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Historical Analysis on Wind Turbine Fire Incidents

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Fires in wind turbines represent a critical issue in the renewable energy industry, as they not only result in significant economic losses but also pose considerable risks to public health and the environment. Given the global growth in wind farm installations, fire prevention and management has become an increasingly relevant challenge. To better understand this issue, a database has been created, compiling 478 wind turbine fire incidents that occurred between 2000 and 2024. This historical analysis includes information on the date and location of the incidents, technical characteristics of the affected turbines, as well as the turbine manufacturers involved. The reported fires have been recorded across various regions, mainly in the Americas and Europe. On average, 20 fires have been reported annually, although various studies suggest that the actual number is much higher. This study provides valuable insights for decision-makers in the wind energy sector, aiming to improve safety regulations and reduce the occurrence of fires in the future.

* 1. Introduction

Today, fossil fuels, such as coal, oil, and natural gas, continue to be the main sources of energy globally. However, its intensive use has generated serious environmental impacts, such as increased greenhouse gas emissions and consequent climate change. In the face of this crisis, more sustainable alternatives have been developed, highlighting renewable energies, such as solar, hydroelectric and wind. These energy sources, derived from inexhaustible natural resources, not only offer a solution to reduce emissions, but also have economic and social benefits, such as job creation and energy independence.

Wind energy is obtained by harnessing the kinetic energy of the wind by large turbines located onshore or offshore. Although the use of wind as an energy source dates back millennia, recent technological advances have optimized its use by means of taller turbines and larger diameter rotors, capable of generating electricity even in areas of moderate wind speeds. This renewable technology has emerged as a key element in the energy transition, although its expansion also entails technical and safety challenges, such as accidents associated with wind turbines, the central theme of this analysis.

A typical modern wind turbine consists of several key components: a rotor, which includes the blades and the supporting hub, a drive train with various rotating elements, a nacelle and a main frame housing the operational mechanisms, and an advanced control system along with an electrical network to manage and optimize power output. These turbines are engineered to adapt to specific environmental conditions, ensuring maximum efficiency and reliability in energy generation, regardless of whether they are installed onshore or offshore (Manwell, 2009).

Wind energy is the fastest growing renewable energy source in recent years, achieving a record increase in the number of wind farms during 2020, a growth that was almost matched in 2021. Due to its profitability, many countries have chosen to invest in this energy source, The 71% of wind energy markets are situated in China, United States, Germany, India, and Spain in 2022 (Asociación Empresarial Eólica, 2022), with China and the United States being the countries where there has been the highest investment in recent years.

However, the increase in the use of new technologies that seek to achieve greater efficiencies and improve the obtaining of this energy brings with it risks. For this reason, research has been carried out that collects data from 478 accidents worldwide, from the year 2000 to 2024, with the aim of understanding the causes of these accidents, to prevent and correct them in the future.

Fires are the second most common type of accident within wind turbines, representing a significant threat to wind turbines, with how hard it is to fight this, most of these fires occur at considerable heights making any attempt at fighting them virtually impossible, making the probability of scattering flaming debris at a high radius from the origin, this way starting wildfires. It is known fires posse a significant danger to wind turbines, what is not know is how much of a danger they pose since most of these types of accidents go underreported, with some estimations as high as 90% of fires going under reported (Uadiale et al., 2014).

* 1. Methodology

An extensive database containing 478 fire incidents was compiled ranging from the start of 2000 to the last months of 2024 with the last accident recorded in September, only fires involving wind turbines were considered omitting those that happened in manufacture, construction or energy storage systems. Most of these accidents were selected from the Scotland against spin accident database, other sources were also used, like Wind Watch, and various news reports to complete the database. For the aim of this historical analysis, this being to analyse trends in wind turbine fires, therefore all the accidents were divided into two blocks, the first one spanning from 2000-2012 and the second from 2013-2024. To make a more robust analysis in some cases it was possible, with the help of the reported location, to find the wind farm were the accidents happened with the help of mostly the wind power database of wind making it possible to learn more about the type of turbine involved in the fire.

* 1. Results and Discussion

There were five main aspects of the accidents that were analyzed, those were the year that the accident happened, the continent, whether it was an onshore or offshore wind farm, the manufacturer and the power of each wind turbine.

It can be seen in Figure 1 that the number of fires per year is consistent there is a small difference between the two blocks, in the firsts there is 209 and in the second 269, assuming that the proportion of reported accidents is the same throughout the years, this is a good indication that fires are not increasing significantly as the production and number of turbines worldwide increases. Especially considering that in the years 2000 and 2001 there wasn’t a lot of information available.

Figure 1: Fire incidents from 2000 to September 2024.

Even though this is a worldwide analysis it is considered that this is the part that suffers the most from the underreporting of fire accidents in wind turbines, in Figure 2 can be seen that Asia and Oceania have a significantly lower rate of fires, this seems strange considering that China is an important producer of wind energy, and a study analyzing different faults of wind turbines in China discovered that Chinese manufactured wind turbines were still in an early manufacturing phase (Lin et al., 2015), therefore it would be expected to have a higher number of accidents, considering there are only three accidents reported in this database. The same can be said for India, although this is the Asiatic country with the most accidents with a total of seven reported accidents.

Around 87% of the accidents in the Americas come from the United States, at first it was thought that the US also had a big problem with under reporting, but upon further analysis of the power of both the US and the European Union, throughout the years the EU doubles the capacity of the US, even though in recent years the later has been closing the gap (Fernández, 2023), which can be reflected on the data, the first block having significantly less accidents than the EU, while the second block has a more comparative number of accidents.

Figure 2: Fire incidents by continent.

Most of the reported fires were on onshore wind farms, this is congruent with the data that around 90% of the wind energy is produced on onshore windfarms (Tumse et al., 2024) as shown in Figure 3, also since most of these reports come from news and different independent reports not necessarily from the industry, therefore it´s impossible to know the actual extent of fires in offshore turbines. There were also thirteen accidents on the database that could not be verified the location of the fires.

Figure 3: Fire incidents by Onshore or Offshore location.

There is a big number of turbines manufactures, which are constantly changing and acquiring other manufactures, from Figure 4 it can be seen that the market leaders are the ones with the most number of accidents, this is also slightly biased since a big part of the accidents are in the west therefore most of the Asiatic manufacturers are not properly represented. The number of accidents without information about the manufacture is the same for both blocks, 49 each.

Figure 4: Fire incidents by turbine manufactures.

For the power analysis it’s noted that on the first block there were 105 accidents where the power of the turbine involved in the fire could not be identified there for, it is possible to see some tendences but it might be misleading, while for the second block the unreported power accidents were only 56 this is a good sign that the power of turbines is becoming more transparent. it is also important to consider that the fires within turbines with smaller powers are those that are private or residential, therefore the peak at 2 MW is expected since this is a common type of turbine to have in a wind farm. From combining both blocks it can be seen in Figure 5 the most at risk are the more common turbines and as well those with 0.6 MW, this most likely signifies older turbines with less modern fire prevention techniques.

Figure 5: Fire incidents by wind turbine power.

* 1. Conclusions

Even though fires maybe an under reported phenomena, from this analysis the data is congruent, for the most part with the wing energy industry, but there are still a lot of gaps where improvements could be made, like the underreporting of wind turbine fires in Asia, and the question if onshore and offshore windfarms have the same probability of fires or if this is solely because offshore fires are significantly underreported. As power is concerned it seems to have no correlation, at least with this amount of data, with the frequency of fires, since it just seems to be that is the most common power capacity, it would be interesting to see the changes in the next years as older turbines with less capacity get retired and new turbines with higher power replace them.

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