ANALYTICAL APPROXIMATIONS IN MODELING OF POWER WIND TURBINES

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Abstract

The paper establishes the analytical approximation regarding a mathematical model based on the characteristic curves. There are presented optimal analytical expression for the moment curves at the axis turbine. The results are applied to a comparative study for different values of rapidity. This study highlights the importance of certain parameters of wine turbine especially the torque for different rapidity, in the process of construction and development of such aero-electrical aggregates and their optimal functioning. Physical model of the turbine is a theoretical concept, which allows evaluation analysis of characteristic parameters of wind turbines. Concept of profile placed in the network is necessary to correct the dimensionless coefficients.

Key words: Analytical approximation, wind turbines, moment curves.

INTRODUCTION

Within aero-electrical aggregates the wine turbine is the component that ensures the conversion of kinetic energy of wind into mechanical energy useable to turbine shaft, through the interaction between air current and moving blade. Wind turbine is composed mainly of a rotator fixed on a support shaft, comprising a hub and a moving blade consisting of one or more blades. Active body of aeolian turbines which made the quantity of converted energy is the blade. The achieving of aerodynamic performances, kinematics and energy curves of the aeolian turbines depend on the choice of certain geometry.

Turbine geometry optimization consists in selecting those forms that maximizing the exchange of energy in certain given conditions (wind speed, engine revs).

The present study aims to present scientific knowledge in the field of wind turbines in order to select a mathematical model useful in aero-electric aggregates dynamic. The objective is extracting energy from the field and turning to the shaft of an engine. The physical and mathematical associated model involves the following components: site offer, exchange energy in the aerodynamic engine, optimized geometry of the motor and the functional characteristic curves of the engine in terms of optimized geometries.

All quantities of energetic interest depend on time, being statistically processed in form of frequency curve or insurance curve.

MATERIAL AND METHOD

Energy performance representation that produces a wind turbine, as a whole operating area, is materialized by the characteristic curves that are operating in the optimization process. They are of two types namely: operating (exploitation) curves, respectively adimensional curves of the type of turbine (Dubau C., 2005).

Taking into consideration [15] and (Dubau C., 2003, 2004), in order to characterize the functionality of various types of turbines three adimensional coefficients are used, respectively: power coefficient, moment coefficient or torque coefficients and axial force coefficient, which have the following calculation expressions:

$$C_P = \frac{P}{\rho \cdot \frac{v^3}{2} \cdot S}; \quad C_M = \frac{M}{\rho \cdot \frac{v^2}{2} \cdot S \cdot R}; \quad C_{F_a} = \frac{F_a}{\rho \cdot \frac{v^2}{2} \cdot S}$$

where we have used the following notations:

S – Area swept by the turbine,
R – Radius of the turbine,
P – Power turbine,
M – The moment at the engine line axis,
F_a – Axial force,
ρ – Mass density of air [kg/m^3],
v – Wind speed [m/s].

The characteristic number, namely rapidity of the turbine, is defined by the relation bellow:

$$\lambda = \frac{\pi \cdot n \cdot R}{30 \cdot v},$$

where n is the speed turbine [rpm].

The characteristic number associated with maximum value of the power coefficient, denoted by λ_0, characterized the rapidity of type turbine.

In the various analyses situations, these quantities are associated to different points of the energy chain of a certain system consisting of turbines, transmission, and generator.

Thus it should be done a distinction between the notations λ and λ_0. The first one representing the current rapidity and the second one is the optimal rapidity related to a certain type of turbine.

There are various types of wind turbines. Between various types of wind turbines the rapid axial horizontal wind turbines are the most development ones. Many studies are also elaborated taking in consideration the turbines with vertical axes. Such a study regarding the adimensional curves was presented by the first author in a recent paper (Dubau C., 2009).

There was made a comparative analysis based on the results yielded by the calculations. There was compared: the vertical turbine V2500 (Gyulai F. et al., 2000 and Gyulai F., 2000 a.) and the horizontal turbine H2500 (Dubau, 2007). The adimensional curves have been constructed $C_P = f(\lambda)$, where these reference curves present the association between characteristic number λ and the maximum power value C_P (Bej A., 2003).

The adimensional curves (of the two types of turbines) (see Fig.1.) allow the construction of the exploitation curves defined through the area exposed to the air blown by the rotor of the turbine (S) and the mode of operation (n) see (Gyulai, 2000 b. and Gyulai & Bej, 2000). The used parameters were:

– *V2500 (Tv)* – $C_{P\max} = 0{,}45; \quad \lambda = 3;$

– *H2500 (Th)* – $C_{P\max} = 0{,}87; \quad \lambda = 3.$

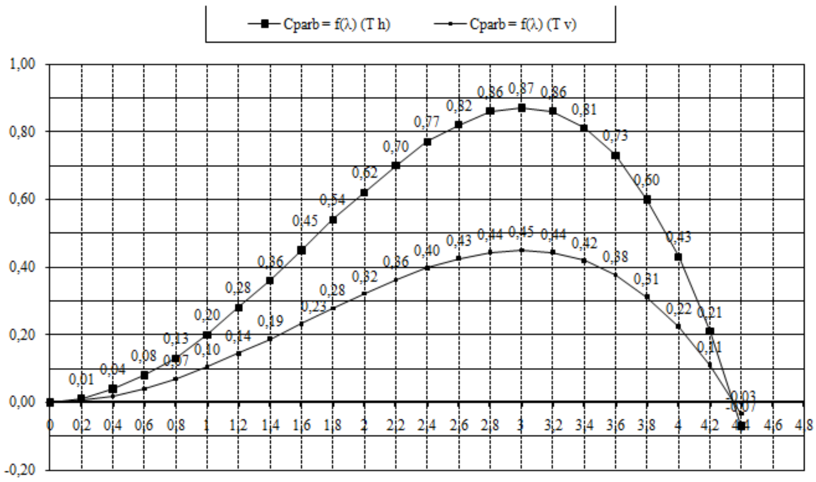

Fig.1. A-dimensional curves

This paper provides a mathematical simulation on the computer of torque for different rapidity, based on the model proposed in the work (Dubau C., 2006 and Dubău C., 2007). The initial values are found also in this study.

RESULTS AND DISCUSIONS

In this section we will establish the analytical approximation in order to construct a mathematical model based on the characteristics curves (see also Gipe P., 2003 and Burton T., 2001) of the wind turbine which implies the moment curves at the turbine axis. The proposed mathematical model is for the start moment. It pursues the analytic approximation:

$$C_M = f\left(\lambda_0, \lambda\right).$$

As a preliminary approximation is accepted the analytic approximation for the start torque coefficient

$$C_{M_0} = \frac{1}{5 \cdot \lambda_0^{\ 2}}.$$

The above approximation follows by the analysis of the existent information in literatures. For the considered case we take $\alpha = 2,0$ and $\beta = 2,3$.

The adimensional characteristics curve of a certain type of turbine: the moment coefficient:

$$C_M = C_{M_0} + a \cdot \lambda^{\alpha - 1} - b \cdot \lambda^{\beta - 1}.$$

For the constants computation which depends on the type turbine we will use different values of the rapidity, pointed in the table below (Table 1):

Table 1

The values of constants for the moment coefficients computation

λ_0	C_{M_0}	A	b
3	0,022	0,3326	0,2103
11	0,0017	0,0326	0,0138

For two values of the current rapidity λ we plot below the moment curves of the turbines (Fig.2 and Fig.3).

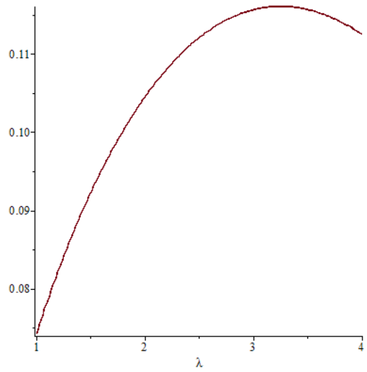

Fig. 2 Characteristic curve for $\lambda_0 = 3$

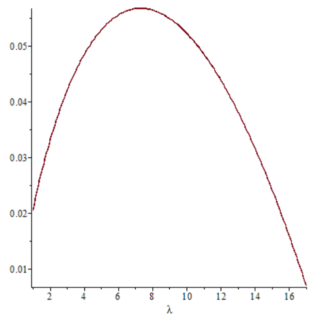

Fig. 3 Characteristic curve for $\lambda_0 = 11$

For each index i regarding the location in the machines chain, the a-dimensional curve

$$C_{P_i} = f(\lambda)$$

has the following interest points:

$$\lambda = \lambda_{0M}, \quad \frac{dC_M}{d\lambda} = 0 \quad \Rightarrow C_M = C_{M_{\max}}.$$
$$\lambda = \lambda_{amb}, \quad C_M = 0 \quad \Rightarrow C_P = 0$$

The relations between C_M and C_P is

$$\frac{C_P}{C_M} = \lambda$$

and it allows the computation of the curve $C_M = f(\lambda_0, \lambda)$ knowing the curve

$$C_P = f(\lambda_0, \lambda).$$

There is only one difficulty in this operation. At the corresponding values of the $\lambda = 0$, denoted by $C_{M_0} \neq 0, (C_{P_0} = 0)$, occurs an indetermination.

CONCLUSIONS

The presented model for the analytical approximation permits a better optimization of the parameters of the turbine also the optimization of energy performance of the wind turbines. They are also permitted a good management of the control and automation. Significant differences occur only in the small rapidity domain. The torque curve influences the characteristics of designed technology, which is centered this time on the moment coefficients.

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