To: Dr. Oman

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Subject: Operation and Assembly Manual CWC Siting Team

The Collegiate Wind Competition Project Development Team has designed a wind power plant of a net capacity of 100MW to present to the Department of Energy in June 2021. The team was able to create a 100MW wind farm by going through the process of wind resources, transmission line grid, turbine placement, and substation. The team has also performed a risk analysis on the local wildlife and structures. With this information, the team then planned mitigation procedures. To keep the site running efficiently, the team has broken down the site construction, deconstruction, operations and maintenance, and risk analysis has been broken down.

1 Construction/Deconstruction

To construct the site, the site would take around ten months to be fully constructed [1]. This includes, laying the foundation, turbine assembly, cable placement, substation creation, watch tower, and other needed structures. Deconstruction is projected to take less than ten months. While deconstruction, the team plans to reduce cost by donating parts and recycling.

1.1 Construction

Construction of the sight will include digging foundations for each turbine. These foundations will then be filled with rebar and concrete. Once this is finished the turbine components can be shipped to the site where they will be assembled. Construction of the site will also include digging trenches for the cabling connecting to the substation. The substation will be constructed in an optimal place that involves the shortest distance needed for the cabling to reach it.

1.2 Deconstruction

At the end of the project, the land itself will be fully given back to the landowners. The site can either be repurposed or sold to another company to continue the wind farm's project life. If the site is not sold, parts that can be recycled will be returned to the manufacturer so more wind turbines can be preproduced sustainability. The cables used in the project will be removed from the ground to recycle them.

The team's plan for deconstruction will help the local community in South Dakota. The remaining parts that cannot be recycled will be given to local schools. Through the schools and donated turbine parts, the team hopes that the younger generations would take interest in the wind energy sector. It is important to the team to make the project a lasting contribution to the community in South Dakota.

2 Operations and Maintenance

Operation and Maintenance define the functionality of the wind farm. During the 20 years of life span team have to keep eye on the site. The available assets need maintenance and immediate assistance if any diagnostic error detected. The Black box modal and The Functional decomposition modal illustrate the whole process in more detail.

2.1 Black Box Model

Displayed in **Error! Reference source not found.** is the black box model for the wind farm. The black box model displays the functionality of the wind farm and the different inputs and outputs of the wind farm. Wind, personnel, and the turbine would be considered the main components for the wind farm to function and produce energy. The kinetic and mechanical energy is then converted into electrical energy through the wind farm. A cut-in and cut-out signal is produced when the turbine stalls and starts up. While the wind farm is operating, the turbines would produce sound as a signal output. The wind farm would also receive and external digital signal input.

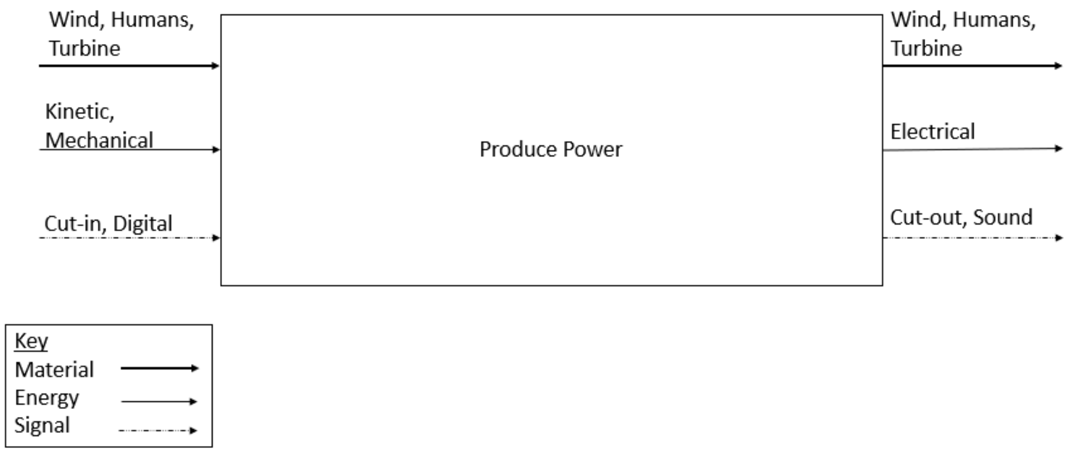

Figure 1 - Black Box Model for Wind Farm

2.2 Functional Decomposition

Figure *2* represents the overall functionality of the operation and maintenance process for the power plant. It focused on the energy and signals that come to the power plant and is exported out of the power plant.

As displayed, one of the major inputs for the power plan is the energy generated from the wind.

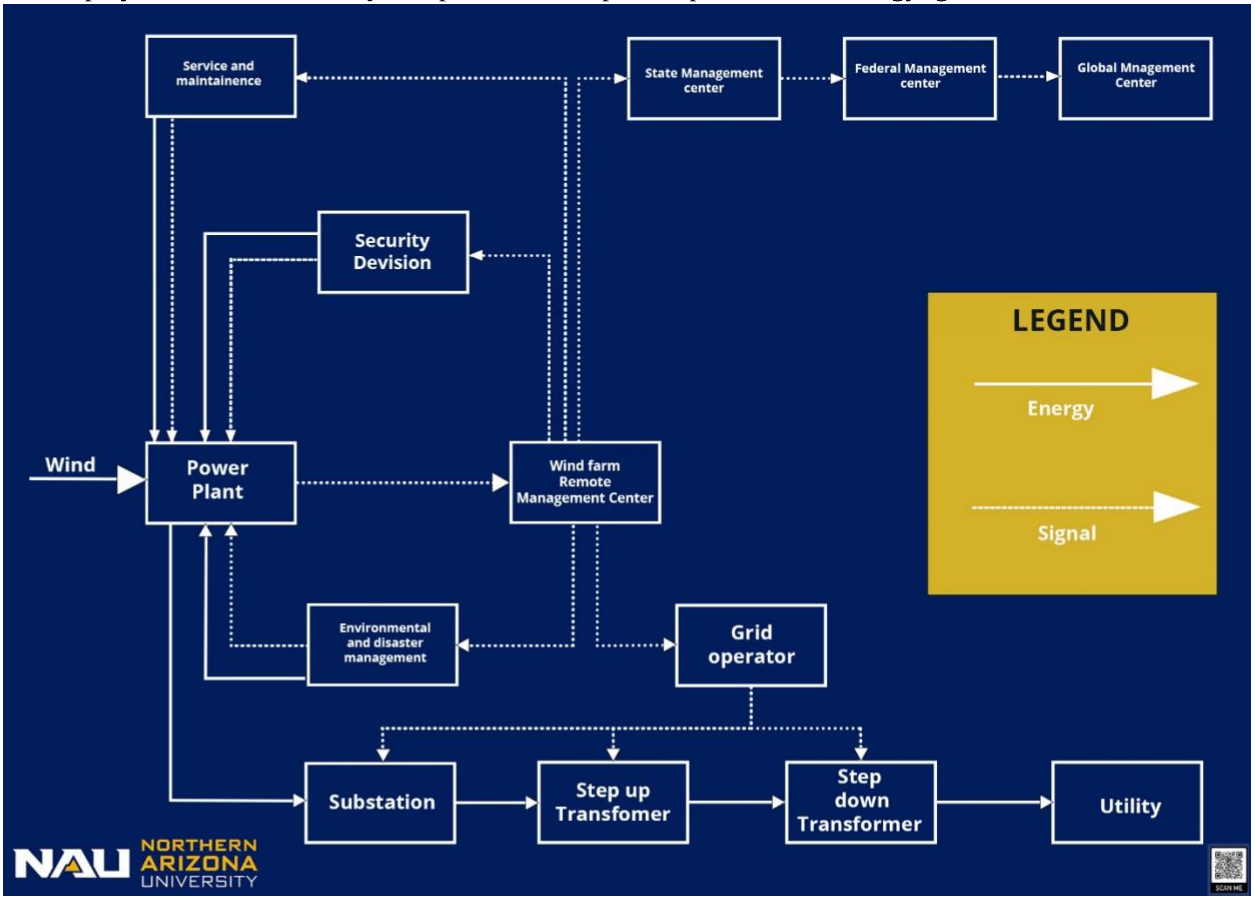

Figure 2 - Functional Model

The overall plant is managed by the windfarm remote management center as the central real-time monitoring network hub. The hub has the power to receive the data that comes from the plant as digital signals. The received data would then be analyzed and stored by them for long-term decisions. The hub can also function to operate the whole wind farm in worst case scenarios. The data collection is given to the state, federal and global government for records of power production. The service and maintenance center, security division, grid operator, and environmental and disaster management center directly link with the central hub to also receive digital signals in worst case scenarios.

The service and maintenance center would monitor the wind turbines and analyze those up to a single level. The maintenance center is responsible for maintaining the mechanical components of the turbine and the consistent lifetime. The grid operator handles the energy from the power plant. The produced energy is sent to the substation and transformers that is hooked to the grid system. The step-up transformer converts this energy into a high voltage to travel long distance. The step-down transformers converts the high voltage back to low voltages for distribution to the locals. The grid operator is responsible for electricity to flow reliably 365 days a year for the customers.

To provide holistic protection for the power plant, Siemens Gamesa security solutions cover plant security, network security, and system integrity. Plant security protects the turbines and cables against unauthorized access. Network security protects the data from cyber-attacks. System integrity security functions prevent the duplication of layout data and information [2]. The environmental and disaster management would monitor the sensitivity of the plant environment and can be prepared for upcoming natural disasters.

2.3 Turbine Maintenance Plan

The team will be using the Siemens Gamesa 5.8-155 wind turbine. Maintenance will include scheduled checkups from wind turbine technicians. During these checkups, technicians will ensure that bearings are greased, electronics are operating properly, gears are meshing correctly, and blades are cleaned and installed correctly. Maintenance of the wind farm will also include making sure the roads are in drivable conditions, as well as keeping the undergrown cables and substation operational. An insurance plan will also be purchased for the farm as well as installing a watchtower.

3 Risk Analysis and Mitigation

In a wind farm, there are failures that could cause damage to the success of a project. When those failures are addressed the failure can be mitigated. Mitigating the risk of failures can help the project produce the correct amount of power as designed, as well as assist in operation and maintenance. If failures are not mitigated, the project life can be cut short, or the project development will not produce the amount of energy that is required. Risk analysis and mitigation is important to the success of the team's project development.

3.1 Potential Failures

A wind turbine is comprised of the main components: blades, generator, gearbox, and tower. All these components have risks of failure. Blade failure is a common concern in a wind farm. Blade sizes can be increased to produce more power, but bigger blades create more stress on the turbine structure [3]. Generator failure can also occur. The generator is important because it converts the mechanical energy created from the wind turbine into electrical energy. A failing generator will not create any power for the development [3]. Gearbox failure is very expensive when it occurs. It is expensive to replace and will cause the shutdown of the turbine. Many causes can create the potential of a gearbox failing. The tower encloses the cables of the turbine. Inclement weather can cause damage to the tower, therefore, damaging the cables. All the failures that can cause these components to become damaged are listed in Table 1.

3.2 Risk Mitigation

All the failures can be prevented through regular maintenance. Preventative maintenance can detect when a component needs attention. Understanding all the ways a turbine can fail can also help mitigate the risk of a failure. These measures are all important because a failure can cause shutdown that in response reduces the amount of revenue the project can development. In Table 1, the prescribed mitigation standards are listed for each failure. The highest risk of failure is the design life of the gearbox. Gearboxes are designed to last 20 years, but most fail in 10 years. This risk needs to be managed through preventative maintenance.

Table 1: Shortened Project Development FMEA

Part # and Functions	Potential Failure Mode	Potential Effect(s) of Failure	Potential Causes and Mechanisms of Failure	RPN	Recommended Action
Blade	Wear	Flying Debris	Debonding	24	Preventative Maintenance
	Wear	Flying Debris	Joint Failure	24	Preventative Maintenance
	Wear	Flying Debris	Splitting Along Fibers	24	Preventative Maintenance

	Wear	Flying Debris	Gel Coat Cracks	36	Preventative Maintenance
	Wear	Flying Debris	Erosion	45	Preventative Maintenance
	Inclement Weather	Loss of Function	Lighting Strikes	28	Preventative Maintenance
	Production Failure	Flying Debris and Loss of Function	Material or Power Regulator Failure	18	Preventative Maintenance
	Impact	Flying Debris	Damage from Foreign Objects	40	Preventative Maintenance
	Production Failure	Loss of Function	Poor Design	16	Preventative Maintenance
	Production Failure	Loss of Function	Poor Maintenance	36	Preventative Maintenance
Generator	Inclement Weather	Loss of Function	Wind Loading	15	Maintenance and Repair Program
	Inclement Weather	Loss of Function	Weather Extremes	48	Maintenance and Repair Program
	Wear	Loss of Function	Thermal Cycling	36	Maintenance and Repair Program
	Wear	Loss of Function	Mechanical Failure of Bearing	18	Maintenance and Repair Program
	Design Flaw	Loss of Function	Excessive Vibration	24	Maintenance and Repair Program
	Operation Flaw	Loss of Function	Voltage Irregularities	24	Maintenance and Repair Program
	Design Flaw	Excessive Heat and Fire	Cooling System Failure	30	Maintenance and Repair Program
	Design Flaw	System Breakdown	Manufacturing Faults	56	Maintenance and Repair Program
	Design Flaw	System Breakdown	Design Faults	16	Maintenance and Repair Program
	Assembly Fault	Loss of Function	Improper Installation	75	Maintenance and Repair Program
	Assembly Fault	System Breakdown	Lubricant Contamination	32	Maintenance and Repair Program
	Design Flaw	Loss of Function	Inadequate Electrical Insulation	40	Maintenance and Repair Program
Gearbox	Design Flaw	System Breakdown	Design Life	210	Preventative Maintenance
	Wear	System Breakdown	Mechanical Failure of Bearing	48	Preventative Maintenance
	Wear	System Breakdown	Mechanical Failure of Gears	36	Preventative Maintenance
	Assembly Fault	System Breakdown	Dirt Contaminated Lubrication	48	Preventative Maintenance
	Assembly Fault	System Breakdown	Water Contaminated Lubrication	27	Preventative Maintenance

	Assembly Fault	Loss of Function	Improper Bearing Settings	32	Preventative Maintenance
	Design Flaw	Loss of Function	Temperature Fluctuations	60	Preventative Maintenance
	Poor Maintenance	Loss of Function	Improper Maintenance	64	Preventative Maintenance
	Poor Maintenance	Loss of Function	Infrequent Maintenance	60	Preventative Maintenance
	Wear	Sudden Accelerations and Load-Zone Reversals	Transient Loads	20	Preventative Maintenance
Tower	Assembly Fault	Loss of Function	Assembly Errors	12	Preventative Maintenance
	Poor Maintenance	Loss of Function	Improper Maintenance	6	Preventative Maintenance
	Design Flaw	System Breakdown	Poor Tolerancing	75	Preventative Maintenance
	Design Flaw	System Breakdown	Overstressing	30	Preventative Maintenance
	Inclement Weather	System Breakdown	Tornadoes	80	Preventative Maintenance
	Wear	Loss of Function	Erosion	48	Preventative Maintenance
	Impact	Loss of Function	Animal Destruction	2	Preventative Maintenance
	Impact	Loss of Function	Damage from Foreign Objects	8	Preventative Maintenance

References

[1] K. A. Martin, U.S. Fish & Wildlife Services, PDF, 2015. [Online]. Available: https://www.fws.gov/midwest/endangered/permits/hcp/r3wind/pdf/DraftHCPandEIS/MSHCPDraftAppA_WindProjectLifecycle.pdf

[2] P. Services et al., "Protect your wind turbine against hacker attacks", siemens.com Global Website, 2021. [Online]. Available: https://new.siemens.com/global/en/markets/wind/equipment/security.html. [Accessed: 19-Apr- 2021].

[3] S. Mein, "Top 3 Types of Wind Turbine Failure," *Firetrace International*, 11-May-2020. [Online]. Available: https://www.firetrace.com/fire-protection-blog/wind-turbine-failure#:~:text=There%20are%20several%20reasons%20why,to%20excessive%20heat%20and%20fire. [Accessed: 19-Apr-2021].