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Critical aspects of wind energy systems in smart grid applications

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ABSTRACT

Wind energy is an important contributor of modern power systems as a renewable energy source. However, wind energy poses new challenges because of its unique characteristics, such as limited predictability, short-term and long-term variability and close-to-zero marginal cost. This paper puts forward the critical aspects of wind energy systems in respect to the transformation of the power system into a "smart grid". Issues discussed include the electro-mechanical matters like the selection of wind turbine technology, the structure of wind system, the robustness of mechanical parts (gear box and blades) and fault diagnosis. In addition, the system operational challenges such as complexity, instability, unbalance loading, grid interactive problems and impact of wind energy on power system are discussed in this paper. Moreover, the economical subjects such as investment costs and energy management, communication requirements, and security are involved as important titles. Finally, environmental aspects of wind energy are also highlighted to show that the wind energy is an environmentally friendly energy source since it is sustainable, clean and safe.

Contents

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1. Introduction

Nowadays, new trends have been made possible to reconfigure the traditional power systems in more efficient way while world energy consumption is being continuously increased. Example of such trends is the development of renewable energy based power plants, energy storage systems, and efficient energy management solutions. To secure future energy demands, a more flexible, smart and configurable power system is required. In order to create such system, smart grids are emerging and becoming more attractive solution. The smart grid is a weak grid formed with different energy sources (renewable and conventional), energy storages, power electronics interfaces, power control systems and different loads. Therefore, proper design and control of these subsystems are essential to obtain more efficient, stable and reliable smart grid system.

The energy sources are the major part of the smart grid system. As a result of increasing environmental awareness and as a consequence of the exhaustible nature of fossil fuels, renewable energy sources (RES) are playing an important role in modern smart grid systems. RES based power generation systems have several and major advantages compared with conventional power generation systems. Some of these advantages are sustainability, pollution-free operation and the possibility of being installed closer to the end users. In the last decades, especially wind-based power generation systems has become more popular than other RES [1].

Smart grids are generally defined as “an intelligent electricity network integrating the behaviors and actions of all users such as generators and consumers connected to it by providing both way communication and control in order to efficiently ensure sustainable, economical and secured electricity supply” [2]. Even though smart grids refer mainly to the transformation of the electricity power system, they should be seen as an integral part of a cleaner, more competitive and more transparent energy system on the whole. As such smart grids will have both a fundamental role for renewables, and especially wind energy, and at the same time will play the role of facilitator for their integration into the energy system by increasing its flexibility.

Components of increased flexibility in a smart grid environment include

- flexible conventional power generation units
- demand-side response and load management,
- storage technologies,
- increased interconnections, system and market integration (i.e. the goal to a unified internal electricity market in Europe) and
- large deployment of bi-directional ICT technologies that increase the observability and controllability of the power system.

Wind energy is used for many different applications varying from windmills to pumping water and sailing boats. As the importance of environmental issues increase, clean energy production becomes more critical in every aspect of energy utilization. Although wind energy is very clean, it is not sustainable for long periods of time. In principle, energy generation from wind changes the fossil-fuelled energy production. There are significant numbers of scientific studies in the field of wind energy, which treat the problem employing various methodologies [2–6]. The energy crises of the 20th century increased the use of RE resources such as wind and solar. In recent years, Germany, Denmark, and Spain as leading countries in Europe have developed the wind energy production and extended it to industrial usage. These successful examples of wind energy penetration have encouraged other countries to think on incorporating wind energy into their electricity generation systems. The benefits of wind energy including environmental sustainability, societal economic gains, modularity, scalability and relative ease of installation later on draw the attention of political and, business circles, as well as that of individuals. These positive contributions of wind energy to society and industry also get great public support according to opinion surveys in Europe [7].

This paper provides an overview on the critical aspects for wind energy based smart grids. The paper is organized as follows. Section 2 discusses wind turbine technologies and grid connection requirements. Then, mechanical aspects of the wind turbine including fault diagnosis and condition monitoring are described in Section 3. After that, the impacts of wind energy on power systems for smart grids are discussed in section 4. Economic aspects and type of energy management techniques in Section 5 are followed by communication and security aspects of the smart grid system in Section 6. Later on, environmental aspects of the wind-based energy generation systems are discussed in Section 7.