Techsan Wind

Texas Tech University Report

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Executive Summary

Techsan Wind is a multidisciplinary group of students at Texas Tech University. Techsan Wind competed at the Collegiate wind Competition for the first time in 2018 at the American Wind Energy Association (AWEA) Conference, in Chicago, IL. In the last year, Techsan Wind has focused on mainstreaming the design process and simplifying their past wind turbine. The students evaluated the failures and pitfalls of the previous design and manufacturing process through a root cause analysis. The current Techsan Wind turbine has a suitable design that meets competition specifications, and will be adaptable to future innovation.

Techsan Wind was able to accomplish tasks by allocating responsibilities according to expertise. Mechanical engineering students were tasked with gear design, aerodynamics, and balancing. Rectification and power electronics layout was design by Electrical Engineering students, and programming was the responsibility of the Computer Engineer. As Wind Energy student have a wide range of related knowledge, they were tasked with the siting project financial analysis, and assisting with knowledge gaps in other disciplines.

In only their second year of competing, Techsan Wind, with the support of Texas Tech University, has created a strong team to lay the foundation of future involvement in the Collegiate Wind Competition. This year's wind turbine was built with a better understanding of wind energy, and the applications and complications thereof. Techsan Wind is proud to represent Texas Tech University at the 2019 Collegiate Wind Competition.

Business Analysis Siting Project

This financial analysis is conducted in the Techsan Wind siting project, in Lamb County, for the 2018 Collegiate Wind Competition. This project would span thirteen thousand acres, using Vestas V126-3.45 MW turbines to build the 100MW farm. In this report, the team has made some assumptions about economic conditions, and in estimating cost and subsidies. The goal of this analysis is to determine viability of the potential wind farm with the goal of reaching a ten percent investor return rate, and a positive net present value.

Financing

For the Lamb County wind farm, Techsan Wind conducted the financial analysis by assuming that the machines would be covered under an established Power Purchase Agreement (PPA) of $39 per MW. Although this is a higher amount in the Southwest Power Pool, the team also considered the imminent merger of the Electric Reliability Council of Texas (ERCOT) into the Texas Panhandle. As a construction date had not been set, the Techsan Wind team assumed that construction would begin in the first quarter of the fiscal year, and adjusted the taxes appropriately.

Capital Cost

To establish the total capital cost of the Lamb County project, the Techsan Wind team consulted with Kassandra McQuillin, a lawyer and Instructor of Law, about the cost of legal negotiations, right-of-way etc. The team also conferred with Dr. M. Chris Pattison, Instructor of Wind, about estimating the cost of substations, overhead and underground transmission lines, collection systems, and general construction. After all of these costs had been established, the team considered depreciation of the assets and maintenance, tax rates and abatements, and the applicable districts.

Viability/Project Life

As determined by the Team the project will be viable. The team was able to reach their financial goals and make the project financially successful. After rigorous deliberating and making many changes the team was able to hit a return rate of ten percent which was their the primary financial goal for the success of the project. The reason for this was the project would need some involvement from investors for the project would to be able to provide a return large enough to interest them. Once the return rate was reached and the net present value of the project was a significant number the team was able to confidently speak on the project's lifetime becoming a success.

Technical Project Report

This is a report of the Techsan Wind project for the 2019 Department of Energy (DoE) Technical Challenge. Documented below is a recording of the research and development involved in the production of the Techsan Wind Turbine. The purpose of this year's wind turbine was to use knowledge of the previous malfunctions and create a new turbine. The team focused on optimizing the rotor to the generator, reducing the use of power electronics, and overall reduction of nacelle size and weight.

Blade Design

There were many iterations of blades reviewed and tested in the previous year. The team review the different airfoils and geometry and selected the IVAN2. This is blade consists of a composite of the Davis ii and NREL s825. This blade was designed for the 2018 Collegiate wind competition, but production issues made it impossible to use. The section of blade with the Davis airfoil is too fine to be 3D printed. With access to metal cutting, the team was able to have the IVAN2 cut out of aluminum. After testing a set of blades, the team had to reevaluate the optimum rpms for the IVAN2 blades, which approximately two thousand rpms. The generator chosen for this project is also optimized for the same rotational speed. As a result, the match between blades and generator eliminated the need for a gearbox.

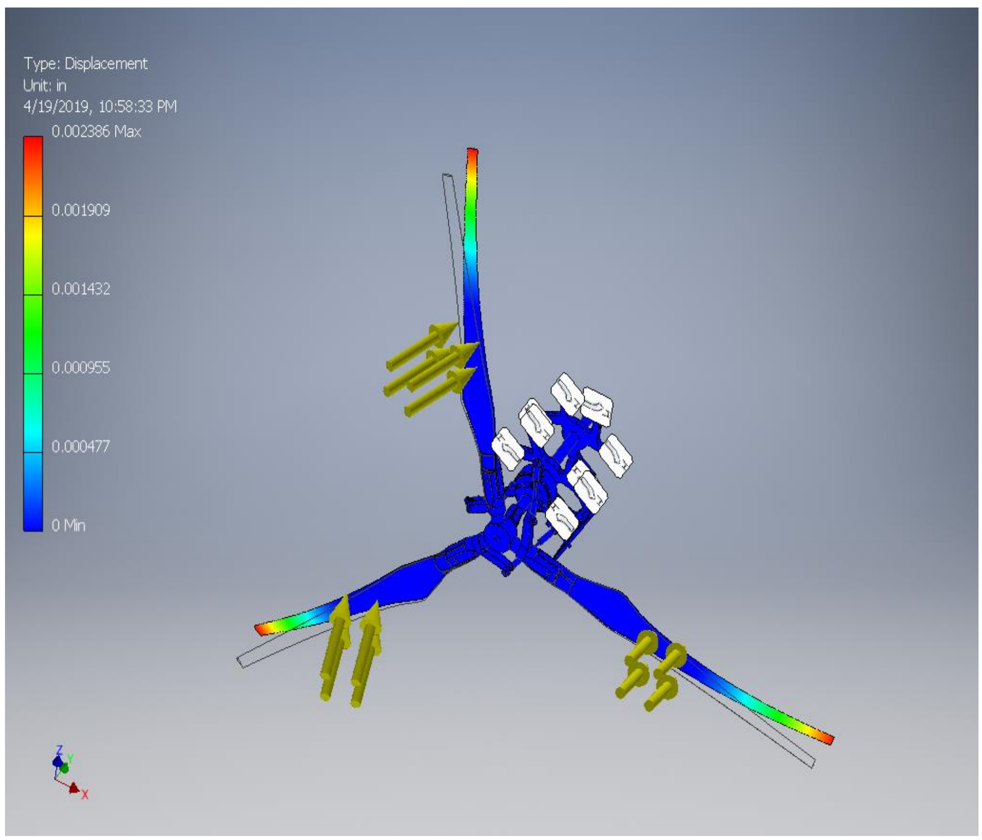

Figure 1: Blade Displacement

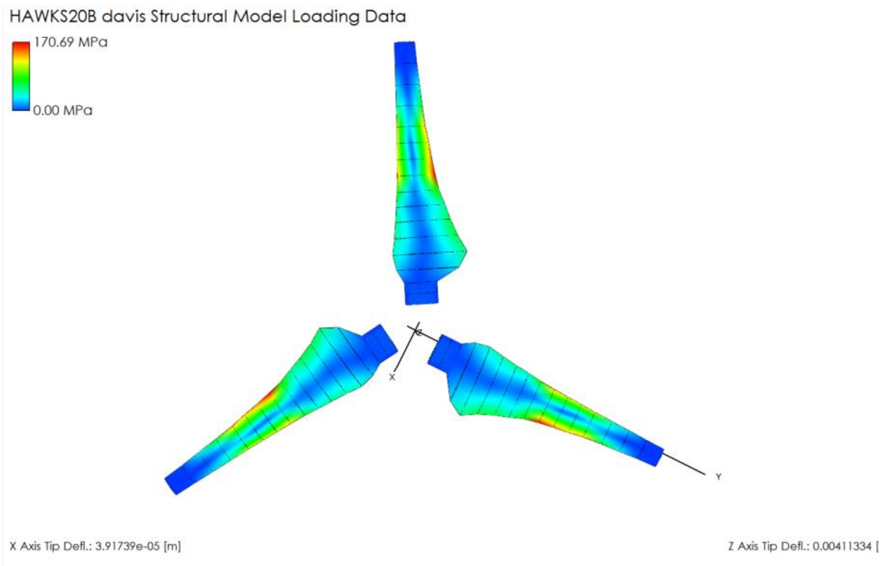

Figure 2: Rotor Structural Loading

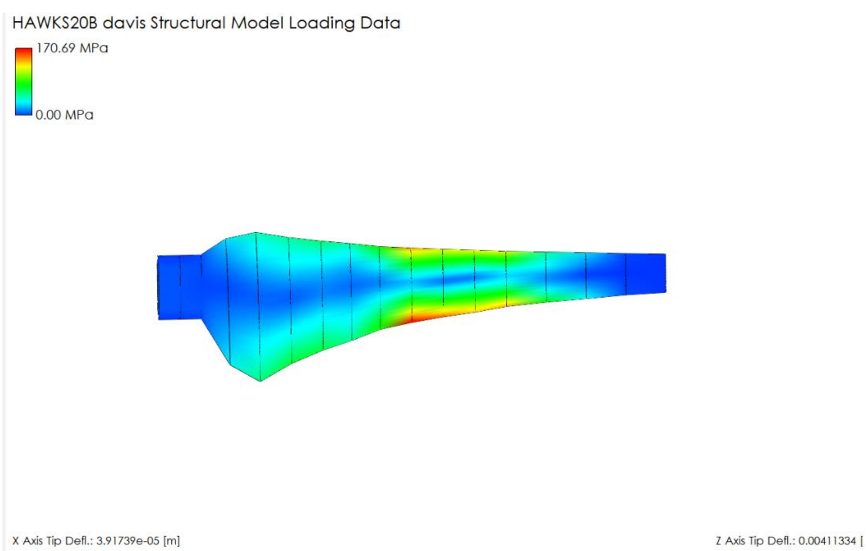

Figure 3: Single Blade Structural Loading

Rotor and Shaft

On the previous wind turbine, the Techsan Wind team struggled to overcome cogging torque in a permanent magnet DC generator. This was still a source of many issues at the competition in 2018. The team conducted a root cause analysis on the cogging torque and determined that trouble spots included the magnetic resistance in the generator and the size of the blades. For this year's project, the team chose a new generator, and replaced to rotor with one that has smaller arms so that the blades are allowed to be longer. The shaft from the rotor assembly will be connected to the main drive shaft such that the diameter matched the generator.

Generator

Techsan Wind chose the Tiger Motor Antigravity MN7005 KV115 for the 2019 design. The optimized rpms on this generator is just below 2,000 rpms, which matches the blade optimization at wind speeds around 10m/s. The team is confident that the generator is at low risk of overheating due to the rotor to generator match.

Item No.	Propeller	Throttle	Voltage (V)	Current (A)	Input power (W)	RPM	Torque (N*m)	Thrust (G)	Efficiency (G/W)	Operating Temperature
MN7005 KV115	T-motor CF24*7.2	40%	47.91	2.02	96.87	1971.71	0.38	1321.93	13.64	66℃ (Ambient temperature : 20℃)
		42%	47.90	2.19	105.04	2032.27	0.41	1407.83	13.40	
		44%	47.90	2.45	117.40	2142.27	0.44	1513.29	12.89	
		46%	47.89	2.64	126.38	2207.45	0.46	1605.94	12.70	
		48%	47.88	2.88	137.65	2283.99	0.48	1706.94	12.40	
		50%	47.87	3.13	149.88	2364.47	0.51	1807.37	12.05	
		52%	47.86	3.51	167.86	2459.65	0.55	1947.18	11.60	
		54%	47.85	3.82	182.93	2541.92	0.58	2068.02	11.30	
		56%	47.84	4.05	193.89	2606.34	0.60	2164.44	11.16	
		58%	47.82	4.39	209.78	2699.27	0.64	2280.31	10.87	
		60%	47.82	4.73	226.09	2777.70	0.67	2397.92	10.60	
		62%	47.80	5.07	242.53	2855.03	0.70	2507.20	10.33	
		64%	47.79	5.45	260.40	2925.79	0.73	2627.14	10.08	
		66%	47.77	5.82	277.92	2998.96	0.76	2755.81	9.91	
		68%	47.76	6.26	299.12	3074.66	0.79	2887.74	9.65	
		70%	47.75	6.71	320.49	3135.62	0.83	3013.60	9.40	
		75%	47.71	7.90	377.00	3342.73	0.91	3346.19	8.87	
		80%	47.68	8.83	421.06	3473.83	0.98	3605.43	8.56	
		90%	47.60	11.29	537.16	3758.03	1.14	4224.37	7.86	
		100%	47.51	14.07	668.56	4038.06	1.32	4783.13	7.15	

Figure 4: Generator Data Sheet

Power Electronics

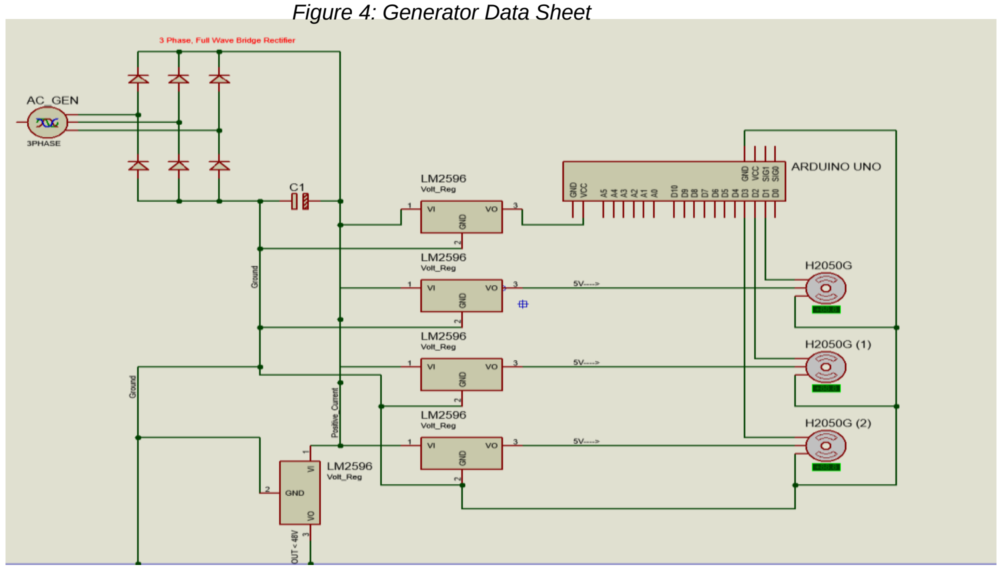

Figure 5: Electrical Design Layout

The purpose of this circuit is to make a wind turbine that provides a maximum of 48V DC to the load. The AC voltage produced by the generator is converted to DC voltage with a 3 phase rectifier. This rectifier gives a 2 phase DC output that is sent to the load. A voltage sensor is used to measure the voltage before entering the load. The analog signal that the voltage sensor produces is converted to a digital signal by the ADC pin of the Arduino. The circuit will be cut off if the output DC voltage exceeds 48V or if the emergency button is pressed. Relays are used to cut the circuit when needed. When the circuit cuts off, the load will get the power from a secondary source that is a 16V capacitor attached in series with the circuit. In case of emergency button is pushed, the entire circuit cuts off.

Yaw Mechanisms

The yaw system consists of a bearing joint that is mounted to the tower where the nacelle will sit over the joint. The Techsan Wind turbine will use passive yaw by the implementing a fin on the back of the nacelle. The fin is made by plastic molding and will ensure that the turbine rotor stays pointed in the direction of the wind.

Testing Data

The Techsan Wind team has access to an open jet wind tunnel. The team used this tunnel to collect rough data on the operating wind speeds and rpms of the rotor. The team was able to confirm that the rotor would being rotating at approximately 5m/s, and reach optimum rotation of 2000 rpms at 9m/s. The team was able to observe that the direct drive design was optimum through failed testing of the rotor connected to the generator with a three-step gearbox. Techsan Wind was also able to observe some issues with shaft vibrations causing the shaft the 'walk' back in the generator. The team worked diligently to problem solve each issue at every simulation.

Structural Analysis of Rotor Assembly

Structural analysis was performed on the rotor assembly using Autodesk Inventor. Constraints were placed at locations where assembly is fastened to frame of turbine. The positioning of the assembly is in the expected position used to maintain/decrease rotational speed. Forces were applied as constant pressure across the blade faces. This pressure is in a normal direction to the faces of the blades and angled to the axial direction of the rotor assembly along the shaft. By using this loading setup, conservatism is greater as the full force applied by the wind in a normal direction is still applied to the blades, however this angle gives a torque to the rest of the assembly as if the mechanism of changing the rotational speed, which is when the greatest stress would occur, is being applied.

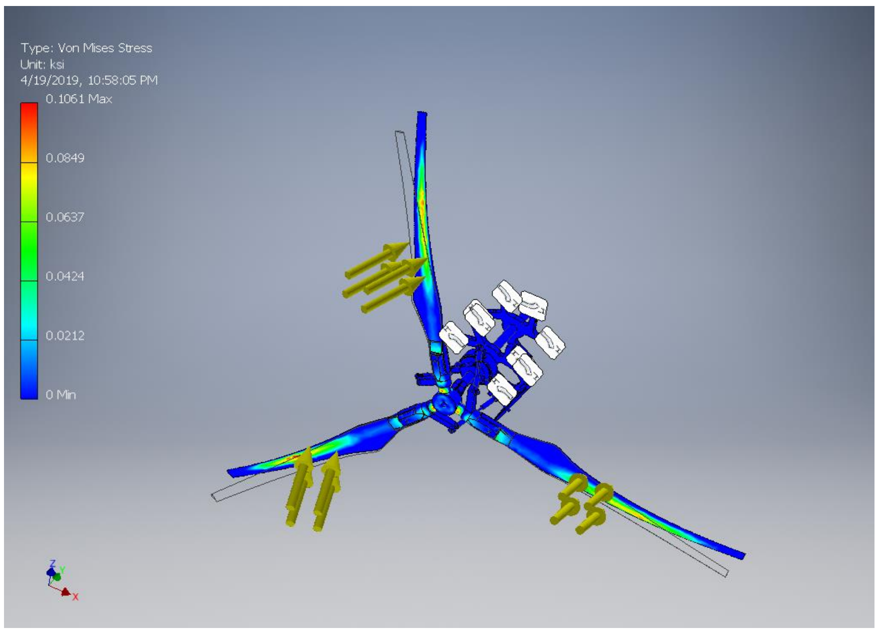

Figure 6: Von Mises Stress

The following report information is from Autodesk Inventor's generated stress report function.

Conclusion

Techsan Wind has completed the goal of developing a simpler, more reliable wind turbine. The team had the opportunity to learn about design, testing, redesign, and learning as much as possible about the wind industry, mechanics, and development. Techsan Wind is better prepared for the 2019 Collegiate Wind Competition, and is ready to continue to develop skills in project design for future competitions. The greatest improvement the Techsan Wind team made this year was in project planning, teamwork development, and resource allocation. The team is proud of the work put into this year's wind turbine, and to represent Texas Tech University in Denver, Colorado.

References

K. McQuillin, March 14, 2019, Personal Interview
M. Pattison, April 5, 2019, Personal interview
Sain, Jacob (1999). Autodesk Inventor