IEA Wind Task 37

Systems Engineering / Integrated RD&D Overview and Work Package 1

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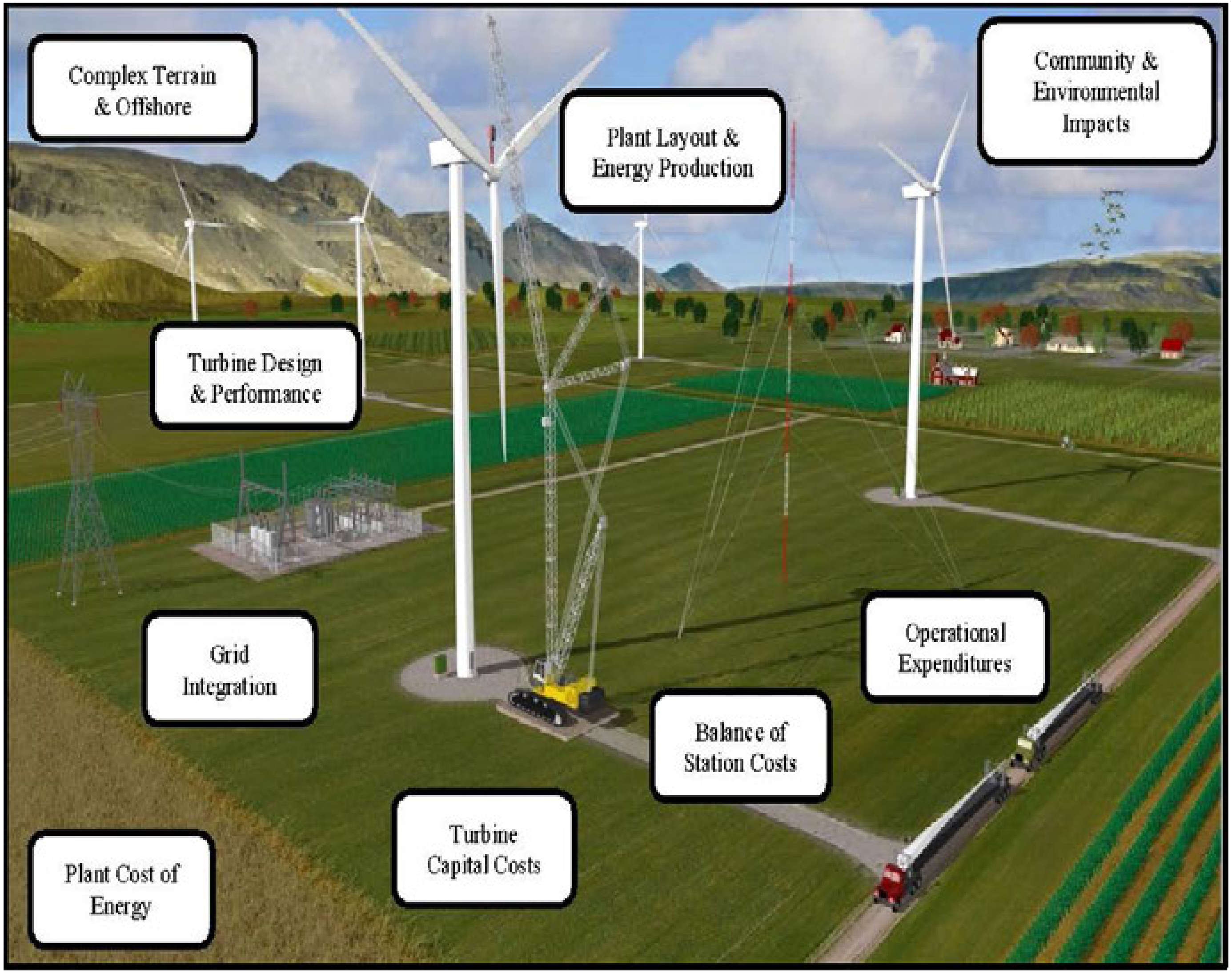
iea wind

IEA Wind Task 37 Overview

Task Objectives & Expected Results

- Project Objectives and Outcomes:
  - Promote general knowledge and value demonstrations of systems engineering tools and methods applied to wind energy RD&D
  - Improve quality of systems engineering by practitioners through development of best practices and benchmarking exercises
- Target audience: wind energy system optimization research and industry community
- Current Term: 2016-2018 (began January 2016)

Example Wind Plant – a Complex and Highly Interconnected System



Work Package Overview

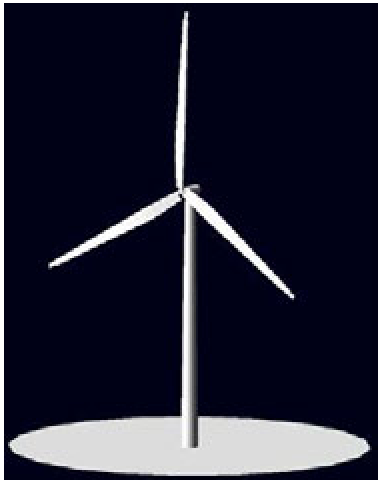
- WP1: Guidelines for integrated wind turbine and plant software frameworks
- WP2: Series of reference turbine and plant designs for supporting integrated analysis activities
- WP3: Best practice recommendations on Multi-disciplinary design, analysis and optimization (MDAO) applied to wind systems

Work Packages

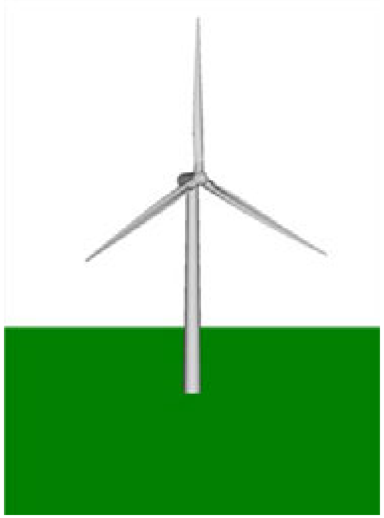
- **WP1: Guidelines on a common framework for integrated RD&D of wind energy systems**
  - Addresses the task goals by creating guidelines for a common conceptual architecture for wind turbine and plant modeling and analysis; this allows:
    - More seamless integration of wind turbine and plant models between different stakeholders
    - More transparent ways to communicate about capabilities of different models and comparisons between models
  - Key activities include:
    - Survey of existing frameworks and MDAO work
    - Development of framework requirements
    - Development of common framework guidelines for turbines and plants

Work Packages

- **WP2: Reference Wind Energy Systems**
  - Addresses task goals by providing RD&D community with a set of turbines and plants to use as starting points for various system-level analyses
  - Key activities include:
    - Determine target reference system markets
    - Determine specific turbines/plants for development and requirements
    - Develop reference turbines (2 planned)
    - Develop reference plants (2 planned)



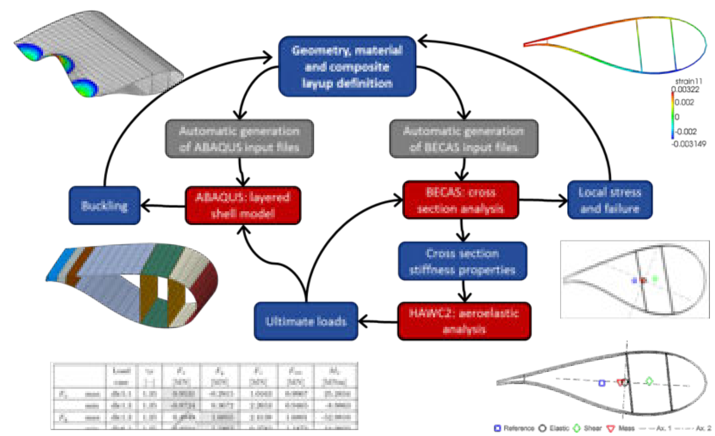
NREL 5MW Reference Turbine



DTU 10MW Reference Turbine

Work Packages

- **WP3: Benchmarking MDAO activities at different system levels**
  - Addresses task goals by benchmarking activities which will exercise frameworks and reference wind energy systems and help inform best practices in MDAO for wind energy systems



Example Aero-structural MDAO for DTU 10 MW Reference Turbine

- Key activities include:
  - Establish benchmarking scope based on WP1
  - Select benchmarking cases and establish evaluation criteria and process
  - Perform MDAO benchmarking for wind turbines (target 3)
  - Perform MDAO benchmarking for wind plants (target 3)

IEA Wind Task 37 WP 1:

Guidelines on a common framework for integrated RD&D of wind energy systems

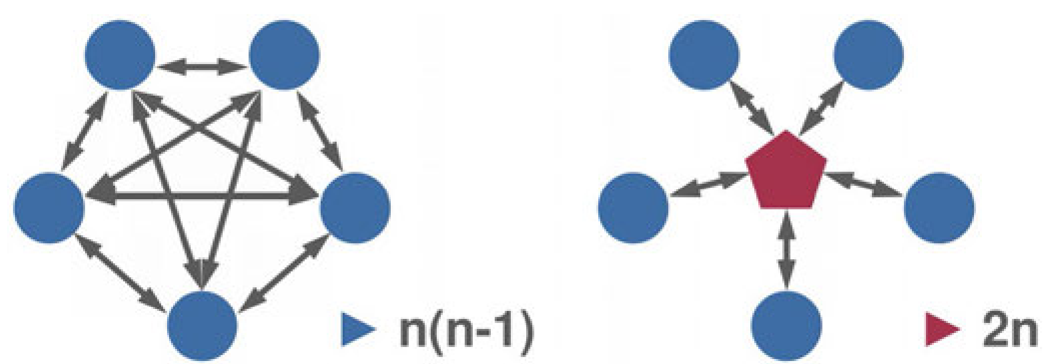
Motivation

Sharing information (for reference wind turbines and plants, benchmarking etc) common data formats are needed for collaboration and comparison

Integrated system modeling where models are interchanged is enabled by standardizing interfaces for how models communicate (what data is shared)

Several integrated systems engineering modeling efforts for wind energy have emerged

CPACS website



Task Goal

This work package addresses the task goals by creating guidelines for a common conceptual ontology and data sharing format for wind turbines and plants so that practitioners can more easily:

- Share descriptions of wind turbines and plants across multiple parties and reduce the effort for translating descriptions between models,
- Integrate different models together and collaborate on model development
- Translate models among different levels of fidelity in the system

Ontology development

- Ontology

Wikipedia definition: “In computer science and information science, an ontology is a formal naming and definition of the types, properties, and interrelationships of the entities that really or fundamentally exist for a particular domain of discourse. It is thus a practical application of philosophical ontology, with a taxonomy. An ontology compartmentalizes the variables needed for some set of computations and establishes the relationships between them.”

- Existing/related efforts:
    - Various taxonomy/ontology efforts (Sandia turbine taxonomy, NREL cost breakdown structure, Delft offshore wind plant domain graph, IRPWind taxonomy)
    - Software frameworks (DTU-NREL FUSED-Wind software framework, CL-Windcon pre/post processing framework, aerospace community CPACS)

Discipline-fidelity matrices

- Identification of relevant disciplines for wind MDAO

Fidelity

	Hi-fi time resolved turbulence modelled CFD		3D solid		[model based]		
	Blade resolved CFD	Time resolved LES CFD	3D shell		[including noise/delays etc]	Time resolved LES	
	Actuator Line CFD	Vortex methods	Super-element		Supervisory controllers		
LES	Actuator Disc CFD	DWM	Elemental non-linearity (GEBT)	Generalized 6x6	Safety protection functions		
RANS CFD	Vortex methods	Engineering unsteady 3D (Veers/Mann)	Multi-body (linear/non-linear)	Timoshenko	Load mitigation		Full BOM and manufacturing process flow
Panel method	BEM	Unsteady uniform	Modal	Euler	Power/speed regulation	Time-based Ffowcs-Williams Hawkings	Empirical design-based
Look-up Table	Look-up Table CT&Power	Steady inflow	Rigid	Analytical solid	Prescribed operation	Semi-empirical	Empirical parametric
Airfoil aero	**Rotor aero**	**Inflow aero**	**Structures**	**Cross-section structures**	**Controls**	**Acoustics**	**Cost**

Disciplines (Turbine - Rotor)

Discipline-fidelity matrices

- Identification of relevant disciplines for wind MDAO

Fidelity

		Hi-fi time resolved turbulence modelled CFD				
		Blade resolved CFD		Supervisory controllers		
		Actuator Line CFD	CFD: LES	Safety protection functions		
	CFD: LES	Actuator Disc CFD	CFD: Rans	Load mitigation		
Downscaling	CFD: Rans	Vortex methods	DWM / Linearized CFD	Power/speed regulation		
Mesoscale	Semi-empirical turbulent inflow	BEM	Field model	Prescribed operation	Semi-empirical explicit electric array cable	CFD based
Data semi-empirical	Steady inflow - windrose	Look-up Table Thrust & Power	Linear semi-empirical	Look-up table	Empirical	Semi-empirical
Resource assessment	**Inflow aero**	**Rotor aero**	**Wakes**	**Controls**	**Loss model - non wakes**	**Acoustics**

Disciplines (Plant - Energy Production)

Ontology first draft

- Initial ontology development
    - Yaml as the schema for implementation - compatible with standard programming languages (C/C++, Java, Python, Matlab) - see http://yaml.org/ for more information
- Initial discipline-fidelity matrices selected are most common on turbine and plant side:
    - Turbine - rotor - aero – BEM
    - Plant - energy - wake - linear wake

Ontology first draft - example

- Portion of wind plant – energy – linear wake

```
$schema: "http://json-schema.org/draft-04/schema#"
title: IEA Wind Task 37 Wind Plant Ontology version 0.1
## The wind plant ontology file properties

# Draft schema definitions for energy model
definitions:
  wind_plant:
    type: object
    properties:
      layout:
        type: array
        items:
          $ref: "#/definitions/wind_turbine"

wind_turbine:
    type: object
    description: An object describing a wind turbine

    properties:
      name:
        type: string
        description: The wind turbine name given by the
wind power plant owner
      position:
        type: array
        items:
          - type: number
          - type: number
        additionalItems: false
        description: The [x,y] position of the wind turbine in
UTM coordinates
        units: m

power_curve:
        description: The wind turbine power curve
        type: array #ndarray([[hub:wind_speed], [power]])
        items:
          type: array
          items:
            - $ref: "#/definitions/hub/properties/wind_speed"
            - $ref:
"#/definitions/wind_turbine/properties/power"
          additionalItems: false
```

Plans for end of 2017 / early 2018

- Continue turbine and plant ontology development by discipline

- Develop report for publication on catalogue, discipline-fidelity matrices, and first version of the ontology
  - Will circulate for review to IEA Wind Task 37 members prior to publication

Thank You!!

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