ELECTROMAGNETIC COMPATIBILITY (EMC) IN WIND TURBINES

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Abstract— Wind Turbines are rapidly becoming an economically viable source of renewable energy. Wind turbine reliability is a critical factor in the success of wind energy. In order to further improve the reliability of wind turbines, the designers have to better the mechanical, electric and electronic components. As recent wind turbines become larger, more complex and more flexible, advanced electronics become necessary to meet multiple objectives. In wind turbines, electromagnetic compatibility (EMC) management has therefore emerged as a critical means of improving the reliability and operating life of the electronic equipment. It requires new methods and careful designs to ensure the reliable operation and excellent performance of the wind turbine. In the world, EMC Directives that regulate the electromagnetic compatibility of wind turbines like all equipment, give more responsibility to both manufacturers of wind turbine and operators in wind farms. In this paper, EMC assessments for a wind turbine are reviewed and discussed.

Keywords— Wind turbine, electromagnetic compatibility, EMC directives

I. INTRODUCTION

In recent years, the importance of renewable energy resources, so the importance of wind energy, is increasing rapidly. Wind energy has relatively minor environmental effects when compared to conventional energy sources. Developed countries not only accept the wind energy as a clean and zero carbon emission power supply but also they have realized its economic support. Therefore, the enforcement of adopted environmental laws and the government supports, to ensure economic development, increase rapidly in this area. According to the projections of developed countries, in next 20 years, the use of wind energy will increase greatly. So the high demand of renewable energies increased the number and the size of the wind turbines. For that purpose, manufacturers have recently turned to more complex turbines to capture power over a wide range of wind speeds and to increase the power of the turbines [1-6].

In the U.S., wind energy is one of the electrical energy sources that are growing rapidly. The growth has been linear at a rate of about 20% to 30% per year over the last decade. The U.S. Energy Information Administration estimates that U.S. electricity demands 39% increase by 2030. This led to a collaborative effort to explore a modeled energy scenario in which wind provides 20% of U.S. electricity by 2030. The 20% of Wind Scenario would require delivery of nearly 1.16 billion MWh of wind energy in 2030. Also, the 20% of Wind Scenario projects will offer potentially positive impact, such as avoiding air pollution, reducing electric sector CO_2 emissions by 825 million metric tons annually, reducing water consumption for the electric sector by 8% and generating new income source for local and federal economies.

The main challenge for wind energy developments and the main objective of the technology evolution is the reduction of cost of wind energy. This needs to be obtained through reductions in capital investment and maintenance costs and through maximizing the annual energy production. To ensure these aims, the development in wind turbine technology will play a key role.

But this rapid growth also brings challenges. The increasing number, rated power, and complexity of wind turbines create unwanted interaction between electrical devices which is strengthening problems with electromagnetic compatibility. In the literature, there is two kinds of research concept related to EMC. One is EMC requirements inside the wind turbine and the other is the electromagnetic interference of wind turbine farms with the environment. Wind turbines may be a source of disturbance in the radiation fields of TV broadcast transmitters. Scattering produced by the wind turbines on the electromagnetic waves may be a source of disturbance for different radio communication services propagating through them. Studies show that EM disturbances can even cause electricity meters to measure incorrectly, with obvious financial consequences.

II. EMC REQUIREMENTS OF WIND TURBINES

A. Turbine Technology

Current turbine technology needs innovations such as new drive train systems, advanced materials, modern control systems e.g. to obtain increased reliability, reduced maintenance costs. (Fig.1)

M.C. Esteban et.al, present the assessment of EMC in the design of the electronic systems for wind turbines. They address the studies and methods that have been carried out to guarantee the correct integration of the electronics to meet the new growing challenges of the wind turbines. The analysis carried out in their study is part of the EMC-based design approach to defining the type of cable (shielded or unshielded), shield connections, filters and configuration of the traducer /

front-end electronics required to ensure the good performance of the wind turbine and the functional safety of the system [6].

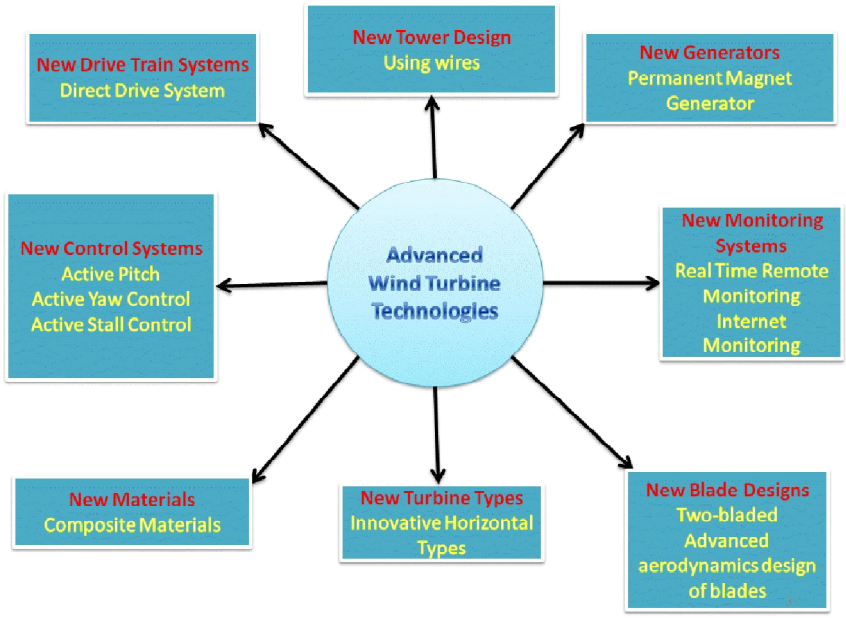


Figure 1. Advanced wind turbine technology

B. Wind turbine impacts on the surrounding environment

Wind turbines (WT) cause electromagnetic interference (EMI) via three principal mechanisms, namely near field effects, diffraction and reflection/scattering [1-4].

Near field effects refer to the potential of a wind turbine to cause interference to radio signals due to electromagnetic fields emitted by the generator and switching components in the turbine nacelle or hub.

Diffraction occurs when an object modifies an advancing wave front by obstructing the wave's path of travel. Diffraction effects can occur when the object not only reflects part of the signal but also absorbs the signal. Reflection/scattering interference occurs when turbines either reflect or obstruct signals between a transmitter and a receiver. This occurs when the rotating blades of a turbine receive a primarily transmitted signal and they act to produce and transmit a scattered signal. In this situation, the receiver may pick up two signals simultaneously, with the scattered signal causing EMI because it is delayed in time (out of phase) or distorted compared to the primary signal. [10]

A known source of objection is that the wind farm may appear on the display of air traffic control radar.

C. Environmental impacts on the wind turbine

Other important events for the electromagnetic field distribution of a wind turbine are lightning impacts [5]. These lightning events have a strong impact on the electronic systems in a wind turbine. Because of the increasing availability requirements for wind turbines, there is a trend of more complex electronic monitoring equipment for large wind turbines [6,7,10,11] [Electromagnetic Interference on Large Wind Turbines, Electromagnetic Interference on Multi-Megawatt Wind Turbines].

The protection of wind turbines from the effects of lightning is an important issue in today's wind turbine development. Lightning strikes pose a major threat to wind turbines as facilities are increasing both in number and in height. When lightning strikes a wind turbine blade, the lightning current is conducted to ground via the hub. The hub's electronic components make it very sensitive to high currents and electromagnetic fields. Lightning currents and induced electric and magnetic fields to pose a major threat to sensitive electronic components but also to various materials such as the glass fiber reinforced blades. To prevent damage, wind turbines are equipped with a lightning protection system (LPS), as are most modern buildings. Hence, the path of the lightning current is predefined by the LPS. The analysis of risks to common structures struck by lightning has improved through the years such that sensitive structural areas can now be identified [1]. Sensitive areas have been similarly identified for wind turbines, and various methods for their protection have been suggested by the International Electrotechnical Commission (IEC) [2].

D. EMC Directives for wind turbines

Today wind turbines are constructed and operated according to the EMC directives which require EMC approval for safety. The aim of the EMC management is to avoid any interference effects in order to obtain a seamless operation of different components of equipment. EMC approval is required

by law all around to the world (Table I) and it is imperative in order to avoid any emissions that can disrupt the safe and proper functioning of electrical devices.

Table 1. Examples of worldwide EMC requirements [5]

Country	*EMC Directives*
USA	FCC pt. 15
Japan	VCCI
Canada	ICES
Europe	DIRECTIVE 2004/108/EC

The EMC Directive specifies the information that must be contained in the documentation of wind turbines and wind farms for which measures have been taken to ensure compliance with the EMC protection goals. In this case, the system manufacturer, project developer, and wind farm operator are assigned an active role in keeping the EMC documentation for their wind turbines and wind farms up-to-date and thereby provide evidence of compliance with recognized engineering rules. This starts with planning and continues through to assembly and commissioning by the different construction companies that are involved. During operation of the wind turbines, service, maintenance, repairs or modifications that have effects on the electromagnetic compatibility must also be documented.

EMC documentation that conforms to the directive includes the following in particular:

- the assembly, operating and maintenance manuals of the installed devices such as the generators, rectifiers, electrical cabinets,
- the design considerations of the wind turbine that relate to EMC and a description of the solutions for compliance with the EMC protection requirements,
- information on shielding, cable shielding, cable routing,
- measurement reports, if any exist,
- as well as references to applied standards or parts of standards. [7]

EMC measurements must be undertaken in worst-case conditions. Active power and meteorological conditions (air temperature, air humidity, and air pressure) must be monitored during the measurements. Radiated emissions must be measured 30m away from the site and the results must be compared with the IEC 61000-6-4 from December 2010. Conducted emission must be controlled by measuring the voltage or current on all copper lines such as power cables or telecommunication wiring in the wind turbine.

E. EMF Measurement

Electric, magnetic and electromagnetic fields (EMF) can damage human health. In Europe, Directive 2004/40/EC on working safety specifies periodic EMF measurements. Various national laws specify the measurement setup and limits. For example, Germany's BGV-B11 contains all the required information and prescribes measurement of radiated emissions on working places in wind turbines. It is simpler to measure EMF than EMC. The recommended frequency range on wind turbines is between 5 Hz and 32 kHz. The low frequencies require a separate measurement of the electric and the magnetic fields. Under ideal conditions, measuring these fields takes between six and eight hours.

Lightning strikes pose a major threat to wind turbines as facilities are increasing both in number and in height. When lightning strikes a wind turbine blade, the lightning current is conducted to ground via the hub. The hub's electronic components make it very sensitive to high currents and electromagnetic fields. While simple solutions exist to mitigate the threat of lightning current on the control electronics, shielding the electronics from the induced electromagnetic fields is much more difficult. This is particularly true for magnetic fields. A numeric model of the hub and its components can be created in order to specify the magnetic fields inside the hub. Model validation can be done using magnetic field measurements performed inside a large wind turbine hub.

CONCLUSION

In order to further improve the reliability of wind turbines, the designers have to develop better mechanical, electric and electronic components. As recent wind turbines become larger, more complex and more flexible, advanced electronics become necessary to meet multiple objectives. In wind turbines, electromagnetic compatibility (EMC) management has therefore emerged as a critical means of improving the reliability and operating life of the electronic equipment. It requires new methods and careful designs to ensure the reliable operation and excellent performance of the wind turbine. In the world, EMC Directives that regulate the electromagnetic compatibility of wind turbines like all equipment, give more responsibility to both manufacturers of wind turbine and operators in wind farms. In this paper, EMC assessments for a wind turbine are reviewed and discussed.

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