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STUDY OF THE ELECTRICAL CHARACTERISTICS OF THE WIND GENERATOR FOR DISTRIBUTED GENERATION

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Abstract. *This work aims to raise and evaluate technical parameters of commercial generators for use in small wind generation, aiming to obtain their electrical characteristics and performance. The method used will consist of simulating, in the workbench, starting and steady state operations, evaluating its response in the electric power quality generated by these equipment. This work is justified both by the need to seek compliance and technical improvement of the current electric machines used, as well as by reasons of public policies of incentives that promote distributed generation in the country. The preliminary results obtained quantify the electrical energy delivered to the point of connection by the turbine, evaluating the quality of the generated energy, enabling its improvement.*

Keywords: *Distributed generation; small wind turbine; energy quality; performance tests.*

1. INTRODUCTION

In recent decades, there has been an increasing demand for electric energy in Brazil and in the world (EPE, 2016). As Brazilian demand is not being accompanied by its production in the forms of the current sources, problems have occurred in the supply of electric energy, which is verified in the occurrence of "blackouts". With the insertion of new sources in the Brazilian electrical grid and the increase in the cost of megawatt-hours in recent years due to a greater use of thermals, the need for new studies for the technological development of wind generation in the country has increased. In the scenario of wind generation, the Brazilian Northeast region has been highlighted by the quality of its wind resource (Juárez et al, 2014). In order to make feasible the implementation of this source in the country, the procedure of several auctions for the installation of wind farms, with long-term electricity dispatch, using turbines of MW power scale was used.

However, there is a latent and promising market for electricity generation using small wind turbines (Silva et al, 2016). This distributed generation market has been encouraged by regulatory compliances of the National Electric Energy Agency (ANEEL) and by the concessionaires. This energy can be used by way of compensation, that is, the surplus energy of the self-producer can be delivered to the grid or received in the form of credit (ANEEL, 2012).

Given the context and circumstances described above, it is possible to predict the emergence of a new market to establish in Brazil the self-production of electricity through small-scale wind power generation. In order to make the technical sustainability of this market feasible, it will be necessary, among other activities, the one that deals specifically with the design and development of tests of conformity of the various components of the machine.

2. METHODOLOGY

The methodology for the tests will be based on the standards IEC 61400-12-1 (Measuring the power of wind turbines producing electricity) (Oliveira Filho, 2015), 61400-21 (Measuring and evaluating the quality of the energy of wind turbines connected to the grid) and 61400-1 (Project requirements), with its adaptations. The tests will be performed on the bench as shown in Figure 1.

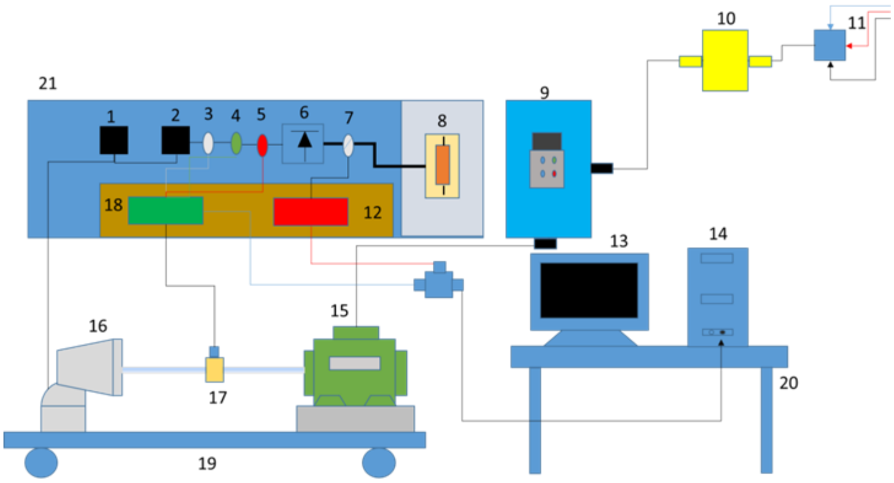

Figure 1. Experimental bench layout. 1-Three pole circuit breaker in short circuit; 2-Three pole protection circuit breaker; 3-Frequency transducer; 4-Current transducer; 5-Tension transducer; 6-Three-phase diode bridge; 7-Clamp meters of recording equipment; 8-Resistive load bank; 9-Variable-frequency drive; 10-Variable-frequency drive circuit breaker; 11-Input of the three-phase electrical grid; 12-Recorder equipment; 13-Computer monitor; 14- Computer CPU; 15-Induction motor; 16-Test generator; 17-Torque transducer and couplings; 18-Data collection equipment; 19-Test stand with wheels; 20-Computer desk; 21-Electric panel.

The scheme shown in Figure 1 is based on the control of rotation and monitoring of electrical parameters of the generator and its behavior before different test conditions. The electrical load used in the test system has an impedance of 1,5 ohm. As shown in Fig. 1, three transducers are used to facilitate measurements during generator operation. Power quality was measured considering the use of resistive electric load.

3. PRELIMINARY RESULTS

As a result, it is expected that the energy delivered to the point of connection by the generator, showing the main faults and point out improvements to mitigate their effects, based on the results obtained with the following analyzes:

- Test of harmonic levels present in the use of diode AC / DC rectification;
- Power quality analysis provided;
- Total Harmonic Distortion (THD%);
- Oscillography of voltage and current waveforms at startup and at steady state;
- Power factor;
- Generator efficiency;
- Variations of voltages and frequency.

Wind variation has a direct impact on the electrical characteristics of the energy supplied by wind turbines. In addition, these characteristics are still influenced by power electronic equipment, an indispensable part of the conversion process, and it can be evaluated through Total Harmonic Distortion (THD) levels, as shown in Figure 2.

4. DISTRIBUTED GENERATION

Distributed generation refers to electrical power generation that is produced close to the systems that will consume its energy, independent of the type of power generating technology. It provides benefits as energy loss during transmission and reduced load on utility transmission and distribution lines.

The connection between the power generation plant and the utility's public network is regulated by the current legislation and must, in addition, comply with the requirements of the concessionaires as to the particularities of the electric system to which the power plant will be connected (Mamede Filho, 2018).

The autoproducer and the concessionaire must carry out electrical studies of load flow and short circuit, called steady-state studies and dynamic stability studies, in order to obtain authorization to connect to the public grid.

In recent years there have been major initiatives to expand and stimulate the distributed generation of electricity from renewable sources in homes, industrial and commercial facilities, hospitals and public buildings, technical schools and federal universities (Silva et al, 2016).

5. ELECTRIC POWER QUALITY

The definition of energy quality is not unique, it depends on the parameters established by the regulatory agent of each region. The term generally applies to the goodness of the electric power supply, its voltage regulation, its frequency, voltage wave shape, current wave shape, level of impulses and noise, and the absence of momentary outages (Chen, 2005).

There are two main classes of electric power quality disturbances: the steady-state disturbance that lasts for a long period of time and the transient. Because steady-state phenomena last for a long period of time, the integrated effects of active power losses (low or high voltage) and inaccurate timing signals may be quite costly. Transient effects tend to be higher level in amplitude and are often quite apparent in harmful effects as well as occasionally spectacular in cost (e.g., causing loss of a manufactured product or causing long-term outages).

To measure the quality of electric power generated, some indices are used. The most widely used index of power quality is the total harmonic distortion, which is an index that compares the intensity of harmonic signals in voltages and currents to the fundamental component.

The Equation 1 is used for the calculation of THD for current, which is limited by current values specified in the standads IEC 61000-3-2, ANEEL (PRODIST) and IEEE 519.

$$THD_I = \frac{\sqrt{\sum_{h=2}^{\infty} I_h^2}}{I_1} \tag{1}$$

where I1 is the RMS value of the fundamental, and Ih is the RMS value of the h-order harmonic component.

This harmonic index was developed to evaluate the quality of service of a power system in relation to the harmonic distortion levels. They are measures of the effective value of a waveform and can be applied to both current and voltage. The PRODIST module 8 document has set limits on the level of allowable harmonics.

6. WIND TURBINE CHARACTERISTICS

According to the manufacturer, the wind turbine used in bench testing has its generator with the following characteristics: rated power: 1000 W; rated wind speed: 12,5 m/s and rated rotor speed: 740 rpm. In this wind turbine, a 3-phase permanent magnet generator is used. The wind turbine generator has been connected to its own 24 V star connected to electrical load by a diode AC/DC rectifier.

The power generated by the small wind turbine has individual specific electrical characteristics, being necessary to quantify them through tests. The Figure 2 shows the power curve of the tested machine that will be used to obtain the generator efficiency and the energy production injected into the grid.

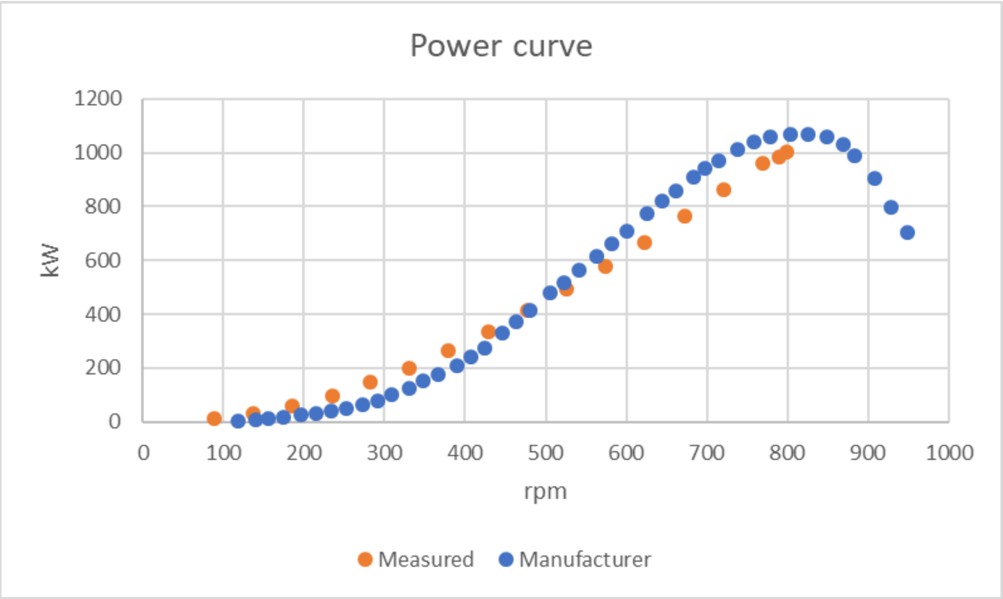

Figure 2. Comparison between the power curve supplied by the manufacturer and that obtained on the bench.

7. RESULT AND DISCUSSION

In this study, three equidistant points of rotation velocities were used simulating the rotation caused by the torque acting on the wind turbine rotor blades. The points chosen for the test were: 740 rpm (rotor rated speed), 530 rpm (where the frequency of generated voltage is 60 Hz, default local grid frequency), and 320 rpm (equidistant point from 530 rpm with respect to 740 rpm value).

Electrical parameters of wind turbine such as voltage, current, frequency, active, reactive, apparent power, power factor and harmonic distortions are given and analyzed as follows. These values are measured and obtained for the time periods of 1 minute, in compliance with IEC 61400-21 standard.

For power quality analysis provided by the generator, will be analyzed histograms of variation of current and voltage values, in addition to the total harmonic distortion. In Fig 3 is shown the voltage and current values of the tested rotation velocities with resistive electric load for a 1-minute test time.

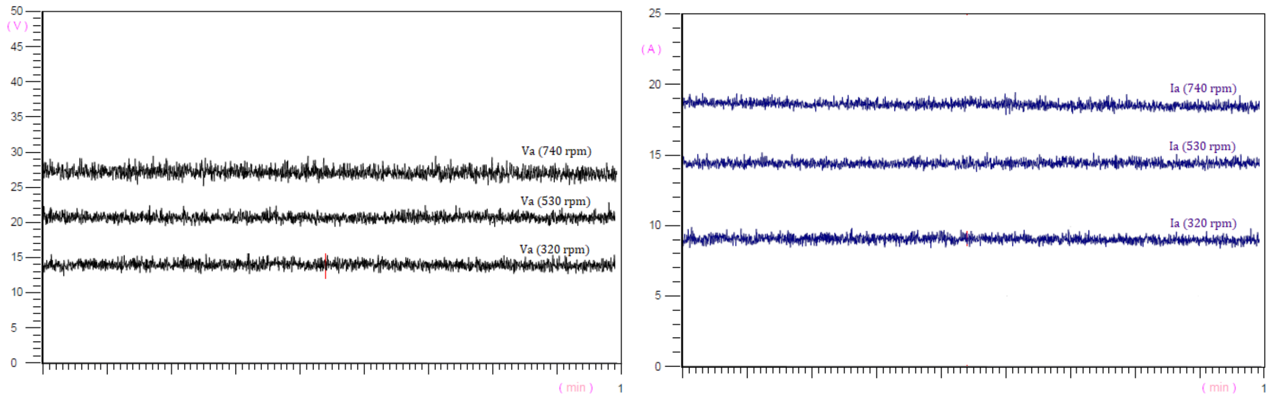

Figure 3. Voltage and current values and waveform of generator output.

Also considering the tests with the resistive electric load, the total harmonic distortion values of the points mentioned above were taken. In Fig. 4 is shown the voltage THD for the rotation velocities mentioned above with rectifier.

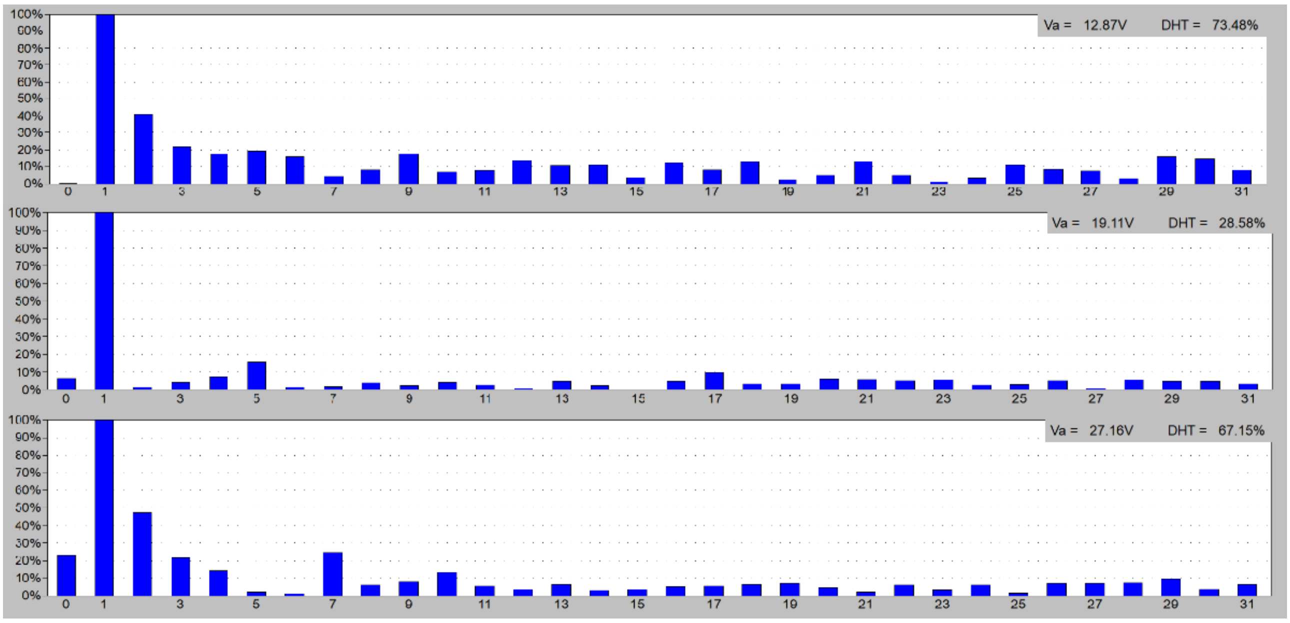

Figure 4. Voltage THD for rotation 320, 530 and 740 rpm, in the order shown.

As seen from Fig. 4, in evaluation of voltage harmonics, THD of voltage for generator exceed the limits in PRODIST module 8 document values of 5%. The deformation of the sine waveform in the rectifier test largely corresponds to the nonlinear characteristic of these components. This feature adds harmonic content upstream of the rectifiers by distorting the waveforms provided by the wind generator.

In the lack of rectifiers, the THD percentage obtained was 10.39% for the voltage of the same phase and under similar conditions. The result shows a significant reduction with this setting. Harmonic distortion in the absence of rectification can be credited to the constructive characteristics of the generator, since the tests were performed with a purely resistive load.

To evaluate the characteristics of the generator, no-load and short-circuit tests were performed analyzing voltage and current, respectively, in one of the generator phases. Harmonic distortion in both cases was below 20%, with distortion of 18.15% for voltage and 13.94% for current, both in phase A.

The dynamic evaluation of generator behavior was performed through voltage and current while the shaft was submitted to rotation acceleration ramps. Two ramps were used from rest until a rotation of 740 rpm times of 60 and 300 seconds (1 and 5 minutes, respectively). Ramps show a linear increase in voltage and current quantities over time, ie with rotation, since the shaft drive ramp relates rotation to time. Distortions are present in both quantities and in all measuring ranges, but are more pronounced at machine start-up as shown in Fig. 5.

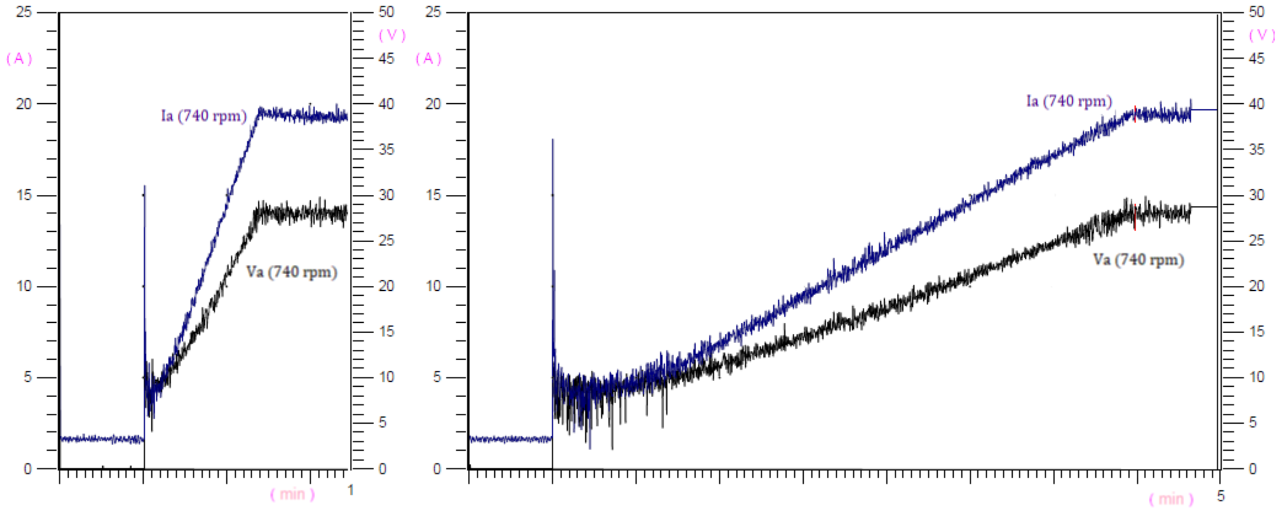

Figure 5. Voltage and current values as an analysis of dynamic behavior of the system in 740 rpm.

8. CONCLUSION

In the tests performed, divergences between the measured and provided values were found. The power curve measured values obtained in the laboratory and provided by the manufacturer show that at an approximate speed of 500 rpm the powers are close, and with the increase in speed the measured curve is below the manufacturer's curve. However, for a rotation of 799.2 RPM the power measured was 1000 W.

To obtain voltage and current waves and voltage THD graphs of one of the phases, a qualimeter was used. The configurations with and without rectification were analyzed, and partial harmonic distortion results from 10.39% at 530 rpm without rectification and 25.13% with rectification were obtained. It was observed that the generator already has a wave distortion of tension by constructive own characteristics and with the rectification this distortion increases.

However, Brazilian standards such as IEC 61400-21 and PRODIST module 8 provide THD limits for input to generation systems and compared to the measured values are quite lower. It can be concluded from the results that the permanent magnet synchronous generator should not be connected directly to the grid, not only because it has frequency variation in power generation and control, but also because it has a high level of harmonics produced. Rectification is a solution for small generators, making a voltage and frequency transformation to grid standards, and thus using a DC / AC frequency inverter.

9. ACKNOWLEDGEMENTS

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11. RESPONSIBILITY NOTICE

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