Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 126 (201709) 690–697

Energy Procedia

www.elsevier.com/locate/procedia

72nd Conference of the Italian Thermal Machines Engineering Association, ATI2017, 6–8 September 2017, Lecce, Italy

Data-based Fuzzy Logic Control Tenchique Appied to a Wind System

Lorenzo Dambrosio[a]

[a]*Department of Mechanics, Mathematics and Management , Via Orabona 4, Bari 70125, Italy*

Abstract

The control problem of a wind system considered as an isolate source of power has been taken into account. The considered wind system is composed by a horizontal-axis wind-turbine connected to an induction generator. The proposed control algorithm relies on the fuzzy logic framework exploiting the knowledge of few steady state working conditions (control input controlled output value pairs). The fuzzy logic scheme, not only properly combines the knowledge within the working point data set, but it is also able to consider the controlled variable deviation (control tracking error) and its first time derivative.

© 2017 The Authors. Published by Elsevier Ltd.
Peer-review under responsibility of the scientific committee of the 72nd Conference of the Italian Thermal Machines Engineering Association

Keywords: wind system; control; fuzzy logic

---

1. Introduction

Wind is a renewable source of energy which can be converted into both mechanical and electrical energy by means of a wind system. It does not produce pollutants during its operating life and its viability is proven. These aspects, in the last few years, led to a great diffusion of wind energy generation and, consequently, to a rapid enhancement in terms of wind turbine technology.

In order to generate electrical energy, the wind turbine drives an electrical generator. Usually, the generated current and voltage are rectified by means of an AC/DC converter and then, thanks to an inverter, they are converted to the AC appropriate values. Such a solution, on one hand, yields the appropriate frequency values by using only passive components (no active control). The drawback of this approach is represented by the energy losses associated to the power electronics. On the other hand, the adoption of an active output voltage control reduces the energy losses. In the present paper, a horizontal-axis fixed-pitch wind turbine and an induction electrical generator will be

---

* Corresponding author. Tel.: +39-080-596-3406 ; fax: +39-080-596-3411.
E-mail address: lorenzo.dambrosio@poliba.it

1876-6102 © 2017 The Authors. Published by Elsevier Ltd.
Peer-review under responsibility of the scientific committee of the 72nd Conference of the Italian Thermal Machines Engineering Association
10.1016/j.egypro.2017.08.299

considered. Appropriate mathematical models are obviously necessary to simulate the static and dynamic behavior of both components of the wind system.

The existing mathematical models to simulate wind turbines can be classified into momentum, vortex, and finite difference models. The momentum models approximate the wind turbine effects by means of actuator surfaces and subdivide the flow domain in many streamtubes (see, e.g., Ref. [1],[2],[3] and [4]) and appear to be more suitable to model the wind turbine for control applications. The vortex models represent the turbine blade effects by means of distributed bound vortices (see, e.g., Ref. [5])). The finite difference models approximate the rotor effects by means of an actuator surface and solve the fluid-dynamic governing equations by means of finite volume or finite difference methods (see, e.g., Ref. [6]). The momentum models are generally simpler and they will be here considered to simulate the wind turbine.

A proper mathematical model for the induction electrical generator can be found in many books (see, e.g., Ref. [7])), where the differential equations governing the dynamic behavior are reported. Ref. [8] suggests to insert a variable capacitor and to use it as the first control variable, being the rotor winding resistance the second one. These control variables are used in [8] to carry out a steady state control analysis of an induction electrical generator. In the present paper, a complete dynamic model of both the rotor and the stator winding will be presented and only the rotor winding resistance will be considered as a control variable. The stator winding capacitor will not be used as a control variable, but it will be preserved and used to ensure the self excitation of the electrical generator [9]).

Classical controls of wind systems can be found in many papers with reference to open loop schemes (see, e.g., Ref. [10]), as well as to closed loop ones (see, e.g., Refs. [11], [12]). Many of them need an analytical model of the controlled system (e.g. transfer function, differential equations). Often, the controlled system model is known only in terms of maps and/or numerical/experimental data. Therefore the controller parameters need several empirical adjustments in order to perform adequately. In some other cases, the control algorithm regards the controlled system as a black box and the control law is evaluated performing an estimation of the controlled system, Ref. [13]. These controllers, although can be very accurate, may include a complex implementation. On the other hand, the fuzzy logic approach, due to its non-analytical structure, has few advantages like it can be designed exploiting numerical/experimental data (no analytical knowledge of the controlled system is required); it can be straightforward scaled or updated by just varying the base of rules (no re-design process is needed). In the present paper the proposed fuzzy logic controller is able to build the fuzzy logic rule base taking into account only a limited set of working points (input-output pairs) that can be provided by numerical simulation or experimental data. In particular, the fuzzy logic rule base, not only considers the working points, but it also includes the working points deviations (control tracking errors) and their first time derivative. This turns in determining a control law, which is able to promptly annihilate the control tracking error.

2. Mathematical Model of the Horizontal Axis Wind Turbine

The mathematical model of the horizontal axis wind turbine here considered is based on a stream tube discretization, which relies on momentum conservation in both the axial and tangential directions. The airfoil aerodynamic characteristics, the lift (C_L) and drag (C_D) coefficients, can be found in [4]. The thrust and torque acting on a blade element dr, at a distance r from the center of the rotor, are given by

$$\begin{aligned} dT &= \rho\pi r\sigma\,(1-a)^2\,{V_0}^2 C_L \frac{cos\phi}{sin^2\phi}\left(1+\frac{C_L}{C_D}tan\phi\right)dr,\\ dQ &= \rho\pi r^2\sigma\,(1-a')^2\,(\Omega r)^2 C_L \frac{sin\phi}{cos^2\phi}\left(1-\frac{C_D}{C_L}\frac{1}{tan\phi}\right)dr \end{aligned} \tag{1}$$

where $\sigma = A_b/A$ is the solidity ratio, while A, and A_b are the rotor swept area and the total blade area, respectively. Moreover, ρ, a, a' and ϕ represent the air density, the axial and tangential induction factors and the inflow angle, respectively. Finally, Ω is the rotor angular speed and V_0 is the undisturbed wind speed. Following Eqs. (1), the wind turbine torque, Q_T, and power, P, are given by

$$\begin{aligned} Q_T &= \int_{Rmin}^{Rmax} dQ,\\ P &= \Omega Q_T \end{aligned} \tag{2}$$

Download English Version:

https://daneshyari.com/en/article/5444518

Download Persian Version:

https://daneshyari.com/article/5444518

Daneshyari.com