Electrical Power and Energy Systems 73 (2015) 400–410

Contents lists available at ScienceDirect

Electrical Power and Energy Systems

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

Voltage performance enhancement of DFIG-based wind farms integrated in large-scale power systems: Coordinated AVR and PSS

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ARTICLE INFO

Article history:
Received 19 May 2014
Received in revised form 2 May 2015
Accepted 5 May 2015
Available online 25 May 2015

Keywords:
DFIG-based wind farms
Voltage performance enhancement
AVR
PSS
Fuzzy coordinator

ABSTRACT

According to large extension of Doubly-fed induction generators (DFIGs) in power systems, providing appropriate operating condition for this type of wind technology in fault situations seems necessary. Among the essential requirements for DFIGs in fault situations, low-voltage ride-through (LVRT) capability is the utmost important issue. This paper deals with voltage performance enhancement of DFIG-based wind farms integrated in large-scale power systems under voltage dips. This aim is satisfied by create coordination between automatic voltage regulator (AVR) and power system stabilizer (PSS) of synchronous generators. In this research, the key tool for the coordination is fuzzy logic. The necessity of coordination for the designed fuzzy controller (fuzzy coordinator) is to eradicate destructive interactions between AVR and PSS in grid disturbance conditions. The fuzzy coordinator adjusts the AVR and PSS gains to enforce them to give the best performance in fault situations. The proposed coordination supports the voltage mitigation in the Point of common coupling (PCC) under voltage dips and decreases the reactive power requirement of the DFIGs. The performance of the designed fuzzy coordinator is demonstrated on the IEEE 10-machine 39-bus power system with different levels of DFIG-based wind farms contribution.

Introduction

Widespread development in utilizing renewable energy resources such as solar, marine, biomass, geothermal and wind for electricity generation is become inescapable newly. Wind energy has the most contribution for power generation among different renewable energy resources; this is so because of its potential advantageous such as free availability of wind, ability to exploit in high power, other land around uses of wind farms and as the important one it is relatively inexpensive to build wind farm [1]. Targets in Europe and the US in 2007 for wind installation will meet 20% of their electricity consumptions by 2030 [2]. Application of this amount of wind power in electrical power systems requires more accuracy and attention. Great information about large integration of wind plants, impacts on power system and deregulated systems has been given by [3].

With introduction of new generation concepts such as Doubly-fed induction generators (DFIGs) with different dynamics of synchronous generators, the stability of power system is confronted to new challenges. When the contribution of DFIGs in power system is in small scale, the stability of power system is affected lowly. On the contrary, with high penetration of DFIG-based wind farms in the power system, the dynamic performance of the grid can be affected significantly by the characteristics of the DFIGs. The transient stability of power systems integrated with DFIGs is investigated in several papers [4,5]. The increased integration of DFIG-based wind farms in power systems can have both beneficial and detrimental effects on small signal stability and transient stability [6]. The safe application without reducing stability of DFIGs equipped with power electronic converter and Low-voltage ride-through (LVRT) capability in a weak grid is demonstrated in [7]. The relation between reactive power control of DFIGs and the rotor angles of synchronous generators in a large-scale power system is addressed in [8]. Reduction in reactive power absorption of DFIGs can diminish reactive power injection by the synchronous generators and helps mitigation large rotor angle swings.

Since that rotor speed of DFIG-based wind turbine changes to extract maximum energy from wind, the LVRT enhancement gains the most attention. In a power system with wind farms, faults even far away from the location of wind farms can cause voltage dips in the terminals of wind turbine. The current in the stator windings of DFIG will increase rapidly after voltage dip in the Point of common coupling (PCC). The magnetic coupling between stator and rotor of induction generator in DFIG causes to flow a current in the rotor circuit. As a result, the overcurrent will be seen in power electronic converter, which may destroy the converter. Given this assertion,

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http://dx.doi.org/10.1016/j.ijepes.2015.05.014
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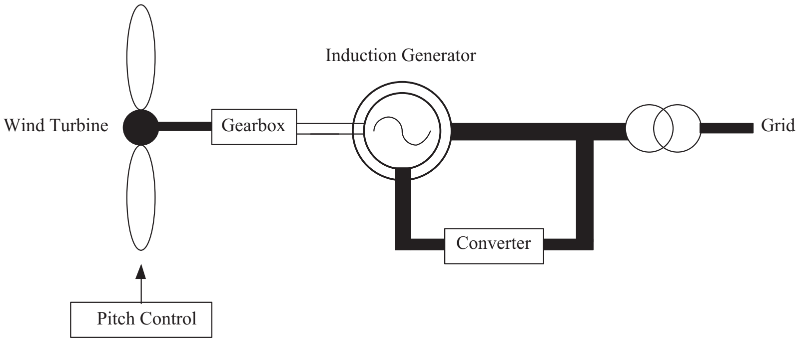

Fig. 1. DFIG model.

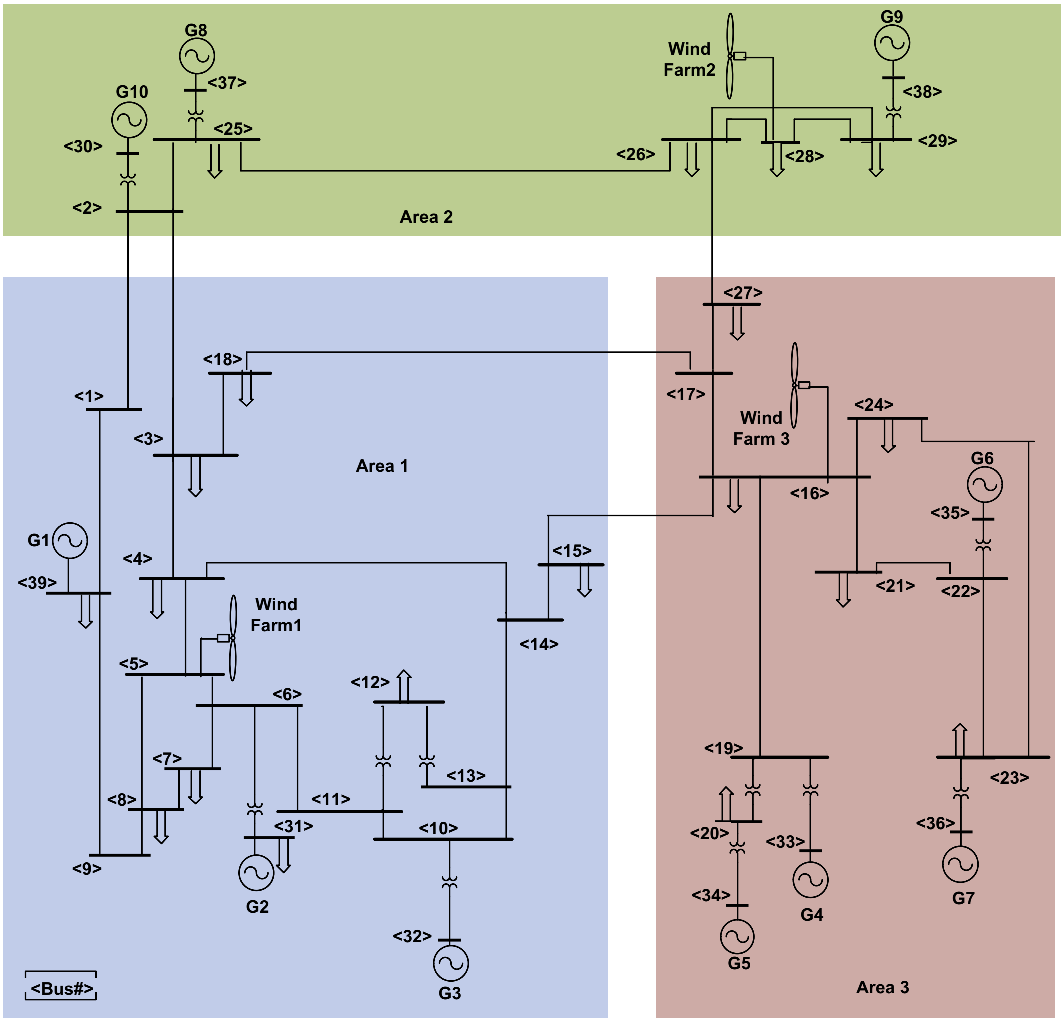

Fig. 2. 39-bus power system.

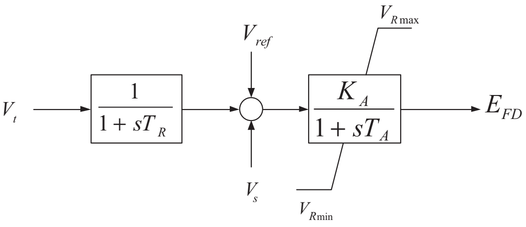

Fig. 3. AVR structure.

most of the studies in the published literature are limited to PCC voltage performance enhancement of DFIGs. To achieve this end, there are two control strategies: from the network point of view, the available control tools such as AVR, PSS and dynamic voltage controllers can be employed. On the other hand, from the DFIG point of view, different control plans can be implemented on the power electronic converter to enhance the PCC voltage.

Using a series damping resistor in the stator circuit, the peak of rotor current in fault situation is reduced in [9]. A robust decentralized output feedback control scheme for rotor-side and grid-side