Chapter 88
Impacts of High Wind Power Penetration on the Frequency Response Considering Wind Power Reserve

Bakhtiar Badmasti
Islamic Azad University—Marivan Branch, Iran

Hassan Bevrani
University of Kurdistan, Iran

Ali Hessamy Naghshbandy
University of Kurdistan, Iran

ABSTRACT

With high wind power penetration, imbalance between generation and consumption is increased, and as a consequence the frequency deviation from the nominal value will be magnified. For frequency control purpose in conventional power systems, the synchronous generators are only responsible. However, it is expected that the renewable energy sources (RESs) are also needed to contribute in frequency control issue in near future. In this paper, impacts of high wind penetration on the frequency control are studied, and an approach is introduced for creating the secondary reserve for doubly fed induction generator (DFIG) wind turbines. This reserve can contribute to load frequency control (LFC) task. Simulation results on updated standard IEEE 39-bus system are presented and it is shown that the wind turbines can contribute in LFC service, successfully.

INTRODUCTION

Nowadays, using renewable energy sources (RESs) such as wind, solar and tidal power for generation of energy is increasing. Among all RESs, the wind power has the maximum contribution to the renewable power generation. China, USA, Germany, Spain and India at the end of 2010 had maximum installed capacities in the world with 44.7 GW, 40.18 GW, 27.21 GW, 20.67 GW and 13.06 GW, respectively; it is expected that, at the end of 2020, total capacity in the world will reach to 1500 GW (World Wind Energy Association WWEA, 2011). With growth of wind energy, the

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power system is faced with new problems such as new challenges in frequency control (Bevrani, Ghosh, & Ledwich, 2010) and power reserve estimation. With increasing wind power in a power system, the initial frequency drop may increase following a load disturbance (Erlich, Rensch, & Shewarega, 2006).

Currently, using of Doubly Fed Induction Generators (DFIGs) is more usual than the other wind turbine technologies, because they can easily provide ancillary services and active/reactive power control. Naturally, the DFIG wind turbines cannot contribute to the inertial response because the rotational speed of them is not directly connected to the network (Lalor, Ritchie, Rourke, Flynn, & O'Malley, 2004; Ekanayake & Jenkins, 2004; Lalor, Mullane, & O'Malley, 2005). But, adding a supplementary loop control to the DFIGs, they can release their kinetic energy and contribute to inertial response and primary control (Lalor, Ritchie, Rourke, Flynn, & O'Malley, 2004; Lalor, Mullane, & O'Malley, 2005; de Almeida & Lopes, 2005; Morren, de Haan, Kling, & Ferreira, 2006; Anaya-Lara, Hughes, Jenkins, & Strbac, 2006; Conroy & Watson, 2008; Chowdhury & Ma, 2008; El Mokadem, Courtecuisse, Saudemont, Robyns, & Deuse, 2009; Tarnowski, Kjar, Sorensen, & Ostergaard, 2009; Ping-Kwan, Pei, Banaka, & Boon Teck 2009; Erlich & Wilch, 2010).

Wang, Sun, Li, and Ooi (2010) have proposed a voltage and frequency control method for DFIG. This method makes DFIG equivalent to a synchronous generator and controls active and reactive power of stator by controlling the voltage magnitude and frequency of the rotor. Kaneko, Uehara, Senjyu, Yona, and Urasaki (2011) used an integral control method for wind farms to reduce frequency deviation in a small power system. In this method, wind farm achieves the frequency regulation objective based on two control schemes: load estimation and short-term ahead wind speed prediction. The proposed methods have some drawbacks such as reduction of wind farm output power, as well as increased pitch action. Bhatt, Ghoshal, and Roy (2010) have introduced an extra frequency control support function which affects the rotational speed of rotor in the case of frequency disturbance and reduces the frequency dip by releasing short term transient active power. For optimal dynamic frequency performance, Thyristor controlled phase shifter (TCPS) and Superconducting Magnetic Energy Storage (SMES) are also used in coordination with DFIG frequency control loop. Mokadem, Courtecuisse, Saudemont, Robynsand, and Deuse (2009) have introduced a primary frequency control based on fuzzy logic for variable-speed wind generators. This method controls the torque generator and pitch angle to keep primary reserve. Senjyu, Kaneko, Uehara, Yona, Sekine, and Kim (2009) have presented an output power control of wind turbine using pitch angle control. In this approach, wind turbines achieve flexible output power control and therefore frequency deviation reduces. Xiangyu, Heming, and Yi (2010) have added a PD controller to the DFIG, and they have introduced a new control loop for participation of DFIG in the frequency control, but this loop only provides the primary frequency control.

Mauricio, Marano, Gomez-Exposito, and Martinez Ramos (2009) used a method for frequency regulation by releasing kinetic energy of rotating mass and, with a communication between the wind turbine and the conventional generator a coordination is also created. Ullah, Thiringer, and Karlsson (2008) have discussed the capability of providing a short-term active power support of a wind farm for the primary frequency control utilizing the kinetic energy of the rotated mass. Khaki, Asgari, Sirjani, and Mozdawar (2008) have shown that coefficient of power of wind turbine can be changed through two different criteria defined for tip speed ratio parameter (the ratio of blade tip speed to wind speed), and from this viewpoint, a novel structure has been proposed for primary frequency control that controls turbine speed reference. Abe, Ohba, and Iwamoto (2006) introduced the disturbance observer for