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US military, airspace, and meteorological radar system impacts from utility class wind turbines: Implications for renewable energy targets and the wind industry

T. Auld [a], M.P. McHenry [a], J. Whale [a,b,*]

[a] School of Engineering and Energy, Murdoch University, 90 South Street, Murdoch, Western Australia 6150, Australia
[b] National Small Wind Turbine Centre, Murdoch University, 90 South Street, Murdoch, Western Australia 6150, Australia

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ABSTRACT

A substantial number of wind energy projects have been stalled or abandoned in the United States of America (US) due to concerns over the effects of wind turbines on radar installations. Between 2008 and 2010, military, airspace, or meteorological radar concerns in the US contributed to the delay or abandonment of an estimated 20,000 MW of wind energy capacity. These delays are a likely major factor influencing the current US Administration's failure to double non-hydro renewable generation from 2008 to 2011; a target stated by the US President in a joint session address to Congress in February 2009. The delays are also a threat to the US Department of Energy's target to produce 20% of electricity from wind energy by 2030 – unless radar-related barriers are mitigated. This work includes interviews with two senior representatives, from the US Department of Defence (DOD) and the American Wind Energy Association (AWEA), discussing the nature of concerns pertaining to the effects of wind turbines on radar and military/aviation in the US alongside approaches that have been trialled that aim to resolve such concerns. This research finds that the Energy Siting Clearing House, established within the DOD to review delayed wind farm projects, has brought much needed coordination to the approval process. A key challenge for any review body, however, will be to deliver an objective outcome that is not overturned by alternative political agendas. Integral to the success of any approach will be a sufficient capacity and mandate to facilitate the technical and non-technical cross-disciplinary and interagency research generating a balance between military, airspace, meteorological, and wind energy industry/political objectives.

1. Introduction

The US's strong commitment to national security policies, with an annual defence budget of over USD650 billion [1], focuses on preventing acts of terrorism on American soil, fighting wars overseas, and the disruption and dismantling of terrorist organisations such as al-Qa'ida [2]. In serving this policy, the US DOD has publicly reported that utility class turbines can have a 'significant impact' on the operational capabilities of air defence radar, can interfere with military testing and training capabilities, and can obstruct Comprehensive Test Ban Treaty monitoring [3]. The objectives of this work are to contextually define the nature of US concerns pertaining to the effects of wind turbines on radar and military sites, determine the impact of these concerns on US installed wind energy capacity, and analyse proposed solutions.

1.1. The US wind industry and renewable energy targets

While the US does not have binding federal renewable energy targets [4], rapid wind energy development is supported by the current US Administration [5]. Wind energy is increasingly viewed as the most commercially viable option to expand renewable energy generation in the US. Installed wind generation capacity in the US accounts for around 20% of current global installed capacity. With approximately 50,000 MW installed and additionally around 9000 MW under construction [6], wind energy has been growing at a faster rate than any other US energy source since 2008 [6,7]. The average production cost of USD0.04 per kWh (with the production tax credit) over the last few years in the US has seen wind energy a direct competitor with thermal fossil fuel electricity generation on a cost per unit basis [8]. At present, 38 US states now have utility

* Corresponding author. School of Engineering and Energy, Murdoch University, 90 South Street, Murdoch, Western Australia 6150, Australia. Tel.: +61 8 9360 2102; fax: +61 8 9360 6346.
E-mail address: J.Whale@murdoch.edu.au (J. Whale).

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class turbines and 14 states each have over 1000 MW of wind installed. The average capacity of installed wind turbines is 2.15 MW and the machines are typically over 400 feet (122 m) tall with 300 feet (92 m) rotor diameters [6,9]. The current US Administration aimed to double US renewable energy generation by 2011 from 2008 levels [5,10]; primarily through supporting wind energy development through government grants and tax incentives, such as the 2009 *American recovery and reinvestment act* (ARRA), which include tax credits, a traditional wind development incentive in the US. Despite government incentives, the 2011 target was not met. In 2008 the renewable energy (non-hydro) installed power capacity was 3.8% of the national total, of which wind energy accounted for 2.3% (25,300 MW) [4,8]. The net energy generation from non-hydro renewables in 2008 was around 125 TWh (3.13% of 4112 TWh), of which an estimated 53 TWh was generated from the wind sector (1.3% of the national total) [8,11]. Three years later in 2011, the net electricity generated by renewable energy was only 195 TWh, 50% greater generation than 2008 levels rather than 100% greater [11]. Whilst the Obama Administration's target was aspirational, in 2008 the DOE envisioned that 20% of the country's electricity could come from wind energy by 2030 [12]. The DOE's '20/30' target, alongside state wind energy targets reinforce this vision of growth. It remains to be seen whether state-based targets and the US DOE's '20/30' target will befall the same fate as the US Administration's target. In Massachusetts for example, the state government aims to have 2000 MW of installed wind capacity by 2020; an aggressive target considering Massachusetts 2009 wind capacity was around 9 MW [13]. State targets such as these may be seriously re-evaluated in the next few years when radar impacts are taken into consideration. The Massachusetts example may be a case in point, as the small state also hosts one of the US's large phased array radars for missile re-entry vehicle detection. Aggressive wind turbine expansion may potentially impact detection and tracking of nuclear weaponry systems without proper planning approaches. The DOE's '20/30' assessment estimates 16,000 MW of wind energy capacity is required to be installed each year by the year 2018 to achieve the 20% target of around 300 GW installed by 2030 [12]. Representatives of the US wind industry are dubious this will be achieved without first resolving radar and airspace concerns pertaining to wind turbines [9,14].

1.2. Radar technology in use in the US, and target detection

Radar is used in both civilian and military operations for air traffic, air defence, and weather forecasting/monitoring. A basic radar system consists of a transmitter, an antenna, a receiver, and a processor, with the transmitter emitting pulses of electromagnetic energy that reflect off objects known as 'targets' in the radar's line of sight. The antenna and processor detect and analyse the information in the reflected signal back to the radar [3,15,16]. There are two main categories of radar surveillance systems, primary and secondary. Primary Surveillance Radar (PSR) provides a two- or three-dimensional representation of a target. A number of factors can influence the quality of PSR: transmitter power; target distance; the target size (or Radar Cross Section [RCS]); antenna geometry; obstructions, and; reflections from other objects. e.g. hills, buildings, wind turbines [3,14,16,17]. In contrast, Secondary Surveillance Radar (SSR) uses coded signals to obtain information about a target, and consequently SSR systems are typically unaffected by reflections such as wind turbines [3].

The DOD, Federal Aviation Administration (FAA), and National Oceanic Atmospheric Administration (NOAA) operate a vast network of radar assets in the US; yet it is an ageing network with around 80% of all US radars being commissioned from the 1950s to 1980s [18]. There are 283 air traffic control (ATC) radars of various models in the US, of which 110 are modern digital ASR-11's deployed in the 1990s, 135 are ASR-10's deployed in the 1980s, and 38 are analogue ASR-8's deployed in the 1970s [19]. ATC radars consist of both PSR and SSR systems monitoring aircraft in and around air fields, and typically have PSR coverage of up to 60 miles (100 km) and SSR coverage of around double that of PSR [20]. In contrast, long range radar (LRR) is used for air defence and to track aircraft in between airports [21]. LRR systems are described as the historical 'back bone of primary surveillance in the US' (Blackman, cited in [19], pp. 24). Two-dimensional FPS-20, the Air Route Surveillance Radars (ARSR) 1 and 2 are the most common type of LRR in the US with 65 systems deployed in the 1950s and 1960s, and upgraded in the 1980s [19]. (See Table 1). Modern 3D ARSR 4s, deployed in the 1990s are the second most common LRR system with 43 in service in the US [22]. There are also 13 ASRS 3s (deployed in the 1970s and upgraded in the 1980s) and 7 Tethered Aerostat Radar Systems (TARS, or moored balloons) deployed in the 1980s [19]. Current LRR systems are digital, and provide coverage up to 290 miles (470 km) [22], while the older systems are analogue [23], ranging up to 200 miles (320 km). The 128 various model LRR types in the US [19] are predominantly located in perimeter states [22]. Missile Early Warning Radar (EWR) are very large, high-powered phased array systems designed to detect and track objects with low radar reflectivity with a high level of accuracy over a range in excess of 5000 km (i.e. nuclear weapon re-entry vehicles and possible counter measures designed to confuse defensive systems). There are only two EWR radars in the US, one on the east coast in Massachusetts and another on the west coast in California [3]. The US weather forecasting and severe weather warning capability is underpinned by NOAA's 159 'Next Generation Weather Radar' (NEXRAD) systems, also known as the Weather Surveillance Radar-1988 Doppler (WSR-88D). The WSR-88D's are used in combination with FAA's 45 Terminal Doppler Weather Radars (TDWR) [24]. The WSR-88D's have an approximate short range of 143 miles (230 km), and a long range of 286 miles (460 km) [25].

1.3. The influence of wind turbines on radar

The influence of wind turbines and wind farms on various radar systems is notoriously complex and differs between technologies. In simple terms it reduces the range and quality of surveillance available, although many aspects are amenable to mitigation

Table 1
Selected US radar in use, and performance/deployment status.

ARSR-1/ ARSR-2/ FPS-20	1950's model, 2D, L-band frequency long range radars with a maximum range of 200 miles (320 km). Radar models are being replaced with ARSR-4 [26].
ARSR-3	3D long range radar providing coverage up to 240 miles (380 km) [26].
ARSR-4	The most modern 3D long range surveillance radar. Radar provides improved reliability, improved ability to track small object (via minimised clutter), and coverage up to 250 nautical miles (460 km) [22].
ASR-8	Analogue Air Surveillance Radar with limited processing capability when compared to modern radar types. Radar type is being replaced with the ASR-11 [27].
ASR-10	Flexible, modern radar that meets the requirements of the US FAA/DOD ASR-11 next generation radar [20].
ASR-11	Digital Air Surveillance Radar providing PSR coverage of 60 miles (100 km) and SSR coverage of 120 miles (200 km) [20]. Radar provides digital processing, improved reliability, and improved performance not available in earlier models [27].
WSR-88D	Modern weather radar using Doppler maps to detect rain, hail, and snowfall [3], with an approximate short range of 230 km, and a long range of 460 km [25].