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Power system integration of wind farms and analysis of grid code requirements

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ABSTRACT

This paper covers the integration of the wind turbines with the national grids which includes the quality of the power generated at the wind plants, the impact to the power systems and the details of connection systems. The distribution system of Trakya area has been considered in detail together with Matlab software program. A power plant for 50 MW, which will be switched on in 2014, has been analyzed with its current situation and for the probably power capacity of 150 and 300 MW in the future. The impact to the national grid and the compatibility with current rules and standards has been checked by using different type of turbines. This praxis has been also repeated for the existing full scaled frequency inverted permanent magnet synchronous generators (PMSG), doubly fed asynchronous generators (DFIG) and fixed speed wind turbines.

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1. Introduction

Wind energy has been used for more than 3000 years all over the world. Until the beginning of 20th century it was only used to provide mechanical energy like pumping of water and grinding of crops. But in 1891, Dane Poul La Cour invented the first wind turbine which generated electrical power [1]. And since that day, the use of wind energy for electrical power generation has increased day by day. The reasons for that can be summarized like; decrease of fossil fuel reserves, subsistence, cleanness, renewability and infinity of the wind energy [2]. Wind energy has been preferred every day more and more to generate electrical power by the improvement of technology and competitive capacity. As per the end of the year 2013, total installed capacity of wind turbines overall the world is at about 318,105 MW [3]. Total installed capacity in Turkey is 2959 MW as per the end of the year 2013 [3]. In other words, the wind energy connected to the national grids is increasing in the last years.

Improved ratio of the wind energy in national grids has brought some balance problems together with. At the beginning

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period only medium sized wind turbines could be connected to the grid and people were focused to their impact for the quality of the voltage. After years, with the innovation of the technology, the installed power of the grids has begun to be higher and higher. People changed their focusing for the impacts to the general power systems. Then, it became a necessity to issue new rules and instructions for many nations and they have issued new rules and standards to restrict the impact of the wind turbines to the power systems of the national grid.

This paper is covering the integration of the wind turbines with the national grids which includes the quality of the power generated at the wind plants, the impact to the power systems and the details of connection systems. The distribution system of Trakya area has been considered in detail together with Matlab software program. A power plant for 50 MW, which will be switched on in 2014, has been analyzed with its current situation and for the probably power capacity of 150 and 300 MW in the future. The impact to the national grid and the compatibility with current rules and standards has been checked by using different type of turbines. This praxis has been also repeated for the existing full scaled frequency inverted permanent magnet synchronous generators (PMSG), doubly fed asynchronous generators (DFIG) and fixed speed wind turbines.

2. Standards related power quality measurements

The term of power quality in wind turbines defines the electrical performance in electrical production system. Grid connected wind farms can affect the power quality of the grid. The basic effects of grid connected wind farms about power quality are voltage variations and harmonics. These effects should be analyzed in advanced to fulfill grid codes of located country. According to results of analysis, if required, essential improvements should be done and the system should be designed considering these effects. The electrical characteristics of wind turbine should be known to perform this analysis [4].

In 1996, International Electrotechnical Commission (IEC) started work to fulfill the need for consistent and replicable documentation of wind power characteristics of wind turbines. After five years, IEC 61400-21 named “Measurement and assessment of power quality characteristics of grid connected wind turbines” was published in 2001. Second edition of this standard was developed in 2008 as wind farms have started to connect to transmission system rather than distribution system [5]. As a result, today’s wind turbines are capable of controlling both active and reactive power in steady state and transient state. They handle the need of power control and low voltage ride through capability [6].

Many of the wind turbine manufacturers define the electrical characteristics of wind turbines according to this IEC standard. Apart from IEC, Measuring Network of Wind Energy Institutes (MEASNET) and Fördergesellschaft Windenergie e.V. (FGW) standards are used for power quality measurements. Before IEC 61400-21, there was not any procedure to define the power quality characteristics of a wind turbine. Simplified rules were used to determine the capacity of wind farm to connect to grid like minimum short circuit ratio of 25 or upper limit of voltage raise of 1%. These simplified rules seriously limited the development of the wind farms as they necessitate supporting grid which is a costly operation. When the IEC 61400-21 standard is started to be used for sizing the capacity of the wind farms, it is recognized that larger wind farms can be connected to the grid smoothly. IEC 61400-21 is one of the most important standards for measuring power quality of wind turbines. It contains definitions about power quality characteristics how to measure and which methods should be used for characteristics like flicker, harmonic, etc. The data obtained from these measurements provides a basis about evaluating grid connection of wind farms. Beyond the measurements, IEC 61400-21 gives advice about grid connection to corporation who is responsible on this evaluation. MEASNET is a measuring network of wind energy institutes. Its target is to present necessary standards to ensure measurements results to be recognized and to be agreed commonly by members. Power Quality Measurement Procedures issued in 2000 is suitable with IEC 61400-21. However, it is stated that more detailed measurements should be done about harmonic currents. In 2008 after second edition of IEC 61400-21, the difference of standards has been reduced. FGW standard is used to measure power quality of wind turbines in Germany. Most recently in 2002, this updated standard is similar with IEC 61400-21 in principle, but there are some differences about the measurement methods of these two standards and they are not comparable [4].

Grid integration of large-scale wind farms affects the stability of power system. In recent years, growing penetration level of wind farms causes serious alterations in the dynamic behavior of wind farms. Therefore, in many countries transmission system operators have changed grid codes according to these requirements. Also in Turkey, in January of 2013, Electric Market Grid Code was changed with the article of Appendix – 18 for wind farms which have a capacity of 10 MW and more. Grid codes generally state the features of wind farms which they should supply about low voltage ride through (LVRT) and power control. Low voltage ride through (LVRT) capability of wind turbines is required to avoid generation loss in case of a grid fault. Before the 2000s, in the event of any grid fault wind turbines would be expected only disconnected from the grid to avoid high rush current. However, over the years, due to increasing penetration level of wind farms in power systems disconnecting from grid may cause the system to crash because of voltage and frequency control problems. LVRT is entirely related to controller design that makes wind turbines stay connected to grid in case of a fault. At the same time, LVRT demand also determines how to fix the voltage after a fault. LVRT capability depends on the technology of wind turbines. Traditional wind turbines would disconnect from grid even in the smallest fault due to old grid codes because they do not have such a capability. Modern wind turbines with a frequency converter protection system may continue to remain connected to the network during and after the fault. Also if they are equipped with the appropriate control for network support, they can support the power system and improve the behavior of other wind turbines which have old technology [7].

Power control capability of wind farms is also requested in grid codes. Power control can be defined as active and reactive power regulation of wind farms in short or long term in addition to voltage and frequency control.

3. Case study according to grid code in Turkey

Capacity of grid connected wind farms have increased in conjunction with development of technology. In the past, wind power plants mostly connected to the distribution system, but nowadays they are connected to the transmission systems. Influence to the power system becomes more important than to the power quality when investigating the interaction between wind farm and grid with the connection to the transmission system. According to this issue, related standards were revised. The areas which have a good wind potential are mostly located far away from residential areas. The wind farms located to the far areas are connected to grid at weak points because of long transmission lines. Connection of large-scale wind farm from a weak point can affect the steady state voltage. Many of the countries published grid codes which define the requirements needed for system reliability and stability. In Turkey, grid connected wind farms should be compatible with Electric Market Grid Code, Appendix – 18 which was revised in January 2013 [8]. According to this grid code, all wind farms connected to the