Project

Streamlining Wind Turbines

Project Record:

Turbine Monitoring System Test Stand Design Record

Version 3.0

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Current Author(s): Sage Sobek, Jonathan Behrens

Previous Author(s): Sage Sobek, Jonathan Behrens

Version History

Version	Date	Detailed Description/Notes
1.0	12/12/2024	Initial Submission by Sage Sobek.
1.1	12/18/2024	Revisions by Sage Sobek, by comments made by Dr. Burdett.
2.0	2/21/2025	Update with details of initial prototype by Johnathan, future improvements, and editing of abstract and conclusion done by Sage.
2.1	2/26/2025	Edits and revisions based on peer reviewing by Noah Hege were made by Sage Sobek and Jonathan Behrens.
2.2	3/18/2025	Jonathan Behrens and Sage Sobek revised the document based on comments by Dr. Burdett.
3.0	4/29/2025	Update with details of initial testing by Jonathan, future improvements, and editing of abstract and conclusion done by Sage. All new changes are made in green.

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Abstract
This document presents the design process, prototyping, and initial testing of a simulated turbine test stand. This Turbine Testing Stand (TTS) will be utilized for evaluating the Turbine Monitoring System Version 2 (TMS-V2) and battery performance with 3-phase power. The test stand consists of the head of the Air X turbine and a motor to drive it. The turbine produces a 3-phase alternating current to simulate the waveform of the Wind Aid's turbines. The current prototype requires improvements involving optimizing the resistance value for testing as well as increasing the power capacity of the resistor.

Context
It would be beneficial to the Streamlining Wind Turbine (SWT) team to create a system that generates 3-phase AC power to simulate power coming from a turbine. With this simulated power, the Turbine Monitoring System (TMS) and the battery can be tested in a controlled environment. Additionally, this interior test design will be quicker to set up and easier to control different power inputs to the system.

Preliminary Design
Specifications
WindAid is partnering with Laplace Laboratories to develop a new 3-phase generator with the following specifications:

- 500 W at 800 rpm
- 48V at 800 rpm
- 60V at 1,000rpm

The TMS V2 (Diagrammed in Figure 1) is in development to add a direct measurement of the three-phase power generated by the turbine with an accuracy of 5%. Currently, the SWT Team has no method of generating three-phase power at a similar magnitude to the new Laplace Labs generator. Thus, a test stand is needed to generate three-phase power. The test stand will include a 3-phase generator, charge controller, battery, dump resistor, and the TMS V2 system. It will generate power for the dump resistor and data that is recorded in the TMS V2. The timeline requirement for the test stand is to have it done by the end of work cycle 3.

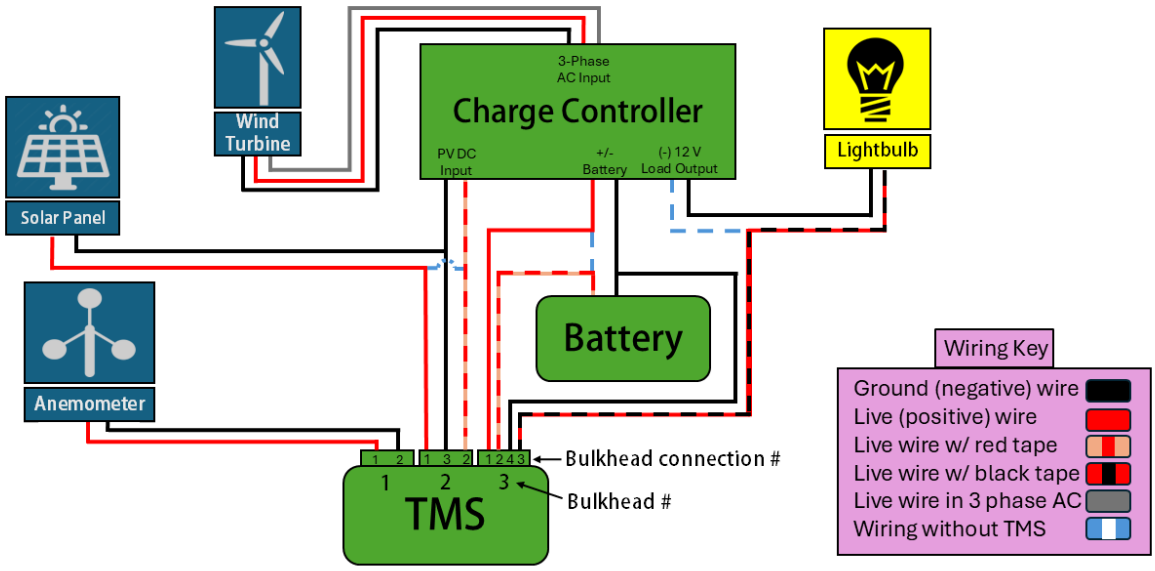

Figure 1 – Field TMS System

3-Phase Generator

There are three main options available to use as a 3-phase generator. The first option is a large 3-phase induction motor, as seen below in Figure 2. While this does produce the necessary waveform, the motor operates from 230/460V (Figure 3). Any voltage greater than 25.6V would be too great for the charge controller to handle. To overcome this, there would need to be some circuitry to limit the input voltage into the charge controller.

The second option for the system is to use the disassembled turbine head of the Air X turbine (Figure 4). Spinning the turbine head would produce the waveform and power that would be seen if the turbine were erected, since it is the turbine head. The battery needs to have a minimum of 13.8V to reach full charge, and 14.9V to reach full charge in a reasonable time. The turbine head has been selected as the best option moving forward until confirmation of the specification that exceeds the charge controller occurs.

The third option that was considered was a complete setup made by Dr. Underwood that featured a DC motor spinning a 3-phase AC motor. The setup was previously used in a lab, however, the voltage for the system was not able to exceed 12V, and thus, the generator would not be able to charge the battery adequately.

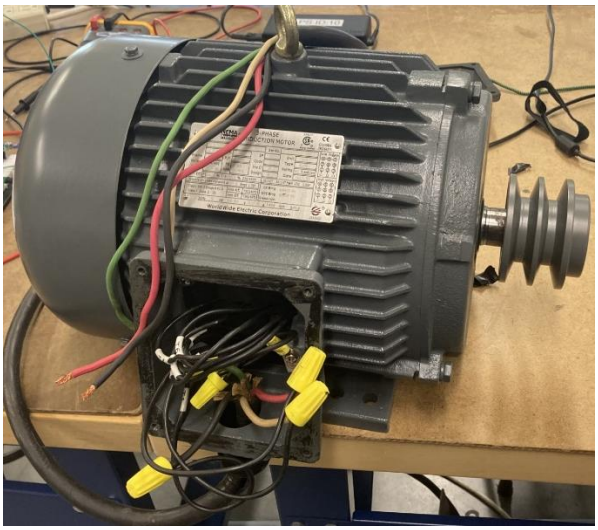

Figure 2 - Three-Phase Motor

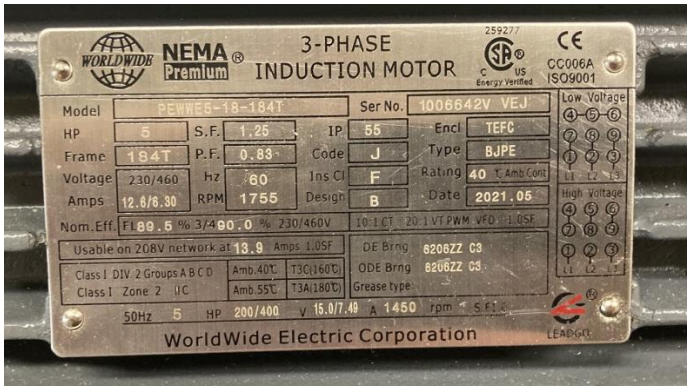

Figure 3 - Three-Phase Motor Specifications



Figure 4 - Turbine Head

Drive Motor

The goal of the drive motor is to regulate the speed of the 3-phase generator, which will, in turn, control the generator's power output. The available drive motor is pictured below in Figure 6, and the specifications are in Figure 5. Attached to the motor shaft is a V-belt pulley that fits the shaft, as pictured below in Figure 6. If the large 3-phase generator is chosen, the V-belt pulley will be used to connect the two motors. If the turbine head is used, we can either connect the V-belt pulley to the spinning turbine face with bolts or directly connect the shaft of the motor to the turbine.

A problem with this motor is that we cannot directly control the speed of the motor, as the motor is to be plugged into a standard outlet. To help with this, the motor can instead be plugged into a Variac, which will vary the voltage of the outlet that the motor is plugged into.



Figure 5 - Drive Motor Specifications



Figure 6 - Drive Motor

Initial Prototype

The current design utilizes the AC drive motor selected during the second work cycle. It features the aforementioned motor driving the turbine generator, which in turn is connected to an AC-DC rectifier that takes the place of the charge controller. Below is a detailed breakdown of each element of the test stand.

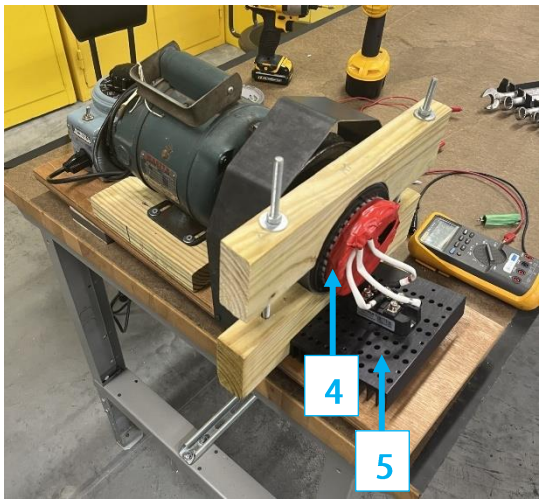

Figure 8 - Assembled testbed.

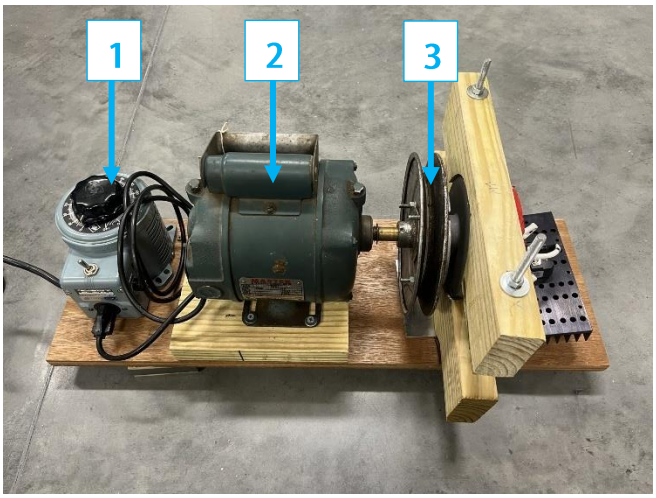

Figure 7 - Testbed with safety cover removed.

The layout of the testbed is illustrated in Figures 7 and 8. All components are anchored to the wooden baseplate and aligned to minimize external shear stresses on the shaft between the motor and the testbed. The Variac (1) is connected to external 120V AC power. This allows us to control the voltage sent to the motor (2), which in turn drives the shaft. Component 3 is the adapter we built. Figures 9 and 10 show either mounting faces of this adapter.



Figure 10 - Motor-facing adapter plate.



Figure 9 - Turbine-facing adapter plate.

The motor face of the adapter is a keyed shaft, sourced from a V-band pulley that came with the motor. The turbine face uses the blade adapter from the Air X turbine. This features a reverse-threaded bolt threading onto the shaft of the generator itself (4). The final component (5) is the black heat sink, which is our 3-Phase AC to DC rectifier. This was installed to provide a DC voltage output for initial power readings using a Digital Multimeter across a resistor, but will eventually be replaced by the charge controller for full testing.

To assemble the system, the Variac and motor were screwed down to the base, the latter of which has a second block of wood underneath to elevate for clearance over the V-band pulley. The adapter was then mounted to the generator by screwing down the reverse threaded bolt, which can be accomplished using an 11/16-inch Allen key. This was then clamped into the two 2x4s using threaded rods at their ends. That system could then be aligned with the motor shaft, spinning the system to keep low stress on the system, and once temporarily secured with clamps, the bottom 2x4 was screwed into the baseplate. Once this initial process is complete, disassembly only requires removing the top 2x4 and sliding the generator and adapter off the motor. A bent piece of sheet metal is also provided as a safety guard, covering the rotating assembly while in use.

Completed Improvements

The first improvement to the system was to run the drive motor clockwise instead of counterclockwise. Since the turbine's threaded nut is reverse threaded so that the force applied by the blades tightens the nut, our motor should also spin in the turbine’s natural direction of rotation. Therefore, higher torques can be applied from the motor than previously.

The second improvement to the system was changing the V-belt pulley since the current part is warped. As the previous pulley spun, it rattled the drive motor and turbine head back and forth. At medium to high speeds, the test stand shook significantly. To provide a safe testing environment as well as produce sufficient power, the V-belt was replaced.

Initial Testing

To validate the system’s power and rotational speed characteristics, the following procedure was implemented. The Turbine Testing Stand (TTS) was set up as shown in Figure 11, with a Digital Multimeter attached to the outputs of the rectifier, and a power measurement system attached to the power lead to the system. In addition to these measurement devices, a tachometer was used to measure the rotations per minute (RPM) of the common shaft to which the adapter plate is affixed.

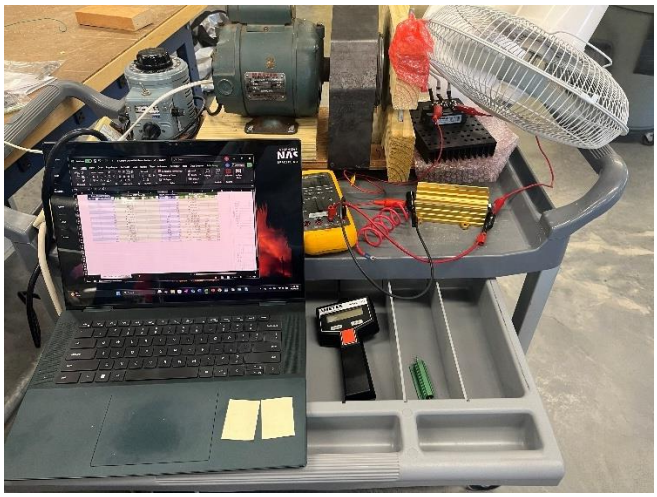

Figure 11 - The TTS in the validation configuration

Table 1 - Sample data from TTS validation

Input Characteristics		8ohm 250W Resistor			
Pin (W)	Vin (Voltmeter)	Vout	Pout (W)	RPM	Res MEAS
64	20	2.2	0.6	305	8.1
75	22	3.7	1.7	445	8.1
87	24	5.1	3.2	570	8.2
100	26	6.5	5.2	681	8.2
121	28	9.1	10.1	912	8.2

From these measurements, we were able to extract the information shown in Table 1 and the Appendix, varying the input voltage of the Variac and recording all the associated outputs. We attempted with the resistors on hand to measure many data points across the 0-50W desired output range. In future work cycles, we will finish this testing, following the steps above, to finish the validation process, and then implement the system for testing the TMS V2. One potential issue addressed in the system was resistor heating. The Res MEAS (Measured Resistance) column (Table 1) was added to combat this. Further, to mitigate the problem, the fan shown in Figure 11 was added to improve airflow over the resistor's heat shield. We have not yet completed testing of the cooling system to know if this is sufficient, as will be discussed in the following section.

Future Improvements

The largest improvement that our system needs is to optimize our resistor for further testing. Currently, there are two different resistors that we can use, a 250W-10ohm resistor and a 100W-.5 ohm resistor. As seen in the initial testing, the output power drastically varies based on the resistance values, and therefore, an optimal resistance should be found at which we can comfortably operate at 50W. Additionally, if the heating of the resistor continues to be

problematic, improved cooling or a higher-rated resistor, or improvements to the cooling system are advised.

Conclusion

The second prototype of the turbine test stand has been completed; however, some improvements need to be made for the system to achieve the given specifications. The disassembled Air X turbine head is spun by a drive motor to produce a 3-phase AC waveform to power the charge controller. The current prototype is not able to run for extended periods, however, improving the cooling system and concentricity of moving parts will allow for the TMS and battery to be tested in a safely controlled environment.

Appendix

Table 2 - Current Testing Data

Input Characteristics		8ohm 250W Resistor			
Pin (W)	Vin (Voltmeter)	Vout	Pout (W)	RPM	Res MEAS
64	20	2.2	0.6	305	8.1
75	22	3.7	1.7	445	8.1
87	24	5.1	3.2	570	8.2
100	26	6.5	5.2	681	8.2
121	28	9.1	10.1	912	8.2
138	30	11.6	13.6	1150	9.9
155	32	13.7	23.2	1336	8.1
176	34	14.5	26.0	1411	8.1
197	36	15.2	28.5	1471	8.1
216	38	15.6	30.0	1503	8.1
234	40	15.8	30.4	1526	8.2
260	42	16	31.2	1547	8.2
281	44	16.2	32.0	1560	8.2
301	46	16.4	32.8	1570	8.2
322	48	16.5	33.6	1588	8.1
351	50	16.6	34.0	1596	8.1

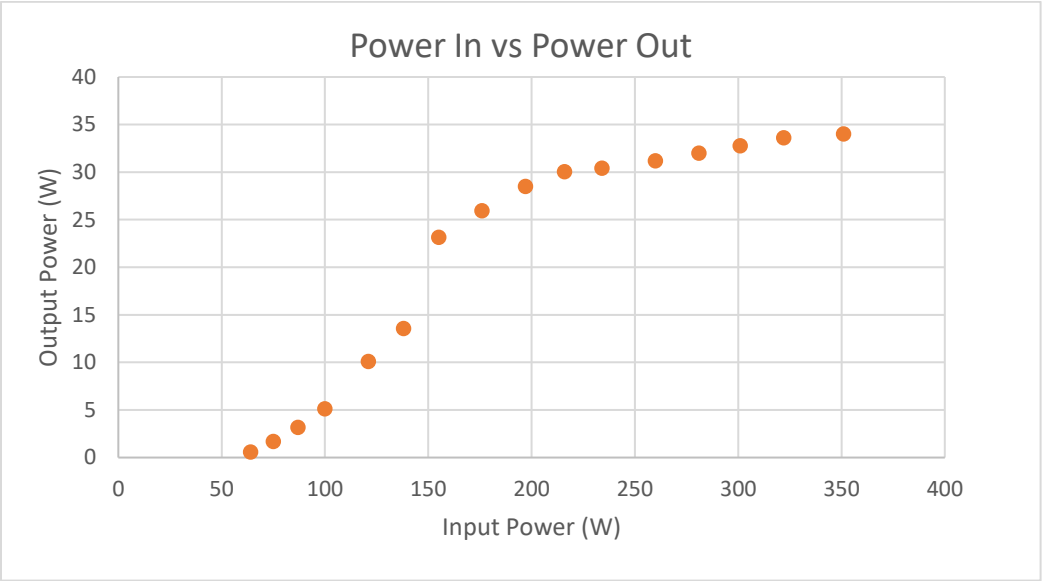

Figure 12 - Power Characteristic Plot

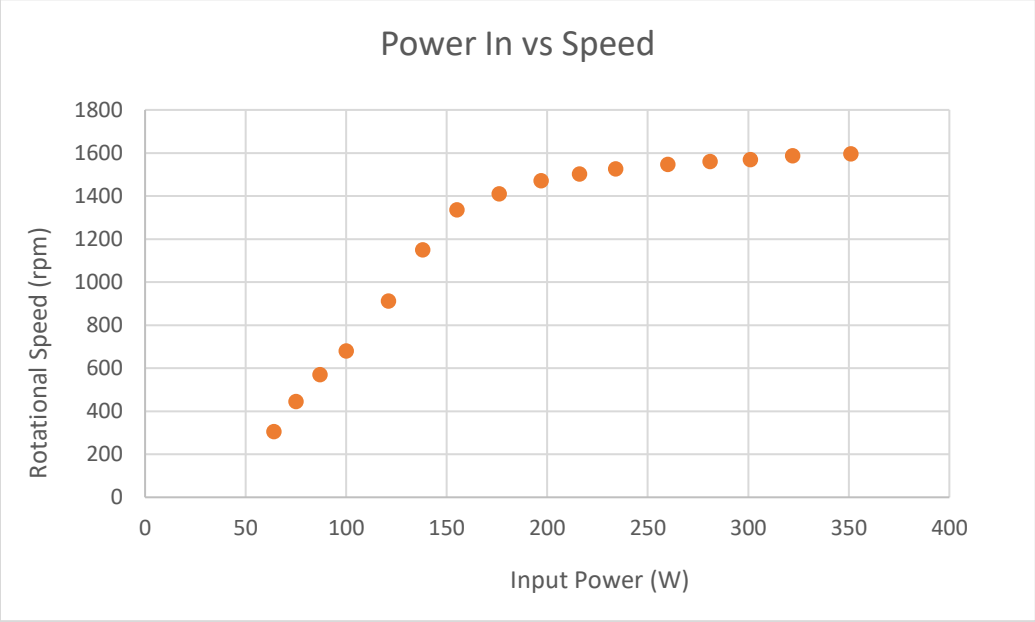

Figure 13 - Rotational Speed Characteristic Plot