

**ELG4126**

**Distributed Generation and Renewables**

Case Study of

**Renewable Energy and Smart Grid**

of Three Phases

# Phase One: Wind Farm

- Conduct a feasibility study for initiating a profitable wind energy farm in Ontario. You may add electricity storage to your project to benefit from the peak premium! Generally the development and operation of a wind farm can be subdivided into the following four steps:
- **Initiation and Feasibility (concluded by go/no-go)**
  - Municipal consultation.
  - Site selection and wind assessment (proposed site; available wind resource; wind power forecasting)
  - **Technical feasibility:** Description of candidate turbines; See next page!
  - Main risk assessment: Obstacles and impacts.
  - Planning requirements of local authorities.
  - Economics based on annual energy production: Revenue, costs, economic indicators.
- **Prebuilding (concluded by go/no-go)**
  - Wind farm design including energy yield predictions (wake losses; grid losses; availability)
  - Planning procedures (environmental issues; noise; visual impact; safety)
  - Grid connection
  - Selection of suppliers
  - Project financing.
- **Building**
  - Overview of the building process
  - Quality control during production and construction
  - Commissioning and handover.
- **Operation and Maintenance**
  - Daily operation
  - Warranties and insurance
  - Maintenance and repair.

# Visit: CANWEA

- Building a Wind Farm:

[http://www.canwea.ca/farms/planning\\_e.php](http://www.canwea.ca/farms/planning_e.php)

- Wind Farms in Canada:

[http://www.canwea.ca/farms/wind-farms\\_e.php](http://www.canwea.ca/farms/wind-farms_e.php)

- Wind Projection:

[http://www.canwea.ca/farms/future\\_e.php](http://www.canwea.ca/farms/future_e.php)

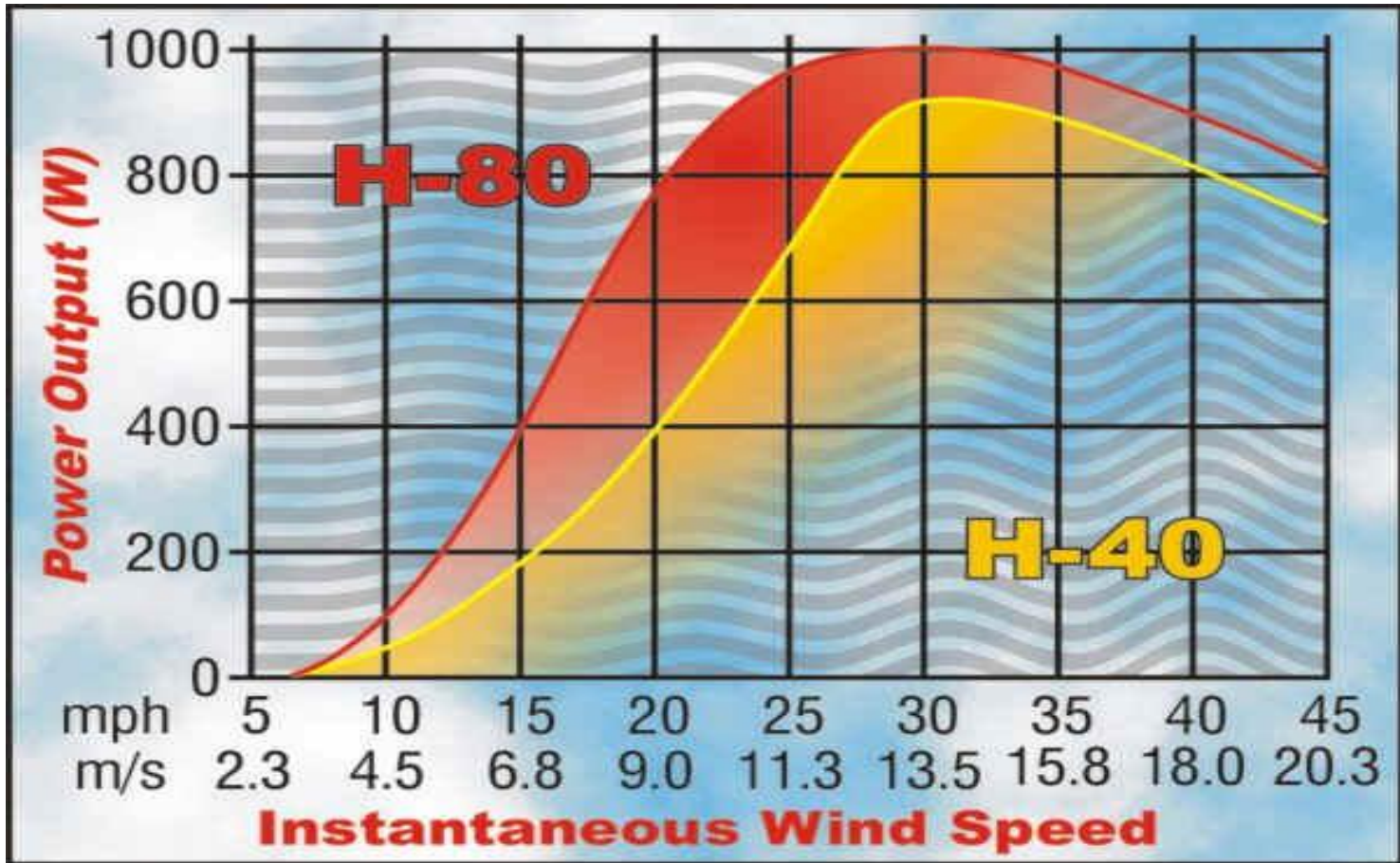
- Case Studies

[http://www.canwea.ca/farms/casestudies\\_e.php](http://www.canwea.ca/farms/casestudies_e.php)

# Wind Power Forecasting

- The main tool for assessing the wind resources at prospective wind-farm sites is “**measure, correlate, predict**” (MCP) analysis.
- This involves comparing a short-term sample wind measurement at the site itself with years' worth of historical wind data taken from a nearby airport or permanent weather station.
- Using statistical models to take account of the difference between the target site and the reference site, developers may then build a detailed picture of the potential wind resources.
- Once wind turbines are up and running, the forecasting focus shifts from long-term averages to short-term specifics.

# Power versus Velocity



# Wind Turbine Energy Production

- While wind turbines are most commonly classified by their rated power at a certain rated wind speed (power curve), annual energy output is actually a more important measure for evaluating a wind turbine's value at a given site:

$$\text{Energy} = \text{Power} \times \text{Time}$$

- Expected energy output per year can be reliably calculated when the wind turbine's **capacity factor** at a given average annual wind speed is known. The capacity factor is simply the wind turbine's actual energy output for the year divided by the energy output if the machine operated at its rated power output for the entire year.
- A reasonable capacity factor would be 0.25 to 0.30. A very good capacity factor would be 0.40. For example, for a 100 kW turbine producing 20 kW at an average wind speed of 15 mph, the calculation would be

$$20 \text{ kW} \times 8760 = 175,200 \text{ kWh}$$

# How to Calculate Capacity Factor?

- **Capacity Factor**
  - Start with 100%
  - Subtract time when wind speed is less than optimum
  - Subtract time due to scheduled maintenance
  - Subtract time due to unscheduled maintenance
  - Subtract production losses:
    - Dirty blades
    - Shut down due to high winds.
  - Typically 33% at a 6 m/s wind site.
- **Performance Improvements due to:**
  - Better siting
  - Larger turbines/energy capture
  - Technology Advances
  - Higher reliability
- Capacity factors > 35% at good sites.

# Wind Turbine Technical Specifications

- Installed Power: 10 MW (Hypothetical )
- Determine Energy Use in Terms of MWh/year.
- Draw the outline of the regional grid and Specify:
  - Transformer(s) and Bus(s) Specifications.
  - Voltage Ratings.
  - A scheme of Integration with the Grid.
- Determine:
  - Number of Wind Turbines
  - Hub Height
  - Rotor Diameter
  - Foundation
  - Nacelle Weight
  - Tower Weight
  - Life Span

# Interconnection to the Grid

- The grid requires to perform distributed energy resource (DER) impact studies under regulatory time constraints.
- The following IEEE and IEE standards define requirements and test procedures for DER projects.
  - *IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems*, IEEE Std. 1547-2003 (reaffirmed 2008).
  - *IEEE Standard Conformance Test Procedures for Equipment Interconnecting Distributed Resources with Electric Power Systems*, IEEE Std. 1547.1-2005.
  - *IEEE Application Guide for IEEE Std 1547, IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems*, IEEE Std. 1547.2- 2008.
  - *IEEE Recommended Practice for Measurement and Limits of Voltage Fluctuations and Associated Light Flicker on AC Power Systems*, IEEE Std. 1453-2004.
  - *Measurement and assessment of power quality characteristics of grid connected wind turbines*, IEC Std. 61400-21 ed. 2, August 2008.

# General Requirements for Connection to the Grid

- Wind turbine generator (WTG) size as a percentage of peak feeder segment load. This should be 15% or less to accept the project without further study. If higher, the possibility of unintended islanding exists.
- WTG fault contribution, which should be no more than 10%. If higher, a protection coordination study should be done.
- Capacity factor for wind, which is important for the developer to evaluate economic benefits. For the interconnection, a higher capacity factor may increase the risk of unintended islanding.
- System source strength at the point of common coupling (PCC), which is useful in flicker, harmonic, and voltage change evaluation.
- The maximum steady-state voltage change as the DER cycles between zero and full output. This should be no more than 5%, and some utilities limit the change to 3%. The DER operating power factor affects this value.
- Flicker severity estimate, or if WTG flicker data is not available, the maximum WTG flicker coefficients to meet the IEEE planning limits.

# Technical Aspects

- There are many technical aspects related to the grid connection of wind turbines:
  - Feeder concept between wind turbine / wind farm and grid
  - Grid protection
  - Reactive power requirements
  - Voltage control and tolerance of voltage deviations
  - Short circuit power
  - Dynamic and transient stability
  - Low voltage ride through
  - Participation in frequency control and tolerance of frequency deviations
  - Neutral point treatment
  - Insulation coordination
  - Flicker and harmonics

# Interconnection: Requirements for the Case Studies

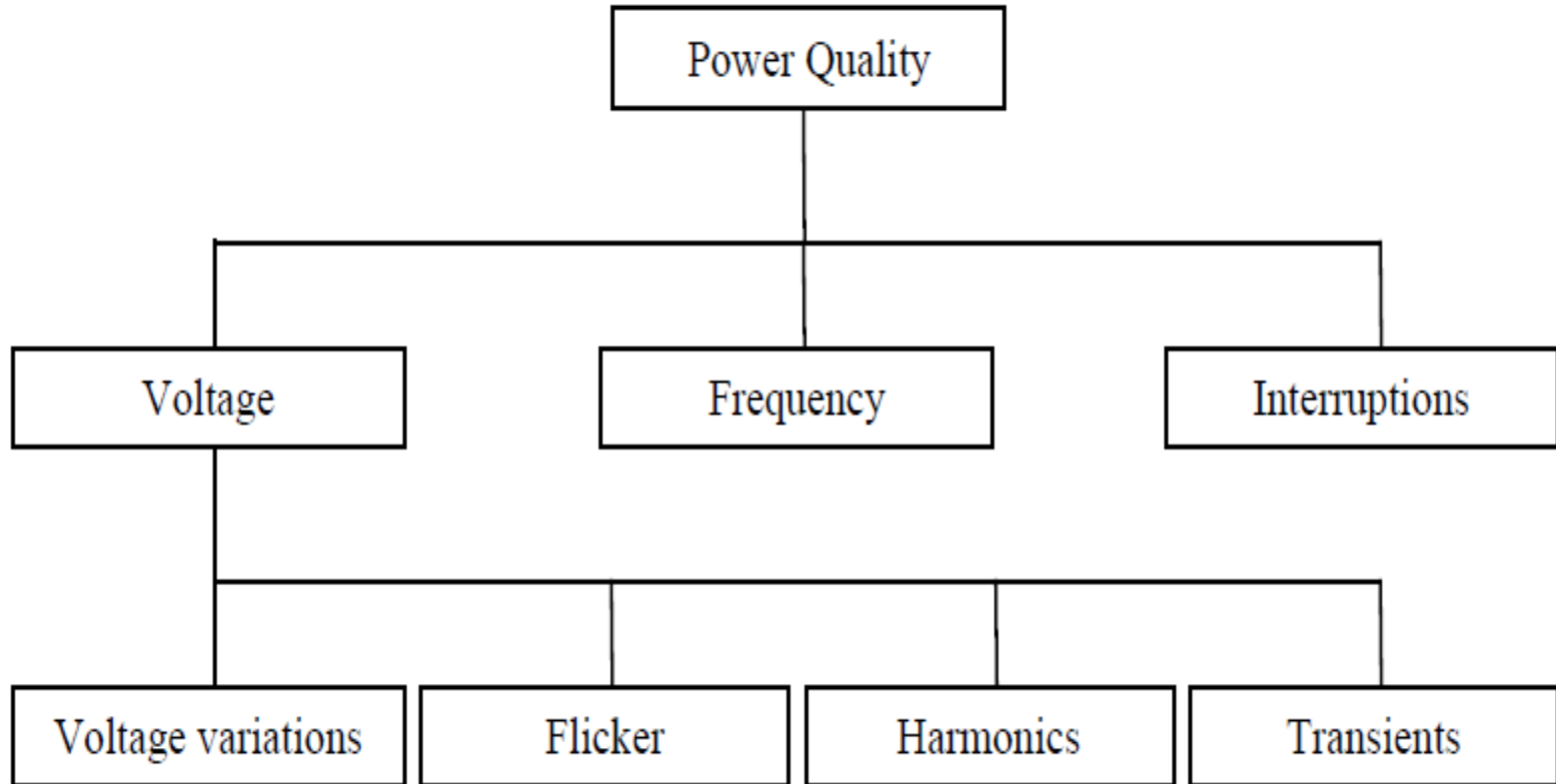
- Type of the Wind Turbine
- Type of the Generator
- Per Unit Fault Current
- Operating Power Factor
- Feed Inputs
- Substation Transformer Capacity
- Feeder Primary Voltage
- Wind Turbine Distance from the Substation
- Peak Load
- Capacitor Bank (kVAR Capacity)
- Regulator Distance from the Substation
- Protection Schemes

# Power Quality Issues

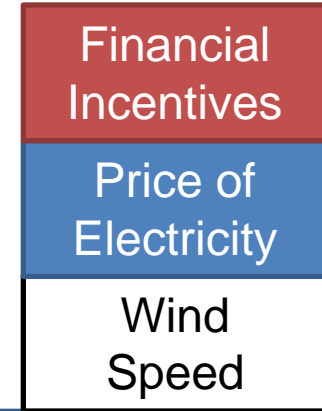
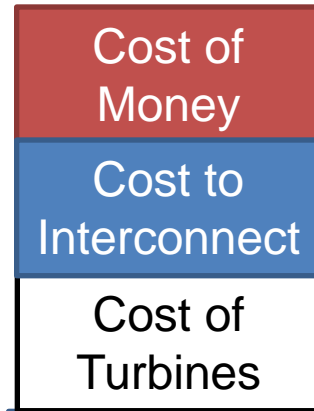
- Special attention should be given to flicker and flicker calculations, according to this recommendation:

The operation of wind turbines has an impact on the power quality of the connected grid. Depending on the grid configuration and the type of wind turbine used, different power quality problems may arise. All wind turbines have an uneven power production following the natural variations of the wind. If the wind turbine is operating at fixed-speed, the tower shadow and wind speed gradients will result in fluctuating power. The power fluctuations caused by the turbine may cause flicker disturbances. In order to evaluate the significance of flicker, measurements and subsequent flicker calculations must be performed. In the case of variable-speed wind turbines, one drawback is the injection of harmonic currents into the grid. Depending on the type of inverter used, different orders of harmonics are produced.

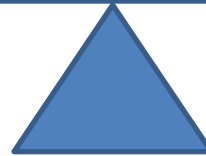
# Power Quality Problems



# Economics of Wind Generation: Balance of Factors

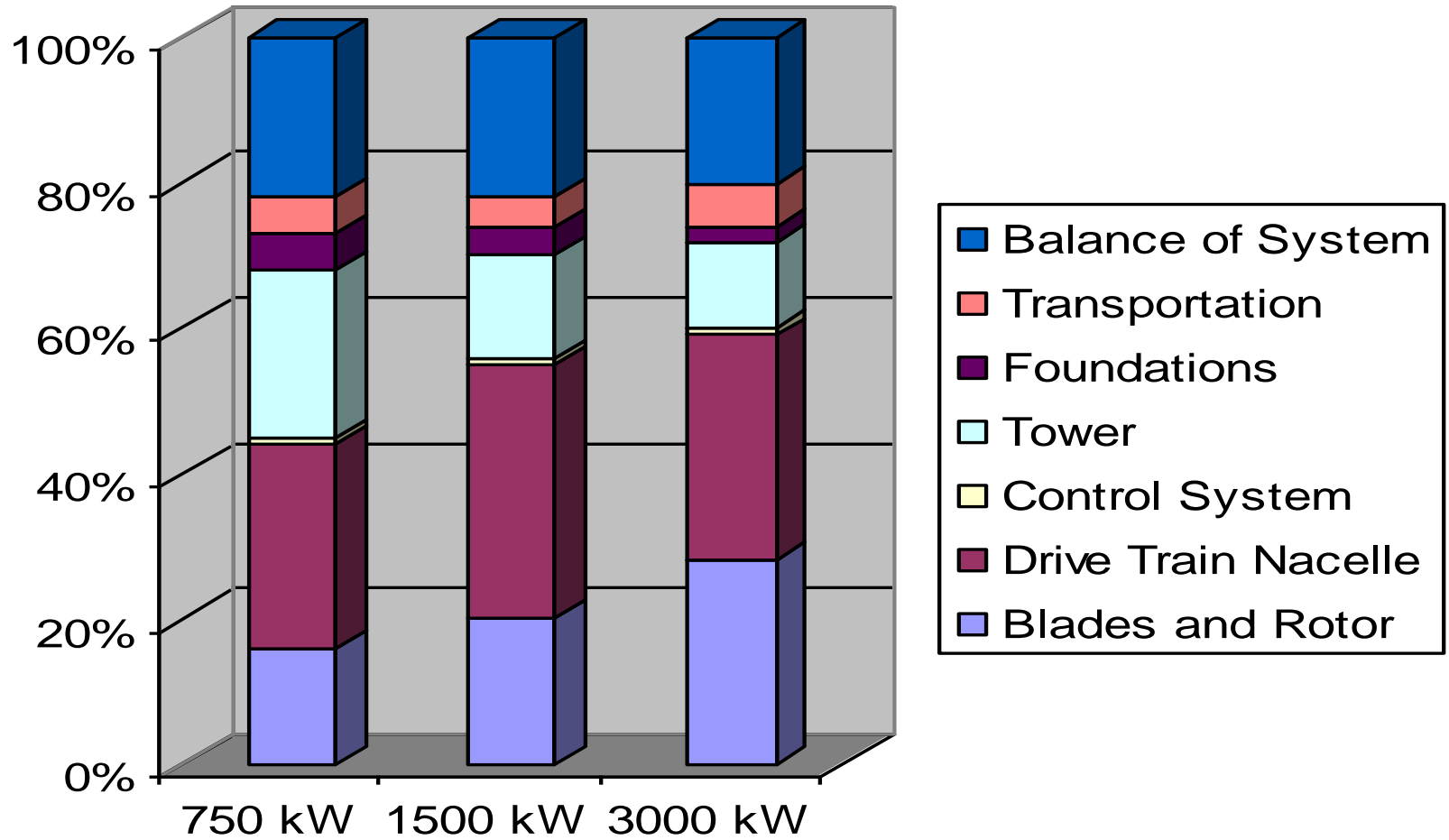


Higher Values  
**DISCOURAGE**  
Wind  
Generation

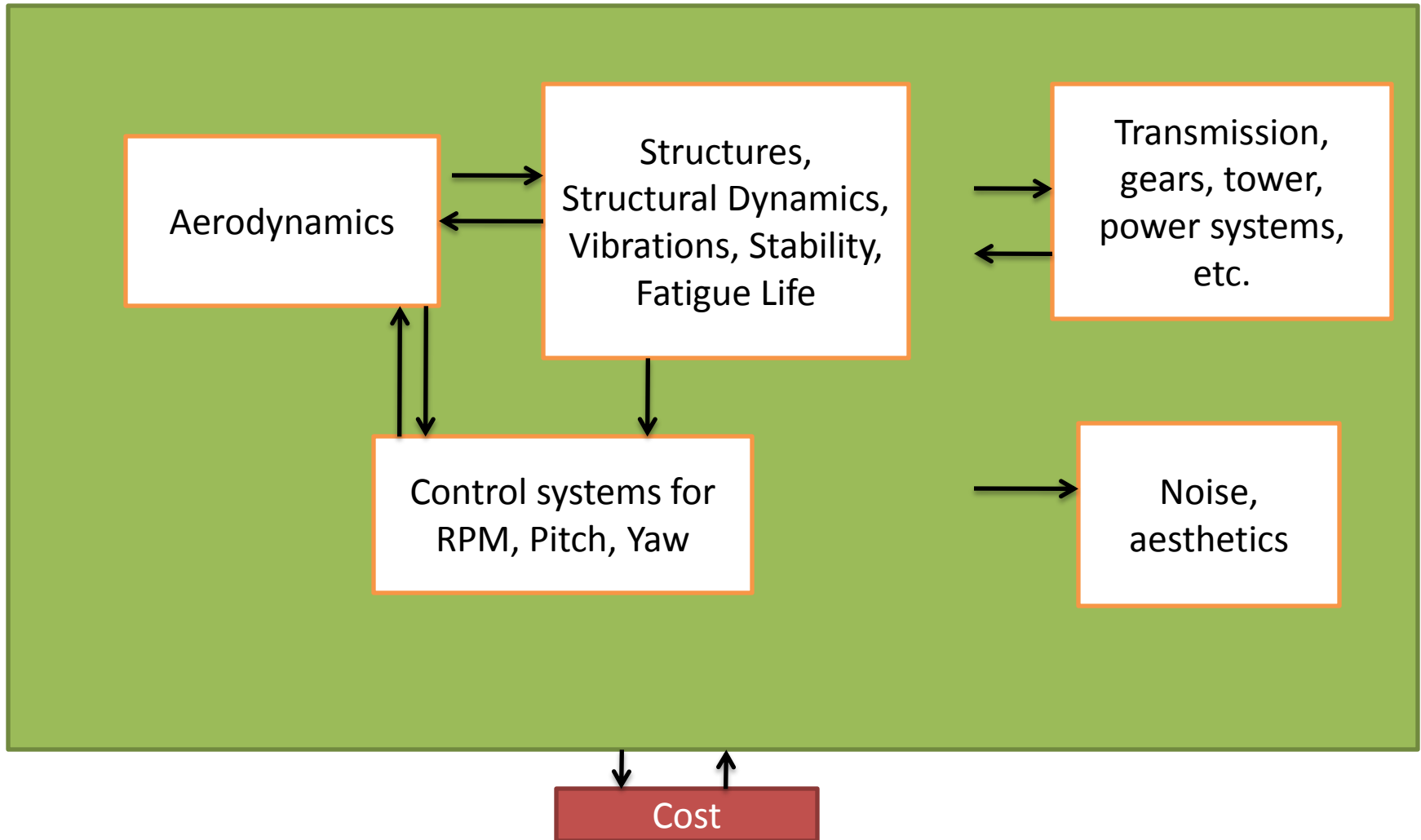


Higher Values  
**FAVOR**  
Wind  
Generation

# Wind Turbine Cost Components



# Wind Turbine Design is an Interdisciplinary Problem



# Parameters to be Chosen

- We need to decide on
  - Number of blades
  - Blade platform (for example, how does chord vary with radius)?
  - Blade radius
  - Blade twist distribution
  - Airfoils
  - RPM
  - Decisions about variable RPM, variable pitch
- We need to consider cost, noise, vibrations, fatigue, etc as well.

# Wind Turbine Size-Power Comparison

