Electrical Power and Energy Systems 53 (2013) 287–296

Contents lists available at SciVerse ScienceDirect

Electrical Power and Energy Systems

journal homepage: www.elsevier.com/locate/ijepes

Performance and efficiency control enhancement of wind power generation system based on DFIG using three-level sparse matrix converter

Nabil Taib *, Brahim Metidji, Toufik Rekioua

L.T.I.I. Laboratory, A. Mira University of Bejaia, Bejaia 06000, Algeria

ARTICLE INFO

Article history:
Received 18 October 2012
Received in revised form 3 May 2013
Accepted 3 May 2013

Keywords:
Sparse matrix converters
Multilevel converters
Three-level sparse matrix converter (SMC3l)
Doubly fed induction generator
Variable speed wind turbine
Power control

ABSTRACT

Nowadays, the power generation systems based on wind turbines is increasing continuously in the world. Hence, there are intense efforts provided by researchers for the development of this area. In high power system applications, multilevel converters are a competitive alternative to the two-level inverters. In this paper, a three-level sparse matrix converter (SMC3l) associated to a grid connected variable speed wind generation (VSWG) scheme using a doubly fed induction generators (DFIGs) is investigated. Therefore, the dynamic behavior of a wind generator, including models of the wind turbine, DFIG, SMC3l control algorithm and power control is studied. Simulation results of the dynamic models of the wind generator are presented, for different operating modes sub-synchronous, synchronous and hyper-synchronous, to show the good performance and the efficiency control enhancement of the VSWG system using the proposed SMC3l.

1. Introduction

The doubly fed induction generator (DFIG) has many advantages for variable speed operation at medium and high power applications. The machine is robust and requires little maintenance. The power electronics interface, usually consisting of two back-to-back PWM voltage source inverters, is connected between the stator and rotor and, for restricted speed range applications, is rated at only a fraction of the machine nominal power [1–3]. In the latest years there has been an increasing interest in direct power conversion schemes, offering an all silicon solution for AC–AC conversion, with sinusoidal input and output currents without passive components in the dc link existing in rectifier-inverter based systems [4].

Another topology of the matrix converter appeared. It is named indirect matrix converter. This converter consists of an input current source rectifier and an output voltage source inverter [5–7]. This topology has similar characteristics as direct matrix converter, but the existence of a DC link offers some other possibilities such as multi drive operation, change in the DC link voltage magnitude [8], operating at different switching frequency in the input and output stages to reduce losses and essentially upgrading a voltage level numbers at the output stage. The main drawback of this type of converter is the limited input–output voltage ratio, which can be upgraded applying an over-modulation technique. However, there are applications which no need a full input–output voltage ratio such as wind generators system that operating at reduced speed range where the rated rotor voltage, i.e. the output voltage of the voltage source inverter, can be adjusted depending on the maximum slip velocity and the stator to rotor turn ratio.

Many recent research papers have been interested by the control of the wind power generation systems based on DFIG. A part of papers dealt with the energy storage systems [9,10] where the others concerned the control techniques to improve the performances of the generation system [11–14]. Nevertheless, there are few papers introduced a matrix converters in the wind generation systems [15–19] these last years. Most of these latter use the direct topology of the matrix converters because it is a well developed one for more than a quarter century. The indirect topology of the matrix converters has been declared till now with the wind generation only by a little research papers [18,19] where only the full structure at the rectification stage and a two-level structure at the inverter stage were used.

As known, the wind generation systems are a high power systems which use high power components in terms of generators, power converters and also energy storage system if it is included in the system. The multilevel converters are competitive solution to a two-level inverters or a classic matrix converter [15,16] which make them more attractive to a researchers [20–25]. It is often mentioned that the necessary of DC supply sources for the multilevel inverters as one of the limiting factors of their penetration.

* Corresponding author. Tel.: +213 550488224.
E-mail addresses: taib_nabil@yahoo.fr (N. Taib), metidji77@yahoo.fr (B. Metidji), to_reki@yahoo.fr (T. Rekioua).

0142-0615/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.ijepes.2013.05.019

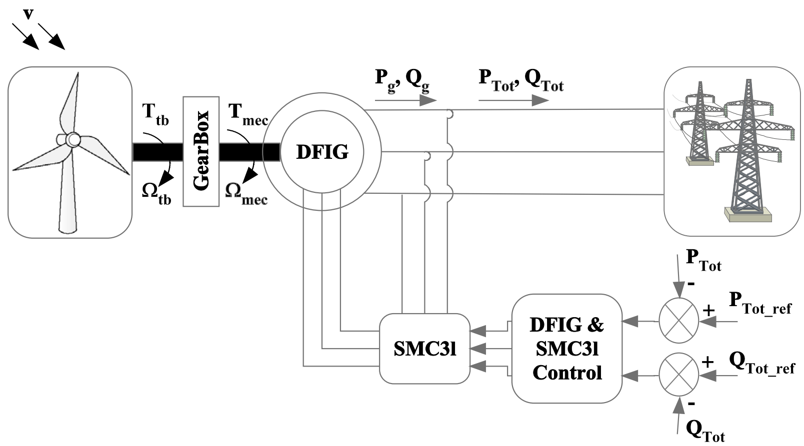

Fig. 1. Studied system diagram.

For this reason, several researchers are redirected to the application of the multilevel structures in photovoltaic generation systems and High Voltage Direct Current (HVDC) transmission links [22] where the DC supply is implicitly provided.

Based on the sparse topologies of the matrix converters [7,26], a new multilevel sparse matrix converter will be proposed and integrated in a wind energy system. In this work, the vector control of active and reactive power of a DFIG, in a variable speed energy system, using a three-level sparse matrix converter is presented. The scheme, shown in Fig. 1, uses a reference frame oriented along the stator flux vector and the operation above and below synchronous speed is presented. The added values for the VSWG based on DFIG by using the proposed topology are emphasized.

2. Control of DFIG description

2.1. Wind turbine and gearbox model

As known, the wind turbine provides the aerodynamic power P_{tb}, given by (1), which depends on the power coefficient C_p:

$$P_{tb} = \frac{1}{2} C_p(\lambda) \rho \pi R^2 v^3 \tag{1}$$

where ρ is the air density, R is the blade length and v the wind velocity.

Thus, the turbine torque is given by (2) at a known turbine shaft speed Ω_{tb}

$$T_{tb} = \frac{P_{tb}}{\Omega_{tb}}. \tag{2}$$

The wind turbine and the generator shaft are coupled through a gearbox whose gear ratio G is chosen in order to set the generator shaft speed within a desired speed range. Assuming that the transmission losses are neglected, the torque and shaft speed of the wind turbine, referred to the generator side of the gearbox, are given by:

$$T_{mec} = \frac{T_{tb}}{G} \quad \text{and} \quad \Omega_{tb} = \frac{\Omega_{mec}}{G} \tag{3}$$

where T_{mec} is the driving torque of the generator and Ω_{mec} is the generator shaft speed respectively.

A wind turbine converts only a part of the captured wind power. This amount is represented by the parameter $C_p(\lambda)$ (Fig. 2) which is function of the ratio (λ) between the angular speed of the turbine and the wind speed, given by (4) [9,10]:

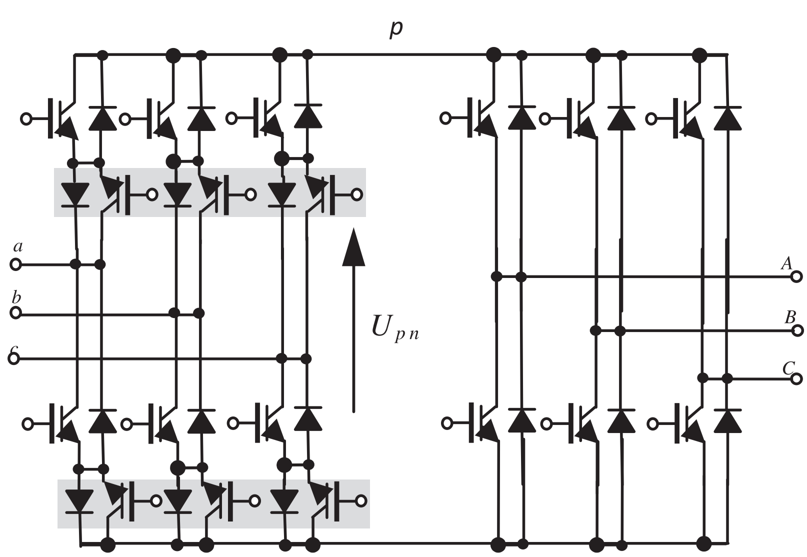

Fig. 2. Indirect matrix converter topology.