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Fuzzy logic control strategy of wind generator based on the dual-stator induction generator

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ABSTRACT

The work presented in this paper is the evaluation of the variable speed wind turbine based on dual star induction generator (DSIG) connected for power optimization in the conversion chain connected to the electrical grid. This optimization is concretized by two methods, namely, the Maximum Power Point Tracking 'MPPT' algorithm in the case where the characteristic of the turbine is known and the nonlinear method based on the theory of fuzzy logic controlled torque which is most appropriate when there is a lack of information on the characteristic ($C_p(\lambda)$) of the turbine. However, the limitation of power is performed by action on the generator control only. Simulation results are presented and discussed.

1. Introduction

In recent years, the renewable energy sources have attracted the great interest because conventional sources of energy are limited and a number of problems are associated with their use like: environmental pollution, large grid requirement, etc. Governments of the worldwide are forced to use alternative energy sources such as wind power, solar energy. All renewable energy resources can be considered as distributed generation resources. The wind is one of the most important renewable energy sources [1].

Currently, the installed wind turbines can be classified according to two categories: wind turbines with fixed speed and with variable speed. In the present work, wind turbines with variable speed are adopted. Indeed, the latter present several advantages, namely the best exploitation of wind energy and reduction of the torque oscillations [2].

The wind turbine during its functioning does not cause a maximal energy, in order to overcome this problem, the method MPPT was used by several authors [2,5,6,8] for the search for maximal power point. However, This technique do not always guarantee the optimization because of the absence of the turbine parameters as well as the conditions climatic, For these cases, The application of the technique of MPPT by fuzzy logic suits best. In this context, the present work is inserted whose objective is the control of a wind turbine connected to the electrical grid based on DSIG via a static converter. DSIG has like advantages, segmentation power, high reliability and minimizing torque ripples and rotor losses [3], more than conventional cage induction machines. The system is modeled, simulated and validated in MATLAB/Simulink environment. The modeling details of the scheme studied in Fig. 1 are described in detail in further sections.

2. Modeling of various parts of the wind generator

2.1. Modeling of the wind turbine and gearbox

A wind turbine can only convert a certain percentage of the captured wind power. This percentage is represented by C_p which is a function of the wind speed, the turbine speed and the pitch angle of any specific wind turbine blades [4,5].

The mechanical power (P_t) extracted from the wind is mainly governed by three quantities namely: the area swept by rotor blades (S), the upstream wind velocity (v_{wind}) and the rotor power coefficient (C_p) by following equation:

$$P_t = \frac{1}{2} C_p(\lambda) S v_{wind}^3 \tag{1}$$

where ρ is the air density, C_p is the turbine power coefficient that is a function of tip speed ratio λdefined by Eq. (2) and pith angel of the blades β, (in this paper $\beta = 0$).

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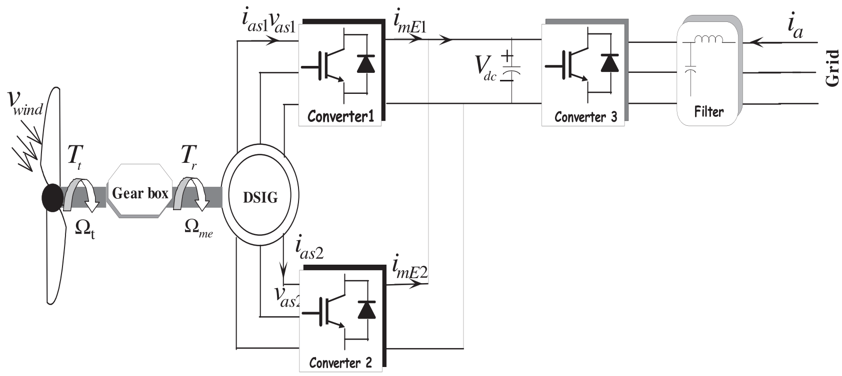

Fig. 1. Scheme of the studied device.

$$\lambda = \frac{R\Omega_t}{v_{wind}} \tag{2}$$

The Betz limit, C_{p_max} (theoretical) = 16/27, is the maximum theoretically possible turbine power coefficient. The rotor efficiency curve $C_p(\lambda)$ is a nonlinear function of the tip speed ratio (TSR), λ, which is determined by the blade design, and the pitch angle [6].

From Fig. 2 it is clear that there is a value of λ for which C_p is maximized, thus maximizing the power for a given wind speed. Because of the relationship between C_p and λ, for each wind velocity, there is a turbine speed that gives a maximum output power.

The turbine torque is the ratio of the output power to the shaft speed Ω_t:

$$T_t = \frac{P_t}{\Omega_t} = C_P(\lambda)\frac{\rho}{2}Sv_{wind}^3\frac{1}{\Omega_t} \tag{3}$$

The torque and shaft speed of the wind turbine, referred to the generator side of the gearbox are given by following equations:

$$\Omega_t = \frac{\Omega_{me}}{G} \tag{4}$$

$$T_r = \frac{T_t}{G} \tag{5}$$

From the previous equations, a functional block diagram model of the turbine is established. It shows that the turbine rotation speed is controlled by acting on the electromagnetic torque of the generator. The wind speed is considered as a disruptive input to this system (Fig. 3) [7,8].

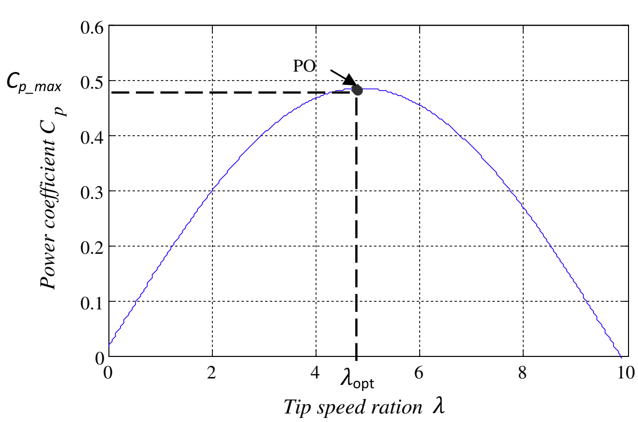

Fig. 2. Power coefficient for the wind turbine model.

The wind speed varies over time, and to ensure maximum capture of wind energy incident, the rotational speed of the wind turbine must be continuously adjusted with that of the wind. This is achieved using the MPPT technique.

2.2. Maximum Power Point Tracking (MPPT)

As discussed previously, variable-speed wind turbines are able to operate at an optimal rotation speed as a function of the wind speed. When the latter exceeds the rated speed of the turbine, a power limitation is imposed on the wind system due to electrical constraints on the elements of the conversion system. This limitation leads the generator to operate above its rated speed, as shown by Fig. 4.

In practice, an accurate measurement of wind speed is difficult to achieve for two reasons:

- The anemometer is located behind the turbine rotor, which disrupts the reading of the wind speed;
- The diameter of the area swept by the blades is significant; a sensitive variation in the wind appears according to pitch where the anemometer exists. The use of a single anemometer thus leads to use only a local measure of wind speed which is not thus representative enough of its average value appearing on all the blades.

Incorrect measurement of wind speed leads necessarily to non-optimal extraction of power. That is why most of the wind turbines are controlled without speed control, However this latter possesses a major inconvenience which is the static error.

Because of all these constraints and knowing that both methods already mentioned require the knowledge of the turbine parameters as well as the climatic conditions (Temperature, Air density, etc.), applying the MPPT technique by fuzzy logic is developed in the Section 6. In this work, the control of the system depends on the operating zone.

Zone I: The use of the algorithm MPPT allows determining the mechanical reference power

$$P_{me\_opt} = -\frac{C_{p\_max}}{\lambda_{opt}^2}\frac{\rho\pi R^5}{2}\frac{1}{G^3}\Omega_{me\_opt}^3 \tag{6}$$

$$P_{me\_opt} = k_{opt}\Omega_{me\_opt}^3$$

where $k_{opt} = -\frac{C_{p\_max}\rho\pi R^5}{2\lambda_{opt}^2}\frac{1}{G^3}$

$$T_{r\_opt} = k_{opt}\cdot\Omega_{me\_opt}^2 \tag{7}$$