

COMPUTER ASSISTED STAND FOR SIMULATING AND STUDYING WIND ENERGY CONVERSION INTO ELECTRICITY

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Summary: *Actual global challenges, like the depletion of conventional resources and global warming forced the society to adopt sustainable development policies, which implies achieving growth without compromising the chances of next generations. Among the objectives of sustainable development, one of the most important is referring to the limitation of climate changes and its negative effects on environment and society, by implementing green energy solutions. Wind energy is one of the renewable energy powers which accomplished a rapid growth during the last decade. Consequently, promoting and enhancing knowledge related to wind energy systems became a priority. So, a computer assisted experimental stand was designed and realized, to simulate and study the wind energy conversion, suitable for both academic research and teaching activities. The device has all major components of a real wind system and two distinctly different configurations - horizontal and vertical axis - available for the turbine design. Experimental tests designed and carried out using the stand allowed the modelling of the influence factors constructive parameters of wind turbines and wind characteristics - action on the electrical power generated. The paper also presents the response surfaces and the contour plots of this objective function. The results obtained enable the understanding of the influence of different factors on the performance of the wind energy conversion process into electricity.*

Keywords: *energy, data acquisition system, experimental modelling*

1 Introduction

Over the years, economic growth and the development of the human society were sustained by material and energy resources utilization. High energy demanding activities conducted to the depletion of the fossil fuels and to the increasing of their costs. On the other hand, irrational and extensive utilization of conventional energy sources, together with the continuous population growth generated high greenhouse gas emissions, contributing to global warming.

The society response was to adopt sustainable development policies. Therefore, the production of energy using renewable resources has become the solution from ecological as well as economical point of view. Wind energy is one of the renewable energy powers which accomplished a rapid growth during the last decade. Important factors, both technological (high-strength fiber composites for constructing large low-cost blades, variable-speed operation of electrical generators to capture maximum energy ...) and economic (falling prices of the power electronics, green certificates policies ...) have accelerated this development [1].

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Despite its important potential, wind energy use has some restrictions caused by the following characteristics: variability, unpredictability, accessibility, and large areas distribution. Thus, optimized operation of wind energy systems involves a detailed analysis of the influence of different factors on the conversion process. For attaining this purpose, a computer assisted experimental stand was designed and realized, to simulate and study the wind energy conversion into electricity, suitable for use by several target groups, especially students, undergraduate or post-graduate level and all those involved in the design, manufacture or operation of wind turbines.

2 Equipment and methods

The simulating stand (Fig. 1) has almost all major components of a real wind turbine: high speed axis **1**, multiplying gear mechanism **2**, low speed axis **3**, rotor blades **4**, DC generator **15**, and tower **13**. Artificial wind is generated with different speeds by means of a ventilation unit **5** and an adjustable resistance. Both electrical analogue signals, current and voltage, are converted into numerical signals using *ARDUINO UNO V3* data acquisition board **9** and displayed on a PC monitor **8** [2]. The same board and an IR emitter/detector pair **11** allow the measuring of the rotors number of rotations per minute. The wind speed is measured separately, by means of an anemometer **7**. A different configuration for the stand is available, mounting vertical axis rotors **6** on the support **12**.

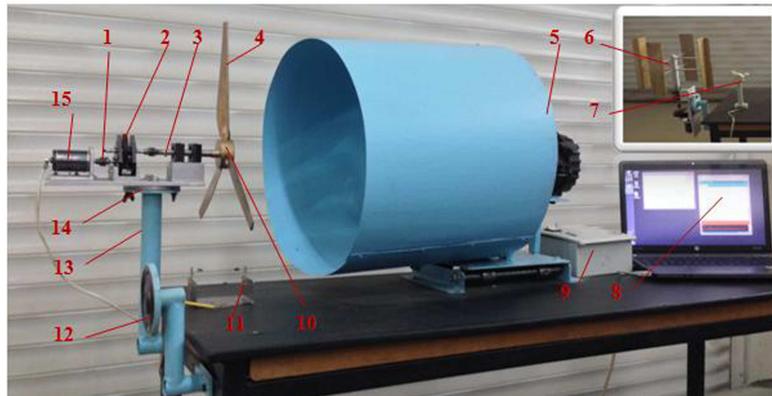


Figure 1: General view of the wind energy conversion simulating stand

For studying the conversion process, the experimental equipment has a set of removable rotors, with different aerodynamic profiles and diameters. Also, in case of the horizontal axis rotor, the attack angle of the blades can be varied between operating limits. This angle is defined by the profile chord and the rotation plane of the rotor and has its maximum value at the base of the blade. Moreover, the nacelle **14** of the wind turbine can be rotated, thus changing the wind direction on the rotor plane. Different types of experiments can be carried out, selecting the variables shown in the systemic analysis (Fig. 2).

For modelling the influence of the independent variables on the electric power generated using the simulating stand, a two-level factorial experiment, in two blocks, without randomization, was designed and carried out [3]. This experimental strategy allows reducing of the experimental volume while maximizing the precision of estimation of a polynomial model. Due to their practical importance, three influence factors, easy to adjust, were selected: wind speed v [m/s]; attack angle β [deg]; incidence angle of the wind α [deg].

The variation ranges for these input variables were chosen based on the existing information and on some preliminary experiments. Physical values corresponding to the inferior and the superior levels for each factor are presented in Tab. 1.

Ignoring interactions greater than order 2, the model to develop was:

$$y = b_0 + b_1x_1 + b_2x_2 + b_3x_3 + b_{12}x_1x_2 + b_{13}x_1x_3 + b_{23}x_2x_3 \quad (1)$$



Figure 2: Systemic analysis of the conversion process

3 Experimental results

The values obtained after carrying out the experiment are shown in Tab. 1.

Table 1: Experimental matrix

Run no	Levels of the influence factors						Measured values		
	$x_1 = v$		$x_2 = \beta$		$x_3 = \alpha$		$y = P$ [mW]		
	coded	[m/s]	coded	[deg]	coded	[deg]	y_{i1}	y_{i2}	
1	-1	4,9	-1	20	-1	0	46,34	49,5	
2	+1	9,8	-1	20	-1	0	376,62	385,34	
3	-1	4,9	+1	35	-1	0	31,15	31,58	
4	+1	9,8	+1	35	-1	0	257,97	277,91	
5	-1	4,9	-1	20	+1	10	39,72	34,47	
6	+1	9,8	-1	20	+1	10	312,25	290,21	
7	-1	4,9	+1	35	+1	10	27,88	23,78	
8	+1	9,8	+1	35	+1	10	230,56	189,87	

The regression coefficients, which show the influence of the factors selected and of their interactions on the electric power P generated by the wind energy conversion stand, were obtained after processing the experimental data. The sign and the value of each coefficient indicate the direction and the amplitude of the correspondent influence. Maintaining only the significant effects, the model becomes:

$$P = 162,822 + 254,539v - 57,9687\beta - 38,4587\alpha - 44,0587v \cdot \beta - 30,2788v \cdot \alpha \quad (2)$$

Using the model achieved, the response surface of the dependent variable, for each two of the influence factors, were represented, some examples being shown in Fig. 3. By sectioning the response surface with level planes, the contour plots for the electric power are obtained (Fig. 4)

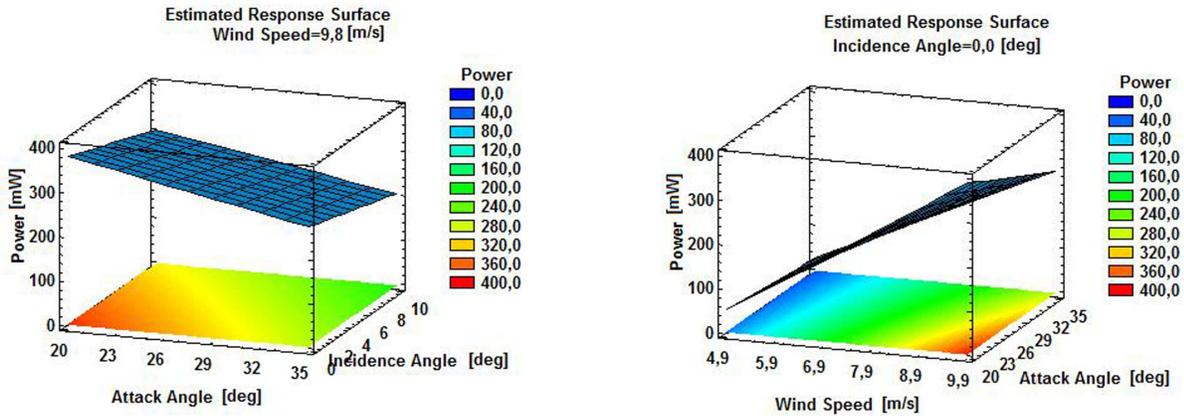


Figure 3: Response surfaces for electric power P

The procedure performed also allowed the hierarchy of both main effects and interaction effects on the response function (Fig. 5).

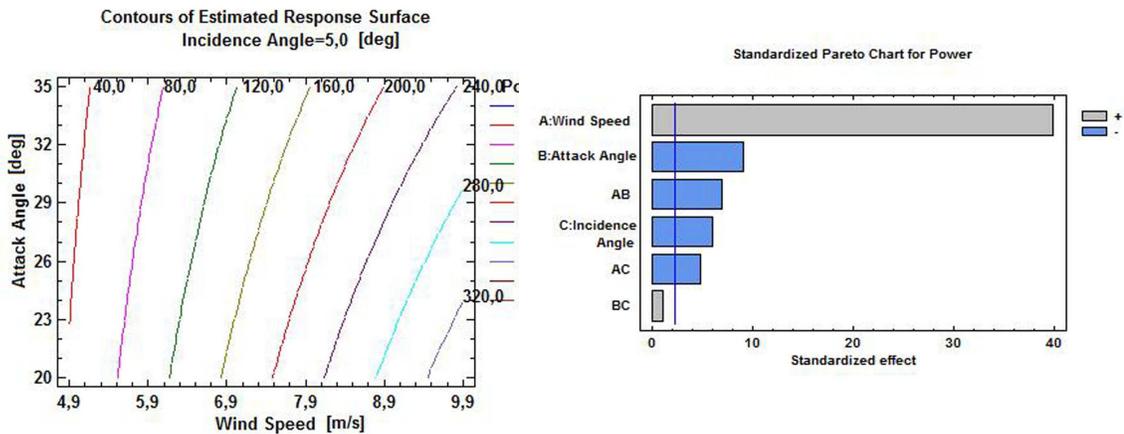


Figure 4: Standardized Pareto Chart

Figure 5: Standardized Pareto Chart

4 Conclusions

According to the obtained hierarchy, the power generated is mainly influenced by the wind speed v , and then by the attack angle β , and the interaction between these two factors. The experimental results confirm that the power varies with the cube of wind speed. Since the power developed by a wind turbine must not exceed the nominal power of the generator, an applied solution for the output power regulation can be achieved with pitch-control [1], i.e. by changing the attack angle.

References

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