



OneWind

Concepts and Products

Urs Wihlfahrt

2015 Wind Energy Systems Engineering Workshop



Agenda

Fraunhofer IWES

OneWind Concept

OneWind Modelica Library

OneWind Software Products

Extensions

Conclusion



Agenda

Fraunhofer IWES
Fraunhofer-Gesellschaft
IWES

OneWind Concept

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Conclusion

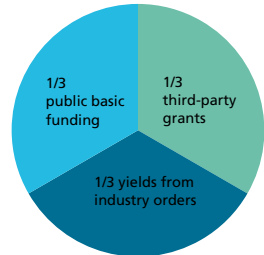
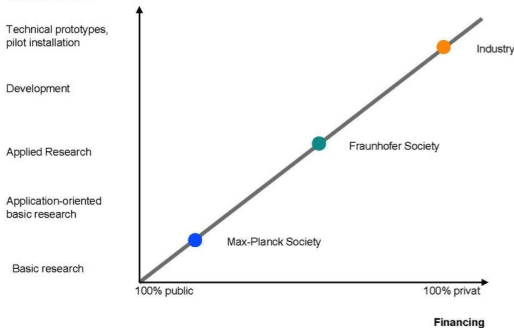


Fraunhofer-Gesellschaft:

Industry focus as success factor

- ↪ Largest organization for applied research in Europe
- ↪ More than 80 research institutions, including 67 Fraunhofer institutes in Germany
- ↪ More than 24,000 employees, mainly with natural or engineering science education
- ↪ € 2.0 billion annual research budget totaling

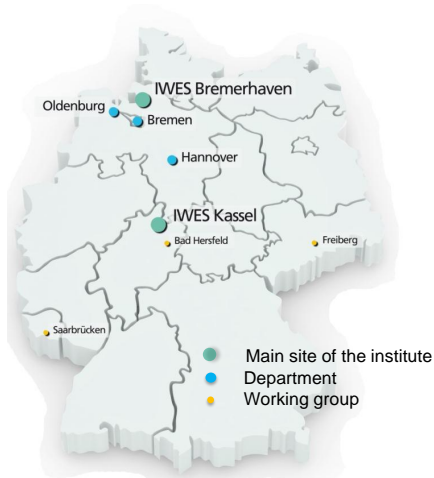
Type of Research



Fraunhofer

IWES

Fraunhofer Institute for Wind Energy and Energy System Technology (IWES North-West)



- **Managing Director::**
Prof. Dr.-Ing. Andreas Reuter
- **Research Spectrum:**
Wind energy from wind physics up to energy network feeding
- **Budget 2014:**
around €14 million
- **Staff:**
150 employees
- **Previous investments in the establishment of the institute:**
€50 million
- Strategic Association with ForWind and the German Aerospace Center (DLR)



Accelerated time-to-market by realistic testing

Rotor Blade Test Hall up to 90 meter

- ↪ Testing of design prior to series production
- ↪ Simulation of 20 year life-spans in a few months
- ↪ max. static bending moment 115,000 kNm; max. dynamic bending moment: +/- 30,000 kNm



DyNaLab with 10 MW Drive Performance / Peak 15 MW

- ↪ Norminal torque: $> 8,6 \text{ MNm}$
- ↪ Rotor load application unit for dynamic bending moments, thrust and radial forces
- ↪ Artificial network: 44 MVA installed inverter power



Support Structure Test Center

- ↪ Testing support structure fatigue behaviour
- ↪ Solving production problems through design changes
- ↪ Scale of 1:10 - 1:3,5

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Agenda

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OneWind Concept

Background

Consistent modeling

Base technologies

OneWind Modelica Library

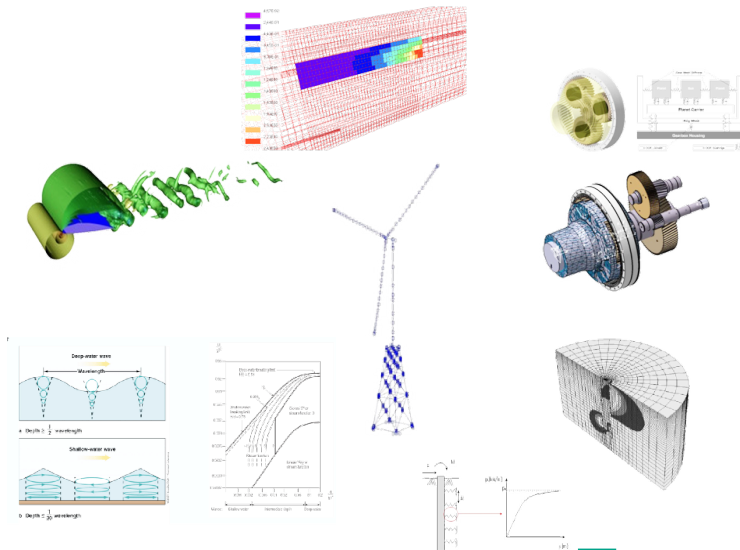
OneWind Software Products

Extensions

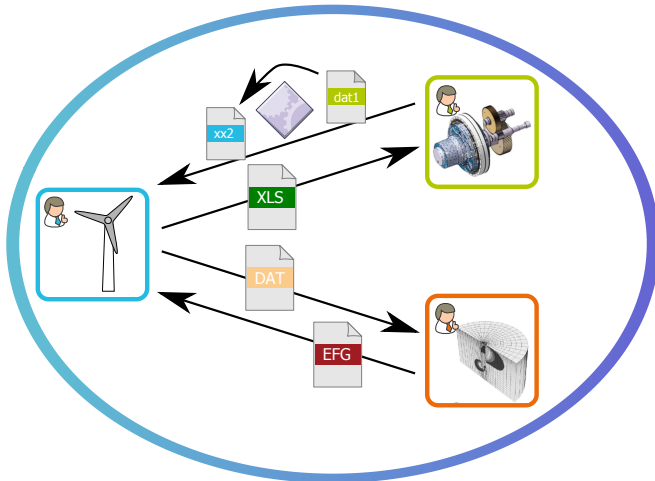
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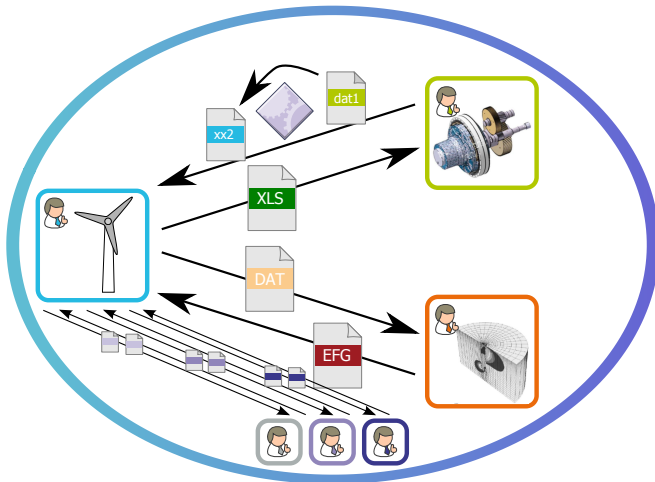
Multiple domains



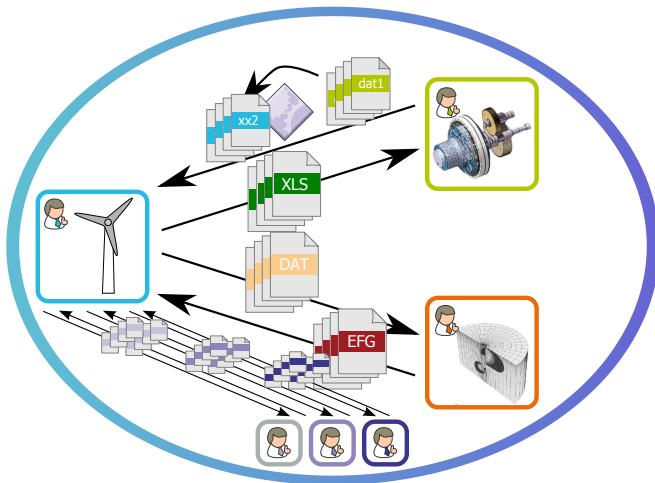
Cooperation in the design process

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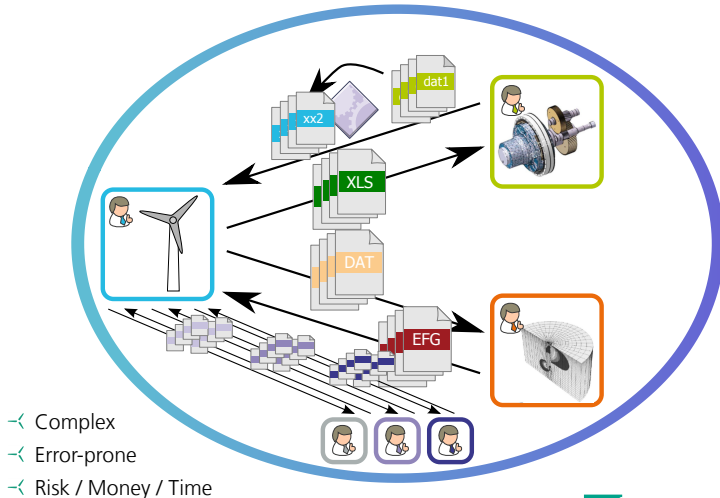
Cooperation in the design process



Cooperation in the design process



Cooperation in the design process



Consistent modeling



All components of a wind turbine

- in **one** numerical model
- with **different** levels of detail
- and automatic **transformation** of models

Consistent modeling



All components of a wind turbine

- in **one** numerical model
- with **different** levels of detail
- and automatic **transformation** of models

Project OneWind

duration: 2009 – 2014
 budget: 5.7 Mio. €
 personnel: ≤ 10 employees

Supported by:



Federal Ministry
for Economic Affairs
and Energy

on the basis of a decision
by the German Bundestag

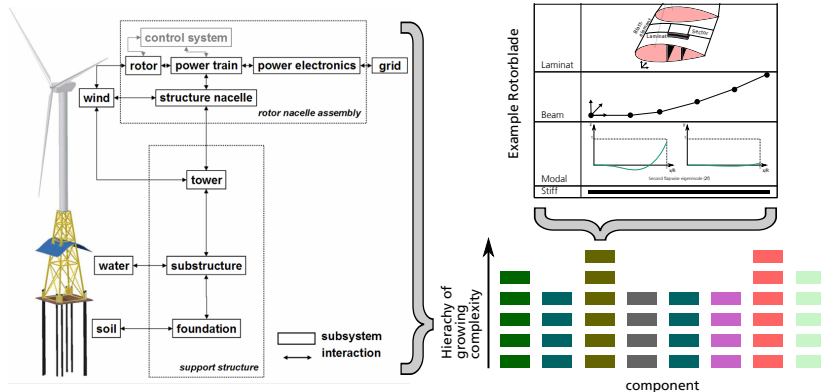


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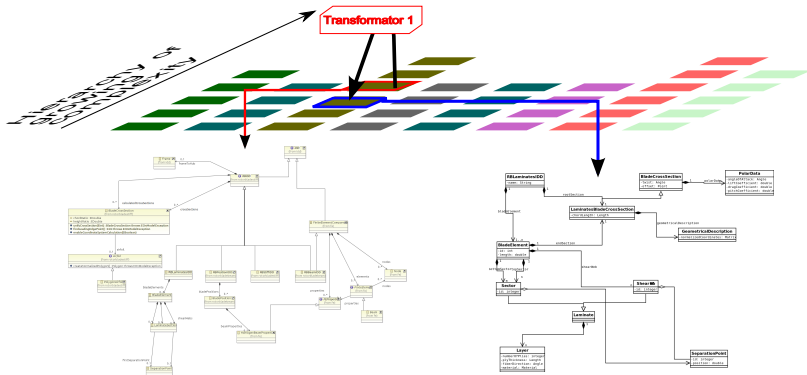
Concept

→ Purely parametric component models (Engineer Design Data)



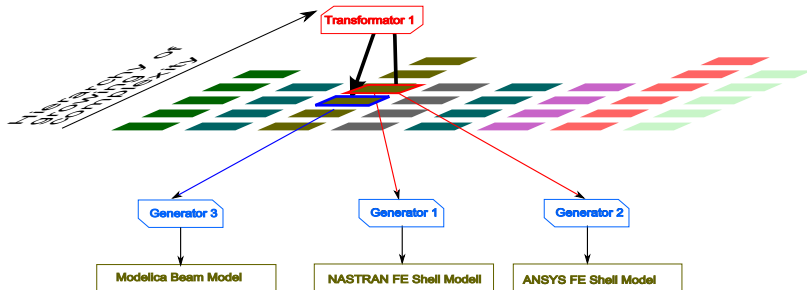
Concept

- **Purely parametric** component models (Engineer Design Data)
- **Transformation** between different levels of detail



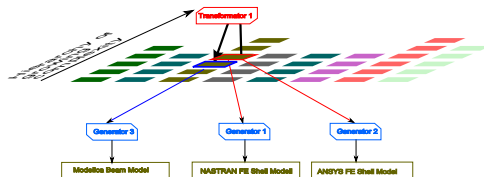
Concept

- **Purely parametric** component models (Engineer Design Data)
- **Transformation** between different levels of detail
- **Generation** of models for calculation



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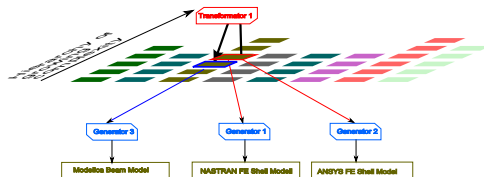


Advantages:

- Consistency of the models with different levels of detail
- Decoupling of model and tool knowledge

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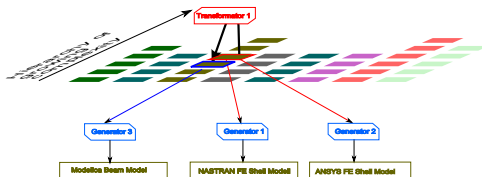


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Concept

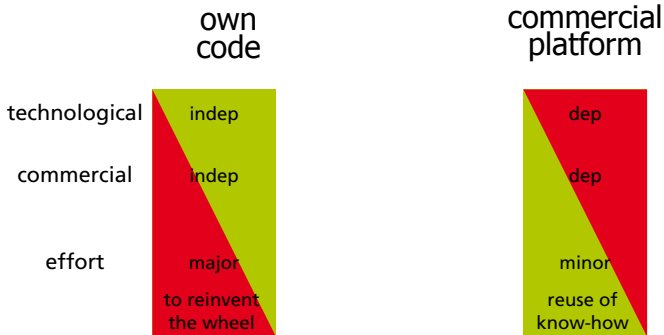
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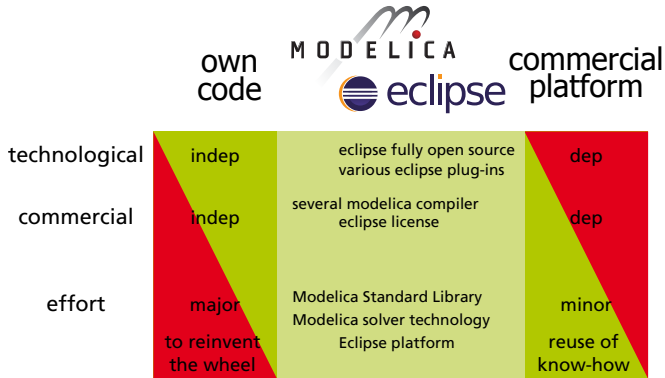
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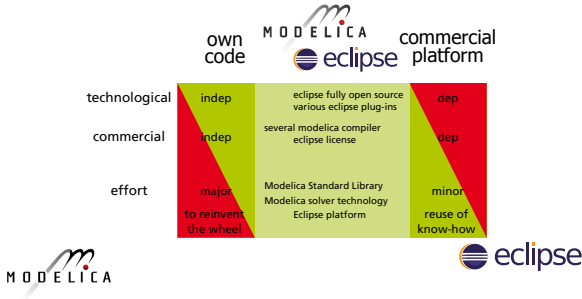
OneWind base technologies: Modelica and Eclipse



OneWind base technologies: Modelica and Eclipse

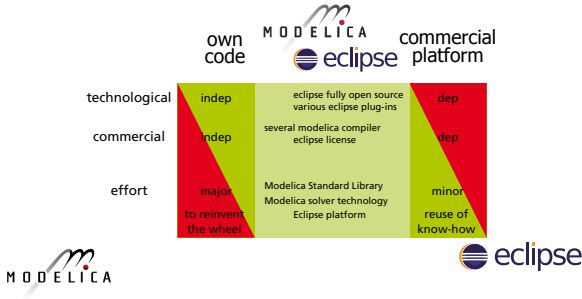


OneWind base technologies: Modelica and Eclipse



- Open source language for physical modeling (ODE)
- Separation of physics and numerics and
→ intuitiv to engineers
- Extensive Modelica Standard Library (MSL)
- Vendor independent, component based, extensible

OneWind base technologies: Modelica and Eclipse



- Open source language for physical modeling (ODE)
- Separation of physics and numerics and → intuitiv to engineers
- Extensive Modelica Standard Library (MSL)
- Vendor independent, component based, extensible
- Open source community
- Reuse of techniques from software development: plug-in framework, support for collaboration (subversion, tickets)
- Domain specific models → EMF
- Example: Eclipse Automotive Industry Working Group

Agenda

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OneWind Concept

OneWind Modelica Library
Architecture
Verification

OneWind Software Products

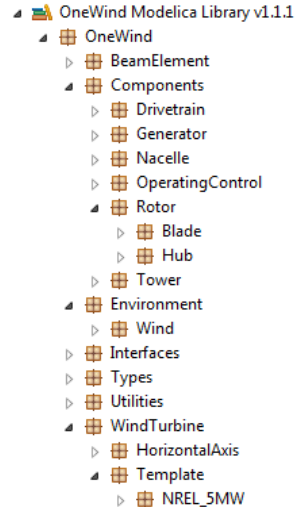
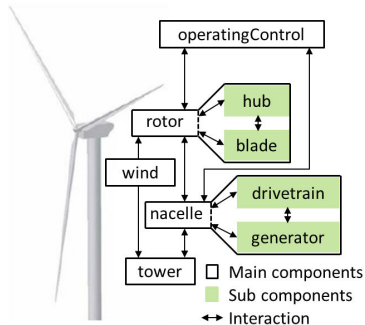
Extensions

Conclusion



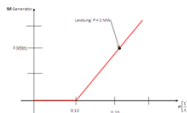
OneWind Modelica Library

- Modelica based
- Component based (exchangeable, extendible)
- Source code / no blackbox
- Modal reduction of blades and towers
- Including NREL offshore 5MW baseline wind turbine
- Verification OCx

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Modelica Example: Generator

Characteristics



Equation of motion

$$M_{\text{Rotor}} - J_{\text{Rotor}} \cdot \ddot{\omega} - J_{\text{Generator}} \cdot \ddot{\omega} - M_{\text{Generator}} = 0$$

```
model Generator
```

```
...
```

```
equation
```

```
if omega <= 0.12 then
```

```
  Mgenerator = 0;
```

```
else
```

```
  Mgenerator = (62500000 * omega) - 7500000;
```

```
end if;
```

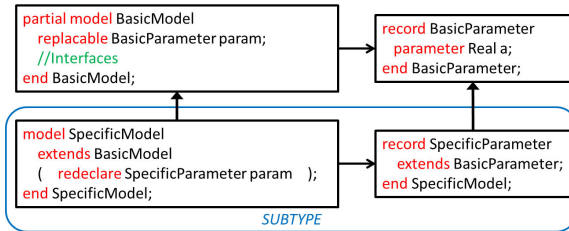
```
omega = der(rotFlangeShaft.phi);
```

```
Mrotor - (Jrotor + Jgenerator) * der(omega) - Mgenerator = 0;
```

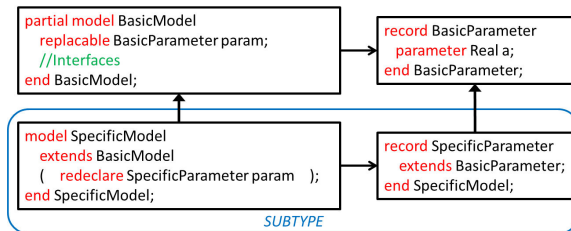
```
end Generator;
```

**Fraunhofer**

Inheritance concept of library



Inheritance concept of library

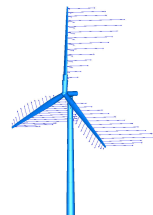


Example Code

```

model WindTurbine
  extends OneWind.OnshoreWindTurbine
  (
    //=== rotor ===
    redeclare OneWind.RotorModal rotor
    //=== tower ===
    ,redeclare OneWind.TowerModal tower
    //=== nacelle ===
    ,redeclare OneWind.NacelleRigid nacelle
    //=== operating control ===
    ,redeclare OneWind.Control operatingControl
    //=== wind ===
    ,redeclare OneWind.WindTurbulent wind
  );
end WindTurbine;
  
```

Graphical output

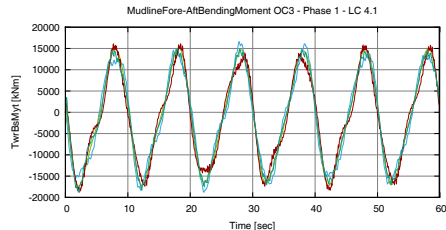
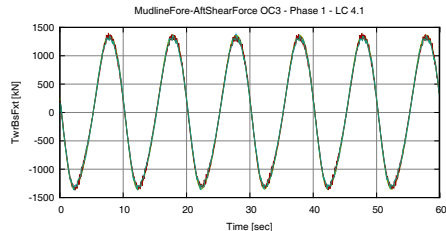
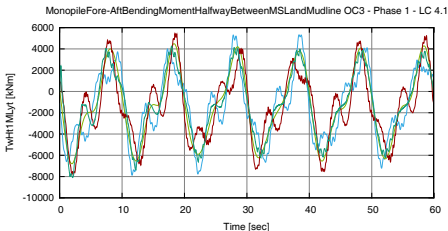


Verification

OC3 Phase 1 loadcase 4.1

- Flexible offshore structure
- constant wind
- no waves

NREL FAST GH Bladed Risoe HAWC2 IWES OneWind



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IWES

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OneWind Concept

OneWind Modelica Library

OneWind Software Products

Framework

Product overview

Look and feel

Extensions

Conclusion



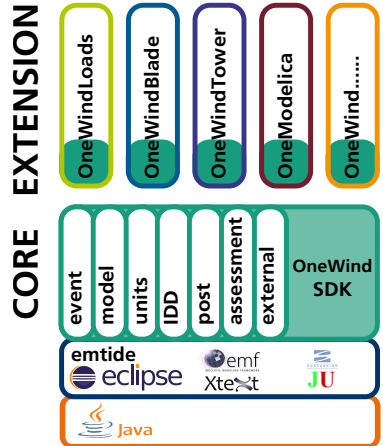
OneWind-framework structure

Concept

- Modeling windturbines and workflow
- Engineering Design Data
- Core / extension

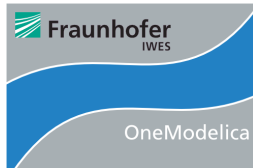
Software engineering

- Eclipse Rich Client Platform (RCP)
- Continuous integration build
- Documentation within products
- Tests within the products



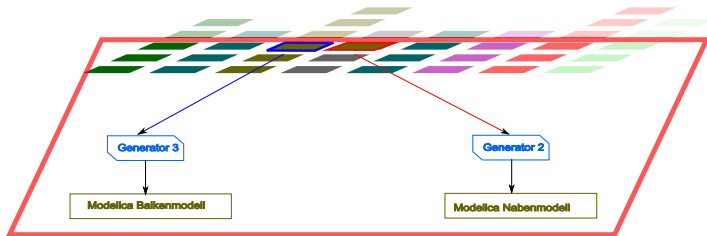
OneWind-Products

- ↪ OneWindLoads Load calculation
- ↪ OneWindBlade Structure design of rotorblades
- ↪ OneModelica Integrated development environment for Modelica
- ↪ OneWindSDK Software Development Kit for OneWind products



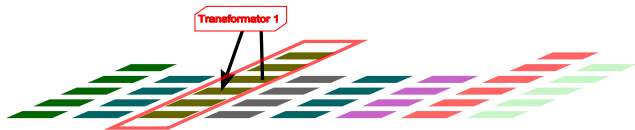
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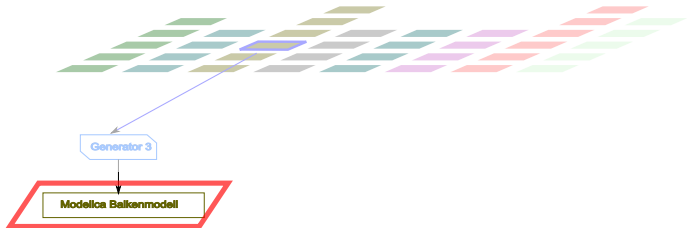
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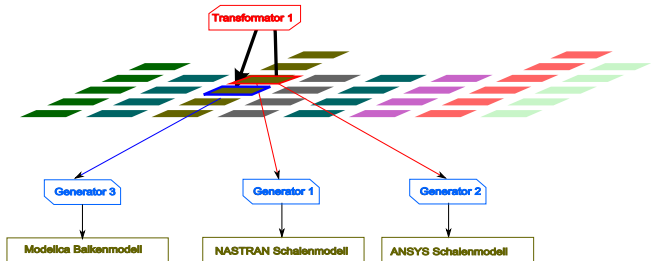
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- ↪ **OneWindSDK** Software Development Kit for OneWind products



Look and Feel of OneWindLoads

The screenshot displays the OneWindLoads software interface for configuring a wind turbine model. The main window shows the 'Tower Properties' for 'NREL5MW_Tower'. The 'Damping description' is set to 'Damping coefficients' with a value of 0.039 and a damping ratio of 0.0. The 'Drag coefficient' is set to 0.7. Below this is a table of 'Ring Stations' with columns for Position, Outer Diam., Wall Thickness, Point Mass, Material, Linear Density, Bending Stiffness, and Youngs Modulus. The table lists 15 stations, each with a corresponding material (NREL Stahl) and properties.

Ring Stations	Position	Outer Diam.	Wall Thickness	Point Mass	Material	Linear Density	Bending Stiffness	Youngs Modulus
0.000	6.000	0.027	0.000	NREL Stahl	4306.506	4.745e+11	2.100e+11	Delete
10.000	6.000	0.027	0.000	NREL Stahl	4306.506	4.745e+11	2.100e+11	Delete
17.760	5.782	0.026	0.000	NREL Stahl	4030.444	4.131e+11	2.100e+11	Delete
25.520	5.574	0.025	0.000	NREL Stahl	3763.440	3.578e+11	2.100e+11	Delete
33.280	5.361	0.025	0.000	NREL Stahl	3505.519	3.083e+11	2.100e+11	Delete
41.040	5.148	0.024	0.000	NREL Stahl	3256.656	2.641e+11	2.100e+11	Delete
48.799	4.935	0.023	0.000	NREL Stahl	3016.859	2.248e+11	2.100e+11	Delete
56.559	4.722	0.022	0.000	NREL Stahl	2786.129	1.901e+11	2.100e+11	Delete
64.319	4.509	0.021	0.000	NREL Stahl	2564.465	1.595e+11	2.100e+11	Delete
72.079	4.296	0.021	0.000	NREL Stahl	2351.867	1.328e+11	2.100e+11	Delete
79.839	4.083	0.020	0.000	NREL Stahl	2148.336	1.095e+11	2.100e+11	Delete
87.599	3.870	0.019	0.000	NREL Stahl	1953.871	8.949e+10	2.100e+11	Delete

The bottom window shows a plot of 'tower.towerBottom.cutTorque.entries[1]' over time. The y-axis ranges from -90,000,000 to 0, and the x-axis ranges from 0 to 10 seconds. The plot shows a sinusoidal wave oscillating between approximately -80,000,000 and -10,000,000 N*m.



Fraunhofer

Look and Feel of OneModelica

The screenshot displays the OneModelica IDE interface with the following components:

- Project Explorer:** Shows the project structure, including 'example', 'MSL', 'OneWind Modelica Library v1.1.1', and 'NREL_SMW'.
- Source Code Editor:** Displays the 'MyTurbineSimple.mo' file with the following code:


```

within test;
class MyTurbineSimple
extends OneWind.WindTurbine.Template.NREL_SMW.NREL_SMW_simple;

Modelica.SIunits.Length;
//
equation
end MyTurbineSimple;
      
```
- Problems View:** Shows 1 error and 1 warning. The error is 'mismatched input ; expecting RULE_ID'. The warning is 'No comment found for component.'.
- Modelica Doc View:** Provides documentation for the 'Angle' type, stating it is a Real final quantity with a final unit and display unit, and includes conversion functions from non-SI units to SI units and vice versa in the subpackage 'Conversions'.
- Outline View:** Lists the components of the 'MyTurbineSimple' model, including 'world', 'controlBus', 'rotor', 'nacelle', 'tower', 'operatingControl', 'wind', 'hubWindSpeed', 'generatorPowerOutput', 'generatorPowerLoss', 'distanceHub2Shaft', and 'overHang'.
- Plot:** A graph titled 'controlBus' showing 'generatorPowerLoss [s]' over 'Time [s]'. The power loss starts at 0 and increases linearly to approximately 20000 W at 10 seconds.



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Extensions

- Approaches to extend

- Ongoing work

- Dual license

Conclusion



Extension of the framework

“Fast approach” – Modelica based

- Enhancements of single component
- Usage within library for loads calculation
- OneModelica

“Complete approach” – OneWind-Framework based

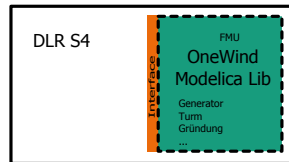
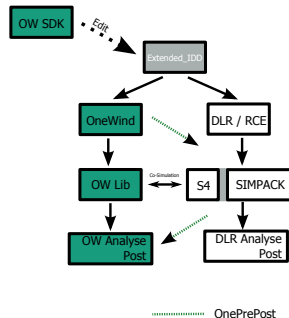
- Engineer Design Data – model for new component
- Transformations, generators and assessments
- Core / Extension based ⇒ OneWind Product
- OneWindSDK



Ongoing work

Project Wind Muse

- Cooperation IWES – DLR
- Combine tools from IWES and DLR
- Modelica model exchange via Functional Mock-up Interface (FMI)
- combined parametric model **Extended_EDD**
- Enhanced load case management
- OnePrePost (alternative simulator)

**Fraunhofer****IWES**

Dual license

- ↪ commercial license
- ↪ noncommercial usage
 - ↪ Restrictive Open Source License
 - ↪ Extensions / Modifications
 - ↪ Reference to "OneWind"

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IV. MISCELLANEOUS

1. Duration and Termination of Agreement

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Conclusion

OneWind is

- Consistent modeling with different levels of details
- “OneWind Modelica Library” tool for loads calculation
- Extensible software framework for wind-energy applications





THANK YOU FOR YOUR ATTENTION

Any questions?

urs.wihlfahrt@iwes.fraunhofer.de