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Classification of Wind Power Plants (WPP)

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Abstract:
In time wind Power Plants (WPP) which are an alternative source of energy have developed into a largely fast growing energy sector due to production of power at comparatively low costs with modern day technology & configurations. The main goal behind this paper is to make aware the various configurations of wind power plant, & draw a comparison with them. This will help us determine, differentiate, & associate the various pros & cons before a certain type of wind power plant is setup. Thereby determining the type of wind power plant suited for a particular geographical location. This study will be based on the classification & differentiation of various types of wind power plants on various criteria's.

1. Introduction

SINCE time, the energy from wind is been used & harvested into efficient work by man in different ways, through windmills. They were initially used to pump water & milling of grain. The modern day wind power plants use the power of the wind to produce electricity. With attention now focused on the damaging impact of greenhouse gases, wind energy is rapidly emerging as a low carbon, resource efficient, cost-effective sustainable technology in many parts of the world [1].With the advancements in power electronics & new design concepts in wind generators the overall efficiency & reliability have been considerably increased with an added edge of low maintenance costs.

Figure 1: Wind used for milling & water pumping systems
Source: inheritanceofseniorsfrance.blogspot.com

During the mid - 1980's, scientists & researches have always wondered whether WPP's as large as 250 kW (of diameter 23-30 m) could be built economically. Less than 10 years later, similar doubts were raised about the emerging 500-600 kW (of diameter 34-44 m), not to mention the daring plans for commercial 1.5 MW wind turbine. Today, wind turbines up to 6 MW is a reality [2]. This technological advancement in wind power plants was possible due to the new emerging concept & various design types in wind power plants.

2. Research Goal

Our major study of focus will be on the Horizontal-axis wind turbine (HAWT"s). There is no standardized classification of wind power plants, hence we can differentiate & classify WPP's on the following set of criteria's, which include:

i. Type of Axis
ii. Standalone & Grid Connected WPP's
iii. Upwind & Downwind WPP's
iv. Blade Count
v. Geared, Direct-drive & Hybrid WPP's
vi. Single Gearbox with Multiple electrical Generators

3. Classification of Wind Power Plants (WPP's)

Before venturing into any new technology it's always important to know the different types of technologies prevalent today & then make an attempt to modify or eliminate the cons so as to maximize performance, efficiency & minimizing maintained costs involved in running the mechanism to a minimum. Wind Power Plants (WPP'S) can be classified & differentiated on the following set of criteria's, as follows:

3.1. Type of Axis

The axis of the WPP is determined by the direction of the rotor shaft along with the gearbox & turbine generator, whether they are horizontal or vertical with respect to the ground.

Hence, based on axis there are totally two types of Wind Turbines:

1. Horizontal axis wind turbine (WAWT)
2. Vertical axis wind turbine (VAWT)

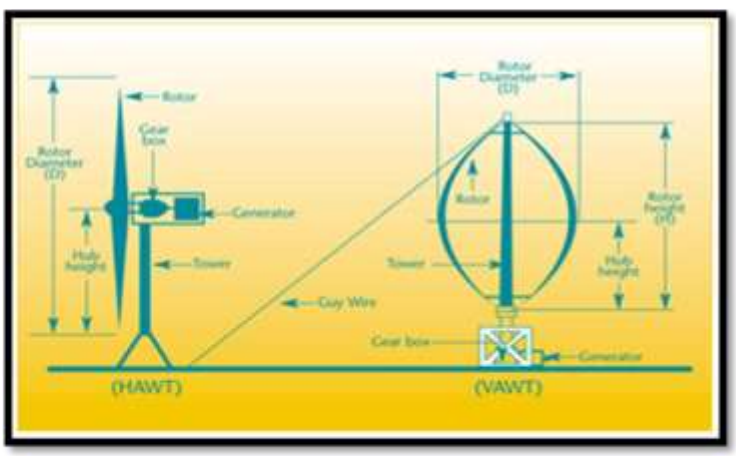

Figure 2: HAWT & VAWT WPP's
Source: colonizeantarctica.blogspot.com

In HAWT as shown in Figure: 2 (Left Hand Side), the rotor shaft along with the gear box & generator are at the top of the tower & horizontal to the ground. The VAWT as shown in Figure: 2 (Right Hand Side) on the other hand has its rotor shaft along with the gear box & generator perpendicular or vertical to the ground.

Hence, the advantages of VAWT's are as follows:

i. They are Bidirectional, i.e. they can use the effective power of wind from any direction.
ii. Therefore, they do not require a Yaw drive, which effectively reduces the overall cost & complexity of the system.
iii. Maintenance operations can be carried out with ease as the Nacelle (which boxes the gearbox, generator & protective equipment along with various sensors) is at ground level.
iv. Since the Nacelle is at ground level, the tower doesn't need to support it.
v. Since it is bidirectional, no bending or twisting of the blades are required. Thereby, keeping the design of blades easy & simple, which further adds to the cost effectiveness.

However, even with the above advantages the HAWT are still preferred over the VAWT due to the following crucial pros:

1. HAWT make efficient use of the stronger wind speeds available at higher altitudes having minimum air turbulence.
2. Therefore, VAWT due to their lower altitude will operate with weaker wind speeds & higher air turbulence. Thereby effectively reducing its efficiency, as compared to HAWT.
3. Due to higher wind turbulence, there will be a pulsating torque produced during every revolution.
4. Resulting in the faster, wear & tear of the blades.

3.2. Stand Alone & Grid Connected WPP's

A Stand Alone WPP refers to a WPP without any direct connection to the Power Grid system. The energy derived from the Stand Alone WPP will be either stored in a battery for subsequent use from the battery or it can be coupled to any generator system, creating an off-grid hybrid system. These systems are mostly used in remote parts were transmission of electricity is not possible either due to the land terrain & initial cost parameters for transmission in very far remote places.

A Grid Connected WPP is directly connected to a Power Grid System, wherein the energy derived from the WPP is given to the grid. By suitable Power Electronic system, so as to match the electrical parameters (such as voltage, frequency & power factor) supplied by the WPP with the grid.

3.3. Upwind & Downwind WPP's

The Upwind & Downwind WPP's is determined by the position of the rotor turbine & tower with respect to the wind direction. In the Upwind WPP, the wind tends to hit the blades first before it hits tower. Conversely, when the wind hits the tower first % then the blades of the WPP it is known as Downwind WPP. Wherein both Upwind & Downwind WPP's are very well illustrated in Figure: 3.

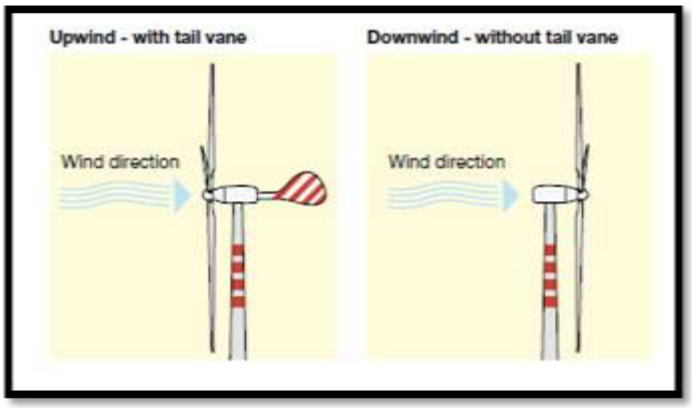

Figure 3: Upwind & Downwind WPP's
Source: www.cleanenergybrands.com

Hence, the advantages of the Upwind WPP's are as follows:

1. They operate in an undisturbed Airflow.
2. Upwind WPP's are less prone to the "Tower Shadow Effect", as the wind hits the blade first before the tower casing lesser turbulence. Conversely, "Tower Shadow Effect" is high in Downwind WPP thereby increasing the mechanical stresses on the blades& thumping sounds on each blade passing through the tower shadow.

Hence, the advantages of the Downwind WPP's are as follows:

1. As shown in Figure: 3, in Upwind WPP the force of the wind tends to turn the WPProtor blades downwind, hence requires a Yaw system. So as to keep the rotor facing Upwind. Wherein the Downwind WPP doesn't require an additional Yaw system, as it has to pass the tower before it reaches the rotor blades.
2. Hence, overall cost of the system is reduced along with additional Yaw mechanism complexity.

3.4. Blade Count of WPP's

Blade count in the WPP is another crucial criteria in the WPP, wherein usually all modern day WPP's have three rotor blades. The reason being WPP's with even number of blades gives stability problems because when the uppermost rotor blade tends to bend backwards due to the extreme wind pressure, the consecutive lowermost wind blade passes into the wind shade causing stresses. As in the case of a rotor blade with odd number of blades can be visualized as a 'Disc', which tends to maintain the stability within all the odd blades reducing the stresses developed on them. Blade count can be broadly classified into 4 types:

<u>3.4.1. One Bladed WPP's</u>

The One Bladed WPP has only one blade, therefore stability tends to become a major problem, though it tends to effectively reduce the cost as only one rotor blade is used. So as to compensate for the stability issue a counter weight is used on the other side of the blade but tend to emit more noise. Another drawback of this system, is that it tends to require higher wind flow as compared to WPP with more than one blade count. Hence, overall efficiency tends to be reduced.

3.4.2. Two Bladed WPP's

The Two Bladed WPP has two blades, which are even in number causing stability problems & stresses on the blades, though cost effective as compared to the Three Bladed WPP as only two blades are utilized. However, the two bladed turbines tend to capture slightly less energy, approximately 97% of as much as a Three Bladed design can, with the same rotor diameter [2].

3.4.3. Three Bladed WPP's

Most modern day WPP's effectively utilize the Three Bladed concept, wherein the blades are odd in number which tends to maintain the stability of the system & eliminate imbalances caused. As three blades are used the efficiency of the system is increased, along with reduced noise effect.

3.4.4. Multi Bladed WPP's

The Multi Bladed WPP's are mostly used in grain mills & water pumping systems as shown in Figure: 1. they basically have more than three rotor blades, which makes this system very expensive as compared to the others. Hence, they are not used for Power Generation.

3.5. Geared, Direct-drive & Hybrid WPP's

Now, WPP's can be classified on the drive system adopted by them as well, giving us another method of classification. The WPP's can be classified on their drive type, which are Geared, Direct-drive & Hybrid WPP's.

3.5.1. Geared WPP's

Geared WPP's have a Gear Box placed in between the rotor turbine & the Generator. Wherein, generator rotates at speeds of 1500 rpm from wind speeds ranging from a low of 8-10 rpm in large WPP's to 25-30rpm of relatively smaller WPP's [2]. Therefore, the gear box arrangement provided is a step-up gear box arrangement to provide high speeds i.e. 1500rpm at the electrical generator side.

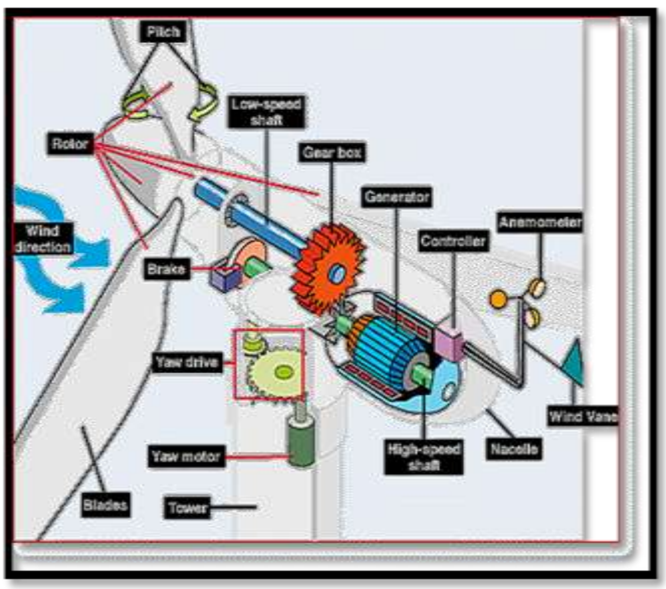

Figure 4: Geared WPP's
Source: way2science.com

Sr. No	Parameter	Geared WPP
1	Type of Generator	Induction Generator
2	Speed Range of Generator	1000 - 1500 rpm
3	Top Head Mass (THM)	Very Low
4	Maintenance	High
5	Grid Compatibility	Very Low
6	Failure	High
7	Cost	Low
8	Electric Circuit Complexity	Very Low
9	Mechanical Noise	High

Table 1: GEARED WPP

3.5.2. Direct Drive WPP's

Direct Drive WPP's are connected directly to the turbine which tend to rotate the generator very slowly at the same variable speed provided by wind turbine rotor. The generator used is either a Multi-Pole Wound Rotor Synchronous Generator of a Multi-Polar Permanent Magnet Synchronous Generator., which tends to match the speed of the rotor turbine. Due to the size of the generator involved, the Top Head Mass (THM) of the WPP is relatively high.

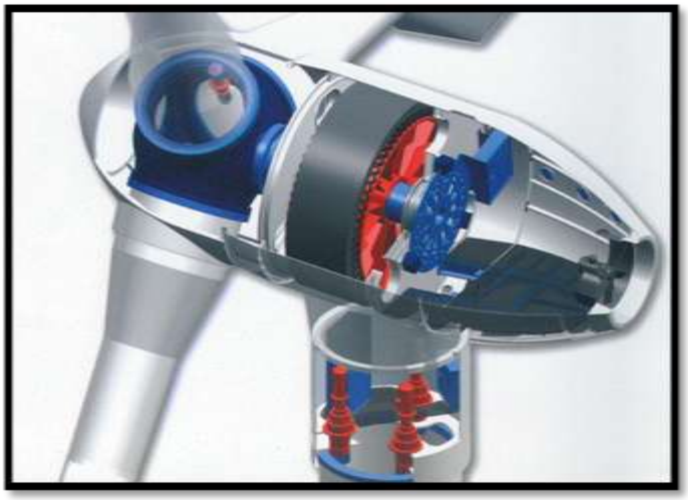

Figure 5: Direct Drive WPP's
Source: www.wind-energy-the-facts.org

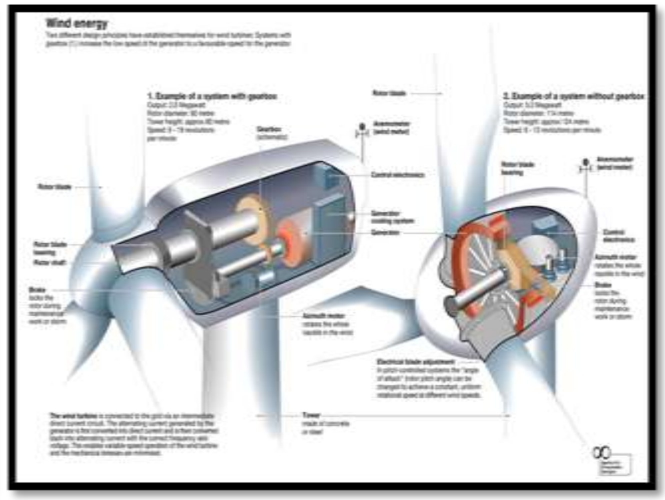

Figure 6: Comparison with Geared & Direct Drive WP
Source: www.greencollarjobtraining-free.com

Sr. No	Parameter	Direct WPP
1	Type of Generator	Synchronous Generator
2	Speed Range of Generator	15 - 35 rpm
3	Top Head Mass (THM)	High
4	Maintenance	Very Low
5	Grid Compatibility	High
6	Failure	Low
7	Cost	High
8	Electric Circuit Complexity	High
9	Mechanical Noise	Very Low

Table 2: DIRECT DRIVE WPP

3.5.3. Hybrid WPP's

Hybrid WPP's merge the direct drive type & the geared type WPP's together, thereby equipping it with reliability & compactness from both the systems. Hence, the resulting in comparatively low Top Head Mass (THM), that's rotates at medium speeds.

Sr. No	Parameter	Hybrid WPP
1	Type of Generator	Permanent Magnet Synchronous Generator
2	Speed Range of Generator	100 - 150 rpm
3	Top Head Mass (THM)	Low
4	Maintenance	Low
5	Grid Compatibility	Low
6	Failure	Low
7	Cost	High
8	Electric Circuit Complexity	Low
9	Mechanical Noise	Low

Table 3: HYBRID WPP

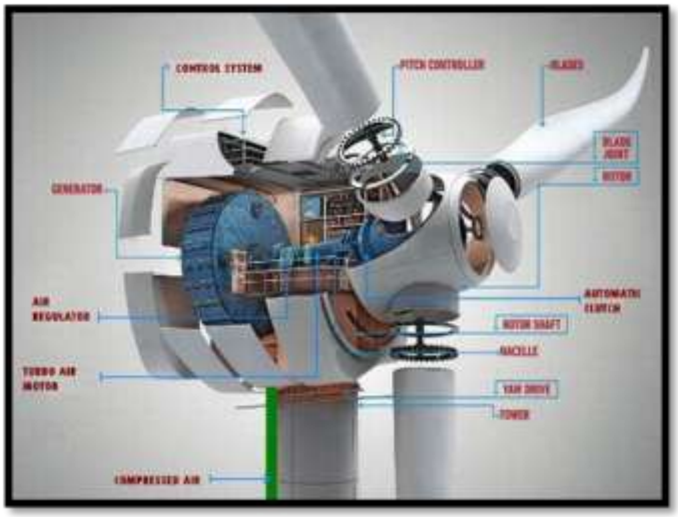

Figure 7: HybridWPP's
Source: www.inhabitat.com

3.6. Single Gearbox with Multiple Electrical Generators

In the early days, WPP's were mostly connected from a single gear box arrangement to only one generator, to produce power. But in modern times due to the advancement in technology, Power Gear Transmission systems are used. Wherein the turbine loads are spite up by multiple gear arrangement, so as to transfer the mechanical power from the rotor turbine to two or more generators with a suitable Power gear box arrangement. The Power Gear Transmission Systems basically support multi generator drive systems wherein two or more generators can be connected.

However it even tends to increase the overall complexity of the system, & should have a proper design concept. As if the design is not to specs it could result in failure permanently. However modern day manufactures have already started the designing of Single Gearbox with Multiple Generators successfully. They are basically of two types of Single Gearbox with Multiple Electrical Generators:

1. Single Gearbox with Two Electrical Generators
2. Single Gearbox with Four Electrical Generators

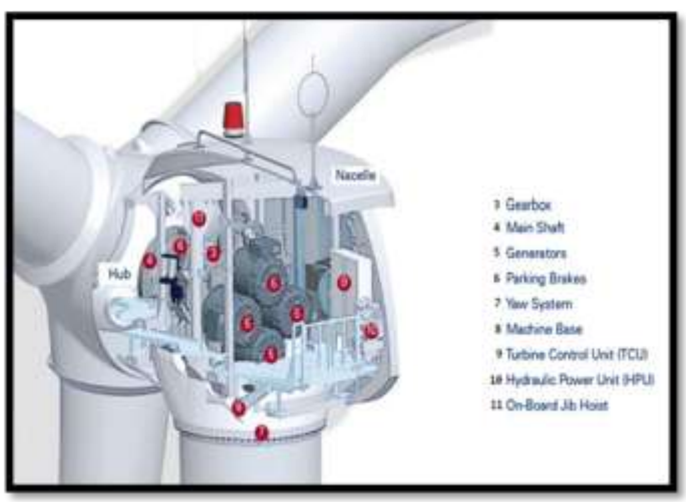

Figure 8: Single Gearbox with Four Electrical Generators
Source: www.windpowerengineering.com

4. Results & Discussion

Therefore by understanding the different types of Wind Power Plants based on various parameters, their true designing & constructional technology comes to light. This will help us determine, differentiate, & associate the various pros & cons before a certain type of wind power plant is setup. Thereby determining the best type of wind power plant suited for a particular geographical location with attention to economic considerations as well.

5. References

i. Vijay Devabhaktuni, “Wind Energy: Trends and Enabling Technologies,” EECS Department University of Toledo
ii. Joshua Earnest & Tore Wizelius, “Types of Wind Power Plants” in Wind Power Plants & Project Development, 1th ed. PHI, New Delhi, INDIA
iii. Tore Wizelius&Joshua Earnest, “Wind Power in China,” Peoples Republic of China (PRC)
iv. Wind Electricity Generation, 1st ed., Practical Action Co., LA, USA