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ScienceDirect

Procedia Computer Science 127 (2018) 454–463

Procedia Computer Science

www.elsevier.com/locate/procedia

The First International Conference On Intelligent Computing in Data Sciences

# Neural Networks for Stable Control of Nonlinear DFIG in Wind Power Systems

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**Abstract**

This paper presents an Artificial Neural Network (ANN) based Direct Power Control (DPC) strategy for controlling power flow, and synchronizing Double Fed Induction Generator (DFIG) with grid and Voltage Oriented Control (VOC). In order to cope with the complex calculations required in DPC, the proposed ANN system employs the individual training strategy with fixed-weight and supervised models. The ANN controller is divided into five subnets: 1) real and reactive power measurement sub-net (fixed-weight) with dynamic neurons; 2) reference real and reactive calculation sub-net (fixed-weight) with square neurons; 3) reference stator current calculation sub-net (supervised) with log-sigmoid neurons and tan-sigmoid neurons; 4) reference rotor current calculation sub-net (fixed-weight) with recurrent neurons; and 5) reference rotor voltage calculation sub-net (fixed-weight or supervised). The results obtained demonstrate the feasibility of ANN–DPC. The proposed ANN-based scheme incurs much shorter execution times and, hence, the errors caused by control time delays are minimized.



*Keywords:* artificial neural network; direct power control; double fed induction generator; wind power systems.

## 1. Introduction

Double Fed Induction Generator (DFIG) is an attractive solution for variable-speed systems with limited variable speed range [1]. In addition to the cost of the converter becoming lower, there is also less losses compared to a system where the converter has to handle the total power. DFIGs have the ability of reactive power control and decoupling of real and reactive power control by independent control of torque and rotor excitation currents [2]. The

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10.1016/j.procs.2018.01.143

variable speed wind turbine using a doubly fed induction generator (DFIG) is becoming a popular concept and thus the modeling of the DFIG based wind turbine becomes an interesting research topic.

In fact, several advanced DFIG control algorithms, such as artificial intelligence vector control [3], [4], model-based predictive control [5], sliding mode control [6] and non-linear control [7], have appeared in recent years.

Two direct active and reactive power control strategies for a DFIG-based wind energy conversion system, based on the fuzzy logic controller (FLC) are proposed in [8], the fully fuzzy-based direct power control directly calculates the rotor reference voltages from the instantaneous power errors using an FLC, while in the fuzzy-based direct power control, proper feed forward terms are added to the FLC outputs to improve the dynamic performance. However, the simulated performance of both methods under harmonically distorted and imbalanced grid voltages show that they cannot successfully maintain their normal operation, with just increased power ripples which are more evident for the fuzzy-based direct power control.

A decoupling control strategy for the active power and reactive power of DFIG was proposed in [9], and it has been widely used in previous research work [10], [11]. The control strategy is based on proportional-integral (PI) controllers; these are well accepted and used in the engineering field for their reliability and robust control performance. It is well recognized that suitable parameters are needed for controllers in order to achieve better control performance for system stability. The decoupling control algorithm of a wind turbine with DFIG consists of five different PI controllers. It has been found that the coordination among these controllers using the traditional trial and error parameter tuning method is a very difficult and challenging task.

Artificial neural networks (ANNs) are well known as a tool to implement nonlinear time-varying input-output mapping. To overcome the drawbacks of the methods in [12], [13] propose a multilayer perceptron neural network based wind speed estimation method for a direct-drive small wind turbine generator system. This method provides a fast and smooth wind speed estimation from the measured generator electrical power. However, it is based on a lumped-mass shaft model and does not take into account the power losses of the wind turbine generator. For a wind turbine generator with a gearbox, such as the wind turbine with a doubly fed induction generator (DFIG) considered in this paper, this method could not accurately estimate the wind speed because of the non-negligible power losses and the complex shaft system dynamics of the wind turbine generator.

However, it is verified that the use of neural networks has not been widely used in the active and reactive power control of the doubly fed induction generator based on wind energy conversion system.

This paper presents an ANN based DPC strategy for controlling power flow, and synchronizing DFIG with grid and VOC. In order to cope with the complex calculations required in DPC, the proposed ANN system employs the individual training strategy with fixed-weight and supervised models. The ANN controller is divided into five subnets: 1) real and reactive power measurement sub-net (fixed-weight) with dynamic neurons; 2) reference real and reactive calculation sub-net (fixed-weight) with square neurons; 3) reference stator current calculation sub-net (supervised) with log-sigmoid neurons and tan-sigmoid neurons; 4) reference rotor current calculation sub-net (fixed-weight) with recurrent neurons; and 5) reference rotor voltage calculation sub-net (fixed-weight or supervised). The results obtained demonstrate the feasibility of ANN–DPC. The proposed ANN-based scheme incurs much shorter execution times and, hence, the errors caused by control time delays are minimized.

## 2. Modeling of the DFIG

When modelling the DFIG, the generator convention will be used, which means that the currents are outputs instead of inputs and real power and reactive power have a positive sign when they are fed into the grid. Using the generator convention, the following set of equations results.

$$v_{ds} = r_s i_{ds} - \omega_s \lambda_{qs} + \frac{d\lambda_{ds}}{dt}. \tag{1}$$

$$v_{qs} = r_s i_{qs} - \omega_s \lambda_{ds} + \frac{d\lambda_{qs}}{dt}. \tag{2}$$