Wind Resource Assessment: Analysis of the Vortex Bladeless Characteristics in Puerto Cortés, Honduras

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Abstract. In the department of Cortés, many cities such as San Pedro Sula and Choloma truly invest in auto consumption installations for the residential and commercial sector; however, Puerto Cortés being one of the most prominent cities in Honduras, currently lacks any incentive of interest from its residents or authorities to implement distributive generation of any kind. Under this criterion, it was sought to study a renewable alternative distinct from solar energy suitable for its implementation in Puerto Cortés; Vortex Bladeless being a new concept in wind energy technology. A technical analysis was performed for the Vortex NANO device in situ to develop projections for a Vortex Tacoma device under the same conditions. The electrical performance of the device, the behavior of the wind resource and the power coefficient (Cp) were determined; analysis and results are based of the collected date on the 3rd quarter of the year. A demand analysis (load profile) in the residential sector to determine the range covered with one (1) Vortex Tacoma device given its projections.

1. Introduction
The technical analysis of the Vortex Bladeless technology is carried out, applying it in the residential sector of Puerto Cortés under constant monitoring, making a correlation analysis between demand and power generation. The Vortex wind turbine takes advantage of small gusts of wind to convert the kinetic energy of the wind into electrical energy through a patented alternative to conventional electromagnetic induction [1] of any type of renewable energy excluding solar. This new energy conversion is based on the resonance concept studied in the Tacoma Narrows Bridge [2]. The analysis of the Vortex equipment and the monitoring is carried out based on real field conditions for the city of Puerto Cortés, where power and performance curves will be expressed based on the generation of the device for the magnitude present in the month of September. The correlational analysis between energy demand and Vortex generation will be carried out based on a common final consumer of the residential sector and given the generation behavior of the Vortex NANO, a generation projection of the Vortex Tacoma at a reference height of 12 meters. [3]
Due to the wind resource available in Puerto Cortés, the implementation of Vortex Bladeless technology is sought to motivate the end consumer to opt for self-consumption sizing based on wind generation using this technology. The NANO device is specifically used due to its low power and easy handling for analysis and study, same studies can be observed for miscellaneous studies and previous simulations. [4, 5]
2. Methodology

2.1. Instruments and materials
A meteorological station was used to have accurate weather data and the Vortex NANO device itself for the analysis, placing both in the same place and installation height. The instruments applied for the technical analysis were the SolidWorks software to render a 3D model and perform a flow simulation, Excel for data tabulation and graphics generation, PVGIS to validate the data from the UMA Pto. Cortés. [6] Figure 1 and 2 shows the main devices used for the investigation.

![Figure 1. Vortex NANO device.](image1)
![Figure 2. Weather Station.](image2)

2.2. Study methodology
An analysis of the demand of a residential sector subscriber was first carried out, based on the load profile corresponding to his consumption history. Then, the area to be analyzed technique is delimited; the location and roughness of the project, the meteorological analysis, the generation analysis and a correlational analysis between demand and generation with a Vortex. The calibration of the device due to a previous break present in the mast conditions the generation of the wind turbine based on the expected theoretical performance. All the data obtained are constructed under a constant generation measurement of the Vortex NANO device.

Considering a low roughness in the project location, obstacles were implemented around different volumes to obtain a greater roughness; however, as demonstrated in the analysis of fluid behavior on structures installed near [7], there was a trend of greater oscillation-generation and the implementation of structures near the device was ruled out.

2.3. Technical specifications
The specifications of the equipment to be used for the analysis of Vortex Bladeless in Pto. Cortés are presented a priori in table 1:

| Specification        | Value         |
|----------------------|---------------|
| Nominal Power        | 1 W           |
| Total height         | 0.85 mts      |
| Oscillation angle    | 4.5 ° per side, 9 ° total |
| Storage              | 3,000 mAh     |
| Output voltage       | 5 Vdc         |

The device used is for the experimental analysis of the technology, Vortex Bladeless devices with nominal powers to enter the market begins with Vortex Tacoma and based on that device certain projected technical analyzes will be carried out.
2.4. Validation methodology
The analysis made in the validation methodology determines the way in which the results obtained are presented and supported. The project being pre-experimental, the first validation was in accordance with the literature review applied to the theories of support on the new technology. An analysis of the UMA data with the meteorological station located in the project. The demand analysis will be verified with the load profiles available in EEH under invoicing and the generation data obtained is based on measurements carried out in the field.

3. Analysis and results

3.1. Demand analysis
An energy audit is carried out on a subscriber to the ENEE service to determine a historical consumption and to be able to define a typical load profile in the residential sector where the Vortex Bladeless wind turbine is located.

3.1.1. Load profile. Within the residential area of Pto. Cortés after having carried out an energy audit, an analysis of consumption readings and consumer behavior was carried out, the load profile that will be typical in the sector because the only changes that will occur with other consumers will be in magnitude, but not in consumer behavior. Figure 3 represents the average load profile of a residential consumer.

![Figure 3. Residential subscriber load profile.](image)

Typical consumption reflects consumption peaks in the morning, noon and grows gradually at night. With an average of $142 per energy cost per month considering a historical consumption of a full year. The energy parameters of the final consumer can be seen in Table 2.

| Parameter                        | Value |
|----------------------------------|-------|
| Average monthly consumption [kWh]| 611   |
| Average monthly consumption [$]  | 141   |
| Average daily consumption [kWh]  | 42    |

3.2. Technical analysis
Vortex NANO is a small power generation device, its generation behavior will be the basis for projecting the Tacoma generation that will serve for the correlational study. Since regardless of the height of the device, the concept and energy conversion are preserved.

3.2.1. Meteorology of the place. Based on the data obtained from the Pto. Cortés meteorological station, the information on the wind resource present in the place was tabulated. To validate the UMA data, a mini meteorological station was installed at the point of the project to obtain more accurate results and at the specific height of the project, given that the UMA meteorological station is 3km away. [8] Table 3 shows the meteorology in Pto Cortés.

![Table 3. Meteorology in Pto Cortés.](image)
Table 3. Meteorology UMA Pto. Cortés

| Parameter             | Temp. [° C] | Magnitude [m / s] | Pressure [Pa] |
|-----------------------|-------------|------------------|---------------|
| Average per year      | 35          | 1.91             | 101,214       |
| Maximum per year      | 45          | 6.9              | 102,605       |
| Minimum per year      | 16          | 0.11             | 100,344       |

The wind resource is presented on an atypical evaluation day; September 1st. This profile makes it possible to calculate the power available in the wind at a certain reference height. For the location of the project, it will be taken at 4 meters and 12 meters high to project the Tacoma. Figure 4 shows the wind profile as an average in a day in September.

![Wind speed graph]

Figure 4. Behavior of the wind resource in Puerto Cortés

On average, the wind resource for the third quarter of the year is 2.72 m / s. A resource that will be evaluated to determine the conversion of kinetic energy into electrical energy and its coefficient of power (Cp) using a Vortex NANO.

3.2.2. Performance and CP. The technical analysis in the field was based on the Vortex NANO device. However, under these data it was projected what would be a generation and behavior of the Vortex Tacoma given its greater height and nominal power; 100W. For the Vortex NANO power analysis, the following results were obtained considering the Hellmans average speed calculation to project the Vortex Tacoma power at a higher installation height. The tabulated wind resource for NANO is obtained from the data from the meteorological station at the experimental site, the tabulated wind resource for the Vortex Tacoma power is based on a projection of 12 meters in height using Hellman’s calculation. Table 4 shows the results of NANO generation and Tacoma projection from the wind resource available.

Table 4. NANO generation results and Tacoma projection

| Wind speed [m/s] | Power Vortex NANO | Wind speed [m/s] | Power Vortex Tacoma |
|------------------|-------------------|------------------|---------------------|
| 1.5              | 0.005             | 3.5              | 1.09                |
| 2                | 0.04              | 4                | 3.26                |
| 2.5              | 0.09              | 4.5              | 6.96                |
| 3                | 0.17              | 5                | 12.7                |
| 3.5              | 0.28              | 5.5              | 19.8                |
| 4                | 0.3               | 6                | 29.3                |
| 4.5              | 0.54              | 6.5              | 42                  |
| 5                | 0.54              | 7                | 55.3                |
| 5.5              | 0.77              | 7.5              | 71.6                |
| 6                | 0.85              | 8                | 87                  |
| 7                | 0.84              | 9                | 111                 |
Figure 5. Vortex NANO power curve

Figure 6. Cp NANO curve

Figure 5 and 6 represents Vortex NANO power and Cp curve obtained from field analysis. Based on the wind resource present, the AC output power of the device was measured, resulting in the power graph under a real field analysis with roughness present. Vortex NANO reaches 0.9W of generation in nominal magnitudes and starts to generate according to 2 ~ 2.5 m / s. The measured NANO device does not reach its rated power at higher magnitudes due to a previous breakage of the mast that required repair and resulted in axial asymmetry of the device. There is a deviation of 2 ° with respect to the vertical by which the behavior of the Vortex is conditioned given the direction of the wind where it affects, making the Vortex have preferable oscillation angles.

The power coefficient of the wind turbine determines how efficiently the device converts wind energy into electrical energy. Based on the energy generated with the energy available in the wind at a height of 4 meters, the coefficient was calculated. Vortex NANO generates more efficiently with magnitudes between 2-3 m / s, resulting in an advantage given that in a residential and urban sector with greater roughness these magnitudes of wind exist more frequently. Vortex in this case, would be making the most of the available power given its performance. For the correlational analysis, the Vortex Tacoma generation projection will be used given its attractive power rating. Figure 7 and 8 shows the Tacoma Power and Cp curve.

Figure 7. Tacoma Power Curve

Figure 8. Cp Tacoma curve

The Vortex Tacoma device has a performance curve of the same behavior as the NANO, but with a higher magnitude generated, reaching 110W in reference magnitudes of 9 m / s. The Cp is plotted based on the power available in the wind. The Vortex Tacoma's power coefficient has a well-defined bell trend,
peaking at magnitudes of 7 m/s in conversion efficiency. The data to be used in the correlation analysis will be that projected by the Tacoma's performance curve and power coefficient.

3.2.3. Available power. For the field analysis of the Vortex NANO, the calculation of the available power in the wind resource of Puerto Cortés at 4 meters high for the month of September was carried out based on the meteorological tabulation. The Betz limit is plotted, which is the actual power available in the wind under ideal conditions. However, every wind turbine in real field conditions never reaches this Betz limit. The same calculation is made based on the Tacoma projection. The calculations are arranged as follows in figure 9 and 10:

![Figure 9. Power available at 4 meters](image1)

![Figure 10. Power available at 12 meters](image2)

The power in the wind available in Pto. Cortés at a height of 4 meters reaches 35 W/m², the Betz limit being 59% of this power allows, in ideal conditions, a use of approximately 20 W/m². Given its height, Vortex NANO wastes all the potential available since it is experimental in nature. The Vortex Tacoma has the following behavior:

For an installation at a height of 12 meters with greater roughness than the one present in the project site, the energy projection was carried out using the height of a Vortex Tacoma (2.75mts). The power in the wind at that height reaches values of 500 W/m², the achievable limit in ideal conditions is close to 300 W/m². The power of the wind turbine in nominal conditions reaches 110 W, that is, it uses one third of the real usable energy. Vortex Tacoma has a field efficiency of approximately 30% under these conditions, while other wind turbines reach values of 20% in ideal conditions at magnitudes of 9 m/s.

3.3. Correlational analysis

The correlation analysis was performed based on the demand profile of the subscriber or final consumer within the residential sector of Puerto Cortés and the energy projection for the Vortex Tacoma given that the Vortex NANO is not a device with considerable nominal power to satisfy a demand real. The correlation analysis helps to determine by what percentage of generation the demand for electricity is covered on average by a consumer with an average monthly demand of 611 kWh. Based on this analysis, the single use of one (1) Vortex Tacoma device and not a site is understood; using 2 or more Vortex Tacoma.

Figure 11 represents the correlational analysis from customer’s demand and Vortex’s generation.
Where:

- **Wh LOAD** is the behavior of the final consumer demand in the residential sector.
- **Wh G** is the behavior of the Vortex Tacoma device.
- **Windspeed \[ m/s \]** is the behavior of the typical wind resource in September.

The daily demand of the residential subscriber according to the energy audit based on its historical consumption dates from 42 kWh per day, where observing the generation behavior of the projected Vortex Tacoma, it could generate 4.5 kWh per day if the wind behavior were typical. It turns out that the percentage of demand that an installed Vortex Tacoma device satisfies is 9.8%. A quite attractive percentage given that it is a single installed device, when installing more than one Vortex Tacoma, the consumption is satisfied at a higher percentage. These results are tied to certain conditions such as wind speed resource behavior for September, a 4 mts of height installation and considering a Reynolds number low enough to make the Vortex wind turbine to keep generating power [9] constantly during the day.

The analysis to determine the demand value covered by a Vortex over a year will depend on the provision of an accurate wind behavior analysis over a year. Using data from the UMA of Puerto Cortés, it was confirmed that the data obtained, given the difference in height and distance, does not include exact data that can be used to project the behavior of Vortex for a whole year. However, the behavior of a subscriber in the residential sector is typically typical for the rest of the year, except for the acquisition of new household appliances or some substantial change in consumer behavior.

4. Conclusions

After determining a friction coefficient of 0.10 and interpolating the air density to 1.135 kg/m3, the wind power available for the area of Puerto Cortés was plotted. Resulting in a power density available up to 35 W/m2 at 4 meters height and 500 W/m2 at 12 meters height not considering the Betz limit (59.7%). It was found that the Vortex Tacoma device located in Puerto Cortes will perform 30% in the real field at a height of 8 meters of installation. A higher efficiency when compared to other vertical axis wind turbines that reach 20% in ideal conditions and the Cp peaks at a magnitude of ~6m/s. Given the differences in height and size with Vortex NANO, the generation and performance magnitudes are lower than Vortex Tacoma. In general, the performance curve of both devices will have the same trend, but at different wind ranges.

The Cp of the Vortex NANO at its peak reaches a value of 0.14 at an approximate wind resource at 2-3 m/s; however, its highest generation is reached at 7 m/s without reaching its rated nominal power. The coverage of a single Tacoma device for the specific subscriber in the residential sector reaches 9.8% based on its projection.

5. References

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