Design and Manufacture of Auxiliary Components for Small Wind Turbines

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Motivation and Background

The U.S. Department of Energy and the World Wind Energy Association estimated that, as of the end of 2015, nearly 1 million Small Wind Turbines (SWTs) were operative around the world, providing almost 950 MW to diverse on- and off-grid systems [1,2].

The world's small wind energy market has shown annual growth rates that have ranged between 5% and 14% during the last decade and it is expected to grow at a minimum rate of 12% per year, reaching 1.9 GW of combined installed capacity by 2020.

However, despite the increased demand for SWTs, the industry is facing new challenges, such as the higher cost of small wind relative to solar photovoltaics [3], the expiration of federal residential renewable energy tax credits, and the general downward trend in state incentive funding levels and programs. Hence, *there is a pressing need to make the small wind energy industry to thrive* and remain an attractive solution.

Objective

The **objective** of this work consists in designing and manufacturing adaptable and cost-effective auxiliary components for a small wind turbine prototype. These include: (1) the nacelle, (2) the hub, (3) the nose cone, (4) the tail boom and vane (including couplings), and (5) the nacelle-tower coupling.

The design was conducted considering all relevant physics and the aero-electromechanical properties of an existing rotor-alternator assembly based on the Silver Blue C6354 alternator [4] and an optimized set of NACA-4412 blades [5].

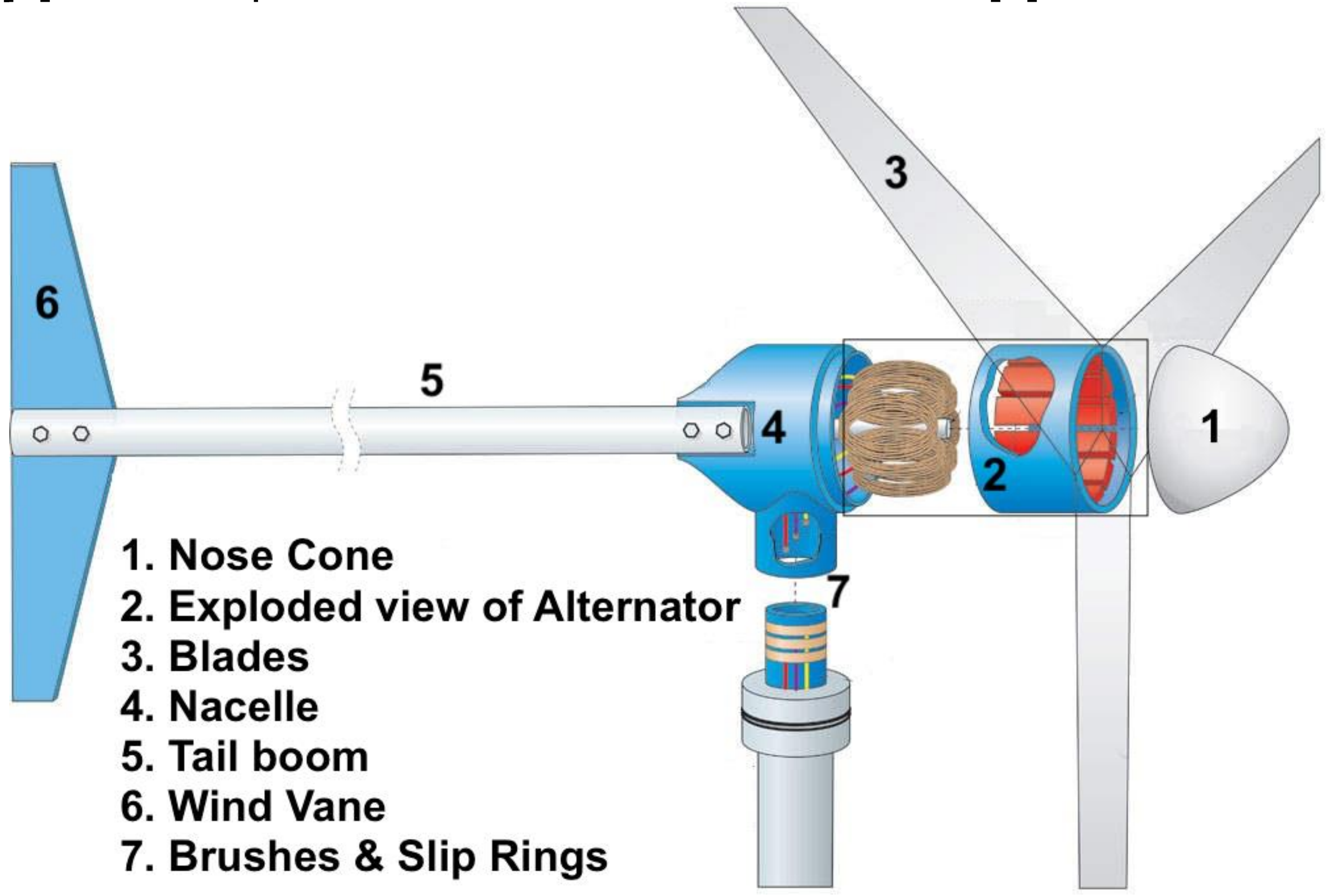

Figure 1. Schematic Diagram of a Conventional Small Wind Turbine.

Methodology

The auxiliary components were firstly designed in SolidWorks and included the following features:

- The nacelle was designed to enable the installation of different electric generators. Minor modifications may be required to have screw-hole matching in the nacelle-alternator assembly.
- The hub was designed so as to install rotors with different geometries and number of blades.
- The tail boom consist of a standard threaded rod that can be easily attached to the respective nacelle-vane assembly.
- The nacelle-tower coupling was designed so as to enable the use of towers with different diameters and the use of commercially-available slip rings, which prevent wire twisting.
- The vane includes a sturdy, yet simple, coupling with the tail boom. Its shape and area were determined based on the aerodynamic momentum needed to correct the orientation of the turbine in low wind regimes.

Manufacture was conducted using a RAISE Pro2 Plus 3D printer. Acrylonitrile Butadiene Styrene (ABS) was used as the primary printing material due to its high impact strength and temperature-related properties. High Impact Polystyrene (HIPS) was used as support material during the printing process.

Results

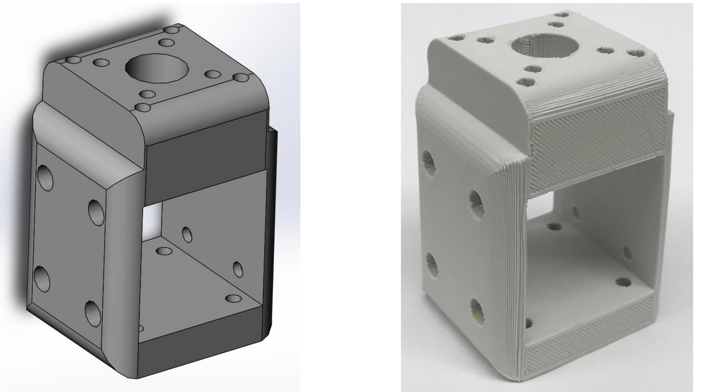

Figure 2. Nacelle - Alternator - Tail Boom Coupling

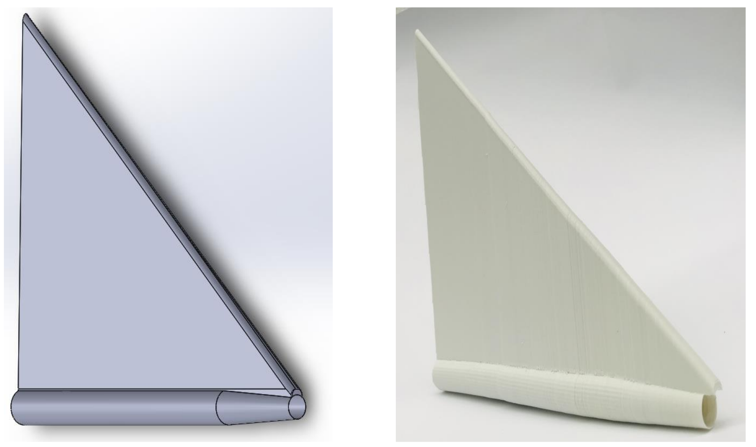

Figure 3. Vane

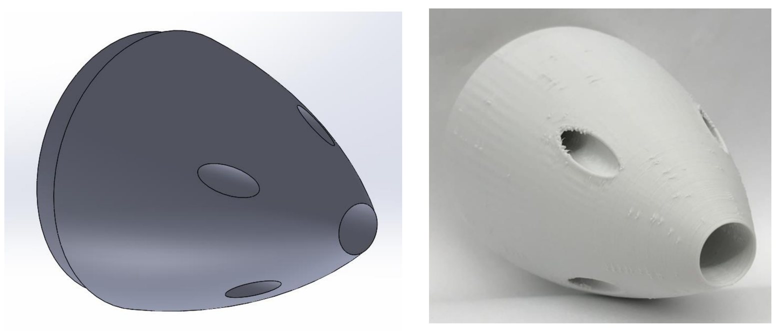

Figure 4. Tail Boom Coupling

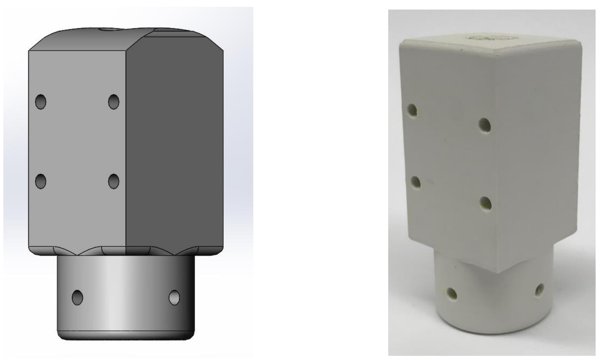

Figure 5. Nacelle - Tower Coupling

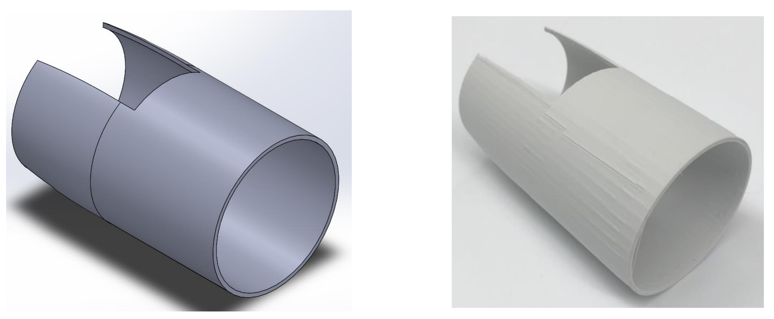

Figure 6. Nacelle

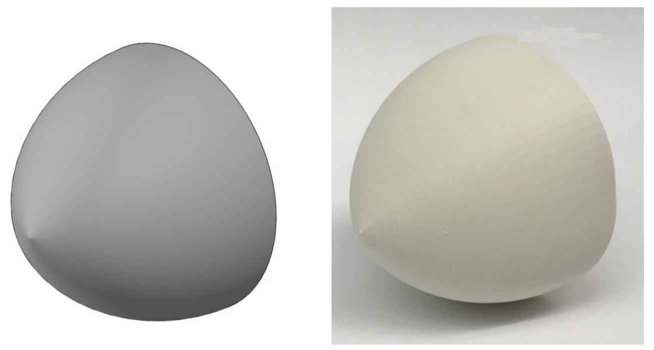

Figure 7. Hub and Nose Cone

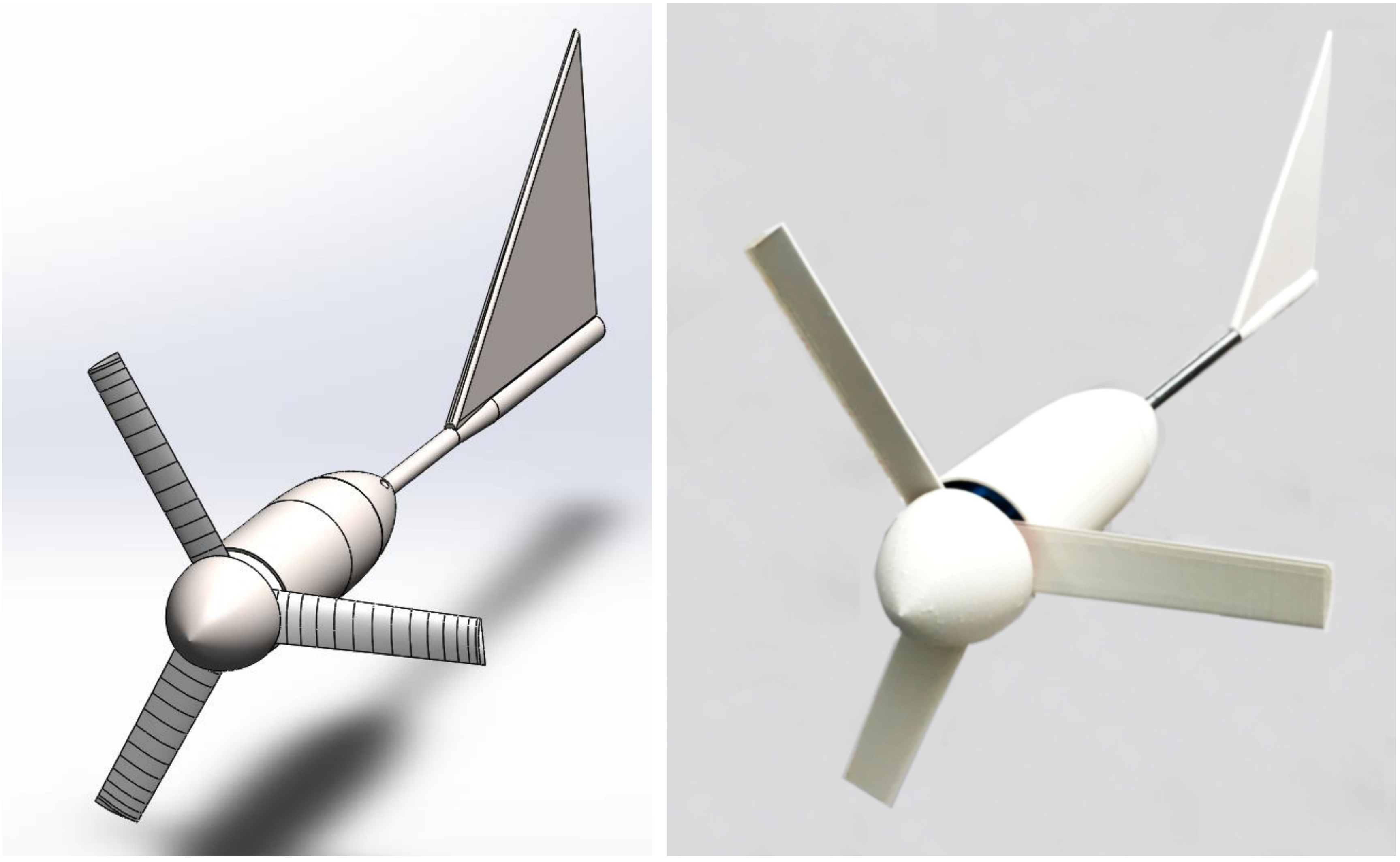

Figure 8. Complete Assembly

The figure above presents the conceptual design and the manufactured prototype. The nose cone is attached directly to the three-bladed rotor, which turn is connected to the front end of the alternator through a threaded shaft. The rotor and the nose cone rotate together as the turbine converts wind power into mechanical power. The only component that was not 3D printed, apart from the alternator and the slip ring, was the tail boom. All the auxiliary parts were manufactured in white ABS so as to reflect solar radiation and reduce unwanted heat transfer between the wind turbine and the environment.

Summary

Adaptable and cost-effective auxiliary components for a small wind turbine prototype were designed and manufactured using state-of-the-art CAD software and rapid prototyping technologies.

The distinctive feature of the set of auxiliary components with respect to conventional ones is that they enable the installation of different rotor-alternator assemblies.

Future work involves developing a field-ready variant of this first-generation assembly and verifying the reliability of the complete system in controlled conditions (e.g., within a wind tunnel) and in atmospheric conditions. Geometrical optimization can also be carried out to minimize passive wake effects that may degrade the net efficiency.

References

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[5] Herbert-Acero J-F et al. A Hybrid Metaheuristic-Based Approach for the Aerodynamic Optimization of Small Hybrid Wind Turbine Rotors. Math Probl Eng 2014; 2014:1-18.