The data collected from the trials revealed clear and consistent differences in energy generation among the four wing-integrated wind turbine (WIWT) designs. The Parallel-to-Wind turbine produced the highest power output, with a mean output of 0.258 volts and a narrow range of 0.02 volts. This consistent performance demonstrates the reliability and efficiency of the Parallel-to-Wind design in capturing airflow energy when integrated into a wing structure. The Savonius turbine generated moderate power, averaging 0.164 volts with a range of 0.03 volts, indicating some variability in performance. Both the H-Rotor and Horizontal-Axis turbines produced negligible energy, with mean outputs of 0.004 volts and 0.002 volts, respectively, confirming their limited suitability for wing integration under the tested conditions.

Figure 1: Data Gathered

Type of Wind Turbine	Energy Generated (20V)						
	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Mean	Range
Savonius	0.18	0.16	0.17	0.15	0.16	0.164	0.03
H-Rotor	0.01	0	0.01	0	0	0.004	0.01
Parallel to Wind	0.25	0.26	0.26	0.27	0.25	0.258	0.02
Horizontal-Axis	0	0.01	0	0	0	0.002	0.01

The null hypothesis for this experiment stated that the Parallel-to-Wind turbine would not generate more energy than the other WIWT designs. To test this, a one-way analysis of variance (ANOVA) was conducted to evaluate whether the differences in mean energy output among the four turbine types were statistically significant. The ANOVA results revealed a p-value of less than 0.01, indicating extremely strong confidence that the differences observed were not due to random variation but were instead attributable to the turbine design itself. The F-statistic of 1800 further supports this conclusion, demonstrating a clear separation in mean energy output between at least some of the groups. This analysis confirmed that the choice of turbine type had a substantial and measurable effect on power generation, validating the need to investigate specific designs for WIWT implementation.

Figure 2: ANOVA (One-Way) Summary

Effect	**Degrees of Freedom (df)**	**F-statistic (MS / MS residual)**	**P-value**	**Interpretation of P-value Explain**
Turbines	3	1800	<0.01	A P-value of <0.01 means extremely strong confidence that the groups are

				different.		
Residual	19	-	-	-	-	-

Following the ANOVA, post hoc pairwise comparisons were performed to determine which turbine types differed significantly from one another. The Parallel-to-Wind turbine generated significantly more energy than the H-Rotor, Horizontal-Axis, and Savonius turbines, with mean differences of 0.255, 0.257, and 0.0943 volts, respectively, and p-values below 0.01. The Savonius turbine also produced significantly more energy than both the H-Rotor and Horizontal-Axis turbines, with mean differences of 0.161 and 0.162 volts, respectively. In contrast, no significant difference was observed between the H-Rotor and Horizontal-Axis turbines, as indicated by a mean difference of -0.00167 volts and a p-value of 0.98. These post hoc results demonstrate that turbine orientation and blade design are primary factors affecting energy generation and provide strong statistical support for the conclusion that the Parallel-to-Wind design is the most effective among the turbines tested.

Figure 3: Post-Hoc Comparisons

Pair	**Mean diff**	**P-value**	**Interpretation of P (Auto)**	**Interpretation of P (Manual)**
Horizontal-Axis + H-Rotor	-0.00167	0.98	Means: no evidence that the groups might be different	Parallel-to-Wind significantly higher
Parallel to Wind + H-Rotor	0.255	<0.01	Means: extremely strong confidence that the groups are different	Parallel-to-Wind significantly higher
Savonius + H-Rotor	0.161	<0.01	Means: extremely strong confidence that the groups are different	Parallel-to-Wind significantly higher
Parallel to Wind + Horizontal-Axis	0.257	<0.01	Means: extremely strong confidence that the groups are different	Savonius significantly higher
Savonius + Horizontal-Axis	0.162	<0.01	Means: extremely strong confidence that the groups are different	Savonius significantly higher
Savonius + Parallel to Wind	-0.0943	<0.01	Means: extremely strong confidence that the groups are different	No significant difference

The results clearly supported the experimental hypothesis, showing that the Parallel-to-Wind turbine consistently generated the highest energy among all tested designs. Its alignment with the airflow and streamlined integration into the wing structure allowed it to harness accelerated wind effectively, resulting in both high power output and consistent performance across trials. The Savonius turbine produced moderate energy but was limited by its vertical-axis design, which is less suited to the predominantly laminar airflow over a wing, leading to slightly more variability between trials. The H-Rotor and Horizontal-Axis turbines demonstrated minimal energy generation, underscoring the limitations of conventional turbine configurations when applied to wing-mounted applications.

Examining both the mean outputs and trial-to-trial variation provided additional insight into the reliability of each design. The Parallel-to-Wind turbine's narrow range confirmed predictable performance, while the Savonius turbine showed modest fluctuations that may affect continuous energy generation in practical aviation scenarios. These observations emphasize that consistent output is as critical as maximum energy generation when evaluating turbine designs for integration into aircraft wings.

Collectively, the findings highlight the importance of blade design and orientation in WIWT performance. The Parallel-to-Wind turbine effectively captures high-speed airflow over the wing while minimizing drag, demonstrating the potential for WIWTs to serve as a dependable supplementary power source in electric aviation. This study underscores the need to optimize aerodynamic compatibility in turbine design to achieve both efficiency and reliability, reinforcing the feasibility of WIWTs for advancing sustainable aviation technology.