DEVELOPMENT OF A 1.5MW VERTICAL AXIS WIND TURBINE

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ABSTRACT

This paper presents the development of an experimental prototype of wind turbine to be installed in Rio Grande do Norte, which is a preliminary result of the R & D project ANEEL PD-00063-3024/2017 DE3024 - DESENVOLVIMENTO DE TURBINA EÓLICA DE EIXO VERTICAL – TEEV, COM TECNOLOGIA INOVADORA. The project consists of simulations and computational tools to design a wind turbine. The main goal of this work is the development of a Vertical Axis Wind Turbine – VAWT with 1.5 MW rated power, using innovative proprietary technology with a smaller cost per watt-peak and featuring low installation and maintenance costs. The main innovative features are: i) a rotor with special design consisted of two different “blades” with a particular combination between them for greater efficiency; ii) a simpler installation process without the use of high crane. Finally, the logistics of its installation will be much simpler without the need of special licenses and vehicles. The last design and the assembly process will be presented, as well as the preliminary results of the operation in a controlled environment.

Key words: Wind turbine; vertical axis;

1. INTRODUCTION

In order to mitigate the impact of energy consumption from fossil fuels, which dominate the global energy mix, and possible damage the environment, the global economy seeks to evolve towards sustainability and energy efficiency. Faced with this challenge, Renewable Sources have received increased attention from governments, especially after the signing of the Kyoto Protocol in February 2005 (the effective date).

Studies based on the Energy Revolution report, compiled by the Global Wind Energy Council (GWEC) and Greenpeace, show that wind energy can produce up to 12% of world energy demand and avoid, thus, the issue of 10 billion tons CO2 in 12 years. The planet needs to be placed in another direction, to the environmental commitment of the people who inhabit it, and at that time, wind power has played a key role in this process, since no other technology comes close to this goal at least in electricity production.

In Brazil, the costs for wind generation are the smallest compared with other renewable sources, yet it is believed that it is possible to further reduce it. Among the main obstacles to reducing costs, there is the initial investment, in particular part of mobilization, installation and maintenance among others. Difficult access coupled with lack of local skilled labor in addition to the assembly and maintenance costs can become elements which increase the project' cost.

Thus, even with extremely favorable climate, one of the best quality wind resources in the world, with constant, intense and steady winds, there is always need to study new forms of energy production from wind power.

Having this in mind, the main goal of this paper is to present a new form of wind power conversion product of a research and development project carried out by CPFL, V/LEAF and Fiedler. The project's main focus is the development of a wind turbine with a rated power of 1.5 MW composed of modular elements that bring the following advantages: ease of assembly, transportation and finally, simplified maintenance. The turbine in development is a vertical axis one produced with simple elements and with 100% national technology at low-cost.

The project includes the installation of a prototype with a 1.5 MW capacity. But the project will also develop a smaller prototype with 250 kW in order to prove the concept and theory behind it as well as its operation and technical feasibility. At Figure 5 a 3D model of the 250 kW prototype can be seen.

2. BACKGROUND

Despite vertical axis wind turbines (VAWT) have never been produced in large scale, and very little research have been done in the last decades when compared with horizontal axis wind turbines (HAWT), there are a number of studies that already insure some advantages of this technology, such as easier maintenance, lower incidence of noise and no need for alignment of the rotor with the wind, which can cut production costs and maintenance.

In addition, the vertical alignment of the axis on this type of turbine allows the positioning of the generator at lower heights or even on the floor, reducing installation and maintenance costs.

Furthermore, the vertical turbine blades are easier to manufacture and transport, when compared to the horizontal turbine blades, generating cost savings in transportation, assembly, maintenance, among others.

3. TECHNOLOGICAL DEVELOPMENTS AND VLEAF TURBINE

The VLeaf wind turbine is a type of VAWT, which is being developed since 2009 (timeline showed in **Figure 1**), which rotor is designed in a creative way, with tensile structure technology and a high resistance membrane produced with a material called polyvinylidene fluoride (PVDF). This unique combination of technology and equipment act to give wind resistance (leading the rotor to rotate on its axis), and also as a structural element, generating stability to the entire structure of the turbine.

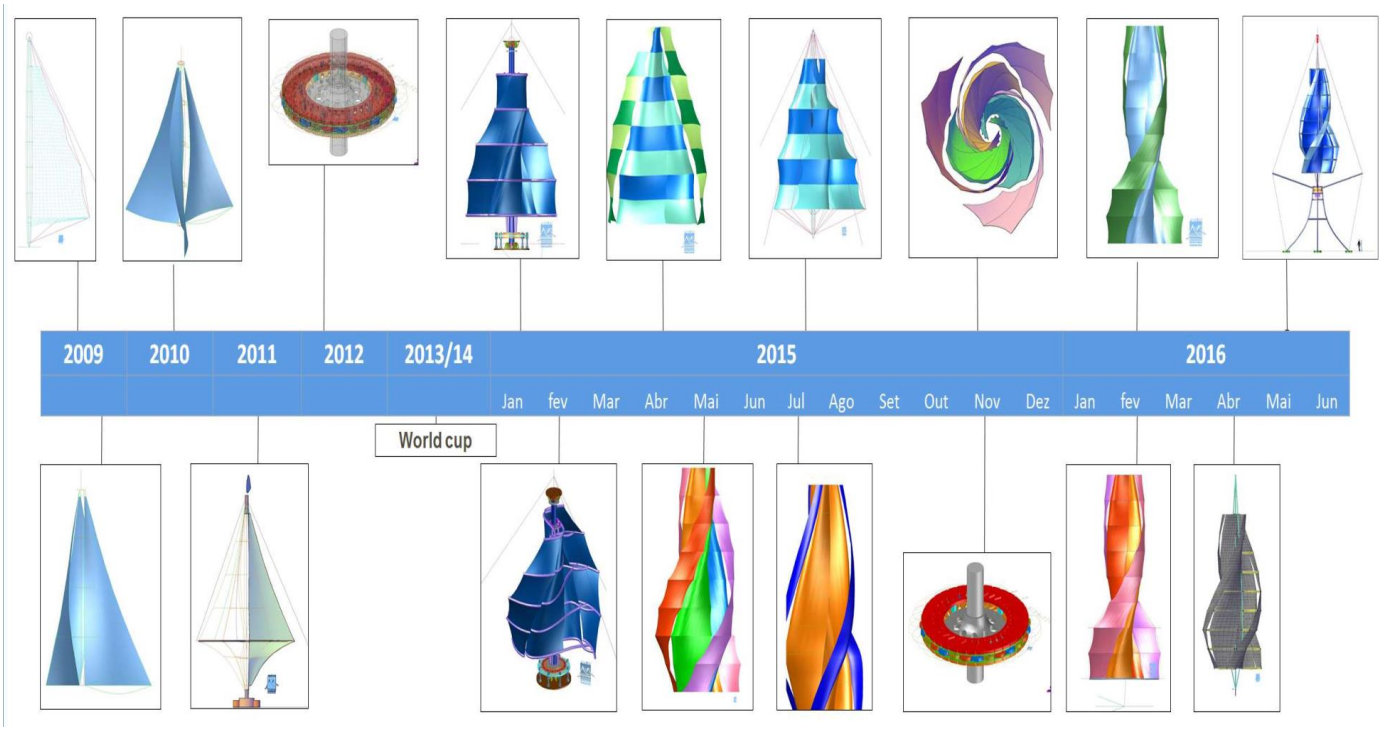

Figure 1 - Technological Development of Wind Turbine V / LEAF.

The rotor of the wind turbine comes from a very original invention, where the surfaces of the rotor blades are produced with PVDF membrane. With aerodynamic simulation and modeling, the membranes are tensioned with double and opposite curvatures, establishing cross vectors forces in pairs and in opposite directions, stabilizing each point of the surface individually and ensuring, thus, extremely efficient aerodynamic shape.

Thus, these blades made of PVDF are tensioned until it reaches their designed form. Their design allows them to work with the combination of aerodynamic lift and drag, increasing the torque of the turbine.

Finally, the base of the turbine has a pyramid shape where the generator will be installed. The generator will be connected directly to the turbine shaft but the use a gear box is also possible and will be tested during the development project.

At Figure 2, Figure 3 and Figure 4 below, we can see the built prototypes and in Figure 5 it is presented the 250kW prototype that is under construction in Guaruja/SP. This smaller prototype will serve as a model for the development of a larger prototype (1.5 MW) that will later be installed in the wind farm CPFL Renewables in Rio Grande do Norte.

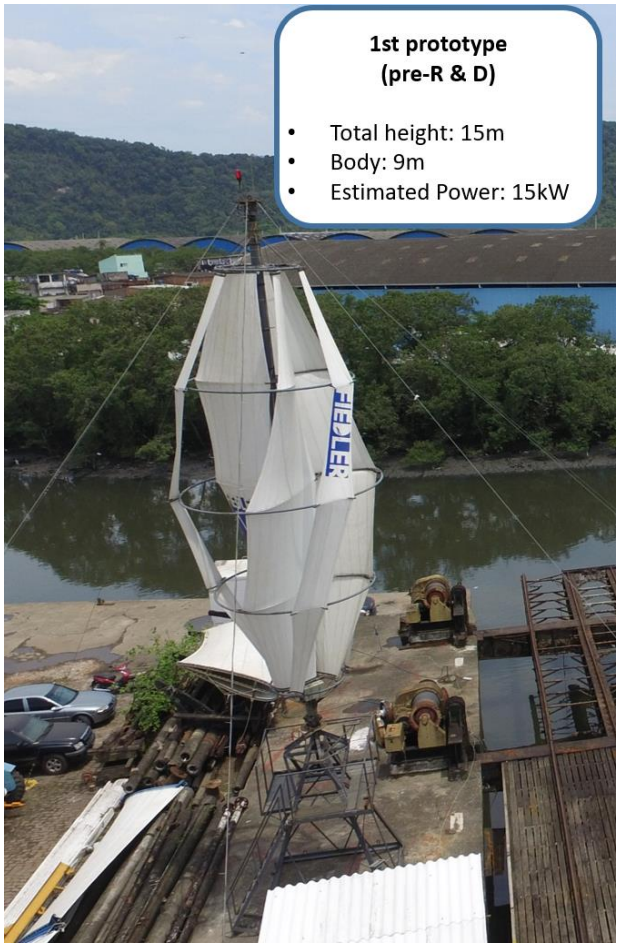

Figure 2 - First prototype (R & D pre-project)

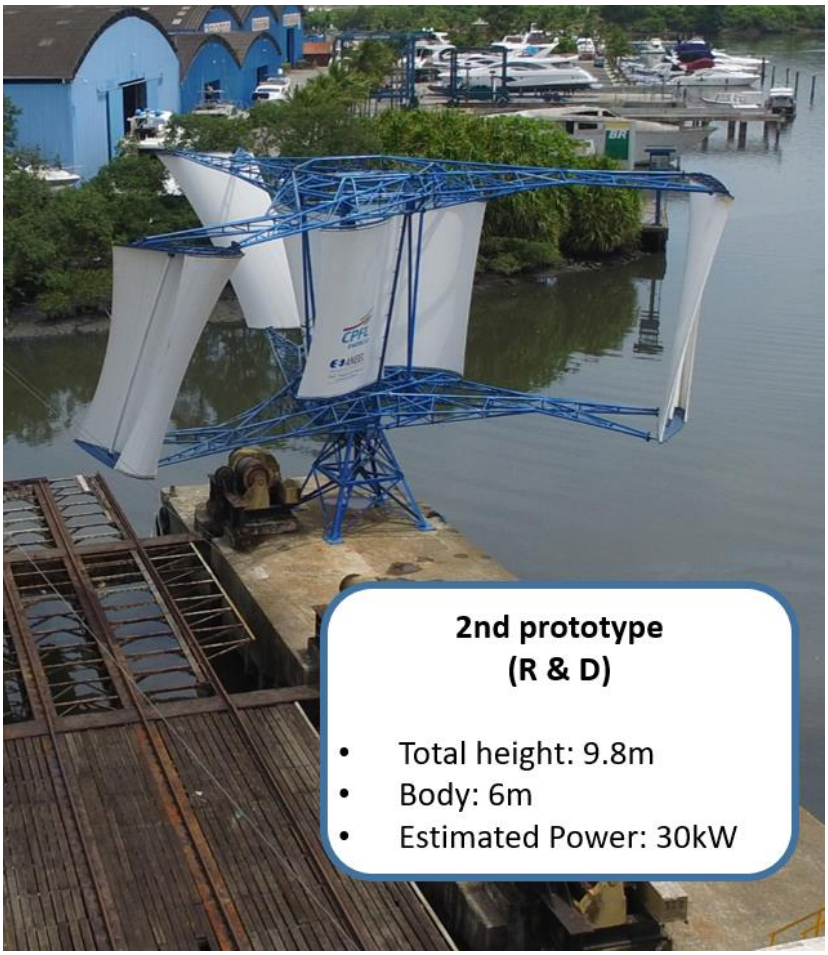

Figure 3 - Second prototype, developed in R & D project

Figure 4 - Third prototype, developed in R & D project

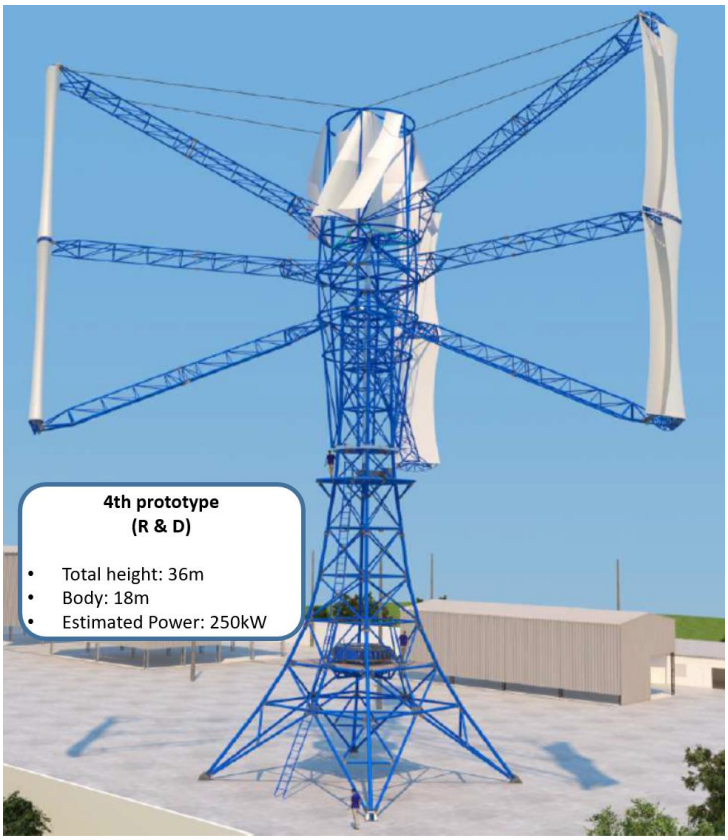

Figure 5 - Fourth prototype, developed in R & D project

4. PROTOTYPE 250 kW

As explained in item 3, the first element developed was a prototype of 250 kW which is being manufactured by Fiedler, a company partner in the project development, at Guarujá / SP. Despite the low wind speed in this region, it is possible to assemble the prototype and analyze the main structural elements as well as to compare the measurements to the designed parameters and to validate the model that will be manufactured in a larger scale (1.5 MW).

The prototype is in test phase and will be equipped with a synchronous generator. For this purpose, the mechanical connection between turbine and generator will be made through a gear box, very similarly to current commercial wind turbines. The generator system adaptation and the turbine itself is a very detailed engineering work.

5. FINAL INSTALLATION

For the tests in proper conditions of wind and under more severe conditions, the prototypes will be installed in a wind farm of one of the project participants, CPFL renewables.

The turbines' location of assembly are nearby wind farms, located in the same area that the 1.5 MW wind turbine will be installed.

6. CONCLUSIONS

The wind power market is growing fast and is continuously reducing its costs. The project presented in this paper is primarily describing the development of a large wind turbine and its installation, operation and maintenance with reduced costs.

Regarding the installation, it is expected that the use of a modular wind turbine will allow the reduction of costs with logistics, since the use of smaller trucks and lower requirements for cranes and carrier's capacity, as well as lower infrastructure demand are needed. As for the O & M costs, it is estimated that its reduction and the use of simplified parts leads to a lower operating cost when compared with today's cost.

The presented prototype has demonstrated reliable operation and validated the theoretical model so far. It is estimated that the facility will be soon assembled in its final location, Campo dos Ventos, CPFL Renewables. Once in Campos dos Ventos many mechanical stressing tests with bigger mechanical loads and fatigue will occur due to proper wind speed availability and it is expected that the tests will validate the structural model of the turbine and also validate its power curve prediction for both the 250 kW prototype and its larger version of 1.5 MW.

REFERENCES

[1] G. Shafiullah, AM Oo, AS and Ali P. Wolfs, "Potential challenges of integrating large-scale wind energy into the power grid-A review."

[2] H. Zhao, Q. Wu, S. Hu, H. Xu and CN Rasmussen, "Review of energy is wind power storage system integration support," 2014.

[3] F.-J. Lin, H.-C. Chiang, J.-K. Chang and Y.-R. Chang, "Intelligent wind power smoothing control with BESS."

[4] KB d. Cunha, M., Smith, G. d. F. Viscondi, Ferreira AL AF and d. Silva, "Priorities for the integration of variable renewable sources in the electricity system," São Paulo, 2016.

[5] A. Farrius, "intermittency Wind," 2016.

[6] EPRI, Energy Storage for Grid Connected Wind Generation Application, Washington, 2004.

[7] Eyer J. and G. Corey, "Energy Storage for the Electricity Grid: Benefits and Market Potential Assessment Guide," Albuquerque, 2010.

[8] P. Rosas, "Dynamic Influences of Wind Power on the Power System," in 2003.

Biographies

Ji Tuo received his Phd's degree in Electrical Engineering department of Washington State University (2014), majoring in Power Systems. After graduation, he worked in SGCC Jiangsu Research Institute as a specialist and leader of R&D projects. In 2017 he started his position in SGID (State Grid International Development Co. Ltd) and worked as the Assistant Director of Strategy & Innovation Department of CPFL Energia, responsible for the strategy planning and R&D projects of the company. He is experienced in technologies of power sector as well as developing and managing R&D projects, and has lead and participated in several significant projects both in China and Brazil.

Ding Hongwu holds a Master's degree in Economics and a Master's degree in Business Administration, as well as PMP (Project Management Professional). He works in SGCC, the largest utility in the world, and has over 15 years' experience in the power industry. His specialty is Electrical Engineering, International Project Management, Supply Chain management and has participated in several important scientific and technological research and management consulting projects of SGCC.

Chen Xinjian holds a degree in Automatic control from the Shanghai University of Electric Power (2003), studying for a Master's degree in Business, Zhongnan University of Economics and Law (2008). He has worked in Jinshuitan Hydorpower company, Shitang Hydropower company and Liandu power supply company. He has a wealth of experience in different areas such as hydropower company management, administrative management, board operation, Investor Relations Management and capital operation. For the past 14 years, he has held the following positions: Office Manager of Jinshuitan Hydorpower company, Secretary of the Board of Shitang Hydropower company, Management Advisory Committee Member of Ouneng Electric Power Group and Oulong Real Estate Investment Group, Maintenance Manager of Jinshuitan Hydropower company. Now, he is the CEO assistant of CPFL Geração, alternative board member and operation committee member of CPFL Renováveis.

Augusto Chierice Venerando da Silva holds a degree in Electrical Engineering from the State University of Campinas (2015), studying for a Master's degree in Electrical Engineering in the Department of Energy Systems, State University of Campinas. In 2012 he participated in the graduation program sandwich at the University of Lisbon-Portugal. He works in the management of R&D projects in the electrical sector, as well as prospecting new Technologies and solutions, and has experience in Renewable Energy Generation, Internet of Things and Automation with emphasis on Energy Efficiency.

Tiago Michele Ziruolo holds a degree in Metallurgical Engineering from Polytechnic School of the University of São Paulo (2008). Has three years of experience on consulting projects related to productivity and process improvement, logistic and budget plan. Participated in a six-month trainee program in Stuttgart, Germany, developing a camshaft design, as well as investigating failures in

metal structures. Worked with camshaft design, production line development and project management for more three years.

Pedro Rosas, Ph.D.

He received his Ph.D. from Technical University of Denmark in wind energy and power systems. Was researcher at Risoe National Lab from 1999 to 2003. Actually he is full professor at electrical engineering department UFPE and has supervised several Works on MSc and Ph.D thesis as well as coordinated projects on R&D wind power related. Lately has been working with Moura and CPFL developing applications for batteries and power systems.