Introduction to Offwind tool

Prediction tools for offshore wind energy generation

Offwind Group

(IRIS, SINTEF, VattenFall, LTH, Aalborg Univ, Megajoule, NRG-Soft, NREL, Norsk Vind, Kiel GMbH)



Outline

- •Offwind Project specification
- Offwind Code specification
 - Engineering LevelAdvance CFD Level
- Meso-Scale wind results
- Wind-Wake simulation Results
- •Wind-Wave Simulation Results
- •Now-Casting



Introduction: Market outlook (2011 - 2020 - 2030)

2011:

Total installed capacity of 4,000 MW

- Meeting 0.4% of total EU electricity demand
- Annual installations of 1,000 MW

2020:

- Total installed capacity of 40,000 MW
- Meeting 4% and 4.2% of total EU electricity demand
- Annual installations of 6,900 MW
- ·2030:
- Total installed capacity of 150,000 MW
- Annual installations of 13,700 MW
- Meeting 13.9% of total EU electricity demand



FIGURE 1.8 HISTORICAL ONSHORE GROWTH (1995-2005) COMPARED TO EWEA'S OFFSHORE PROJECTION (2010-2020)



Source: EWEA

FACTS (Offwind Project)

•Type: Research project;

•Project Owner: IRIS; International Research Institute of Stavanger, Norway; •Project Manager: Jafar Mahmoudi

•Project Manager: Jafar Mahmoudi,

•Financing: NER (Nordic Energy research); VattenFall (Research and

Development) and Own Financing;

•**Period:** 2012-2014;

•Partners: 10 partners:

Norway: IRIS; SINTEF; Norskvind,

Sweden: Lund University,

Denmark: Aalborg Univ; Vattenfall (Research and Development),

Portugal: Megajoule,

Germany: FuE-Zentrum FH Kiel GmbH,

US: NREL, National Renewable Energy Laboratory (associated member) Russia: NRG Soft Ltd.



FACTS (Offwind Code)

- •Outcome: Software for power prediction from a wind farm
- •Application: Offshore (as well as on Shore)
- •Utilility: Design and Operation
- •Open Source code for Offwind Association
- •Code Validation based on IEA- Task 31, VattenFall & NorskVind Measurements /Results
- Software Architecture:
 - **Engineering Level:** User manual friendly for engineer (not researchers), Web based (as well as local installation)
 - Advanced Level: CFD, Computational Fluid dynamic (Cloud based as well as local installation), including:
 - Coupling between meso- and microscale (CFD) models
 - Wind-wave interaction
 - MetOcean-CFD modelling approach
 - Wind data based on Google Earth Map and WF-AEP world wide wind map

Offwind Objectives

•The primary objective of the project is to develop tools for design and operation assessment and forecasting for offshore wind farms.

The tools will lead to optimal localization of a wind farm and more importantly how to locate future wind farms with respect to each other within the same wind energy cluster.
The tools will also lead to a more safer wind farm operation as the operation parameters can be more accurately predicted and thus reduce the probability of wind turbine failure under severe weather conditions.



Offwind Work packages

- •WP 1: Numerical modeling for wind turbine and wind farm performance predictions
- •WP 2 Experiments and model validation and calibration
- •WP 3 Fully coupled wind-wave interaction model
 •WP 4 Now-casting of available farm power based on data driven modelling
- •WP 5 Database



Offwind Project Partners

Organization	Country	Main partners	Participate
IRIS (Research center)	Norway	Wp1, Wp2,	Wp3, Wp5
SINTEF (Research center)	Norway	Wp1, Wp3	Wp4, Wp5
Norsk Vind Energi AS (Industry)	Norway	Wp2	Wp5
Aalborg (University)	Denmark	Wp4	Wp5
Vattenfall (Industry)	Denmark	Wp3, wp5	Wp1, Wp2
Megajoule	Portugal	Wp3	Wp1
Lund university (LTH)	Sweden	Wp1, Wp3	Wp5
FuE-Zentrum FH Kiel GmbH	Germany	Wp5	Wp2
National Renewable Energy Laboratory-NREL	USA	Wp1	Wp3
NRG Software	Russian	Software Development	Associated Call

Scientist: creates model

Hey, I've got a great idea and designed math model for that simulation process. I've also made up these algorithms in code. Go ahead, use them!

Gradient

Momentum transpo	rt				
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e-07, No Iterations 4 g for pd, Initial residual = 0.000	J	findVerticalCellLevels.H
06, No Iterations 4 g for pd, Initial residual = 3.444 07 No Iterations 3	J	findVerticalFaceLevels.H
g for pd, Initial residual = 4.480 09, No Iterations 6	J	findWindHeight.H
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Wind = (6.36396097062 6.3639609844 0.000651185246025 -0.0006567919184	J	openFaceStatisticsFiles.H
olving for T, Initial residual = 1	J	readABLProperties.H
	_	



Engineer: uses the solver

Please, tell me how to use that function that you've created? It doesn't even compile on my machine. How am I supposed to feed it with input data filling these txt-files? I don't understand why it is failing at line 81. Oh, god... why do I need that weird library XYZ? I'm wasting my time dealing with that...

> transportModel Newtonian; LEVEL ST REFINE echo " selecting cells to refi 27 // Molecular viscosity mpirun -np \$((Snodes*Scores)) to nu [0 2 -1 0 0 0 0] 0.0; 28 nu 30 // Reference temperature refining cells...' echo " [0 0 0 1 0 0 01 300; mpirun -np \$((\$nodes*\$) shift -> FOAM FATAL ERROR: dSmagorinsky") done pool IPstream::init(int& argc, char**^{ry";} From function UPstream::init(int& # Make the mesh using blockM in file UPstream.C at line 81. echo "BUILDING THE MESH WITH blockMesh > log1.blockMesh 2 OAM aborting # Get rid of any initial fil #0 Foam::error::printStack(Foam::Ost ibOpenFOAM.so"



Offwind: merge two worlds

Hello, Engineer! I'm going to ease you that part! I will ask Scientist about what should be done and provide it to you in an optimal way. Just click here, input some data in these forms and go drink some coffee!



LES SGS model

betaM

gammM



Engineer: focuses on his tasks

Great! That saves me time!



Offwind Code Specification





Offwind Code specification

•The code has been developed for industrial purpose and engineers (not necessarily researcher). Looking to this, we have put lots of time and effort on very user friendly interface (Using Baltic call & IRIS) in two different levels. •Engineering tool (based on empirical equations): While engineers can easily get the results in accurate level and very fast (minutes). This will be mainly Web based design •Advanced Level (CFD): Again, using Google Earth, wind data and based on our solver (Offwind solver) based on OpenFoam. His part will be combined based on web- Cloudbased and local installation.

•The Offwind code has been developed to be "**Open Code**" to

Offwind-WEB-GUI

Offwind Home Engineering Tools CFD About

Welcome to Offwind!

This is a start page, where you can choose what to work with.



Engineering Tools

Here you can run a number of tools which will help you to make quick calculations and estimations.

Go to Engineering Tools »



With CFD you can utilize big power of OpenFOAM standard solvers and a industry-specific SOWFA product. The simulations are being run at our backend servers in fully parallel mode thus providing optimal performance for most CFD tasks.





Offwind Web: Architecture







•URL: <u>http://proc.offwind.eu</u>
•OS: Ubuntu Linux
•CPU: Intel i7 2700 (4 cores)
•RAM: 32 Gb
•HDD: 750 GB (no redundancy)
•Location: IRIS, Norway



Offwind Web: Sequence Diagram





Meso Scale Wind- Web

MESO WIND

A / Engineering Tools / Meso Wind / Database

Database

I Current Data

- I Velocity Freq.
- * Wind Roses

WAKE SIMULATION

- General Properties
- Turbine Coordinates
- ❷ Simulation
- Post-processing

WIND WAVE POWER

- Input Data
- Power Output
- Power Output Adv.



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37	0	0E_37N.dat.tab
38	0	0E_38N.dat.tab
39	0	0E_39N.dat.tab
50	0	0E_50N.dat.tab
52	0	0E_52N.dat.tab
54	0	0E_54N.dat.tab
55	0	0E_55N.dat.tab
56	0	0E_56N.dat.tab

Import Selected

Showing 1 to 10 of 7,005 entries

2 3



The OpenFOAM database rapidly supplies the user with a general view of the local winds, based on global data information

Meso Scale Wind

Results



10.24

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.63	226.88	203.54	193.27	181.46	196.51	154.74	167.39
.63	211.63	192.72	182.69	158.10	179.75	161.63	144.40
.56	102.00	122.91	130.77	142.52	144.20	146.79	122.84

MESO WIND



Meso Scale Wind

OFFWIND Goal regarding Mesoscale ::

to supply mesoscale results to provide data to configure microscale simulations at set-up or through coupling between models

Operational set-up not yet ready to be able to run mesoscale simulations upon request from user

=> information is collected from global analysis and reanalysis databases and made available on the OFFWIND web-platform => user may set-up microscale simulations using his own measured data or mesoscale results

The OpenFOAM database rapidly supplies the user with a general view of the local winds, based on global data information





Mesoscale wind Model

Procedure:

Identify typical meteorological year at any site by analysing one or more analysis/ Reanalysis datasets (eg. FNL and MERRA, as used in OFFWIND). Once year is identified, simulate it on 3x3km meshes

Two possibilities are then available:

Engineering version: use mesoscale data series at the site to identify relevant sectors and dominant wind speeds per sector. Configure CFD simulations accordingly.

Advanced version: extract boundary conditions for OpenFOAM from mesoscale 3D fields

- . either in time-dependent mode (costly), or
- . averaging bc's per sector to produce steady-state simulations.



Lillgrund Test Case :: Mesoscale

The FNL Analysis database was analysed at a location near Lillgrund (at point 13E, 56N). The Long-Term Climate was defined using the period 2003-2012 for FNL, in terms of annual, winter and summer velocity and direction distributions.



The mesoscale modelling of the Lillgrund test site had two goals:

1. To compare results between the mesoscale model and local data

2. To use mesoscale results to configure or force the CFD simulations

Lillgrund Test Case :: Mesoscale

A similar analysis was performed then for each individual year, and a statistical procedure carried out to identify the year that most resembled long-term behaviour, both annually and seasonally. From this, the year 2008 emerged as the most representative of the long-term climatology, followed by year 2004.





Lillgrund Test Case : Mesoscale

The mesoscale simulation was performed using the WRF mesoscale model, on 3km meshes, using FNL Analysis forcing and the following parametrisations:

PBL model: Surface Layer model: Etc.

The following wind distribution and statistics were obtained at point (55.50°N, 12.76°E)



Lillgrund Test Case :: Mesoscale (ongoing)

Next steps:

- Extract boundary conditions from mesoscale model to couple with CFD simulations
- Test steady-state (average bc's per wind direction) or time-dependent coupling
- Compare results with measurements, and traditional CFD simulations, by season, hour of day, stratification class, etc.







Lillgrund Test Case :: Mesoscale



Advanced CFD tool- Web Model Submit the job on the cloud Server



/ CFD / Processing / Simulation

Here you can start/stop simulation process. When it starts, the job is submitted to CFD Processing server. You will find a download link as soon as job finishes.

Preview case Run simulation

Stop simulation

BOUNDARY CONDITION 8

Transport Properties
 Earth STL Generator

PRE-PROCESSING

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- * epsilon
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Wind- Wake Model

OffWindEng: Base on Jensen Model Advanced: OffWindSolver : (PisoFoam+ Actuator Line/Actuator Disk)

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Validation - Lillgrund Computational set up



Wind- Wake Model- Web Model

	A / Engineering Tools / Wake Simulation / General Properties			
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Bower Output		Q File Name PROJEC/OFFWIND_WAKE_ENG/FLOW.q		
· Fower Output				

Power Output Adv.

Time-averaged power of turbine normalized by the first turbine power in the row



Computational Domains for Dominant Wind Directions (WD)



Instantaneous Velocity Contour at the Rotor Hub Height

t = 100 s not fully developed



t = 300 s - fully developed









Time-Averaged Power Normalized by the Farm Average Power





- WD – 221 determines the loss in power to the largest number of the turbine of the wind farm





Instantaneous Velocity Contours: horizontal plane at the rotor hub height

WD -191⁰



A high wind turbine interaction, to a larger number of turbine is noticed for $WD = 221^{\circ}$



1.04e+019.88e+00 9.36e+008.84e+008.32e+00 7.80e+00 7.28e+00 6.76e+00 6.24e+00 5.72e+00 5.20e+00 4.68e+00 4.16e+00 3.64e+003.12e+00 2.60e+00 2.08e+00 1.56e+001.04e+005.20e-01 0.00e+00

WD -281⁰

WD -2210

Wind-Wave Model- Web Model LES Based Model

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MES

Wind-Wave- Advanced Model



The Wind Velocity profiles along vertical lines





Wind-Wave Model- Advanced Model





Nowcasting



Short-term forecasting up to 60 minutes (Nowcasting)

Controller dynamics affect the wind flow

- Realistic farm and turbine control algorithms
- Using fast statistical models for wind prediction
- Estimation of power production within the next short time period



Nowcasting

Simple wind/wake model

Current front row wind speed propagates to next rows

Wind farm dependent time scale





Nowcasting

Fast online power production estimates.

Continuous input from real wind farm/CFD simulator





Wind farm controller modes



👑 OFFWIND

Wind farm controller modes



Wind farm controller modes



OFFWIND Workshop

22-23, Oct, 2013 Stavanger Free registration

Jafar.Mahmoudi@iris.no



Thank you for your attention