E3S Web of Conferences **419**, 01028 (2023) https://doi.org/10.1051/e3sconf/202341901028
WFCES 2023

Analytical research of wind farms damage

Andrey Martyanov, *Dmitry* Antipin*, and *Gleb* Ryavkin
South Ural State University, Polytechnic Institute, Electric Power Generation Stations, Networks and Supply Systems Department, 454080 Chelyabinsk, Russia

Abstract. Wind farms are expensive and technically complex equipment. Maintaining it in working condition is an important task not only from an economic point of view, but also from a practical point of view. Even minor breakdowns and damages should be quickly eliminated. Wind farms are constantly being upgraded and improved. They are produced under specific operating conditions. However, this cannot completely exclude emergency situations. Therefore, engineering services involved in monitoring the operation of a wind farm should conduct inspections with some frequency. Until recently, such inspections were carried out entirely by people, which was associated with various problems and risks. People put their lives in danger; money is spent on the departure of a team of engineers to perform a relatively simple inspection operation. This study can be useful in the development and design of computer vision systems aimed at operating during inspections of wind farms.

1 Introduction

Recently, with the development of unmanned aerial vehicles, the practice of using them to inspect wind farms has appeared. This makes it easier and cheaper to inspect. It is enough for several engineers to control an unmanned aerial vehicle to conduct at least an external inspection of the wind farm. Due to the fact that unmanned aerial vehicles are beginning to be used when inspecting wind farms, there is a large practical sphere of how to use them most effectively. There are various ways to increase efficiency, one of which, for example, the use of computer vision. It can be used to process images obtained from cameras during the inspection of the station. This helps to simplify, speed up and automate the inspection. Before proceeding to the classification of damages, it is necessary to evaluate in detail all the statistics currently available on wind turbines: their number, power, distribution, geographical location, accident rate. For this purpose, a review of various literatures was conducted. Various articles containing detailed statistics, reporting data of international agencies in the field of renewable energy and wind energy, websites of various companies engaged in the analysis of statistical data on this issue were reviewed. It should be noted that the statistics of wind energy development are quite detailed and open, while the damage statistics on the contrary are very limited. It is hardly possible to establish exact numbers, but some data from different sources are well combined with each other. Therefore, the data found from various sources will be sufficient for damage classifications.

* Corresponding author: pte2017pte@mail.ru

2 Materials and methods

A wind farm is a complex technically complex device. When designing it, geophysical and artificial loads are taken into account. Geophysical loads include: the weight of the structure, seismic loads, loads from snow, rain, ice, hail, wind, exposure to temperature and humidity. Artificial loads include shocks, vibrations, stresses and deformations, variable loads of various natures. There are various rules and regulations governing the procedure for calculating loads when designing such structures. They contain recommendations for determining the loads on the projected structures, recommendations for dynamic calculation, and examples of calculations are given. There are also various rules and regulations governing the calculations of internal electro-mechanical equipment. Maintenance is carried out to monitor the condition of the wind turbine. It includes inspection of all units of the installation, their complete inspection, modernization or repair, washing and cleaning. Maintenance can be carried out every month, every quarter, every six months and every year. Every month, the fasteners are checked, the nodes are inspected, the electrical parameters of batteries, generators, converters are checked, the brakes are checked. Fasteners and battery charge are checked every quarter. Every quarter they check the oil in the generator, fasteners, all electrical systems, the condition of the blades, bearings, brakes. Every year, the presence of cracks on the moving parts, the battery is checked, oil is replaced and the gearbox and generator are cleaned. Despite the fact that these rules and inspections are sufficient in most cases, there are still cases of destruction of wind farms. Some of these cases do not contradict the design rules, but are associated, for example, with the failure of the internal equipment of a wind farm. In order to draw conclusions on damage and give recommendations on how to avoid such cases, it is necessary to collect statistics. During the initial review of the literature, it was found that there is a large variety of data from different data. At the same time, there are no sources where this information would be combined. No damage classifications have been given; no general conclusions have been drawn. To make a classification of types of damage, it is necessary to collect statistics. To analyze the damage, statistics obtained from open sources were collected. These sources include annual reports of energy departments of the world and Europe, articles. It was possible to obtain data on the number of operating wind farms, the average capacity of power plants, the geographical distribution of total capacity, the number of accidents that occurred, the frequency of accidents, places of damage, downtime, causes of damage, geographical distribution of accidents, the consequences of damage. Since data is tracked from different sources at different times, one period from 2000 to 2018 was chosen for research. The data found contains information mainly about the number and frequency of breakdowns, the geographical distribution of wind farms, and the types of damage. It was possible to obtain information about the most frequent places of damage, the most frequent causes of damage and the most frequent consequences of damage. In order to identify the most important injuries in each group, the Pareto method was applied, according to which it is enough to consider 80% of all injuries in order to determine all the injuries effectively. Graphs were plotted showing each group and a percentage of the total.

3 Results

Full-fledged statistics were obtained, allowing drawing conclusions about the accident rate, to make damage classifications. As of 2018, the number of operating wind farms is approximately 300,000. There is a gradual slowdown in the growth rate of their number. The average capacity of a single wind farm is constantly growing and in 2018 it approached 2 MW. The total power is distributed unevenly around the world. Almost half of the total power is generated in Asia, mainly in China, in Europe, mainly in Germany and North America, mainly in the USA. The number of accidents that occurred by 2018 reached 70,000. There is a tendency for an increase in the number of accidents. However, there is also a tendency to reduce the number of broken wind farms. This suggests that the protection systems of wind farms are constantly being improved.

It was possible to determine the most frequent places of damage. These include the tower and nacelle, blades, brakes, rotor, gearbox, generator, yaw system, sensors, hydraulic and electrical systems, control and energy conversion systems. Control systems, electrical and hydraulic systems most often fail. The longest downtime is caused by gearbox breakdowns, damage to the blades. The classification of accidents by location includes: electrical system, control system, sensors, hydraulic systems, blades, brake in fig.1.

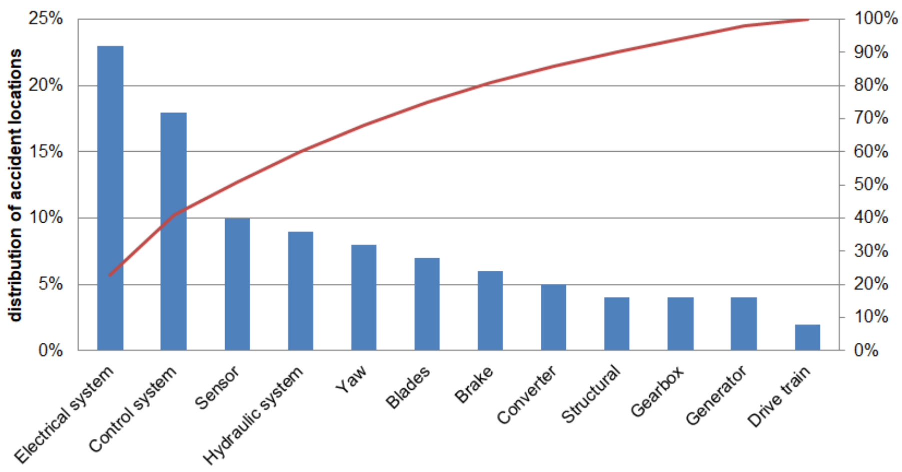

Fig. 1. Locations of accidents.

It was possible to determine the most common causes of accidents. These include strong winds, lightning strikes, icing, and pollution, wear of generator and gearbox parts, climatic conditions. The most common damage to the blades is caused by lightning strikes. The quantitative characteristics of these injuries, described in different sources, are well combined with each other. An equally important factor is the geographical location. Thus, the average frequency of lightning hitting the blade in Europe ranges from 3.9% to 8%, in Japan from 10 to 20%, in North America from 5% to 6%. It is expected that each wind farm in 20 years of operation will receive at least two lightning strikes capable of causing significant damage. In mountainous areas, 14% of wind farms are affected by lightning, and in flat terrain 7.4% of wind farms and 5.6% of wind farms located on the coast.

It was possible to determine the most frequent consequences of accidents. These include the destruction of the tower and gondola, the destruction of the blades from a lightning strike, the destruction of the blades from corrosion and erosion, fires, loss of life, noise, wind power plant shutdown, reduced energy production, environmental damage. The most frequent damages are damage from lightning strikes and erosion and corrosion of the leading edge. The most common type of lightning damage was blade stratification Damage to more than one blade is extremely rare. The main cause of damage to the other two blades is considered to be the transition of the discharge between them during rotation. More than 88% of lightning strikes occur in an area located within 1 meter from the end of the blade. Erosion of the leading edge leads to deterioration of aerodynamic characteristics and an increase in aerodynamic losses by 0.45–0.50%. Erosion and corrosion of the leading edge can reduce annual energy production by 2-4%. The annual energy production of severely damaged blades is reduced by 10-13%. Erosion leads to noise. Corrosion and erosion of the blades depend on temperature, humidity, pollutants in the atmosphere and wind speed.

4 Discussion

When analyzing the literature sources, it was found that there are no classifications of injuries for the use of computer vision. Such classifications would simplify the development of computer vision systems aimed at monitoring wind farms in order to maintain them in a timely manner. So we can distinguish three classifications of damage: by localization of damage, by causes of damage, by consequences of damage. According to the Pareto principle, those damages that make up 80% were identified.

Classification of accidents by causes includes: strong wing, lightning, wear of generator parts, wear of gearbox parts in fig.2.

Classification of accidents by consequences includes: outage and reduced energy production, blades destruction, people's death, destruction of the tower and nacelle in fig.3.

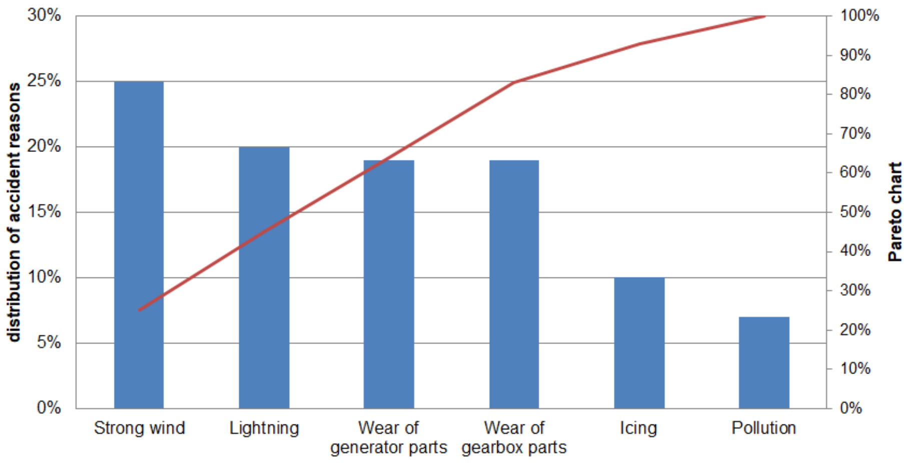

Fig. 2. Reasons of accidents.

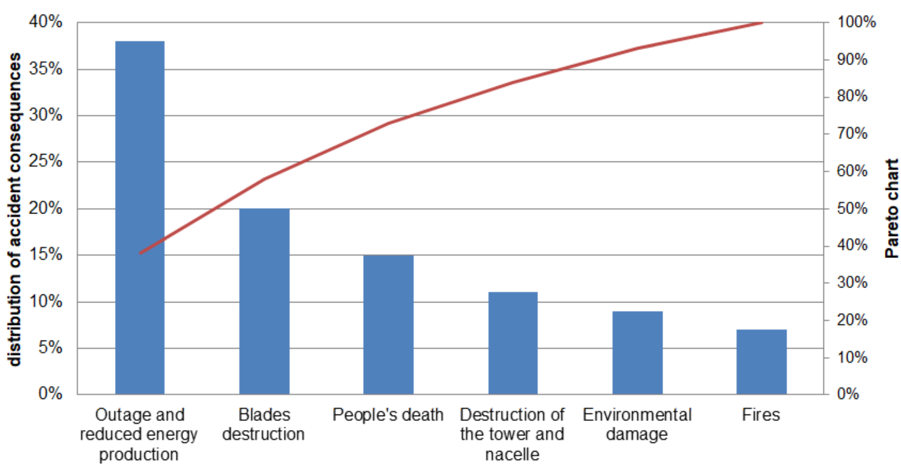

Fig. 3. Consequences of accidents.

The practical significance lies in the fact that using these classifications in the development of computer vision systems, it is possible to detect 80% of the most frequent and serious damage. The novelty lies in the fact that such classifications are not given anywhere.

5 Conclusion

The statistics of the prevalence of wind farms and their accidents were investigated. According to available data from open sources, the following conclusions can be drawn:

1. The number of installed wind farms around the world, as well as their average and total capacity, is growing every year. The leaders in the distribution of wind energy are Asia (42% of the total global capacity), Europe (33% of the total global capacity) and North America (20% of the total capacity). The leading countries in these regions are China (35% of the total world capacity), Germany (10% of the world capacity), the USA (17% of the world capacity), respectively.

2. The relative number of accidents is decreasing every year, which may indicate an increase in the effectiveness of methods for protecting wind farms.

3. Three classifications of damages were identified: by localization, by causes, by consequences. The most frequent damages affect electrical systems, control systems, energy converters and blades. The most common causes of damage are adverse weather and climatic conditions and mechanical wear of parts. Lightning strikes are most often distinguished from unfavorable weather and climatic conditions. The most frequent consequences of accidents are the destruction of the blades (20% of all cases), the death of people (15% of all cases), the destruction of the tower and gondola (11% of all cases).

4. The most common external damage is damage to the blades, namely damage from lightning strikes and corrosion of the leading edge. It was noticed that 60-88% of lightning hits in the blade fall on its last meter, and 90% of hits – on the last 4 meters. The remaining 10% fall on the area located at a distance of 5 to 10 meters from the free edge of the blade. Lightning strikes at a distance of 10 meters are extremely rare. The most frequent consequence of a lightning strike is the separation of the blade, which accounts for 97% of all described cases. The second most important consequence is corrosion. It was revealed that over 15 years of operation, at least 0.67 of the blades will be corroded, and half of them will be severely worn out.

5. Three classifications were obtained, which will allow determining 80% of the most frequent and serious damage. The classification of accidents by location includes: electrical system, control system, sensors, hydraulic systems, blades, brake. Classification of accidents by causes includes: strong wing, lightning, wear of generator parts, wear of gearbox parts. Classification of accidents by consequences includes: outage and reduced energy production, blades destruction, people’s death, destruction of the tower and nacelle.

The study was supported by the Russian Science Foundation grant No. 23-11-20016, https://rscf.ru/en/project/23-11-20016/

References

1. G. Ertek, L. Kailas, Sustainability **13**, 1-34 (2021)
2. W. Wang, Y. Xue, C. He, Y. Zhao, Energies **13(1)**, 120 (2021)
3. A. Olabi, A. Wilberforce, Energies **14(1)**, 144 (2021)
4. W. Qiao, D. Lu, IEEE Trans. on Ind. **62(10)**, 6533-6535 (2015)
5. A. Shohag, E. Hammel, D. Olawale, Wind Engineering **41(2)**, 185-210 (2017)
6. Z. Caichao, L. Yao, Intec. (2018)
7. W. Eng Ewe, A. Fudholi, K. Sopian, E. Solomin, M. Yazdi, N. Asim, N. Fatima, G. Pikra, H. Sudibyo, W. Fatriasari, A. H. Kuncoro, C. Supriyadi A. Nandar, H. Abimanyu, Th. Science and Eng. Progress. **34**, 101445 (2022)

8. E. Solomin, A. Terekhin, A. Martyanov, A. Shishkov, A. Kovalyov, D. Ismagilov, G. Ryavkin, Energy Conv. and Man. **254(9)**, 115255 (2022)
9. E. Solomin, J. of King Saud University – Eng. Sciences (In Press) **1** (2022)
10. A. Alsabery, M Yazdi, E. Solomin, H. Öztop, I. Hashim, J. of Comp. Design and Eng. **9(2)**, 598-615 (2022)