from a nearby radar to supplement coverage.

Coastal high frequency radars

- These radars are utilized by the Coast Guard for search and rescue missions, among other purposes.
- In 2021, BOEM published a study by the leading developer/manufacturer of coastal HF radars. Among the key findings of this report were, "The location of the wind turbine interference in the Doppler spectrum is predictable and can be determined from the rotation rate of the wind turbine" and "Mitigation methods that remove signals from the Doppler spectrum based on the wind turbine rotation rate estimates are effective methods of mitigating wind turbine interference."
- This was elaborated on in a webinar hosted in 2020 by the U.S. Department of Energy (DOE) and the Interagency Wind Turbine Radar Interference Mitigation Working Group.
- The panelists on this webinar, echoing the prior study, noted there are opportunities to mitigate the impacts today and additional concepts are in development. Wind turbine interference on coastal HF radars was characterized by a one of the radar experts on the panel as a "solvable problem."
  - The potential mitigations discussed included:
    - Tune the radar differently (i.e. change the sweep rate)
    - Establish filters to avoid processing returns from the wind turbines
    - And supplemental coastal HF radar data with additional sensors attached to offshore wind turbine platforms
- Offshore wind project developers have been working with the National Oceanic and Atmospheric Administration (NOAA) to implement measures to address the potential impact.

Underwater sonar

- Sonar is not underwater radar. Sonar is used to detect, locate, and characterize objects underwater by emitting sound waves and analyzing reflections.
- Unlike radar, which uses radio waves to detect objects in air or on land, sonar relies on acoustic signals because radio waves propagate poorly in water. Sonar is widely used for underwater navigation, communication, mapping, and detection in military, commercial, and scientific applications.
- Wind turbines have fixed structures underwater (e.g., the turbine foundations), which produce predictable acoustic signatures, easily accounted for in modern sonar processing, unlike moving threats, meaning the sonar would still be able to identify and track underwater vehicles.