POWER CURVE OF SMALL WIND TURBINE GENERATORS – LABORATORY AND FIELD TESTING

Fabiano Daher Adegas, Gustavo de Marsillac Pena
Jorge Antonio Villar Alé*, Gabriel Sirilo Simioni

Pontifical Catholic University of Rio Grande do Sul
NUTEMA – Renewable Energy Laboratory
Ipiranga Av, 6681. Zip Code: 90610-001 - Porto Alegre, RS, Brazil.
*villar@pucrs.br

Abstract. Small Wind Turbine Generators (SWTG) market has been increasing significantly. There are more than 50 manufacturers around the world, and most of them are small companies with financial and technical limitations to obtain the power curve of their machines. The power curves are made by the manufacturers, each one following some methodology without any normalization that certifies the quality of the results. Therefore, a lot of SWTG are introduced in the market with no certification neither respective power curve. The present work deals about two methodologies that allow obtaining the power curve of SWTG. With these studies, we hope to collaborate for standardization of SWTG testing.

The first method developed by our group tests SWTG in laboratory, stimulated by the airflow provided by an axial fan. Testing wind turbines in laboratory is a promising way of reduce power curve test costs. The other method tests SWTG in field on natural wind conditions, using the standard IEC614000-12 as reference. On both of them, the instantaneous power, wind speed and air temperature were monitored and measured. The power curve was build using bins-average method, on standard air conditions. The comparison of results of results obtained until now for both tests showed that SWTG can be tested in laboratory with great quality. The power curve of the wind turbine studied was lower than the one supplied by the manufacturer, but closer to the ones found in the bibliographical references.

Keywords: Power Curve, Characteristic Curve, Performance Test, Small Wind Turbine, SWTG.

1. Introduction

Small Wind Turbine Generators (SWTG) market has been increasing significantly in the world. There are more than 50 manufacturers that represent more than 125 different models. Turbines from 50W to 50kW are available in the market. In spite of the technological development in the last 10 years and the growth of the market of such machines there isn't a pattern for the certification and tests of these turbines.

The present work deals about two methodologies that allow obtaining the power curve of a SWTG. With these studies, we hope to collaborate for standardization of SWTG testing.

The first methodology developed by Renewable Energy Laboratory of NUTEMA tests SWTG in laboratory, stimulated by the airflow provided by an axial fan. Testing wind turbines in laboratory is a promising way of reducing power curve test costs. The other method tests SWTG in field on natural wind conditions, using the standard IEC614000-12 as reference. The main results obtained until now are presented here and compared with the manufacturer's information and consulted references.

2. Laboratory Methodology

In order to obtain the power curve from a SWTG, a special methodology was developed, performed in laboratory, in which the wind turbine is triggered by an air flow coming from a 7.35 kW axial fan. In order to obtain the wind turbine curve, it was prepared an autonomous wind system, including battery storage, DC load, and a charge and battery voltage regulator. In order to measure the variable required, it was used a data acquisition system (data logger), recording the wind speed measured by a three-cup anemometer and the wind turbine power with a power transducer developed exclusively for this project. The rotation of the wind turbine was measured with a digital tachometer. A barometer, a humidity sensor and a temperature sensor were also used for posterior correction of the air density. Batteries storage was formed by four 12V/100Ah batteries connected in parallel with a capacity of 400Ah. For the load there were used four 55W/12V lamps, summing up to 325W of load. To avoid the complete discharge of the battery during the tests, it was used a load controller (TRACE C-40). Data logger has sample time of 1 Hz, and was configured for the collecting of data every one minute with average calculations of wind speed, maximum, minimum, average and standard deviation calculations of the power generated, according to the recommendations of standard IEC 64100-12. More details on the laboratory procedure adopted can be found on Peña (2003).

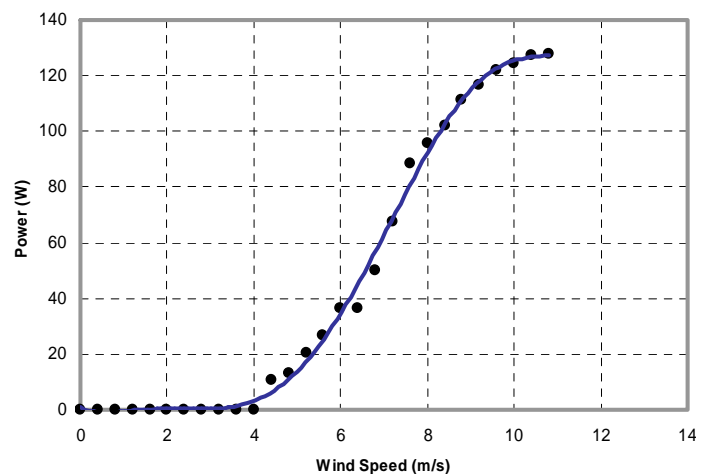**(a)** AIR403 wind turbine
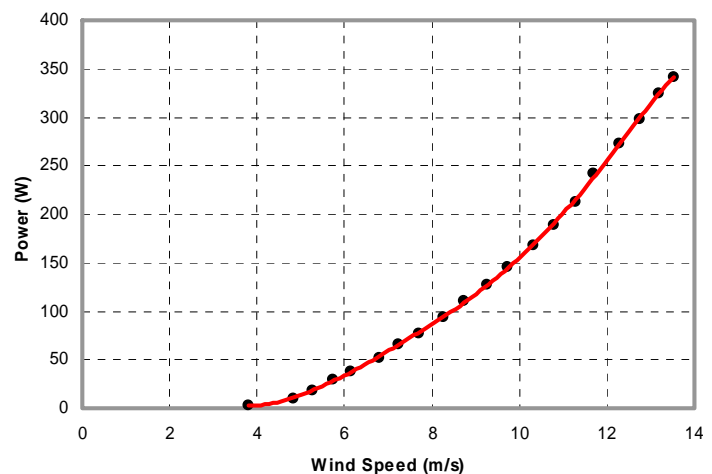
(b) W200 wind turbine

Figure 1. AIR403 (a) and W200 (b) in laboratory and their respective power curves.

Two turbines have already been tested with this methodology. One of them is the American Southwest Windpower commercial wind turbine, model AIR403 of three blades and 1.17m of diameter with nominal power of 400W/12V to a speed of 12.5m/s. The wind turbine does not

have a gearbox and the generator is a permanent-magnet type. The wind turbine generator produces three-phase alternate current (AC) internally rectified for direct current (CC). The wind turbine blades are manufactured in fiber injected and molded carbon. With speeds higher than 19m/s, the blade presents an aeroelastical deformation originating stall, breaking and protecting the wind turbine from extreme wind speeds (Stall Control). The other SWTG is the German WTL GRB model W200 of three blades and 1.5 m of diameter, having nominal power of 200W at 10 m/s. This antique wind turbine has a three-phase magnet permanent type generator that produces AC current that is rectified externally by load control equipment. A mechanical system "breaks the nape" of the wind turbine back for protection of extreme wind speeds, and the spring included on this system brings back the turbine when wind speed is normal for operation.

Figure 1 illustrates the turbines and its respective power curves tested in laboratory. This power curves were obtained by doing first "bins method" from the data colleted, represented by dots, and the result was approximated by a 6th order polynomial regression curve.

3. Field Methodology

In order to compare tests made on laboratory to field tests, the same test structure was used to obtain the power curve of the AIR403 wind turbine in field. A modification on the load control had to be done. Instead of increase the load consume to almost match energy produced by the turbine, Trace C-40 were used to control load. The control logic is simple. If the batteries are fully charged for six minutes, the controller connect load until the batteries remains 6 minutes in low charge, then the load is disconnected again.

Data logger was configured as laboratory tests, sampling data every second and collecting with 1 minute average calculations of wind speed, maximum, minimum, average and standard deviation of the power generated, according to the recommendations of standard IEC 64100-12.

Figure 2. Wind turbine and test system on a mast tower, located on a farm.

Power data should be collected for all SWTG operation range, so field place must have considerable time of high wind speeds (high Weilbull shape factor). The city of Imbé at sea land of our state was chosen, having it an annual mean temperature of 18.9^{o}C, annual mean wind speed of 7.0 m/s at 50 m high and Weilbull shape factor of 2.4 (Amarante et al, 2002).

The SWTG test system was installed in a tower of 13m high, located on a private farm as illustrated on Fig. 2. Figure 3 is a map of the place in 1:50000 scale, where the dot A1 is the wind turbine location.

Figure 3. Map of the place where wind turbine is installed (1:50000 scale).
Dot A1 is the location of the mast tower.

Local roughness is characterized almost by wet land with small bushes, having a roughness description of Z_o of 0.04 m for all sectors (Riso, 2002). The determination of roughness length is important for extrapolation of the wind speed from anemometer high to turbine hub high. As seen on Fig. 2, anemometer and turbine are installed at different highs. Turbine hub was installed at 13m high and anemometer at 10m high. Logarithmical method was used to extrapolate wind speed data.

There are some objects near the tower that were treated like obstacles: two trees, a house and a barn. The results presented on this work don't exclude obstacles influences. IEC 61400-12 recommends considering data just from sectors that doesn't suffer influences from obstacles. Obstacles interferences will be excluded when more data are available. The field results until now leads in consideration wind data from all sectors to obtain the SWTG power curve.

The support used to sustain the anemometer and wind vane was projected to avoid turbulence interferences from either turbine and tower mast. The distance used from anemometer to tower is 2m, and distance used from anemometer to wind turbine hub is 3.6 m

4. Results and Conclusions

Until now 17320 field data points were collected, about 13 days of data. The amount of data collected, mainly the few data of high wind speed isn't adequate to take definitive conclusions about the laboratory methodology, but can show a tendency that those tests accomplish the proposal of obtaining a SWTG power curve. Figure 4 illustrates all power data collected in field, have it already been corrected to standard air conditions.
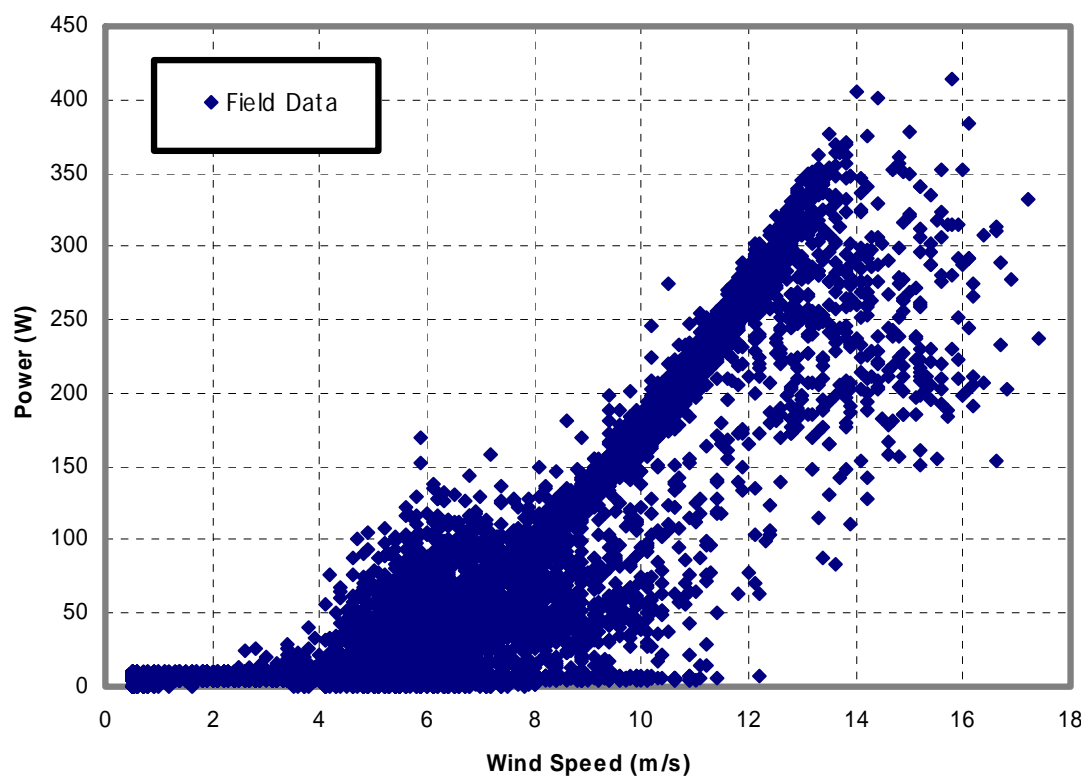
Figure 4. All power data collected in field and corrected to standard air conditions.

Figure 5 illustrates power curves of AIR403 obtained in this work and others from bibliographical references. The comparison between field test, laboratory test and Gipe, 2000 tests shows a good agreement between them until 12 m/s. Field test doesn't reflect the machine performance over 12 m/s because there is few data points. With data collection period of two months or more the results over this range can indicate the machine characteristics.
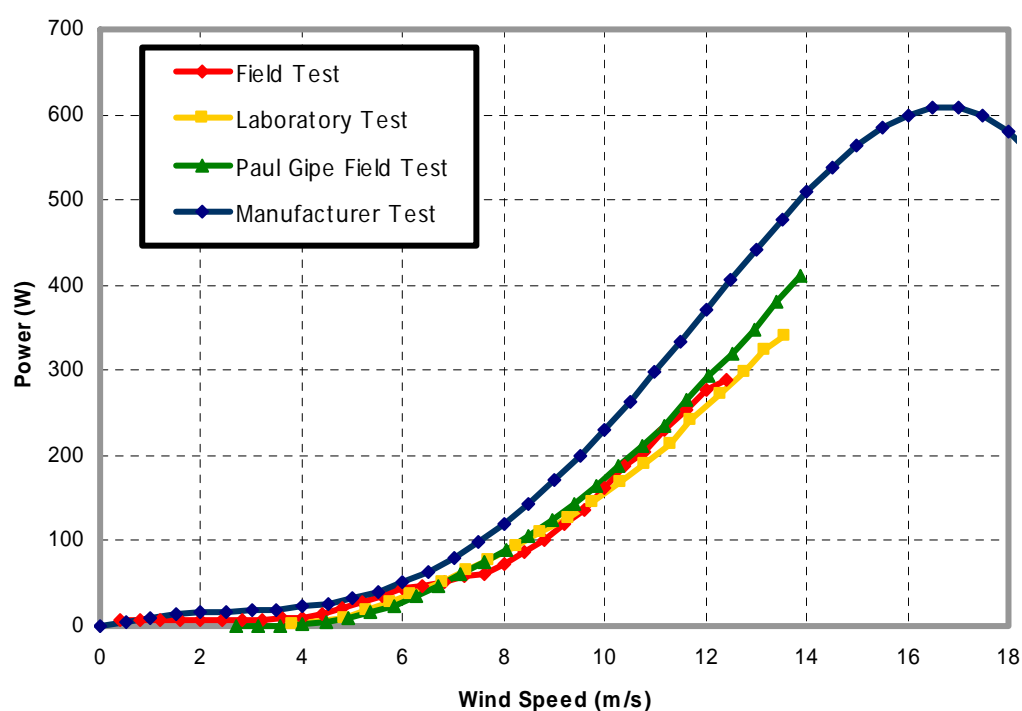

Figure 5. Power curves obtained in this work using "average-bins" method compared to other ones from bibliographical references.

Tests up to now accomplished with the present methodology in laboratory allowed encouraging results when compared to measurements in field and to consulted bibliographical references. The W200 turbine is being installed in other location to be tested on field, and the results will be compared to laboratory tests.

5. References

Standard IEC 61400-12, International Electrotechnical Commission (IEC) (2002). *Wind Turbine Generator Systems Part 12 –Wind Turbines Power Performance Testing: Wind Turbine*. 88/66 CDV.

Peña G.M., Alé, J.A.V., Adegas, F.D., 2003. *Power Curve Test of Small Wind Turbine Generators*. AWEA Windpower2003 Proceedings CD-ROM, Austin, Texas.

Amarante, O. A. C., Silva, F. J. L., 2002. *Wind Atlas of Rio Grande do Sul*. Porto Alegre, SEMC, pp.9,31-49.

Riso, 2002. *Wasp Help Facility*. Wasp 7.3 help program, section *Table of Roughness Lengths*.

Gipe, P. (2000). *Testing the Power Curves of Small Wind Turbines*. WindStats Newsletter, Vol.13, nº3.

6. Acknowledgments