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Impact of African Dust Events on Wind Energy in the Canary Islands: A Review on Key Challenges

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Abstract. Wind energy is by far the largest renewable energy source in the Canary Islands, accounting for 73.7% of the renewable energy production. Although renewable sources in the archipelago account for only 21% of the total generated electricity, this percentage is expected to sharply increase over the next 20 years as part of the push for energy sovereignty and sustainability. It is thus critical to identify the main challenges faced by renewable energy sources. In this regard, the African dust events affecting the Canary Islands pose a local and specific problem to wind energy production. In this work, we identify and review four challenges caused by airborne dust on wind turbines – blade surface deterioration by dust erosion and accumulation, dust accumulation in the nacelle, increase of temperature, and modification of the aerodynamic properties of the air-dust flow. In the light of previous studies, we briefly discuss the causes and solutions to these issues, highlighting the complexity and local character of the problem, which requires further specific studies to be carried out in the Canary Islands.

Key words. Wind energy, African dust, Canary Islands, renewable energies, air quality

1. Introduction

Within the current world-wide push for the implantation of renewable energies, understanding the challenges faced by the different renewable energy sources is of the utmost importance. In the case of the Canary Islands, renewable energy production accounts for 21% of the total produced electricity [1], but this percentage is expected to increase significantly over the next 20 years [2]. In addition to strategic planning, the simplification of administrative procedures introduced by the regional Climate Change Law [3] aims to streamline the authorization process for renewable installations, thus accelerating project developments while ensuring environmental and territorial guarantees. In this context of rapid projected growth, understanding the environmental and meteorological challenges affecting renewable energies becomes even more critical.

African dust outbreaks, where airborne dust particles originating in North Africa travel over the North Atlantic, particularly affect the Canary Islands due to their proximity to the African source areas, see [4] and references therein. The presence of airborne dust in the air flow poses a complex challenge for the production of renewable energies, affecting both photovoltaic (PV) and wind energy production. It should be stressed that this challenge is quite geographically specific, affecting only certain areas, and then with large differences from one region to another, due for example to the gradual deposition of dust, depending on the particle size, along its path.

Wind energy is the largest renewable source in the Canary Islands, nowadays accounting for 73.7% of the renewable energy production, thus making it critical to analyze in detail all the challenges this energy source has to face. Regarding the specific effect of airborne dust on wind energy, previous studies have been mostly focused on the erosion and accumulation effect of dust on the blades of the wind turbines [5]-[12], although other topics, such the accumulation of dust inside the nacelle and on the cooling system, and the associated effect on the operating temperature [13]-[17], or the effect on the aerodynamic characteristics of the air-dust flow [18]-[21], have also been investigated.

In recent years, exceptionally intense African dust intrusions have been recorded in the Canary Islands, which has stimulated the interest of the scientific community in quantifying the effects of dust not only on air quality and human health, but also on other sectors such as aviation, renewable energy production, and economy [22]. However, published studies on the effects of African dust on renewable energy production in the Canary Islands remain scarce. Most have primarily focused on the impacts of extreme dust intrusion events on PV output, reporting reductions from 6% [23] up to 50% [24]. Regarding wind energy production, a 10% decline has been observed, attributed to decreased wind speeds during these episodes [23]. We can also highlight the research on the effect of airborne dust on wind turbines being currently carried out by the *Plataforma Oceánica de Canarias* (PLOCAN) and the *Universidad de Las Palmas de Gran Canaria* within the framework of the "AIRE" project of the European Union's Horizon programme [25].

This work aims to identify the main challenges posed by the African dust events on wind energy production in the Canary Islands. This paper is organized as follows. In Sec.

2 we provide a description of the African dust events which affect the Canary Islands. In Sec. 3 we examine the importance of wind energy production in the Islands. In Sec. 4 we analyze the key challenges faced by wind energy production due to the African dust events. Finally, in Sec. 5 we provide some closing remarks.

2. African dust events

The Canary Islands are located in the subtropical Eastern North Atlantic, approximately 100 km from the northern coast of Africa. Due to its proximity to several dust sources in the Sahara region, African dust outbreaks over this archipelago are frequent and sometimes intense. The mean annual frequency of occurrence was 6% of days for the period 1980-2022 [23], although in particularly active years such as 2020, this proportion has reached up to 44.7% of days [26].

African dust intrusions over the Canary Islands are more frequent and intense during winter (December to March), with shorter duration compared to summer episodes (June to September). In the winter, these episodes affect directly to low and mid-altitudes, where wind farms are typically located in the archipelago. In the summer, African dust intrusions take place at higher altitudes and affect lower altitudes by dust gravitational deposition [27]. Dust particles arriving at the Canary Islands are coarser than those reaching continental Europe [27],[28].

The synoptic meteorological scenario most commonly associated with these situations is a high-pressure system over Europe extending its influence over northern Africa. Additional circulation patterns that favor the transport of African dust toward the Canary Islands involve a low-pressure center located to the northeast or southeast of the archipelago interacting with anticyclonic systems over Northern Africa and/or the Mediterranean basin [4].

3. Wind energy in the Canary Islands

As of early 2026, the installed wind power capacity in the archipelago stands at 676 MW, representing a key pillar of the regional electricity mix alongside solar PV generation. This capacity constitutes 57.5% of the total installed renewable power in the archipelago. During 2025, wind energy accounted for 15.8% of the total electricity generated in the Canary Islands, and 73.7% of the renewable energy produced [1].

Figure 1 shows the distribution of wind farms in the two largest islands of the archipelago, Tenerife and Gran Canaria, according to the latest detailed official data from 2023 [29]. In Tenerife, wind farms are concentrated in the south-east of the island, in the municipalities of Arico (159 MW) and Granadilla de Abona (66 MW). In Gran Canaria, wind farms are more spread out across the island, but again the largest ones are located in the south-east, in Agüimes (103 MW), San Bartolomé de Tirajana (102 MW), and Santa Lucía de Tirajana (69 MW). The data from 2023 show similar wind power generation in both islands, 227 MW in Tenerife and 295 MW in Gran Canaria. Wind farms are also present in the smaller islands, with 65 MW in Fuerteventura, 31 MW in Lanzarote, 12 MW in La Gomera, and 8 MW in La Palma. Fuerteventura and Lanzarote electricity systems were interconnected in late 2022, and Tenerife and La Gomera, in early 2026.

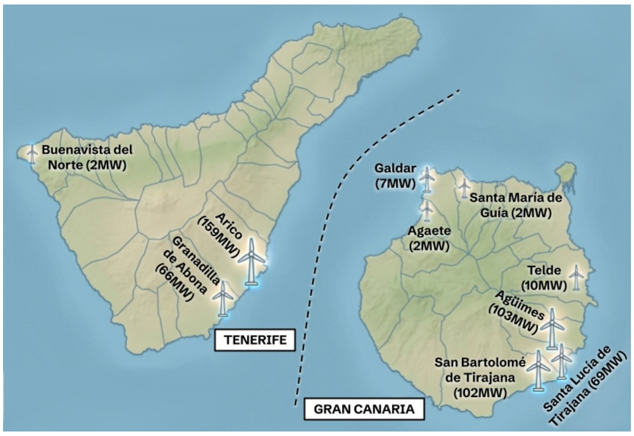

Figure 1. Distribution of wind farms by municipality in the islands of Tenerife and Gran Canaria, according to data from the year 2023 [29].

The role of wind energy in the Canary Islands is expected to expand significantly over the coming decade. According to the regional sustainable energy planning framework [30], achieving a renewable penetration of approximately 60% in electricity generation by 2030 would require a total installed renewable capacity of about 3410 MW. The largest contribution within this expansion is expected to come from wind energy technologies, with approximately 1613 MW of additional onshore wind capacity and 423 MW of offshore wind capacity.

Offshore wind energy, in particular, represents a major strategic opportunity for the archipelago. The Spanish Roadmap for Offshore Wind and Marine Energies [31] identifies the Canary Islands as a highly suitable region for the deployment of these technologies, especially floating offshore wind systems, due to favorable wind resources and deep-water conditions close to the shore. The development of offshore wind would not only increase renewable penetration but also diversify the technological mix and potentially stimulate local industrial and technological capabilities.

4. Key challenges

We can identify 4 main challenges caused by the African dust outbreaks on wind energy production. Perhaps the most obvious one pertains to the direct effect of the airborne dust on the blades of the wind turbine. Although the outer surface is usually protected by gelcoats or special coatings designed to resist erosion and environmental degradation, these layers can be deteriorated throughout time, especially during intense African dust outbreaks. The impact of particles might erode the surface of the blades, affecting their aerodynamic characteristics. Furthermore, dust can also deposit directly on the blades, thus affecting their weight and aerodynamics. The size of the dust particles plays a role in both effects, as well as the wind speed (which affects the force of the impact) and the meteorological conditions (which affects the deposition on the blades).

To avoid erosion, blades are usually made of composite materials, mainly fiberglass-reinforced polymers, often combined with carbon fiber to enhance stiffness and reduce weight. Since dust does not affect all areas of the blade in the same way, it has been proposed to apply different coatings to different zones, the leading edge of the blade being the most sensitive area [32]. Different types of coatings are available, many of them including polyurethane, although more advanced materials, using ceramic nanoparticles or graphene, have also been proposed [33]. Lately, self-healing materials have also been discussed [34]. Leading edge erosion is likely the most analyzed effect of dust, because it is easily observable and has a large effect on power production, and many previous studies exist on this topic, see e.g. [5]-[12].

Although not so widely studied, measures to mitigate the effect of dust deposition have also been analyzed, ranging from the use of specific blade designs, less sensitive to the surface roughness caused by the dust accumulation, to the application of special surface finishes and coatings to prevent dust accumulation, see [35] and references therein. See also [36] for an example of commercially-available dust-abatement products that can be applied periodically to existing wind turbines. Once the dust has been deposited, cleaning, either by manual or automatic methods, is of course the ultimate solution. Given the risk and complexity of the manual operation, automated robotic systems have been proposed [37]. Lately, air drones have been successfully used to clean PV solar panels. In some cases, the cleaning process does not even require any water, see e.g. [38], a particularly important aspect for dry areas like the Canary Islands. However, in the case of wind turbines, air drones seem to be mostly used to monitor the blades [39].

Besides the blades, dust can also affect other parts of the wind turbines. Fine dust particles may penetrate through ventilation systems and accumulate over time on mechanical and electrical components. While the electrical machinery and power converters are usually well protected against particle intrusions, over time dust can accumulate inside the nacelle [13],[14], making regular cleaning mandatory. African dust events should thus be taken into account when scheduling maintenance. Complicating things further, dust might affect the cooling system. Air filters and heat exchangers are particularly susceptible to clogging, which may reduce cooling efficiency and increase operating temperatures. Furthermore, high temperature conditions during African dust outbreaks might also present a challenge for the operation of wind turbines. Previous studies have analyzed the effect of temperature on the efficiency of wind turbines and the importance of cooling systems, see [15]-[17] and references therein. Proper installation and regular maintenance – especially after heavy dust events – of air filters should prevent most issues.

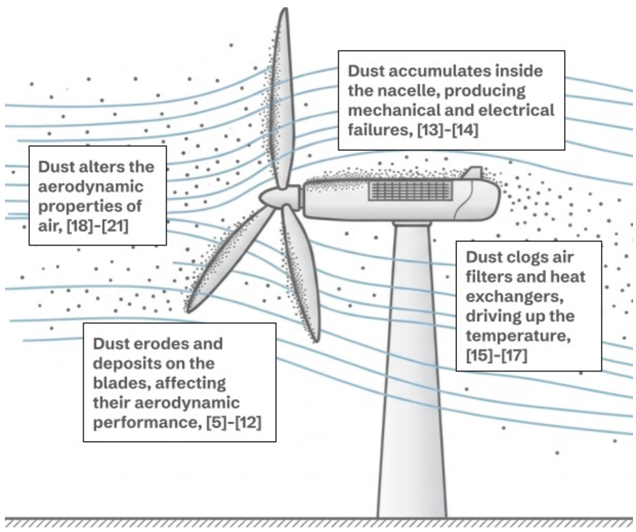

Figure 2. Graphical summary of the four main challenges faced by wind turbines operating in the presence of dust.

Finally, the presence of dust affects the Reynolds number of the air-dust two-phase flow, in turn affecting the aerodynamic performance of wind turbines, see [18]-[21]. Both particle concentration and size play an important role in this case. Some types of wind turbines are more affected than others – the airfoils in particular being a key element, see [5] and references therein. Local dust conditions should thus be taken into account during the wind farm planification stage. As a side note, a striking effect of this interaction between airborne dust and wind turbines is the increase of dust deposition near wind farms [18] – indeed wind farms can also affect the local temperature and humidity, see [20] and references therein.

Figure 2 shows a summary of the four above-mentioned challenges – blade surface deterioration by dust erosion and accumulation, dust accumulation in the nacelle, increase of temperature, and modification of the aerodynamic properties of the air-dust flow. It should be noted that these four challenges are intertwined, with all of them possibly taking place at the same time. Furthermore, to examine their effect on wind energy production, variables such as the size of the dust particles and the wind speed at the specific location of the wind farm must be taken into account.

5. Conclusions

The effect of African dust on wind energy production poses significant research challenges, but nevertheless the impact of airborne dust in the Canary Islands must be taken into consideration to fully account for the present and future production of renewable energy. We have identified four significant issues which are also intertwined. Furthermore, there is also a large dependency on local variables such as the dust particle size, thus making it difficult to extrapolate results from studies in one area to another. Studies on the impact and mitigation techniques should thus be carried out to tackle the specificities of the Canary Islands. Following previous works, these studies could involve the combination of numerical simulations with a model wind turbine used for real-life tests, see e.g. [32].

Besides energy production itself, maintenance of the wind turbines is likely the aspect most affected by airborne dust. Even with the help of automated systems, it should be noted that stopping or even slowing the wind turbines to clean and/or replace parts can produce a noticeable hit on energy production, and thus must be carefully planned. In this regard, it is important to have accurate predictions of the onset date and duration of the African dust outbreaks. In a previous study, we proposed the deployment of large scale networks of low-cost sensors to gather the necessary data for these predictions [40] and although that study was focused on PV power plants, the same recommendation can be extended to wind farms. Indeed, some of the tools already developed to address the effect of dust in PV power production can likely be adapted to wind power – this is the case for example of the machine learning methods for power production prediction we discussed in [41].

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