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# Design of Portable Vortex Bladeless Wind Turbine: The Preliminary Study

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**ABSTRACT**

The objective of the work is to design an environmentally friendly vortex bladeless wind turbine for residential areas and buildings to aid in the production of a systematic and clean energy supply. The study largely centered on the extensive conception of the vortex technology incorporated with the vortex bladeless wind turbine design. Moreover, it has the ability to accomplish two motions (oscillation and vibration) rather than one single motion found in traditional wind turbines. All designs were taken under the assessment of performance, cost, and portability offered in the functional decomposition and decision matrix leading to the type of generator that should be installed. Through certain filtering stages, two different designs of the bladeless wind turbine were deduced. Each of them has different specifications and features that make it distinct from the other. The first allows two types of movement, which are rotational and vibration whilst the other contains a vortex generator. It is also cheaper than ordinary turbines and has a lower maintenance cost. The generator, battery, and spring affect the performance of the vortex bladeless wind turbine. From the study, it was observed that portability, ease of maintenance, and simple installation are the key advantages that bring vortex bladeless wind turbines to the top.

## 1. Introduction

The idea of vortex bladeless wind turbine (VBWT) came from the idea of vortex technology mainly based on the vortex shedding phenomenon of energy harvesting. The idea of vortex-induced vibrations (VIV) is applied to generate electric current by the vibrations or oscillations occurred by the wind flow known as one degree of freedom movement. Of course, Reynolds number, frequency, drag, and lift forces have significant impact on VIV as well. One of the things that makes this kind of turbine different is the absence of mechanical parts like gear, bearings, and the need for lubrication. This concludes another advantage that the vortex technology is not only a clean source of energy, safe for birds' migrations, and noiseless but also low in cost [1].

If Reynolds number is increased, the frequency of vortex shedding on a mounted structure might match to the resonance frequency of the structure (i.e., natural frequency) thus enhancing the

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vibration modes [2]. A study done by Shlash and Koç [3], based on the energy enhancement for the VBWT, which consists of 3 different types of turbines with 3 different heights and different power outcomes. All of them work with the starting speed of 3 m/s, and a stopping mechanism at 30 to 35 m/s of wind speed for safety purposes. First is the Vortex Nano which is a 1 m height to generate power of 3 W. Second, Vortex Tacoma, 2.74 m height to generate power of 100 W. Last is the Vortex Atlantis between 9-13 m height with 1 kW of power generation capability. Moreover, the average weight of existing VBWT in the market weights 15 kg and the generator used could suppress up to 30% of the construction capacity. The main objective is to let the turbine generates energy based on the wind speed of the region.

In this preliminary design work, a function decomposition chart was created by listing down all the possible ways of designing multiple different alternatives, as shown in Figure 1. After that, eight different alternatives have been designed with the basic bladeless wind turbine components as mentioned before as a reference/base of the alternatives, and then a decision matrix was created to compare the designs with some specific criteria. Then a selection of the best 4 design alternatives was done. Next, a selection of the best material for each component in the design was done based on their properties, high efficiency, and low cost, as shown in Table 1. After that, a new decision matrix was create adding the estimated cost after the material selection. Then a selection of the best 2 design alternatives was done. Furthermore, the selected springs that can be used (one of the components) is shown later on in this study. In addition, the suitable type of generators, and batteries will also be selected. In addition, as shown in the title of the study that portability is one of the key design areas, which will be explained in detail at the end of the paper.

**Table 1**
Decision Matrix

| Average | Weight | Importance Weight (%) | Alternative 2 | Alternative 4 | Alternative 6 | Alternative 7 |
|---|---|---|---|---|---|---|
| Safety | 0.15 | 15 | 8 | 7.5 | 8 | 7 |
| Performance | 0.2 | 20 | 6 | 5 | 8.5 | 7 |
| Complication | 0.1 | 10 | 6 | 7 | 5.5 | 7 |
| Energy | 0.2 | 20 | 6.5 | 7 | 9.5 | 7 |
| Eco-friendly | 0.1 | 10 | 8 | 8 | 8 | 8 |
| Cost | 0.15 | 15 | 7.5 | 7 | 6.5 | 7.5 |
| Portable | 0.1 | 10 | 7 | 6 | 5 | 6.5 |
| Rank | 1 | 100 | 6.925 | 6.675 | 7.625 | 7.125 |
| Efficiency Weight (%) | 100 | - | 69.25 | 66.75 | 76.25 | 71.25 |

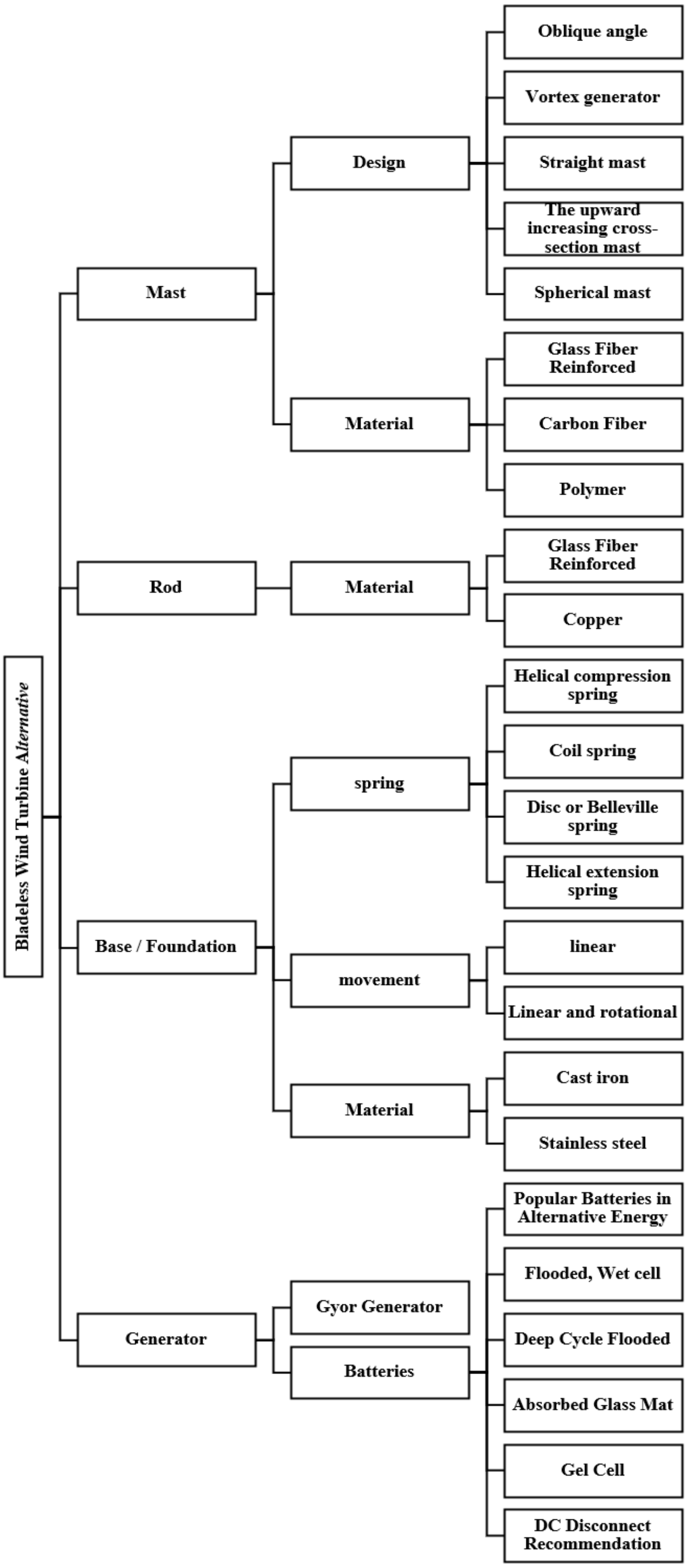



**Fig. 1.** Function Decomposition

## 2. Wind Turbines

In the wind turbine, the best total efficiency and effectiveness can be achieved through the right amount of blades to suit the engine characteristic curve. The experts and designers observed that using three blades is the highest effective and lowest intrusive way in order to harvest wind. Air resistance and aerodynamics are the two parameters that depends on the turbine blade [4]. The horizontal axis wind turbines are the most common among the wind turbines and uses principle similar to that of windmills. In horizontal axis wind turbine, the generator is connected to the shaft, which turns to produces electrical energy and its shape is very close to that of a propeller hang on the top of a mast or tower [5].

Another type of turbine is the vertical axis wind turbine, which is similar to the horizontal axis turbine, but the difference is that the turbine blades are install in the column vertically which rotate to produce energy. This arrangement gives this type of turbine an advantage in energy production when it comes to wind direction. As it can receive winds from all directions, it is preferred in locations where the wind direction is variable, as it can induce its rotational movement as long as there is wind flow from any direction [6].

Recently many studies started to focus on the bladeless turbines that use something known as vortex technology, which makes the blades unnecessary part to be use for wind turbine. The advantage of vortex bladeless wind turbine is that it does not have any rotating parts, like gears, bearing, and does not need lubrication. The concept behind it depends upon the aero-elastic resonance phenomena, which harnesses energy through the direct connection with the wind on the emission of vortex shedding. To sum up, the difference between traditional and bladeless wind turbines are the lack of rotary blades on the bladeless wind turbines. In other words, the energy harvested through the wind is absorb by the effect of vortex shedding, while for the traditional wind turbines the rotary blades often react with the airflow generating lift or drag while converting it to a circular movement. This means that the generators transform the rotating movement into electric power, but bladeless turbines cannot. The bladeless structure can aid to decrease friction process loss, which in turn reduces stress [7].

In addition, according to the calculations and simulations done by Shlash and Koç [3], the technology could increase in size to incredibly large devices that could be similar in the dimensions and strength of the turbines existing currently. The size that it can achieve depends on the materials that will employ and Reynold's number that can work with it. There is currently some research done on the feasibility of 150 m height devices. However, developing and prototyping such a massive vortex system is a tremendous task, to make the VBWT output energy and size similar/equal to the wind turbines system, therefore it will take many years for it to be done and successful.

## 3. Vortex Induced Vibration (VIV) through the Design

Renewable power is power derived through sources that instantly regenerate and remain indefinitely within the surroundings. Green energy supplies, unlike fossil resources, produce power without any pollution or emissions into the atmosphere [8]. Global usage of clean energy is increasing quickly. In fact, wind greening energy is one of the most widely used natural energy [9]. The Vortex-Induced Vibration driven system appears to be a solid concept for greening the energy sector, especially given its capacity to produce power at minimal current speeds. Engineers often attempted to reduce the occurrence of VIV due to its destructive impact on vibrating systems. A striking illustration of the destructive impact happened in 1940 when the Tacoma Bridge fell owing to the presence of VIV. Moreover, Professor Michael Bernitsas invented utilization of the phenomena of VIV in 2005 called VIV for Aquatic Clean Energy, and it operates by putting a cylindrical shape horizontal in a stable structure and allowing an oscillating motion of the vibrating body to convert possibly damaging vibrations to renewable as well as green energy.

A bladeless wind turbine harvests wind energy through a resonance phenomenon caused by an aerodynamic process known as vortex shedding. This enables the gadget to oscillate at low wind speeds without the need for lubricants [10]. Reynolds number (Re) is affecting the phenomena of vortex shedding directly, which is more dependent on the free stream velocity and viscosity.

$$Re = \frac{\mathrm{UD}}{\vartheta} = \frac{U\rho D}{\mu} \tag{1}$$

where D is the diameter of the cross-section normal to the stream velocity direction U, ν and μ are the kinematic and dynamic viscosity of the fluid respectively.

The separation causes vortex shedding and the production of a wake behind the cylinder, which is at a fixed frequency, vortices are shed alternately from the upper and bottom surfaces of the cylinder. The vortex-shedding phenomenon produces lift force, causing the structure to oscillate across the structure. By knowing the phenomenon of vortex shedding the existence of the VIV theory, which is vortex-induced vibration will be known [11].

Figure 2 shows the VIV of a cylinder structure. The Strouhal number (S) is a non-dimensionless parameter that relates the vortex shedding frequency to the flowing fluid.

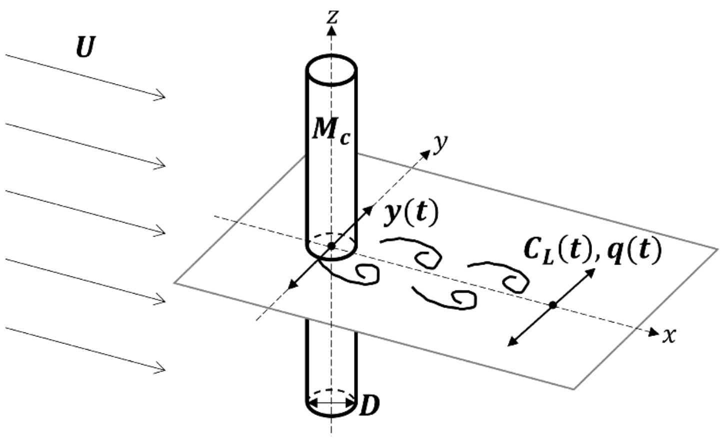
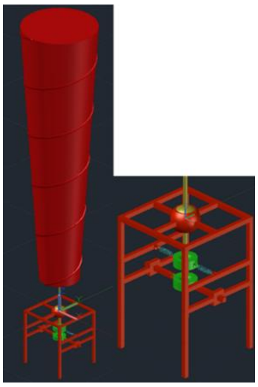
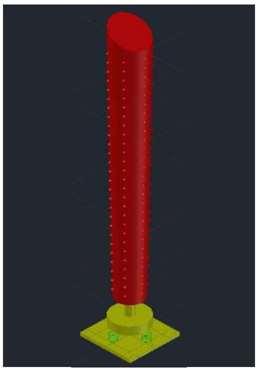



**Fig. 2.** VIV of a Cylinder

$$S = \frac{Df_s}{U} \tag{2}$$

where $f_s$ represent the vortex shedding frequency, D and U are cross-section diameter and free stream velocity respectively. VIV creates an electric current by using the oscillations or vibrations caused by the wind. When the frequency of these forces approaches the structural frequency of the body, it begins to oscillate and enters resonance with the wind. Moreover, when a body interacts with an externally flowing fluid that has a certain velocity, the motion produced by the body is nothing more than the VIV, which means when fluid pass over an item VIV produces vibrations that are perpendicular to the object [12]. In other words, when a fluid flows through a blunt object, forces induced by vortices shed exist, resulting in an unstable flow with different flow velocities according to the size and shape of the body (Table 2). Figure 3 shows the alternative design with both rotation and vibration motion whilst Figure 4 exhibits the design with vortex generators. According to the author Maftouni *et al.,* [7], when using VIV phenomena in an energy harvesting technique aids in the conversion of fluid energies to electrical power output by an aerogenerator.

**Table 2**
Designs Descriptions

| Designs | Description | Components | Material |
|---|---|---|---|
| Alternative 1<br><br>**Fig. 3.** Alternative 6 (1) | This design is constructed based on the principle of allowing rotation and vibration simultaneously aiming to achieve two types of movement which will allow us to generate more energy. Based on that, a base was created with two joints, one of which allows vertical movement and the other allows rotational movement. In addition, the surface of the mast is modified and inserted with a longitudinal topography wrapped around it in order for the funnel to rotate along with the direction of the wind. | Mast<br>Flexible Rod<br>Base | Carbon Fiber Reinforced Polymer<br>Aluminum Alloy<br>Cast Iron |
| Alternative 2<br><br>**Fig. 4.** Alternative 7 (2) | This design construction stands out since VG is employed. The intention of this design is to keep the wind as close as possible to the mast in order to achieve enough power that will permit vibration. Whilst considering that there will be a spring connected to the mast as well as the flexible rod from inside. | Spring<br>Vortex Generator (Only for design 2) | Carbon Steel<br>Stainless Steel |

In vortex bladeless wind turbine, vortex shedding is an aerodynamic effect that causes the resonance phenomenon, which is the main aspect of capturing wind energy. VIV effect is based on fluid turbulences. Consequently, the bladeless wind generator will adapt very quickly to wind direction and intensity changes, no matter the turbulences which also means that a fully developed laminar wind flow is not required for a vortex turbine to function properly [13]. The kind of body shapes experienced by VIV will be the structures that are tall and uniform in size and shape, the vibrations can be damaging and ultimately lead to fatigue failure. Masts or towers are highly susceptible to vibrations induced by vortex shedding [14]. There are two types of VIV, self-oscillations which is the type that occurs naturally when the vortex shedding frequency and the natural frequency are approximately the same. Additionally, this type is considered the real VIV phenomenon. Then there are the forced oscillations, which is the type that occurs at velocities and amplitudes that are preset and controlled independently of fluid velocity. Moreover, this type is considered not the real VIV phenomena, this is vibration-induced vortices [14].

A cylindrical or bluff-body-shaped object oscillates due to the alternate vortex generation on the boundary layers by negative fluid pressure, which is how VIV behaves. The oscillation is a function of the generated unstable lift force. Later, electrical energy is created which is through a spring attached in order to convert the oscillation to electrical power. The mass applied and spring stiffness [11]

$$Mass\ Applied\ = (\rho_{air}) \times\ (V_{Cylinder}) \tag{3}$$

$$k = (f_s \times 2\pi)^2 \times\ Mass\ Applied \tag{4}$$

where $\rho_{air}$ is the density of air, $V_{Cylinder}$ is the volume of cylinder, k is the spring stiffness constant, $f_s$ is the shedding frequency and $Mass\ Applied$ is the total mass applied in the system.

The natural frequency of oscillation ($f_N$) is required to find the total power P(t) generated from a one-unit length.

$$f_N = \frac{1}{2\pi} \times \sqrt{\frac{k}{Mass\ Applied}} \tag{5}$$

$$P(t) = v(t) F_L \sin(2\pi f_N t) \tag{6}$$

where $F_L$ is the lift force, $v(t)$ is the velocity, and t is the time.

VIV generates infinite oscillations from infinite flowing streams, making it a useful alternative method of infinite oscillation generation. The majority of frequently employed VIV systems employ a cylinder with a circular cross-section. Additionally, vortices are produced as a result of the viscosity brought on by the boundary layer and friction between the fluid and the body [15]. In a larger application, a VIV system consisting of one unit will not be able to generate sufficient power, so multiple cylinder units are required to generate enough power for this type of VIV application. The current renewable energy application systems, such as solar, wind, and tidal energy, can also be combined with VIV [16].

## 4. Generator, Batteries, and Springs

Through this research, there are three things complementary to the design, that are not subordinate nor basic, which is the generator responsible for converting energy from mechanical to electric and storing it in the battery which is the second part. As for the last part, it is the spring responsible for the connection between the rod and the external model.

### *4.1 Gyro Generator*

A gyro generator is a gyroscopic reaction-based variable transmission technology used for generating electricity from wind and wave power resources. Gyro Torque can achieve huge speed ratios without the use of gears. Because of Gyro Torque's infinitely changeable nature, more power from wind and wave sources can be gathered and regulated to generate electricity at a lower cost. Gyro Torque prevents the turbine from putting too much mechanical and electrical strain on other sections of the system, such as the generator [17]. In a static system, the input torque is conveyed to the output by a speed ratio, which means that the input is directly linked to the output via physical constraints such as gears or belts. While in Kinetic this does not happen in the kinetic kind; instead, power transmission torque is generated within the transmission. This means that the input and output can move freely without being physically constrained. Gyro Torque is a kinetic type of torque [18]. Moreover, Gyro E-generator is made up of a gyroscopic rotor housed in an inner ring (sub-frame) that can pivot freely in an outer ring (main frame). In the transmission housing, the mainframe is free to spin. Linkage (off-set pin) connects the sub-frame to the input mechanism, pivoting the sub-frame in the mainframe. Under the impact of gyroscopic reaction, the mainframe, subframe, and linkage spin simultaneously. A one-way clutch connects the mainframe to the output (spinning shaft) and the transmission casing, which makes it easy for maintenance and variable operation. If considerable transmission capacity is necessary, two or more gyro Torque units can be used simultaneously [19].

### *4.2 Batteries*

The batteries listed below are the most used for storing energy generated by wind turbines or solar panels. Each has advantages and disadvantages [17].

i. Flooded, Wet cell
   a. This is the second most common battery kind.
   b. Release hydrogen gas, which should be evacuated to the outside.
ii. Deep Cycle Flooded.
iii. Renewable Power Batteries as a brand-new product available.
iv. Release hydrogen gas, which should be evacuated to the outside.
v. Absorbed Glass Mat.
vi. Investing in a genuine deep cycle battery is a costly choice.
vii. Does not require venting, may be laid on its side, and lasts longer than just a moist cell.
viii. Gel Cell.
ix. Expensive and charging-sensitive.
x. Such batteries would be damaged if they are permitted to be overused.
xi. DC Disconnect Recommendation.

### *4.3 Springs*

Springs are elastic objects (typically made from steel) that can be twisted, pulled, or stretched. Once the force is withdrawn, they will revert to their previous shape. In other terms, it is referred to as a resilient member [20]. Four helical springs, one attached to the circular disc and the other to the device's foundation. They are utilized to give the mast both vibratory and constraining motion. The four springs are attached to the bottom of the vertical mast to allow it to vibrate for longer durations and with more amplitude by converting its vibrational energy into spring potential energy. Springs are attached to provide vibration and constrain the motion of the mast. Below are the best types of springs [21]. and there are four types of Disc/Belleville Spring, Coil Spring, Helical Extraction Spring as well as Helical Compression Spring.

### *4.4 Wind Turbines Springs*

Disc Springs are utilized in the wind energy market's safety brakes for turbines. When the turbine is not in operation, these brakes are employed to stop it from spinning. Another use for Belleville disc springs in turbines could be to sustain the generator. Two spring stacks are employed in this application to compensate for the generator's unequal loading. The torque created by the load input causes this unequal loading [22].

## **5. Portability**

VBWT known for its small size compared to the traditional WT, which is massive in size, and have huge blades attached to it in addition to the loud noise it produces. This vintage style is always placed in very far non-residential areas, fixed to the ground with no possible way to move, sending the energy it enhances to the generator that is placed under the ground through the pipeline to the whole city. Meanwhile, the VBWT is a mechanical system without mechanical parts, a vibrating mechanism without loud noises, and a movable source of clean energy. Due to its light build, it can be move and placed wherever as per the user requirement. The size of the VBWT is quite small which is typically around a height shorter than 180cm and this type could produce enough energy for an area in a building or possibly a floor in a house. Moreover, the length of the turbine could go beyond that or with two motions instead of one as designed in alternative 1 (6), making the turbine able to produce energy for a house. For example, when the user wants to place the turbine on the roof of the house, this means that the turbine needs to be easy in terms of transportation to the roof for placement. Moreover, once the turbine is taken to the top, it should be in an area that will let it stay in its place without moving while it is in operation as well as should not fall when the wind speed is high. Figure 5 shows the chosen alternatives with the idea of the transporting station. In addition, Figure 7 depicts the fixed station, with the same mechanism but different shapes and designs to suit both different bases of the designs.

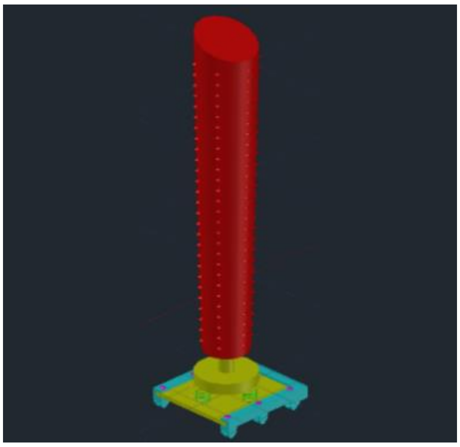


**Fig. 5.** Overview of Transporting station for Design 1

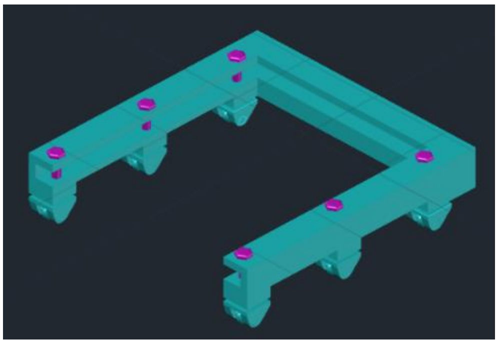


**Fig. 6.** Transporting Station for Design 1

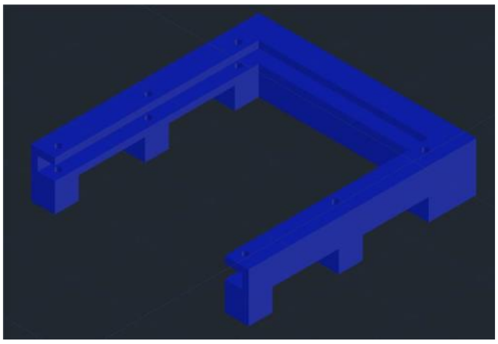


**Fig. 7.** Fixed Station for Design 1

The transporting station aims to move the turbine from a certain place to another easily. Therefore, a station with wheels will be manufactured specially to suit the turbine and withstand the weight of the turbine “So Plug your Vortex and Go”. However, for the second design, only wheels are to be placed without the frame of the station (Figure 8). Then, Figure 9 and Figure 10, presents the fixed station: this station will be placed on top of the roof or where it is required. The most important thing to note is that the station should be fixed to the ground with no way of moving it. When the turbine is transferred to the station, it will not be able to move from its place and at the same time, this station is created in a way that will not restrict the movement of the upper part of the turbine.

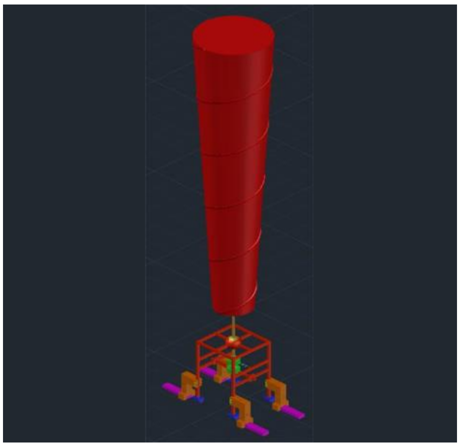


**Fig. 8.** Overview of the Connections for Design 2

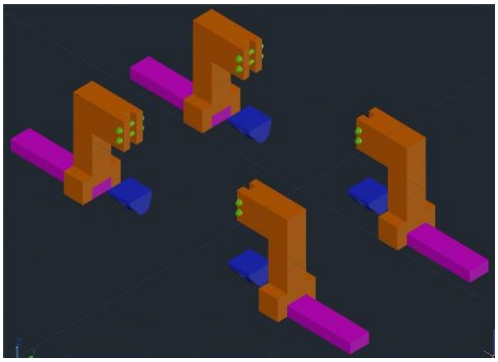


**Fig. 9.** Station at Position 1 (while transforming)

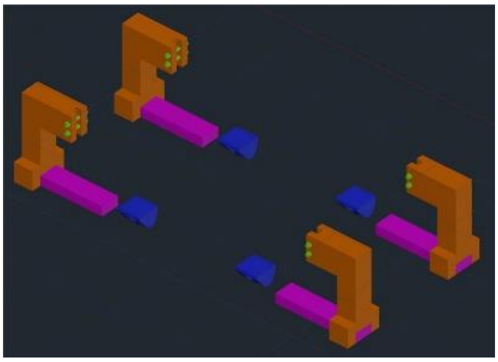


**Fig. 10.** Station at Position 2 (after transforming to the fixed point)

*5.1 VBWT Real Life Visualization*

VBWT is a new concept of utilizing wind energy to generate the electricity required for buildings and homes (Figure 11 and Figure 12). VBWT is beneficial to communities and is harmless to wildlife while being quiet and noiseless compared to conventional turbines. Moreover, VBWT is much cheaper than a traditional turbine in terms of cost and maintenance due to the lack of gears, rotary equipment, and lubricants in the design. Furthermore, it benefits the building residents/owners to save money by creating a sharp decrease in financial consumption spend on conventional energy sources and their monthly bills.

**Fig. 11.** View 1 for Bladeless WT on Top of a House

**Fig. 12.** View 2 for Bladeless WT of Top of a House

## 6. Conclusion

In conclusion, the field of bladeless turbines is a fairly new field with broad prospects and advantages that allow it to be compatible with modern life and the future vision of civilized societies. As it is considered one of the least polluting energy products and safe for the surrounding environment in addition to birds. The vortex technology was studied and defined to be used later in the development of bladeless turbines that depend on the vortex technology to produce energy. It is also cheaper than ordinary turbines and has a lower maintenance cost. There are some parts that affect the efficiency of the turbine, which are the generator, battery, and spring. Each of these parts has a specific effect on the performance of the turbine. The spring can help the turbine maintain vibration for as long as possible. The generator and battery can affect the amount of electricity the turbine absorbs or even the amount that it can produce. These parts must be carefully selected to match the requirements and capabilities of the turbine. In this study, the turbines have been modernized in a small size to be used in residential areas, which makes them easy to move around, so they can be placed on the balcony of the house or on the roofs of buildings. “Minimal cost, simple installation, minimal maintenance. Connect the vortex and go!”.

Currently, this is a preliminary analysis. More work is needed to be performed on the structural analysis, vibration parameters, as well as computational fluid dynamics analysis for the oscillation of VIV motion. The structural analysis will be performed on each component of the turbine that will be subjected to failure. Dynamic meshing will be applied to accommodate for the oscillation VIV motion.

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