What is the Best Generator Type for a 5MW Wind Turbine?

A Comparison of Doubly Fed and Permanent Magnet Generators for Wind Turbines

Executive Summary

The author performed a concept study of power system architectures for a 5MW offshore wind turbine designed for manufacture and installation in China. At the time of the study, the wind turbine manufacturer had already specified rotor size, drivetrain configuration, and gearbox ratio. Factors including generator type, converter topology, system voltage, and electrical component placement were assessed regarding up front cost, lifetime cost and reliability, tower top weight, and annual energy production.

This paper focuses on the results of the generator type assessment, specifically on the two most popular and available generator types for wind turbines: Doubly Fed (DFIG) and Permanent Magnet (PMG).

For a multi-megawatt offshore wind turbine, a permanent magnet generator is a clear choice for optimizing all factors affecting the cost of energy of the installed turbine with a high reliability and a greater than 2% increase in annual energy production.

Method

The two generators were each evaluated on a nominal wind turbine at a nominal IEC wind class site.

Nominal wind turbine:

5MW, upwind, 3 bladed, active pitch, variable speed

148 meter LM rotor, 3 stage gearbox with 97:1 gear ratio.

Site conditions:

IEC class II: 8.5 mps, sea level density, 18% turbulence

Efficiency assumptions:

Efficiency curves for blades, gearbox, DFIG and PMG generators from suppliers

Generator Types

Doubly Fed (DFIG)

The generator stator is directly connected to the grid while the rotor current (30% of total) passes through slip rings and is controlled by a converter.

Considerations:

- Lower upfront cost
- Partial converter uses smaller (or fewer) modules and is therefore less expensive, lighter, and more compact
- However to meet grid codes including LVRT and power factor support, unit approaches size and cost of full converter
- Difficulty in export due to modification for 50/ 60Hz.
- Negative impact on turbine reliability due to increased gearbox tooth loads from grid transients.
- Generator encoder vulnerable to lightning, contamination, and bearing failure due to vibration and shaft bending.
- Slip rings require inspection at 6 month intervals and frequent replacement.
- High induced shaft currents. Can be mitigated with insulated bearings and grounding brushes.

Permanent Magnet (PMG)

The generator has permanent magnet rotor. The stator is connected to a full 4-Quadrant converter which is used to control torque on the generator.

Considerations:

- Lower weight for the same nominal power output.
- Shorter overall nacelle length due to no slip rings and better heat characteristics
- Good grid code compliance, meets all requirements for harmonics, power factor control, and grid fault ride through.
- High reliability and low maintenance cost.
- Concerns about long term decrease in performance.
- Concerns about rare earth supply, and future price trends.

Side by Side Comparison

	DFIG	PMG
Nominal Power	5400	5500
Dimensions	frame 800/ 3.4m L	frame 710/ 2.7m L
Weight	16.5T	14T
Upfront Cost Gen	$230k	$255k
Upfront Cost Conv	$180k	$300k
Service Cost	high	low
Grid Compatibility	fair	excellent

AEP Results

The PMG has the highest Annual Energy Production (AEP)

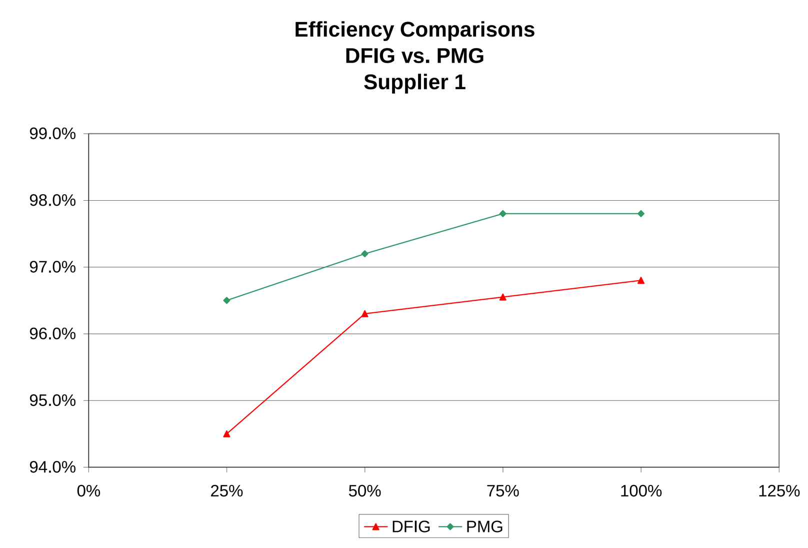
- The PMG has a higher efficiency at partial power, where the highest number of operating hours are spent.
- The PMG also has a wide speed range. The cut in rpm of the PMG can be as low as 20% of the rated rpm.
- The DFIG has a higher efficiency at rated speed. Additionally, the converter losses are only applied to 30% of the power output of the generator. This results in lower overall losses *at full power.*
- The DFIG has a narrower operating speed range. This results in poor power capture at low wind speeds. The speed of the DFIG is limited to the synchronous speed +/- 30%.

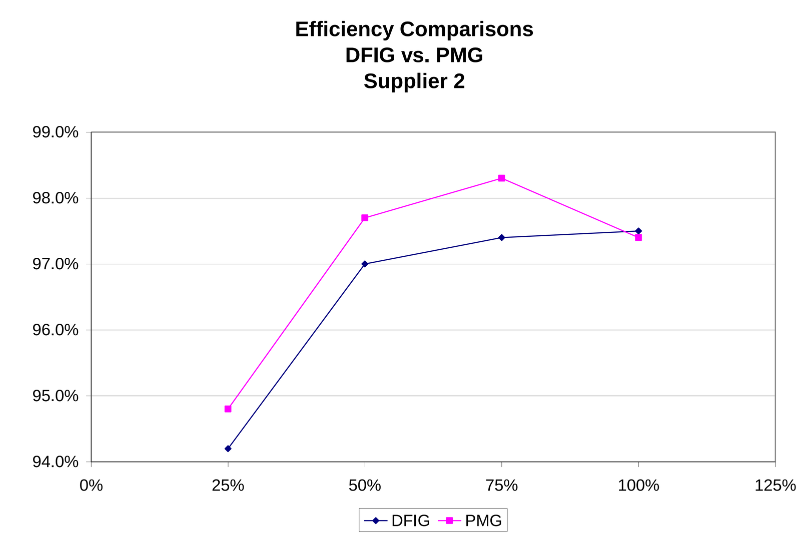
The difference between PMG and DFIG becomes larger at lower average wind speeds

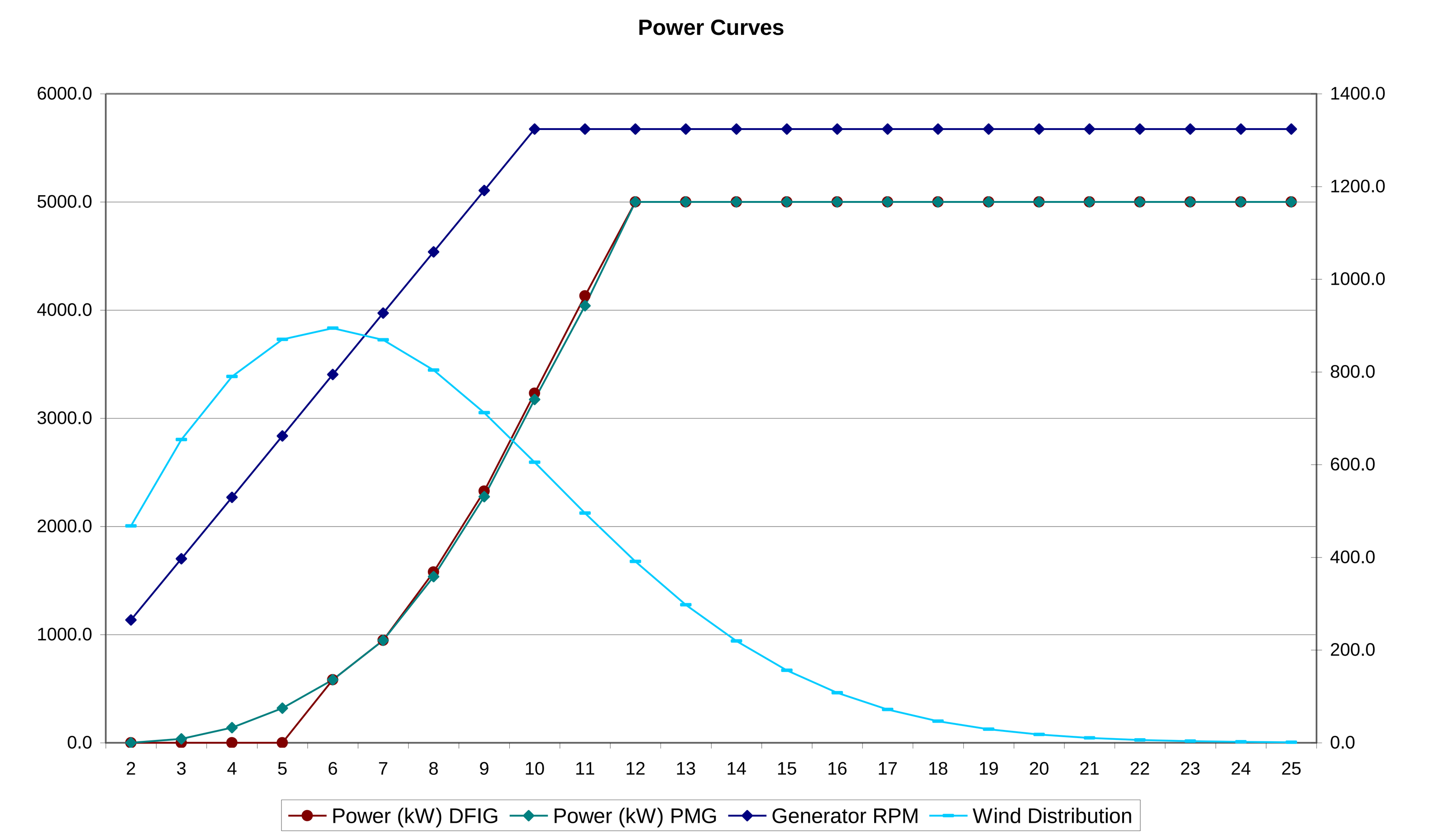
- And becomes less significant at higher average wind speeds.
- This is due to better performance of the PM at partial power.

The difference also becomes larger when the rotor size is increased

- This is due to the lower operating speed.







Comparison of Wind Classes				
Constants				
clean blade, steady power curve				
148m rotor				
97:1 Gearbox Ratio				
EIC Class	**class I**	**class II**	**class III**	**class IV**
Avg. Windspeed	10mps	8.5 mps	7.5 mps	6 mps
DFIG	baseline	baseline	baseline	baseline
PMG increase in AEP	1.39%	2.20%	3.24%	6.91%

Comparison of Rotor Sizes		
Constants		
IEC Class II		
8.5 mps		
97:1 Gearbox Ratio		
Rotor Diameter	**126**	**148**
DFIG	baseline	baseline
PMG increase in AEP	1.85%	2.20%

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