Digital Anemometer and a Wind Direction Sensor Based on Microcontroller

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Abstract

This paper has the goal to show the project of a digital anemometer with a wind direction sensor, developed in the Federal University of Ceará. The equipment is of easy construction, low cost and built with materials found in the Brazilian market. The instrument measures the wind speed and direction having as a base a mechanical system coupled to a optic sensor and linked to a computer, that makes the collection of data automatically through a program elaborated to interpret the received data, saving them for applications in the energetic area.

1. Introduction

The last hydroelectric power plants in the Brazilian Northeast region were built in the last decade. Furthermore, this region has a great wind energy potential. This is true mainly in the State of Ceará, which is leader in the use of wind energy in Brazil, with an installed wind power capacity of 17.4 MW, whereas the present total wind capacity in Brazil is now 22 MW. To support the wind parks to be installed in the region is necessary the development of a wind industry. One of the most important wind industry sectors is that of measurement instruments and sensors.
The function of an anemometer is to measure the wind speed. Cup anemometers are widely used for many reasons. They are generally well suited to definition of mean wind speed, tend to be cost attractive and are very robust. On the other side, cup anemometers have limitations [IEA99]:

- Non-ideal sensitivity to angle of attacks out with the horizontal plane;
- Dynamic response;
- Non-linearity of calibration and variation in calibration caused by mechanical friction or due to the shape of the cups;
- Changes in calibration sensitivity with horizontal wind direction.

The cup anemometer conventionally consists of three hemispherical or conical cups arranged in a vertical rotor configuration that drives the signal generation [BLACKADAR85], as shown in the figure 1:

Figure 1: The developed cup anemometer

A cup anemometer for wind energy applications can be expected to experience a range of environmental conditions during operation. Table 1 shows the operating ranges in which accuracy is important for power performance assessment. The limit values reflect wind turbine operating ranges and typical climatic conditions.

Table 1: Operating ranges for a cup anemometer [IEC99]

Parameter	**Units**	**Minimum value**	**Maximum value**
Wind Speed	m/s	4	16
Turbulence Intensity	%	5	100*(1.13/u+0.12), where u is the prevailing wind speed
Air Temperature	°C	-10	+40
Air Density	kg/m^3	0.90	1.35
Slope of Terrain	°	-10	+10

2. Development

The developed digital anemometer with a wind direction sensor has as a base the microcontroller 8051 INTEL, with the possibility of data acquisition using a PC with an adequate software. In this way, the developed equipment has the advantage of using a low cost microcontroller that is easy of obtaining in the Brazilian market; it offers also the possibility of data acquisition in intervals of programmable periods.

The main program screen is shown in figure 2, with a window for the wind speed and for the wind direction and a table for the collected data.

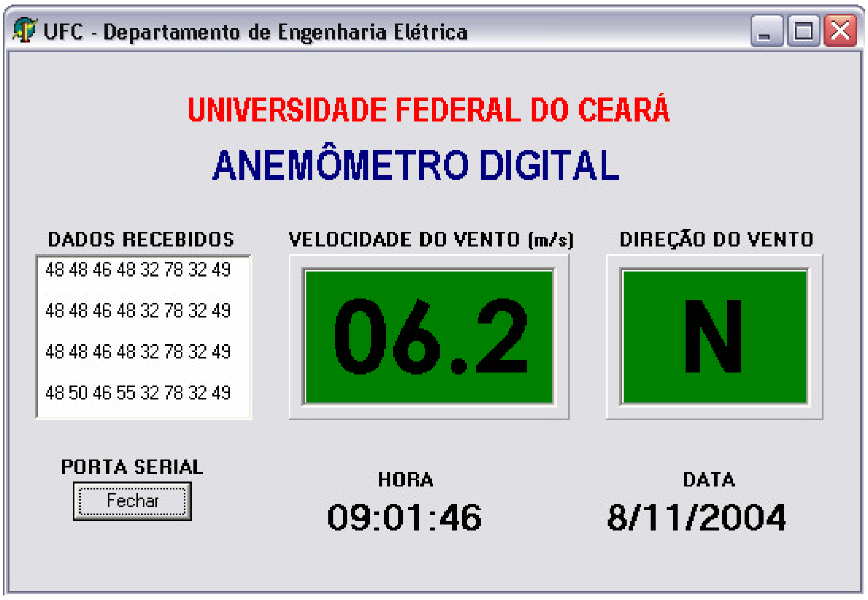

Figure 2: The main program screen

The basic data acquisition structure is composed by a optic sensor and a disk with 30 holes, as can be seen in the figure 3. In the digital equipment, each rotation of the disk generates an electric pulse, that is captured by an electronic system of data acquisition. As 30 pulses correspond to the distance of a turn, being counted the number of pulses in an interval of time one has the distance traveled by the wind. With the distance and the time the medium wind speed is calculated.

The optic sensor reads the pulses obtained by the rotation of the disk, that is a function of the wind speed. These pulses go to a circuit for signal treatment and are later sent to a microprocessor with the goal of making the data processing, which consists of counting how many pulses are read per time unit. For the exact calculation of the wind speed, it was created a calibration variable that can be adjusted easily so that the developed equipment shows the same speed of calibration equipment, in this case used as a pattern.

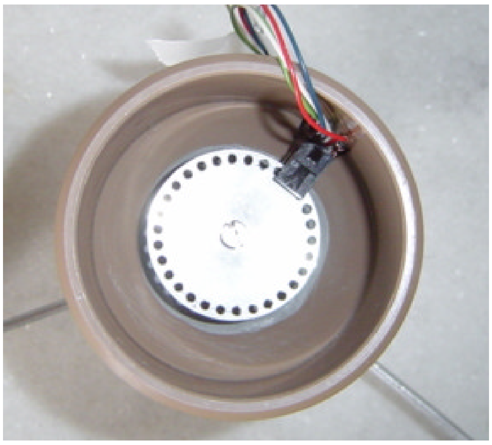

Figure 3: Wind speed sensor

For the wind direction measurement, another optic sensor was used, which consists of a disk codified in sections that are read by the microcontrolador for each of the resulting directions, as shown in the figure 4; table 2 shows the codes for the wind direction. Figure 5 shows the basic steps of the measurement unity.

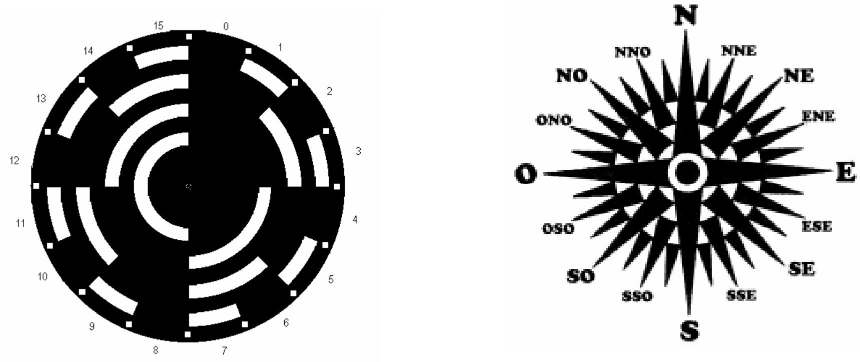

Figure 4: Wind direction sensor

Table 2: Codes for the wind direction

CODE	**DIRECTION**	**CODE**	**DIRECTION**	**CODE**	**DIRECTION**	**CODE**	**DIRECTION**
0000	N	0100	E	1000	S	1100	O
0001	NNE	0101	ESE	1001	SSO	1101	ONO
0010	NE	0110	SE	1010	SO	1110	NO
0011	ENE	0111	SSE	1011	OSO	1111	NNO

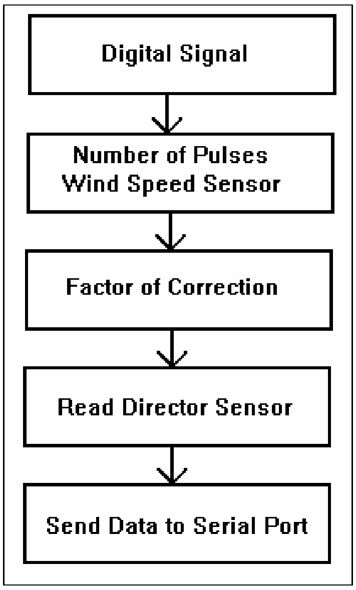

Figure 5: Steps for the data acquisition

3. Results

The present research has as result the development of a digital anemometer with the following hardware characteristics:

- Microprocessed circuit with communication serial with a PC;
- Measurement gap: 0.0 to 29.9 m/s;
- Optical sensor for the wind direction in 16 steps;
- Date hold;
- Display with 3 digits (optional);
- Low energy consumption.

Measurement tests were made and the results were compared with a standard anemometer, according to table 3. It is observed that the developed prototype has a satisfactory performance in all the speed ranges, being the measurement error smaller than 1.2%.

Table 3: Measurement errors: developed versus standard anemometer

Speed range	Error	Speed range	Error	Speed range	Error
0 – 3 m/s	+0.10 m/s	6 – 12 m/s	+0.32 m/s	16 – 24 m/s	+0.86 m/s
3 – 6 m/s	+0.16 m/s	12 – 16 m/s	+0.52 m/s	24 – 30 m/s	+1.18 m/s

The anemometer was tested under constant wind, having as reference other anemometer with the goal of obtaining the instrument correction factor. In the figure 6 can be visualized the obtained values and the respective curve of the instrument, that demonstrates a linear function

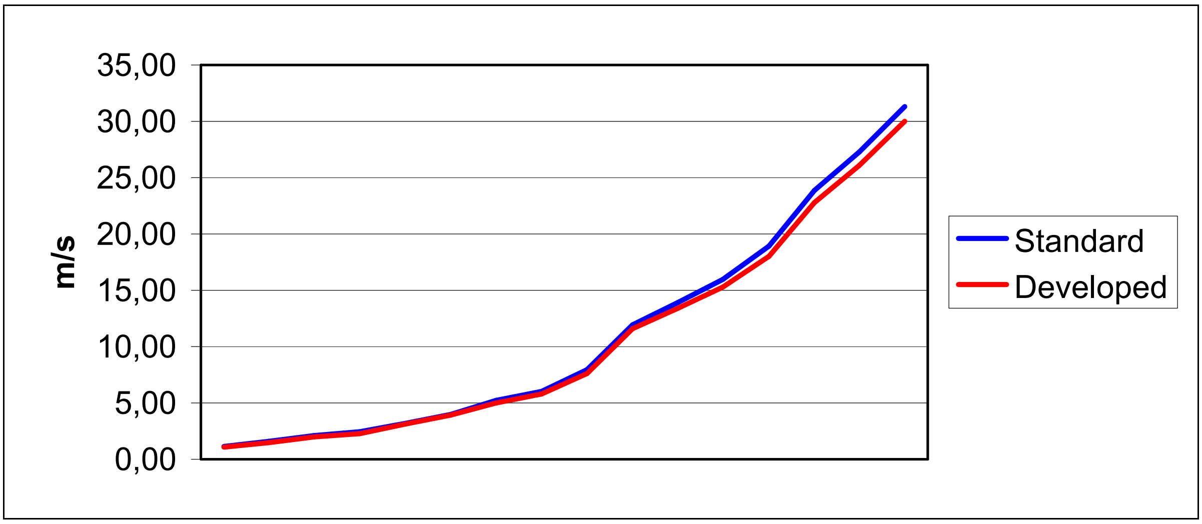

Figure 6: Developed versus standard anemometer

4. Conclusion

The developed anemometer shows a good answer to the changes of wind speed. The curves of calibration have a linear behavior that allows the use of a simple routine of adjustment in the data acquisition software. The use of a optic sensor allows a frequency of pulses collection in a high rotation of the disk, not generating attrition with the disk. In this way, an appropriate signal is supplied in a digital format, reducing the number of components in the interface with the computer.

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