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Investigation of possible societal risk associated with wind power generation systems

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ABSTRACT

There is a progressive acceptance about the proposal of wind as an alternative source of energy to meet future global demand and significant reduction of environmental pollution. In this context, from design to decommission, safety doubtless represents an integral element of wind turbines. Based on historical accident data the quantitative risk measure of societal risk in connection with wind farms was evaluated in the present work. It was considered the CWIF database which contains information on accidents, incidents and fatalities related to wind technology from the 1970s to October 2011. The data were presented in its absolute values and normalized by the capacity of wind power installed worldwide over the years. The security level observed due to the wind turbine operation tends to increase with the increment of installed capacity. The social risk was calculated for two particular cases (characteristically arbitrary). As observed by the results (the curves in the F–N diagram) obtained for both scenarios, the risk does not exceed the upper limit of ALARP criterion. Nonetheless, the required application of principles for the integration of safety to tackle the hazards linked with wind turbines must not be neglected. Safety must be increased as the wind energy production expands, as well as there should be a need for regular reconsideration.

Contents

1. Introduction

As a renewable source of energy, the wind provides a significant contribution to renewable energy targets. Wind power industry has been developing rapidly, and high penetration of wind power into grid is taking place, which directly pushes the wind technology into a more competitive area [1]. Due to a singular technical identity, wind turbine technology has an unique demand in terms of methods used for design [2].

Among its benefits the wind energy has no radiation hazards, the source is free, incurs no transport costs and produces some of the lowest rates of pollution/thermal emissions for electric-power generation into the atmosphere or nearby water resources. Currently (October 2012) the worldwide capacity of installed onshore wind farms stands at more than 250 GW (and above 280 GW involving offshore projects) [3] with a sustained growth rate predicted over the present decade. Maintaining such growth necessitates research into the management of economic and environmental risks associated with the operation of large-scale commercial wind ventures [4].

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Unquestionably, safety as an integral element of the turbine – from design to deployment – must always be in the foreground. Wind turbines are extremely sophisticated machines. The vertical tower (which carries the key components of the wind turbine inside the nacelle, e.g. the gearbox, mechanical brakes, electrical generator, control systems, etc [1]) and the turbine rotor (consisting of rotor blades and hub) are the main components subjected to highly variable forces as the blades rotate. As the wind speed changes, the variation in the forces increases, resulting that these components are subjected to severe fatigue [5,6]. Therefore, to help with their decision-making process, managers of health care, the environment, and physical infrastructure systems should all incorporate risk analysis [7]. There are several commonly used measures of risk, so the question arises as to which should be used.

Apropos, the term risk usually expresses not only the potential for an undesired consequence, but also how probable it is that such a consequence will occur, while the term hazard expresses the potential for producing an undesired consequence without regard to how likely such a consequence is [8]. Risk has been considered as the chance that someone or something that is valuated will be adversely affected by the hazard [9], while hazard is any unsafe condition or potential source of an undesirable event with potential for harm or damage [10]. Risk management is a tool that can be used to determine the risks associated with the hazards in any work process, machine, or chemical process. Risk assessment is a part of risk management. Once the hazards are identified, the risk assessment can be performed. Furthermore, risk assessment is an essential and systematic process for assessing the impact, occurrence and the consequences of human activities on systems with hazardous characteristics [11]. It constitutes a needful tool for the safety policy of a company, keeping in mind that completely controlling behaviors through rigid and voluminous procedures cannot be done. This happens because of the complex nature and design of the equipment and the complexity of facilities [12]. To put it another way, there is a basic recognition that “zero risk” is not attainable and that the real aim must always be to identify, control and reduce the risk. Contrasting, there is still a belief that application of good practice embodied in design and other standards removes risk [13].

The main contribution of this work is the presentation of the quantitative measure of possible societal risk associated with wind turbines based on documented historical accident data. While statistics on accident rates (accident per inventoried capacity per year) should be considered inaccurate, these data may give a satisfactory description of the types of accidents which can occur, as well as their consequences. Thus the societal risk conceptual framework, traditionally applied in part of risk assessment task developed in industries such as chemical, nuclear, oil, and gas, is verified in the context of the wind energy systems technology.

This paper is organized as follows. After the introduction, in Section 2 the societal risk technique and ALARP principle are summarized. In Section 3, it is outlined some of the types of accidents related to wind turbine technology. In Section 4, the historical data are presented and examined and finally the conclusions of the present paper are stated in Section 5.

2. Quantitative societal risk technique

The individual risk (IR) can be defined as the probability (frequency) of lethality for an unprotected person in the vicinity of hazardous location [7]. Nonetheless, there are situations not completely described by IR technique, as is the case of a single accident that could result in fatality (or injure) to a large number of people. These situations can be addressed by estimating the societal risk (SR), expressed as a relationship between the accident scenario (an accident category), the frequency of this scenario (evaluated as probability per time unit), and the consequences (the number of injuries and fatalities) [14].

Several advantages count in favor of SR technique [7]:

- It is easy to apply
- It usually encompasses both public and worker risk
- It depicts the historical record of incidents
- It is both a quantitative and graphical technique
- The information about societal risk is illustrated by simple F–N diagrams
- It depicts criteria for judging the risk tolerability
- The system is characterized as tolerable or intolerable graphically and easily
- It provides a consistent basis to analyze the individual and societal risk.

Aforementioned, SR is usually represented as an F–N curve. In such a graph, it is plotted the expected (annual) frequency (F) of the number of casualties (N). The whole surrounding area (arising from all possible dangerous incidents at a hazardous site) is considered. Three regions are deemed in the F–N diagram:

(1) The risk is so high that it is intolerable
(2) An intermediate level where the ALARP (As Low As Reasonably Practicable) principle applies
(3) The risk is so low that it is considered negligible (or acceptable) [15].

In region 2, the so-called ALARP principle is adopted. An ALARP evaluation process will include a dedicated search for possible risk reducing measures, and a subsequent assessment of these in order to determine which should be implemented [16]. Nowadays widely applied in safety decision-making, the ALARP principle requires that those responsible for safety in the workplace – and, indeed, public safety – should reduce risks to levels that are “As Low As Reasonably Practicable”. As such, the principle involves effective recognition of the fact that, while in most circumstances risk can be reduced, beyond some point further, risk-reduction is increasingly costly to implement [17]. The ALARP criterion is considered a more fundamental approach to the setting of tolerable risk levels and should be particularly suitable for regulatory purposes [15,18].

3. Accident hazard scenarios

The identification of the hazard exposure that may be encountered during the execution of a task or a job constitutes the primary purpose of a hazard/risk evaluation [12]. Therefore, some pertinent questions addressed when performing the identification of hazards related to onshore wind turbine plants can be listed:

- The kinds of risks caused by wind turbines
- The distance at which vulnerable objects need to be considered in the risk analysis
- The probability of a person or object be hit by a turbine fragment and
- The safety and risk criteria that are valid and should be met.

Studies were carried out to assess the damages to wind turbines and their components. Superficial cracks, geometric concentrator (the local geometry of stress concentrator in the