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" Assessment of using wind power to charge electric vehicles batteries"

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Dedication

With the help of God Almighty and the success of the Almighty, this research was accomplished.

And I dedicate first to my parents... my role models in life, who have the first and last credit for achieving this achievement through their support and encouragement to my education.

My honorable professors, supervisors and faculty members who have never been stingy in giving any information and any valuable idea.

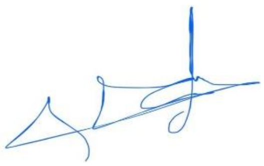
My colleagues and comrades who have never been stingy in helping me.

Declaration

I certify that this thesis submitted for the degree of the master is the result of my research, except where otherwise acknowledged, and that this thesis, neither in whole nor in part, has been previously submitted for any degree to any other university or institution.

The work was done under the supervision of Dr. Husain Alsamamra from the physics department-Al-Quds University.

Name: Osama F. Eghrayeb

Signed: 

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Abstract

Technological progress has become impressive, everyone thinks about the means of survival on this planet and takes the initiative to solve problems that are foreseen in advance by modern technology science. One of the major problems that is expected to happen is that the fossil fuels used to generate electric power will run out over the next few years, so all developed countries have taken the initiative to develop new systems that can supply the world with electricity. Among the most prominent of these discovered sources are solar cells and turbines, as these sources are considered among the best sources discovered so far and used in generating energy in all countries of the world. The transportation sector is one of the most important pillars of its movement, as it depends on diesel and gasoline extracted from fossil fuels, which are about to run out. Therefore, those interested in the transportation sector thought of exploiting alternative energy sources to run vehicles on the energy extracted from them, as these systems were applied and installed on vehicles and their performance was good. In their latest versions, they even found that vehicles run entirely on electricity by storing it in batteries without the need for internal combustion engines that depend entirely on fuel. In this work, how it is possible to benefit from wind energy by studying the possibility of installing 4 turbines to generate energy from wind and providing it with an electric vehicle battery, considering the appropriate location for it so that it does not add any forces that hinder the movement of the vehicle. The power needed to charge the vehicle battery adopting a wind speed of 15 m/s was 138 W, but when the speed is above 23 m/s, the generated power will be more than 1 kw. When the turbines operate together, the generated electricity that will be stored in the battery will be enough to reach the break-even point (92.6 km, 58 kWh) between the rate of discharge and charge and then begin to charge positively (The point after which the amount of electricity generated is greater than the amount consumed).

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Chapter One

Introduction

Todays, one of the main and main axes of the transition to a permanent energy system is renewable energy, as the interest of the whole world has increased in how to increase its efficiency in producing electricity through it. Renewable energy is the third of the seven goals of the 2030 agenda for sustainable development adopted by the United Nations in September 2015, in addition to its prominent role in preserving the environment and reducing harmful emissions, taking into account the Paris Agreement on change at the 21^{st} session of the United Nations Conference of the parties, which includes making available $100 billion annually until 2025 for developing countries to help them in the areas of mitigating emissions and adapting to the effects of climate change (Ameri et al., 2017).

The wide spread of renewable energy applications has resulted in a noticeable decrease from solar energy exporters, in the cost of electric energy produced, especially direct (depending on solar photovoltaic technology) and wind energy, while its use in the areas of heat production/heating or in the transportation sector is still lower much. By 2022, the rate of electricity generation from renewable energy sources is expected to increase by about a third, to a limited extent in the heat/heating sector, and slightly in the road transport sector (Ahadi et al., 2018).

Many countries are interested in renewable energy sources, especially after international organizations confirm their cleanliness and the lack of environmental impacts, compared to non-renewable energy sources that help exacerbate the problems of internal pollution resulting from the increasing amounts used of coal, oil, natural gas and uranium. And the Arab world is the ideal region for investing wind energy in terms of location, climate, and vast area, which is a region for the passage of winds in winter and summer, in addition to low production costs in investing wind energy to generate electric power compared to other renewable energy sources (Cerna et al., 2019).

Wind energy is the kinetic energy that is extracted through rotating turbines that generate electricity in their movement. It is considered one of the clean energy types used as an alternative to fossil fuels. It is a permanently available and renewable energy that does not emit any toxic gases or emissions harmful to the environment during operation (Rahman et al., 2019).

One of the disadvantages of wind energy is that there is usually no synchronization between peak production and consumption, and this means that the burden on conventional power plants has not decreased during peak consumption. As for wind turbines that are used in homes, their production is not sustainable, and this problem can be solved by connecting them to the public electricity network directly, or storing the generated electricity in batteries, and then it can be used throughout the day (Mandal, et al., 2019).

Wind turbine farms can be built both on land and at sea. Onshore turbine farms are hundreds of individual turbines that are connected directly to the grid to transmit electricity as they are inexpensive and competitive. In addition, it can be used to provide electricity to remote areas and is cheaper than power stations approved for generating electricity on gas and coal .... etc. As for the farms of offshore turbines, they are more powerful than onshore turbines, but they require much higher construction and maintenance costs (Bergin et al., 2017).

Wind is a clean source of energy. It has no effect on the greenhouse effect in the atmosphere. It is a substitute for fossil fuels like coal, petroleum, natural gas, etc. Although coal, petroleum, natural gas, etc. are the main source of fuel for electricity production, but the availability of such fossil fuels is limited. Globally, 67% of the energy generated is from fossil fuels, 13% from nuclear energy and the remaining 20% from renewable energy source such as hydro, solar, wind, tidal, etc. (Najafi et al., 2019).

So, we see how much the world depends on fossil fuels to produce electricity and that is why we are focusing on wind energy and other renewable energy sources to generate electricity to overcome dependence on fossil fuels. The cost of running electricity using wind energy is very low. Once the turbine is installed, there is not much maintenance required for a long time (Maghami et al., 2017).

Wind power electricity generation system takes some land for installation, but we can use most of the land for farming. So, land is not a big problem for wind turbine generation systems. In most cases, wind plants are installed at a good height to have sufficient wind energy to produce electricity. It is now the world's fastest energy supplier (Das et al., 2019). The turbine farms need large and open areas to be able to catch the largest possible amount of wind to generate electricity, and therefore it is not recommended to use them in cities because of the buildings that hinder the speed of the wind and therefore cannot be used well. The most suitable place for its installation is the countryside, as there are no large buildings. Rather, its buildings are small, and its spaces are vast and open, and therefore the wind can benefit from a large percentage (Elmouhi et al., 2019). But if these turbines are used in vehicles, the air will not be cut off because it will accumulate because of the vehicle's speed. Its use in vehicles will help reduce the vehicles' dependence on fuel, which will reduce emissions resulting from the combustion of the fuel needed to operate them (Contreras et al., 2019).

1.1 Literature review

In this work, the combustion of fossil fuels for cars was taken as the main cause of air pollution in the world. The combustion of fossil fuels produces toxic and harmful gases that cause global warming that harms the planet. According to the US Environmental Protection Agency, a family car produces about 4 tons of "CO_2" per year from fuel combustion, while a pickup truck or four-wheel drive vehicle emits as much as four tons of carbon dioxide to six tons per year. However, it has taken years for society to realize the deterioration of the planet (Archer et al., 2018).

There are many possibilities that indicate the possibility of extinction of species of living organisms due to excess greenhouse gases, which affects the environment. In addition, the amount of demand for oil has increased all over the world, and this indicates the exhaustion of the remaining amount of it, as some scientists expect that oil is about to run out in the next sixty years (McElroy, 2017).

For these reasons, people became fully aware of everything related to energy and began to search for other sources that could obtain energy through them so that it would be permanent. As a result, people are becoming increasingly aware of energy-related measures and have begun to search for a sustainable alternative source. Wind energy began to be used as early as 3000 BC using sailboats. The wind energy was captured by the sails to pull a boat on the water. Wind vehicles were introduced in the 21st century. Wind-powered vehicles have been introduced (Dulepet, 2017).

In 2011, the Wind-Explorer traveled over 5,000 km in a wind turbine at only eight meters high and three meters in rotor diameter to charge its battery. However, the battery can only be charged when the car is not working (Mediavilla et al., 2011)

The abundance of wind while the vehicle was traveling was the reason for thinking of using wind turbines on it, as the amount of air is unlimited and there is no need for any source to generate it. The energy can be obtained from the wind pickup device independently of the day or night. In addition, the cost of its maintenance is low after purchase and long-term (Besuner et al., 2012).

Renewable energy has made significant progresses in last decade. By 2018, about a third of global total electricity capacity was accounted for using renewable sources, of which 7.9% was contributed by wind energy (Koebrich et al., 2020). Moreover, renewable energy has become more cost effective. Since 2010 the global weighted average of Levelized Cost Of Electricity (LCOE) of most available renewable sources, wind energy included, has been within the range of fossil fuel-generated power costs as per a report by International Renewable Energy Agency (Almasoud et al., 2019).

The LCOE for offshore wind generated power is more than twice as much as that of onshore wind and hydropower, which are the two least expensive renewable sources. In the US, renewable energy reached 20.5% of cumulative power capacity by 2018 (Koebrich et al., 2020). Wind power has been one of the fastest-growing sources in capacity since 2000 replaced hydropower in terms of largest capacity by 2016. However, American wind power has been entirely dependent on onshore wind (Wiser et al., 2015).

The development of American offshore renewable energy, comprising of offshore wind and marine hydrokinetic (wave, tidal and current) energy, is still at very early state but with enormous potential capacity. An assessment by National Renewable Energy Lab (NREL) estimated technical resource capacity of 2,858 GW for offshore wind in the US, which is more than double of 2018 total electricity capacity of 1,219 GW from all fossil and renewable sources (Musial et al., 2016).

Other investigations on energy resource from wave, tidal streams, and ocean currents by Electric Power Research Institute (EPRI) and Georgia Tech provide technical resource potential estimations of 898–1,229 TWh/year for waves energy (Jacobson et al., 2011), 222–334 TWh/year for tidal streams energy (Haas et al., 2011) and 45–163 TWh/year for ocean currents energy (Haas, 2013). So far, there has been only operational 30MW offshore wind project, the Block Island Wind Farm in Rhode Island, while Marine Hydrokinetic (MHK) power in US and worldwide is still in pilot deployment and test-site stage (Koebrich et al., 2020).

Interests in offshore wind have soared due to recent release of Biden-Harris administration's ambitious Climate Agenda, with offshore wind as the driving force of renewable energy. The administration aims at expanding offshore wind energy off the US East Coast with the vision of generating 30GW of electricity by the end of the decade and has approved the first commercial scale offshore wind farm, the Vineyard Wind in Massachusetts, with a generating capacity of 800MW. The target likely leads to more wind energy areas being added to existing proposed offshore wind energy projects in the 25.8GW pipeline reported by (Musial et al., 2019), as well as acceleration in development of the projects.

In the reported pipeline, North Carolina is one of three states that possess most offshore wind capacity with nearly 4GW anticipated from potential wind farm deployments off Kitty Hawk and Wilmington. Governor Roy Cooper in a letter to Bureau of Ocean Energy Management expressed the needs to proceed with activities to lease the Wilmington wind areas by the summer of 2022, and to identify additional wind energy areas off the North Carolina coast (Jacobson et al., 2011).

Improving cost competitiveness has been one of the biggest challenges of offshore renewable energy. Policies and investments have been focused on improving wind energy technologies and expanding large-scale offshore wind projects. The offshore wind LCOE is predicted to continue declining both globally and in the US since new projects can deploy state-of -the art technologies, e.g., larger, and more efficient turbines, and utilize developers' global experiences (Musial et al., 2019).

On the other hand, the MHK industry in the US and worldwide is still in pilot-scale testing modes and must overcome major obstacles, including improvement of technology reliability, and reducing energy cost, before commercialization. It is important now to direct more attention and available resources to MHK energy for a sustainable future of offshore renewable energy. The combined exploitation of wave and offshore wind energies in same marine environment is a promising approach to improving competitiveness of both sources (Koebrich et al., 2020).

European Union (EU) considers collocated and hybrid offshore renewable energy approaches as fundamental component in EU energy policy and has financed two projects named ORRECA and MARINA to explore possibilities to develop diversity and combination across marine energy resources (Laws and Epps, 2016).

Integrated systems, in the form of co-located and/or hybrid systems can be attractive deployment options. Colocation refers to placement arrays of MHK devices in the vicinity of wind farms. A hybrid system, whether bottom-fixed or floating, combines wind turbine and wave and/or current converters on shared structure and anchoring. Integration of wind and MHK devices can potentially increase the energy yield per unit area of marine space and optimize the costs of installation, operation, and maintenance, and supporting infrastructure (Doronzo et al., 2016)

As such, the LCOE of combined marine energy system can be significantly improved in comparison with stand-alone wind and wave energy farms. LCOE of wave energy system can be reduced by more than 50% when switching from stand-alone farm to co-located farm with existing monopole wind turbines (Astariz et al., 2015).

Therefore, the opportunity to deploy wave and current devices integrated with offshore wind farms can enhance economic viability of wave energy and propel the MHK industry into expedient deployment and operation of full-scale arrays. Some studies that have been done on the possibility of installing wind turbines on the back of vehicles did not consider the effect of aerodynamics and weight on them because using them on the back of the vehicle works on the presence of additional weight on it. Researchers Rory Handel and Maxx Bricklin have designed a new system for mounting turbines on a vehicle that is more appropriate but at the same time unsuitable for the vehicle's shape (Maheshwari et al., 2021).

At the end of 2013, wind energy served 12% of global demand at 318.13 gigawatts (GWEC, 2013). In addition, they have low cost (0.12/kWh), low carbon content (<5CO_2/kWh) and minimal sound at pressure level (50-60 dB at 100 feet). Commercial wind turbines (WT) are not suitable for small-scale use because they require large space, lack energy storage and are not portable, and high installation cost. Therefore, the idea of installing a WT on the vehicle came to generate energy from the wind formed on a small scale (Ravi et al., 2019).

This study aims to propose a set of guidelines and best practices for public managers, public authorities, owners of wind farms and other renewable energy sources on the perspective of sustainable development for surrounding communities. The research was conducted in three phases: review of the literature on sustainable development; A case study in major communities (A) and small communities (B, C, and D) where wind farms have been implemented; Develop best practices and guidelines, through brainstorming, focus, present reality tree and create shared value (Sheriffian et al., 2018).

The results of the political dimension of sustainability appear as a root cause for the backwardness of societies. A set of 22 guiding principles and best practices that contribute to the sustainable development of societies are proposed. There are many challenges posed by the fluctuating nature of wind when integrating the electric grid with wind energy, and the high costs of wind farms that can be included to build those farms in addition to the ongoing studies that are being worked on for evaluation (Nassar et al., 2018).

Not like conventional energy, on the contrary, wind speed varies from place and time to time, which increases the fluctuations we face in wind energy production (Fernández-González et al., 2018). There are many variables that reduce energy output such as temperature, pressure, wind direction, etc. (Sheriffian et al., 2018).

There are things to consider when integrating the electric grid with wind energy, such as the prediction of wind speed values (Ammar et al., 2018). Considering the things that need to be done to combine them (such as forecasting, filtering, simulation, and fitting the distribution curve) helps make better decisions to develop the wind sector and better manage the electricity system. In addition, future wind speed prediction helps improve the reliability and safety of wind farm operation (Staid et al., 2015).

Wind energy is clean and renewable energy and is therefore classified as an attractive energy source (Burton et al., 2011). Therefore, future forecasts indicate an increase in the contribution of wind energy to energy production, to reach at least 18% by 2050 according to the International Energy Agency. The total and cumulative total of energy production, according to what the World Wind Energy Council indicated in 2017, was 11% of the total at the end of 2016, approximately 487 gigawatts, and the global production of wind energy in 2017 remained above 50 GW. In addition, it is becoming a commercial and unsupported technology as it competes successfully against internationally highly subsidized fossil fuel and nuclear companies. Based on the international classification, 30 countries have an installed capacity of more than 1 GW, and 9 countries have an installed capacity of more than 10 GW (Almohanadi et al., 2018).

Since cars run near one another at high speeds, the effect of drag reduction when traveling behind another vehicle (known as drafting or slipstreaming) is an important factor. However, the advantageous effect is not solely limited to the trailing vehicle. The trailing vehicle in most cases reduces the drag of the leading vehicle as well, particularly in 3 passenger car derived racing formulae. This results in the phenomenon of several vehicles being a lower drag configuration than an isolated vehicle and forms the basis for platooning research related to autonomous commercial and passenger road vehicles (Ghawre et al., 2020).

Buildings account for 75% of the state's electricity consumption and 40% of the total energy in the United States. The main and biggest reason for the increase in this consumption is the cooling of buildings during the summer, which represents 32% and 53% of the total energy in commercial and residential buildings. The great development in car companies and the conversion of all vehicles to electric will increase the burden on electric networks because electric vehicles are charged from household electricity. The change in the nature of solar cells and wind energy is increasing the challenges facing the electricity network to provide demand for customers in full, and with the increase in the use of electric cars, the demand for household electricity will increase if special electric charging stations are not built for vehicles by 2025 (Sedaghatizadeh et al., 2018).

The increase in electric cars requires the presence of electric charging stations, which calls us to find flexible sources to help achieve a balance between demand and supply of electricity. Energy storage is important in its role to achieve this budget by improving the consumption pattern of electricity according to needs. The research shows a comparison between the hybrid storage system and the one-type storage system, as the hybrid has stronger capabilities. There are limitations and challenges, which is that most studies apply improvement methods. In addition, there may not be public access to modern programs that are used to improve energy (Zheng et al., 2021).

An important flaw in the authors' analysis, linking ideal and pseudo-energy capacities, is that they do so at peak time rather than over a period depending on the energy load. In addition, their studies do not consider car charging and photovoltaic energy, but this problem can be easily solved because the analysis can be easily repeated (Shakoor et al., 2016).

Figure 1.1 shows the correlation of the contrast between wind force and torque with respect to vehicle speed. The figure shows that the relationship between wind force and torque depends on the vehicle's speed. As the car speed increases, the torque increases with the increase in the wind force, which increases the amount of energy produced. Figure 1.2 shows the increase in power output as the vehicle speed increases (Muzammil, 2015).

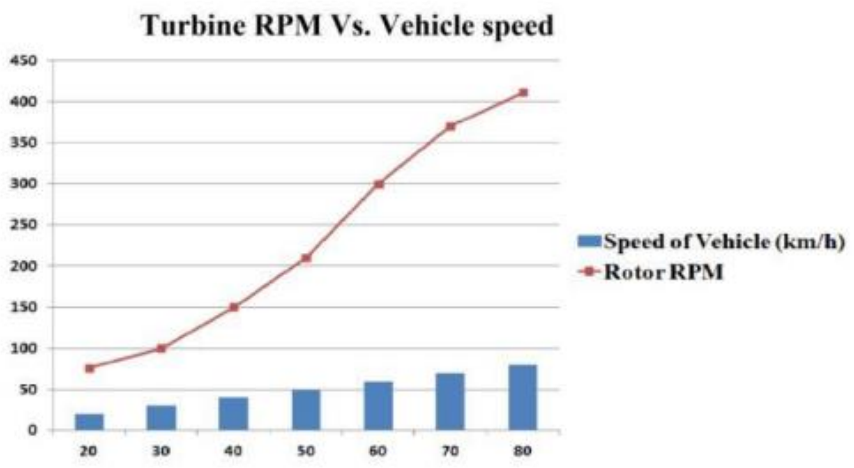

Figure 1.1: Shows relationship between turbine RPM and vehicle speed Reprint (Muzammil, 2015).

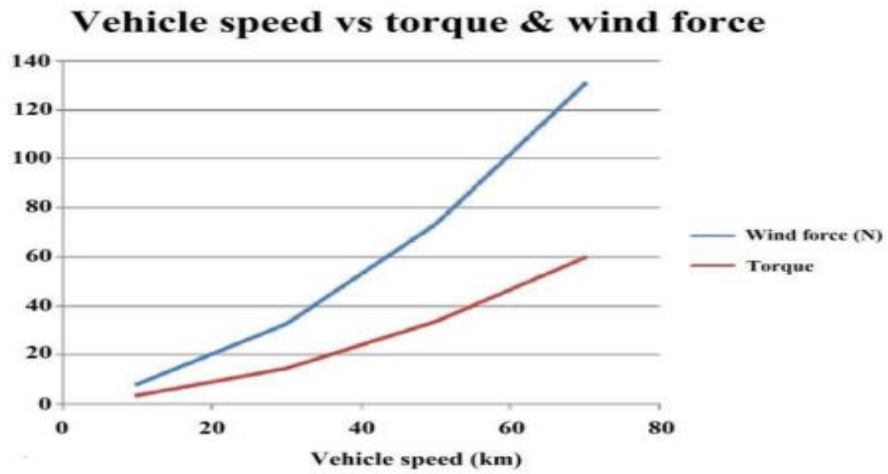

Figure 1.2: Shows wind force and produced torque vs. vehicle speed Reprint (Muzammil, 2015).

In this condition, if the airflow around the vehicle (which had not interacted with the vehicle before) is allowed to enter the interior and allow it to flow backwards; so, the energy lost by the car can be exploited to overcome the air resistance to its movement by installing the turbine in the front, thus exploiting these currents of air to generate energy and work to bring the air out on both sides of the car by stagnation in the front (Xiaoxia et al., 2016).

Now, if these wind-vehicle interaction-generated fluxes are captured within the vehicle so as not to impose additional drag in the direction of vehicle propulsion, Recharge the battery with wasted energy or used by traditional roaming methods, and the turbines can do this for this purpose. At the same time, this will help to increase the pressure at the rear of the turbine (according to Bernoulli's equation, the pressure will increase if the speed decreases and the speed will be reduced at the rear of the turbine after energy extraction), which will reduce the drag force that existed previously with the conventional design of the vehicle (Windustry, 2022).

Thus, the vortex effusion will be reduced at the back. So, it's important to adjust the design of the car to ensure that the air goes through it. On the other hand, the turbines position is important since they must be put so that they don't create additional resistance on the car. The position of the turbine can do the trick because the air force acting on the turbines will cancel by each other out (Milligan et al., 2015).

The world is facing many difficulties that threaten the necessities of life that have become impossible to dispense with. The most important of these necessities is electricity, which made the officials’ orientations towards thinking about the existence of an alternative source of fossil fuels, which has been and is the main source of energy generation in the world since its discovery. The existence of alternative sources reduces humanity's dependence on fossil fuels to generate electricity and helps in its sustainability (Uchida et al., 2020).

Among the most important alternative sources that have been discovered: solar cells, wind energy, biomass...etc. As for electric vehicles, they are completely environmentally friendly, but they need to be charged when their battery runs out. It is necessary to think of a mobile source that supplies them with energy while they are in motion, as their discharge rate is 0.215 KWh/km (Scott et al., 2016).

1.2 Motivation and statement of the problem

The large increase in the number of cars and vehicles in cities due to the industrial progress witnessed by the means of transportation, is a sure reason for the emergence of road problems and their congestion, in addition to the serious health and environmental problems that endanger human life due to car exhaust as well as affect animals, plants, water and increase the rate of pollution dramatically.

We must stand in front of them for a moment to realize the gravity of the situation and work together in our communities to reduce this percentage to preserve the environment of which we are a part and to preserve our health. All countries find a way to produce and manufacture electric cars; to be able to keep pace with this wide global trend to steer the tendency to rely heavily on this type of vehicle.

There is no doubt that there are many reasons that encourage such a choice, most notably the fuel crisis, and work to protect and preserve the environment, and evidence of the spread of this trend, is that sales of electric cars in China witnessed a jump during the month of November 2021 by up to 18% compared to October 2020 (Paoli etal., 2022).

Given the importance of human health, he must strive to preserve it and avoid polluting the surrounding environment, which is the main source of infection with many diseases, by avoiding the use of polluting devices and machines that cause the emission of harmful gases. Clean energy such as wind, water, and photovoltaic cells. In addition, the awareness of society is detrimental to its use.

Expanding the production of renewable energy from new sources, especially wind energy to generate electricity, constitutes a strong step to enhance energy sources, and according to what some environmental experts have confirmed about the importance of investing in renewable energy to achieve economic and social sustainability, and a relatively pollution-free environment. spreading awareness among the countries of the world about the development of environmentally friendly alternative energy sources; to diversify energy sources.

Among the most important features that distinguish it from others:

- Completely away from nuclear energy and its pollutants.
- Not expensive.
- Not affected by rising fossil fuel prices.
- You do not need to dig and excavate to be extracted, not even for generating stations.
- Its cost is low despite the high fuel prices.
- Renewable as it is impermeable energy.

If the vehicle is traveling at a constant speed of 15 m/s (54 km/h), then a wind current of 15 m/s may be expected to circulate around the vehicle. Sometimes, forces against the movement of the car are formed due to the wind. Overcoming these forces (friction and wind resistance) is one of the energy requirements to enable the car to continue its movement forward (Vedantu, 2022).

In this thesis, our work is to calculate the power that needed to charge the battery of the vehicles, also to determine the appropriate place to install the turbine. The vehicle is assumed to move with zero whether wind speed (calm and constant wind current). The calculations will be made to choose the precise wind turbine; as well as to determine the positively charging point. All these calculations will be done depending on the air flow which created by the vehicle movement. All these steps to make sure if this work can fulfill the objective of this idea.

1.3 Personal statement

Life is based on the role of the educated in developing what benefits and maintains the survival of life on planet Earth safely, and the engineer is one of the groups that bears a great responsibility towards this world. The engineer had a great role in the development of many things in the fields of life, as he is the one who designs facilities such as architecture and construction ... etc., and therefore the role of the engineer is great in his society based on the multiple areas of life.

The importance of the engineer in society is endless, and the science of engineering is mentioned in the pages of history, as it is one of the oldest sciences at all. Therefore, the engineer is considered one of the pillars of life on which society depends and nations rise. As a mechanical engineer specialized in the field of cars, and here I am completing my educational path in the field of renewable energy, it has become my duty to offer all my knowledge, time and effort in the service of my community and the environment in which I live, and to work as much as possible to find good means and methods that help provide Energy and reduce the impact of vehicle use on the environment.

This is one of the reasons that led me to think of using wind energy to charge electric car batteries, because the exhaust and toxic gases emitted from them and polluting the environment do not exist. The wind is always available during the movement of the car and there is no need for a source to provide it to us, and finally there are no toxic gases resulting from the process of power generation. These reasons are worth all the effort and thought in designing and implementing this idea, which may be a reason to maintain a clean environment and provide the energy needed for our daily life.

1.4 Factors affecting wind energy:

There are some natural factors that may affect wind energy and work on its production, in many ways, the most important of which are: (Irfan et al., 2021)

- The sun:
- Temperature difference between aquatic and land areas: (Zhang et al., 2018)

1.5 Advantages of wind energy:

Here are the advantages of wind energy as presented by Langer et al., 2018:

- Preserves the environment as it reduces carbon dioxide.
- Wind energy is free from all pollutants related to nuclear fossils and nuclear plants.
- Inexpensive as it is possible to establish an air farm containing large towers in a week.
- Not affected by rising fossil fuel prices.
- Its cost is low despite the high fuel prices.
- Renewable as non-permeable energy.

1.6 Disadvantages of wind energy:

Here are the disadvantages of wind energy as presented by Wei et al., 2020:

- This energy cannot supply the transportation sector, which leads to the transportation sector's dependence only on petroleum products.
- Although it is renewable energy, it is seasonal, and sometimes the wind speed does not match the electric energy.
- The visual effect of turbine rotation and noise may disturb people living near wind fields, and to reduce these effects it is preferable to establish wind fields in areas away from residential areas.
- Choosing the right site for the turbine construction is difficult.
- Environmental impact of turbine construction and operation.
- Giant turbines sometimes kill some birds, especially during their migration period.

Chapter Two

Design and modeling

2.1 Introduction

There is rapid and remarkable progress in the adoption of electric vehicles, as this rapid adoption of them is making significant progress in solving the problem of increasing emissions of environmental pollutants and greenhouse gases (GHGs) around the world. All car companies aim to convert all their production to vehicles that rely entirely on electricity instead of those that need fuel to operate them, which is one of the main causes of environmental pollution, and this leads to an increase in demand for electricity. These electric cars run on batteries stored in electricity, and this means that there must be special electric charging stations for them like fuel stations (Shah et al., 2018).

There are many ways to charge electric cars, for example (traditional transfer stations, regenerative braking, etc.). Regardless of how long the vehicle needs to travel to reach the nearest electric charging station, the time it takes for the vehicle to fully charge the battery is approximately 30 minutes. Regenerative braking seems to have partially solved this problem (Yang et al., 2022).

Regenerative braking must have solved part of this problem but in spite of that, the amount of electrical that can be produced is limited. Now, when the car is moving, wind currents are formed as a result of its movement and the higher its speed, the greater the amount of air formed around it. If the car is moving at a reasonable speed, it will be enough to power the blades of a small wind turbine. This is what is being worked on in this study (Mehrjerdi et al., 2020).

The idea is to install a small-sized turbine in the chassis of the vehicle, and when the car starts moving, the air currents formed around it will penetrate the chassis of the vehicle and on its way hit the turbine blades and spin them, and as a result, electricity is generated through which the battery will be charged constantly (Gao et al., 2021).

This project is based on the laws of thermodynamics. The law of conservation of energy states: (Artuzo et al., 2021)
"Energy can’t be created or destroyed, and it can only be converted from one form to another."
For this work, wind energy is converted into electricity to charge the battery. The wind is harvested by small wind generators that are mounted in the front of the vehicle. To build the generators, four turbines and four blades will be used. The working principle of engines is quite the opposite with the working principle of generators. The principle of operation of motors is to convert electricity into mechanical energy, while generators convert mechanical energy into electricity. A device called an anemometer, used to measure wind speed, will be used to measure the wind speed while driving a car to find out how fast the wind is reaching the turbines. To measure the voltage, a voltmeter is used to find out the voltage of the electricity generated by the turbines.

2.2 Aerodynamics in the automotive world:

The modernization and development of cars has not stopped since ancient times, perhaps this field is the most advanced and still far from the technology that entered vehicles from its widest doors and we are seeing self-driving cars, there is another aspect of modernity in the vehicle industry, which is its shapes and external design, it is subject to many Factors that some may be ignorant of or may be absent from their minds, so there is a study in itself, which is the aerodynamics of cars, which is concerned with the ability of the car to resist air and ensuring that this is done in the best way and in the best possible way (Wang et al., 2019).

2.3 Importance of Automotive Aerodynamics:

The aerodynamics of the car affects the degree of its stability and cohesion on the road, in addition to the rate of fuel consumption of the car. The rear part of the car is no less important than the front. After the air penetrates from the front, it will reach the meeting point at the rear of the vehicle, which hinders its movement and affects it greatly. Therefore, the car is designed from the back according to rules and controls that will raise the car's ability to resist the resulting pressure caused by air slit (Sadjadi et al., 2021).

Cars undergo a large number of experiments before starting their manufacture and connecting to their final external shape, where car factories test several models of the car by placing them in a dedicated path that includes fans to generate air current, and then the process of measuring the car's resistance to air until reaching a model that takes into account all aspects and in the same Time has the least resistance and ability to penetrate air (Wei et al., 2021).

2.4 How to take advantage of the wind resistance to the movement of the vehicle:

The production of energy using wind is one of the least expensive ways to generate energy, as it does not require a high cost, and we can benefit from the electricity it produces, which reduces the costs involved (Holmberg et al., 2012).

The principle of producing electricity from wind is based on the conversion of wind turbines into wind directed towards them into mechanical energy. Where it goes through a generator to produce electricity, in wind farms the electricity is collected from all the turbines and then transferred to the main electricity grid. The turbines consist of two blades at a height of more than 80 meters (Janabi et al., 2020).

The shape and dimensions of the wind turbine blades are determined by the aerodynamic performance required to efficiently extract energy from the wind, and by the force required to withstand the forces on the blade. The airflow at the blades is different from the airflow away from the turbine. The nature of the way energy is extracted from the air also causes the air to be deflected by the turbine. In addition, the aerodynamics of wind turbines on the rotor surface exhibit phenomena rarely seen in other areas of aerodynamics (Joustra et al., 2021).

The speed at which a wind turbine rotates must be controlled to generate power efficiently and to keep the turbine components within the designed speed and torque limits. The centrifugal force on the rotating blades increases with the square of the speed of rotation, which makes this structure sensitive to over speed. Because wind power increases as a cube of wind speed, turbines must be built to withstand much higher wind loads (such as gusts of wind) than they can practically generate power from. Wind turbines have ways of reducing torque in high winds (Holburn et al., 2019).

Wind turbines are designed to produce power over a range of wind speeds. The cutting speed is about 3-4 m/s for most turbines, and it cuts at 25 m/s, as shown in figure 2.1. If the rated wind speed is exceeded, the power must be limited.

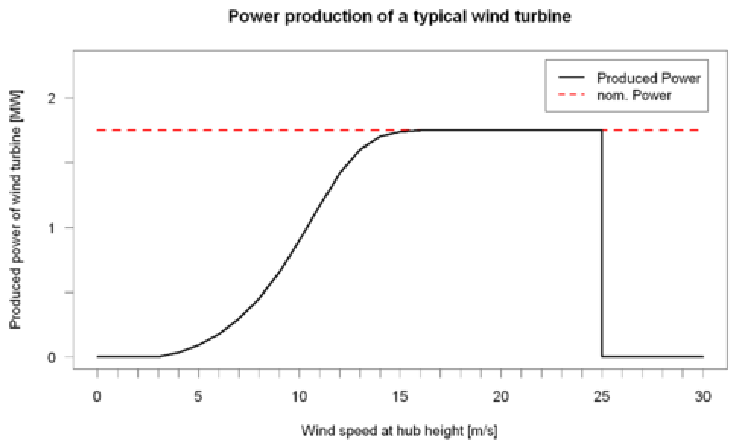

Figure 2.1: power production of a typical wind turbine (A remarkable Watermarking technique, 2018).

It is necessary to find a way to control the angle of inclination of the turbine blade, because the winding process requires work against the torque on it, as this can be achieved using the spindle motor. This drive angles the blade precisely while withstanding high torque loads. In addition, many turbines use hydraulic systems, and these systems are supported by springs that make the blades rotate automatically in the event of any failure in the hydraulic power (Nygaard et al., 2020).

Wind turbines are variable speed machines, when the wind speed is too low, it is supported by the torque of the generator to control the speed of the rotor to generate the largest amount of power. This occurs when the rotor speed is constant at the edge speed by 6 or 7, which means that the speed of the rotor must increase in proportion to the increase in wind speed (Saravanan et al., 2018).

The difference between the aerodynamic torque picked up by the blades and the alternator torque being applied controls the speed of the rotor. The torque of the generator is inversely proportional to the speed of the rotor, as the rotor accelerates when the torque of the generator is low, but if the torque of the generator is higher, the rotor slows down to below the estimated wind speed. There must be a constant control of the torque of the generator, while the angle of inclination of the blades remains constant to be able to catch the largest amount of energy and be flat with the wind (Fleming et al., 2019).

2.5 Design of the Wind Turbine

2.5.1 Wind turbine components:

Wind turbine design is the process of defining the shape and specifications of wind turbines to extract energy from the wind. A wind turbine installation consists of the necessary systems needed to capture wind energy, direct the turbine to the wind, convert mechanical rotation into electrical energy, and other systems for starting, stopping, and controlling the turbine (Enevoldsen et al., 2019).

The shape and dimensions of the wind turbine blades are determined by the aerodynamic performance required to efficiently extract energy from the wind, and by the force required to withstand the forces on the blade. The airflow at the blades is different from the airflow away from the turbine. The nature of the way energy is extracted from the air also causes the air to be deflected by the turbine. In addition, the aerodynamics of wind turbines on the rotor surface exhibit phenomena rarely seen in other areas of aerodynamics (Rezamand et al., 2020).

The assembled turbine, Figure 2.2, is fixed to a frame-like structure provided in place of the vehicle's combustion engine and fixed by a set of bolts with the intake facing the front of the vehicle. The diffuser booster wind turbine is chosen for the design because it is the most efficient wind turbine (Quartey et al., 2014)

Figure 2.2: Isometric Views of the Wind Turbine (Quartey et al., 2014).

The main components of the proposed design are rotor, main shaft, main bearing coupling, alternator, top cover, base cover, inlet safety guard, exhaust safety guard. Fig.5 shows the components of the turbine. The rotor (1) is attached to the main shaft (2) by a set of four hex head bolts. The main shaft (3) and generator (5) are secured to the struts on the base cover (6) by means of a set of hex head screws (shown in figure 2.3) (Quartey et al., 2014).

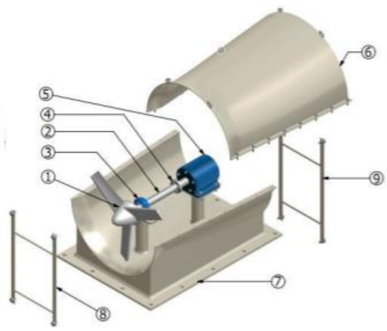

Figure 2.3: Exploded View of the Wind Turbine showing the Main Parts (Quartey et al., 2014).

2.5.2 Main components the turbine

The following figure illustrates the components of the turbine and the function of each part.

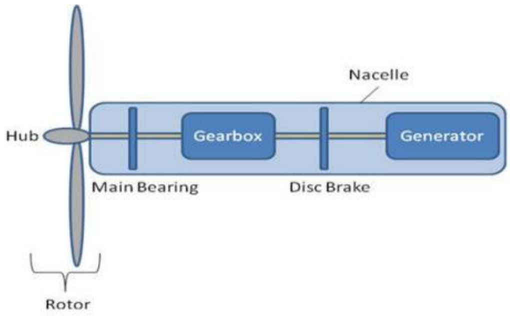

Figure 2.4. Main components of a wind turbine (Leithead, 2016).

1- **Rotary:**

It is the part responsible for collecting energy from the wind. The rotor usually consists of two or more blades that rotate around the axis of the turbine at a rate of speed determined by the shape of the blades attached to it and the speed of the wind striking it. The blades are attached to the shaft, which is attached to the main shaft

2- **Generator:**

It is the part responsible for converting the movement of the rotating blades resulting from moving the air to electricity that is stored in the batteries. Inside it there are coils of wire centered on the rotating axis, where they are rotated in a magnetic field to produce electricity. Some generator designs produce alternating current (AC) or direct current (DC). The rating of the generator or its size depends on the length of the turbine blades: the amount of energy produced depends on the amount of wind captured by the turbine blades.

3- **Shaft:** transmits rotational power to the generator.

4- **Hub:** It enables the blades to rotate and lock as needed.

5- **Nacelle:**

It is the structure that contains the Gearbox (responsible for increasing the speed of the connecting rod, connecting the rotor clip and the generator), the generator (which uses the rotational energy of the connecting rod to generate electricity using the principle of electromagnetism), and the Electronic control unit (responsible for controlling The system stops the turbine in the event of a malfunction, also controls the yaw control mechanism), the yaw controller (which ensures that the rotor is aligned with the wind direction), and the brakes (which stops the connecting rod rotation process in the event of saturation or system failure).

6- **Blades:** The aerodynamic design of the blade is essentially a shape optimization design, which is a critical step in blade design. The advantages and disadvantages of the blade airfoil design in the shape optimization design directly determine the power generation efficiency of wind turbines. Under wind turbine operating conditions, the flow rate of Reynolds is relatively low. The blades usually operate at a low speed and a high lift coefficient. Flow interference between the blades causes flow. very complicated. Due to the complex flow condition of the blade shape and the distribution of the blade shape in different directions, the design of the blade profile becomes very important.

7- Gearbox: The function of the gearbox in general is either to increase the speed and reduce the torque or to increase the torque and reduce the speed as in the car, and in the wind turbine its function is to increase the rotational speed to match the speed required for the electric generator.

8- Disc Brake: It is a system in the wind turbine whose function is to brake the turbine in certain cases and often in serious cases, such as the case of wind speed exceeding cut out speed, which may cause the turbine to be destroyed if the brakes do not work (Chaudhry, 2020).

At present, the blade coil design technology is usually based on the advanced aviation wing design method to design the shape of the blade coil. The advanced computational fluid dynamics (CFD) technology has been widely used in the design of various kinds of aerodynamic shapes (Vinuesa et al., 2022).

For fan operating conditions under low Reynolds number and high lift coefficient, it is necessary to analyze the flow field of the blade coil using the Navier–Stokes (NS) control equation considering the viscosity (Ershkov et al., 2021).

There are several design theories for the shape of the blade, all of which are developed based on the aerodynamic theory of the wing. The first theory of shape design is a simplified design method based on the Bates theory. This method assumes that the wind turbine operates under the best conditions of the Bates equation, without considering the eddy current loss, …etc., and that the efficiency of the designed wind turbine does not exceed 40% (Vučina et al., 2016).

Later, some famous aerodynamics scientists established their own aerodynamic theory. Schmitz theory considers vortex loss in the circumferential direction of the blade, and the design result is relatively accurate. Glauert's theory considers the vortex flow behind the wind wheel but ignores the effect of aileron resistance to blade and blade loss, which has little effect on blade shape, but has a greater effect on wind turbine efficiency (Afzal et al., 2020).

Wilson made improvements based on the Glauert theory, studied the effect of blade loss and lift-drag ratio on the best blade performance, and studied wind wheel performance under non-design conditions, which is currently the most used design theory (Yunhao et al., 2021).

Blade weight control is one of the goals of larger blade systems. Larger blade systems are restricted by the loading that occurs due to the presence of gravity, due to the blade mass being the cube of the turbine's radius. Examples of these loads (tensile, pressure, as well as bending (positions of gravity)). These loads change periodically, and the sharp moments are reversed every 180 degrees of rotation (Weidong e al., 2022).

The load cycles of the turbine blades are expected to be about 10^9. As the wind is considered as an additional source to carry the blades. Bending may occur in flat sweep due to lifting outside the rotating plane. As for the airflow around the blade, it causes a sharp bend in the rotor plane. Panel bending involves stretching downwind and pressing down on the suction side (downwind) (Yue et al., 2021).

2.5.3 The aerodynamics of the turbines:

Wind power generation is the main goal of using wind turbines, and since they will always be exposed to the air, aerodynamics is an important aspect of turbines. There are many wind turbines and all of them have different concepts for extracting energy from them. Some basic concepts apply to all turbines, although aerodynamics is largely dependent on the structure of the turbine. The turbines are divided into two groups, which are either based on lifting or dragging, where the group of turbines that operate on the basis of lifting is considered more efficient. The difference between these groups is the aerodynamic force used to extract the energy. Wind turbines are devices that convert the kinetic energy of the wind into electrical energy, the idea of which came because of the development of engineering windmills for more than a thousand years. (Amrinder, 2020).

Today's wind turbines are manufactured in a wide range of horizontal axis and vertical axis styles. The smallest turbines are used for simple tasks such as charging auxiliary batteries for primary power sources. Slightly larger turbines can be used to supply household power as well as sell unused power to electric power supplier companies. Large arrays of turbines, known as wind farms, are an important source of renewable energy and are used in many countries as part of a strategy to reduce dependence on fossil fuels.

The turbines are designed based on the shape and specifications of the wind turbine to be able to generate the largest possible amount of energy. The turbines are provided with systems that direct the turbines in the direction of the wind and determine the inclination of its angle, in addition to other operations whose function is to convert kinetic energy in mechanical parts into electrical energy. There are other additional systems such as the brake system, take off and control systems (Pavese, et al., 2017).

The German physicist Albert Betz in 1919 proposed a hypothesis about the extraction of wind energy using a machine. According to this theory and based on the basic laws in the conservation of energy and mass, it is not possible to extract more than 59.3% of the kinetic energy of the wind and this limit has been called the Betz limit (Chen, 2019).

The aerodynamics relationship related to wind turbines is not linear. This means that the entry and penetration of air through the turbine is completely different from that after the turbine by a large distance. The nature of the work of the turbine with its rotating blades causes an obstruction to the flow of air through the turbine. In addition, aerodynamics is a phenomenon whose presence is very little in other aerodynamic fields (Evans et al., 2017).

Determining the shape and dimensions of the turbine does not happen randomly, but rather by studying the aerodynamics on it to improve its performance in generating energy from wind. As for the turbine blade, since it is subject to changing wind forces from time to time, it is necessary to make accurate calculations that enable it to resist the forces applied to the wind. The most common model is the horizontal turbine, which is a lift-based turbine with very good performance. Therefore, it is a more widely used and applied option around the world (Yang et al., 2020).

Modern turbines use more advanced aerodynamic principles to ensure greater efficiency while capturing wind energy. Among the basic principles of aerodynamics adopted in the rotor of wind turbines and figure 2.5 shows the shape (Layton, 2020):

The lift force: which acts perpendicular to the direction of the wind.
The drag force: which acts parallel to the direction of the wind.

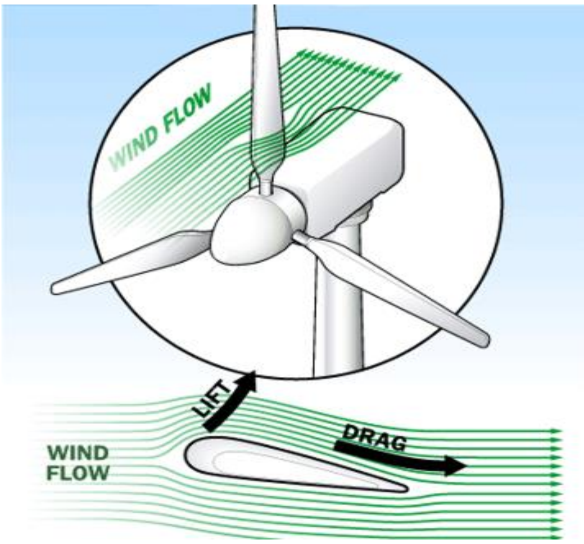

Figure 2.5: An illustration of the aerodynamics of the turbines (Layton, 2020).

The blades of the turbine are very similar in shape to the wings of an airplane and are made using the airfoil design. Observing the latter, one side of the blade is semi-rounded, while the other is relatively flat. Lifting is a very complex phenomenon. To put it simply, as air travels through the windward rounded side of the blade, it must move more quickly to the end of the blade to catch up in time with air running through the flat, upwind side of the blade (opposite the direction the wind is blowing) (Dana, 2020).

Aerodynamics can't be considered the only design in making efficient wind turbines, size matters too, meaning the longer the turbine blades (and thus the rotor diameter), the more energy the wind picks up, and thus the power to generate electricity. In general, doubling the rotor diameter results in a fourfold increase in power output. However, in some areas of low winds, the rotor of smaller diameter can produce more power than the larger rotor, because in the case of this smaller equipment, we need less wind power to rotate the smaller generator, so that the turbine can rotate at full power all the time (Momeni et al., 2020).

The height of the tower is also a very important factor in the production capacity as well, the higher the turbine, the more power it can capture, as the wind speed increases the higher the height, and this is because the things on the ground level disrupt the wind flow, and scientists estimate that the wind speed increases by 12% whenever height doubled (Saeed et al., 2019).

2.5.4 Nozzle

It is a device designed to control fluid properties such as pressure and velocity, and since the nozzle starts with a large cross-sectional area at the inlet and ends with a small cross-sectional area at the exit, it increases the fluid velocity at the exit. The following figure 2.6 shows the shape of the nozzle:

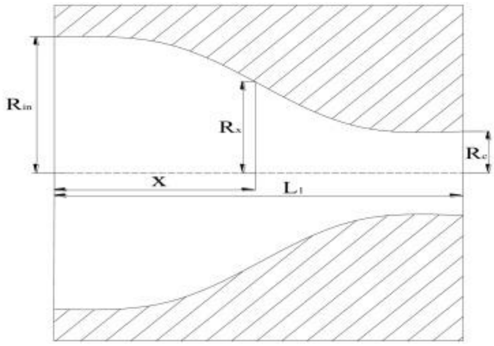

Figure 2.6: Nozzle shape (Workbook, 2022).

We can use the nozzle with the turbines that are installed on vehicles to help reach the required speed to start generating the necessary energy in the least possible time and to fully exploit the air that penetrates it.

One the important concept is the Mass Flow Rate which is defined as the rate of change of the mass of a fluid (liquid or gas) that passes per unit time, in other words the rate of movement of the fluid that passes through one space, and it depends on the density of the fluid, its velocity, and the space it will pass through, and it has A basic principle is the principle of conservation of mass (continuity equation) which is that the value of the mass flow rate when passing through one end must be the same when it exits from the other end with the change in area, speed and constant fluid density for both sides. It is expressed by the following equation (Vedantu, 2022):

$$\rho_1 A_1 V_1 = \rho_2 A_2 V_2 \qquad (1)$$

$$A_1 v_1 = A_2 v_2 \qquad (2)$$

2.6 Wind turbine Principle of working:

A wind turbine turns wind into electricity using the aerodynamic force from the rotor blades. When wind flows across the blade, a difference in air pressure creates both lift and drag. When the lift on the blade is stronger than the drag, the rotor spins. The rotor-hub is connected to the generator through a series of gears known as a gearbox, and the bearings support the movement of the turbine. All these components are housed by the nacelle. As blade rotation speed increases, the translation of aerodynamics to the rotation of the generator creates electricity (Madi et al., 2019).

When the wind penetrates the front chassis of the vehicle, the process of rotating the blades begins. The rotating turbine is connected to a high-speed gearbox. The gearbox rotates the rotor from high speed to high speed. The high-speed shaft of the gearbox is coupled with the rotor of the generator and then the electric generator runs at a higher speed (Chamorro et al., 2014).

The generator is needed to give the required from the magnetic coil of the generated field system so that it can generate the required electricity. The voltage generated at the output terminals of the generator is proportional to the speed and field of flow of the generator. The speed is governed by the outgoing wind energy being controlled by the wind. The exciter current is controlled by a controller that senses the wind speed. Then the alternator output voltage is introduced to a rectifier where the alternator is changed to DC. After that, the approved DC is sent to the line conversion unit to convert it into a stable AC output that is transferred to store the electricity in batteries or to operate the load to be supplied with it (Jahangiri et al., 2019).

The direction of the turbine blades is controlled from the primary axis of the blades. The blades are connected to the central axis with the help of a rotary arrangement through gears and a small electric motor or hydraulic rotary system. The system can be controlled electrically or mechanically depending on its design. The blades rotate depending on the wind speed. This technique is called pitch control. Provides the best possible direction of the turbine blades along the wind direction for optimum wind power (Hansen, 2018).

The direction of the turbine body can follow the change of wind direction to maximize mechanical energy harvesting from the wind. Wind direction and speed are sensed by anemometers (automatic speed gauges) with wind vanes attached to the upper back of the body. The signal is returned to the microprocessor-based electronic control system that controls the motor that rotates the full seat with the arrangement arranged to face the wind turbine along the downwind (Yang et al., 2018).

There are three main types of wind energy to consider: Utility-scale wind, distributed wind, and offshore wind. Utility-scale wind produces anywhere from 100 kilowatts to several megawatts of power that is delivered to a power grid and sent to the user. Distributed wind is a single, small wind turbine that is used to power a home or a small business. Lastly, offshore wind involves large wind turbines built on the continental shelf of large bodies of water, which can generate massive amounts of power (Arvidsson et al., 2021).

The most common use of wind energy is through utility scale power. To create massive amounts of energy needed to power a community, wind farms are used. Wind farms produce electricity by setting an array of wind turbines within the same location. Factors such as wind conditions, terrain, accessibility to electric transmission, and other siting factors dictate the placement of a wind farm (Kaynia et al, 2019).

As wind passes through the rotor, a deficit in wind velocity downstream of the turbine is created. Analytical wake models are designed to capture this behavior. Optimally sitting turbines within a wind farm is dependent on being able to accurately model the wake velocity deficit behind a turbine (Siram et al., 2022).

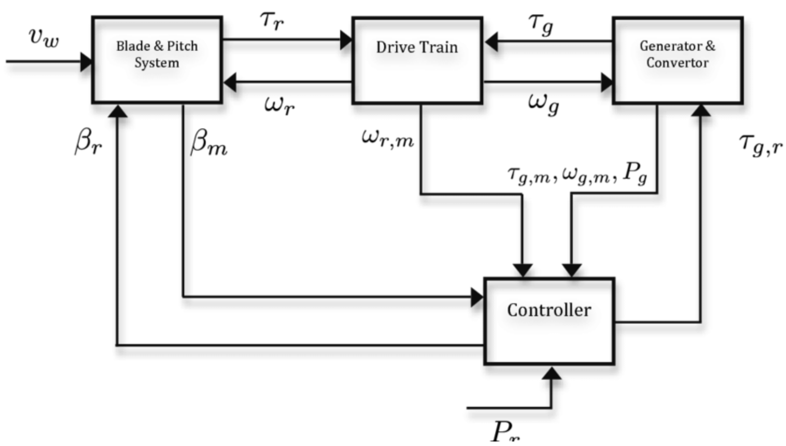

Figure 2.7: Wind turbine interior block diagram (Emmanuel, 2019).

Wind is a form of solar energy that is formed because of three simultaneous events:

1- The sun heats the air unevenly.
2- Surface irregularities.
3- The rotation of the earth.

2.7 Materials

To be able to build this system and install it inside the chassis of electric vehicles, we need some materials to apply this idea and to make it complete and safe to use. From these materials:

- Electric vehicle.
- Turbine
- Blades.
- Generator
- Stands
- Cables
- Speedometer
- Brakes.
- Converter.
- Nozzle
- Cut-out
- Shafts
- Absorbers
- voltmeter

Chapter Three

Results and discussions

3.1 Modeling and theoretical calculations

The wind turbines will be installed in the vehicle as shown in figure 3.1. When the vehicle begins to move, it displaces the air directly in front of it. This causes the surrounding air to flow in a direction opposite to that of the vehicle. The corresponding air stream passes directly in front of the turbine through the turbine blades and thus provides torque to rotate the rotor. Then the rotating energy of the rotor is transmitted to the generator through the main shaft. The alternator is electrically connected to the vehicle's charging system. So, the batteries are constantly charged while the car is in motion (Emmanuel, 2019).

The air flow through the vehicle is given by:

$$Q = C_v A v \qquad (3)$$

Where, Q = flow rate in cubic meter per second.

Cv = opening effectiveness.

[Value for Cv is 0.5 - 0.6 for perpendicular flow and 0.25 – 0.35 for skewed flow]

A = Area in square meter

v = air velocity in m/s

No wind turbine can convert more than 16/27 (59.3%) of the kinetic energy of the wind into mechanical energy. To this day, this is known as Betz's constant or Betz's law. The theoretical maximum energy efficiency of any wind turbine design is 0.59 (i.e., no more than 59% of the energy carried by the wind can be extracted). This is called the "power factor" and is defined as (Wijewardana, 2016):

$$C_{P_{max}} = 0.59$$

Also, wind turbines cannot operate at this limit. The "Cp" value varies from turbine to turbine and is a function of the wind speed at which the turbine operates. Once the various engineering requirements of a wind turbine - strength and durability in particular - are combined, the true limit is well below the Betz limit with values ranging from 0.35-0.45 which are common to even the best designed wind turbines today (Zemamou et al., 2017).

While we consider other factors in the wind turbine system – e.g., gearbox, bearings, generator etc. – only about 10-30% of wind energy is converted into usable electricity. Hence, the power factor must be considered in equation No. (4) And the extractable energy from wind is given by the following equation (Pavese et al., 2017):

$$P_T = \frac{1}{2} C_p \rho Q v^2 \qquad (4)$$

Were,

PT = Power output from the turbine in watt.

Cp = Power co-efficient

(Suppose, Cp = 0.4)

ρ = density of air; 1.225 [kg/m^3].

Q = flow of air [m^3 /s].

v = air speed [m/s].

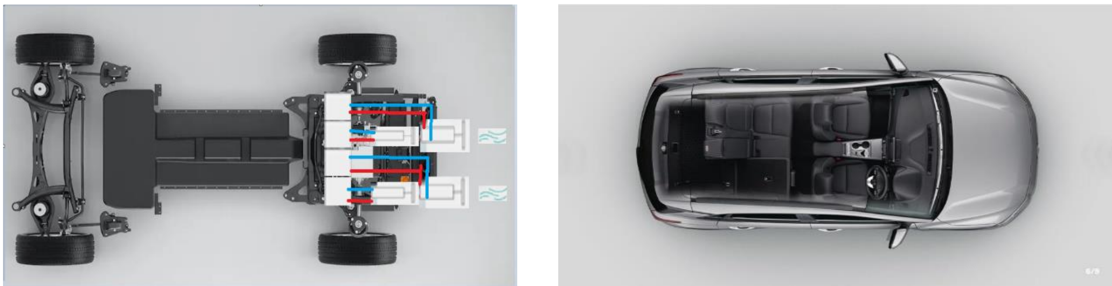

Figure 3.1: Schematic Diagram “modified” (top and Inside View).

3.1.1 Wind turbine

The wind turbine chosen to produce electricity has the characteristics indicated below:

- Three blades.
- Horizontal axis.
- we have chosen $\lambda = 6$. the value of C_p will be 0.4 to 0.45. see figure 3.2 that shows the relationship between C_p and tip speed ratio:

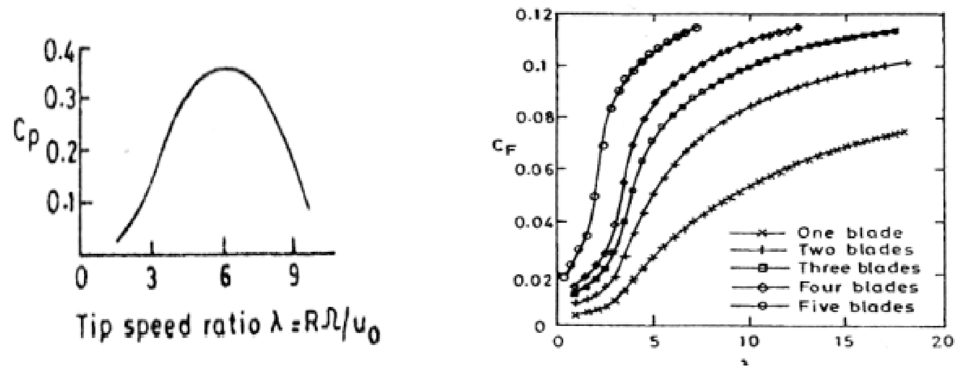

Figure 3.2: Power Coefficient and Axial Thrust Coefficient for HAWT Reprint (Eriksson, 2013).

Were,

C_F = axial thrust co-efficient.

a = the ratio between the air velocity crossing the turbine blades and the upstream velocity of the air

So,

$C_p/C_F \approx 7$

The turbines generate more energy than the thrust forces acting on their blades due to the lift/pull rate that the wing has. Also, the turbines are placed parallel to the air flow.

3.1.2 Wind energy and power

The equation of the available kinetic energy in wind is given by:

$$KE = \frac{1}{2} \times \rho \times A \times V^3 \times T \qquad (5)$$

Were, ρ: the air density,

V: air velocity,

A: the swept area.

T: The required time for the air parcel to travel through the aircraft.

Now, the following equation expressed the wind power:

$$P_w = \frac{KE}{T} = \frac{1}{2}\rho\, A\, V^3 \qquad (6)$$

$$\text{Wind power density (WPD)} = \frac{1}{2} \times \rho \times K \qquad (7)$$

Where K is a value of the distribution pattern which determined by the shape of the wind speeds.

Tip Speed Ratio (TSR): It is a special ratio in wind turbines, which is the ratio between the velocity of the tip of the blade and the actual velocity of the air. The ratio changes from one turbine to another according to the different design of the turbines, the higher the ratio, the higher the noise level from the turbine. The blade tip velocity ratio is of great importance in determining the efficiency and feasibility of a wind turbine (Eriksson, 2013).

$$\text{TSR "}\lambda\text{"} = \frac{\text{Tip speed of blade}}{\text{Wind speed}} \qquad (8)$$

We want to use an AC generator with windings of 3 with an increased number of poles. The poles will be permanent magnets and the pole number will be 8.

$$\lambda = 6 = \frac{\omega R}{vw} \qquad (9)$$

This eliminates the need for a gearbox in the system. We will use a three-phase AC/DC converter to charge the batteries as shown in figure 3.3. The Cúk converter is used to give a constant 60V output. The current of the converter will vary with the variation of the speed of the vehicle or the speed of the turbine by maintaining the voltage at the fixed terminals (Dulepet, 2018).

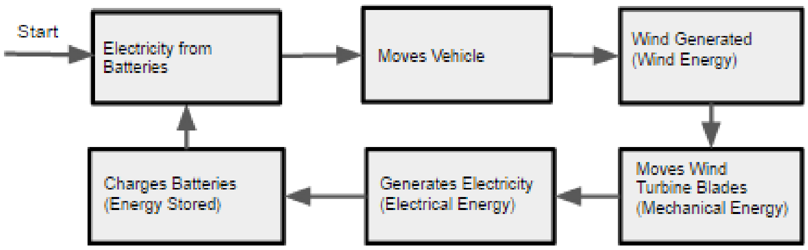

Figure 3.3: Charging and control circuit of the battery (Dulepet, 2018).

Figure 3.4 explain the front section of the swept area.

Using equation (1) we can calculate the amount of air flow at speed 15 m/s,

$$Q = C_v A_v = 0.25 \times 0.8 \times 0.1226 \times 15 \times 4 = 1.994\ m^3/s$$

Here, (radius= 0.23)

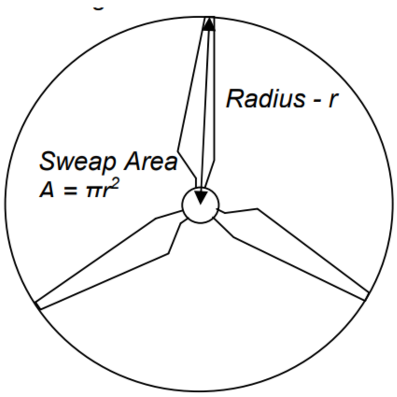

Figure 3.4: front section of a wind turbine (Caduff et al., 2012).

$$A = \pi r^2 \qquad (13)$$

$$\omega = 6\frac{vw}{R} \qquad (14)$$

$$RPM, N = 3{,}736.6\ RPM$$

We supposed that:

$$v = 54\text{kmph} = 15\text{m/s}$$

Here multiplier of C_v is 0.8 as ratio of the inlet and outlet area is 1.38. C_v is chosen as 0.25 as it is a skewed flow.

$$P_T = \frac{1}{2}\rho\, A\, v^3 C_p \qquad (15)$$

So, Power, $P_w = 344.97$ W

Assuming, Cp = 0.4

Then we have, $P_T = 138$ W

Thus, each turbine will produce a power of 138 W. This power will be returned to the battery when it moves at a constant speed of 15 m/s.

These values are determined by turbine designers, but it is important to understand the relationship between all these factors and use this equation to calculate power at wind speeds other than the estimated wind speed. Knowing how a turbine behaves at different wind speeds is critical to understanding the income lost from a turbine at any given time. It is also useful to know how much power the turbine should produce so that if there is a problem with the turbine, it can be revealed due to lower than rated power values (Svanström, 2022).

Predictions of how much energy the turbines will produce is important to the energy market, since in practice the energy is sold before it is produced. This means that accurate calculations of power are very important (Sun et al., 2018).

3.2 Results and discussion

The results in this study were obtained theoretically by using the energy equations of wind energy. In table (3.1), five speeds are considered to find out how much power each turbine produces.

Here, the radius was 0.23 m, considered ρ=1.23, A=0.1662 m^2, v=15 m/s, C_p= 0.4, and this data had been collected through calculating the total power at 15 m/s of wind speed. The total power [watt] generated by each turbine could be as showing in table (3.1) depending on the change in wind speed m/s:

Table 3.1: The difference in power output based on the difference in wind speed:

Wind speed [m/s]	Total power [watthour]
15	**138**
25	**636.07**
30	**1099.75**
60	**21,988**
100	**40,713**

As shown in figure 3.5, and table 3.1 shows that the amount of energy produced at a speed of 15 m/s is very little and is hardly used. But the higher the wind speed, the greater the energy produced. Accordingly, the best amount of energy can be obtained from the turbines when the wind speed is greater than 30 m/s, and the best timing to operate the turbines when the vehicle is moving, and the air has no speed.

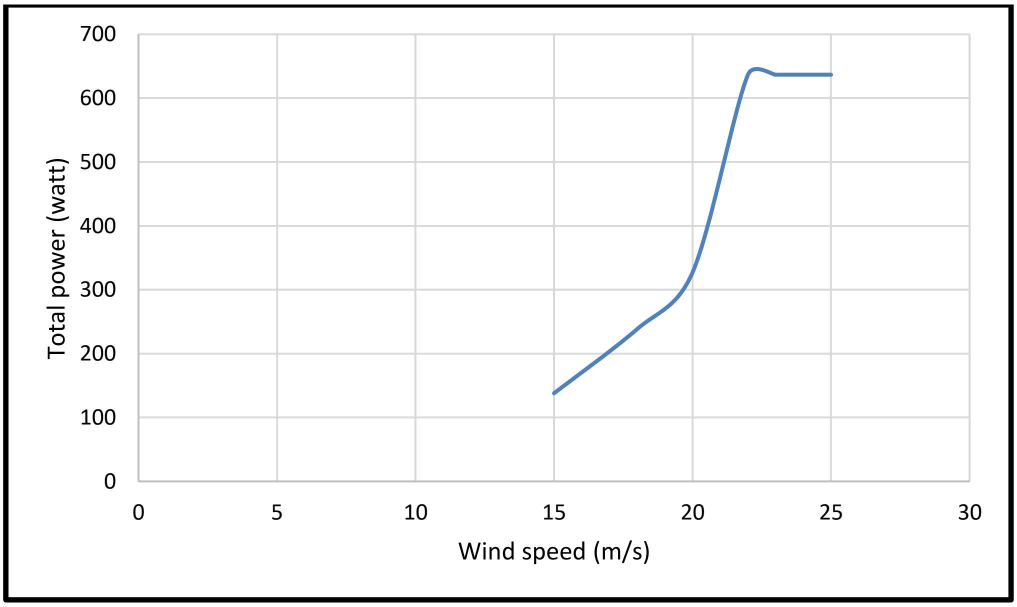

Figure 3.5: The relationship between wind speed and total power.

Wind turbines are designed to produce power over a range of wind speeds. The cutting speed is about 3-5 m/s for most turbines (Quan et al., 2015), and it cuts at 25 m/s, as shown in figure 3.6. If the rated wind speed is exceeded, the power must be limited.

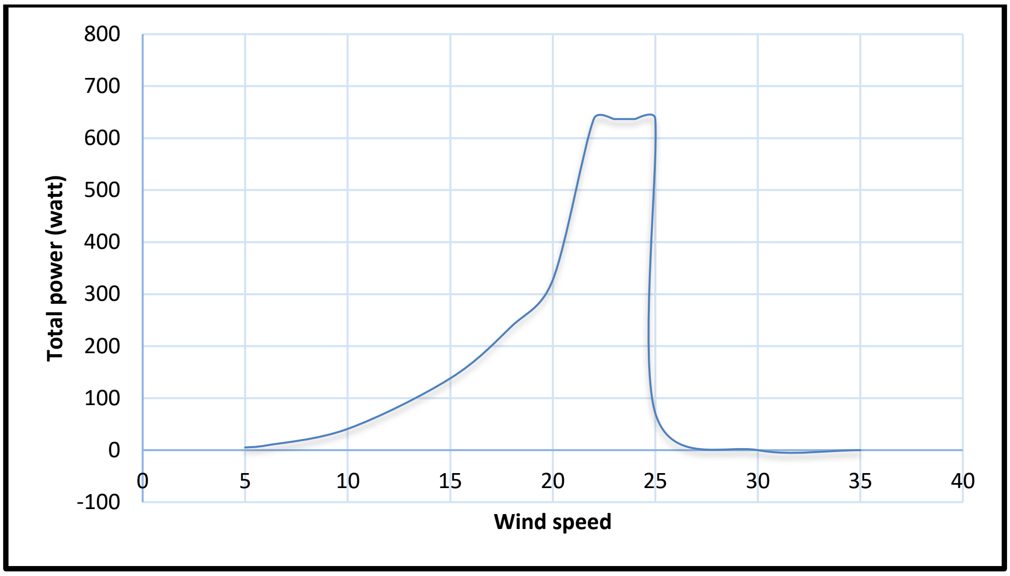

Figure 3.6: Electricity generation and cut-in, cut-out wind speed.

The following illustrative curve figure 3.7 shows the stages of an electric vehicle battery goes through during discharge as the vehicle is in motion compared to the process of supplying the battery with electricity generated by wind turbines. A battery with a capacity of 75 kWh is enough to cover the car for 417 km. As for the charging process, the results presented in this work have been relied upon. As shown in the curve, the point of intersection between the two processes of discharging and charging is at the point (92.6 km, 58 kWh), which means that at this stage the battery charging process begins to increase positively.

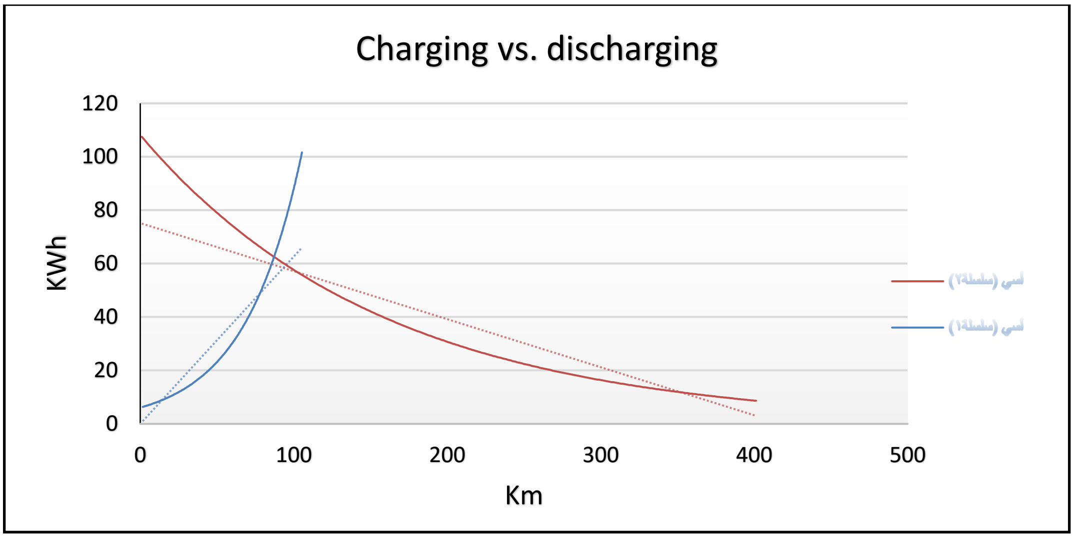

Figure 3.7: Charging vs. discharging processes.

In this work, the possibility of using an alternative source of energy used in the operation of electric vehicles was discussed, which is wind energy, which helps to reduce the burden on household electricity loads. First, having the turbines at the front of the car is a good step in exploiting the dynamic aerodynamic force that affects the car's motion. Therefore, capturing the air in front of the vehicle and using it to drive wind turbines and generate electricity through them has many advantages that enhance the idea of choosing an installation site.

Secondly, the number of turbines used to generate electricity must be sufficient to make up for the shortage in the battery of electricity through which the vehicle operates, thus reaching the highest operating efficiency within a short period of time. In addition, the period the car needs for home charging is greater than it was before the turbine was used.

Third, the idea of using a nozzle is to enable the speed of the turbine blades to reach the highest speed allowed in the operation of the turbine so that we can generate as much power as possible, as well as avoid the passage of velocity. From the turbine blades in the cutting and cutting period and in this way, we used all the limited time to run the car to generate the largest possible amount of these turbines.

Fourth, the design needed to install these turbines on electric vehicles helps in using aerodynamic power to stabilize the vehicle on the road while accelerating and avoid any effect of the lift force that has helped cause many accidents.

Fifthly, the use of these turbines in vehicles disperses the aerodynamic forces that generate forces resisting the movement of the vehicle, which reduces the wasted energy from the forbidden determination to overcome it, which is one of the most positive aspects of using these turbines in installing them on vehicles.

Sixth, there had to be an additional part on the system that would help us bypass the cut-in period so that we could take advantage of the wind entering the engine room, the part that could perform this function, which is the nozzle, a device that increases the speed of any fluid flowing through it and thus performs In turn, it delivers the wind at the beginning of the car's journey to bypassing the cut in stage, which is considered a dead period in the operation of the turbine.

Finally, each turbine generates an estimated amount of energy of approximately 0.64 kilowatts with which the battery is charged, which is enough to increase the vehicle's dependence on stored energy for a longer period, which helps reduce dependence on charging the battery from household electricity, which in turn reduces costs which the owner is obligated to spend.

Table 3.2: Description of equipment.

Generator	Blades	Turbine
Model: HN1010B	Length: 0.18 m	Swept area: 0.46 m
1500/3000 watt	Material: Glass fiber	Weight: 6 kg
RPM: 4000	Weight: 1 kg (each)	Type: HAWT
Mechanical O/p: 2hp	Total blades: 3	Tail: No
Efficiency: 60.35%	Orientation: Central	Direct transmission

Chapter Four

Conclusions and future work

4.1 Conclusions

In this work, the possibility of using wind turbines on electric vehicles was studied and made it a sustainable source of energy that depends on it to charge its battery, whereby these turbines are installed in the interior of the vehicle (in the place of the internal combustion engine in conventional vehicles) with a consistent distribution that fits the room and geometrically it was Based on the flow of wind into the room so that it can catch the largest possible amount of wind and thus generate energy in a larger amount. A specific type of wind turbine has not been determined because a specific type of electric vehicle has not been identified and the engine room differs from one vehicle to another, in addition to the difficulty of conducting this study in practice, we sufficed with studying it through calculations. Choosing a wind turbine for in-vehicle power generation was a good idea, because it has advantages that are not found in any other source of renewable energy, and the most important of these features is the abundance of wind that will not be interrupted while the vehicle is traveling and there is no need for any source to provide it, and it does not hinder the structure The exterior of the vehicle remains in keeping with the design of the parent company. In addition to the light weight, small size, the possibility of increasing the number of cycles and torque, and the costs of installation, operation and maintenance are cheap compared to other sources. By calculations on the wind power equations, it is possible to obtain more than 800 W per turbine with a wind speed of 20 m/s. We can simply store the electricity generated in the vehicle's battery so that we can use it later.

4.2 Future work

The use of this system is not limited to electric vehicles only, but it can also be used in other vehicles such as refrigerated trucks used in distributing dairy and ice cream, as they depend on diesel for their operation and consume (2/3) of the amount of diesel in the truck. The dependence is entirely on electricity, which also helps to reduce the pollution produced in large quantities.

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"تقييم استخدام طاقة الرياح لشحن بطاريات المركبات الكهربائية"

إعداد: أسامة اغريب

الملخص

أصبح التقدم التكنولوجي مثيرًا للإعجاب، حيث يفكر الجميع في وسائل البقاء على هذا الكوكب ويأخذ زمام المبادرة في حل المشكلات التي يتم توقعها مسبقًا من خلال علوم التكنولوجيا الحديثة. واحدة من المشاكل الكبرى التي من المتوقع حدوثها هي نفاد الوقود الأحفوري المستخدم لتوليد الطاقة الكهربائية خلال السنوات القليلة المقبلة، لذلك كانت جميع الدول المتقدمة قد أخذت زمام المبادرة لتطوير أنظمة جديدة يمكن أن تزود العالم بالكهرباء. ومن أبرز هذه المصادر المكتشفة الخلايا الشمسية والتوربينات، حيث تعتبر هذه المصادر من أفضل المصادر المكتشفة حتى الآن والمستخدمة في توليد الطاقة في جميع دول العالم. يعتبر قطاع النقل من أهم الركائز في حركته، حيث يعتمد على الديزل والبنزين المستخرج من الوقود الأحفوري الذي على وشك النفاد. لذلك فكر المهتمون بقطاع النقل باستغلال مصادر الطاقة البديلة لتشغيل المركبات على الطاقة المستخرجة منها، حيث تم تطبيق هذه الأنظمة وتركيبها على المركبات وكان أداؤها جيداً. حتى توصلوا في أحدث إصداراتهم إلى أن تعمل المركبات بالكامل أعلى الكهرباء عن طريق تخزينها في بطاريات دون الحاجة إلى محركات احتراق داخلي التي تعتمد بشكل كامل على الوقود. في هذا العمل، نوضح كيف يمكن الاستفادة من طاقة الرياح عن طريق دراسة إمكانية تركيب ٤ توربينات لتوليد الطاقة من الرياح وتزويدها ببطارية مركبة كهربائية مع مراعاة الموقع المناسب لها بحيث لا تعمل على اضافة اي قوى تعيق سير المركبة. القوة المحسوبة التي تحتاج إلى شحن بطارية المركبات باعتماد سرعة رياح 15 م / ث كانت 0.138 كيلوواط، ولكن عندما تزيد السرعة عن 23 م / ث، ستكون الطاقة المولدة أكثر من 1 كيلوواط. عندما تعمل التوربينات معًا، فإن الكهرباء المولدة التي سيتم تخزينها في البطارية ستكون كافية للوصول الى نقطة التعادل بين معدل التفريغ ومعدل الشحن (92.6 كم، 58 كيلوواط ساعة) وبعدها تبدأ بالشحن الإيجابي (النقطة التي بعدها تكون كمية الكهرباء المولدة أكبر من الكمية المستهلكة).