Agenda

01 Introduction

02 Current Methods
- Drive train
- Tower and Substructure
- Wind Farm
- Value Analysis

03 Future Work

04 Management of ISD Tools
Introduction

• The need for Integrated System Design and Optimization is understood and accepted.

• Driven by market competitiveness – must minimize costs and maximize performance.

• Wind farms fall into the category of “mass customization”.

• Use of Integrated System Design (ISD) has multiple benefits:

  1. Identification of system design drivers $\rightarrow$ reduction of time at early stages of the project; R&D cost savings.

  2. Reduction of cost of energy and project risk $\rightarrow$ more room to optimize and identify critical risks due to multiple results.

  3. Increases competitive advantage $\rightarrow$ enables OEM’s to deliver optimized solutions to customers, reduces time to market.
01 Introduction

02 Current Methods
- Drive train
- Tower and Substructure
- Wind Farm
- Value Analysis

03 Future Work

04 Management of ISD Tools
Alstom Current Methods

Component Level
- SAMCEF
- ANSYS
- Ncode
- modeFrontier
- Hyperworks
- Matlab
- Excel
- Several others

Turbine Level
- SAMCEF
- modeFrontier
- BLADED
- Matlab
- FAST
- Excel

Wind Farm Level
- Openwind
- Excel

Applications for various system levels and phase in the design process
Drive train
Conceptual Design: Haliade™ 150-6MW

Major design choices targeting to reduce wind offshore CoE

1. Drive Train

2. Rotor diameter

3. Power rating

Direct Drive decision derived at the wind farm level

© ALSTOM 2013. All rights reserved. Information contained in this document is indicative only. No representation or warranty is given or should be relied on that it is complete or correct or will apply to any particular project. This will depend on the technical and commercial circumstances. It is provided without liability and is subject to change without notice. Reproduction, use or disclosure to third parties, without express written authority, is strictly prohibited.
Cost-benefit analysis during conceptual design phase

Net Present Value of costs: 500-800k€ estimated lifetime extra costs for a 6MW geared turbine

- Considering one gearbox change over 20 years
- 2 campaigns of 50% of gearbox replacement around WF midlife
- Assuming perfect planning of gearbox repairs (predictive condition monitoring avoiding unscheduled downtime)
- Extra preventive maintenance for lubrication and oil changes

NPV of Gearbox specific costs (Alstom estimate)
Drive train – Component/Turbine Design Level

Alstom uses SWT - Samcef Wind Turbines
- Global analyses of complete machines or local analyses of single components available in the same environment
- Also use Samcef Field for PRE and POST-Processing.

Modules that are called from SWT or Samcef Field:
- Samcef Dynam: Solver for modal analysis, superelement creation.
- Samcef Mecano: Solver for time-domain analysis.
- Samcef Nonlinear Motion Analysis: to simulate flexible dynamics with high accuracy.

Integrated aero/hydrodynamic loads and FEA.
Tower and Substructure
Tower & Substructure - Integrated System Design

• Integrated structural dynamics:
  • Accurate structural dynamics
  • Accurate load response
  • Accurate numerical integration
  • Accurate extreme and fatigue structural design

• What we have in-house:
  • Know-how on complex sub-systems (SSI, WSI, Structural Analysis, and SAMCEF knowledge)
  • SAMCEF Multibody code → combines the aero-servo-hydro-elastic + FEA capabilities into 1 code.
  • modeFRONTIER → Software manager & optimization platform. Able to couple input-output codes in a single workflow.
Tower and Substructure
Project integrated load & structural analysis - Iteration Process

Loop 0.0
Loads for Generic Wind Conditions & Substructure

Loop 0.1
Generic Substructure & Site Specific Wind Conditions

Substructure
Preliminary Substructure & Tower design (V1)

Load Loops
Substructure and Tower Designs (V2...Vn)

Site Assessment - Wind
Hub Height
Substructure Concept

© ALSTOM 2013. All rights reserved. Information contained in this document is indicative only. No representation or warranty is given or should be relied on that it is complete or correct or will apply to any particular project. This will depend on the technical & commercial circumstances. It is provided without liability and is subject to change without notice. Reproduction, use or disclosure to third parties, without express written authority, is strictly prohibited.
Optimization with modeFrontier

Key Features:
- Allows for integration of various simulation tools
- Design of Experiments
- ~30 types of optimization algorithms
- User interface – GUI driven
- Analysis “wizard”

To optimize 1 tower:
- 17K – 20K cases
- ~15.5 hours of runtime
- Runs on a dual core mobile workstation

© ALSTOM 2013. All rights reserved. Information contained in this document is indicative only. No representation or warranty is given or should be relied on that it is complete or correct or will apply to any particular project. This will depend on the technical and commercial circumstances. It is provided without liability and is subject to change without notice. Reproduction, use or disclosure to third parties, without express written authority, is strictly prohibited.
Wind Farm Level
Farm-Level Analysis and Optimization

- Alstom uses **Openwind** for farm layout optimization – turbine location and spacing; model different turbine configurations in a single farm.
- **COE**: maximize production, minimize installation and BOP costs.
- Used in conjunction with our Pro Forma analysis tool.
Economic Value Analysis – “Pro Forma”

- Rotor
- Drivetrain
- Mech/elec subsystems
- Tower
- Foundation
- Site Conditions
- Installation
- O&M
- Finance

Pro Forma

CAPEX
OPEX
AEP
COE
IRR
ROE
Economic Value Analysis – “Pro Forma”

Results of component / subsystem analysis are inputs into a detailed technical and financial model.

- Inputs owned by specialist in area (WTG subsystems, O&M, finance, etc.)
- Multiple scenario comparison
- Comparison to market

Pros

- Excel-based
- Low licensing cost
- No specialized knowledge required (programming)
- Flexible, varying levels of complexity, analysis toolkits.

Cons

- Limited number of scenarios
- Low level of integration – currently not set up for parametric studies.
- “Manual interface” with other tools
01 Introduction

02 Current Methodologies
- Drivetrain
- Tower and Substructure
- Wind Farm
- Value Analysis

03 Future Work

04 Management of ISD Tools
Future Work – Platform Evolution

Investigating expanded Integrated System Design capabilities

• Revised Pro Forma with integrated transfer functions
  – Expanded conceptual design tool
  – Improved fidelity in COE optimization

• LMS Boss Quattro for LMS SAMCEF optimization
  – Parametric studies
  – Monte Carlo method
  – Optimization and updating
  – Design of experiments methods

• Integrating economic value analysis and additional subsystems into modeFrontier®.
01 Introduction

02 Current Methodologies
- Drivetrain
- Tower and Substructure
- Wind Farm
- Value Analysis

03 Future Work

04 Management of ISD Tools
Management Considerations

Factors for ISD platform selection, design and use

Goals

- Conceptual design
- Marketing strategy
- Product specification
- Detailed design
- Plant optimization

Cost

- Features/capabilities
- Cost of implementing
- Cost of maintaining
- Complexity

Resources

- Size of team
- Skill level of team members
  - User interface
  - Programming needs
- Computing system requirements

Execution

- Ownership/champion
- Communication between user groups
- Internal/external marketing
- Demonstrate value, quantify benefits.
Conclusion

• Integrated systems-level design is needed to compete in the marketplace and deliver optimized wind farm solutions.

• Alstom methodology currently uses a variety of tools at the component, turbine and wind farm levels.

• Tools and methods continue to evolve into a more integrated platform.

• Select the platform/tools appropriate for organizational goals.

• Intuitive user interface will increase accessibility/usage.

• “Sell it” internally and externally, demonstrate the value of new system design capabilities.

• ISD serves as a differentiator and increases an OEM’s competitive advantage.