

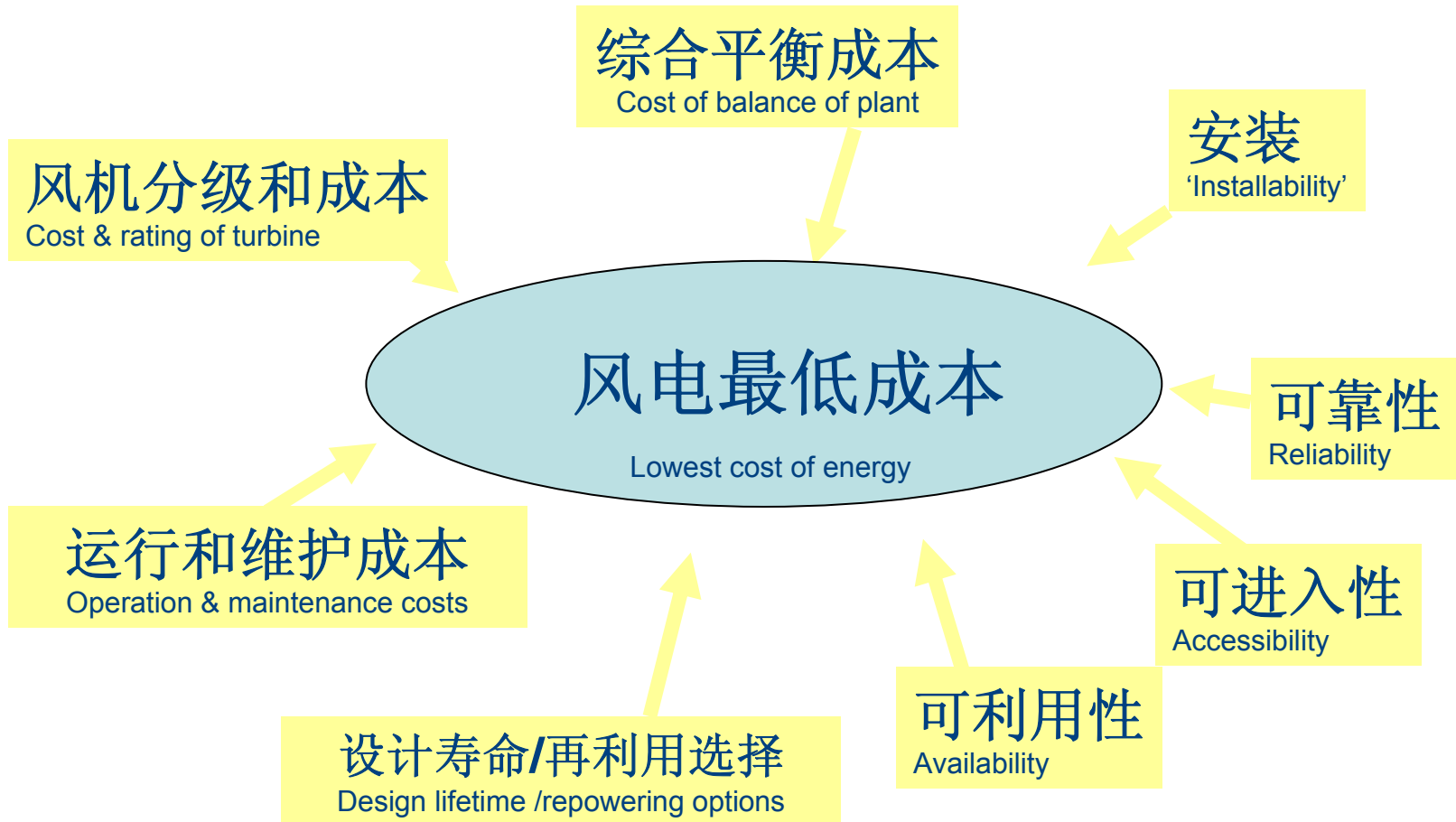


海上风机设计选型

Offshore wind turbine design options



涉及支配因素 Design driver...



概要 Outline

- 额定功率
What power rating?
- 叶片数
How many blades?
- 转速
How fast?
- 上风向风机还是下风向风机?
Upwind or downwind rotor?
- 传动链配置
Drive train configuration
- 海上风机支撑结构
Offshore support structure options

风机系统的发展

Growth of Wind Turbine Systems



1960, 24 米



2007, 126 米 直径diameter

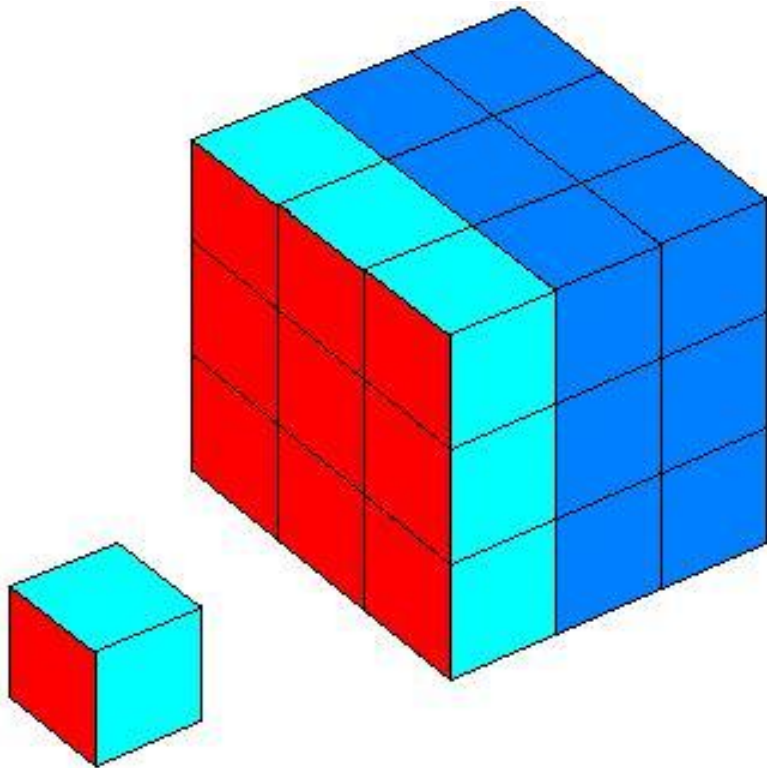
尺寸的效果和成本

The benefits & costs of scaling

- 风机叶片扫掠面积与半径的平方成正比
Rotor swept area scales with the square of the linear dimension
- 如果只考虑叶片重量引起的疲劳，叶片质量成本是尺寸的三次方，而轮毂质量阶次更高
Blade mass & cost cubic, hub mass higher power if design driven by blade weight fatigue
- 传动链的质量和成本也是按三次方增加
Drive train mass & cost essentially cubic overall for any given configuration
- 多兆瓦级风机在根本上讲经济效益差
Turbine systems are fundamentally less economic in the multi-megawatt range
- 从整个风场的经济性来看，海上风场需要大型风机
Balance of station economics justifies larger (multi-megawatt) units offshore
- 限制风机发展尺寸的因素是经济性，而不是技术
Size limits are economic long before they are technological

多叶片概念

Multi-Rotor concept?



叶片数?

How many blades?

2个叶片

2-bladed rotor

3个叶片

3-bladed rotor

能量获取

Energy capture



容易安装

Ease of installation



视觉效果

Visual attractiveness



载荷

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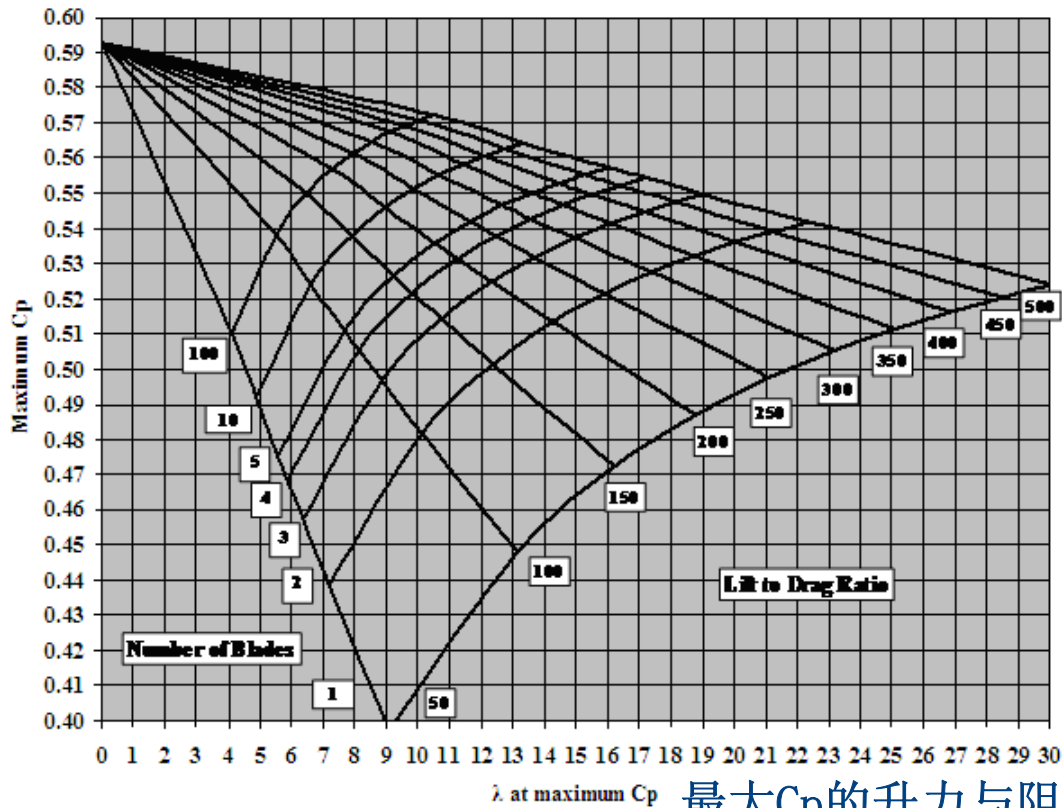


风轮单价

Net cost of rotor



最大叶片数目Cp



- 能量获取—能量获取上的小差别能影响整体的经济性
Energy capture – small differences in energy capture can be significant in overall economics

转速多快？

How fast?

- 较高叶尖速度对成本有较大的好处，在同样的功率水平下，因为高速减少了主轴扭矩意味着减少主要部件的质量和成本

Significant cost benefit in higher tip speeds. Higher speed with reduced torque at given power level means less mass and cost in major components.

- 弄明白限制约束是很重要的一噪声对于人类和海洋生物的影响，叶片前缘磨损，气动阻尼和阻力

Very important to clarify constraints – noise for humans or sea mammals, leading edge erosion, aerodynamic damping & drag

- 最新技术，能在尖速比高达**10**的时候，达到最优气动效率

State of the art, high lift aerofoils can allow optimum aerodynamics at tip speed ratios as high as 10

- 叶片设计的挑战是更有效的利用碳纤维

Challenge to blade design making the use of carbon more efficient?

是上风向还是下风向风轮？

Upwind or downwind rotor?

- 在岸上，因为噪声限制，最大叶尖速度通常在最大**65—75m/s**
Onshore, tip speeds are generally constrained by noise to a maximum of 65 -75m/s
- 在海上，噪声限制允许放宽，可以有更高的叶尖速度
Offshore, noise constraints may be relaxed to allow higher tip speeds.
- 随着叶尖速度的增加，风轮实度随着叶尖速度的平方递减→一个按**120m/s**叶尖速度优化设计的叶片的宽度仅是按**60m/s**叶尖速度设计的叶片的**1/4**
As tip speed is increased, the optimum rotor solidity reduces inversely as the square of tip speed → an optimum rotor for 120 m/s tip speed will have ¼ of the width in its blade sections of one designed for 60 m/s tip speed.
- 随着叶尖速度的增加,叶片更加柔软,很难运用于塔架上风的风轮设计
Blades become increasingly flexible as tip speed is increased & so difficult to operate upwind of the tower
- 下风向设计更合适—但是却会产生更多的噪声
Downwind configuration looks attractive – but other noise issues arise

传动系统选型

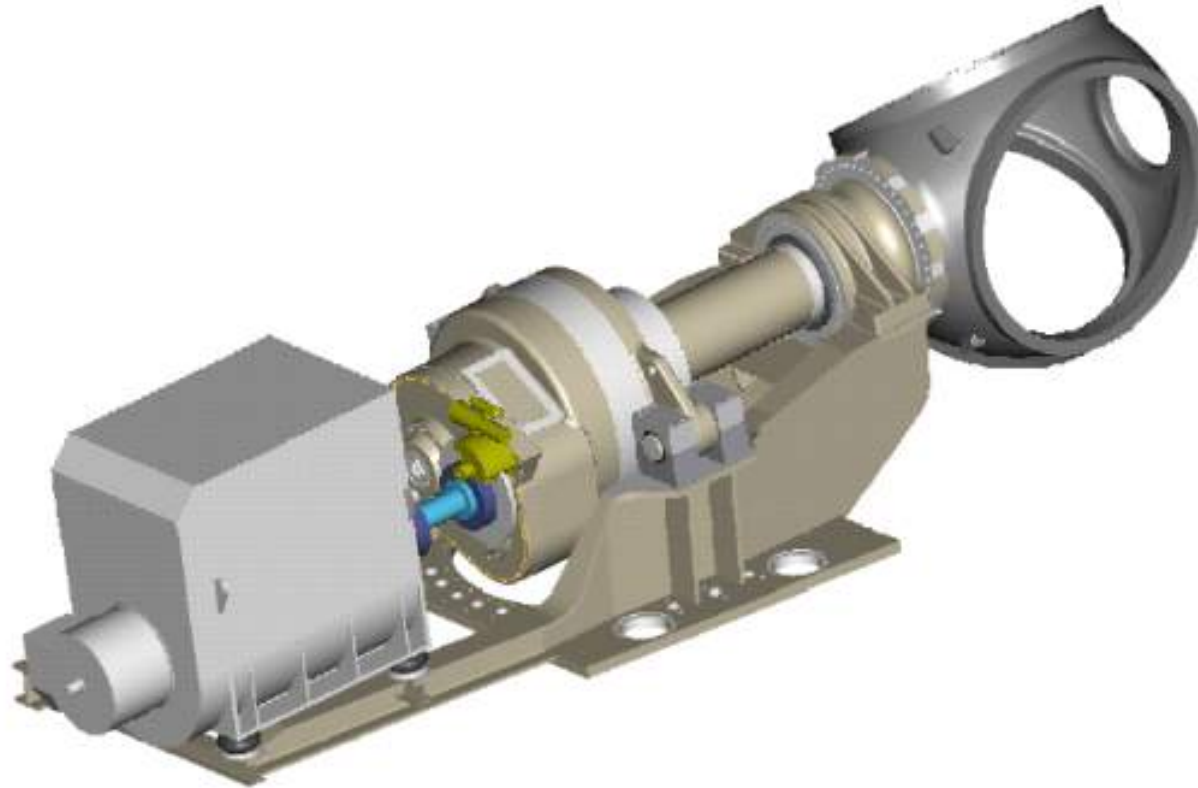
Power train options

- 齿轮箱和高速发电机
Gearbox and high speed generator
 - 常规解决方案
“Conventional” solution
 - 模块化设计或者一体化设计?
Modular or integrated?
- 直驱
Direct drive
- 混合驱动
Hybrid drive
 - 带有中速发电机的单级传动平台
Single gear stage with medium speed generator
- 多发电机系统
Multiple generator system



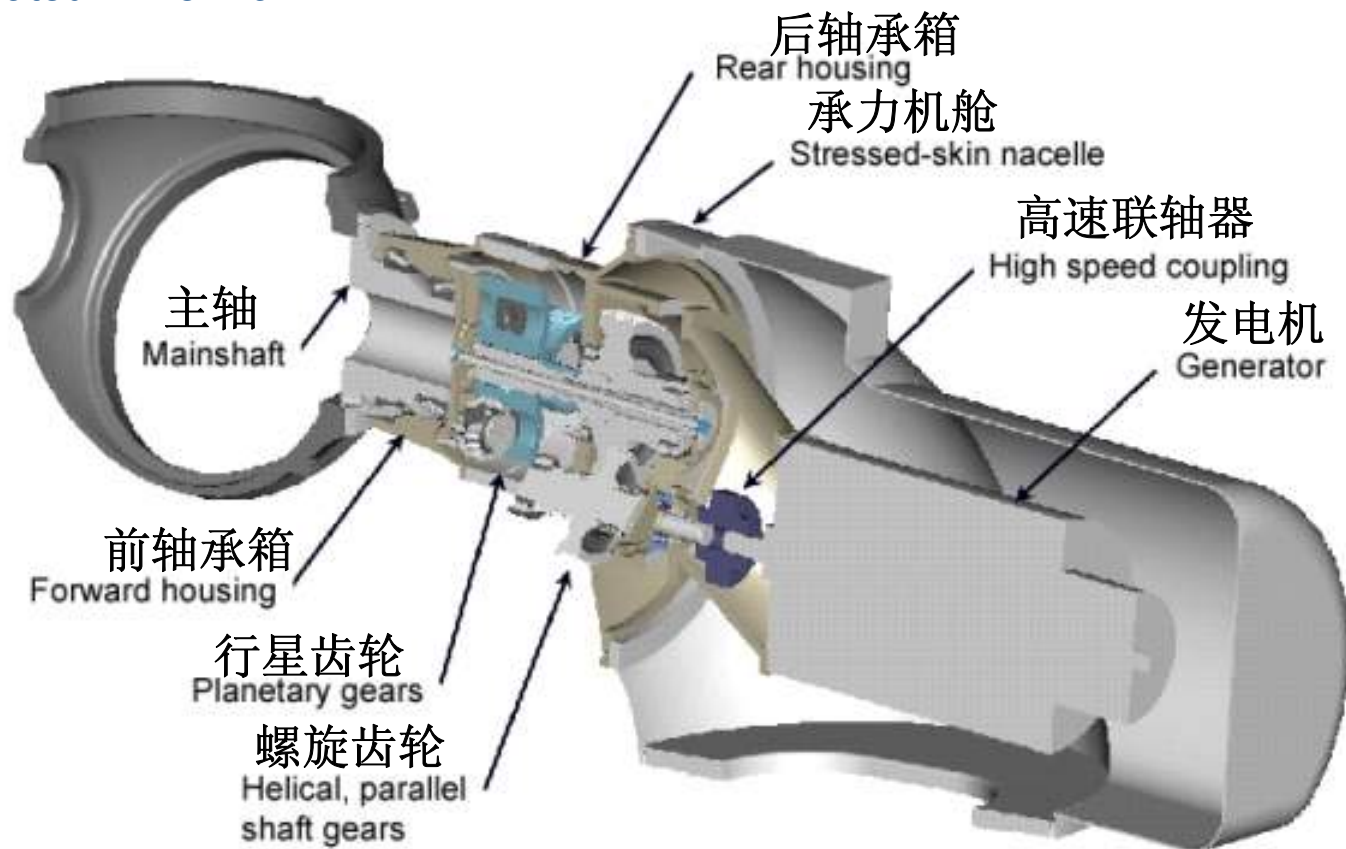
齿轮箱和高速发电机

Gearbox and High Speed Generator



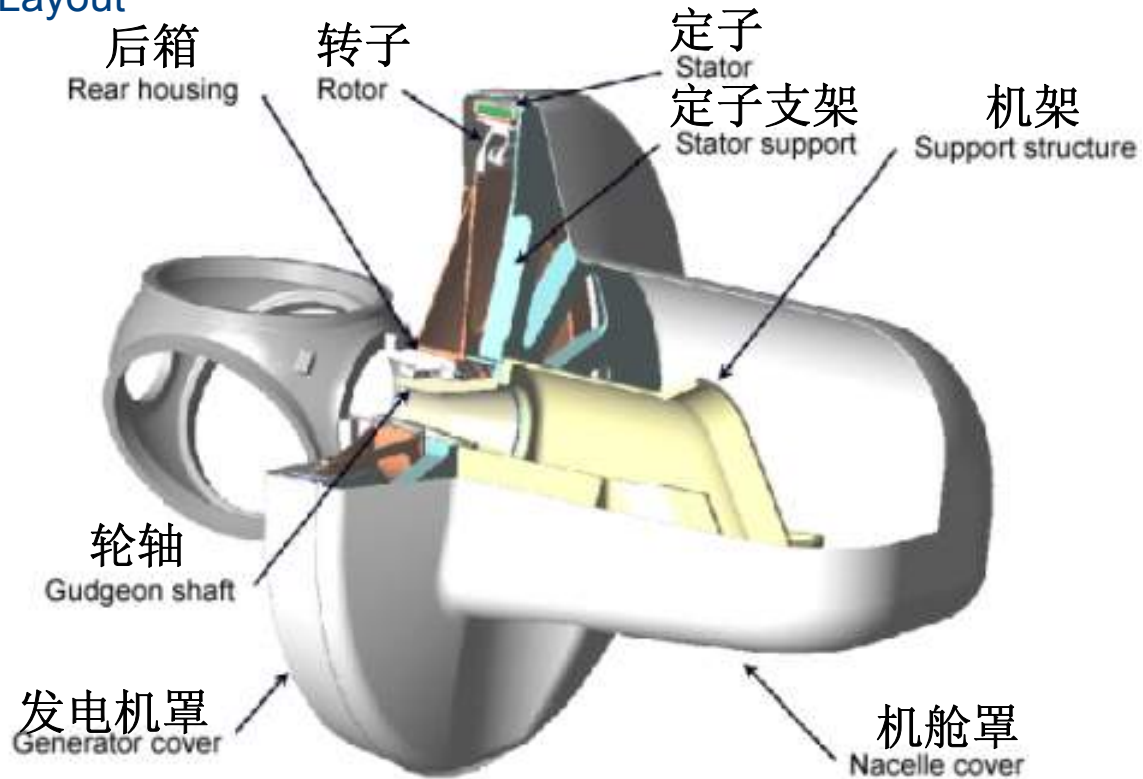
一体化传动链

Integrated Drive Train



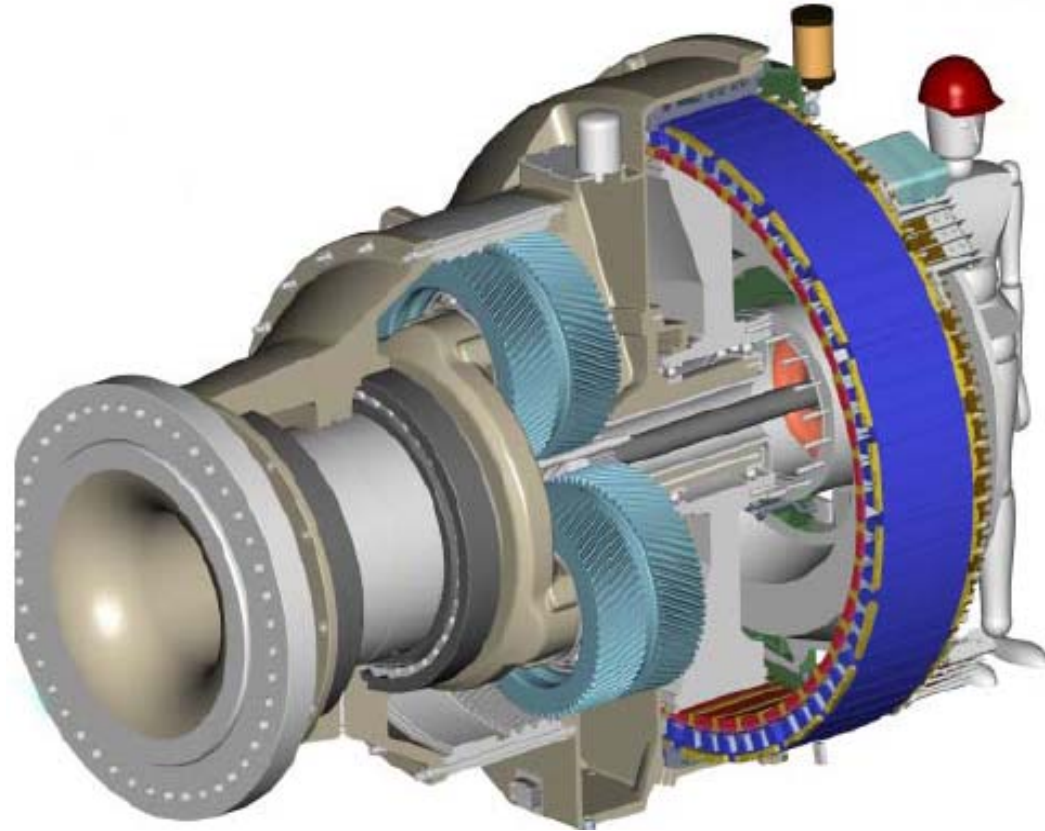
直驱布局

Direct Drive Layout



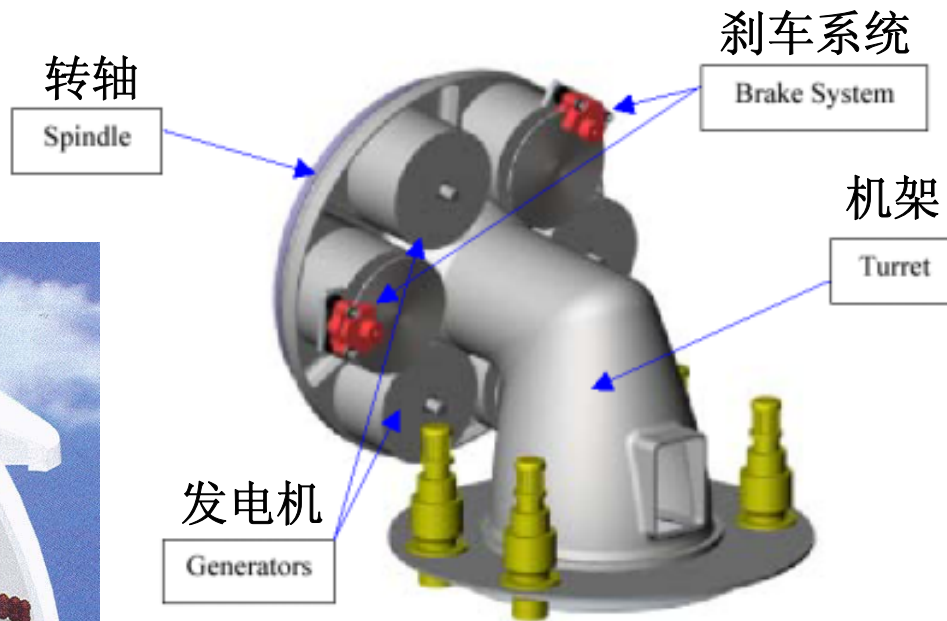
混合传动系统

Hybrid Transmission System



多发电机系统

Multiple Generator Systems



支撑结构概念选型

Support structure concept selection

2007: 1.2 GW



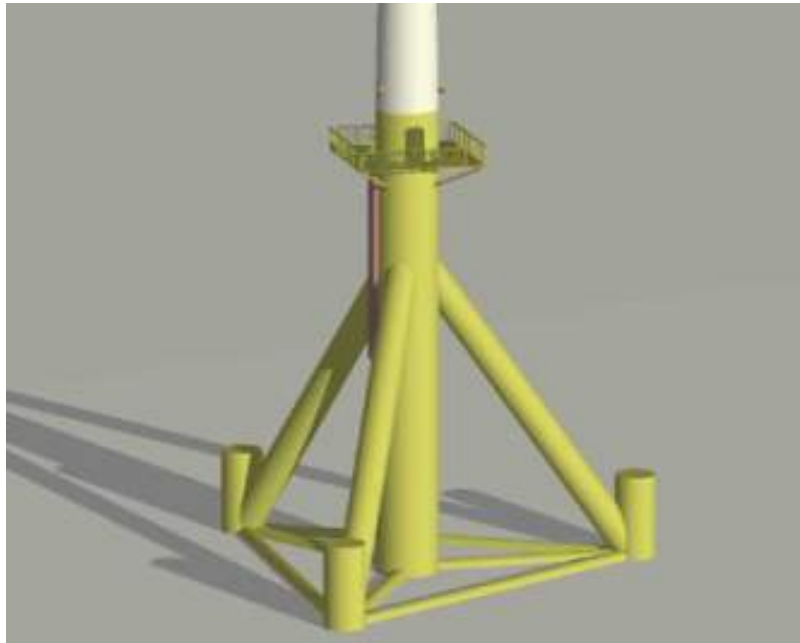
www.offshorewindenergy.org



可能的刚性解决方案

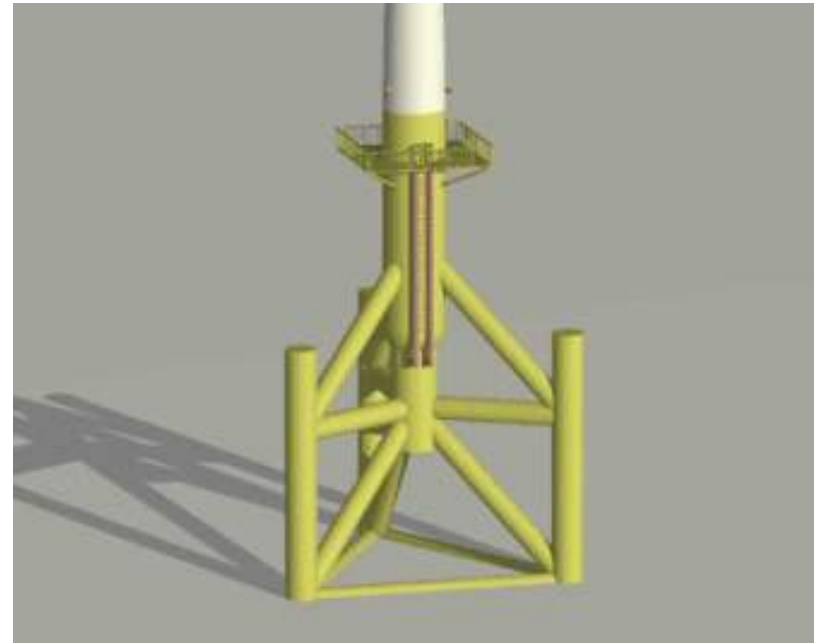
Possible “stiff” solutions

www.offshorewindenergy.org



简单三桩支撑/四桩支撑

Simple tripod / quadrupod



复合三桩支撑

Complex tripod

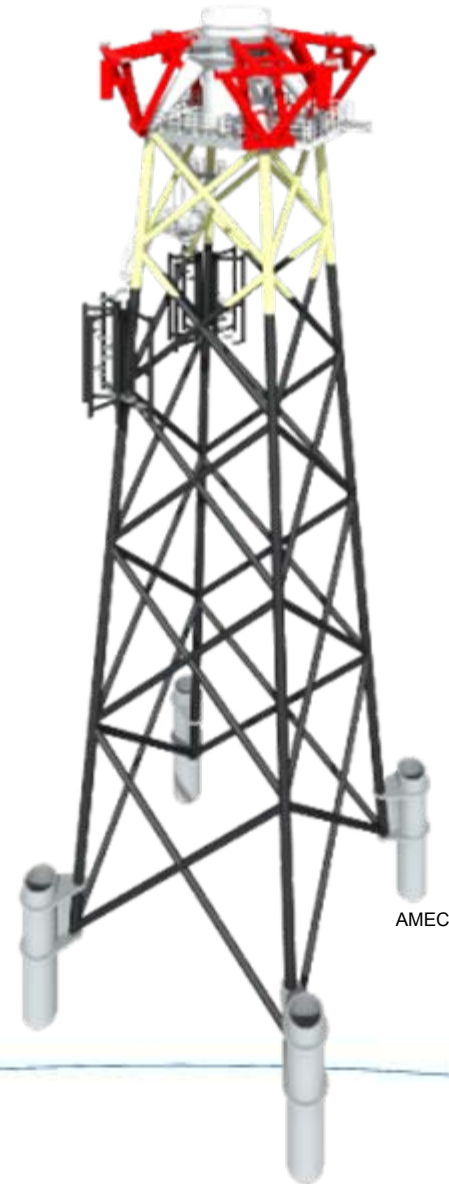
可能的刚性解决方案

Possible "stiff" solutions



REpower

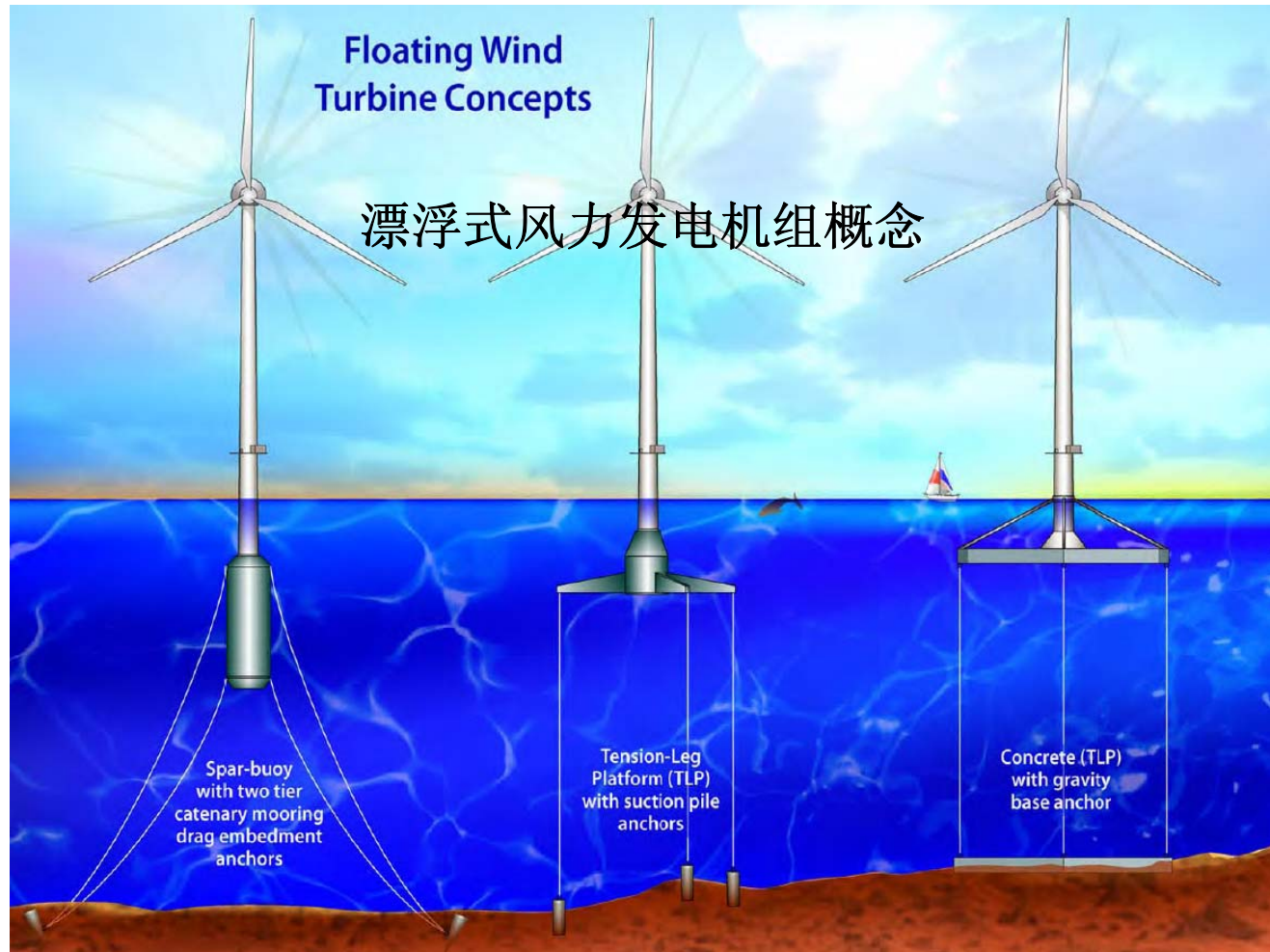
Downwind 下风向 / Beatrice



可能的柔性解决方案

Possible "soft" solutions

NREL



未来的技术发展趋势

Future trends in technology

- 高于5MW ?
Above 5MW?
- 所有的风力发电机组都趋向PMGs?
Towards PMGs in all turbines?
- 趋向直驱和混合驱动
Towards direct and hybrid drives
- 智能型叶片
Towards the intelligent blade
- 海上浮动风场?
Floating systems offshore?