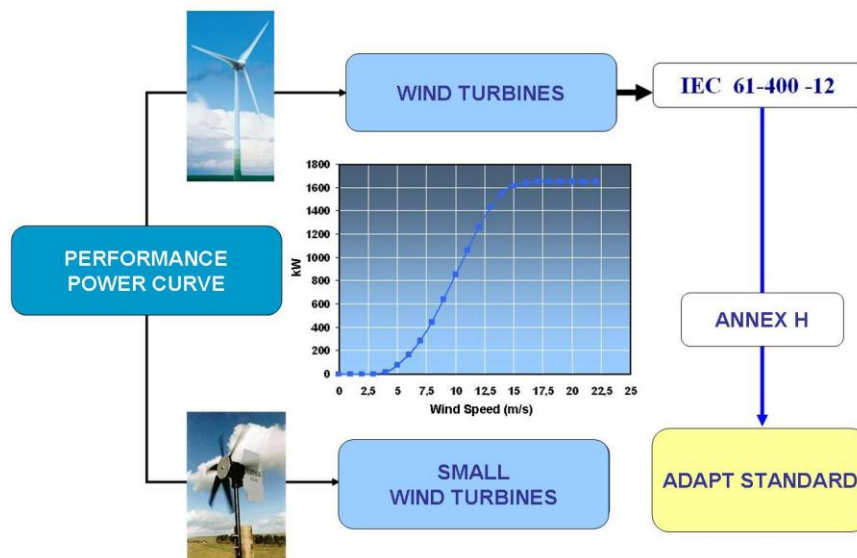## PROCEDURES LABORATORY FOR SMALL WIND TURBINES TESTING

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ABSTRACT: Brazil presents favorable conditions for the use of wind energy, increasing even more the current power production with renewable energy sources. Currently, the installed capacity is approximately 700MW, even though it has a potential of about 150GW, and in order to step further in the more dynamic way into the usage of this energy, it is necessary that the country present specific politics for the scientific and technological development of wind energy in Brazil, allowing technological resource exchange and creating mechanisms for professional development. The present paper describes activities and the results obtained to testing small. wind turbines in laboratory including methodology for evaluation of static bending test and cyclic loads for small wind turbines using as references standards and procedures.

1. PERFORMANCE OF WIND TURBINES ON WIND TUNNEL

The international standard IEC 61400-12-1[1] has the methodologies for power curve test of wind turbines (Fig. 1). The annex H of this standard has the procedures for small Wind turbines, and the present paper uses this information as reference, however adapted to measure the power curve on a wind tunnel. Other references [2, 3] present procedures and results of small wind turbines.

Fig. 1 Standard for performance test of wind turbines

2. METHODOLOGIES DEVELOPED IN LABORATORY

2.1 Small Wind Turbine Power Performance

The wind tunnel procedure presented in this paper doesn't have the intent of replacing the field tests to measure the power curve of wind turbines, as specified in the IEC 61400-12-1. It's a complement method that can be used as an aid to help preliminary tests in machines still under development and verify its performance. The system is formed by the wind turbine, battery bank, resistive load bank, load controller and a wind tunnel with open flow. The wind speed is measured with a cup anemometer located between the aero generator and the end of the wind tunnel (Fig. 2). A preliminary procedure is necessary to obtain the relation of the speed read by the anemometer and the speed at the turbine plane. Later, this relation is used to correct the power curve.
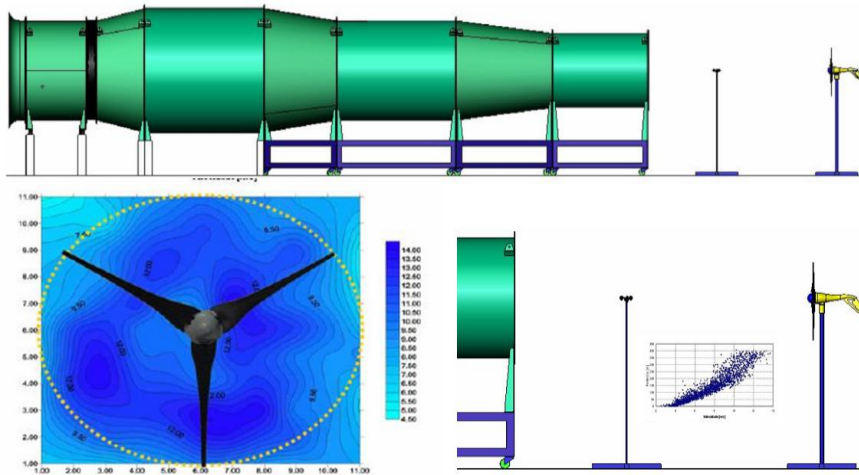

Fig. 2 Wind turbine testing procedure in wind tunel

The system assembled at the laboratory (Fig.3) uses a battery bank with capacity for 300Ah, an RMS power transductor of 5kW with accuracy of 0.2% of reading, wind tunnel controlled by a frequency inverter of 74kW, resistive load bank with maximum power of 3kW, calibrated anemometer and other meteorological sensors. The load controller was set to the diversion control mode, in which a resistive bank is used to redirect the excess power instead of letting it go to the battery. The operation range of this controller was set to 10% of the test voltage.
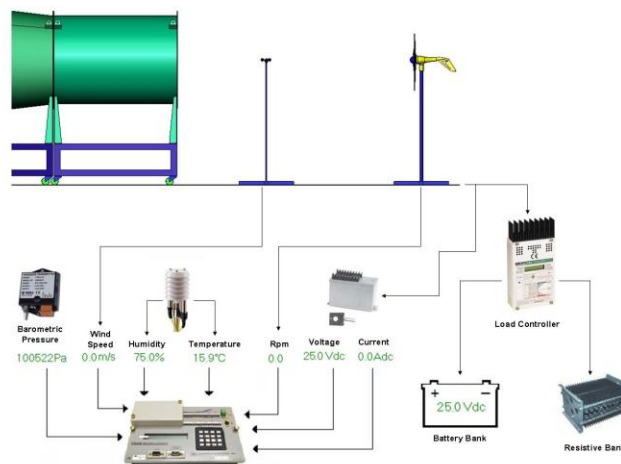

Fig. 3 Data acquisition structure to wind tunnel test

The variations of wind speed on the wind tunnel is automated, allowing to test the turbines in a reduced time, the procedure of measuring the power curve lasts less than three hours. To achieve that, a micro controlled system is connected to the frequency inverter that turns the wind tunnel's fan on and controls the increase and decrease of the wind speed at the turbine automatically.

2.2 Small Vertical Axis Wind Turbine Performance.

Besides the power test generators with small horizontal axis wind turbines whose methodology has been presented in previous [3]. Currently are developments an methodology for the mechanical torque rotor vertical axis wind turbines with the primary purpose of raising the coefficient of power and torque coefficient of this rotors.

In the test, the permanent magnet generator is used as an electromagnetic brake in order to produce a torque on the rotor axis wind. This allows a current control in the permanent magnet generator which in turn will control the torque to be applied in the wind rotor. This control is carried out a preliminary test for the maximum torque of the rotor to determine the maximum brake rotor. These parameters are needed for the control of the braking doing a more thorough analysis covering the full range of rotation and torque of the rotor.

This procedure uses beyond the majority of sensors already specified for the power curve, and also, a torque wrench to measure the dynamic torque of the rotor wind. With the torque characteristic curve obtained is possible to determine the coefficient of mechanical rotor power (Cp), as essential to determine the best generator to be mounted on the rotor for the construction of a wind turbine with a satisfactory return. In previous tests, tests were made with various geometries [3], obtained with a wind tunnel under the current these limitations are the range of speeds and test section. The results found previously are important since they show the first results of performance rotors wind with new geometry tested in the laboratory.

For new tests with the rotors in the laboratory was needed to build a new structure to support the wind turbine, including a mechanical system with the generator, a torque wrench, flexible couplings and optical sensor for measuring revolutions per minute. A typical testing of prototypes is shown in Fig. 4.

Fig. 4 Vertical axis wind turbine testing in wind tunnel

2.3 Results of Small Horizontal and Vertical Axis Wind Turbines

Fig. 5 show the power curves obtained in laboratory for one small turbine made in Brazil. The graphic show the data read by the datalogger as well as the power curve using the bin method. Fig. 6 shows result of the torque to small vertical wind rotor. The torque is important because it allows evaluate the aerodynamic performance of rotor wind for optimal integration with the electric generator. The preliminary results Fig. 5 and Fig. 6 were obtained through small rotor of high solidity from 1.0 m height and 1.0m diameter. In tests it was observed that the machine has smooth running and low noise proved to be suitable for urban applications. These tests will be repeated with the wind tunnel current.
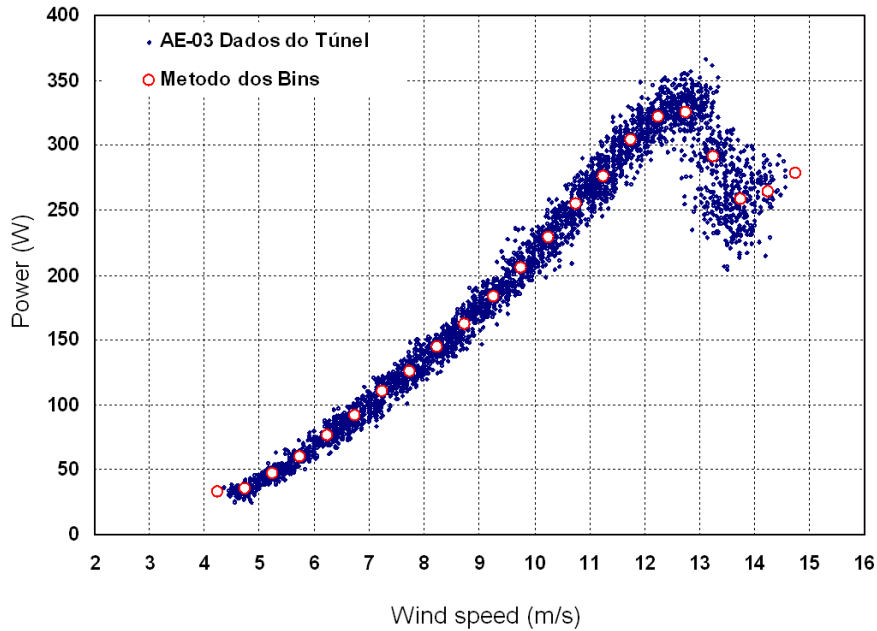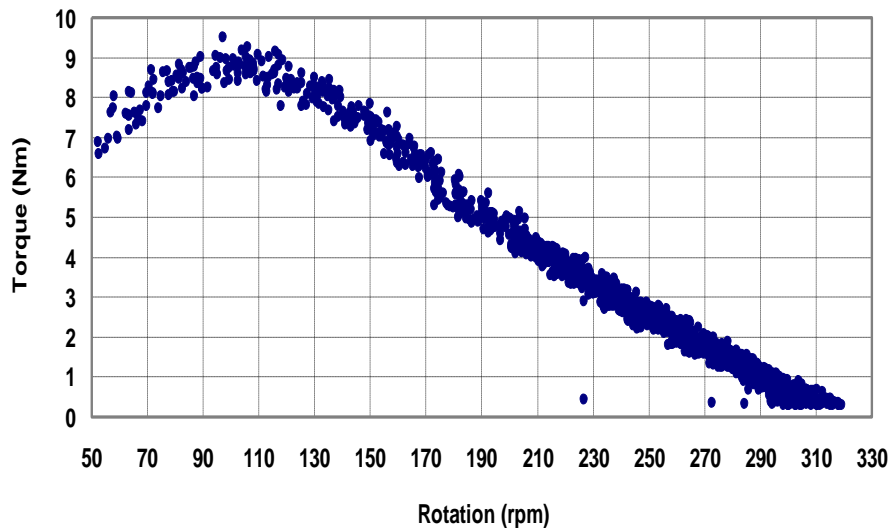
**Fig. 5 Power performance small wind turbine**

Fig. 6 Torque performance of small vertical axis wind rotor

3. PROCEDURES FOR CYCLICAL TEST WIND TURBINE BLADES

A wind turbine is subjected during lifetime to a large number of dynamic loads produced by the rotation of the blades as well as the turbulent nature of wind on the blades. Fig.7 shows schematically the coordinate system of the blades of a turbine and the load caused by the forces of wind and a detail of a blade to analyze load test bench.
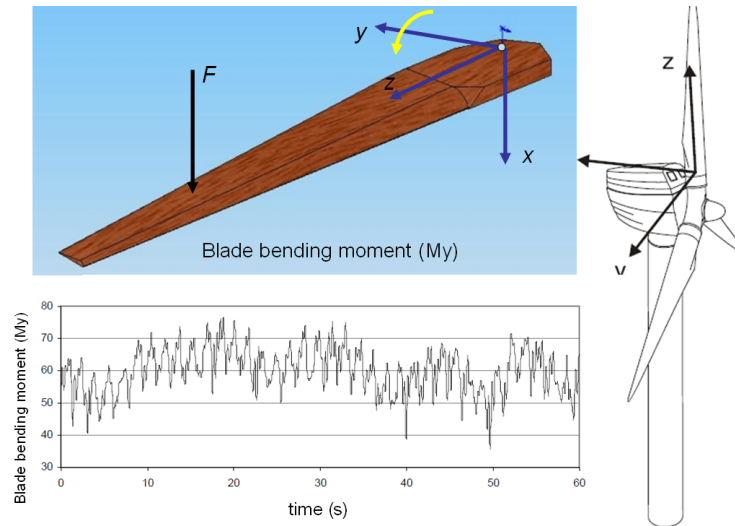
Fig. 7 Bending load representation in blade wind turbine

The main objective in cyclic tests is to evaluate the test bench efforts to determine the fatigue life of blades. Fatigue is a phenomenon that causes a gradual reduction in operating capacity of the material when subjected to repeated loading. In the case of the blades of wind turbines it is a cyclic loading. The fatigue comes from the action of stresses that vary in less time not exceeding the elastic limit of the material. These loadings cause cracks and rupture of the material.

There are several methods used to study and predict the fatigue of materials, and the so-called Wohler method has been used to study wind turbine blades. This method studies the behavior of fatigue by S-N curves, which relates the history of elastic tension acting on the structure with the number of cycles that the material support before failing. To quantify the damage caused to the material by cyclic loading of different amplitudes and different average values are used to accumulation rule called linear Palmgren-Miner. In agree with this rule the damage suffered by that part under the action of each amplitude of the cyclical stress is directly proportional to the number of cycles loads that actuation on the amplitude stress.

3.1 Developing Cyclic Load Bench Test

The present section describes the methodological aspects as the project is in run-up in test bench for testing the fatigue and static testing to determine preliminary magnitude of forces. They can be used to wind turbine blades with a length up to 2.7 m. In the near future is expected to continue with new publications show results of the bench in development. The test bench will have a load cell located in the connecting rod between the ruler and the blade to read their charges at the point of force application. The main reference used is the work of Epaarachchi [4]. The blade is instrumented along its length at locations pre-defined with strain gauges with a view to measure the deformation. The test will apply a cyclic load on the blades for a wide range of frequencies and displacement. Tensions received by the blades of wind turbines are caused by aerodynamic forces and inertial forces. This work is expected to reproduce the same effort by shifts through a point of application of forces in the bench test show in Fig. 8. This device induces the structure of the blade bending loads only, however the

actual functioning originates efforts both bending and axial stresses. The system requires an input of data adjusting the offsets and frequencies in the device test. A data acquisition system is used presenting two main parts: strain gauges placed along the blade in preselected locations and data logger for collecting and processing data.
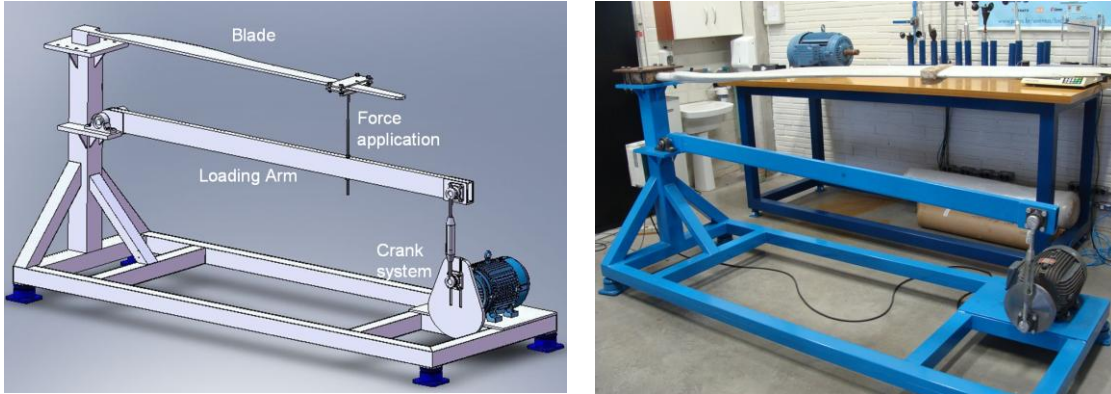

Fig. 8 Fatigue Bench test to small wind turbine blades

In the work of Epaarachchi [4] the load levels based on the most critical point of the blade are predetermined and later used in the tests with the aid of the loads determined by means of finite elements (FEA). This work will be assessed on the best methodology that can be adopted to determine the fatigue test conditions.

3.2 Preliminary Results of Static Bending Test

This section presents the tests of the three-point bending machine to analyze the mechanical behavior of the blades when subjected to mechanical stress. The test consists of applying a load in the center of the sample of the blade (proof body) supported at two points according to standard ASTM E 855-90 [5]. The applied load came from an initial and slowly increased until failure of the proof body. The value of the applied load versus the displacement of the central point was the response of the test. Was used at a speed of 0.02 mm/s for the application of the load, and tested two specimens under identical conditions. The distance between supports was 142 mm and was given a preload of 150 N before doing the test. Fig.9 show an example of the test result where you can observe the application of the preload, the region of elastic behavior, the region of plastic behavior and the subsequent fracture. The average value for the force was 1500 N and the strength of the early fracture of 1650 N. The samples had a mean total displacement of 11 mm.
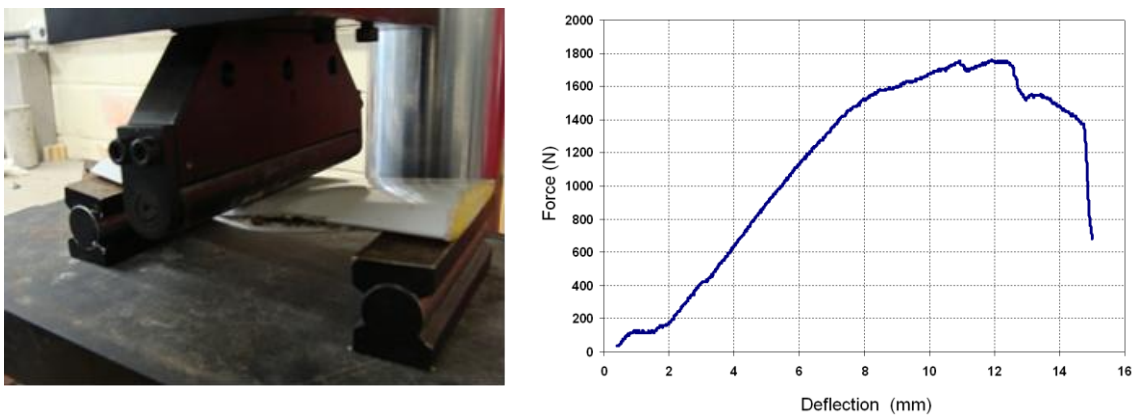
Fig. 9 Behavior of blade material in the static test machine

CONCLUSIONS

The paper shows the automation procedure to obtain small wind turbine power performance in open-jet wind tunnel adapting the IEC 61400-12 [1], specific for field tests of wind turbines. The second part of this article allowed us to evaluate the following scenario about the fatigue tests: (a) The test bench designed and built is ready for the testing of fatigue in the blades, including the installation of load sensors, strain and controllers; (b) The results of preliminary tests of flexion allowed the determination of the forces of the beginning of the rupture of the specimens and the displacements suffered by them; (c) These values will be used as initial parameters for establishing the conditions of fatigue tests.

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