Wind Turbine Hazard and Management

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Abstract. With the popularity of sustainable development, wind energy has become a popular clean energy alternative to fossil energy in recent years. The current wind power generation is developing vigorously. With the substantial increase in the number of wind turbines installed, the future material handling and disposal will generate demand due to the quantity. The purpose of this article is to discuss this possible problem with the disposal of unit materials and to find ways to avoid it. This paper introduces the background of wind development, analyzes the reasons for possible waste generation in the future, and analyzes some possible solutions in the future from three perspectives. The main material of generators and towers is steel, most of which can be recycled. However, the blade is made of fiber material. Although the quality is light and corrosion-resistant, it is difficult to react and be damaged. After disassembly, appropriate treatment methods should be allocated reasonably. For the disposal of these materials, traditional methods such as incineration, landfilling and physical recycling may consume a lot of energy and generate secondary pollution. Perhaps prolonging the lifespan or in-situ transformation is a feasible path, which also gives material disposal new direction. Enterprises and governments should also consider the future waste utilization issue within their own concerns, and do not let the original intention of wind energy end up in waste. This paper brings some ideas of sustainable development to the readers of government and enterprises and provides possible research directions for researchers and researchers.

Keywords: Wind turbine; composite waste; waste management; wind generator system.

1. Introduction

With the popularity of sustainable development, wind energy has become a popular clean energy alternative to fossil energy in recent years. In 2019, wind power generation accounted for 5% of total energy, which is a considerable amount in a system still dominated by fossil energy [1]. Because for the overall power generation, fossil energy power generation still accounts for more than half of the scale. In this condition, Global installed wind power capacity reached more than 730 GW, which over 100 GW is added during 2020, mostly in China. Among them, China and the United States will account for more than half of the world's wind power generation in 2019-2020 and will continue to grow linearly. It should expand much faster in the future, by over 1% of electricity generation per year [2].

But with the installation of a huge number of wind turbines, although the production of so-called clean energy has increased, wind energy itself has also brought processing problems. The average service life of wind turbines is about 20 to 30 years. Based on such installations, in the United States alone, 43 million tons of composite waste will be generated in 2050, all from wind turbines. With so much equipment reaching end of life, every company and government requires a lot of manpower and transportation to dispose of this waste. Not only that, but these materials that are supposed to be used as clean energy also need to be treated as waste. In this process, most of the treatment methods will cause secondary pollution, which goes against the concept of wind power generation itself. In the concept of sustainable development, the recycling of energy and carbon should be achieved. It is unreliable sustainable development to use more resources and energy in the future to deal with the present new energy. Therefore, how to properly dispose of these materials is an issue for new energy sources in the next 20 to 30 years, which not only reduces secondary pollution, but also balances the cost of recycling.

The purpose of this paper is to propose potential problems arising from the mass installation of wind power generation equipment, and to analyze the reasons from the point of view of the material itself. At the same time, the existing or proposed treatment methods will be compared, and their advantages and disadvantages will be compared. Finally, from the perspectives of technology, business and government, some feasible paths for thinking from different perspectives will be given macroscopically. Different groups have different perspectives and goals for sustainable development, and they need to link up and achieve the ultimate balance.

2. Wind Turbine Generator System

As we know, the wind turbines generate power by converting wind energy to mechanical energy, which expressed as blades rotating following the wind, then the electrical energy. Typically, the traditional horizonal turbine generator consists of these 3 components to achieve the converting process: Rotor (mainly the blades), generator and surrounding structure. Frequently installed turbines have a height of 260 ft (80 meters) which have a power generation of 1.5 megawatts, consist of a huge body including 48,000 lb rotor, 115, 000 lb generator and 58, 000 lb tower [3].

2.1. Blades

2.1.1 Material

Recently installed wind turbines blades in nearly few years seeking to increasing the efficiency whether in designing or material using. The designing way to pushing this thought is extending the length of blades to enlarge the rotating diameter, and in material, updating materials to meet the needs of stiff, strong, light and resistant to fatigue. Materials with these properties are considered as polyester, epoxy, and glass fiber and carbon fiber are used for reinforcing because the blades need to function over 100 million load cycles over a period of 20 to 25 years working life. Often, the fiber glass is used as main reinforcement of the blade stiffness. Among them, the glass and epoxy composite for blades contain up to 75 percent glass by weight [4]. Thus, hybrid material reinforcement was designed to reach the cost. According to the research, a full replacement blade material by carbon fiber would save up to 80 percent of weight by increase costs by 150 percent, while a 30 percent replacement would save 50 percent of weight and increase cost by 90 percent. Also, approximately 0.5 percent weight of additional nano-reinforcement in the polymer composite on interlaminar layers can improve the toughness by 30 percent and increase the lifetime up to 1500 percent [5].

2.1.2 End-of-life and Hazard

Older turbines were in some early cases not required to be removed when reaching the end of their life. Some in the US still stand, waiting to be recycled or repowered. Nearly 85 percent of turbine materials are easily reused or recycled, but the blades indeed, which made of composite material, are far more difficult to process [6]. The material of the blade has been mentioned above. To achieving the purpose of improving efficiency, its material has the characteristics of corrosion resistance, strong stiffness and light weight.

Considering the composite and special properties of the blades, the existing End-of-life options for a rotor are landfill, incineration with municipal waste, incineration in cement kilns and mechanical recycling [7]. Landfilling is clearly the most feasible and cost-effective way to operate in the current state, like people did in the last century, dumped the waste into the soil. Incineration makes the blades degradable and reusing them in other fields. However, incineration is accompanied by energy consumption and contamination formation, which does not meet the concept of sustainable development, meaning more energy consumption is used to deal with clean energy. The method of mechanical recycling will not lead to pollution and degradation problem. However, as mentioned above, the energy consumption will be formed which does not fit the clear energy concept to physically crushed them if the quantity of blades came to End-of-life option using this way.

At the same time, there is the problem that the production of scrap blades will rise rapidly within a few decades as the existing installations expand, and the disposal methods at that time will not be sufficient to deal with such many blades. To make matters worse, blade disassembly and recycling are separate issues. Most wind turbines are installed in mountainous areas far away from people, and there is not enough money and manpower to handle them [8].

2.2. Generator and Tower

2.2.1 Material

Wind turbine parts other than the rotor blades are largely made of steel. The function of the generator set is to convert the mechanical energy from the wind blades to generate power and electrical energy. Thus, the main components of the whole unit are steel. Some smaller turbines use aluminum for these components to make turbines lighter and more efficient. Modern turbines use a couple of tones of copper for generator, cables and such. As of 2018, global production of wind turbines uses 450,000 tonnes of copper per year. Pre-stressed concrete has been increasingly used for the material of the tower, but still requires much reinforcing steel to meet the requirement of the strength. In addition, a greater supply of the rare earth metal neodymium would be required due to the gearbox are being replaced with variable speed generators, which requires magnetic materials [2].

2.2.2 End-of-life and Hazard

The wind turbine generators are recyclable and can be reused through repairing or replacement. The replaced generator could be treated as normal steels and reuse [4]. The power towers are not normally recycled due to their concrete and steel component. Removing the towers could cost a high budget and, in another hand, the replaced generator and blades can also be installed on the retired tower. This is also the reason that the wind turbines will have certain impact on the local environment, which may affect the land using and aggravate soil erosion. But in general, the recovery rate of the unit and tower is obviously higher than of the blade, the energy consumption of the treatment will be less, and the impact on the surrounding environment will be less.

2.3. Cost

The cost of the wind turbines depends on its scale. Home or farm-scale turbines are generally under 100 kilowatts and cost about $3000-$8000 per kilowatt of capacity. A large house would need a 10-kilowatt turbine and the installation cost would be about $50,000-$80,000. The rotor (blade) takes up approximately 20 percent of the wind turbine cost. The generator takes up approximately 34 percent of the total cost, and the surrounding structure is 15 percent considered. Other costs include land rent, service and repairing, insurance, administrative tasks, power and miscellaneous. In detail, typical cost for a single turbine is $ 1.3 million per megawatt at initial and will be followed with 1-2 cents per kilowatt-hour produced, or $42,000 - $48,000 per year [6].

For end-of-life option, the most expensive part is the process of demolition. According to the research (Aubryn Cooperman et al.), the teardown cost could take up more than 80 percent in all different types of the turbines (Fig. 1). In this way, waste generation is not the first choice in terms of economy and price, and instead, the process cost of operation will be considered. And more, disposal costs other than transportation and labor vary by disposal method. Of these, the cost of landfilling is the lowest, but multiple factors need to be considered, including energy recovery and carbon emissions.

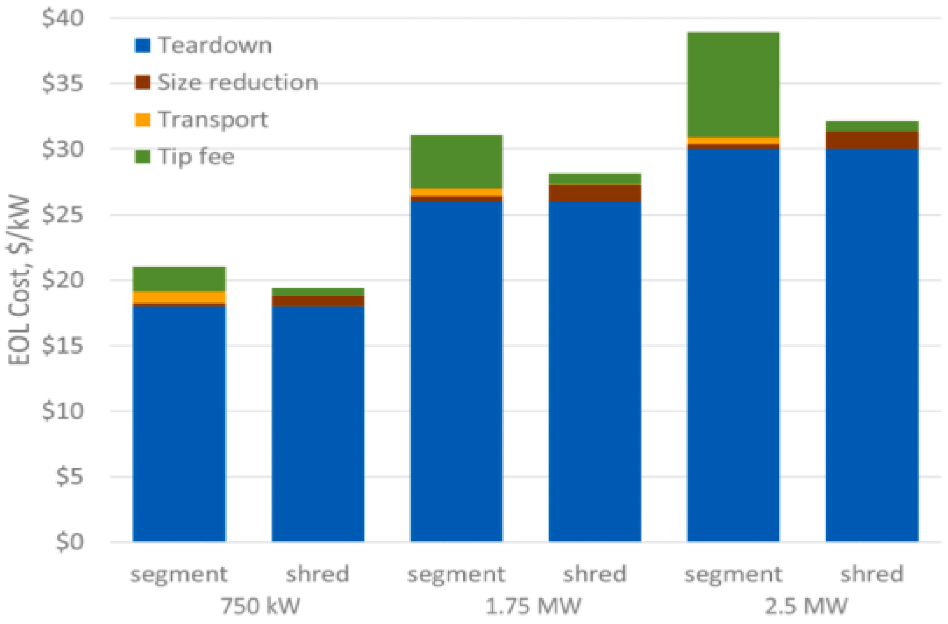

Fig. 1 EOL cost variation with turbine size [6]

3. Waste management and disposal

3.1. Technology

3.1.1 Shredding

All the waste from the wind turbine needs to be shredded into smaller size first to meet any following treatment procedures This, requires the pre-step of teardown the equipment from the installation sites and transportation conveyance of large amount of waste more than 200 km on average due to the long distance from the installation sites to living areas [9]. The average capacity of the trucks to sending materials are considered as 16 to 32 tonne and the waste materials will be shredded into approximately 0 to 100 mm particles [9].

3.1.2 landfilling

The first technical option, and the method that has been largely applied, is the landfilling. Wind turbine blade materials sent to landfill are assumed to be treated as plastic waste mixture in a sanitary landfill. It is still the main method in China and the United States related to its simplicity and low cost. But it was banned in Europe 10 years ago due to its high carbon content and glass fiber content, and the landfill method does not have any energy recovery.

3.1.3 Incineration

Thermosetting polymers have a calorific value and can be combusted as a source of energy. This fits the concept of the energy cycling. As glass fiber and the mineral fillers used in composites are incombustible, the calorific value of a composite depends principally on the proportion of polymer [6]. Incineration in a cement kiln is assumed to produce heat that can replace petroleum coke on an energy equivalent basis with an efficiency loss of 3%. However, 60% of the scrap is left behind as ash after incineration [9]. Due to the presence of inorganic loads in composites, this ash may be a pollutant, and is, depending on the type and post-treated options, either dumped at a landfill or recycled as a substitute construction material. The inorganic loads also lead to the emission of hazardous flue gasses in that the small glass fibre spares may cause problems to the flue gas cleaning steps, mainly at the dust filter devices.

3.1.4 Mechanical Recycling

Mechanical recycling of the composite wind turbine enables recovery of glass fiber and fine material suitable as a filler for composite polymer application. These crushed physical recycling can be used as building materials through cement plants. Recovered filler material can substitute calcium carbonate, however, as the energy inputs and GHG emissions associated with production of calcium carbonate are very low, this benefit of recycling is excluded from the current study. But another use of physical recycling is the reuse of whole blocks, which will be mentioned later in corporate recycling [9].

3.1.5 Lifetime extension

One of the most effective ways to reduce the environmental impacts of current installed wind turbine blades is to extend their lifetime. Using blades for more than 20 years improves their life-cycle energy balance and reduces the need to manufacture new blades. If future recycling and disposal volumes are not up to current levels, then their operation time will need to be extended. In this way, it is necessary to consider the development of newer innovation in terms of materials, making them long-lived and degradable. Researcher Larry Bank has put up the idea of giving them a second life for alternative industry to transform their shape and reform. This has applied by their team and reform the materials into pedestrian bridges, cellphone towers and fencing. Also, companies in Netherland and Denmark, which had applied the wind energy in the early years, did similar jobs as well. Their innovation group reused the blades and tower to work as bike shield, public monument, and children’s playgrounds. Manufacturers of wind power components are also using degradable materials for new installations.

3.2. Enterprise

At present, the main technologies used by enterprises are still landfill and incineration, and the method of landfill is still the main consideration related to the consideration of the cost. For the engineering companies, it is cheap to just dump the waste into the land and bury them. But the companies and their researchers has realized the problem due to the growing size of the material and lack of practical experience of recycling. The installed wind-turbines are still relatively young for a few years. In this way, enterprises should develop new materials in terms of technological innovation. For the parts that are confirmed to be complicated to recycle and will produce secondary pollution, try to make them easy to degrade and recycle. For the whole unit, make it easier to operate and more reusable during dismantling and transportation. In the final processing link, the selected method should not only be within the calculated cost, but also should be selected according to the different environments and locations, and a method with relatively simple processing and less secondary pollution should be selected.

3.3. Government

The government's measures are comprehensive management considerations. The first consideration is the issue of installation and recycling volume. Now wind clean energy is developing vigorously, however, most countries have insufficient experience and preparation for the recycling of the whole unit. When reaching the end of life, there will be a huge amount waste materials that need to be transported, disassembled, and processed. This needs to consider the amount of landfill land used, the amount of recycled material received. In Dr. Bank's research, there was a big problem that the amount of recycling was not enough to support the decommissioning rate of waste. The government can add the proportion of such recycling projects in urban planning to solve the waste. At the same time, the government needs to consider the issue of cost as well. Reasonably allocate the proportion of different treatment methods to improve the energy recovery rate, and fully consider the construction site of the wind turbine to prevent demolition and traffic consumption. Finally, properly calculate carbon consumption, try to achieve carbon neutrality, and avoid a large amount of carbon emissions. Then, although the wind energy has been vigorously supported in terms of policies, corresponding management measures must be introduced, including production, transportation and installation, and post-processing, and corresponding standards will be generated for these. Finally, in terms of processing in various places, the requirements for its processing method and capacity are specified, and it cannot be disposed of at will.

4. Conclusion

Wind energy has been vigorously developed in recent years, and a great number of wind power plants have been installed, but the disposal of these materials after the life cycle is not a problem now. The full text introduces the development of wind power in recent years and the problems that will be faced in the future and analyzes the reasons for the large amount of waste generated by wind power generation from the perspective of the material itself and the amount of installation. The challenges in material recycling are divided into dismantling transportation and blade handling. The material of the unit and tower is steel, which can be largely used in recycling. However, the material of the blade is composed of composite fibers, and the material is difficult to degrade after the blade is scrapped, and the material will pollute the environment. For the disposal of these materials, traditional methods such as incineration, landfilling and physical recycling may consume a lot of energy and generate secondary pollution. Perhaps prolonging the lifespan or in-situ transformation is a feasible path, which also gives material disposal new direction. Enterprises and governments should also consider the future waste utilization issue within their own concerns, and do not let the original intention of wind energy end up in waste. This paper comprehensively considers the problems encountered by wind power generation after the expiration of its life and gives readers some feasible ideas for research and reference.

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