TRANSIENT ELECTROMECHANICAL CHARACTERISTICS OF A CSCF WEC

A. I. Estanqueiro; F. Marques da Silva; C. Marques; J. G. Saraiva

Läboratório Nacional de Engenharia e Tecnologia Industrial
Departamento de Energias Renováveis
Az. Lameiros, Est. Paço do Lumiar, 1699 Lisboa Codex
Portugal

ABSTRACT

A modified version of the Propshaft computer code allowed to determine the torque vs rotational speed characteristic of an induction generator equiped WEC.

Experimental measurements tends to validate the model. For both purposes, numerical model and experimental data, the upwind HAWT sited at LNETI's pilot plant was used and, for the latter, signals of wind speed, torque and rotational speed were measured through a data acquisition board together with a personal computer.

Results are presented as the rotor torque characteristic and by examples of the acquired data.

1 · INTRODUCTION

The transient electromechanical characteristic of a constant speed, constant frequency (CSCF) WEC equiped with an induction generator is often unknown because the rotor speed is not really constant, varying within imposed limits of the induction generator stable slip.

The Propshaft code for analysis of rotors [1,2] (both turbines and propellers) is based on constant rotational speed, so the code was modified to include the possibility of rotational speed variation in order to obtain the rotor's rotational speed characteristic at variable wind speed.

The program's output combined with the induction generator's torque electromechanical characteristic achieved this aim.

Data used in the model refers to an upwind horizontal axis wind energy converter with a rated power of 20 kW and a 12 m diameter rotor, sited at LNETI's pilot plant.

2 · MODEL

Propshaft computes HAWT performance using Glauert momentum strip theory . As input blade sections twist, chord and airfiol aerodynamic characteristics (lift and drag) must be known.

In the modified version input parameters are extended to the wind and turbine rotational speed values in wich variations are allowed.

As the blade rotates each element sweeps out an annular strip. The Glauert strip theory determines the WEC performance by equating the blades forces, both axial and circunferential, determined by two-dimensional airfoil theory, with the change in momentum of the air going through the annular strip. Once the change in momentum is known the axial and circunferential interference factors are computed. This allows computation of the flow velocity and angle of attack at the blade element, closing the problem.

3 · PROTOTYPE

Rotor blades are glass fiber reinforced plastic (GRFP), each one being 5.7 m long. Their cross section varies from a NACA 4424 airfoil profile near the root, through NACA 4421, 4418 and 4415 close to the free end. Thickness varies from 0.13 m at 0.75 m of span to 0.04 m at 5.65 m of span; profile's chord goes from 0.45 m to

0.13 m at the same sections. The blades are twisted around 17° in the same direction, Fig. 1.

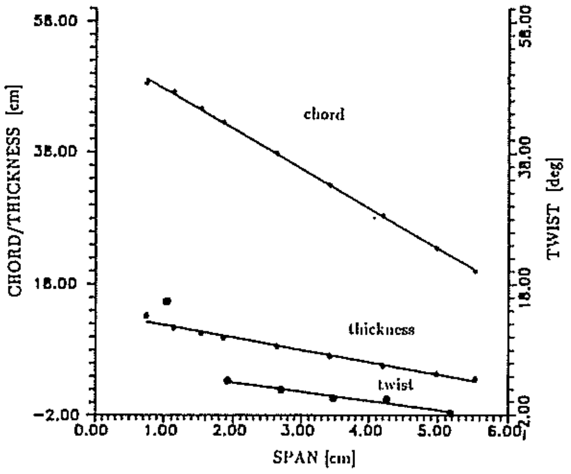

Fig. 1 - Blade geometric variations [7] .

4 · EXPERIMENTAL FACILITIES

For wind speed measurements a Lambrecht DC generator anemometer was used, levelled with the turbine's axis, placed on a meteorological mast aproximatly three diameters upwind (for dominant wind direction, N-NW). The anemometer was previously calibrated in a wind tunnel.

A strain gauge HBM T3FN torque meter, placed between the turbine's gear box (1:17.2) and generator allowed torque measurements.A DC voltage was obtained as output by signal conditioning, Fig. 2.

Rotational speed was measured through a home made optometer device placed on the generator's axis, Fig. 2. The measuring chain includes a frequency-voltage converter as well as signal conditioning.

Data acquisition is made through a Data Translation 2805 board together with a Zenith Z180 personal computer, and using a program developed at DER\LNETI. Signal analysis was accomplished using DADISP software.

5 · RESULTS

5 · 1 - Model's results

The torque vs rotational speed characteristics at variable wind velocity obtained with the modified Propshaft code are presented in Fig. 3.

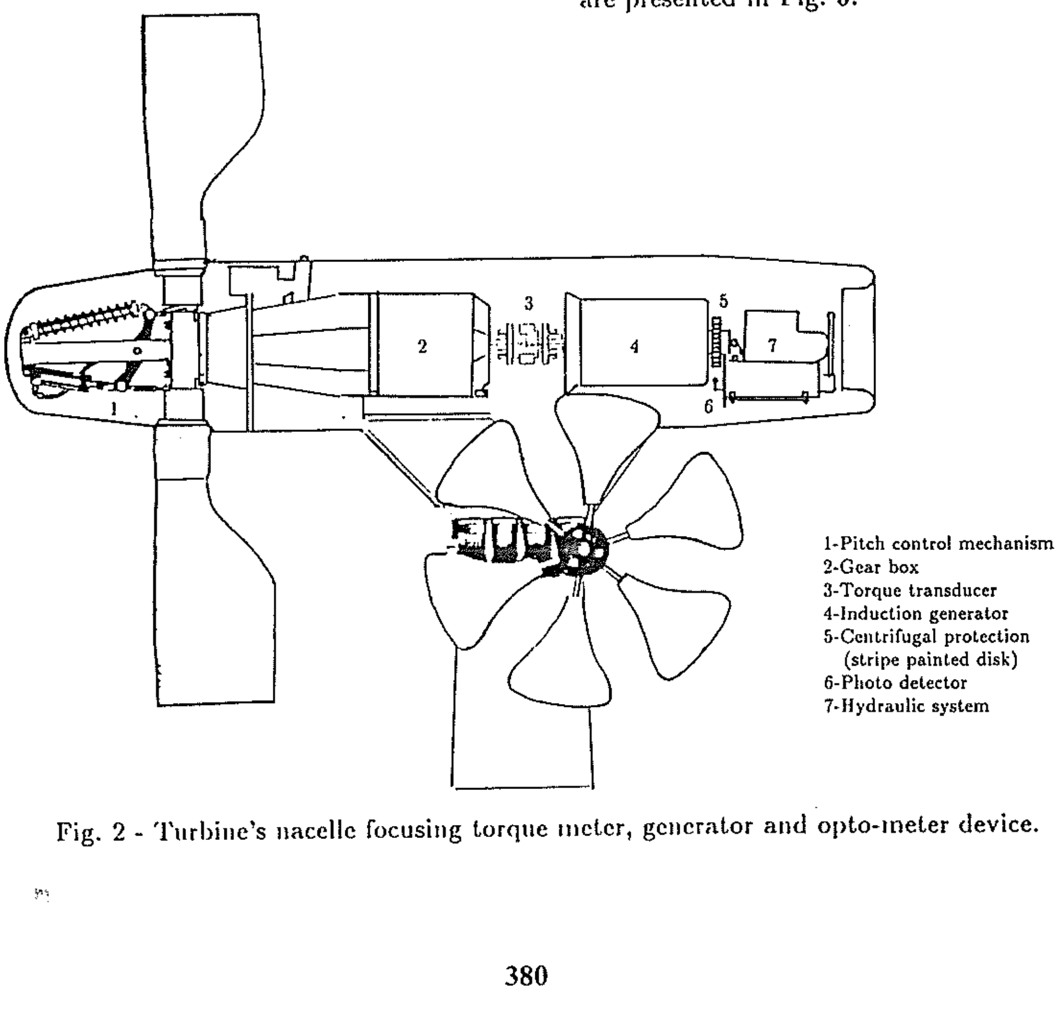

Fig. 2 - Turbine's nacelle focusing torque meter, generator and opto-meter device.

As the working range of CSCF WEC is quite narrow, in Fig. 4 these characteristics are displayed for the prototype's rotational speed working range. In this range the characteristics are almost linear, changing slope with variable wind velocity.

Results showing the same behaviour were obtained by Mercadier [3] using both numerical simulation and a wind tunnel test model.

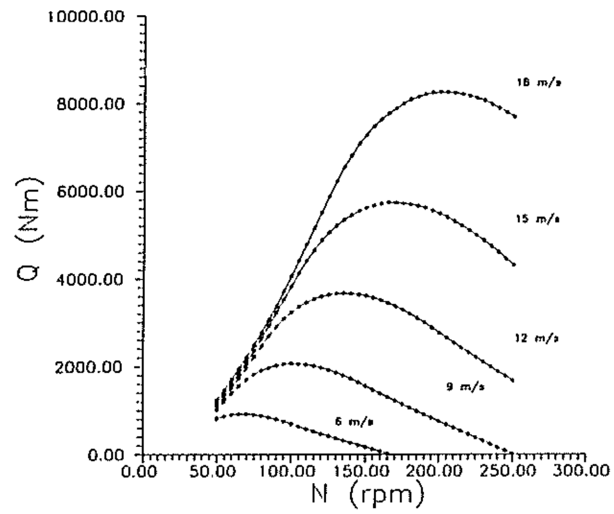

Fig. 3 - Torque characteristics vs rot. speed at variable wind velocity.

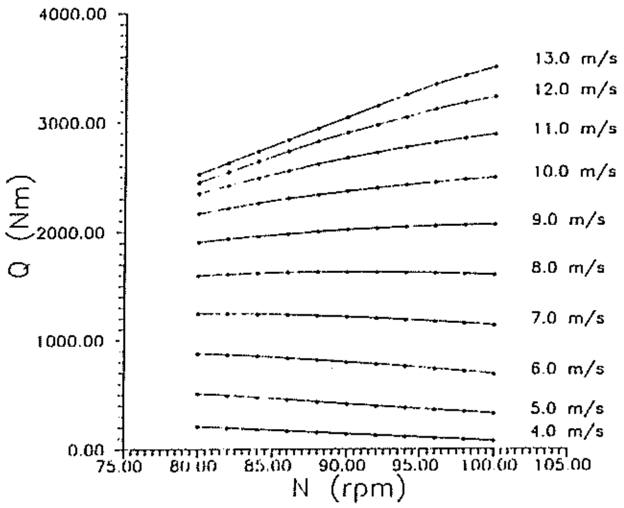

Fig. 4 - Torque characteristics at rot. speed working range

5 - 2 - Experimental data

The induction generator's electromechanical characteristic (Fig.5) was previously obtained [6] by the Heyland method, widely used in induction machine analysis.

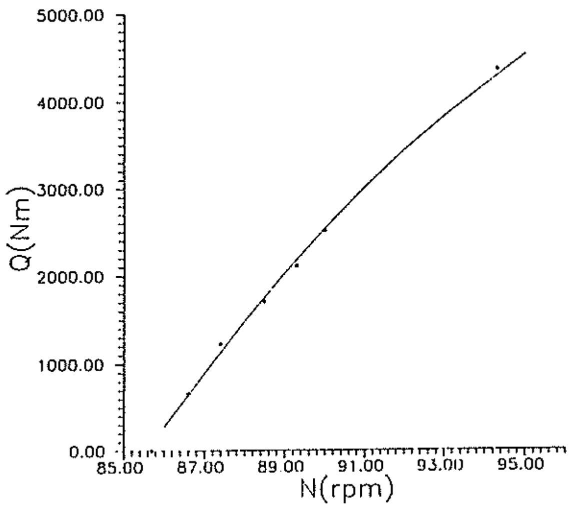

Fig. 5 - Induction generator's electromechanical characteristic.

Two sets of wind velocity, torque and rotational speed data are presented, Figs. 6 - 7. Each set consists of a two minutes long acquisition at a sample rate of 20 Hz. The mean values are respectively $\overline{U}$=11.5 m/s, $\overline{Q}$=2777 Nm, $\overline{N}$=91.8 rpm for the set shown in Fig.6 and $\overline{U}$=11.1 m/s, $\overline{Q}$=2685 Nm, $\overline{N}$=91.7 rpm for the set shown in Fig.7.

6 - DISCUSSION

The two sets of mean values obtained, agree well with the wind turbine's numerical simulation (errors are 2% and less than 1% respectively).

All sets of data were acquired under very strong wind conditions, most of which were for the turbine's power control mode that lies outside the numerical model's simulation range. For the complete model's validation, further data with lower mean wind velocities is required. Good agreement between the simulation and experimental data can be expected from these two sets of data obtained under normal operating conditions.

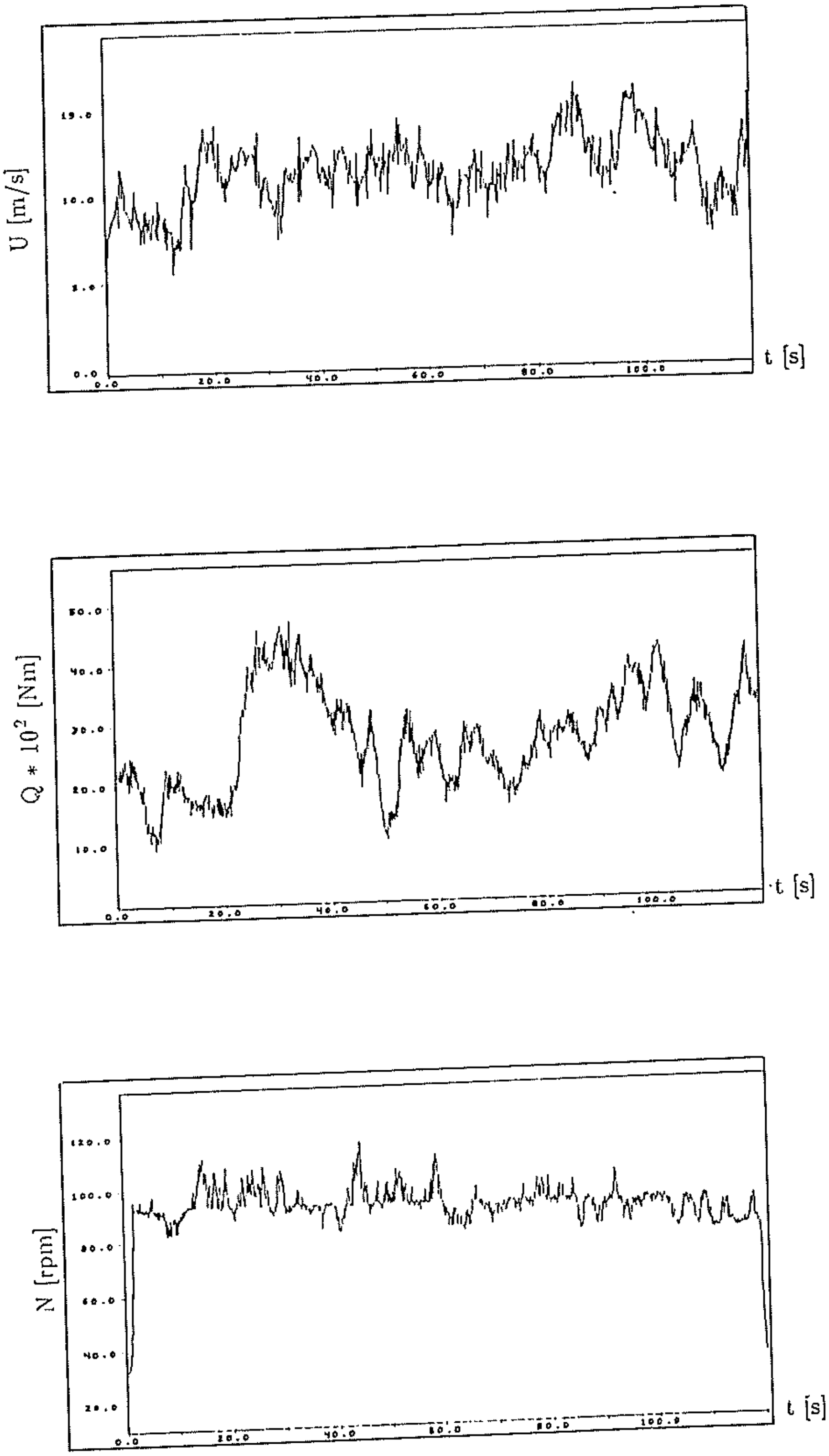

Fig. 6 - Experimental data: a)wind velocity b)Torque c)rotational speed

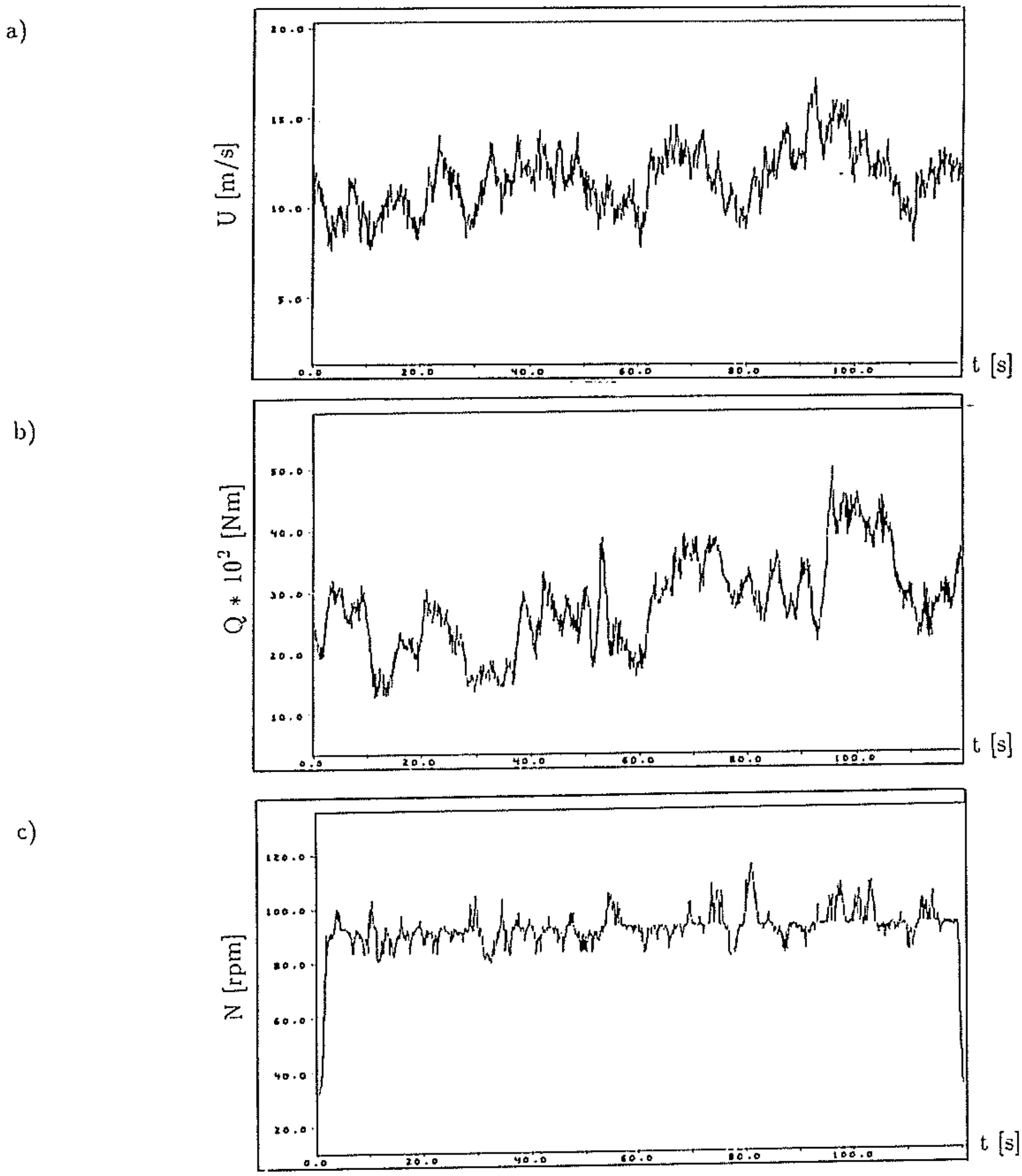

Fig. 7 - Experimental data: a)wind velocity, b)Torque, c)rotational speed

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