Power System Architecture: Finding the Best Solution for a 5MW Offshore Wind Turbine

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Introduction

History






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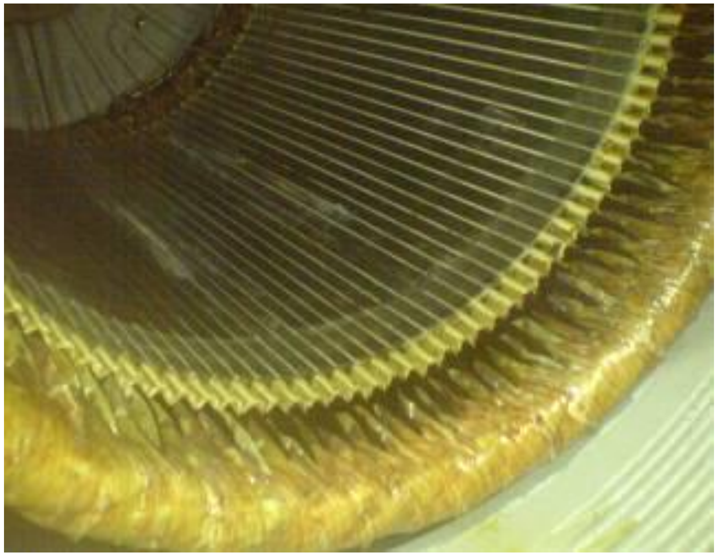
Early DF Reliability Issues

- Slip Rings
- Heat
- Insulation Breakdown
- Bearing Currents

Early PM Reliability Issues

- Surface Mounted Magnets



Introduction

History

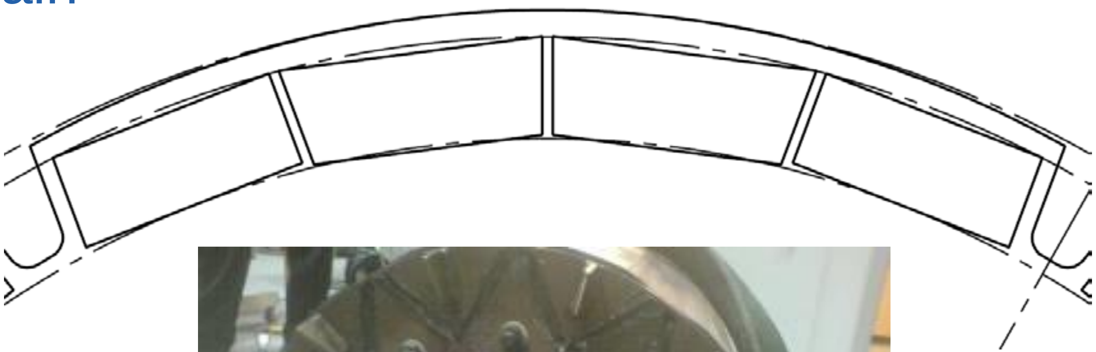
Some issues solved, some remain

Improvements in DF

- Better Cooling
- Insulated Bearings
- Robust Electrical and Mechanical Design

Improvements in PM

- Embedded Magnets
- Robust Electrical and Mechanical Design



Question Statement

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We are designing a 5MW Offshore wind turbine.

- What kind of generator should we use?
- What kind of converter should we use?
- Which system will be more reliable?
- Which system will be less expensive?

- Why?

Question Statement

Constants

5MW

Offshore

148 Meter Rotor

Gearbox with 97 to 1 ratio

Reference Site IEC Class II

Question Statement

Power System Options Considered

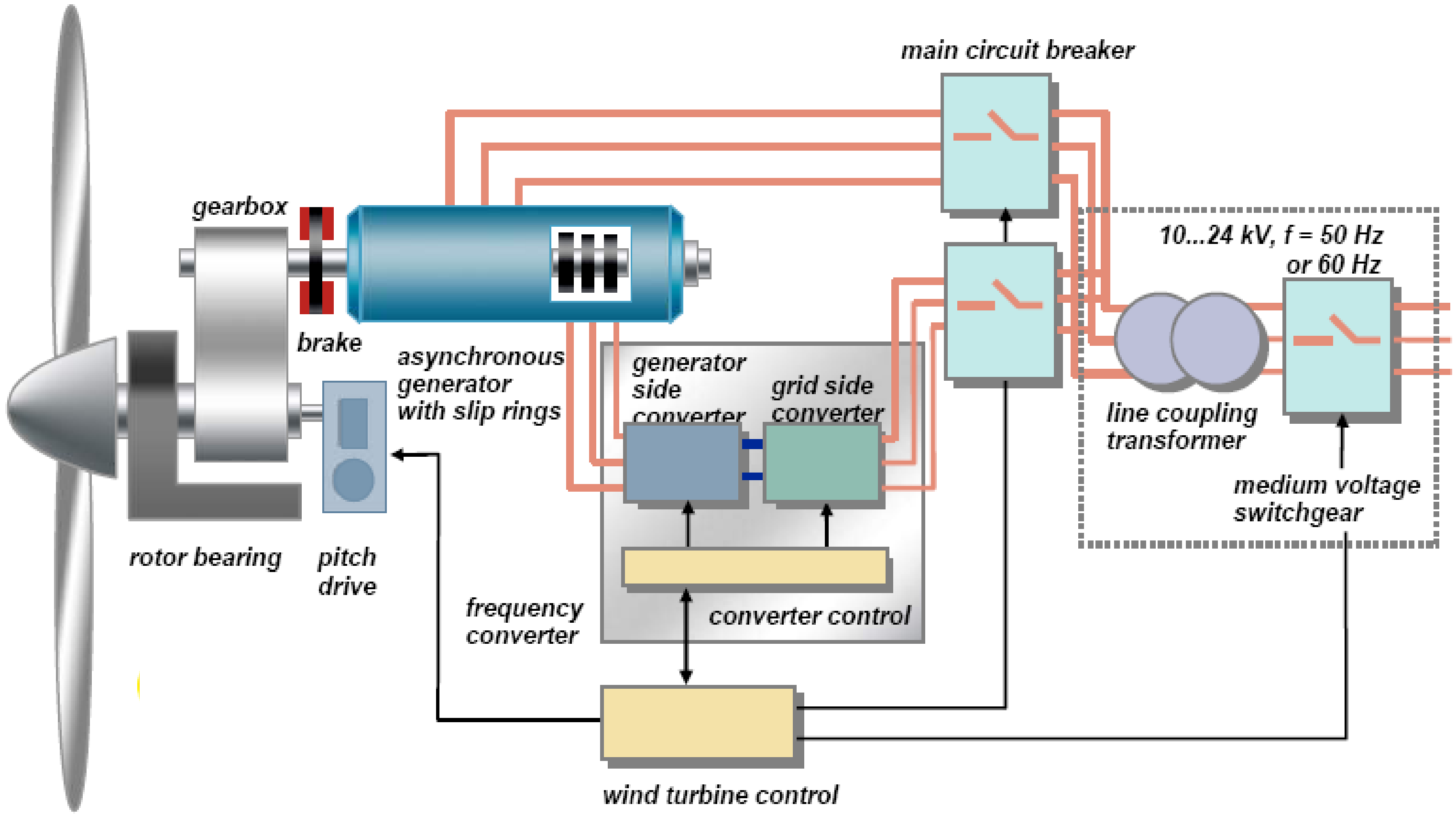
Generator Type

- Permanent Magnet (PMG)
- Doubly Fed (DFIG)

System Voltage

- “Low Voltage” 690V
- “Medium Voltage” 3.3kV or higher

Generator Type - DFIG



Layout of DFIG power system, courtesy ABB

Generator Type - DFIG

Low Upfront Cost

Shorter lead time

Poor reliability

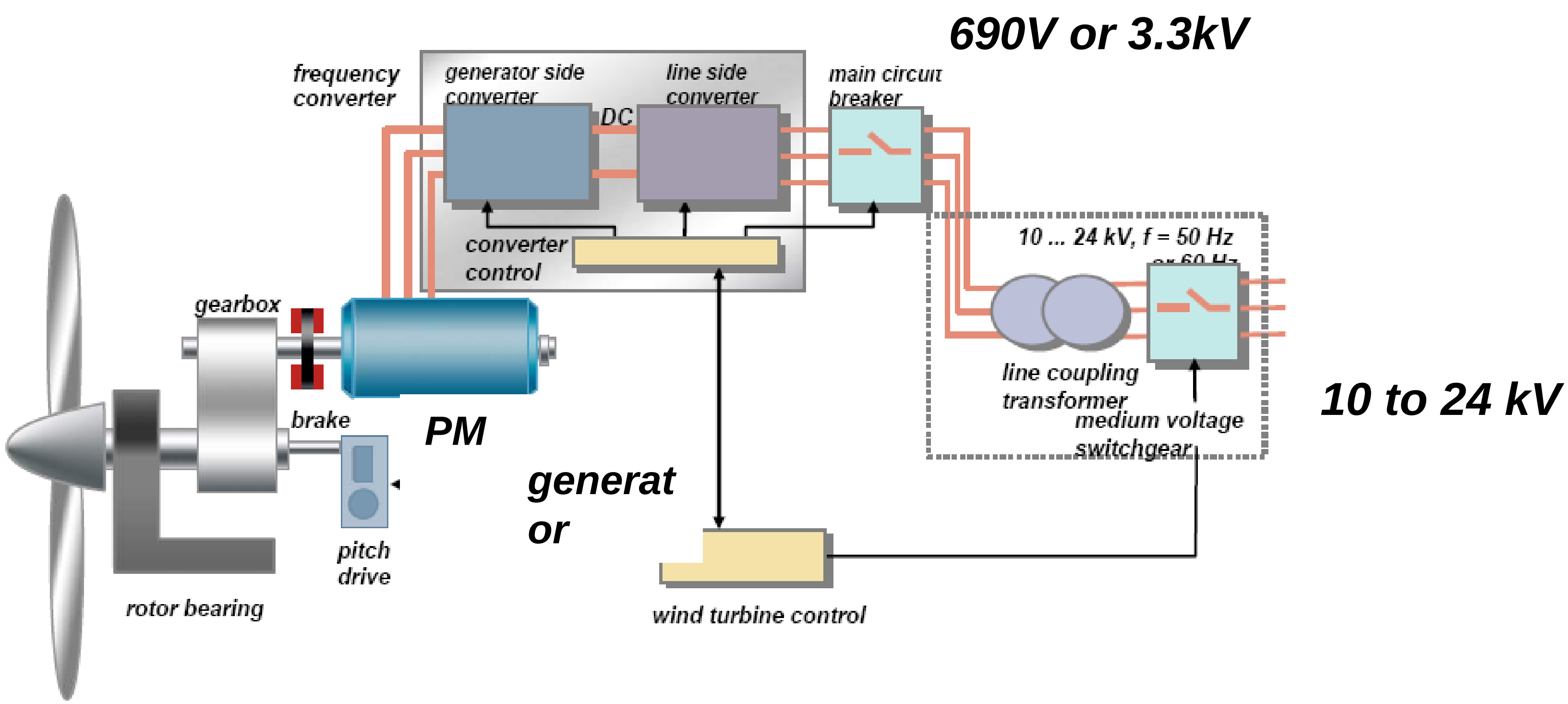
Lower Power Output

Highest weight and length

Poor grid code compliance

Design change required for 60Hz market

Generator Type - PMG



Layout of PM or Induction Generator based power system, courtesy ABB

Genenrator Type - PMG

Excellent Grid Code Compliance

Highest Power Performance

High Reliability

Low Lifetime Cost

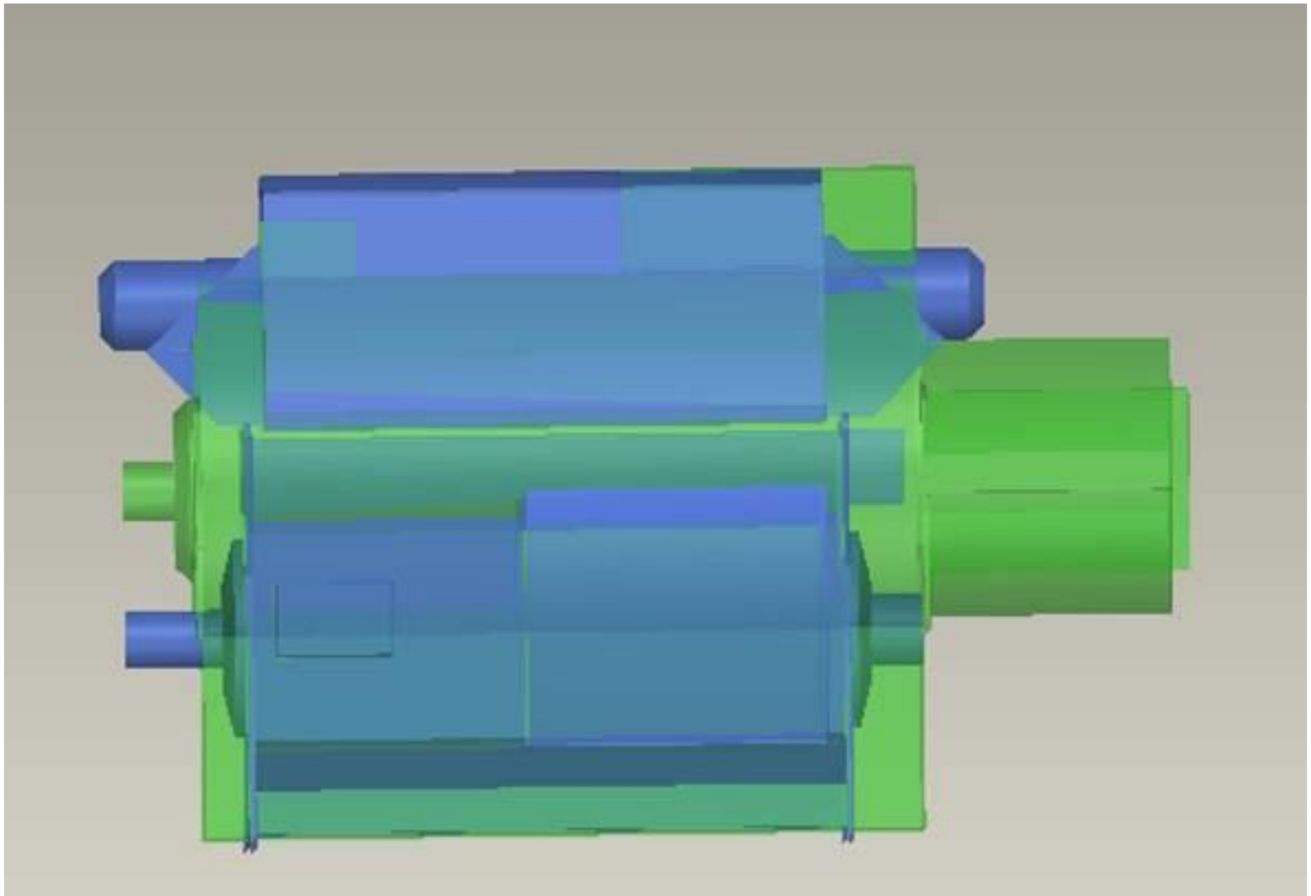
Lowest Weight/

Short Nacelle Length

Longer Lead Time

Higher Upfront Cost

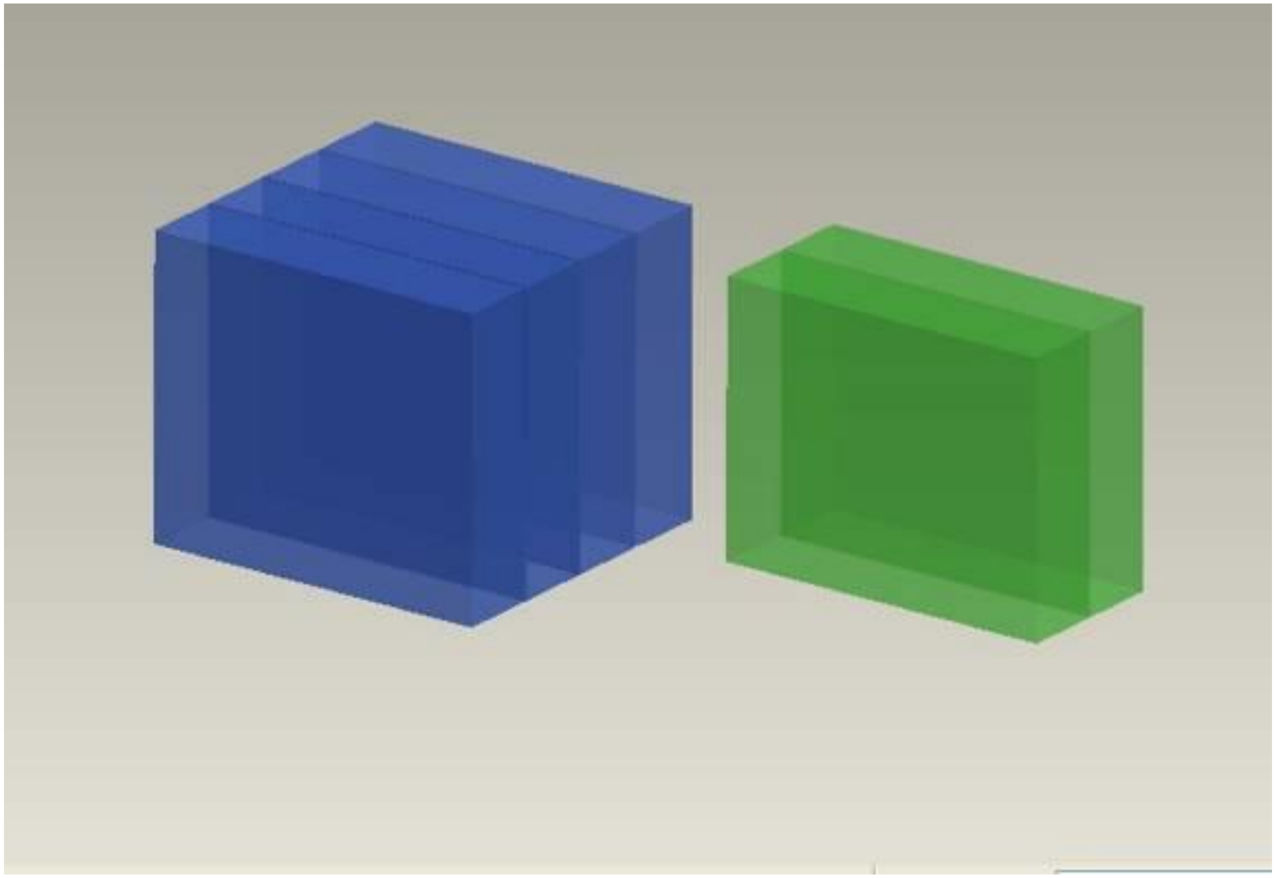
Size Comparison
DFIG and PM Gen



Blue = PMG

Green = DFIG

Size Comparison
DFIG and PM Conv



Blue = PMG

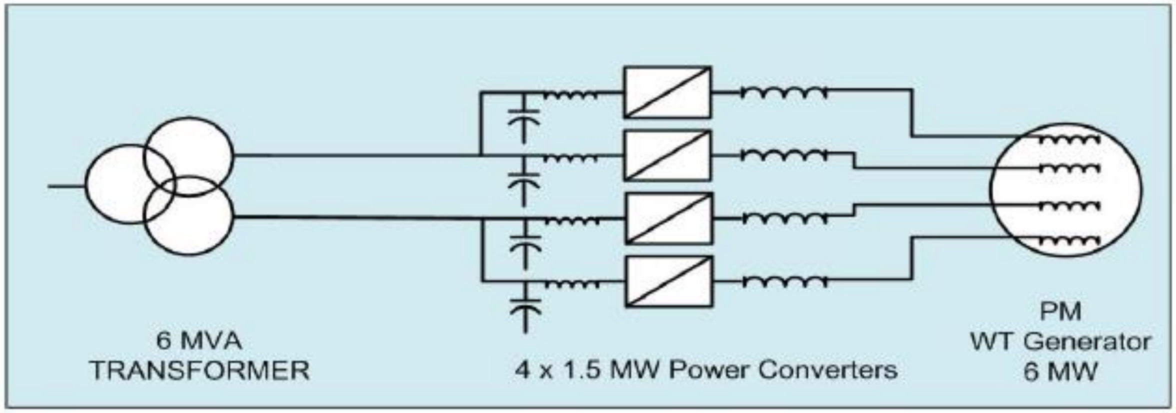
Green = DFIG

System Voltage

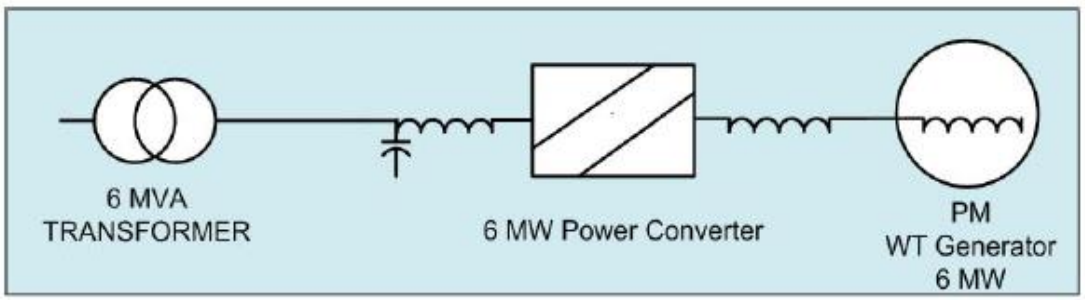
Example 690V converter (the Switch)

Example 3.3kV converter (ABB)

System Voltage



6 MW LV (690 V) full-power converter system for wind turbine



6 MW MV (3300 V) full-power converter for wind turbine

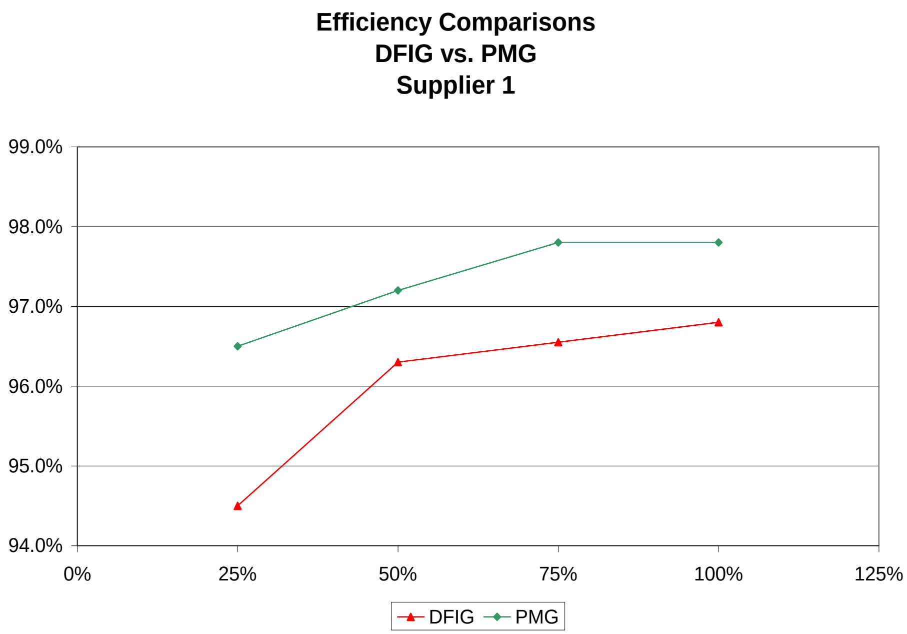
Low voltage design incorporates parallel windings and converters for redundancy

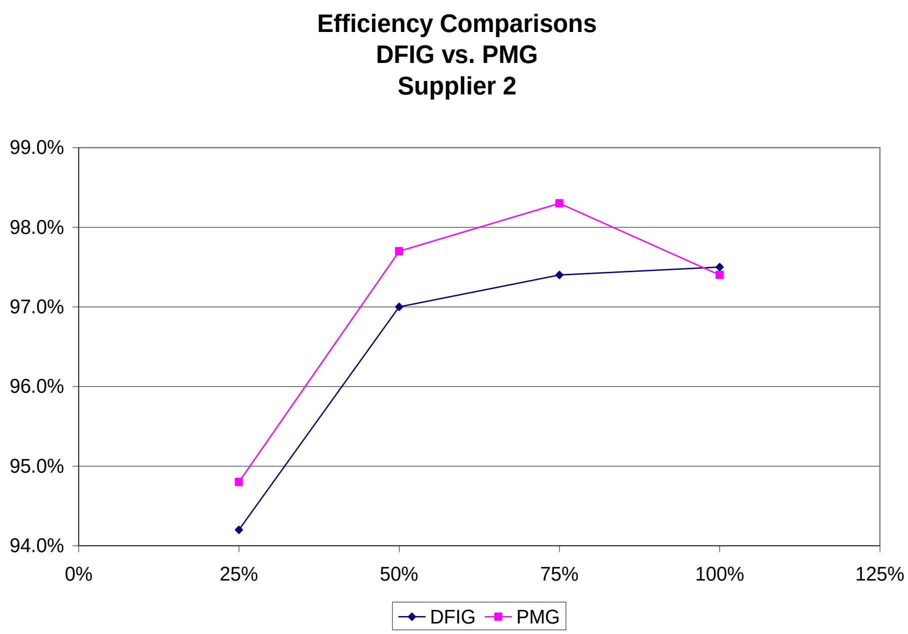
THE SWITCH

System Voltage

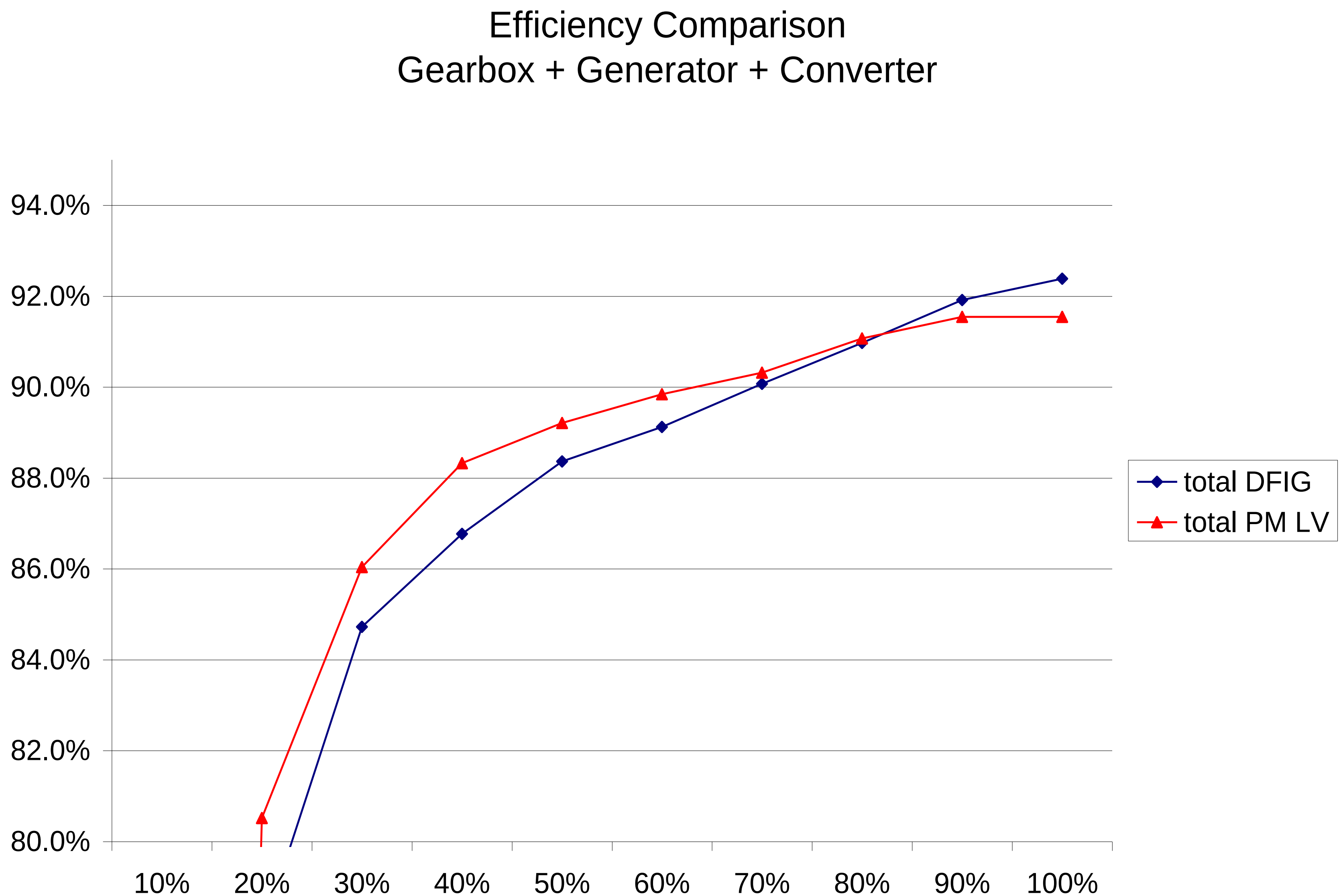
690V Advantages	3.3kV Advantages
Lower Upfront Cost	Higher Power Performance
Redundancy in Design	Lower Weight Generator
Standard O&M Procedures	Lower weight converter
Standard Cable Connections	Less cabling

AEP Calculations



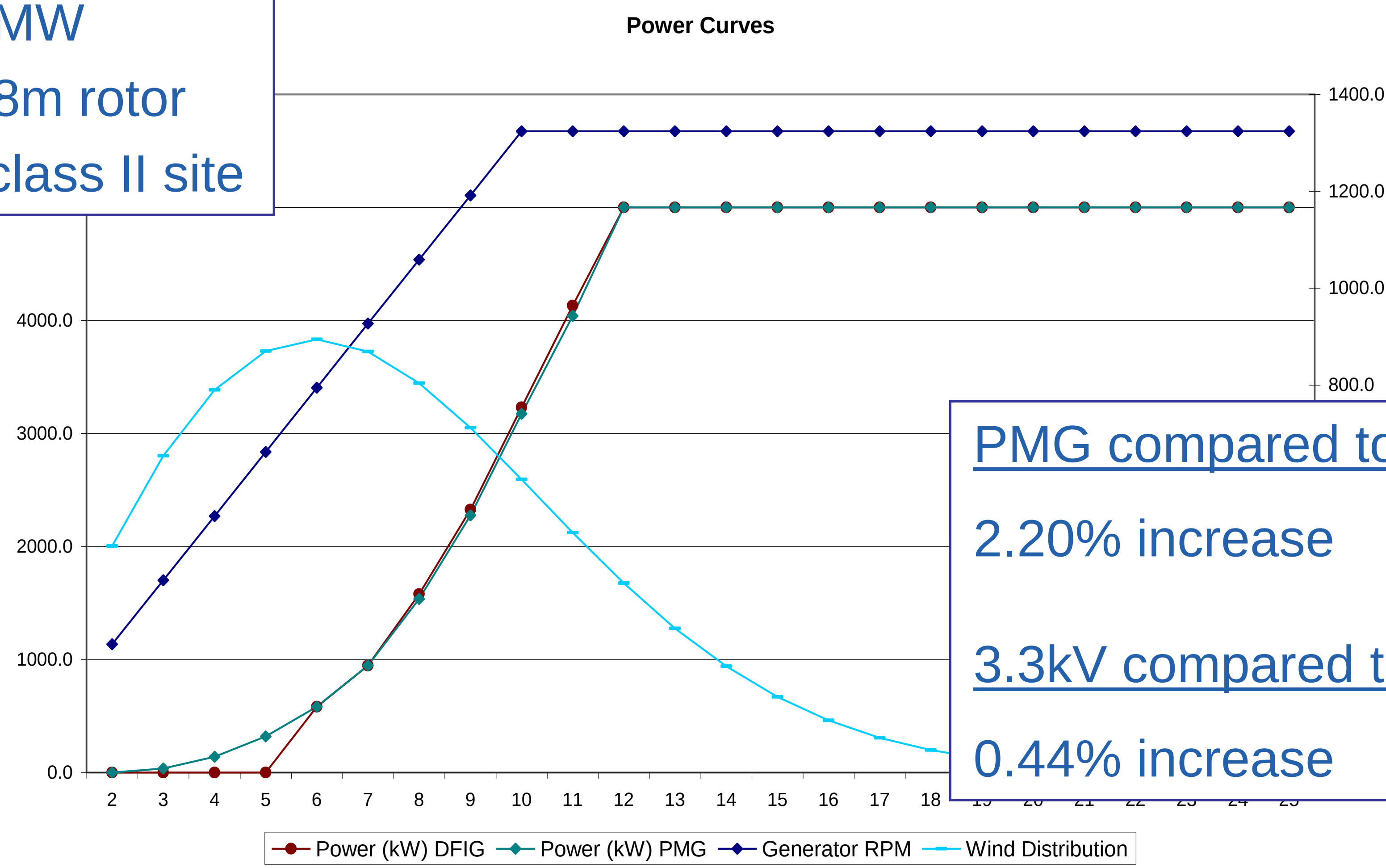


AEP Calculations



AEP Calculations

For a 5MW
with 148m rotor
at IEC class II site



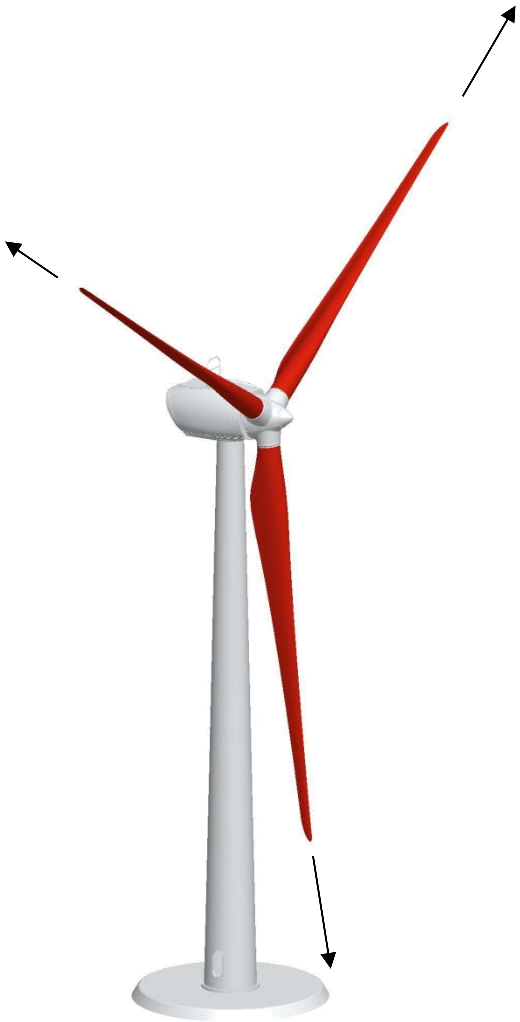
PMG compared to DFIG

2.20% increase

3.3kV compared to 690V

0.44% increase

Effect of Rotor on Generator Type

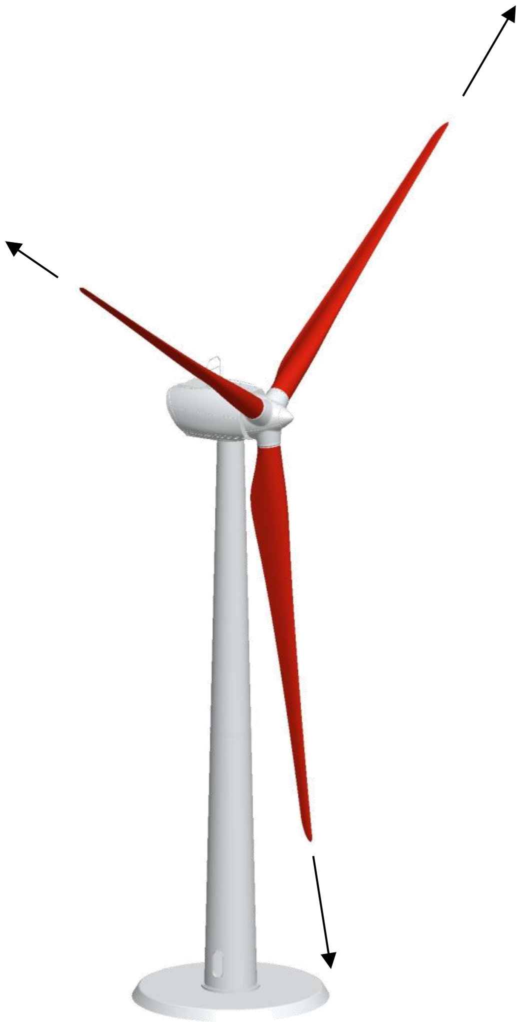


Comparison of Rotor Sizes For Generator Type		
Constants IEC Class II 8.5 mps 97:1 Gearbox Ratio		
Rotor Diameter	**126**	**148**
DFIG	baseline	baseline
PMG increase in AEP	1.85%	2.20%

Effect of Wind on Generator Type

Comparison of Wind Classes for Generator Type				
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	1.39%	2.20%	3.24%	6.91%

Effect of Rotor on Voltage



Comparison of Rotor Sizes for System Voltage		
Constants		
IEC Class II		
8.5 mps		
PMG		
97:1 Gearbox Ratio		
Rotor Diameter	**126**	**148**
690V	baseline	baseline
3.3kV	0.49%	0.44%

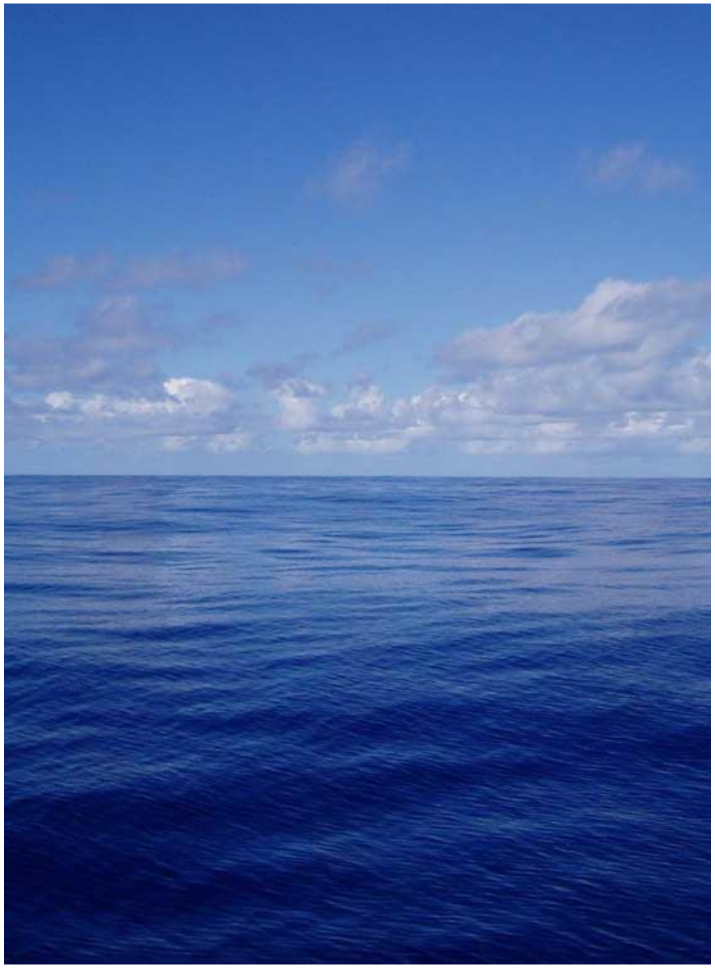
Effect of Wind Class on Voltage

Comparison of Wind Classes for System Voltage				
Constants clean blade, steady power curve 148m rotor PMG 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
690V	baseline	baseline	baseline	baseline
3.3kV increase	0.37%	0.49%	0.60%	0.81%

Conclusions - Generator

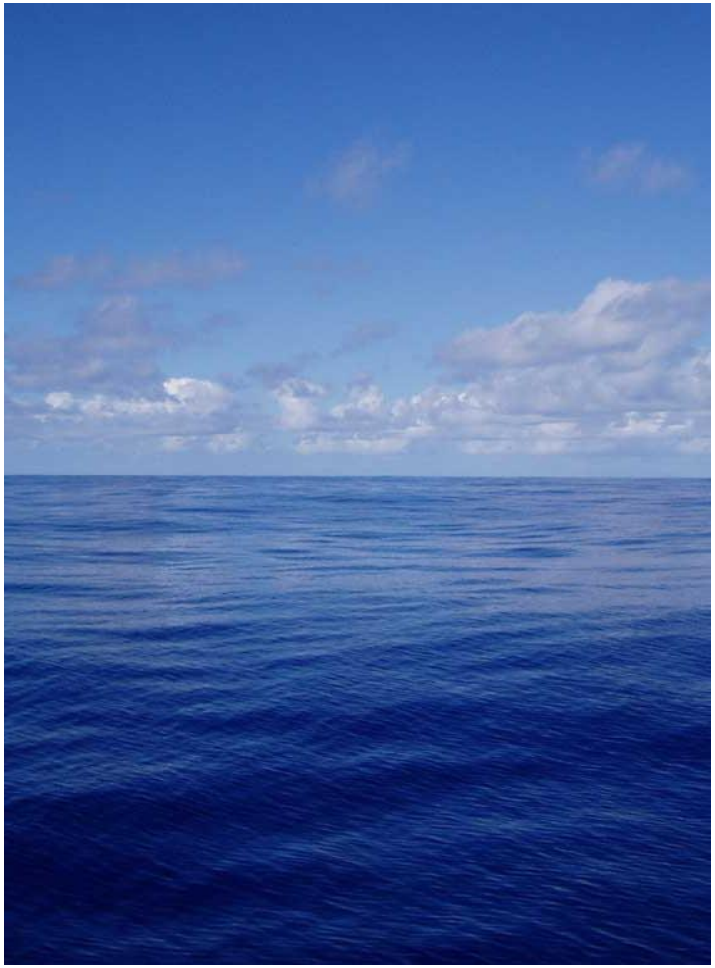
- PM Has a higher Annual Energy Production (AEP)
- This effect is stronger at low wind sites with larger rotors
- The PM has higher reliability

→ The PM has the lowest Cost of Energy (COE)



Conclusions - Voltage

- MV Has a higher Annual Energy Production (AEP)
- This effect is stronger at low wind sites
- This effect is lower with larger rotors
- The MV has easier system integration for large turines



Thank You

For more information about wind turbine design services please contact

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