Critical Design Review

MISCE project

Mechatronics for Improving and Standardizing Competences in Engineering

Competence: Wind Energy

Experimental platform: Mini Wind Turbine

Workgroup: Universidad de Castilla-La Mancha

Universitat Politècnica de València

This document is the Critical Design Review of the technical competence ‘Wind Energy’. It details the complete design of the Mini Wind Turbine platform.

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Visit https://misceproject.eu/ for more information.

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1 Introduction

1.1 Scope

This document presents the detailed design of the Mini wind turbine platform developed in the framework of MISCE project.

The final objective is to use the develop platform in the practical lectures of engineering degrees to contribute to the technical competence:

C1. Wind Energy

which related skills are (see Table I):

Table I. Skills of Wind Energy

S1.1.	Understanding the different turbine designs
S1.2.	Being able to engineer and design turbine components and systems
S1.3.	Practical skills in setting up onshore turbines
S1.4.	Ongoing maintenance of wind farms
S1.5.	Assessing site suitability of wind farms

1.2 Preliminary definition

This experimental platform has been studied for teaching purposes in renewable energy and wind systems education (e.g. [1,2]). It consists of a complete mini wind turbine, including a nacelle that can rotate to align with the wind direction and blades with configurable angle of attack. It integrates sensors to measure wind speed and direction, and the rotational motion is coupled to a small generator to evaluate energy production (see Figure 1).

Figure 1. Mini wind turbine platform

This proposal requires mechanical, electronic, and control systems capable of adjusting the turbine orientation and blade configuration, as well as measuring environmental and output parameters in real time. These features enable students to explore aerodynamic principles, energy conversion, and system optimization in a tangible way.

The main advantage of this platform is its realism: it allows learners to understand all the main subsystems of a wind turbine and to experiment with different configurations. This hands-on experience fosters deeper insight into the mechanical and electrical dynamics of wind energy.

On the contrary, the main drawback is the system's complexity. Its complete mechatronic integration demands significant design and assembly effort, which may require additional technical guidance for effective implementation in academic settings.

1.3 Technical requirements

The technical requirements to efficiently contribute to the achievement of skills of Table I are:

R1. The platform shall allow real-time control of the nacelle orientation (yaw angle) and blade pitch angle to simulate variable wind conditions and optimize energy capture.

R2. The system must integrate wind speed and direction sensors, enabling experimental analysis of wind turbine response under controlled airflow or fan-based excitation.

R3. The electrical generation subsystem shall include a low-power generator and measurement circuit capable of displaying voltage, current, and power output in real time, allowing analysis of energy conversion efficiency.

R4. The platform must include a microcontroller-based control unit (e.g., Arduino or ESP32) that allows students to implement open- or closed-loop control strategies for yaw and pitch motors.

R5. All key components (nacelle, blades, generator, sensors) shall be accessible for replacement, upgrade, or fault simulation to enable hands-on learning in maintenance and diagnostic procedures

R6. The total platform footprint shall not exceed 40×30×30 cm, allowing deployment in standard lab desks while maintaining visibility and ease of handling.

2 Hardware design

2.1 Functional parts

The hardware design includes some functional parts that shall be easy to find and to acquire by the teaching professionals. In this case, the following functional elements have been selected:

- DC Motor/gearbox set 12V and gearbox ratio between 10 and 100 with 64 CPR hall encoder:

Figure 2. DC-motor/gearbox set

- DC Motor 12 V without gearbox or encoder:

Figure 3. DC-motor (Generator)

- Microcontroller ESP32-WROOM-32E:

Figure 4. ESP32-WROOM-32E

- BreakOutBoard FNK0091:

Figure 5. BreakOut board FNK0091

- Driver module L298N:

Figure 6. Driver module L298N

- Converter module FT232 usb c:

Figure 7. Converter module FT232 usb c

- Incremental optical encoder LPD3806-360BM:

Figure 8. LPD3806-360BM optical encoder

- 10kΩ Rotary Potentiometer 10-Turns 1-Gang:

Figure 9. Rotatory potentiometer (10kΩ)

- External Power Supply 12V-5A:

Figure 10. Generic external power supply 12V (up to 5A)

- Additional elements: This item includes cables, connectors, screws, … see the Mounting Instruction document for more details.

With these functional elements the hardware architecture of the device is shown in Figure 11.

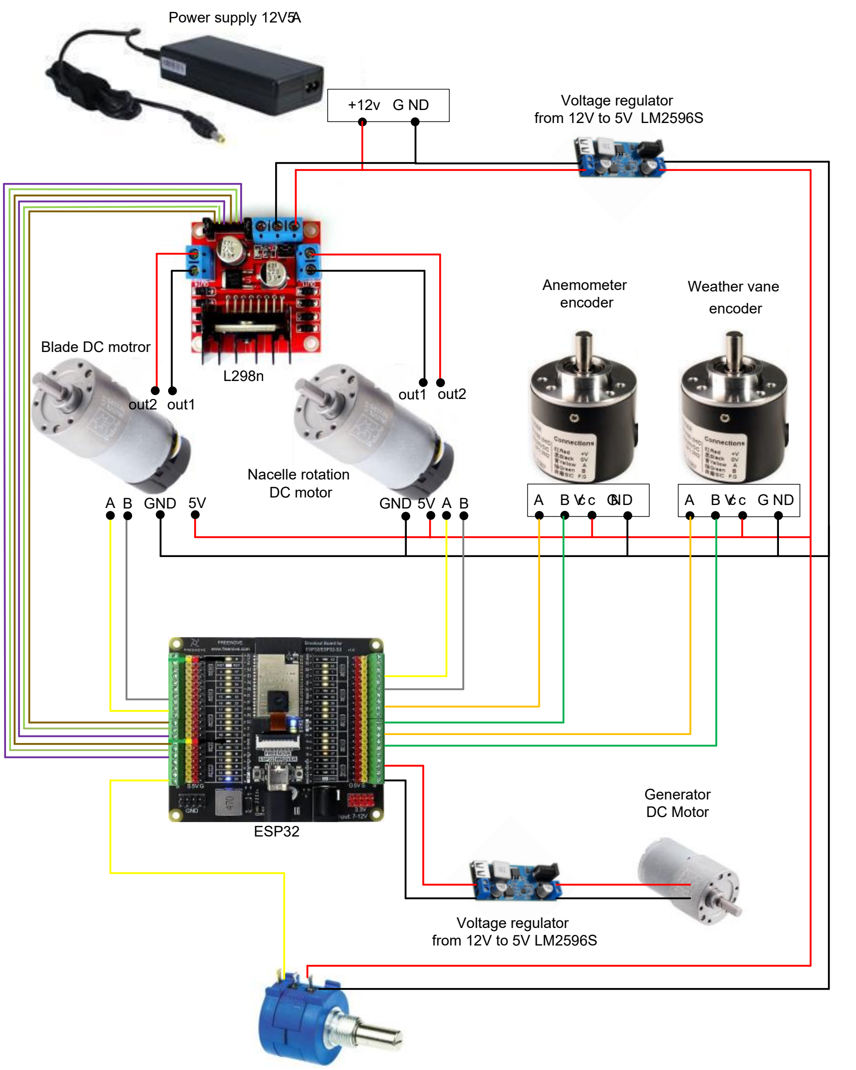

Figure 11. Hardware architecture of the experimental platform

2.2 Mechanical design

The mechanical design of the device has been carried out to be mostly built with a conventional 3D printer. The elements that are not printable, but easily obtained, are the tube connecting the hub and blades to the frame and the frame where all the electronic is mounted. The tube is made of 60 mm PVC, and the frame is designed to be laser cut. Note that the frame can be of different materials such as wood or carbon steel, always 3mm thick. Although it is designed to be laser cut, it could also be 3D printed if needed.

Apart from the 3D printable parts of the mechanism, the platform where all is mounted includes the hardware elements aforementioned in the previous section. The design and placement of all the elements allow the experimental platform to be as compact as possible. Figure 12 shows some renders illustrating the designed experimental platform. The .STL files to print the different parts can be downloaded at: www.misceproject.com.

Figure 12. Mini wind turbine platform renders

The final aspect of the experimental platform is shown in Figure 13.

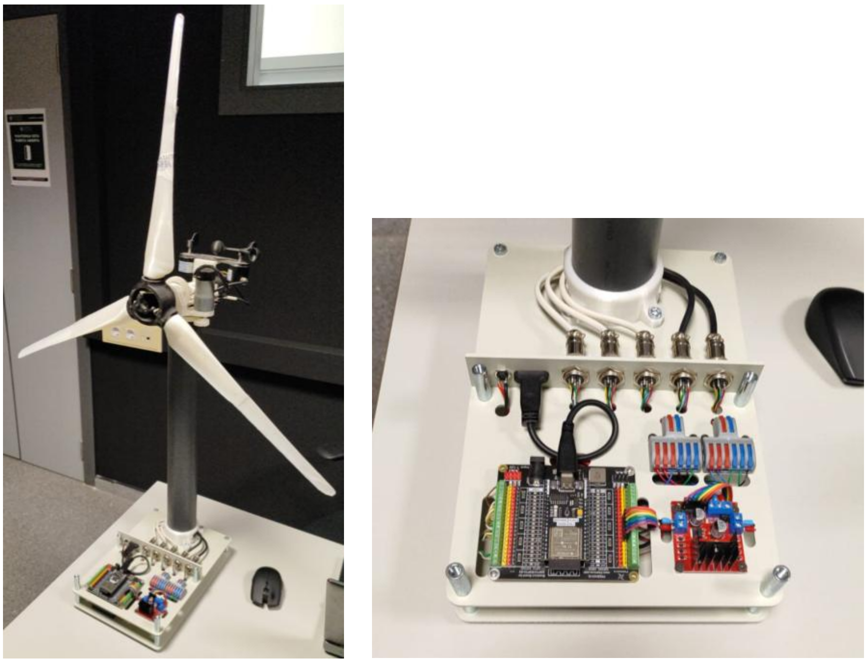

Figure 13. Experimental platform overview

3 Software design

3.1 Preliminaries

The software architecture developed for the mini wind turbine platform supports experimental learning in wind energy by enabling real-time monitoring, control and data acquisition. It is intended for use by both professors and students in academic environments. The implementation is open and license-free: the embedded control is programmed in the Arduino IDE (https://www.arduino.cc/en/software) for the ESP32 microcontroller, while the graphical user interface (GUI) is developed in MATLAB® App Designer (https://es.mathworks.com/products/matlab/app-designer.html)., ensuring compatibility with commonly used academic tools.

Communication between the embedded system and the GUI is established via USB, which is usually available in any desktop or laptop computer. Figure 14 illustrates the software architecture.

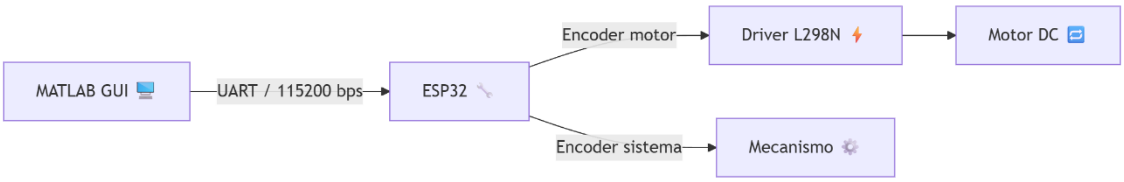

Figure 14. Software architecture of the experimental platform

The end-user of the device only has to download the ESP32 Program from MISCE project webpage and upload it into ESP32-WRROM-32E board and to install the Matlab designer app.

3.2 App design (Matlab®)

The MATLAB® application serves as the main user interface (HMI), enabling students to configure experiments and define input parameters, monitor real-time variables, such as position, velocity or acceleration, visualize and export results.

The code of the Matlab® app and its corresponding installer file are available, under demand, in MISCE project webpage.

3.3 Embedded Software Design (ESP32/Arduino®)

The embedded control program running on the ESP32 is written in C++ using the Arduino IDE. The programming code is also available, under demand, in MISCE project webpage.

References

[1] Cabrera, F. C., Nascimento Filho, L. P. B., Cardim, H. P., de Oliveira Botan, M. C. C., Cardim, G. P., De Conti, C., ... & dos Santos, R. J. (2025). Utilização do kit educacional turbina eólica como ferramenta para uma aprendizagem significativa. Engineering & Technology Scientific Journal, 1(1).

[2] Baños, R., Alcayde, A., Montoya, F. G., Arrabal-Campos, F. M., & Jara, A. J. (2021). Wind Energy Education through Low-Power Wind Turbines and Advanced Software Tools. RE&PQJ, 19(4).