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WHITE PAPER

Integration of Wildlife Detection and Deterrent Systems in Wind Power Plants

Prepared by:
Kaj Skov Nielsen, Independent Consultant

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AWWI White Paper:

Integration of Wildlife Detection and Deterrent Systems in Wind Power Plants

American Wind Wildlife Institute
1110 Vermont Ave NW, Suite 950
Washington, DC 20005
www.awwi.org

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AWWI is a partnership of leaders in the wind industry, wildlife management agencies, and science and environmental organizations who collaborate on a shared mission: to facilitate timely and responsible development of wind energy while protecting wildlife and wildlife habitat.

Find this document online at https://awwi.org/resources/technology-integration-white-paper/

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1. Introduction

Currently there is significant focus on developing technologies for detecting and deterring wildlife around wind power plants. For these technologies to become long term commercial successes, they have to be effectively integrated into wind power plants and the functionality must align with the workflows in the plant's local and remote control rooms. If the integration of detection and deterrent systems is difficult and thus costly, this may delay the deployment on a large scale, prolong the risk to the species that need protection, and in the end result in increased leveled cost of energy as well as increased cost of service to the energy consumer.

By sharing technical details and considerations among stakeholders, the hope that the process of integrating all these technologies into effectively operating wind power plants can be streamlined, and also that the end user will have a better experience using the new technologies as an integrated part of the plant control strategy.

2. Glossary

Term	**Description**
Curtailment	Operation with reduced power output at the turbine or plant level
Detection device	A sensor system able to detect wildlife
Deterrent	A system activated to dissuade wildlife from approaching
EMC	Electromagnetic Compatibility: Designs that ensure that the turbine controller can operate safely without interference from transmitters or other high frequency sources in the vicinity
IEC	International Electrotechnical Commission: An organization issuing standards and guidelines for a large number of electric, electronic, and communication systems; IEC standards are often used in substation and transmission equipment
NERC	North American Electric Reliability Corporation: A nonprofit organization that identifies and quantifies current and emerging reliability challenges and issues, and provides risk recommendations for the electric power industry
O&M	Operation and maintenance organization or staff
P&E	Permitting and Environmental: Description of job tasks associated with the operation of a wind power plant
Plant operator	Organization responsible for the control of the plant and continuous decision making about activities in the plant
SCADA	Supervisory Control and Data Acquisition: System used in wind power plants to monitor status and performance as well as to collect data and issue commands to the turbines
VLAN	Virtual Local Area Network: A system of multiple networks on the same wire of fiber connection segregated by advanced network configuration tools

3. Assumptions

In order to define the vision of what we expect future wind power plant capabilities to be, we will have to make some assumptions. The assumptions may be a best guess, or more or less given at this point, but it is important to state the assumptions to ensure that further discussions are based on a common understanding of the vision.

- There will be multiple different suppliers of both detection and deterrent systems available to the wind power plant developers and operators.
- Detection and deterrence may involve turbine curtailment, activating deterrent devices that do not affect turbine operation, or a combination of the two.
- Wildlife mitigation solutions may reside exclusively in external systems OR they may reside in the wind power plant SCADA/plant controller combined with additional external systems.
- In order to get the most reliable functionality at the plant or fleet level, there will need to be some level of integration between the external wildlife mitigation systems and the wind power plant SCADA/control systems.
- During the lifetime of a wind power plant there will be multiple revisions of the software applications for a subset of systems in the plant. Reducing the efforts related to restoring wildlife mitigation functionality after such upgrades will be desirable.
- Due to security concerns, there will be increasing requirements and changing security protocols that protect operation of the SCADA control systems from unauthorized manipulation.
- There will be plants where multiple detection and deterrence systems will be installed in the same plant.

A complex hypothetical plant is illustrated below for discussion purposes:

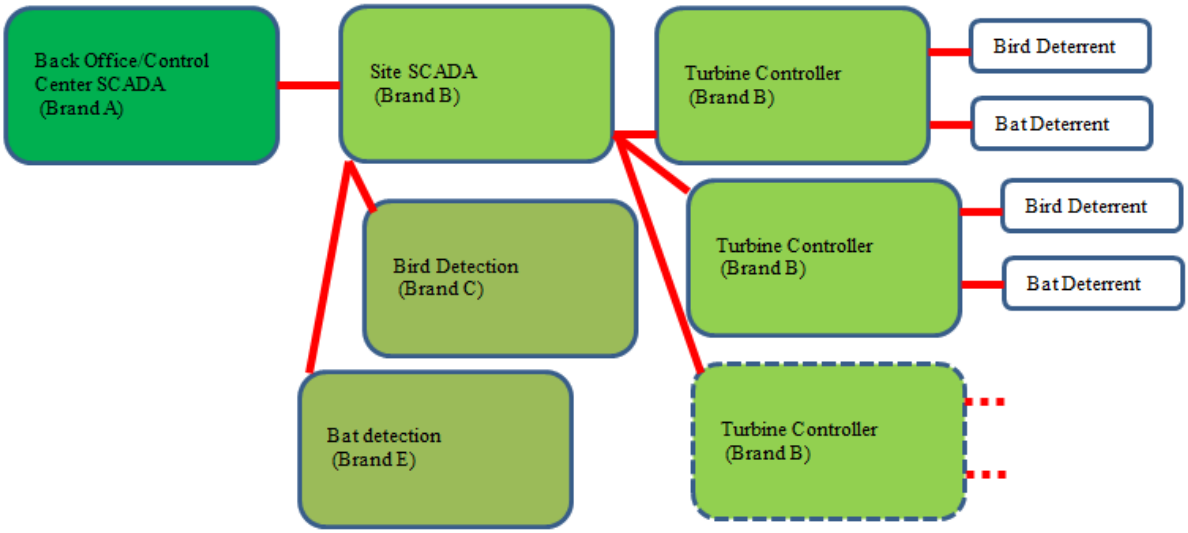

Figure 1. Illustration of a complex hypothetical detection/deterrent configuration in a wind power plant.

As consequence of an increase in the number of detection and deterrent systems brands, the wind power plant developers and operators will have many combinations of interfaces for the plant to configure and maintain during the lifetime of a project. Having a coordinated strategy across the industry will make it possible to steer this mix of interfaces towards standardized designs that can reduce the integration cost

for wind power plant developers and turbine manufacturers, and reduce the risk that new technology developers launch products that need to be redesigned before deployment. The detection/deterrent domain is most likely not mature enough for a full standard, but it could be advantageous to pick up some lessons learned from the existing IEC 61400-25 communication standard work early rather than letting interfaces develop in a vacuum and begin to look for standardization later. The IEC-61400-25 covers data models and naming conventions in order to improve inter-operability of equipment from different technology vendors.

As illustrated in Figure 1, a wind power plant may consist of a back office or control center level SCADA system as well as a site level SCADA system. Typically these may not be the same brand, as wind power plant developers tend to use the SCADA brand of the turbine manufacturers at the site level, and a single third party system supporting the entire turbine fleet of multiple wind turbine brands at the control center level.

The actual location of the detection and deterrent systems cannot be fully defined, but for this exercise it may be less important whether the detection or deterrent is deployed at the project- or turbine-level, because the bottom line is that there needs to be some type of interface connecting the devices back to the control points. Similarly, the actual location of the detection and deterrent system may evolve or vary between brands, so this is purely an illustration of a hypothetical scenario.

In addition to the signal paths indicated in Figure 1, the detection system may be designed to send commands not to the SCADA server but instead directly to the individual wind turbines. Using the SCADA server as a gateway will reduce the risk of communication conflict on the communication network. Supporting a network with parallel data servers requires that the turbine communication drivers are able to support multiple sources and that both sources have implemented the right kind of “hand shake” commands or authentication if such options are selected. For simplicity it would be most efficient to have the detection system interface to the site SCADA server and have the SCADA server relay commands for wildlife-related actions to the individual turbines or groups of turbines.

4. Wind Power Plant Stakeholders

For wind power plants with complex detection and deterrent systems, and often with multiple users, it may be helpful to be quite specific about the individual stakeholders and their sometimes unique sets of needs. For this purpose, a subset of stakeholders mainly related to the operation and maintenance of the equipment in the field will be included, even though there may be a larger number of stakeholders. Those included will be:

- Plant operator
- Turbine manufacturer
- Permitting and Environmental (P&E) manager
- Project developer

Some stakeholders will not be involved in all aspects of a project for the entire life cycle of a project. More details about the specific needs for each of the stakeholders listed will be discussed in the following sections.

For owners and developers, it may be difficult to define the actual solution so it may be helpful to focus on high level requirements, which can be used for further inspiration when developing a new project or contemplating upgrading an existing project with a wildlife mitigation system.

The lists of suggested requirements below are not complete, but illustrate at least one way to specify expectations for a detection and a deterrent functionality. The key is to define the requirements in a way that can be validated after the installation whether the function performs as expected or not. Also key is to focus on the actual requirement, and not define the solution and risk limiting the technology developer's ability to apply their domain knowledge toward finding the best way to actually meet the requirement.

There are other ways of addressing requirement management, but especially if a portion of a functionality resides on the SCADA or turbine side and a different part of the functionality resides in a separate system, then the roles and the definitions of the combined capability that meets the requirement becomes even more important. If the detection and deterrent systems can be designed to operate autonomously, then there is not much need for defining a data interface between such systems, but if the operation of one system is supposed to control the operation of the other system, then the definition of the interface is necessary.

It is not possible to define where all functionality will reside, be it at the turbine controller or at the detection or deterrent system. This will be a commercial agreement between the developer and the equipment suppliers depending on the requirements specified, so the examples below may not apply to all such commercial agreements and can only be viewed as examples.

4.1 Plant Operator Perspective

The plant operator has many objectives and goals to satisfy. First and foremost, it is important to operate the plant in a safe manner for the staff and the equipment; make sure that the regulatory requirements for grid integration as well as regulatory requirements or use permits are satisfied; and operate the plant to be profitable for the entire lifetime. Data and operational cybersecurity requirements embodied in NERC and other security standards must be continuously addressed during the project life cycle.

If there are any faults or sub-optimal operating behavior, the plant operator needs tools to restore the functionality as fast and effectively as possible. Also, the focus on the commercial side may pose special needs at the system level in order to continuously monitor the commercial impact of any changes made during the lifetime of the project. This may involve quantifying each source of de-rating in order to better prioritize where potential optimization resources could be spent with the biggest potential commercial impact.

Below is a list of example plant operations requirements formulated in a way that will be familiar to those who manage requirements for technology developers. The actual requirement is very focused on identifying the core need, and not dictate a specific solution, while the "Details" section may suggest a solution, provide a rationale or provide further clarification for the developer of the technology.

Table 1. Sample requirements from a plant operator perspective.

	Description	Details
4.1.1 Crew Safety	It shall be possible to identify from the control room if there are any systems active that pose a hazard to service crews or visitors in the field.	Even if the technologies for detection and deterrents are not fully defined and may not fully evolve for some time, there needs to be some means of identifying if and where it may not be safe for technicians in the wind power plant. The hazard may be exposure to radar, intense light, loud sound, or even drones.
4.1.2 Shut off control	It shall be possible to remotely temporarily disable or	During operation there needs to be ways to provide safe access to all parts of the plant for performing

	Description	Details
	eliminate human hazards caused by detection and deterrent systems.	inspections or service, as well as areas where detection or deterrent at times could be considered a hazard to the staff.
4.1.3 Time stamp	It shall be possible to synchronize the time stamps between sub systems if timing accuracy is important.	Wind power plants typically have one or two time servers to ensure that all events are time stamped such that a true sequence of events can be established when looking at the time stamped records. The management of daylight savings and the date and time format need to align in order for the operator to be able to fully establish when an event took place. Also, the format is critical for identifying a sequence of events. The time stamp for grid events may contain milliseconds or even nanoseconds. In order to ensure as accurate a time stamp as possible, the time stamps may need to be assigned as close to the event source as possible. (Time source/format/resolution)
4.1.4 Wildlife protection system health	It shall be possible to have positive feedback that subsystems related to the wildlife protection systems are working properly.	In order to monitor the availability of the detection and deterrent systems, a set of positive feedback signals need to be available to the operator confirming the health of the wildlife detection and deterrent systems. Also, it shall be possible to continuously inform the plant operator of the detection/deterrent active status if it could affect plant output, production, or management of power delivery when the wildlife mitigation systems are active.
		If the wildlife mitigation systems stop working, it may require the operator to initiate service calls and/or change the mode of operation in order to retain full compliance with the regulatory rules for the project. (System off/System enabled/System active/System fault)
4.1.5 Wildlife protection system event log integration	It shall be possible to merge events from the wildlife detection and deterrent system into the plant historian or historic records.	In order to get a full picture of what is happening at the plant level, it is helpful to have all events merged into a single table rather than having to extract data from multiple different sources every time a sequence of events needs to be established.
4.1.6 Wildlife protection system data security	It shall be possible to secure the plant from external disruption of the operation.	Except in limited cases where detection and deterrents are independent of plant control systems, data security regulations or policies need to be observed by the wildlife detection and deterrent systems, so that these do not pose a weak link in the defense against cyberattack on the wind power plant. Cybersecurity is in itself an entire area of discussion and this will not be addressed in detail in this document. For additional guidance please refer to

	Description	Details
		NERC-CIP resources. NERC-CIP covers: physical protection to virtual private networks, user name, password management, encryption, failed log on attempts, reporting requirements, disaster recovery in case something goes wrong, etc.
4.1.7 Wildlife protection system grid impact	It shall be possible to comply with the grid codes or inter-connection agreements, also when the wildlife mitigation systems are active.	Any kind of function that systematically starts or stops turbines may have an impact on the grid code compliance. This may include requirements for frequency response, ramp rate restrictions, voltage control, inertial response, or any other functionality defined in relation to the grid performance of the plant. Therefore, during the lifetime of the plant it may be required that responses to wildlife need to be moderated or designed in such a way that the plant can still be compliant with the local grid needs. Satisfying the grid code requirements may not mean that the wildlife system should be disabled, but merely that it is designed to support compliance.
4.1.8 Wildlife protection system maintainability	It shall be possible to perform upgrades of subsystems without having to commission the entire wildlife mitigation system or all the subsystems for each system update.	Turbine control software or plant operating software are periodically updated, as are plant operation hardware platforms. These updates may be needed for a number of reasons, and the operator needs to have some flexibility in deploying such upgrades without losing a significant amount of energy or having to expend a significant number of hours restoring normal operation.
4.1.9 Wildlife protection system reporting	It shall be possible to collect data for reporting.	Reports may include events, duration, energy impact, commercial impact, species related impact, etc. The actual report may not need to be generated, but the data needed to generate such reports will need to be collected and warehoused in order to implement continuous improvements of the plant productivity and profitability or demonstrate compliance with requirements. The data format may need to be aligned with the format of the Plant Historian or database structure.
4.1.10 Alarm severity	It shall be possible to highlight faults that require attention from other events.	The control room is busy during emergencies and the operators need to be able to stay focused on information that requires action and temporarily disregard other information. It is desirable to assign a severity to alarms so that they can be addressed in a systematic/strategic way.
4.1.11 Remote support	It shall be possible to get remote support for troubleshooting	Remote control will have data security implications and any kind of impact on the data security shall be documented.

	Description	Details
4.1.12 Differentiate Species	It shall be possible to differentiate between different species or species groups.	For birds it is important to differentiate between species, so that the wind power plant operation is only modified in response to the specific species that need protection. This means that there will have to be some means of differentiating the species that may have to be aligned between the detection system and the deterrent systems. For example, an owl may require a different deterrent than an eagle or a sage-grouse.
		Note: May apply to bats as well, but only as a “nice to have” option.
4.1.13 Differentiate deterrent	Is shall be possible to differentiate the deterrent	If a wind power plant operates more than one type of deterrent there needs to be a kind of reference for the species detected, and for the appropriate deterrent for that species so that the appropriate deterrent is activated, and not other possible deterrents that may not be effective and may potentially even be counterproductive.

4.2 Project Developer Perspective

During the development phase, all the subsystems need to be installed and commissioned to ensure that the plant level functionality performs as intended, and it needs to be demonstrated to the owner that all systems are delivered as specified in the contract.

Table 2. Sample requirements from a plant developer perspective.

	Description	Details
4.2.1 Wildlife protection system compatibility	It shall be possible to have detection/deterrent systems from multiple technology vendors co-exist on the same communication network.	The goal is to reduce the risk of communication conflict between systems, and as long as there is some level of configurability to the naming of devices this should be possible.
4.2.2 Wildlife protection system communication	It shall be possible to use the same fiber network that the wind turbines use for communication. Note: May not be possible for video-based systems requiring a significant amount of communication bandwidth.	When possible, the fiber communication network for the wind turbines shall be used for transmitting commands between detection systems and deterrent systems in order to reduce the installation cost. The use of virtual local area networks (VLAN) may be available in most projects for separating traffic to third party systems.
4.2.3 System commissioning	It shall be possible to commission the system simulating detection signals and simulating deterrent signals.	In order to isolate potential system faults during integration it may be necessary to simulate both system health and detection and deterrent to specific turbines, and the tools to do this need to be available on a user interface for the project developer.

	Description	Details
4.2.4 System fail-over	It shall be possible to apply a fail-over strategy so that failure of a bat detection or deterrent subsystem does not result in a complete stop of the plant.	If the primary bat collision mitigation system is based on detection and deterrent systems and either one of those fail, it shall be an option for the developer to fall back on a centrally based model-based system. This may require a set of system health signals from all the sub-systems or some other means of determining if a fail-over function needs to be activated or if the plant will need to stop in order to not compromise regulatory requirements. Note: Simple models for bat collision risk may be included in the SCADA system.
4.2.5 Spare Parts and Repairs	It shall be possible for plant O&M staff to replace defective components, purchase and inventory spare parts, and conduct repairs to non-specialized hardware. Note: Especially important after the warranty period	
4.2.6 System configuration backup	It shall be possible to archive the detection or deterrent configuration.	There needs to be some way of logging the configuration for later comparison, restoring programming or firmware, or for restoration of the functionality if hardware needs to be replaced at some point during the lifetime of the project. (Parameters/options/ID etc.)
4.2.7 Species differentiation	It shall be possible to operate a deterrent for one species without causing harm on a non-target species.	The detection/deterrent vendor must design the system to minimize the chance of harm to non-target species and provide evidence to the developer or operator prior to installation.

4.3 Turbine Manufacturer Perspective

Turbine manufacturers are very focused on offering competitive prices for the equipment and harmonizing the supply chain so that a product can be used in as broad a market as possible. Keeping the number of wind turbine models low requires that the wind turbines include a large number of configurable options and wildlife mitigation systems will most likely be treated as just another option that can be configured.

Table 3. Sample requirements from a turbine manufacturer perspective.

	Description	Notes
4.3.1 System integration	It shall be possible to integrate the wildlife detection/deterrent system without any negative impact on the life expectancy of the wind turbine.	Electrical loads for inrush and steady state shall not exceed specifications. Cooling and heating specifications for the turbine components cannot be compromised. Resilience to lightning and EMC shall not be altered. Protection from water ingress and corrosion protection cannot be compromised. Impacts to structural elements shall be strictly controlled in

	Description	Notes
		conformance with turbine manufacturer's equipment strength limits, mounting specifications, or detailed engineering strength analysis.
4.3.2 Turbine Service	It shall be possible to perform service and maintenance without spending additional time or effort due to the wildlife detection or deterrent systems.	The required clearances for worker safety and accesses required to perform inspections must not be compromised.
4.3.3 System compatibility	It shall be possible to use the same fiber network that the wind turbines use for communication. **Note**: May not be possible for video-based systems requiring a significant amount of communication bandwidth.	When possible, the fiber communication network for the wind turbines shall be used for transmitting commands between detection and deterrent systems in order to reduce the installation cost and keep a low overall component count.

4.4 Permitting and Environmental Manager Perspective

The P&E manager has the responsibility to ensure that the regulatory requirements for mitigation are followed in addition to company environmental policies. This may mean setting up the mitigation system and ensuring that it performs as specified, or it may be much more involved and require continuous monitoring of the efficacy of the implemented solution in one format or another.

The need to tweak, adjust, or correct the functionality in addition to documenting past performance and comparing effectiveness of different settings may be part of this work.

Table 4. Sample requirements from a P&E manager perspective.

	Description	Details
4.4.1 System Configuration	It shall be possible to monitor the configuration of the applications.	The system configuration at installation, and as any modifications are made over time, must be documented and able to be confirmed by the P&E manager.
4.4.2 Configuration editing	It shall be possible to edit or adjust the detection or deterrent settings.	Operator control of detection/deterrent settings, date ranges and time of day/night when active, thresholds for activation, and conditions for return to normal operation must be adjustable over time as results of operation or performance verification become known.
4.4.3 Performance reporting	It shall be possible to report on historic performance of the wildlife mitigation system.	As appropriate, system up-time, fault logging, number of detections, date and time of detections or deterrent triggerings, etc. must be available for compliance verification.

Again, these are just suggested requirements, and P&E managers could provide many more details for both general requirements and project-specific requirements related to their unique needs from a wildlife mitigation system. Specifically, it may be valuable from a lifetime perspective to make sure that the detection and deterrent systems offer acquitted flexibility to refine the functionality over time. As more

knowledge is accumulated for the specific site and the specific species, sensitivity may need to be changed, new turbines may need to be added, etc. without total dependence on the original supplier of such equipment for each little change. Stating all such requirements in a way that will look familiar to both turbine manufacturers and technology suppliers will simplify the hand over at project completion and reduce the risk that critical functionality is overlooked during the development or the integration of all the subsystems.

5. System Wide Resilience

System designers for critical systems need to consider failure modes and what the response to each failure mode should be. Wind turbine suppliers already are used to this way of thinking, and some of the same thought processes need to be applied to wildlife mitigation at a system level. Such considerations may fall on the owner/developer designing the plant, and require a detailed understanding of the capabilities of each of the subsystems in order to achieve the most functional resilience possible.

Relevant issues to consider include the severity of outcome if non-compliance occurs, costs of restoring expected operation or risk minimization, risks to wildlife, and regulatory implications. Developers or operators should consider these scenarios and develop management plans in advance, so that operators can respond appropriately should failures occur over time.

Systems that stretch over large territories rely very heavily on communication, so a failure mode to consider is the loss of communication, and the response to loss of communication may need to be set up at the turbine level in addition to the central control level. Operation plans should consider what a local turbine controller should do when communication to the SCADA or the detection system is lost, or when the system-wide deterrent system no longer indicates that it is healthy.

6. Grid Stability Impact

Historically, it has not been much of an issue to start or stop a single wind turbine or even a few turbines at the same time. Given that the wind turbines have been small, and the contribution to the overall production at the grid has been insignificant, this approach has been perfectly acceptable in most locations. However, as the wind turbines are increasing in size and the percentage in wind energy contributing to the overall grid is rapidly becoming more significant, it cannot be assumed that this approach will continue to be acceptable in all locations. As of right now, the biggest known wind turbine in development for the commercial market is a 12 MW machine, and even a modest wind power plant consisting of 50 such turbines would represent 600 MW or the equivalent of a significant size power plant. Sending a stop command to all 50 turbines at the same time may, in some locations, have a measurable impact on the grid frequency and may reduce the grid stability; therefore projects with very large wind turbines, for projects in locations with very weak grids, or locations with very high local turbine penetrations, issuing stop commands may need to be considered from a grid impact perspective, and the commands may need to be staggered to the extent possible in order to properly support the grid stability.

Similarly, most modern wind power plants include plant controllers that perform closed loop controls on active power and reactive power, so “randomly” sending stop or start commands to wind turbines under the closed loop controls could potentially be optimized by combining the use of spinning reserve or some other gradual approach to stopping the turbines sequentially instead of a broadcast of stop commands to larger groups of turbines simultaneously.

For a measured response to detecting a bird or a bat, the range of detection needs to be such that the plant controls have time to react before the risk of collisions is too high. If there is a need to identify a

species, this may need to be completed before a command can be issued, and a slow identification algorithm will use up precious time needed to respond from when a possible turbine stop command has been issued to when the turbine needs to have completed the response in order to reduce a collision risk. From a lifetime impact perspective, the response used for a detection system that is more sensitive or offers a bigger detection range may eventually justify using a slower turbine response in order to reduce the mechanical loads on the turbine structure, especially for stops during higher wind speeds.

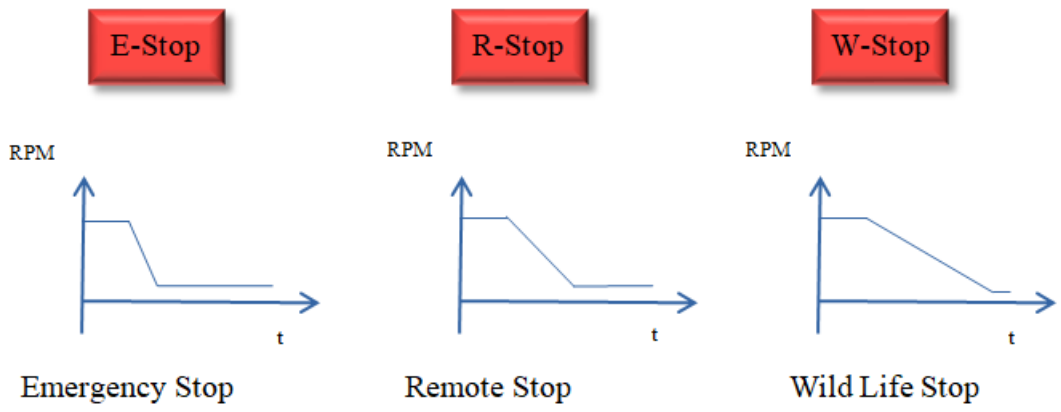

Figure 2. Dedicated stop types for different purposes. (Some manufacturers may have even more differentiated stops so this is only a simple illustration of the concept.)

7. Turbine Response

It is not known how often the turbines may be stopped for bird or bat mitigation during their lifetime, and repeated stops, if significantly large in number, will likely impact the turbine life expectancy. If the response to a wildlife stop command is very fast, the resulting loads will increase. One way of mitigating this potential impact on the turbine lifetime is to designate a series of stop types for different purposes. The wildlife stop may only be one of a list of different stop commands. By designing the response to a wildlife command to exert as small a load on the mechanical structure as possible, the turbine will be able to handle a larger number of activations without detrimental impact on the turbine life expectancy.

Even if it is possible to stop a turbine faster with other stop types, at some point the number of stops may reach a level where using the designated wildlife stop type may improve the life expectancy of the turbine. Fortunately, wildlife stops for bats in particular tend to be during relatively low wind conditions, so the resulting impact of these stops could be expected to be smaller than stops issued for birds of prey, which tend to fly at much higher wind speeds.

If developers or wildlife biologists use such designated wildlife stop commands they also ensure that the stop is assigned the correct down time category calculated by the controller for the availability. The operator can then later distinguish wildlife stops periods from other conventional remote stops issued from the control room.

Having a designated stop for wildlife at the turbine controller level frees up the turbine manufacturer to modify the response to that particular stop command without impacting other stop types where the response time may be even more critical.

Wildlife stops for bats are expected to be very frequent during the bat season but normally at relatively low wind speeds, so the impact on the mechanical structure is limited. Wildlife stops for birds are less common but will happen up to much higher wind speeds, so the potential impact on the lifetime of the wind turbine may be more significant. If a plant is in a location where wildlife stops for both birds and bats are performed, it may be beneficial to differentiate the two stop types, so that the overall impact on the equipment lifetime is minimized. Specifically for bird mitigation, the detection range and the identification delay will determine the amount of reaction time available at the turbine level. A long detection range will support a slower response time on the turbine end and reduce the loads on the turbine. On the other hand, a turbine that can handle a fast response will allow the birds to come closer before stopping, so the number of birds entering the critical distance may be reduced, thus reducing the number of needed stops. Finding the sweet spot of detection range, turbine wildlife stop response time, and turbine lifetime impact may need to be studied for a specific plant in order to squeeze every last MWh out of the wind power plant as possible.

Modern turbines with pitch control and power inverters are able to respond much more gradually than older stall control turbines where the only option was to activate the large mechanical brakes. Stall controlled turbines will experience a much larger load impact from each stop than the modern turbines, so applying mitigation systems that cause stop of turbines to older legacy projects may pose a unique set of issues and may not be possible without a more comprehensive study of the resulting impact on such older turbines.

The communication infrastructure will also be a factor in determining the response time, as some older plants use relatively primitive communication networks compared to what is best practice today with full fiber optic Ethernet between the turbines. Legacy plants may only be configured to transmit commands to the turbines every 30-60 seconds, while more modern plants may distribute commands to the turbines every few milliseconds. A stop command submitted to a more recent SCADA system may in some plants reach the turbine controller in less than one second and may be executed at the turbine level in a matter of a few seconds. But the rotors are large and heavy and it will take several seconds before the rotor slows down to a slow idle.

Pitch controlled wind turbines experience smaller loads when they are coasting, compared to wind turbines where the rotor is fully stopped and the mechanical brakes are applied. As a result, the normal stops for wind turbines mean that the rotor is brought down to a very slow idle and only under very special circumstances will the mechanical brakes actually be applied during a stop condition, and the rotor brought to a complete stand still. The term “stop” can therefore be misinterpreted. It may be better to discuss the tip speed requirement instead of whether the turbine is stopped or not. Revolutions per Minute (RPM) may also not fully define the risk to wildlife as the rotor diameters increase even a 2 RPM for a 100 meter blade would represent a significant tip speed compared to 2 RPM for an old turbine with a 50 meter blade.

The process of starting a turbine when a wildlife stop is no longer needed can be achieved by sending a turbine start command. But the developer will have to ensure that sending such a start command does not inadvertently override any other kind of stop command sent to the turbine for other purposes unintentionally. If, for example, a turbine gets a remote stop as a response to transmission constraint, the wildlife mitigation system may not release such turbines to operation. There can be multiple other responses for turbines to temporarily be stopped and any release from wildlife stop will have to be coordinated in logic or process to ensure proper definition of action in such situations.

8. Data Security/NERC CIP

North American Electrical Reliability Counsel Critical Infrastructure Protection (NERC CIP) is relevant because either the given plant falls under the category of critical infrastructure or the control room for the operator has other plants connected that are deemed as critical infrastructure and any entry point to small plants may therefore also need to be compliant. The aim of the NERC CIP program is to improve the stability of the electrical grid and help ensure that the bulk electrical system is safe from external hackers who potentially could trigger trips of portions of the electrical system. For wind power plants this may mean stopping turbines or creating instability that could cause other systems connected to the grid to trip. If a wildlife detection system is used for stopping turbines, it is conceivable that a hacked system potentially could be used to cause disruption to the electrical grid and disrupt critical production. Similar to wind turbine controllers and communication infrastructure, the design and the management of such detection and deterrent systems would have to manage and potentially mitigate risk of such third part intrusion into the plant. It would not be appropriate to describe detailed security designs and solutions in a public white paper, so for this paper only a few general guidelines will be listed below.

- Restrict the access to unused ports and connectors.
- Actively manage user access and passwords to restrict external treats, including from former staff. (No hard coded passwords.)
- Log “log in” activity.
- If the platform requires active malware protection, design a safe method for performing such tasks.
- All remote connections shall be considered from a data security perspective.

9. IEC 61400-25 Communication Data Model

Multiple vendors in the wind industry support the IEC 61400-25 communication standard, and if designers of detection and deterrent solutions use data models, data formats and other attributes defined in this standard, it will ease the integration with other subsystems in the wind power plant.

The detection/deterrent domain has not matured enough to define a complete standard, but by picking up aspects of an existing standard, some valuable considerations that operators need may be already defined in a way that can directly be adopted and carried over into this new domain. The aim is to cut integration cost and get systems commissioned effectively with all the different variations that the developer may run across between projects. Products that use proprietary protocols will be a hurdle every time any subsystem needs to be revised for any reason, and with an expected life time of 20 + years there is certainty that operators will have to update subsystems on several occasions during the lifetime of the project. Historically, processors, operating systems, and in many cases application software are only supported for a limited number of years, and having difficulties updating freely may impact the plant productivity if wildlife mitigation systems temporarily will be disabled after such system updates. The aim is also to keep the Operational and Maintenance cost down associated with upgrades or replacements during the lifetime of the wind power plant.

The IEC 61400-25 supports a series of communication formats including:

- IEC 60870-5-104
- OPC
- XML
- DNP3

There are regional or historic preferences for different formats depending on the project, and each option has some strengths and drawbacks, so it comes down to a compromise of what kind of data needs to be transferred, including answering the questions of what level of security is desired, what bandwidth is available, etc.

Detection and deterrent vendors may only support a subset, and for integration to be successful, the wind power plant owner may need to be specific about what format should be used in order to ensure inter-operability with the rest of the plant.

Until the detection and deterrent domain matures further, it may be enough to just start with a common naming convention for signal exchange between devices.

Table 5. Example of systematic naming of wildlife related tags aligned with IEC61400-25. "State" indicates a tag for information gathered by the technology; "Command" indicates a tag for instructions to implement risk reduction measures based on information gathered.

Tag Name	Description	Tag Type
WENV.Bat1	Bat species 1 detected	State
WENV.Bat2	Bat species 2 detected	State
WENV.DrtBat1	Activate Bat deterrent type 1	Command
WENV.DrtBat2	Activate Bat deterrent type 2	Command
WENV.Bird1	Bird species 1 detected	State
WENV.Bird2	Bird species 2 detected	State
WENV.DrtBird1	Activate Bird deterrent type 1	Command
WENV.DrtBird2	Activate Bird deterrent type 2	Command

Additional resources can be found at the user group web page: http://www.use61400-25.com/

10. ISO/IEC 81346 Reference Designation System (RDS)

The RDS standard is mostly used among large offshore developers and provides a reference structure that can be used to both assign part numbers to physical parts, designate a location of a part in a large complex plant, and identify a sensor source to a given data field.

If a developer is using this standard and the detection/deterrent system also should comply with this standard, the owner/developer will have to spell out the required details for the equipment supplier during tender so that the part numbers, locations, and data tag naming can be coordinated with the rest of the plant design.

No additional details about the RDS will be included in this white paper, just the mention that the format exists and is used by a subset of wind power plant developers. For readers interested in more details, please consult the web page: https://www.iso.org/standard/50858.html

11. General Integration

This section provides more background details mostly related to wind power plants and how they work.

11.1 Wind Speed Measurement

The wind speed measurement in wind turbines has mostly been used to ensure that the turbine begins to yaw at the appropriate wind speed, that the turbine transitions to operate mode or feathers into the wind when the wind is high enough for production and to ensure that the wind turbine is stopped when the maximum wind speed for safe operation is reached.

In addition, the wind speed measurement has been used to generate the power curve and monitor turbine performance. For these turbine-related functions it was not super critical to have an accurate wind speed measurement in very low wind speeds. If the wind speed reading now will be used to control turbines for bat mitigation during very low wind conditions, the accuracy of the measurement and the associated calibration at the low end of the wind range may need to be investigated and validated.

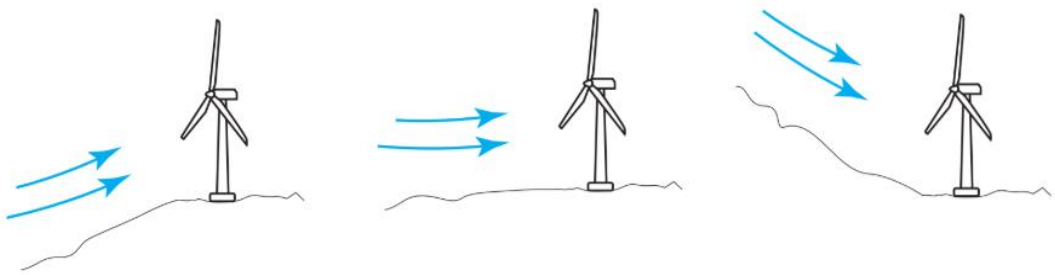

Figure 3. Wind speed measurement behind the rotor accuracy impacted by terrain.

Different types of wind sensors have different characteristics, and the fact that most wind turbines have wind sensors mounted behind the rotor means that there is set of calibration factors in the wind turbine controller correcting the measured value to get something equivalent to a free stream wind speed. The transparency or access to these settings by owners may be limited, and changes may impact contractual agreements or yield calculations. The impact of the rotor and the airflow around the nacelle on the measured accuracy at very low wind speeds will not be the same for all types of wind sensors, and factors like yaw error, blade position, and wind sensor locations may influence the measurement accuracy.

Adding to the complexity, the terrain may need to be taken into account as the airflow may not be horizontal from all wind directions, so in some cases the wind may flow around the wind turbine from slightly above and from other wind directions the wind may flow around the wind turbine from slightly below.

Using a single set of calibration values to represent a free wind speed reading for all wind directions will, under all circumstances, be a compromise that adds variation to the wind speed reading accuracy. Finally, we must add the consideration of wind shear to the equation, where a significantly lower wind speed is observed at the surface compared to the wind speed observed at hub height. During the daytime, there will typically be more mixing of the air flows between the surface and at hub height, whereas the air may exhibit a more laminar flow at night resulting in a bigger variation in wind speed observed at the surface compared to the wind speed observed at the nacelle.

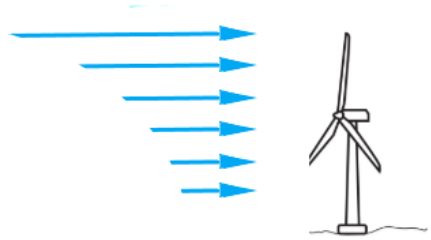

Figure 4. Wind shear contributes to a difference in wind speed at the nacelle compared to the wind speed at the lower tip height.

There may be other factors, such as whether the rotor is rotating or standing still, that impact the accuracy of the wind measurement from the nacelle wind sensor. For operators and biologists trying to set up the trigger limits for a bat curtailment function, it can be important to consider the context and the source of the measurement used for this logic, and understand the variations in measurement accuracy associated with the different operational states when these measurements are going to be used for other control purposes.

As rotor blades have increased in length, the distance from the wind turbine nacelle wind sensor to the lower tip has increased, and this will impact how accurately the nacelle wind speed represents the wind speed observed at the lower tip height. If the wind speed that is critical for the bat mitigation algorithm is the wind speed at the lower tip height, then at some point, with longer blades being introduced, the nacelle wind speed measurement may need to be corrected in some fashion in order to more accurately represent the lower tip height wind speed.

11.2 Control Stability

Given the wind speed measurements that are available on a wind turbine and all the factors that potentially impact the accuracy of the measurement described above, deterrents that affect turbine operation must ensure that the algorithm is stable also in conditions that only rarely will be observed at the turbine. It may be useful to think of an analogy like using the accelerator and the brake on the car when driving. We switch between both as needed, and if we tried to describe how to use the two pedals in logic terms we would want to avoid the algorithm resulting in any rapid alternating activation of both pedals.

For purposes of this section we use the term “stop” to mean slowing the rotor down to a slow rotation that is not harmful to wildlife; it may be less than 0.5 m/s tip speed not necessarily zero RPM. If a given wind speed measurement can trigger a stop, and also trigger a start of a wind turbine, then what is there to prevent a rapid alternating activation of start and stop for an extended period of time? This may be more harmful to the mechanical structure than an extensive number of stops by itself. In the case of the wind speed measurement, the act of stopping the rotor from rotating will cause the wind sensor to read a different wind speed, and the act of starting the wind turbine and releasing the rotor to spin will cause a change in the wind speed reading. This in itself can pose a risk of some level of instability, and even if the actual wind speed is totally steady right at the trigger wind speed, this risk of unintentional stop and start behavior will need to be addressed. Control algorithms typically do this by introducing some kind of hysteresis, or small difference in the trigger level for start and the trigger level for stop. Another mitigation may be to sample the wind speed measurement for stops commands shorter than the sample period for start commands.

Along the same lines, it is possible to create systems that automatically switch between measurement sources, be it a primary and secondary wind sensor on the individual turbine or a wind sensor in a remote location. For such a scenario, a similar consideration about control stability will have to be taken into account to ensure that the controls also will be stable if the control algorithm repeatedly switches between the primary and secondary measurement source.

For evaluation of the appropriate functionality of a given bat mitigation function, it may be valuable to analyze how well the algorithm starts and stops turbines in response to changes in the wind speed. However, for the plant, it may also be appropriate to analyze if there are starts or stops that are so short that they are unlikely to be effective and may even be counterproductive, not just for the wind turbines themselves but possibly also for the survival of the bats.

11.3 Wind Power Plant Communication Network

Older wind power plants built prior to the mid-1990's typically used some version of twisted pair communication supporting 2400- 9600 baud rate communication protocols. Wind power plants build in the 1990's to 2010's typically used fiber optic networks but since the data loads were very small, the switches and supporting networks were less able to handle high amounts of data compared to post 2015 fiber optic networks at wind power plants. In general, only recently have data networks been able to handle high data loads that could result with some detection and deterrent technologies. Also, the time it takes to scan data from a group of turbines or distribute a set of commands to a group of turbines would typically take longer with the older data network. From the time a detection signal is registered and communicated to the local SCADA system until it is distributed to the designated turbines may take up to about 60 seconds under normal conditions, and could potentially take longer if the SCADA system is in the process or retrieving daily logs or backup files or other processes that temporarily increase the data traffic. The time it takes to execute the actual command locally in the turbine further depends on the turbine type and model. (Please refer to section 11 for additional details.)

There are also wind power plants relaying on various versions of microwave links or radio frequency links between the control room and the turbines. In order to reduce the response delays, it may be appropriate to take this infrastructure into account when designing a detection or a deterrent solution for older wind power plants, and make sure that transmission delays are minimized when possible.

Even for modern fiber networks, the very largest wind power plants may run into bandwidth limitations if the operator uses video-based monitoring of any kind or if the data logging is configured to collect very high resolution operational values from the turbines. Also, for new projects it will be necessary to consider the plant-level communication requirements and make sure that the specified communication infrastructure can support the functionality that is expected from the plant. A way to reserve bandwidth for various subsystems on a fiber network is to define virtual local area networks (VLAN) on a fiber connection to assign each subsystem a portion of the bandwidth. It is not easy to provide specific rules for what level of communication will be available because the different detection/ deterrent technologies may have very different requirements, and in some cases it may even be necessary to opt for a dedicated network for such systems in order to ensure a predictable latency of such commands.

12. What is Next?

This document may only have touched on a small subset of issues related to integration of wildlife detection and deterrent systems in wind power plants. And as all these technologies evolve and mature, additional details may show up and completely new concerns may need to be addressed in order to further simplify integration and reduce cost of operation while at the same time reduce the impact on wildlife.

Some areas still to explore in the future may be:

- Data security requirements and procedures
- Communication infrastructure case study
- Bat collision risk models in SCADA systems features and options
- Equipment impact and lifetime impact
- Real life operational statistics