



## MONITORING SMALL WIND TURBINE USING 3G CELL PHONE TECHNOLOGIES

VILSON GRUBER<sup>1</sup>, LÍRIO SCHAEFFER<sup>2</sup>, JUAREZ BENTO DA SILVA<sup>3</sup>,  
JOVANI CASTELAN<sup>4</sup>, ANDERSON DIOGO SPACEK<sup>5</sup> and  
TERESA RESTIVO<sup>6</sup>

<sup>1</sup>SATC Faculty and UFRGS, Brazil  
e-mail: [vilson.gruber@satc.edu.br](mailto:vilson.gruber@satc.edu.br)

<sup>2</sup>UFRGS, Federal University of Porto Alegre, Brazil  
e-mail: [schaefer@ufrgs.br](mailto:schaefer@ufrgs.br)

<sup>3</sup>UFSC, Federal University of Santa Catarina, Araranguá, Brazil  
e-mail: [juarezbs.silva@gmail.com](mailto:juarezbs.silva@gmail.com)

<sup>4,5</sup>SATC Faculty and UFRGS, Brazil  
e-mail: [jovani.castelan@satc.edu.br](mailto:jovani.castelan@satc.edu.br)  
e-mail: [anderson.spacek@satc.edu.br](mailto:anderson.spacek@satc.edu.br)

<sup>6</sup>FEUP, University of Porto, Porto, Portugal  
e-mail: [trestivo@fe.up.pt](mailto:trestivo@fe.up.pt)

### Abstract

Wind energy generating systems are growing in the world market, according to the Global Wind Energy Council which represents the associations working in this market [1]. Increasingly, these systems require real-time monitoring and follow-up. The equipment is generally installed in remote places and far from technological resources such as phone cables and fiber optics. This makes remote management systems expensive. Advances of wireless technology are growing on an industrial

Keywords and phrases: wind turbine, remote monitoring structures, 3G cell phone networks, communications system, data acquisition, mechanics of analysis.

Received October 14, 2010

and commercial scale in renewable energy markets and in other markets, and further rises are expected. Costs and reliability of reports on the experience of some Telecommunications services operators show evidence that in many industries of other sectors and worldwide 3G Cell Phone Networks are a feasible alternative for data management [2]. These technologies supply long-distance access, reliability and accessibility to the users. A 3G cell phone system can save a company millions of dollars in installation tariffs and the technologies have proved themselves in the field [3]. An experiment is performed using an interface for communication and data collection using the 3G cell phone network simulating the remote monitoring of a wind turbine system where 2 (two) variables are monitored at a distance to analyze the data acquisition.

### 1. Introduction

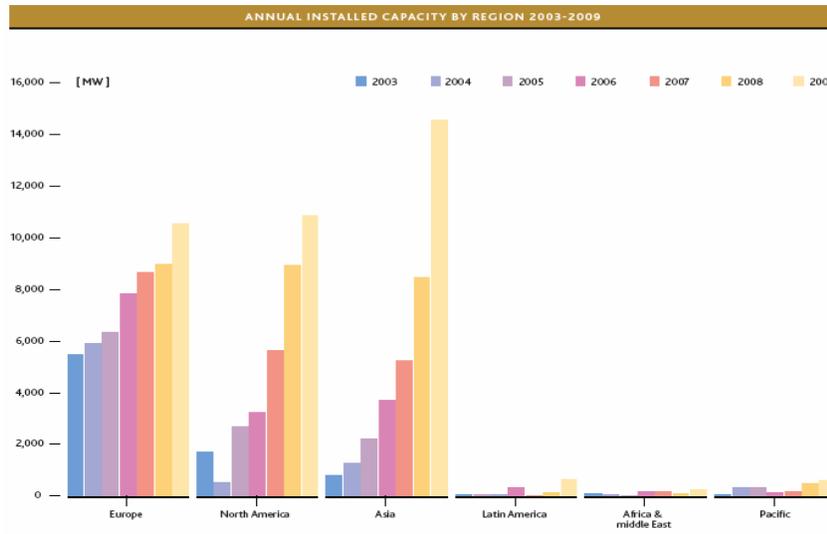
Currently, data transmission is an essential data monitoring tool in many market sectors. The economic development and high technology of today require instantaneous communication, and it is like a strategy for our survival in the market, where simultaneous communication will be decisive to conquer new customers [4]. Due to the growing need to obtain information from several places at the same time showing online results, there is an increasing presence of data communication media in the daily life of people and businesses, requiring a constant search for new techniques and means to establish this communication. It is not at all easy to make monitoring, supervision and data control platforms available online in machines and equipment in real time [5].

In the investment strategy, the appropriate choice of technologies and the means to establish this communication when integrating the different types of equipments distributed to different “remote” sites are a major factor for the success of the data that are to be monitored. The 3G cell phone network technologies provide very useful resources that can be applied to integrate different technological systems to learning and distant experiments.

These systems can reach extreme or remote locations where it is impossible to install fiber optics or even implement a complete wireless communication system. In order to enable the use of renewable energy systems, we need them to be self-sufficient or to require minimal maintenance. Remote monitoring systems play this role, providing distant management of one or more wind generation units. Reducing unnecessary visits by maintenance staff is already a major advantage of remote

monitoring. Currently, several technologies are used for this purpose, but wireless communication channels are still a paradigm for many [6].

There is an increasing visibility of the use of renewable energies such as wind generation. According to data on installed global capacity, Figure 1, conscientious countries are already seeking to reduce CO<sub>2</sub> emissions, and the energy revolution is already here [7], increasing our daily comfort, consuming less energy and providing clean energy.

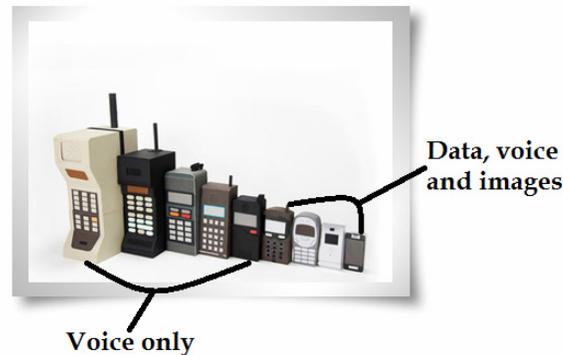


**Figure 1.** Annual installed capacity by region 1996-2009. Source: Global Wind Energy Council.

## 2. Object of Study - Motivation

Cell phones are the fastest growing branch of telecommunications. This success is due to terminal mobility, the area covered by the service, the increasing possibility of roaming and, especially, the competition of private companies. The latter have used an improved marketing technique to challenge the state-owned companies to do more and get out of their comfort zone. In addition, the prices of subscriptions and tariffs are considered reasonable by the users [8]. With cameras, music and location tools, cell phones are no longer simply voice communication equipment. Today more digital cameras are sold as part of a phone than separately. In coming years, the

mobile phone networks will be responsible for most hits on the internet [9]. The evolution of voice and data technologies and the cell phone system technology standards worldwide are shown in Figure 2.



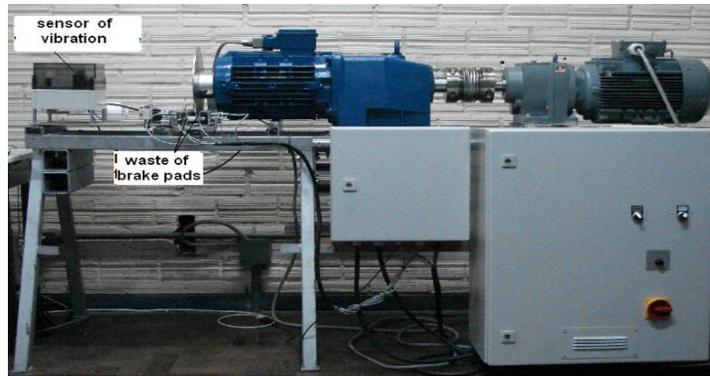
**Figure 2.** Evolution of cell phone system.

This paper attempts to identify the most relevant aspects of the context of using a new technology, that will contribute to a substantial improvement in situations where emergency decisions may have to be taken to solve problems based on events, and thus possibilities that from this new perspective, evaluation situations can be created, identifying actions and adding value to their services, with new ways to improve the remote monitoring of Wind turbine. In this context, distance monitoring via a 3G cell phone network will provide:

- ✓ More efficient remote supervision of events;
- ✓ Reassessment and readjustment of repair time, in case of flaws identified by the system, thus reducing the mean time to receiving attention (TMA);
- ✓ Better use of labor;
- ✓ Reduced maintenance and reworking costs incurred by the distant monitoring system.

### **2.1. Description of the Wind turbine system studied**

Below, the Wind turbine system is described, set up on a bench with 7.2kW potency and a braking system with a disk brake and sensors to simulate and analyze: winds, temperature, wear of the brake pads, tower vibration and exit tension, as represented in Figure 3. The Wind turbine used is classified as small and can be connected to the electrical grid or used in isolated systems.



**Figure 3.** Wind turbine: front view.

## 2.2. Braking system



- 1 Brake disk
- 2 Brake pad
- 3 Brace
- 4 Pressure spring
- 5 Magnetic coil
- 6 Ferromagnetic cylinder
- 7 Magnetic lever system
- 8 Motor to release the brake

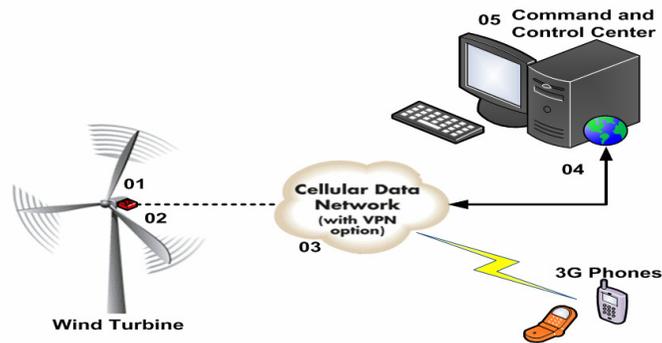
**Figure 4.** Braking system of the Wind turbine.

Small Wind turbines have a disk brake. It is configured as an emergency brake, but in isolated operation, it is also used as a regular brake. A regular brake means that it is used for often repeated normal braking processes. This happens when, in an autarchic system, the energy generated cannot be absorbed, so that the machine must be turned off and stopped. Emergency brakes only intervene in cases of casual interferences in normal operation by triggering the vibratory switch. In addition, the brake is used for maintenance work. A machine can be stopped with different braking systems. However, a cheap, simple alternative must be found which will not make the existing wind turbine bear additional high costs. There are eight action principles in the market that would make it possible to brake the Wind turbine. They are shown in Figure 4: disk brake, drum brake, band brake, electromagnetic brake, electric brake, retarder, aired resistance break, electric regenerative brake. In the article “Análise de Desgaste em Materiais de Atrito Orgânicos e Sinterizados,

Utilizados em Aerogeradores de Pequeno Porte”, (Wear Analysis in Organic and Sintered Friction Materials used in Small Size Wind Turbine) [10], the importance of the wear behavior of types of materials used in brake pads is analyzed.

### 2.3. Structure of the communications system via 3G cell phone network for distance monitoring

The remote monitoring system via 3G cell phones network comprises of five key process elements: (1) Intelligent machines and/or sensors, (2) Remote terminal unit, (3) Communication base, (4) Data transmission and reception system, and (5) Control and command center, as shown in Figure 5.



**Figure 5.** Data acquisition system.

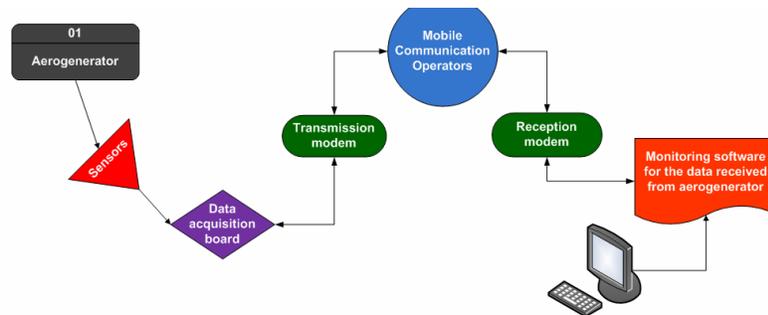
For the system analyzed, a system consisting of sensors installed in the Wind turbine was used to simulate brake pad wear, tower vibration analysis, and a data acquisition plaque developed and configured to transmit signals. The system will transmit the data to a server on Internet. For this purpose, the system must have the capacity to connect with the Internet. Therefore, it was decided to use transmission and reception via 3G cell phone network, using the structure of a local phone company network.

### 2.4. Experimental bench

Wind turbines are usually installed near homes, but these may be far from town, making it difficult to transmit data concerning the generator to a central station. There are a few solutions to this problem which will be presented below. Two sensors must be monitored in the Wind turbine built for bench tests. One is the

vibration sensor at the tower, which is to prevent generator collapse, and the other is the disk brake wear sensor which informs when it is time to change brake pads. Data from each sensor were collected directly in the generator by simulations and sent to a remote computer using the 3G cell phone system.

The medium used to transmit these data was via the 3G cell phone network configured as follows: A data acquisition plate captures the sensor data and sends them to the phone transmitter; the latter in turn is to transmit to the receptor at a certain distance from the generator, where the data are collected. Figure 6 shows the schematic of the solution presented.



**Figure 6.** Diagram of the solution to monitor variables in a Wind turbine.

## 2.5. Methodology to apply remote monitoring using the 3G cell phone technology

The methodology presented below can be used for various applications [11], but to prove how it functions, we applied it to a small wind generation system. This system has a vibration sensor on the tower, informing when there are strong winds (vibration). Above standard winds may damage the Wind turbine, thus requiring maintenance [12]. Another sensor is used for brake pad wear. Since this Wind turbine is small, there is a brake system for possible breakdowns of the system. The problem is to define the time when the brake pad must be changed, therefore, a system of sensors was installed specifically to indicate their level of wear. For the study shown, the tower vibration and pad wear sensors were used to verify the variables monitored and transmitted over a distance by 3G cell phone networks.

### 5.5.1. System operation

The monitoring system developed is based on a cell phone modem which will

receive the onboard electronics system signals. Software with a high level language receives the modem signals and processes them. This processing means to evaluate the sensor values and determine the best action to be taken. For instance, if the vibration sensor shows excessive vibrations on the wind turbine tower, then the screen shows an alarm indicating the problem in the system.

In this way, a professional at the center of operations may take the required measures. After the entire operational system is initialized and the access to the 3G phone network is configured, acquisition of the vibration data from the wind turbine tower and of brake pad wear begin based on an acquisition board. This acquisition system monitors the sensors and when some pre-defined, off normal signal appears, the system triggers the remote access connecting to the 3G cell phone and transmits the values generated. The analog and digital converter receives a command requisitioning the tower vibration data, from the acquisition system via 3G network. The function that performs the transmission establishes the PPP connection, [13] between the system and the WEB monitoring platform.

Once the connection is established, the micro controlled acquisition system sends the data through a requisition to the monitoring and control center as shown in Figure 7.

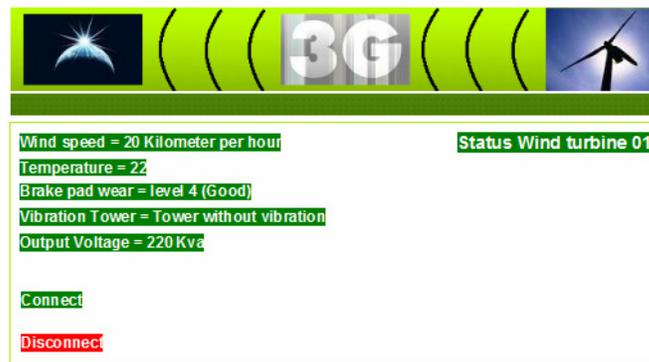


Figure 7. Monitoring and control system.

### 2.5.2. Obtaining remote data for the Wind turbine

The remote monitoring systems controlled are the main sources of information available to the operators of the monitoring and control center, which enabled the online diagnosis before the stage of system restoration. The only data are those

obtained by the sensors and transmitted to a computer by means of the 3G cell phone network. Several transmission and reception tests of the variables were simulated for the study. Below is the description of two bench tests performed, described as shown in Figures 8, 9(a) and 9(b).

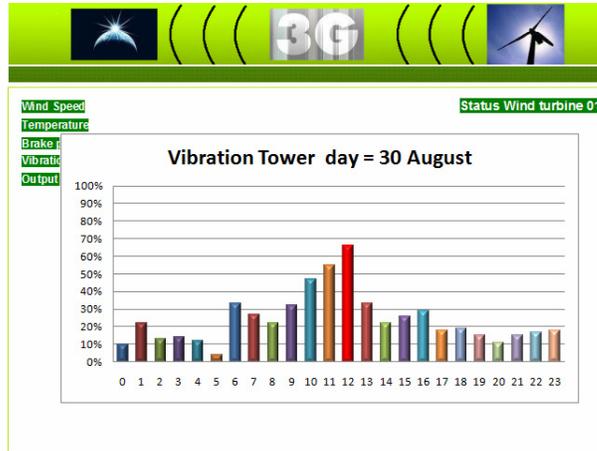


Figure 8. Tower vibration evaluation period.

Transmission and reception of data on wear of the first set of brake pads, option LEVEL GOOD.

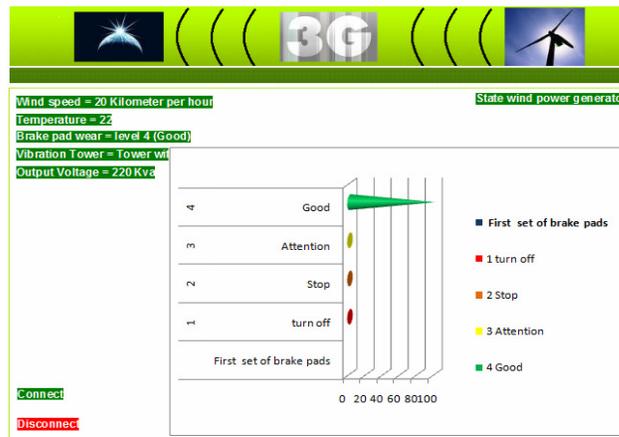


Figure 9(a). Wear screen of the first set of brake pads, option LEVEL GOOD.



**Figure 9(b).** Wear screen of the first set of brake pads, option LEVEL STOP.

**Transmission and reception of brake pad wear data, wear screen of the first set of brake pads and option LEVEL TURN OFF.** The system at this level will send a command to disconnect/turn off the Wind turbine automatically, without any intervention by the system operator.

### 3. Results

After the tests were performed with the first set of brake pads, these pads were replaced and the monitoring of the second set began. Analyses can be performed infinitely every time the brake pad set is changed for each wind turbine equipment that we wish to monitor. The data will be useful for several analyses of components and materials we wish to monitor, providing continuous improvement in the manufacturing process of several components installed in the wind turbine equipment.

It is possible to interact remotely with the device and obtain constant information about its operation variables using existing communication networks by reading the measurements it is performing.

### 4. Conclusions

Among the items proposed, since the beginning of the project, it is concluded that the results of all tests performed were satisfactory. The project proved versatile

because, since they are communication systems, it can easily be adapted for implementation of remote automation systems for the different sectors of the market and the industry at large.

The project shows how easy it is to interact with equipment remotely, using the existing communications networks. IT provides a broad overview of possible applications in many fields.

Study of wind turbine variables transmitted by Remote Monitoring Systems via 3G cell phone will provide a greater control of the use of Wind turbine installed, not only in the laboratory where tests are performed, but also at all those that are to be monitored.

Future prospects of existing technologies are the unification of the different networks of access to telecommunications, including cell phone networks, wireless, satellites and fiber optics, in the different existing technologies. Not only the fixed cell phone public networks will be integrated, but also the wide area networks (WANs) will be interconnected, allowing the connection of laptops and other devices to infinity of new wireless service providers, practically anywhere in the world.

This study also shows that, at remote locations which are difficult to access, or where the physical lines do not reach the wireless communication or cell phone network employed in this study, the use of frequencies and operating in the bands cleared by the agencies responsible for telecommunications services is currently the technology which presents as a safe, reliable and an appropriate solution for data communication.

It is also found that, a 3G cell phone network will allow reducing investment costs in a possible implementation for remote locations, knowing that **most of the wind turbine equipment is** installed at sites where it would be very difficult to place a cable transmission system. This is due to requests for authorization to pass through, implementation and maintenance costs, and others.

### References

- [1] WWEA-World Wind Energy Report Association, March 2010.
- [2] A. Dorman, Wireless Communication: O guia essencial da comunicação sem fio, Tradução Fabio Freitas, Rio de Janeiro/RJ. Editora Campus, 2007.

- [3] C. M. Scheitzer et al., *Tecnologias de Redes sem fio: WPANs, WLANs e WMANs, Desafios de Segurança, Vulnerabilidades e Soluções* – Universidade de São Paulo – USP, São Paulo/SP, 2006.
- [4] A. M. Ferrari, *Telecomunicações: Evolução and Revolução*, 2ª. ed., São Paulo/SP, Editora Érica, 2008.
- [5] V. Lee, H. Schneider and R. Schell, *Aplicações Móveis: arquitetura, projeto e desenvolvimento*, São Paulo/SP, Editora Makron Books, 2005.
- [6] V. Fiorese, *Wireless: Introdução às Redes de Telecomunicações Móveis Celulares*, Rio de Janeiro/RJ, Editora Brasport, 2005, p. 336.
- [7] L. Qiao and S. Sawyer, *Global Wind 2008 Report*, GWEC – Global Wind Energy Council, 2008.
- [8] A. M. Ferrari, *Telecomunicações: Evolução and Revolução*, 1ª. ed., São Paulo/SP, Editora Érica, 2009.
- [9] E. Dahlman, S. Parkvall, J. Skold and P. Beming, *3G Evolution, Second Edition: HSPA and LTE for Mobile Broadband*, 2a ed., Porto Alegre/RS, 2008.
- [10] L. Schaeffer, F. Arrieche and J. Lewis, Jr., *Análise de Desgaste em Materiais de Atrito Orgânicos e Sinterizados, Utilizados em Aerogeradores de Pequeno Porte*, Porto Alegre/RS, 2007.
- [11] G. T. Tateoki, *Monitoramento de dados via internet baseado em telefonia celular*, Dissertação de Mestrado da Universidade de Campinas/SP, 2007.
- [12] O. Lutz, *Situação, necessidade de desenvolvimento, concepção de configuração e perspectivas de aerogeradores de pequeno porte a serem utilizados no Brasil*. 2006. 149 f. Dissertação de Mestrado da Universidade do Rio Grande do Sul - Porto Alegre/RS, 2006.
- [13] A. S. Tanenbaum, *Sistemas Operacionais Modernos*, 2ª. ed., Editora Prentice Hall Brasil, Rico, 2007.

Paper # PPH-1010039-EC

Kindly return the proof after correction to:

*The Publication Manager  
Pushpa Publishing House  
Vijaya Niwas  
198, Mumfordganj  
Allahabad-211002 (India)*

along with the print charges\*  
by the fastest mail

**\*Invoice attached**

Proof read by: .....

Copyright transferred to the Pushpa Publishing House

Signature: .....

Date: .....

Tel: .....

Fax: .....

e-mail: .....

Number of additional reprints required

.....

Cost of a set of 25 copies of additional reprints @ U.S. Dollars 15.00 per page.

(25 copies of reprints are provided to the corresponding author ex-gratis)