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

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Introduction

History

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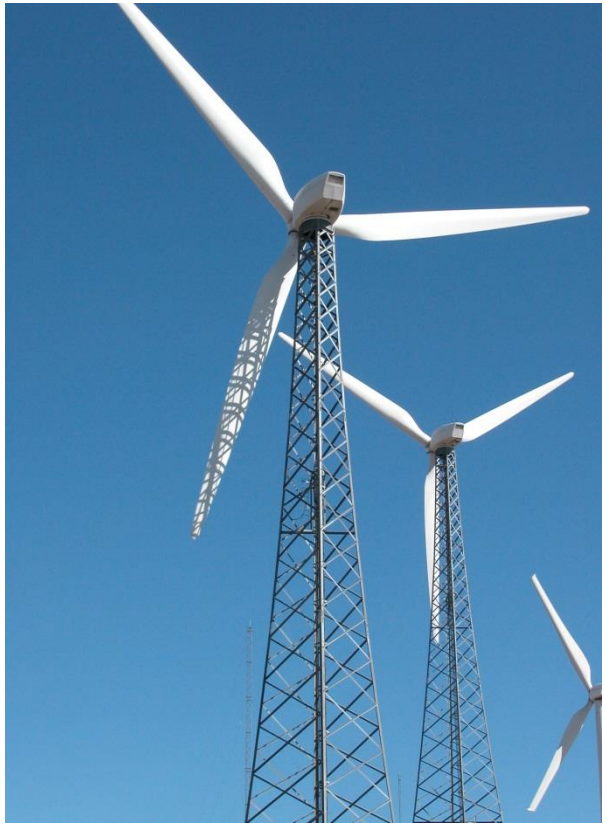
History



Introduction

History

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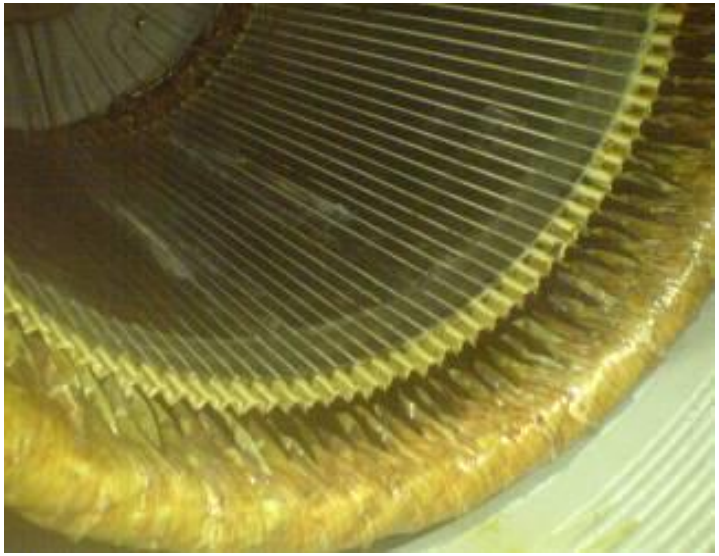
History

Early DF Reliability Issues

- Slip Rings
- Heat
- Insulation Breakdown
- Bearing Currents

Early PM Reliability Issues

- Surface Mounted Magnets



Introduction

History

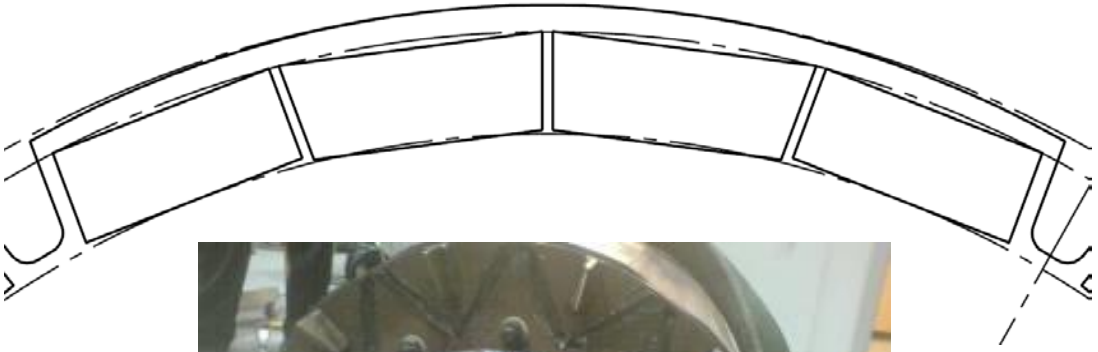
Some issues solved, some remain

Improvements in DF

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

Improvements in PM

- Embedded Magnets
- Robust Electrical and Mechanical Design



Question Statement

Question Statement:

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

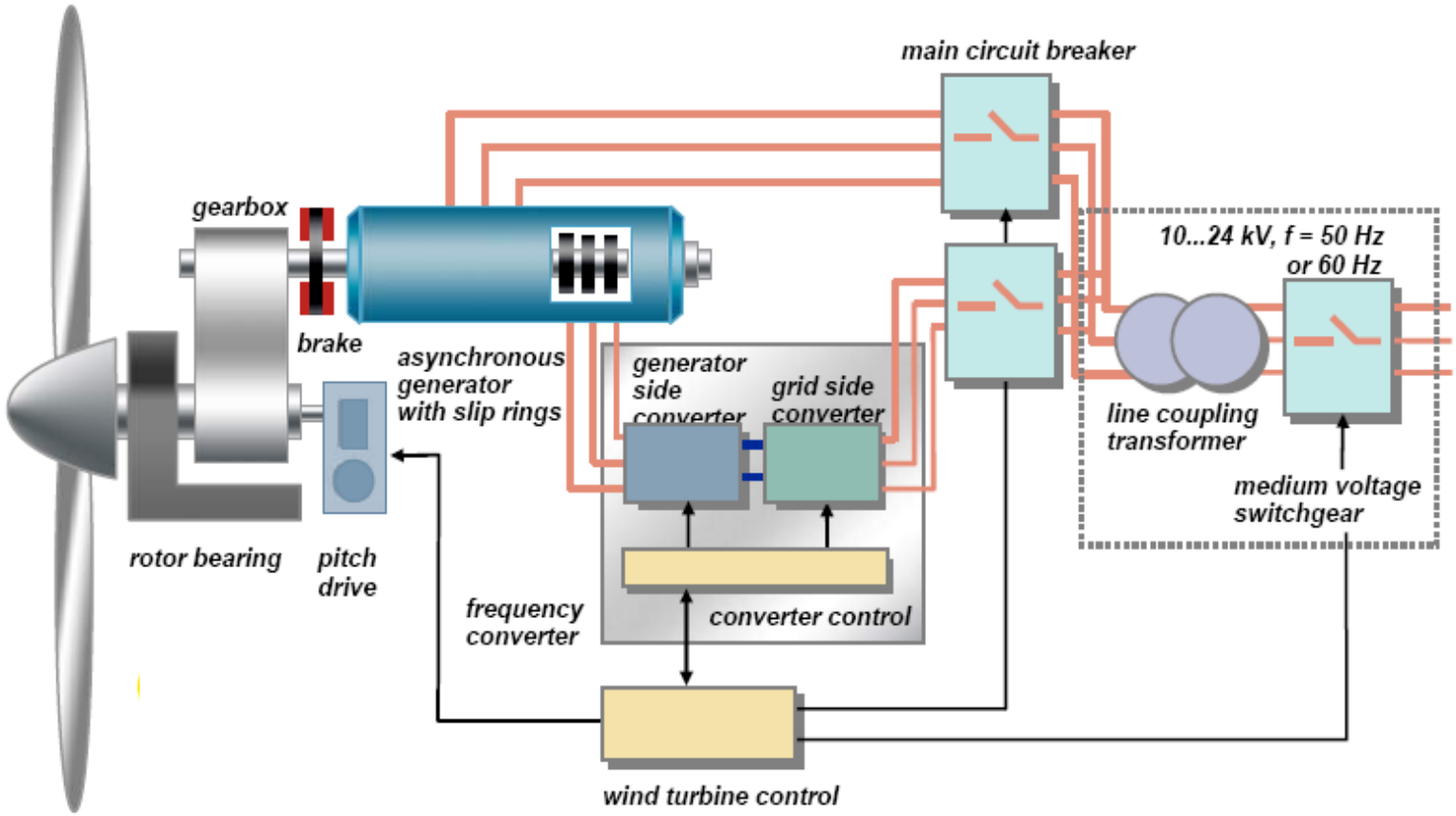
Generator Type

- 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

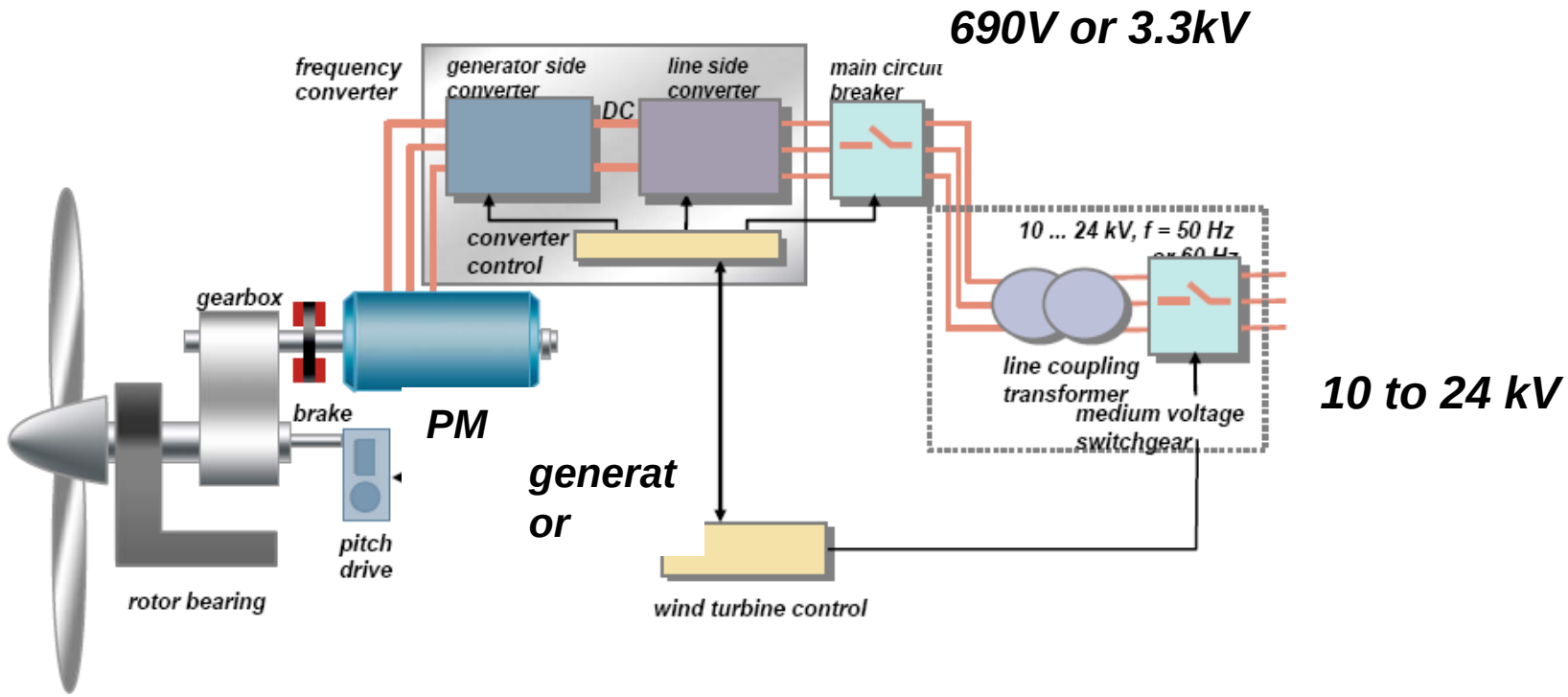
Lower Power Output

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

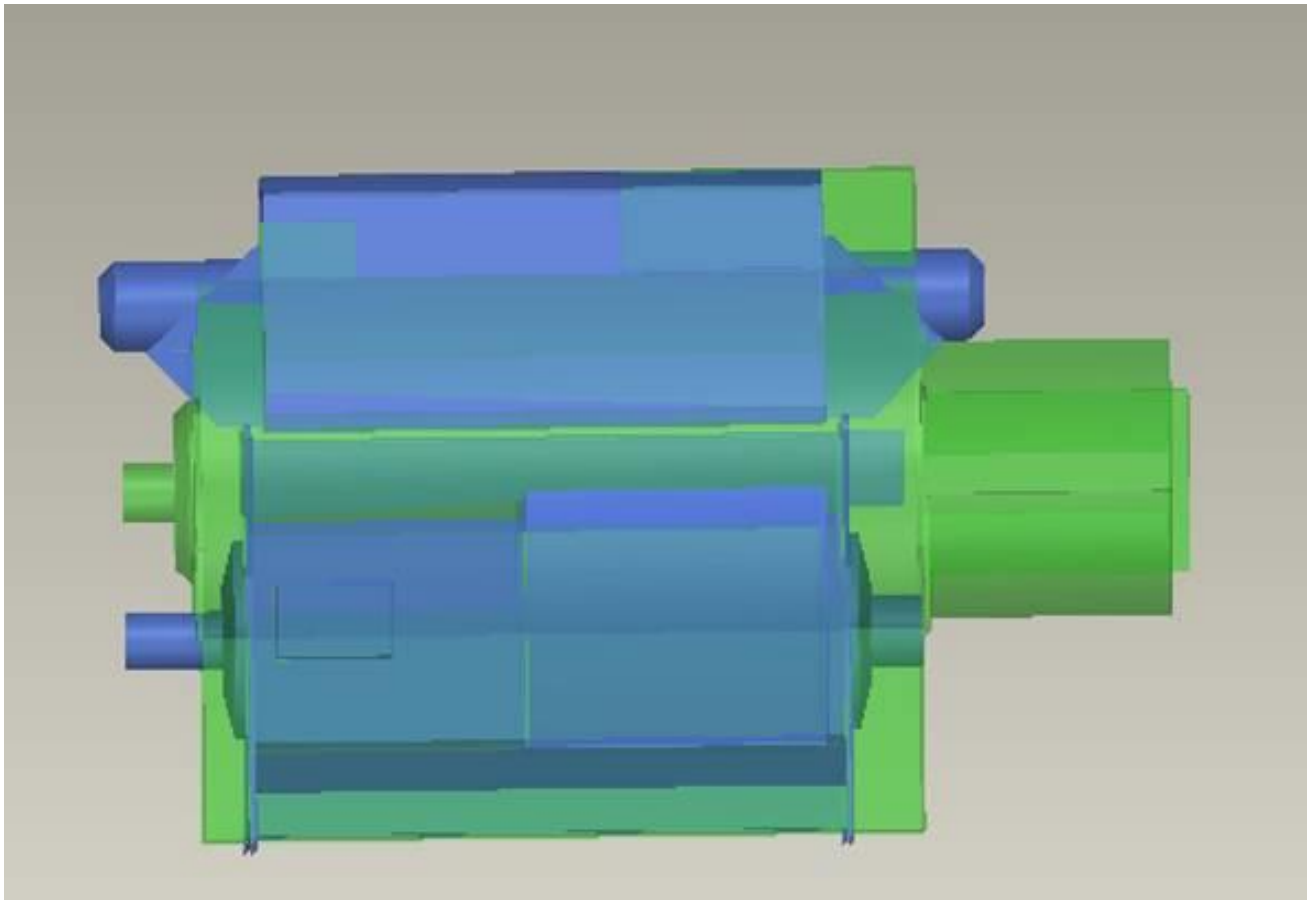
Lowest Weight/

Short Nacelle Length

Longer Lead Time

Higher Upfront Cost

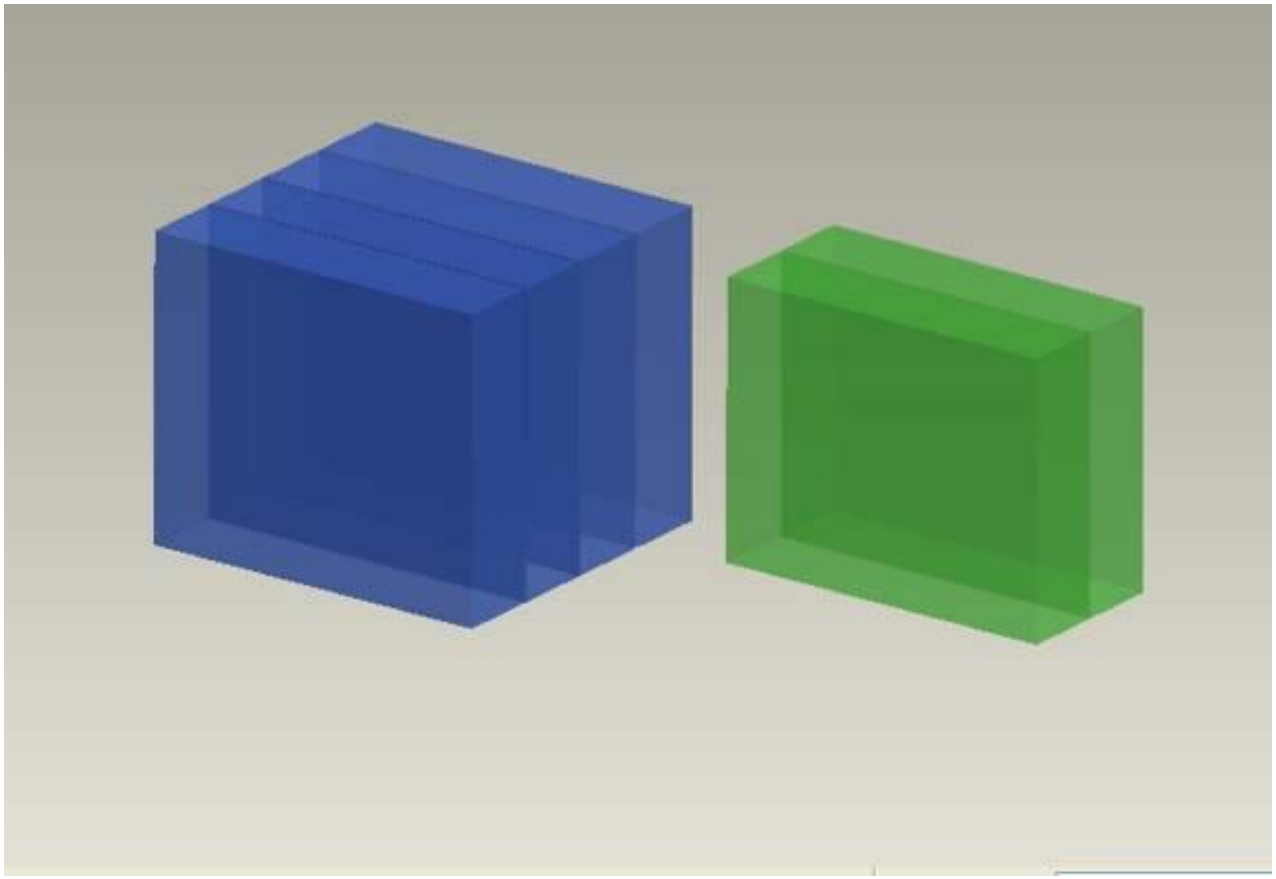
Size Comparison
DFIG and PM Gen



Blue = PMG

Green = DFIG

Size Comparison
DFIG and PM Conv



Blue = PMG

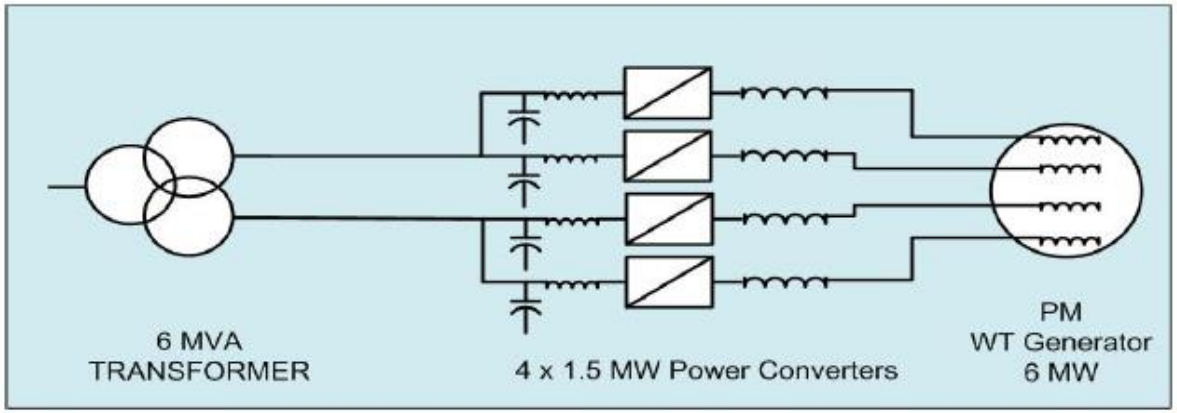
Green = DFIG

System Voltage

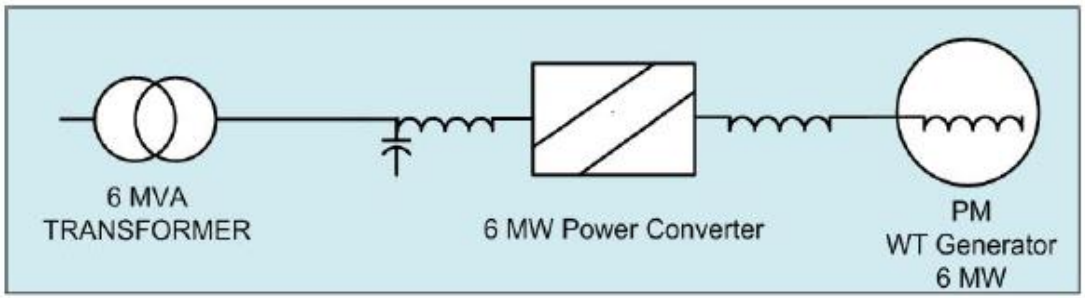
Example 690V converter (the Switch)

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

System Voltage

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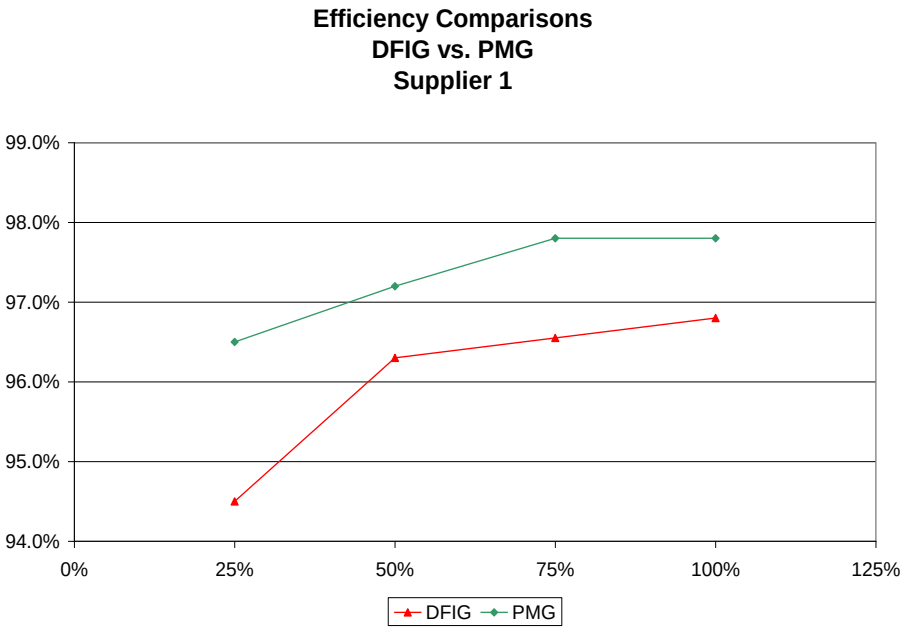
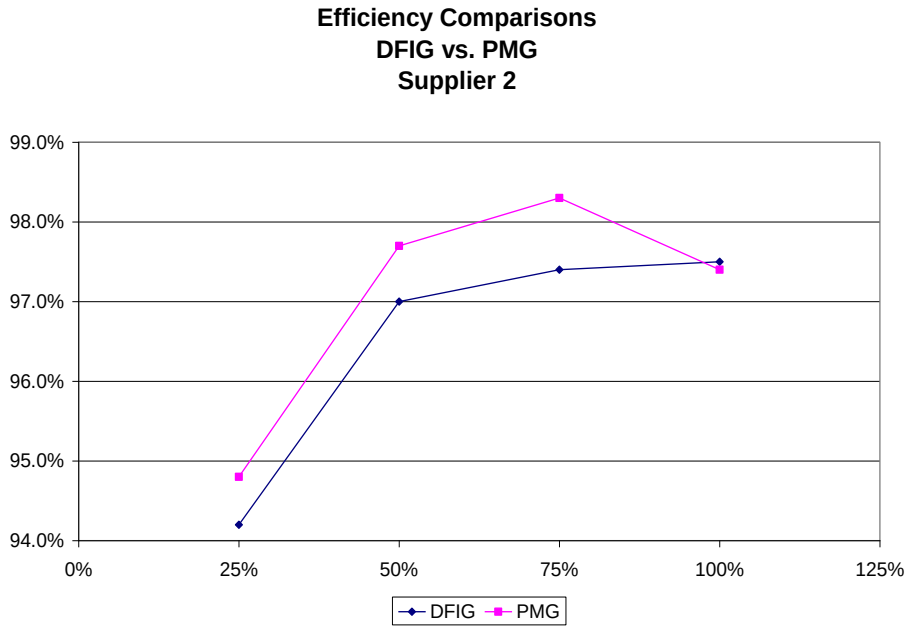
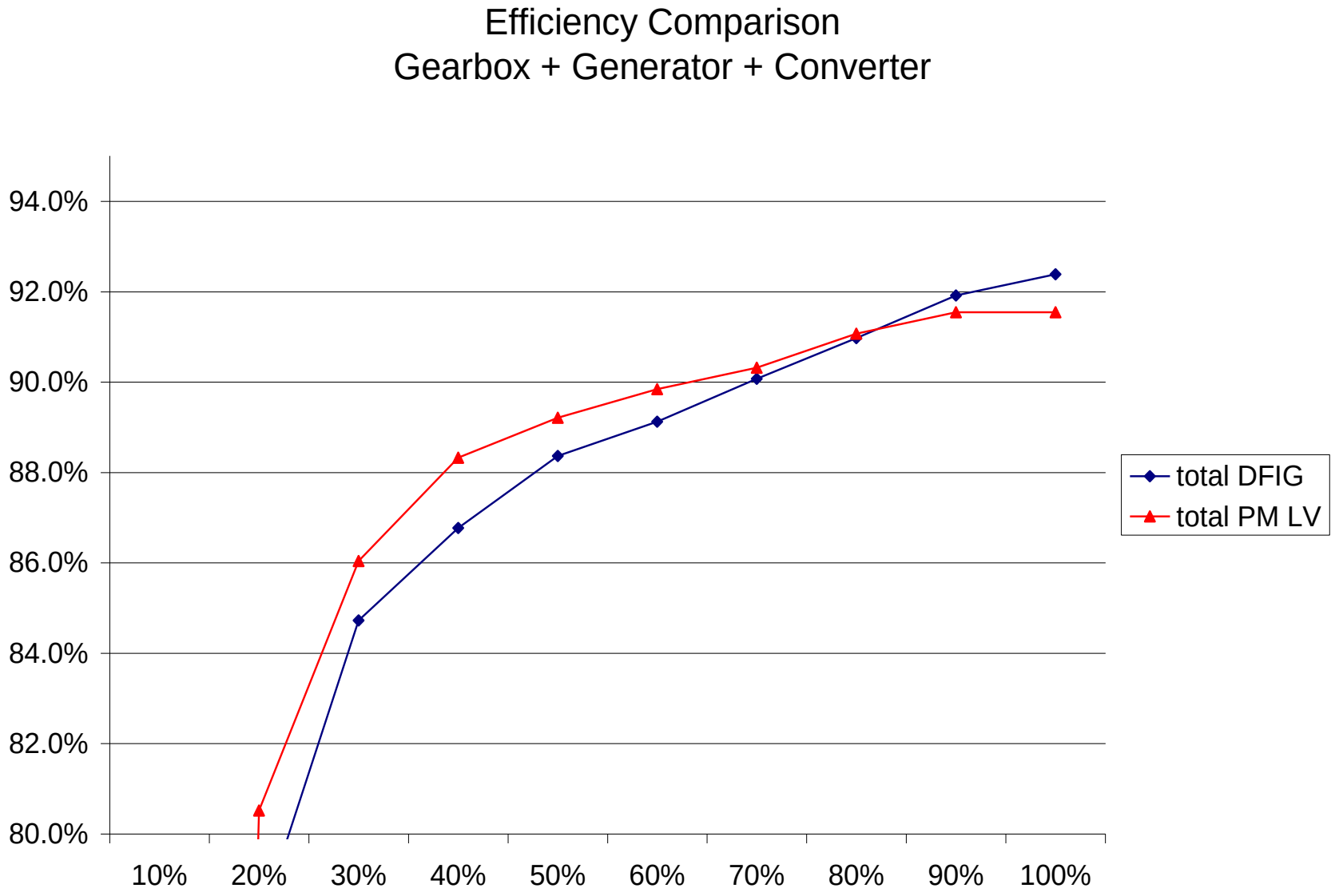
690V Advantages	3.3kV Advantages
Lower Upfront Cost	Higher Power Performance
Redundancy in Design	Lower Weight Generator
Standard O&M Procedures	Lower weight converter
Standard Cable Connections	Less cabling

AEP Calculations



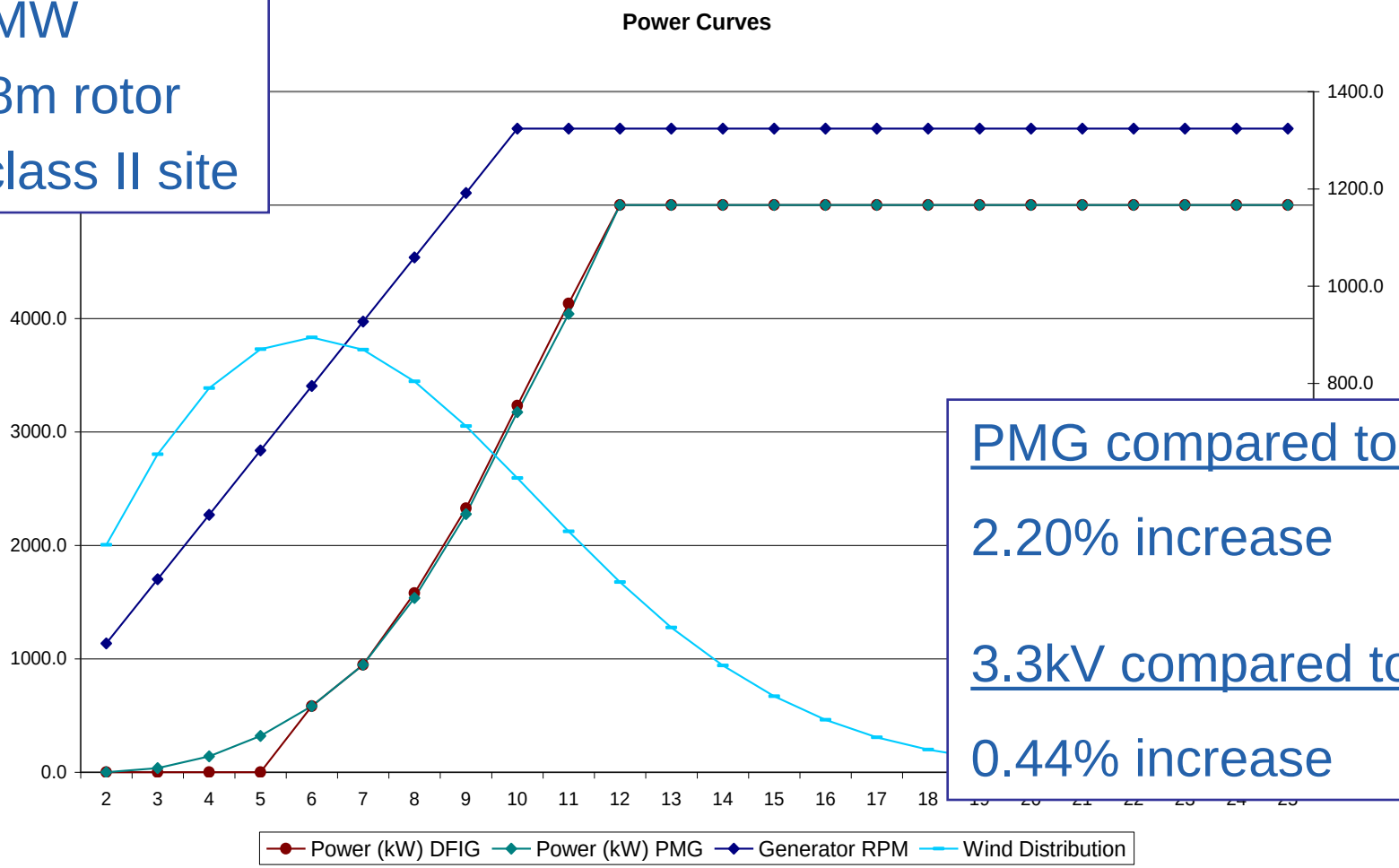


AEP Calculations



AEP Calculations

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



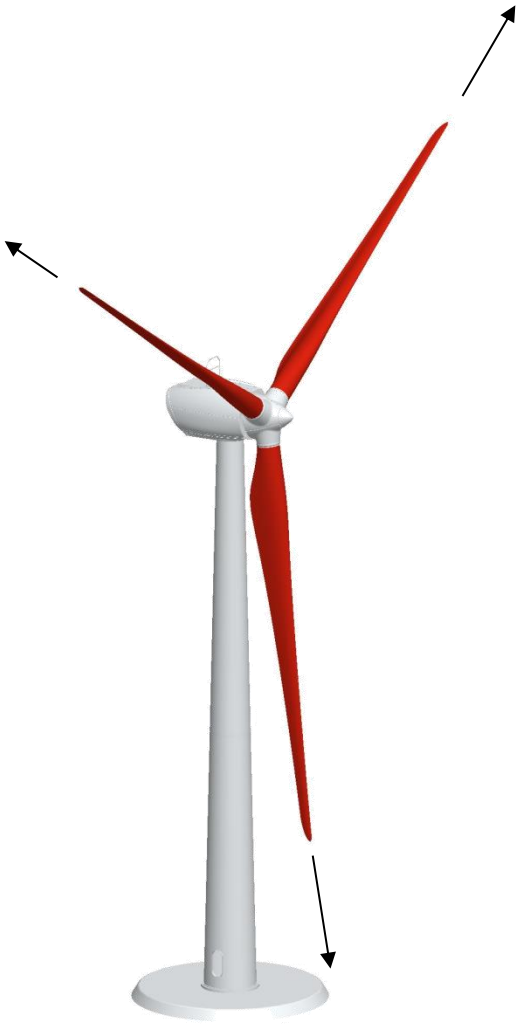
PMG compared to DFIG

2.20% increase

3.3kV compared to 690V

0.44% increase

Effect of Rotor on Generator Type

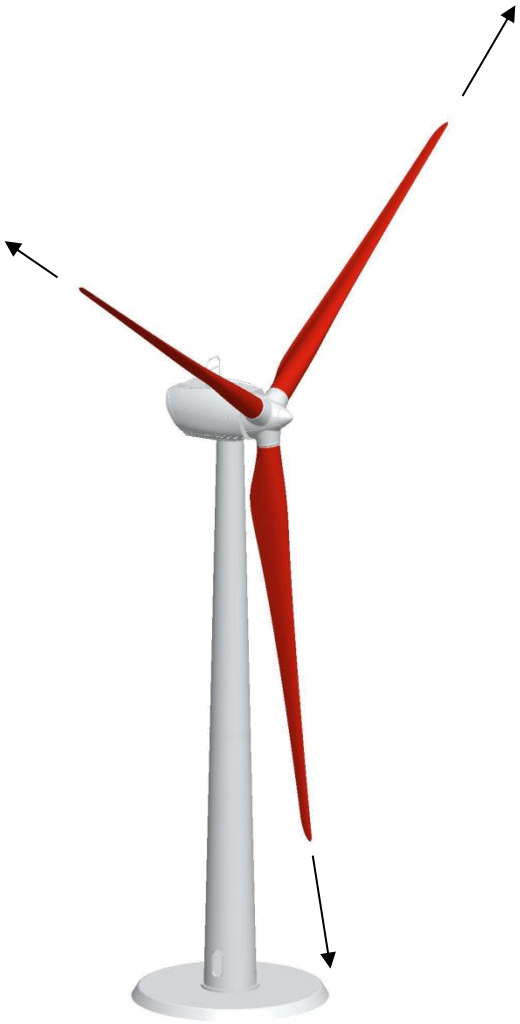


Comparison of Rotor Sizes For Generator Type		
Constants IEC Class II 8.5 mps 97:1 Gearbox Ratio		
Rotor Diameter	**126**	**148**
DFIG	baseline	baseline
PMG increase in AEP	1.85%	2.20%

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%

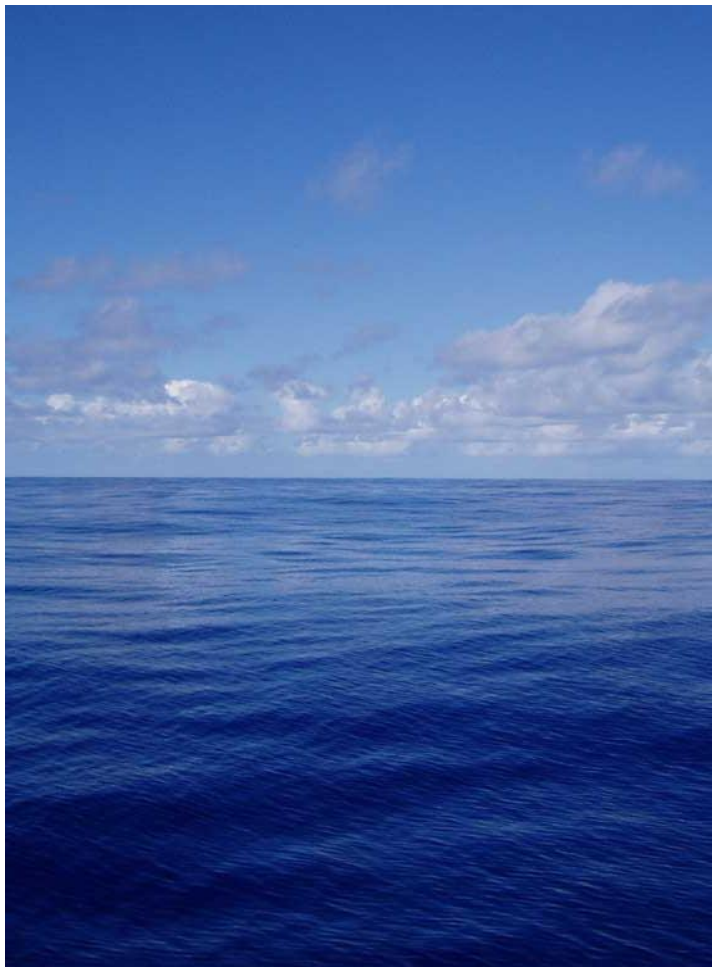
Effect of Wind Class on Voltage

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

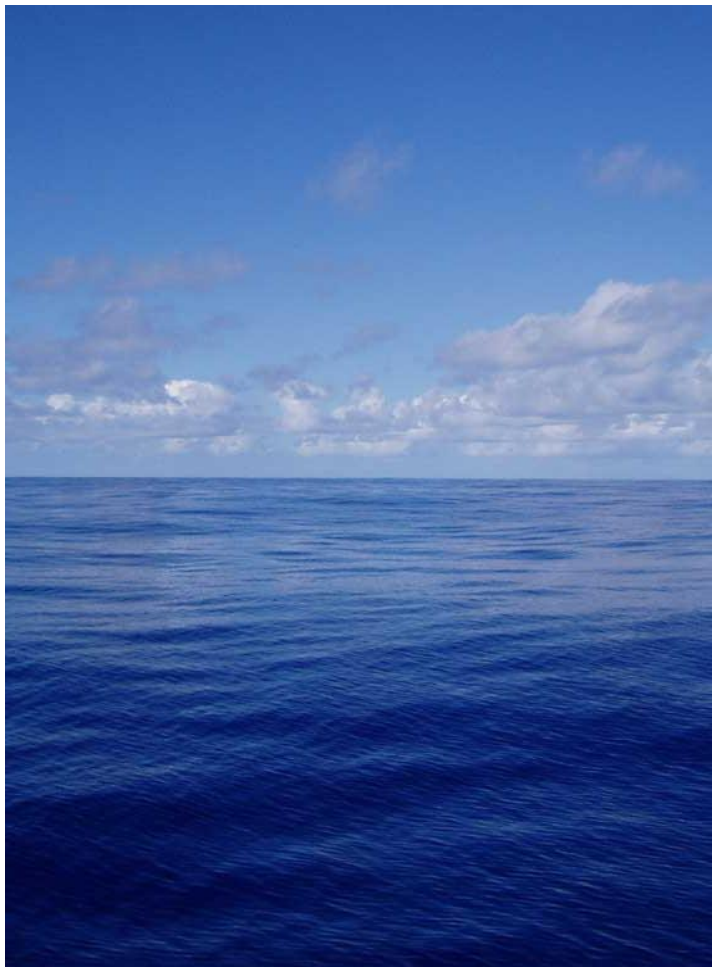
- PM Has a higher Annual Energy Production (AEP)
- This effect is stronger at low wind sites with larger rotors
- The PM has higher reliability

→ 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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