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Short Communication

Robust nonlinear predictive control of permanent magnet synchronous generator turbine using Dspace hardware

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ABSTRACT

In this paper, a robust nonlinear predictive control (NLPC) is applied to a wind energy conversion system, using a variable speed turbine coupled directly to permanent magnet synchronous generator (PMSG) with PWM rectifier and a load. The principle of this control consists in elaborating a control law such that the predicted output can optimally track a desired predicted reference in presence of the disturbance. The predictive control will be optimal if the finite horizon cost function is minimized. The purpose of control in our case is to adjust the rectifier voltage amplitude and the stator current of the PMSG even with the change in wind speed. This control has-been Implemented using Dspace DS1104 card, the latter allowed us to control the system in real time. Finally, the practical results and those obtained by simulation using MATLAB/Simulink are compared to illustrate the performances of the proposed control regarding tracking of the reference and the disturbance rejection.

Introduction

Environmental issues have become a part of daily problems mainly in the generation of electrical energy which constitutes one of the pollution sources. Therefore, Recourse to the use of green energies has a very high growth. Among renewable energies, wind energy is one of the more used for conversion into electrical energy [1,2].

The last high power units use generally doubly fed induction generators (DFIG) or synchronous generators mainly with permanent magnet excitation (PMSG). The use of DFIG has the disadvantage of requiring a system of rings and brushes along with a gearbox inducing significant maintenance costs especially for offshore projects located in a saline medium. Consequently, PMSG is more and more preferred due to their

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high efficiency, possibility of direct drive operation and no need of excitation [3].

Nevertheless, the control of PMSG remains complex especially when good transient performances under all operating conditions is desired. This is due to the fact that PMSG is a nonlinear, multivariable, time varying system subjected to unknown disturbances and variable parameters [4].

Therefore, PI-type control methods are not effective to achieve the control of such machine with the performance needed [11]. To take into account nonlinearities of PMSM, different approaches have been adopted such as nonlinear control [12], sliding mode control, H∞ control theory and neural networks [13,14].

The predictive control (PC) is an advanced method of process control that has been in use in chemical industries and oil refineries since the 1980s [5,6]. PC method aims to obtain certain desired performance in the presence of disturbances and internal variations. In a general way, it generated a great number of applications in various practical fields [4] and its extension to the control of nonlinear systems has recently been the subject of many research [5] leading to the proposal of several algorithms [15–26].

In this study the nonlinear predictive control applied to a wind energy conversion system is suggested. The system is modeled, simulated under Matlab/Simulink and implemented using Dspace hardware. The obtained experimental results are presented and compared to those obtained by Matlab simulation.

Modeling of studied system

The studied wind power device consists of a variable speed turbine coupled directly to a permanent magnet synchronous machine (PMSM) connected to a DC bus through a PWM rectifier (Fig. 1).

Model of permanent magnet synchronous machine

Using Park transform, the equations of the PMSM can be written in a d-q rotating frame linked to the rotor as follows [7]:

$$\begin{cases} V_{ds} = R_s I_{ds} + L_{ds}\frac{d}{dt}I_{ds} - p\omega L_{qs}\, I_{qs} \\ V_{qs} = R_s I_{qs} + L_{qs}\frac{d}{dt}I_{qs} + p\omega\, L_{ds} I_{ds} + p\omega\, \phi_f \end{cases} \tag{1}$$

With:

R_s: Resistance of the stator windings.
I_{ds},I_{qs}: Stator currents in the Park rotating frame.
V_{ds},V_{qs}: Stator voltages in the Park rotating frame.
L_{ds},L_{qs}: Inductances along the direct and quadrature axes whose values are different in the general case.
p: Number of pole pairs.
$\omega = p\cdot\Omega$: Voltage pulsation (rad/s).
ϕ_f: The magnetic flux created by the permanent magnet through the stator windings.

The expression of the electromagnetic torque in the rotating frame is given by:

$$C_e = \frac{3}{2}\, P\left[(L_{ds} - L_{qs}) I_{ds} I_{qs} + \phi_f I_{qs}\right] \tag{2}$$

Rectifier modeling

The model of the rectifier is made by a set of ideal switches. The latter are complementary; their states are defined by the following function [8,9]:

$$Sj = \begin{cases} +1, \bar{s} = -I \\ -1, \bar{s} = +I \end{cases} \quad \text{for } j = a, b, c \tag{3}$$

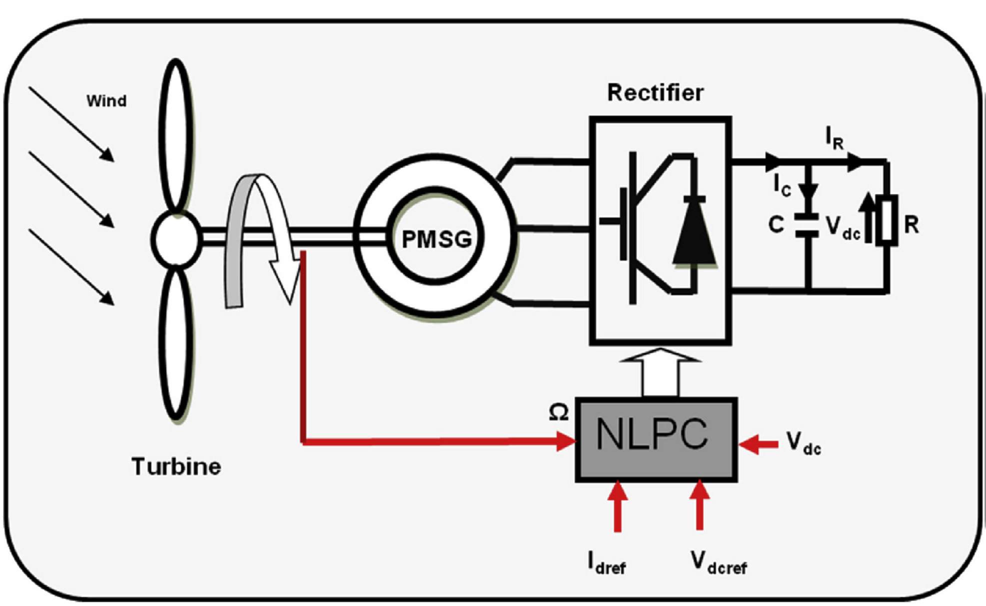

Fig. 1 – Overall scheme of the studied system.

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