Dismantling of wind turbines

An overview of methods

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Abstract

This paper outlines the three main areas relevant to dismantling: the rotor blades, hub and nacelle, the tower and the foundation. The paper discusses the dismantling procedures, including the removal of the top structure, the tower and the foundation, and evaluates various methods of dismantling the tower, such as modular dismantling, collapse blasting, folding blasting, wrecking ball demolition and hydraulic ram demolition. The assessment of these methods in practice and the potential challenges and considerations for future dismantling, particularly as wind turbine heights increase, are also addressed.

Keywords: dismantling, disassembly, deconstruction, demolition, blasting, onshore, wind turbine, repowering

1 Introduction

Germany currently has around 28,500 onshore wind turbines in operation [1]. Since the expansion in 2000, there has been an increasing number of questions about their continued operation and eventual dismantling. On the one hand, dismantling is necessary because the technical service life of the turbines is limited. On the other hand, the subsidy period for wind turbines under the Renewable Energy Sources Act (EEG) ends after twenty years [2]. Given the trade-off between revenues from alternative marketing channels and the costs of continued operation, it is generally the operator's decision whether and when to decommission a wind turbine. Based on the date of installation, decommissioning is expected to peak in the years up to 2030 [3]. The development of wind energy is a key pillar of the energy transition, which is intended to enable the phasing out of fossil fuels and nuclear power. According to the current coalition agreement of the German government for 2021-2025, two per cent of the country's land area is to be designated for onshore wind energy [4]. The detailed formulation of the area target is to be set out in the Building Code § 249 [5]. The importance of the necessary expansion of wind energy is also reflected in current geopolitical changes, such as the war in Ukraine. The current German government has set itself the goal of doubling the amount of electricity generated from renewable sources by 2030 [4]. Wind energy has an important role to play. The "Wind-an-Land Gesetz" aims to significantly accelerate the expansion of wind energy in Germany by requiring the federal states to designate 2 % of the federal territory for wind energy by the end of 2032 [6]. By 2027, 1.4 % of the country's land area should be available, with priority given to repowering measures at the same location [6]. Many wind turbines therefore need to be dismantled. There are several methods of dismantling wind turbines. This paper will list and compare these methods.

2 Methodology

The methodology for this essay on the "Dismantling of Wind Turbines" involved a targeted literature search using keywords such as

- "Demontage von Windkraftanlagen" (dismantling of wind turbines),
- "Rückbau von Windenergieanlagen" (decommissioning of wind energy plants),
- "Onshore-Windenergie Rückbau" (onshore wind energy decommissioning),
- "Repowering",
- "Sprengen" (blasting) and
- "Rückbauverfahren" (dismantling methods).

The search was conducted in both German and English to ensure comprehensive coverage of available literature. Due to the limited literature on the topic, publications from the Umweltbundesamt (UBA) and DIN SPEC 4866 were primarily used as key sources. These selections were made to provide a well-rounded overview of legal frameworks, standards, and methodologies in the field of wind turbine decommissioning. An interview was also conducted. The literature

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search was conducted systematically in GoogleScholar, ResearchGate and FINDEX, considering search results in both German and English. The selected sources were carefully analyzed to ensure they represented current standards and developments in the field of wind turbine decommissioning. A literature map was developed with assistance from the AI tool Research Rabbit. The analyzed information from the identified sources was integrated into the essay to offer a comprehensive insight into the methods, legal regulations, and current practices.

3 Legal framework for wind turbine dismantling in Germany

The legal framework plays a central role in the context of wind turbine dismantling, as it defines the guidelines, standards and regulations that shape this process. This chapter presents the main legal aspects that influence the dismantling of onshore wind turbines in Germany. These legal standards have a direct impact on the methods, approval procedures and environmental requirements associated with the dismantling of wind turbines. Only public law regulations are considered. The operator of the wind turbine is responsible for the dismantling, or the client who commissioned the dismantling bears the overall responsibility. The areas of responsibility are divided into planning, monitoring and disposal responsibility. If the responsible person does not have his own expertise, suitable specialists must be engaged. Financial provisions in the amount of the expected costs of complete dismantling are required under Section 35 of the German Building Code (BauGB) for the licensing of the plant, so that the public authorities do not have to bear the costs in the event of insolvency[5]. The obligation relates to the dismantling, which includes the building itself, but may also include ancillary facilities, pipes, paths and yards. The soil sealing caused by the installation must also be removed. In particular, wind turbines with a hub height of more than 50 metres require an immission control permit in accordance with § 4 of the Federal Immission Control Act (BImSchG)[7]. This Act requires the site to be restored to its original condition after the plant has been shut down. The protection of soil is of secondary importance in this area and only applies when the specialised laws do not cover the impacts on the soil. In individual cases, additional claims may arise under private law. Annex A of DIN SPEC 4866-2020-10 provides an overview of the applicable laws for the dismantling of wind turbines[8]. From a legal perspective, dismantling and the disposal of the waste generated during dismantling fall under different regulatory regimes. Therefore, the existing regulations for disposal are not presented. Other relevant laws, guidelines and regulations apply during the dismantling process, such as the German Occupational Health and Safety Act (ArbSchG), TA Lärm, AVV Baulärm, as well as the German Waste Management Act (KrWG), nature conservation laws and water legislation.

4 Methods of dismantling windturbines

A modern wind turbine is made up of a large number of components, which can be broadly divided into mineral and metallic components, as well as various types of plastic[9]. The weight of a typical wind turbine can be broken down as follows: Concrete tower systems consist of approximately 80-90 % concrete (tower and foundation), steel tower systems consist of approximately 20-25 % concrete based on the foundation. Even if a steel tower is not used, a large amount of iron is used in the concrete tower. The hub, to which the rotor blades are attached, and the nacelle, which houses the drive train with the rotor shaft, generator and possibly the gearbox, are also mainly made of iron. The rotor blades themselves are usually made of composite materials such as glass fibre reinforced plastics (GRP) and carbon fibre reinforced plastics (CFRP). Small amounts of non-ferrous metals such as copper and aluminium, cable materials such as polyvinyl chloride (PVC) and operating fluids are also used [10].

4.1 Building structure of a wind turbine

A wind turbine can be divided into three assemblies or areas relevant to dismantling: The first consists of the rotor blades, hub and nacelle. In addition to their height, their weight, attachment points and weight distribution are important. The second area is the tower, where information on design, structure, weight with mass proportions of construction materials, radii and segment geometry and their attachment points are important. The third area is the civil engineering with the foundation. Relevant information here is the type of foundation, weight including steel and concrete content, depth and, where applicable, the number and length of piers. Ancillary systems such as cabinets, cabling and other infrastructure are not taken into account [9].

4.2 Dismantling procedure

Regardless of the method of dismantling, the basic procedure will be similar as the preparatory measures will be the same. Before the actual dismantling begins, instructions are given with the site kick-off meeting, ensuring that no voltage is present and that the power supply is disconnected, securing the site and setting up the site. In preparation for dismantling, lubricants and other hazardous substances are removed from open and closed systems. Following the preparatory measures, the three assemblies are dismantled in the reverse order to the assembly of the wind turbine [8].

4.2.1 Dismantling of the upper structure

The first components to be removed are the rotor blades, hub and nacelle. There are two options for the removal of the rotor blades and the hub. In the case of single blade disassembly, the rotor blades are separated from the hub one by one and lowered by crane. The hub is removed separately. This is necessary due to the weight and height at which the cranes have to operate, compared to star disassembly where the hub is lifted together with the rotor blades. The wind turbine manufacturer usually specifies the option of single blade or star disassembly. Due to the size of the turbines, single blade disassembly will be the preferred method in the future. Special cranes, such as mobile cranes or crawler cranes, are used because of their height and weight, and there are very few of these in Germany and neighbouring European countries. The nacelle can then be lifted off, leaving behind the tower, which forms the second assembly. The controlled dismantling of this assembly can only be carried out using special cranes. [9] If it is not possible to dismantle the first assembly in this way, due to an accident or limited stability, the only remaining option is to demolish the tower including the building structures, which results in a large amount of flying debris, mixing of building materials and increased exposure to dust. This does not meet environmental requirements and is not state of the art for systems that do not meet these specific conditions [11].

4.2.2 Dismantling of the tower

Five different methods are available for dismantling the wind turbine tower:

1. Modular dismantling
2. Collapse blasting
3. Folding blasting
4. Wrecking ball demolition with crawler cranes
5. Crumble with hydraulic rams

Modular dismantling Modular dismantling is possible for tower structures that were also built using modular construction methods. This includes tubular steel and lattice towers, as well as concrete towers built using segmental construction. The individual modules are hooked into a special crane, which is also used for dismantling the buildings, separated from the tower by industrial climbers, lifted, swung away and lowered. The size of the modules to be dismantled is based on the size previously determined for construction, so weight and size are not a problem. [12] However, the large number of modules or lattice tower sections results in a large number of crane lifts, which is time consuming. The components can be crushed on site or, after removal, at the dismantling company's premises. The advantages of this method are the low emission dismantling of the tower and the small space required for dismantling, which is limited to the crane site with the handling area. On the other hand, the process is very time-consuming, especially with regard to the use of the special crane, which increases the cost of dismantling. Hybrid towers are a special case. These tower structures consist of a prestressed concrete tower made of precast concrete elements and a steel tower connected to the concrete tower by a transition piece. They are dismantled in the same way as pure steel and concrete towers. If the tower is not of modular construction or cannot be dismantled because the modules are glued together, the tower can be cut into transportable modules using sawing technology. However, there are significant additional costs associated with the use of sawing technology. Modular dismantling offers the possibility of secondary use of the system. However, the market for reuse of systems is small compared to the number of systems to be dismantled [13].

Fig. 1: Execution of a tower demolition using the folding blast method. Using a second explosive charge at 1/3 of the total height, the upper part of the tower collapsed in the opposite direction to the lower part. This method is more space-saving than a conventional tower collapse blasting. © Reisch Sprengtechnik GmbH

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Collapse blasting Collapse blasting usually involves sawing a wedge into the base of the tower, leaving small supports so that the targeted blast will cause the tower to fall. Alternatively, this wedge can be blown up, which is more expensive but increases safety when working on damaged wind turbines. After blasting, the tower falls over lengthwise. The advantage of this method is that it is much faster than dismantling the modules or using mechanical methods. This method also eliminates the need for costly special cranes. This option is economically advantageous for both damaged and very tall wind turbines. In exceptional cases, this method can also be used to demolish wind turbines, including the nacelle, hub and rotor blades. The main disadvantage of blasting is the vibration caused by the impact of the tower and the flying debris from the blast and impact, which also creates a considerable amount of dust. A vibration expert report may be required. [11]

Folding blasting Folding blasting is the process of weakening the tower by sawing out another wedge at a second level, causing it to collapse. This results in a significantly reduced impact on the surrounding area, as a smaller drop bed is required and low impact speeds are achieved, resulting in less flying debris and dust. The advantages therefore lie in the environmental aspects, while the disadvantage is the increased cost of sawing the second wedge and loading the second blast layer. [11]

Collapse by wrecking ball with crawler crane Causing the collapse of a component by deliberately weakening the structure using a wrecking ball as a mechanical method has long been the state of the art. This method has rarely been used to demolish tower structures because the height of the structure does not allow the crane operator to work at a safe distance from the tower. This makes it impractical for tower demolition. [14]

Crumble with hydraulic rams Crumbling the tower with hydraulic rams is a development of the Wörmann Group. The new process is based on a traverse that is inserted into the tower from above using a crane, and then the tower is pushed apart from the inside using hydraulic rams. The advantages of this method are said to be the cost reduction compared to blasting, the avoidance of earthworks and vibrations, and the time advantage compared to modular dismantling. The main disadvantages are the cost of the special crane needed to lift the truss, the lack of proof of stability due to cracks, a high debris shadow due to small spalling, and the low maturity of the truss as there are increasing problems with the iron mesh of the reinforced concrete. [15]

4.2.3 Dismantling of the foundation

Foundation demolition is the final step after the tower has been removed from its foundation. Once the existing topsoil has been removed and the foundation exposed, it can be crushed by conventional demolition using hydraulic chisels on mobile excavators or, alternatively, by detonation blasting. The reinforced concrete is then scooped out and the foundation components removed. It should be noted that the higher the structure, the stronger the foundation. Accordingly, shallow foundations of more than 800 m^3 of reinforced concrete are possible, speeding up the demolition of these heavily reinforced foundations with loosening blasting. The main advantage is the cost saving, as the costs of drilling the blast holes and the blasting process are quickly recouped. The emissions from the hydraulic chisels are also not significantly lower than those from loose blasting. [11]

5 Assessment

The methods are first evaluated on the basis of a survey of the application in practice. Of all the companies surveyed by the Umweltbundesamt, mechanical demolition, such as modular dismantling, was the most frequently used demolition method. The second and third most common methods were blasting to loosen the foundations and folding blasting. In the civil engineering sector, all companies mainly demolished shallow foundations. As with the tower demolition method, all respondents indicated that mechanical demolition was the most commonly used method of demolition prior to blasting, including the demolition of foundations. [16] Although mechanical dismantling was the most common method, blasting is the second most common method of tower dismantling. This is because especially small towers were dismantled and blasting does not block cranes, which will be in high demand in the coming years. The addition of 115 GW of onshore wind turbines under the EEG will tie up a lot of crane capacity [2]. The resulting annual addition of 9 GW is already a major task, which will increase the prices of special cranes due to the supply and demand effect.

6 Conclusion

It should be borne in mind that relatively few turbines have been dismantled to date and that the number of small turbines with low hub heights, which are increasingly in the 90 metre hub height range, has also decreased. Therefore, the experience from the survey does not yet take into account the turbines that will be dismantled in the coming years. In addition, the hub height of wind turbines is currently 175 metres, and taller towers are already being planned, which

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Tab. 1: Overview of the different methods of dismantling the tower

Assessment categories	Modular dismantling	Collapse blasting	Folding blasting	Wrecking ball demolition	Crumble with hydraulic rams
Required time	-	+	+	-	-
Machine utilisation	-	+	+	-	-
Material usage	+	-	-	+	+
Required space	+	-	+	-	+
Debris area	+	-		-	-
Safety during dismantling	+	+	+	-	
Environmental impact	+	-	+		
Authorisation effort				-	
Total costs	-	+	+	-	-

Key: + = relative advantage; - = relative disadvantage; blank = neutral advantage

will make dismantling even more difficult [16]. The situation is further exacerbated by the availability and cost of the cranes needed to erect and dismantle wind turbines. As a result of the increased costs, there will be no alternative to folding blast technology where environmental factors allow. However, a rethink will be necessary in five years' time, as more attention has been paid to dismantling in recent years and the modular construction method has also been designed for dismantling. In particular, the technological changes in machine technology will require a review, as these are developing significantly.

7 Outlook

The new technology for dismantling will initially involve robots or, increasingly, remote-controlled excavators and vehicles, as the use of personnel is costly and risks can be minimised. Automated work in high-risk areas using three-dimensional models and the drilling of blast holes will be the first to enter the market. Developments in crane technology will change applications and costs through faster set-up times and higher lifting capacities. It is not yet possible to predict how the increased use of drones will affect demolition activities in the future. Blasting technology will also continue to evolve. Examples include recently developed emulsion explosives, which are faster, cheaper and safer to use, and ignition technology with electronically programmable detonators.

References

[1] Deutsche WindGuard GmbH. *Windenergiestatistik: Windenergie-Ausbau in Deutschland.* 2023. URL: https://www.windguard.de/windenergiestatistik.html (visited on 07/12/2023).

[2] Deutscher Bundestag. *Gesetz für den Ausbau erneuerbarer Energien (Erneuerbare-Energien-Gesetz - EEG 2023).* URL: https://www.gesetze-im-internet.de/eeg_2014/BJNR106610014.html (visited on 05/12/2023).

[3] Umweltbundesamt. *Windenergie an Land.* 2023. URL: https://www.umweltbundesamt.de/themen/klima-energie/erneuerbare-energien/windenergie-an-land#flaeche (visited on 06/12/2023).

[4] SPD, BÜNDNIS 90/DIE GRÜNEN, and FDP. *KOALITIONSVERTRAG ZWISCHEN SPD, BÜNDNIS 90/DIE GRÜNEN UND FDP.* 2021. URL: https://www.bundesregierung.de/resource/blob/974430/1990812/93bd8d9b17717c351633635f9d7fba09/2021-12-10-koav2021-data.pdf?download=1 (visited on 06/12/2023).

[5] Deutscher Bundestag. *Baugesetzbuch (BauGB).* URL: https://www.gesetze-im-internet.de/bbaug/BJNR003410960.html#BJNR003410960BJNG003604116 (visited on 05/12/2023).

[6] Deutscher Bundestag. *Gesetz zur Festlegung von Flächenbedarfen für Windenergieanlagen an Land (Windenergieflächenbedarfsgesetz - WindBG).* URL: https://www.gesetze-im-internet.de/windbg/BJNR135310022.html (visited on 05/12/2023).

[7] Deutscher Bundestag. *Gesetz zum Schutz vor schädlichen Umwelteinwirkungen durch Luftverunreinigungen, Geräusche, Erschütterungen und ähnliche Vorgänge (Bundes-Immissionsschutzgesetz - BImSchG).* URL: https://www.gesetze-im-internet.de/bimschg/BJNR007210974.html (visited on 05/12/2023).

[8] Deutsche Institut für Normung e.V.(Hrsg.) *DIN SPEC 4866:2020-10.* 2020. DOI: 10.31030/3196083. URL: https://www.beuth.de/

de / technische - regel / din - spec - 4866 / 328634880 (visited on 04/12/2023).

[9] Bundesverband WindEnergie e.V. "Rückbau und Recycling von Windenergieanlagen" (2023). URL: https://www.wind-energie.de/fileadmin/redaktion/dokumente/publikationen-oeffentlich/themen/02-technik-und-netze/09-rueckbau/20230801_BWE-Informationspapier_Rueckbau_und_Recycling_von_Windenergieanlagen.pdf (visited on 04/12/2023).

[10] Bundesverband WindEnergie e.V. "Möglichkeiten zur Wiederverwertung von Rotorblättern von Onshore-Windenergieanlagen" (2017). URL: https://www.wind-energie.de/fileadmin/redaktion/dokumente/hintergrundpapiere-oeffentlich/themen/Technik/20171221_hintergrundpapier_moeglichkeiten_des_recyclings_von_rotorblaetter.pdf (visited on 06/12/2023).

[11] Interview: Reisch Sprengtechnik GmbH, Eduard Reisch, Interviewer: Jannis Reintjes; conducted on: 26.11.2023.

[12] R. W. D. Siebers. "Erfassung von Nachhaltigkeitskennzahlen für die Teilwertschöpfungskette – Errichtung und Rückbau – im Stahlbau". PhD thesis. Bergische Universität Wuppertal, 2020.

[13] Thies Beinke and Moritz Quandt. "Globalisierung des Windenergiemarkts". *GITO Verlag* (2013). URL: https://gito-verlag.de/homepage/im/imhp.nsf/0/5DF4952892BC0417C1257BF700275072/$FILE/beinke_Globalisierung-des-Windenergiemarkts_IM_2013-5.pdf.

[14] Shweta O. Rathi and P.V. Khandve. "Demolition of Buildings – An Overview". *International Journal of Advance Engineering and Research Development* (2014). ISSN: 2348 - 4470.

[15] *Rückbau Windkraftanlagen*. 2023. URL: https://woermann-team-verkehr.de/unser-service/rueckbau-windkraftanlagen/ (visited on 09/12/2023).

[16] Prof. Dr. Sven-Joachim Otto, Dr. Simon Meyer, and et al. "Entwicklung eines Konzepts und Maßnahmen zur Sicherung einer guten Praxis bei Rückbau und Recycling von Windenergieanlagen". *Umweltbundesamt* (2023). ISSN: 1862-4804.