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Direct model reference adaptive internal model controller for better voltage sag ride through in doubly fed induction generator wind farms

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ABSTRACT

This paper presents the function of a direct model reference adaptive internal model controller (DMR-AIMC) with variable gain adjustment mechanism for a doubly fed induction generator (DFIG) in a wind farm. Rotor current is controlled using the above controller with variable gain adjustment mechanism achieved using fuzzy sets and ANFIS to improve the voltage sag ride. Performance of the variable gain and linearly variable gain adjustment mechanisms are compared and their improvements are explored. Simulation results are used to demonstrate the effectiveness and robustness of the proposed control strategy, during variations in the variable gain adjustment mechanism.

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1. Introduction

Wind energy is an important source of green electricity in our country. Lot of research is still going on, to improve the generation of energy from wind. Conversion of wind energy technology is a rapidly developing area. Commercialization of wind energy depends mainly on technology development, making it economically viable.

A variable speed generator is one step ahead to increase the efficiency of wind energy conversion. Recently, doubly fed induction generator (DFIG) is a highly energy efficient variable speed wind generator used in the wind farms, as the variable-speed operation will improve the wind energy production further [1]. Dynamic and transient behavior of the DFIG-based WTs under voltage dips and wind speed fluctuations and rotor current controller is presented in [2]. Alan Mullane et al., says that nonlinear controller design results in considerable improvement in the 'ride-through faults' capability of wind turbines [3]. Boukhezzar and Siguerdidjane [4] has also confirmed nonlinear control strategies bring more performance in the exploitation of wind energy conversion systems. An internal model controller (IMC) is suggested in [5,6]. A direct model reference adaptive internal model controller being a nonlinear controller will be a better option [7]. Performance improvement of wind energy conversion system using matrix converter is described in [8]. Impact of FACTS controllers on the stability of power systems connected with wind energy conversion systems is cited in [9]. Accurate monitoring and estimating the state of power system to identify the voltage collapses is presented in [10].

This paper aims at investigating the function of a direct model reference adaptive internal model controller with variable gain adjustment mechanism to improve the voltage sag ride through performance in a doubly fed induction generator. To compare the effectiveness of variable gain adjustment mechanism, simulation is done using Matlab/Simulink. The comparison in improvement using different adjustment mechanisms is discussed.

2. Modeling of doubly fed induction generator

Fig. 1 shows the general configuration for shunt connected DFIG system. Normally, induction generators are very sensitive to sudden changes in voltage. DFIG is a complex nonlinear and variable speed generator, separately controllable on rotor and stator side. This generator is highly supportive for voltage sag ride through problems due to its high reactive power capabilities, also series and shunt grid connections are possible.

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Nomenclature

V_s	stator voltage (V)	V_{qr}	rotor quadrature axis voltage (V)
R_s	stator resistance (Ω)	i_{qr}	rotor quadrature axis current (A)
i_s	stator current (A)	λ_{qr}	rotor quadrature axis flux (Wb turns)
λ_s	stator flux (Wb turns)	L_r	rotor leakage Inductance (H)
V_r	rotor voltage (V)	L_m	magnetizing Inductance (H)
R_r	rotor resistance (Ω)	L_{sl}	stator leakage Inductance (H)
i_r	rotor current (A)	W_o	base speed (rad/s)
λ_r	rotor flux (Wb turns)	W_k	speed of the reference frame (rad/s)
V_{ds}	stator direct axis voltage (V)	W_m	rotor speed (rad/s)
i_{ds}	stator direct axis current (A)	C	capacitance (F)
λ_{ds}	stator direct axis flux (Wb turns)	J	inertia of the rotor (kg-m^2)
V_{qs}	stator quadrature axis voltage (V)	D	active damping torque (N-m)
i_{qs}	stator quadrature axis current (A)	$p = \frac{d}{dt}$	(derivative function)
λ_{qs}	stator quadrature axis flux (Wb turns)	$R(S)$	set point
V_{dr}	rotor direct axis voltage (V)	$U(S)$	manipulated input of the process
i_{dr}	rotor direct axis current (A)	$Y(S)$	output
λ_{dr}	rotor direct axis flux (Wb turns)		

2.1. Mathematical model of doubly fed induction generator

Important aspects of the modeling are presented below. The system is modeled and simulated using the Matlab/Simulink toolbox. The ode23tb variable step-size solver of Matlab is used to perform the simulations.

$$V_s = R_s i_s + 1/W_O \frac{d\lambda_s}{dt} + W_k M(pi/2)\lambda_s \quad (1)$$

$$V_r = -R_r i_r + (1/W_O)\frac{d\lambda_r}{dt} + (W_k - W_m)M(pi/2)\lambda_r \quad (2)$$

$$M(pi/2) = 90^\circ \text{space rotatir i.e.,} M(pi/2) = [, -1; 1\,0] \quad (3)$$

Flux linkage equations:

$$\lambda_r = L_m i_s + L_r i_r \quad (4)$$

$$\lambda_s = L_s i_s + L_m i_r \quad (5)$$

where

$$L_s = L_m + L_{sl} \text{ and } L_r = L_m + L_{rl}. \quad (6)$$

By applying d–q theory in Eqs. (1)–(5) and rearranging the equations with variables V_{ds}, V_{qs}, V_{dr} and V_{qr} becomes,

$$p\lambda_{ds} = f(V_{ds}, V_{qs}, V_{dr}, V_{qr}) \quad (7)$$

$$p\lambda_{qs} = f(V_{ds}, V_{qs}, V_{dr}, V_{qr}) \quad (8)$$

$$p\lambda_{dr} = f(V_{ds}, V_{qs}, V_{dr}, V_{qr}) \quad (9)$$

$$p\lambda_{qr} = f(V_{ds}, V_{qs}, V_{dr}, V_{qr}) \quad (10)$$

The machine parameters used for simulation is presented in Table 1.

3. Controller design

Fig. 2 shows the general internal model controller and the design algorithm is provided in [11] for a first order system.

The linearized first order Plant model is

$$G_p(s) = \frac{K}{1 + \tau s} \quad (11)$$

Internal model

$$G_{inv}(s) = \frac{1 + \tau s}{K} \quad (12)$$

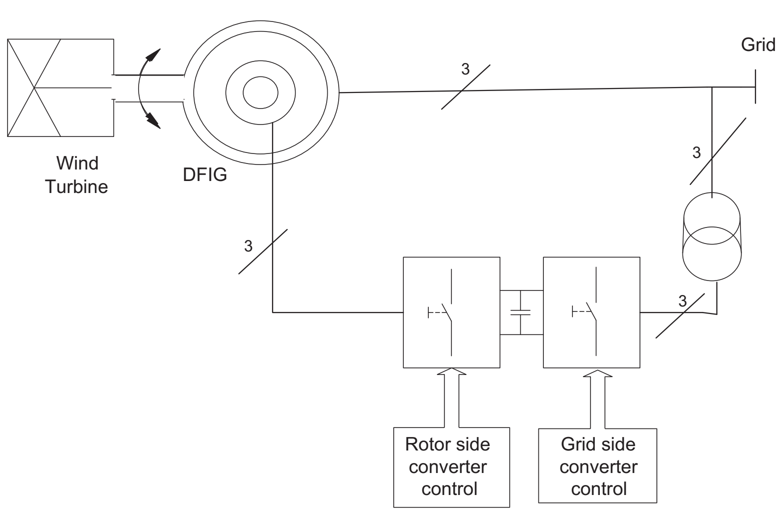

Fig. 1. General configuration for shunt connected DFIG wind turbine system.

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