



Small Scale Wind Emulator As An Educational Tool For The Study Of Wind Turbine Systems

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ABSTRACT-

This paper presents a prototype that allows to configure in a computer the typical wind conditions for some period of the year, as well as to manually control the electric motor that generates the airflow for the required tests of small-scale wind turbines using a variable speed drive. The system is focused on supplying the artificial resource to the renewable energy system of the Universidad Distrital, which is currently used in practice by coupling a DC motor to the mechanical input of the wind turbine, which is varied in speed with a voltage source to see the changes in the voltage generated at the output of the wind turbine, which is not a true approximation to the wind systems involving the stochastic model of reality. For this reason, an integrated solution was implemented by using an embedded system to communicate an algorithm developed in Matlab software and an adjustable speed drive (ASD) to activate a wind extractor to closely reproduce real wind conditions for testing wind turbine equipment and electronic converters for small and medium scale renewable energies.

Keywords: ASD,PWM Inverter,Stellaris,Wind Emulator.

I. INTRODUCTION

Wind energy as renewable energy is one of the most abundant in nature and over time has had great acceptance in many countries of the world because it is clean energy, that is, it does not produce carbon dioxide emissions (CO₂). (World Wind Energy Association, 2014). The wind speed over a certain time is not constant and it is very rare that in most of the areas where the turbines for electricity generation are located, there are winds with high speeds, while the most

common is to observe winds with moderate speeds. (Nelson, 2009). Wind in different conditions presents a probabilistic behavior.

The wind speed at a given place and time is a stochastic phenomenon, the speed will depend on the speeds at previous times and will have completely random components, which makes it difficult to predict this speed accurately. Usually, the probability distribution of the wind speed at a given location and time can be fitted to a Weibull distribution, but not always the probability distribution fits this type of distribution.

This project developed an emulator capable of generating a wind gust that allows testing a wind turbine as a particular application, in a controlled environment to study and develop complementary electrical and electronic systems that have wind turbine systems.

II. PROBLEM FORMULATION

The use of wind resources is a pressing need in our society and our country cannot remain on the sidelines in these technologies. The construction of new conventional power plants of large and medium power is being relegated by the inclusion of wind turbines in energy systems. The wind resource varies significantly in each region and time of the year and it is very important to be able to evaluate the response of these generators for different operating conditions on a small scale to develop solutions according to the geographical conditions of our country. (Robyns, Davigny, François, Henneon, Sprooten, and Robyns, 2021)

The emulator system integrates technologies in software, communications, computational intelligence, electrical machines, power electronics and embedded systems, which allows it, in addition to the original basic function, to be a learning tool for new members of the LASER research group (Laboratory in Automation, Embedded Systems and Robotics) recognized as a research group at the Universidad Distrital Francisco José de Caldas, and Colciencias, in the area of embedded systems and wireless communications, generating new knowledge and opportunities for technological development.

III. SYSTEM DESCRIPTION

Figure 1 shows the block diagram of the implemented system. The electrical motor receives the power signals from the adjustable speed drive (ASD) to generate the wind flow that reproduces the wind resource that would be obtained in the field. The motor was specified to obtain from 2m/s to 20m/s, which are typical speeds of the power curves of commercial wind turbines. The variable speed drive receives the control signals through its communications port that are sent through the card, which in turn receives the data from the computer to establish a specific profile. (Anaya-Lara, Jenkins, Ekanayake, Cartwright, and Hughes, 2009)

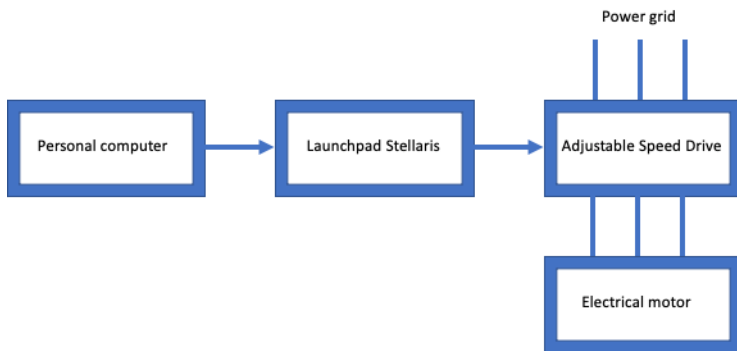


Figure1: Block diagram

Power module

For wind emulation, a motor (extractor) with the necessary power to ensure a wind speed $v \geq 18\text{m/s}$ was sought as a priority, for this task an exhaustive search was carried out in the market for devices that met this essential requirement. In the first step, several motors (extractors) were evaluated using a digital anemometer, finally, we found an extractor that fulfilled this fundamental characteristic, which consists of a three-phase motor of 5 HP at 1800 rpm with aluminum blades, represented in a diameter of 28". The extractor is shown in Figure 2. (Pramod, 2016)

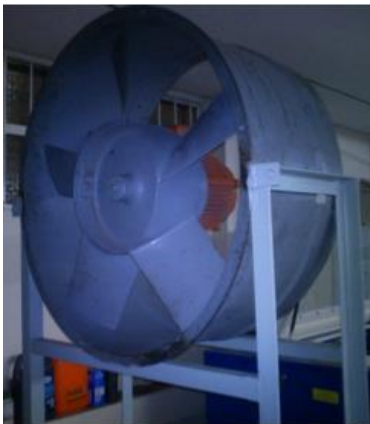


Figure2: Extractor for the wind emulator prototype

To maintain a voltage variation proportional to the frequency, and a linear change in the rotation n , we considered using an ASD. The ASD to be used is a HuanYanf of the same power as the three-phase motor 5-HP at 220-V. To keep the torque constant with the speed variation, the drive is a pulse width modulated voltage source inverter type (PWM-SVI2), the PWM inverter

controls both the frequency and the magnitude of the voltage output. (Nannam& Banerjee, 2021)

The three-phase pulse-width modulated inverter is responsible for shaping and controlling the three-phase output voltages in amplitude and frequency using a constant voltage V_d . To have a balanced three-phase voltage at the output, the three-phase signal is compared, usually with a triangular voltage signal, with three sinusoidal control voltages 120° out of phase.

At low frequencies, a voltage boost is necessary to keep the air gap flux constant for a given torque, the voltage proportional to f at low frequencies is shown with a dotted line, a much higher voltage boost is required at low operating frequencies, due to the voltage drop in the rotor resistance while at large values of frequencies this effect on the rotor resistance can be depreciated.

A variable frequency drive usually consists of a control circuit that accepts the frequency reference signal $f(r,ref)$, a current limiting circuit that compares the actual motor current with the current limit, a slip compensator to keep the rotor speed constant by adding a term to the stator frequency and a voltage boost to keep the air gap flux constant at low frequencies. With a constant torque proportional to the speed, the extractor is characterized to obtain a frequency-dependent function.

Control module

After obtaining the characteristic equations of the emulator, the function data are digitized and processed by the Texas Instruments Launchpad Stellaris, shown in Figure 3.

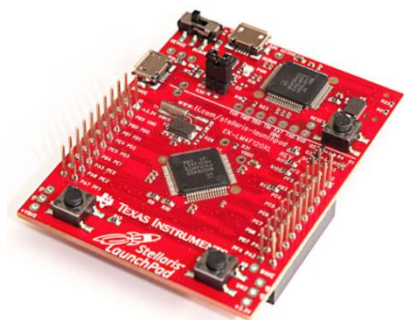


Figure3: Launchpad Stellaris

The digitized signal coming from the microcontroller is converted to an analog signal using an 8-bit DAC made with a resistor array of the form $R-2R$ (Valvano, 2013). The designed circuit works at 15 V, coming from regulating the 24 V reference voltage coming from the ASD control port. (Boldea, 2008)

Figure5: ASD speed controller implementation

IV. RESULTS

Initially, wind speed measurements were taken at different frequencies in an open environment with a hand-held digital anemometer, but when they were taken again to verify the results, it was found that the characteristic curves of wind speed concerning frequency varied considerably, due to external variables such as the wind itself, which greatly altered the results obtained.

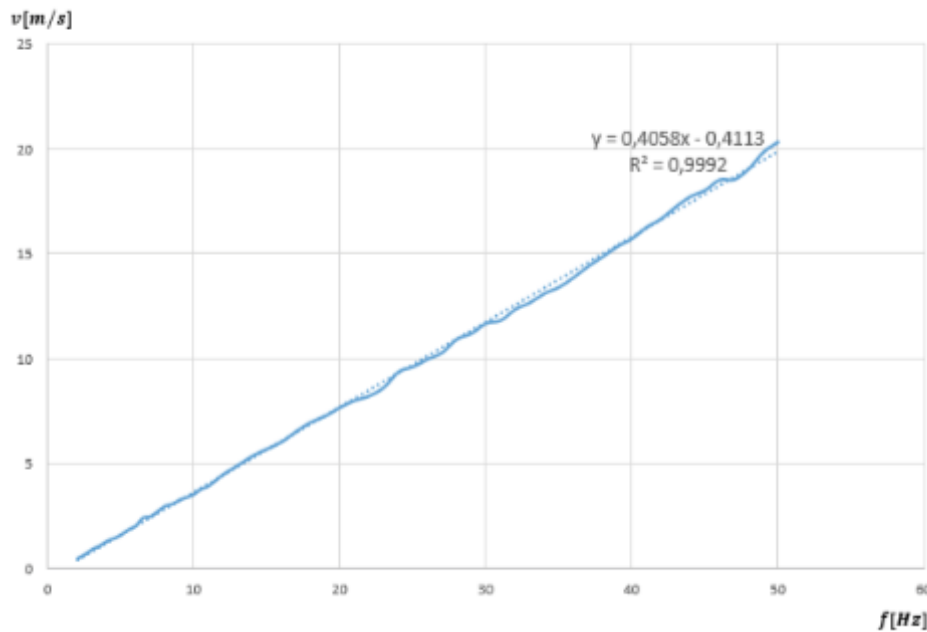


Figure6:Emulator characteristic curve

To emulate the results of the wind speeds, the DAC function is established for each case and the wind speed measurements are made for a speed range of 0.5 m/s to 11 m/s, since this is the maximum value of the data, with steps of 0.5 m/s per measurement. To verify, the measurements are made in the same way as the extractor was characterized, taking the data with the digital anemometer and capturing the data in an interval of 30s, averaging the value of all the data obtained in this time to arrive at a standard measurement of each value of the speed. In the initial data, there is a greater error because they are very small values.

Results at the origin. In this case, we worked with the following function

$$DAC = \text{int}(10.741v + 3.1463)$$

For which the following emulation results were obtained, compared to the real data. See Table 1.

Table1: Prototype emulation error

Real value (m/s)	Averagemeasured value (m/s)	Error(%)
0.5	0.948	89.6
1	1.355	35.5
1.5	1.749	16.6
2	2.177	8.85
2.5	2.649	5.99
3	3,214	7.16
3.5	3.628	3.68
4	4.176	4.42
4.5	4.505	0.121
5	5.106	2.12
5.5	5.335	2.98
6	5.865	2.25
6.5	6.545	0.69
7	6.860	1.98
7.5	7.316	2.45
8	7.835	2.05
8.5	8.067	5.09
9	8.475	5.83
9.5	9.114	4.05
10	9.550	4.49

V. CONCLUSIONS

The development of this project resulted in a functional prototype of a low-cost wind resource generator, which has great advantages for testing low and medium-power wind turbines for the academic community of the Universidad Distrital Francisco José de Caldas.

Through the characterization of the motor and the prototype, the linear behavior of the wind speed concerning the variation of the frequency of the speed variator is highlighted, presenting a low error of linearization for the two proposed distances. However, it is important to highlight the non-linear behavior of the wind speed generated by the emulator concerning the reference

distance, making it difficult to propose an equation or a general model that is independent of the distance.

Since the prototype as such, requires the Matlab tool to generate a desired wind speed in the emulator, with a code very different from the one used to make the prediction, it could be possible to implement software that manages the system modes and is easy to use for anyone. In this way, the prototype will have wider use in practices where it is required to observe the response of a wind turbine to approximate wind conditions. It also enables the improvement and scalability to test different control strategies and circuit design to improve the response of the wind turbine.

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