Wind Energy - A Brief Survey With Wind Turbine Simulations

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Abstract - Today wind energy is very fast growing renewable energy source with enormous amount of advantages. The main part of the windmill is obviously wind turbine. This paper focus on the different wind turbine models using PSIM software and MATLAB SIMULINK Toolbox environment. This wind turbines directly connected with the generator and connected with grid utility after step-up transformer.

Index Terms — Power, Torque, Wind turbines.

I. INTRODUCTION

The continued growth and expansion of the wind power industry in the face of a global recession and a financial crisis is a testament to the inherent attractiveness of the technology. Wind power is clean, reliable, and quick to install; it’s the leading electricity generation technology in the fight against climate change, enhancing energy security, stabilizing electricity prices, cleaning up our air and creating thousands of quality jobs in the manufacturing sector when they’re particularly hard to come by.[1] India rank 4th in all over global market of wind energy and there are many number of installations are there for India in 2010.

II. WIND ENERGY SURVEY

Figure 1. Present Wind Energy Scenario[1]

Figure 2. Estimated Wind Power Potential in India[2]

World Wind Energy Association (WWEA) also has done some prediction. In next 3 years, the installed capacity is going to be doubled. It will reach 160000 MW.

Terms related Wind energy:[2]

Cut-in wind speed: the speed at which the wind turbine starts to operate.

Cut-out wind speed: is the wind speed where the wind turbine stops production and turns out of the main wind direction.

TSR is the speed of the blade at its tip divided by the speed of the wind.

If the rotor of the wind turbine spins too slowly, most of the wind will pass straight through the gap between the blades, therefore giving it no power! But if the rotor spins too fast, the blades will blur (make or become less distinct) and act like a solid wall to the wind.

During entire paper the data sheet of Enercon E-53 is taking as a reference.
The optimum Tip Speed Ratio for maximum power output, this formula has been empirically proven:
\[
\lambda \text{ (max power)} = \frac{4\pi}{n}
\]
where \( n \) (n = number of blades) [3]

Table shows optimum TSRs,

<table>
<thead>
<tr>
<th>Tip Speed Ratio</th>
<th>Number of blades</th>
</tr>
</thead>
<tbody>
<tr>
<td>~6-7</td>
<td>2</td>
</tr>
<tr>
<td>~5-6</td>
<td>3</td>
</tr>
<tr>
<td>~2-3</td>
<td>5</td>
</tr>
</tbody>
</table>

### III. BASIC WIND TURBINE MODELS

With MATLAB environment:[5]

Wind turbine Basic Model (at speed 10m/s):

Wind turbine Basic Model (at speed 15m/s):

Curves at various wind speed for 10m/s, 15m/s and 20m/s of Scope 1:
Now another model is from generalized equation means after the successful completion of turbine design the output is given to the generation system means shaft of any generator so the power and torque equations are important here two another models of power and torque equations are present in the MATLAB 7.8 environment.

The equations of output power and shaft are as under.

\[ P = \frac{1}{2} C_p \rho A V^2 \]  
\[ T_{turbine} = \frac{1}{2} \rho A C_p V \lambda \]  

Where,

- \( P \) = Wind power developed
- \( C_p \) = The power co-efficient
- \( \rho \) = Air density = 1.23 kg/m³
- \( A \) = Area of wind turbine blades in m²
- \( \lambda \) = Tip Speed Ratio

And the torque equation,

Now according to these equation another MATLAB simulation has been done and graph has plotted between output power and speed.[4]

\[ T_{turbine} = \frac{1}{2} \rho A C_p V \lambda \]  

With MATLAB environment,

Now with using PSIM environment from equation (2),

For example in case Enercon wind turbine E-53 data,[6]

- Rated Power 800kW
- Rotor Diameter 52.9m
- Swept Area 2198m²
- Air density 1.225 kg/m³
- Tip Speed Ratio 5

With PSIM environment:
Figure 11. Wind turbine block using PSIM Torque as an Output

So from equation (2), for wind speed = 10m/s,
\[ T_{\text{turbine}} = 1297 \text{ N.m} \]

Figure 12. Torque value

Now from power equation (1),
\[ P = 646\text{kW} \]

Figure 13. Wind turbine block using PSIM Power as an Output

IV. VARIOUS GENERATOR COMPARISON USED IN WIND ENERGY CONVERSION SYSTEM

<table>
<thead>
<tr>
<th>Particulars</th>
<th>DFIG with single stage gear box</th>
<th>DFIG with three stage gear box</th>
<th>Direct drive electrically excited Syn. Generator</th>
<th>Direct drive permanent generator / Alternator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight</td>
<td>Light</td>
<td>Lightest</td>
<td>Heaviest</td>
<td>Active Weight nearly halved</td>
</tr>
<tr>
<td>Reduction of converter cost &amp; converter loss</td>
<td>Low cost solution (Less expensive)</td>
<td>Most expensive</td>
<td>Expensive compared to Generator with gear box</td>
<td></td>
</tr>
<tr>
<td>Cost reduction</td>
<td>Energy yield by cost is Good</td>
<td>Low energy yield due to high losses in gear box</td>
<td>Energy yield is good</td>
<td>Energy is yield is few percent higher</td>
</tr>
<tr>
<td>Further improvement is possible Due to permanent Magnet &amp; power converters used</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

V. CONCLUSION AND FUTURE WORK

From this paper one can easily understand the various type of simulation topologies of wind turbine at
various speed of wind speed and made calculations of torque and speed. This wind turbine connected with various types of generators and connected with grid for pollution free power and act as a very advantageous green energy source.

VI. REFERENCES

[3] Tip to Speed Ratio (TSR) for Wind Turbine Blades: How to calculate and apply TSR to blade selection. www.google.com