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Type-2 Fuzzy Logic Application of a Grid Side Converter Control for DFIG Driven Wind Turbines

O. E. Gouda
Department of Electrical Power &Machines
Cairo University, Egypt
prof_ossama11@yahoo.com

E. M. ElSaied, O. M. Salim, M. I. Awaad
Department of Electrical Power & Control
Benha University, Egypt
{Omar.salim & Mohamed.awad}@bhit.bu.edu.eg

***Abstract* –In this paper, the model of the grid side system GSS is studied in two consequent steps. First, the steady state model of the GSS is developed by using phasor theory; studying the relationships between active and reactive powers, voltage, and currents at different operating modes. Second, control of the grid side converter GSC is studied; developing the grid side dynamic model based on space vector theory. In this paper vector control technique that employs a rotatory reference frame (dq) aligned with the grid voltage space vector is adopted. This control strategy made it possible to achieve the two main objectives of the GSC which are: control of the DC bus voltage and assure transmission of power through the converter, with controlled reactive power exchange. Interval Type-2 Fuzzy Logic Controllers (IT2FLCs) are proposed to control the bus voltage of the DC link. The IT2FLCs proposed in this paper were designed to deal with uncertainty that may occur according to changes during system operation. In this paper, design of GSC controller, which is responsible for the terminal voltage control in addition to the DC link voltage regulation, is done. The developed IT2FLC controller is simulated using MATLAB/SIMULINK software for a 1.5 MW typical wind turbine to verify the performance of the controller.**

***Index Terms* – Wind power generation, Doubly Fed Induction Generator, Grid Side Converter control, Interval Type-2 Fuzzy Controllers.**

I. INTRODUCTION

Wind power has become the most significant option among renewable energy source based electricity generation due to its wider availability and very low environmental pollution [1]. Data published annually by the Global Wind Energy Council (GWEC) show that global annual wind capacity additions increased from 15.2 GW in 2006 to 41.2 GW in 2011, i.e. at an average annual rate of growth of 22%. Growth slowed to less than 9% in 2012, with 44.8 GW of new capacity added (GWEC, 2013) and contracted by more than 20% in 2013, when 35.5 GW was added (global cumulative capacity reached 318.1 GW by the end of 2013 (GWEC, 2014) [2]. However, stability and power quality problems exist due to the intermittent nature of the wind. This problem becomes evident, especially, when the amount of wind power integrated to the system is significantly large. The output voltage variations of a wind farm occur due to two major reasons: (i) the wind gusts and frequent gradual wind speed variations and (ii) mechanical disturbances such as swings in the wind turbine, wind shear effect and tower shadow effect. Wind power plants are vulnerable during certain transient states. For instance, they are susceptible for tripping during system short circuit fault, due to their low inertia constant [3].The wide spread use of wind generation on power network demands that the wind farms should be able to contribute to network support as the conventional synchronous generators do. Hence, new grid codes are emerging which lay down the requirements that should be fulfilled by the wind power developers [4]. These grid codes mainly consider the performance of the wind farm with respect to voltage control capability, reactive exchangeable range capability, frequency control ability and fault ride through capability.

DFIG is a wound rotor induction motor with rotor injection. The speed of the DFIG can be controlled by injecting a variable voltage of slip frequency to the rotor. It has become popular in wind farms, since it enables maximum energy extraction due to its variable speed operation capability [1],[5]. In this paper; control of the GSC is tested by studying steady state and dynamic models of the GSS formed by the grid, the grid side filter, and GSC itself. Moreover, the vector control strategy for GSC is studied. This control strategy enables to fulfil the two main objectives of GSC which are: control the DC link terminal voltage of and control of active and reactive powers exchanged directionally between the machine rotor and the grid.

A. Steady State Model of GSS

The system configured by GSC, filter, and grid voltage can ideally be represented as shown in Fig. 1. The grid voltage (v_{ag}, v_{bg}, v_{cg}) are sinusoidal with constant amplitude and frequency. The voltage imposed by GSC (v_{af}, v_{bf}, v_{cf}) can be modified in both amplitude and phase. The filter considered is a simple filter with a pure inductive part (L_f) and a parasitic resistance (R_f).

For analysis purposes, if an ideal GSS is considered, its equivalent to a single-phase GSS as illustrated in Fig. 2. Thus, it is only necessary to analyze one phase then extrapolate to the other two phases. The output voltage generated by the converter depends on the characteristics of the converter itself (two-level, multilevel topology, etc.) and the modulation