Turbine Life Cycle Engineering

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Life Cycle Engineering

- ✓ Where it all begins?
- ✓ All resources are limited, including ability of the earth and atmosphere to clean itself
- ✓ Major water and atmosphere pollutants, e.g., CO_2, NO_x, and SO_x
- ✓ CO_2 emissions in the energy production process (in particular the wind energy equipment production)
- ✓ Water contamination by industry, e.g., waste disposal, etc.
- ✓ Waste and disposal of contaminants and resources, e.g., electronics, mercury, cellulose (paper)

Sustainable Development

Main goal

- ✓ Meeting our needs without negative impact on the ability of future generations to meet their needs

- ✓ Most disputes evolve around who is going to pay for making the world clean and healthy
- ✓ Is it natural to be sustainable (responsible, no debt, …)

Sustainability Chain in Wind Energy

Energy usage and environmental impact perspective

- ✓ Extraction of natural resources, e.g., iron ore, chemicals, cellulose
- ✓ Transportation of natural resources
- ✓ Production of raw materials, e.g., iron, fiber glass
- ✓ Fabrication and machining – material processing
- ✓ Assembly of subsystems
- ✓ Transportation
- ✓ Final assembly
- ✓ Service (operations and maintenance)
- ✓ Product end of life

Sustainable Manufacturing

- ✓ Sustainability is of paramount importance in wind energy industry due to high material (energy) content, e.g., gearbox, tower, cables
- ✓ Sustainability has not been sufficiently addressed at this time by the wind energy industry due to the wind energy "rush"
- ✓ Now is the very last opportunity (somewhat late) to address turbine life-cycle engineering issues in wind industry

The Four-Criteria Dilemma

- ✓ Maximization of turbine performance
- ✓ Maximization of turbine life-cycle
- ✓ Minimization of energy used to built a turbine
- ✓ Minimization of environmental impacts

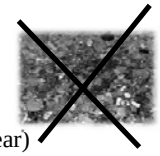
Emerging solution: Predictive engineering

Source of Decreased Wind Turbine Life Time?

- ✓ Problem: Variable loads
- ✓ Key issue: Torque management is a viable solution to reduction of extreme stresses
- ✓ Solution: Anticipation of the extreme loads (wind conditions)
- ✓ Implementation: Predictive engineering

What to Do With an Old Wind Farm Equipment?

Restored 1949 VW Bug



- ✓ Reuse (most preferred)
- ✓ Remanufacture
- ✓ Recycle
- ✓ Disposal (should disappear)

Life cycle engineering

Life Cycle Engineering

Best industrial practices

- ✓ Fuji-Xerox
- ✓ Caterpillar
- ✓ Appliance industry, e.g., washers

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UI's "Wind Turbine Corporation"

Design, process, and mfg engineers:
- ✓ Kevin Langan
- ✓ Robbie Lovstuen
- ✓ Dan Rogge
- ✓ Matt Zanker

UI engineering students

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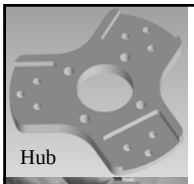
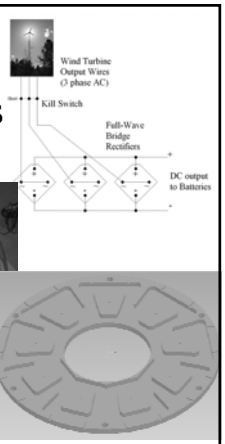
Turbine Components



Hub

Coil manufacturing



Generator components designed for reuse and remanufacturing

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Turbine Components

Vane

Rated power: 750 W
Total cost: $354

Yaw mechanism

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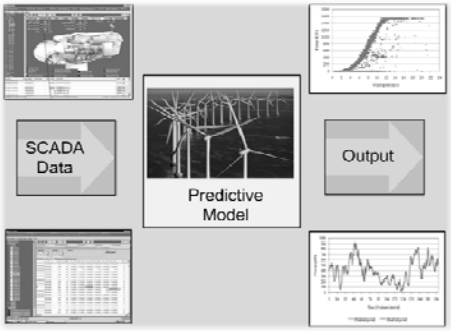
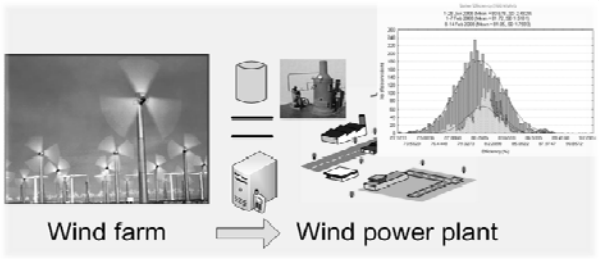
Predictive Engineering and Residual Life



Predictive Engineering and Power Estimation



Sustainable Manufacturing

Life Cycle Engineering covers issues ranging from product (component) conceptual design to its retirement

Basic ways of assembly (component) retirement:
- ✓ Reuse (most preferred)
- ✓ Remanufacture
- ✓ Recycle
- ✓ Disposal (should disappear)

Sustainable Manufacturing

Why reuse?
How long does it take to decompose when disposed in a landfill?

- ✓ Paper: 2 – 5 months
- ✓ Orange peels: 6 months
- ✓ Milk cartoons: 5 years
- ✓ Plastic bags: 10 – 20 years
- ✓ Leather shoes: 24 – 40 years
- ✓ Plastic containers: 50 – 80 years
- ✓ Disposable diapers: 75 years
- ✓ Tin cans: 100 years
- ✓ Aluminum cans: 200 – 500 years

Life Cycle Engineering

Assembly (component) reuse

- ✓ Products involve components and assemblies with different useful life time
- ✓ Estimating (predicting) residual life time of components and assemblies is of importance to their reuse
- ✓ A component (assembly) designed for sustainability may be reused a number of times and serve different product generations

Life Cycle Engineering

Assembly (component) remanufacture

- ✓ Components (assemblies) that can not be reused in "as is" form could be remanufactured and then used in the current or next product generations

Life Cycle Engineering

Assembly (component) recycle

- ✓ Components (assemblies) that can not be reused and remanufactured should be recycled in most environmentally conscious way
- ✓ Components (assemblies) disposal should meet the highest standards of the societal scrutiny
- ✓ The long-term goal should be elimination of the product disposal as the life cycle alternative

Benign Manufacturing and Transportation

- ✓ The turbine manufacturing process itself and transportation should not adversely impact the natural environment
- ✓ Manufacturing processes with minimal adverse impact on the environment should be developed
- ✓ Supply chain logistics should focus on minimizing transportation energy during the wind farm construction as well as operations and maintenance

Ubiquitous Manufacturing and Wind Farm Operations

- ✓ A ubiquitous system involves many sensors, including RFIDs
- ✓ Comprehensive integration of information among physical objects (e.g., machine tools, components) and people for the best outcomes in productivity, quality, and energy use
- ✓ The concept of *ubiquitous* systems could apply to turbine manufacturing, transportation, and wind farm operations

Summary

- ✓ Wind energy industry needs to embrace the principles of life cycle engineering
- ✓ Energy needed to build, transport, and maintain a wind turbine needs attention
- ✓ Design of components (assemblies) for reuse should become a standard practice