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A COMPARISON BETWEEN MATLAB/SIMULINK AND LABVIEW IN THE WIND TURBINE SIMULATION

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Abstract: The simulation of the operation of the wind turbine was performed using two programming media: LabVIEW and MATLAB/Simulink, respectively. MATLAB is a high–level programming environment and language specializing in numerical computing, while LabVIEW is a graphical media and programming language that specializes in interfacing with hardware components. MATLAB/Simulink is predominantly used in simulation because it contains libraries with high–level functions, specialized in fields, which help to quickly develop advanced applications. LabVIEW is mainly used for measurement and data acquisition since it features exceptional compatibility with a large variety of hardware. The goal of this study is to determine which medium is better suited for developing the software component of a wind turbine emulator. The requirements for this task are: complex numerical computing, simplicity and observability, hardware compatibility, data acquisition and storage and the possibility of creating a HMI. These constitute the criteria by which the better suited medium is chosen.

Keywords: MATLAB, Simulink, LabVIEW, wind turbine

1. INTRODUCTION

The simulation of the operation of the wind turbine was performed using two programming media: MATLAB/Simulink and LabVIEW, respectively.

MATLAB is a programming language as well as a high–level programming environment developed by MathWorks specialized for numerical computing. MATLAB is widespread across all scientific disciplines mainly due to a simple syntax, stability and a wide range of applicability. Scientists mainly use MATLAB for simulation, due to the high number of additional libraries and the Simulink add–on. These libraries contain higher–level functions from various areas (control and identification of systems, neural networks, fuzzy logic, statistics, symbolic math etc.) that speed up the development of advanced applications. However, the most important add–on for engineers is Simulink, which allows modeling, simulation and analysis of dynamic systems [1–3].

LabVIEW is a graphical programming environment developed by National Instruments based on graphical programming language G. The biggest advantage of LabVIEW is fast and simple construction of the graphical user interface that facilitates the updating of parameters (no need to interfere with the code) and elegant presentation of the results. Scientists mainly use LabVIEW for interfacing with hardware components. LabVIEW programming environment is the leader in the field of computer based measurement and data acquisition. It features exceptional compatibility with a large variety of hardware. There are also plenty of add–ons which can be used to deploy code to standalone devices, analyze and process signals, control, simulation, system analysis, report creation and database connection [2, 4–5].

Both platforms help engineers and scientists around the world in various stages of design, modeling, simulation, prototype testing, or deployment of new technologies. More experienced users can use a combination of both tools, which communicate via either the API or DLL libraries. Also, most MATLAB functions are accessible from LabVIEW via the MathScript Node, which can actually pass data to m code, execute it and get results back [2].

The goal of this study is to determine which medium is better suited for developing the software component of a wind turbine emulator. The requirements for this task are: complex numerical computing, simplicity and observability, hardware compatibility, data acquisition and storage and the possibility of creating a HMI. These constitute the criteria by which the better suited medium is chosen.

2. WIND TURBINE MODEL

The object of interest is a low power horizontal axis wind turbine (Figure 1), hereinafter referred to as WT, installed in the Ciugud village, Alba County, designed and implemented by UPT within the project [6]. The parameters of WT are shown in Table 1. The objective of the authors is to create an experimental stand for simulating this turbine. The resulting emulator will be used for testing and improving it. In order to emulate

a wind turbine one must start from the fundamental equations which govern the turbine. These indicate the required level of computational complexity.



Figure 1. The Wind Turbine

Table 1. WT parameters

Parameter	Value
Rated power	$P_n=5.5$ [kW]
Startup speed	$v_{cut-in}=5$ [m/s]
Rated speed	$v_{rated}=11$ [m/s]
Cutting speed	$v_{cut-out}=15$ [m/s]
Rated rotational speed	$n=126$ [rpm]
The area covered by the turbine blades	$A=19.6$ [m ²]

The behavior of a wind turbine is modeled using the aerodynamic model. This represents a relationship between the turbine inputs (wind speed) and its outputs (power or torque). The available wind power (P_w) is expressed as (1), where E_c is the kinetic energy, m is the mass [kg], v is the wind speed [m/s], A is the surface covered by the turbine blades [m²], and ρ is the specific density of air [kg/m³] [7].

$$P_w = \frac{1}{2} \rho A v^3 \quad (1)$$

The turbine efficiency is described by its power coefficient (C_p), defined as the ratio of the actual power delivered by the turbine (P_{wt}) to the theoretical power available from the wind (P_w) is (2) [7].

$$C_p = \frac{P_{wt}}{P_w} \quad (2)$$

The theoretical maximum value of the power coefficient is 0.59, known as the Betz limit. This represents the maximum wind power extraction efficiency [8].

The power coefficient depends on a characteristic turbine size called the speed ratio (TSR), denoted by λ , and defined as the ratio between the turbine's rotational speed and the wind speed, expressed as (3), where R is the radius of the turbine blades [m] and ω_r the turbine rotational speed [rad/s] [7–9].

$$\lambda = \omega_r R / v \quad (3)$$

Therefore, the power of the wind turbine is calculated as (4) [8].

$$P_{wt} = 0.5 A \rho C_p(\lambda) v^3 \quad (4)$$

The power of the turbine can be expressed depending on the torque of the turbine using (5), where T_{wt} is the torque of the turbine [N·m] [8, 10].

$$P_{wt} = T_{wt} \omega_r \quad (5)$$

Therefore, the turbine torque can be expressed as (6), where C_T is the torque coefficient [8, 10].

$$T_{wt} = 0.5 A R \rho C_T(\lambda) v^2 \quad (6)$$

The link between the torque coefficient C_T and the power coefficient C_p is as (7) [8, 10]:

$$C_T = \frac{C_p}{\lambda} \quad (7)$$

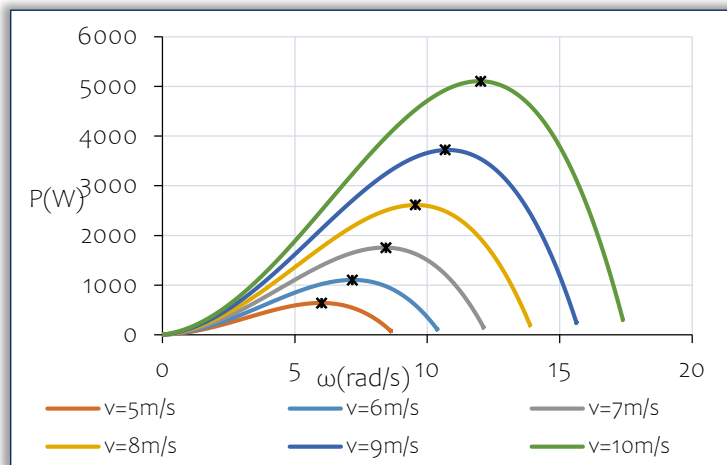
The characteristics of the power coefficient and the torque coefficient as a function of the angular speed are given in Figure 2a, b.

The expression of the torque coefficient was obtained experimentally from [7] as (8), where a , b , C_{T0} are constants.

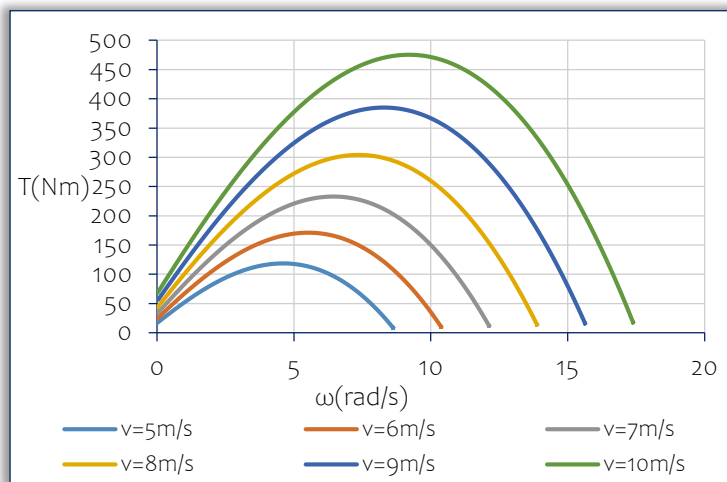
$$C_T = C_{T0} + a\lambda - b\lambda^{2.5} \quad (8)$$

Figure 3 renders the power characteristics of the turbine according to the rotational speed for wind speeds between 5 and 10 m/s.

It is evident that the complexity of the aerodynamic model is quite high. This means that a higher computational effort is required for the simulation. The next step is obviously the simulation of WT in both programming environments to determine which is more accurate. Since the code used in the simulation will itself be used in the design of the software component of the emulator, the simplicity/complexity of the code as well as how clear/unclear it is can also be discerned.



(a)



(b)

Figure 2. WT characteristic curves: (a) Power curves according to wind speed; (b) Torque curves according to wind speed

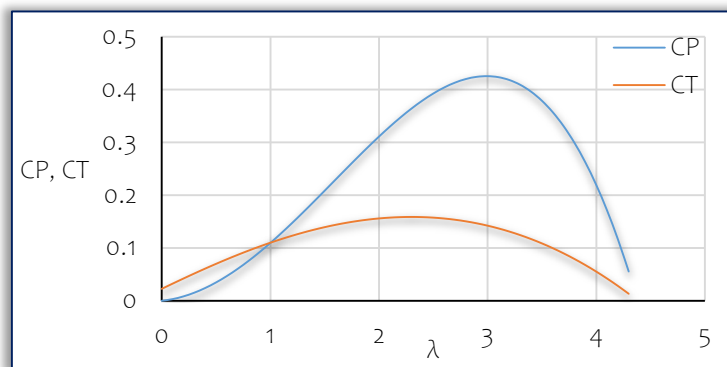


Figure 3. The power coefficient and the torque coefficient according to tip-speed-ratio λ

3. WT SIMULATION IN MATLAB/SIMULINK AND LABVIEW

In order to simulate WT, the parameters of the aerodynamic model are required. These were obtained by using data from WT in [Pet 2013] and are given in Table 2.

Table 2. Aerodynamic model parameters

Parameter	Value
The area covered by the turbine blades	$A = 19.6 \text{ [m}^2\text{]}$
The radius of the turbine blades	$R = 2.5 \text{ [m]}$
Maximum power coefficient	$C_{p_{max}} = 0.42$
Optimum speed ratio	$\lambda_0 = 3$
Constants for the expression of the torque coefficient	$a = 0.0986, b = 0.0113, C_{T0} = 0.0222$
Specific air density	$\rho = 1.225 \text{ [kg/m}^3\text{]}$

The codes for both the MATLAB/Simulink and the LabVIEW turbine simulations are presented in Figures 4 and 5. Since both simulation programs use the same equations, the complexity of the code is identical. The code is clear and easily observable in both cases.

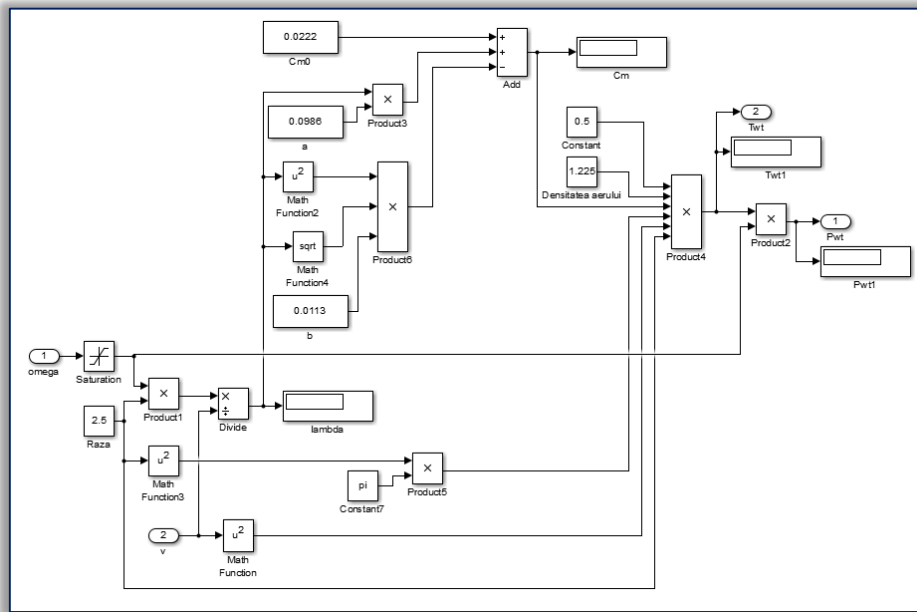


Figure 4. MATLAB code for wind turbine simulation

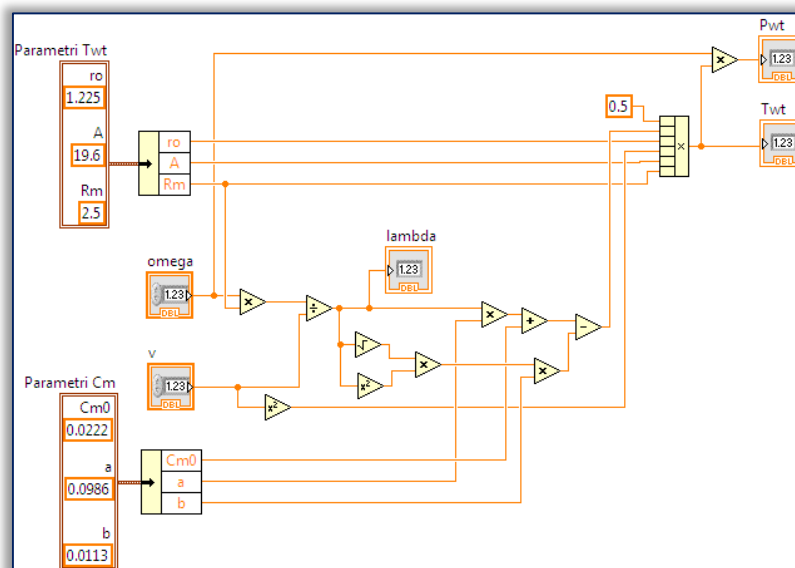
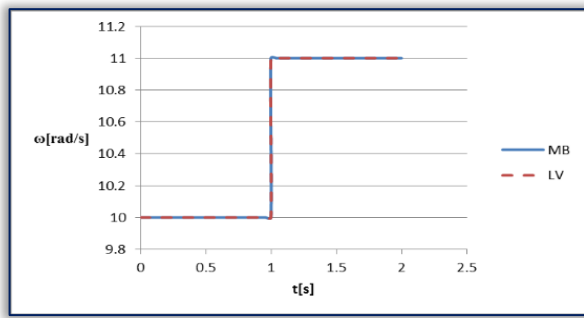


Figure 5. LabVIEW code for wind turbine simulation

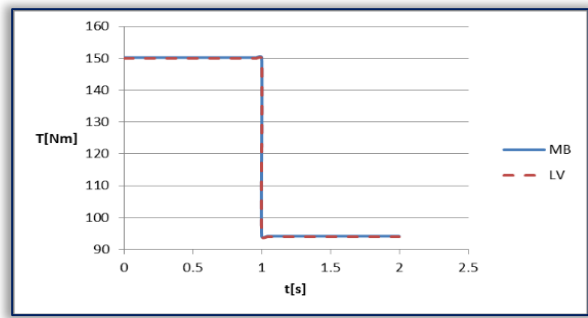
Figure 6 presents the variation in turbine torque and turbine power for a step input in angular speed (10–11 rad/s) under constant wind speed for both programs (MATLAB – MB and LabVIEW – LW). Figure 7 presents the variation in turbine torque and turbine power for a step input in wind speed (7–8 m/s) under constant angular velocity for both programs. The power and torque both show step variations, but in the case angular speed variation, the power and torque values decrease, and in the case of the wind speed variation, these values increase. These variations are consistent with how WT functions.

The error between the values obtained by simulation in LabVIEW and those obtained in MATLAB/Simulink is relatively small: 0.1780194%. The RMSE is 3.78 and the correlation coefficient is 1. Therefore the results obtained from both applications are almost identical.

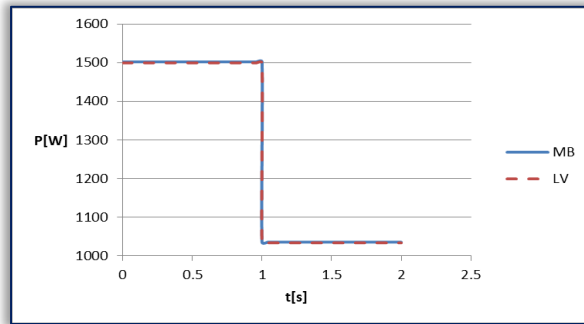
In order to check accuracy for a wider range of values, the authors selected the maximum power points (MPPs) for different wind speeds from [7] and checked the correspondence between them and the values obtained through LabVIEW (LV) and MATLAB/Simulink (MB) simulation for the given angular speed ω . The results are rendered in Table 3.



a) Angular speed

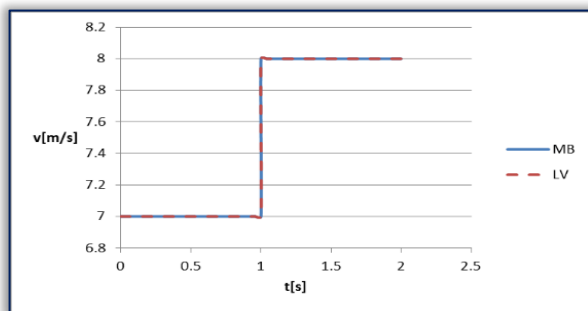


b) Torque

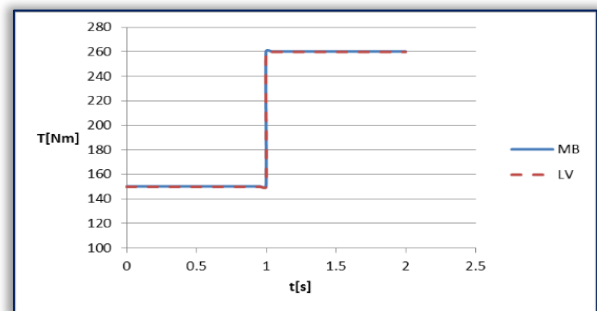


c) Power

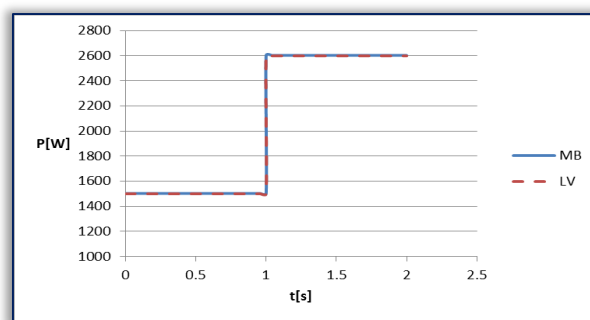
Figure 6. Step variation of the angular speed (10–11rad/s) and constant wind speed ($v=7\text{m/s}$)



a) Wind speed



b) Torque



c) Power

Figure 7. Step variation in wind speed (7–8 m/s) and constant angular speed (10 rad/s)

Table 3. Comparison to experimental data

$v[\text{m/s}]$	$\omega[\text{rad/s}]$	MPP[W]	LV[W]	MB[W]
5	6,03	664,63	638,47	639,61
6	7,16	1118,88	1103,48	1105,45
7	8,38	1769,10	1752,34	1755,47
8	9,58	2627,36	2615,74	2620,40
9	10,77	3730,40	3724,38	3731,02
10	11,99	5127,24	5108,84	5117,95
Quality indicators			RMSE=16,89 Correlation Coefficient=1,00	RMSE= 13,71 Correlation Coefficient=1,00

The authors tried using the true MPPs determined through LabVIEW and MATLAB/Simulink simulation but these points had slightly different angular speed values which would have made the comparison much more difficult. As is, the results are very close to one another. The MATLAB generated values are slightly closer to the experimental data but not enough for its performance to be considered superior to that of LabVIEW.

4. CONCLUSIONS

The results show similar performances from both programs. Therefore the choice between them has to be made by other criteria.

Hardware compatibility will depend on the type of hardware to be used. Generally speaking LabVIEW is specialized in data acquisition and is more likely to work with any board, but there are exceptions. One example of this are dSpace boards which are highly compatible with MATLAB. Other types of boards can more or less be compatible with either one. Therefore hardware compatibility does not offer a definitive answer.

Data acquisition and storage facilities exist for both, however LabVIEW has consistently shown high performance in this department. It is especially designed for this. Therefore, when data acquisition is required, LabVIEW is preferable.

There is also the necessity of creating a HMI, this being another domain in which LabVIEW excels.

All things considered, LabVIEW is the obvious choice for designing the WT emulator.

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