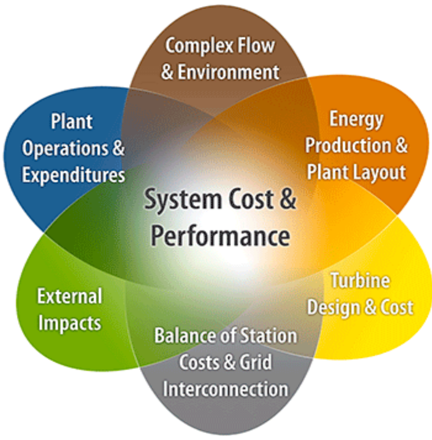
5th Wind Energy Systems Engineering Workshop

CL-Windcon Final Conference



October 2nd – 4th, 2019
Pamplona (Spain)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 72747

Welcome Message

Dear Colleagues, Dear Friends,

Thanks to all the efforts from industrial partners, research centers and universities involved in the wind energy sector, wind turbine and its components design have reached a notable level of maturity, allowing the current leading role that wind energy has in the penetration of renewable energies in the power grids, tenders and market.

The way ahead for further decrease in the cost of energy and increased profitability is through the consideration of the global interactions among all those components. This is where the systems engineering approach reveals to be indispensable, by allowing the integration of concurrent design and analysis processes and tools, as well as holistic multi-disciplinary operation of wind turbines and wind farms.

Good examples of application of systems engineering are the optimized blade design from the aerodynamic and structural point of view, drivetrain optimized design or the integrated design of floating offshore wind turbine and substructure. The latter provides perfect proof of how technological boundaries can be challenged and extended by systems engineering.

Another clear application is wind farm control. The European H2020 project CL-Windcon (Closed-Loop Wind Farm Control), now close to its end, is one of the greatest exponents in this field. It has devoted relevant efforts in multi-fidelity wind farm modelling, wind farm control design and validation by simulation, wind tunnel testing and field testing. Major contributions to the research and industry community are provided through open access publications and open research data.

It is CENER's great pleasure to welcome you to the 5th Workshop for Systems Engineering in Wind Energy (WESE'2019). In this edition, CENER hosts the workshop as a joint event with CL-Windcon Final Conference by partnering with US National Renewable Energy Laboratory (NREL) and DTU Wind Energy.

We hope that you take advantage of the diverse program around systems engineering and wind farm control, and that you follow exciting discussions in this atmosphere of technical exchange.

All the very best,

Mikel Iribas
CL-Windcon Project Coordinator (CENER)

Conference Organizing Committee

Irene Eguinoa	Mikel Iribas	Katherine Dykes	Garrett Barter
CENER	*CENER*	*DTU Wind Energy*	*NREL*

Conference Chairs

Jan Willem van Wingerden	Carlo Bottasso	Alessandro Croce	Mario Garcia-Sanz
TU Delft	*TUM*	*Politecnico di Milano*	*US DOE ARPA-E*
Frederik Zahle		Michael McWilliam	
DTU Wind Energy		*DTU Wind Energy*	

Wednesday, October 02nd, 2019	
8:15 am - 9:00 am	**Registration and Welcome**
9:30 am - 10:00 am	**Institutional Opening** **Introduction: CL-Windcon Project** Mikel Iribas, CENER
10:00 am - 10:45 am	Keynote: Marta Perez Garcia
10:45 am - 11:05 am	Coffee Break
11:05 am - 12:15 pm	**Session I: Wind Power Plants in the 21st Century Electricity system** Chairperson: Garret Barter, NREL Tifenn Brandily, BNEF Philipp Beiter, NREL Andrew PJ Stanley, Brigham Young University
12:15 pm - 1:15 pm	**Lunch**
1:15 pm - 2:25 pm	**Session II: What is Wind Energy Systems Engineering?** Chairpersons: Carlo Bottasso, TUM, and Alessandro Croce POLIMI Carlo Bottasso, TUM Ewan Machefaux, Vestas Wind Systems A/S Christopher Bay, NREL
2:25 pm - 3:55 pm	**Session III: Application of Wind Energy Systems Engineering in Practice** Chairperson: Irene Eguinoa, CENER Javier Alonso, Siemens Gamesa Renewable Energy Arantxa Esparza, NabraWind Sebastian Sanchez Perez-Moreno, Innogy Eugenio Guelbenzu, Acciona Energy
3:55 pm - 4:15 pm	Coffee Break / Posters session
4:15 pm - 5:45 pm	**Session IV: Advanced Methods in Wind Energy Systems Engineering - Plant Controls (CL-Windcon)** Chairperson: Jan-Willem van Wingerden, TU-Delft Ervin Bossanyi, DNV-GL Bart Doekemeijer, TU-Delft Carlo Bottasso, TUM Stefan Kern, GE

Introduction

CL-Windcon Project

Mikel Iribas (CENER)

Abstract:

Presentation of the final results of CL-Windcon (Closed Loop Wind Farm Control) project. CL-Windcon is funded by the Framework Programme for Research and Innovation Horizon 2020

of the European Union (agreement nº 727477) and will last until October 2019, being this event its Final Conference. This project coordinated by CENER (National Renewable Energy Center of Spain), proposes a new way of approaching the design and operation of a wind farm, based on the wind farm closed loop control paradigm. The challenge is to achieve an increase in energy production and efficiency, while reducing its uncertainty and the cost of energy, for both existing and new wind farms. CL-Windcon brings new innovative solutions based on wind farm multi-fidelity dynamic modelling, and open- and closed-loop advanced control algorithms, which will enable the entire wind farm to be treated as a single integrated real-time optimization problem. More information can be found in http://www.clwindcon.eu/

Biography:
Coordinator of CL-Windcon H2020 project, Mikel is Head of R&D of Wind Energy Department at CENER (Spain). Master on "Control Systems and Industrial Engineer" at Universidad Pública de Navarra, he held the leadership of Control Area at CENER for 12 years. He is author of several patents in the field of wind turbine system identification. He has also been Associate Professor at Universidad Pública de Navarra, at the Automatic Control department, and invited as lecturer for several Master and PhD programs at EU level. Throughout his career, he has participated in numerous customer-oriented, and national and EU-funded R&D projects.

Keynote

Spanish experience. Renewable energy integration in Ancillary Services
Marta Pérez García (REE)

Abstract:
Wind energy has been one on the major sources of electrical energy in the Spanish peninsular system for almost a decade. In 2013, it was even the technology with the highest energy produced and it has consistently provided since then around 20% of the electrical energy in this system.

In order to securely integrate such high levels of renewable energy sources (RES) in the Spanish electric system and even higher future levels, regulatory changes were introduced in 2014. These have adapted the regulatory framework in order to delete as much as possible the distinctions between renewable energy resources and conventional generation. The two main changes have been the possibility of participation of variable RES in the balancing markets such as the tertiary reserve market and the introduction of market-based downward redispatching for solving congestions on either the TSO or the DSO's network.

An important issue on the provision of ancillary services with RES generation which has raised recently some debate in Europe is the crucial coordination between the participation on balancing markets of units that may be affected by congestion management. This issue, while not new at all, since conventional generators may as well be subject to congestion management limits in the transmission network, requires further development when applying to a larger number of renewable generators or these generators are connected to distribution grids. The issue of congestion management for TSO connected and distributed flexibilities has been coordinated by the Control Centre for Renewables (CECRE) in Spain since its commissioning in 2007, but a new degree of coordination needs have recently been introduced once these resources participate also in the ancillary services markets.

Biography:
Marta Pérez obtained her Industrial Engineering degree in 2004 from ICAI-Comillas University in Madrid. Since then she has been working for Red Eléctrica de España (REE) in the Control Centre Department (CECOEL) supporting the day to day real time work of the Dispatch Centre as well as working actively for the Control Center of Renewable Energy Sources (CECRE) to maximize the integration of renewable generation in the Spanish System keeping always the security of the system.

Session I: Wind Power Plants in the 21st Century Electricity System

Session Chair: Garret Barter (NREL)

LCOE: update of recent trends (general and offshore)

Tifenn Brandily (BNEF)

Abstract:
Solar power and onshore wind are now the cheapest source of new bulk electricity generation for two-thirds of global population, according to BloombergNEF. Competitive tenders, economies of scale and innovation keep pushing cost declines and industry consolidation. With onshore and offshore wind becoming key components of future power systems, the industry will need to look beyond the cost of generation and tackle the challenges of integration and value. This presentation draws on BloomergNEF's quarterly energy economics research to put the latest global onshore and offshore wind levelized cost into perspective. It will highlight the key technology and market trends that brought us here and discuss what might shape the wind industry in the future.

Biography:
Tifenn Brandily is an analyst at BloombergNEF based in London. He is part of BNEF's energy economics team and specializes in power generation and storage technology costs as well as asset valuation. Tifenn manages BNEF's levelized cost of electricity analysis, a bi-annual assessment of power costs involving more than twenty analysts globally. He is also responsible for delivering the economic analysis underpinning BNEF's New Energy Outlook, a long-term forecast for the power sector. His main areas of coverage include the economics of wind, solar, battery storage and gas peaking plants. Tifenn has a background in mechanical engineering and also holds an MSc.

LCOE Alternatives: System Value and Other Profitability Metrics (capacity value, time varying revenue, etc.)

Philipp Beiter (NREL)

Abstract:
The Levelized Cost of Energy (LCOE) is a widely used metric in the comparative assessment of electric generating assets and in wind energy systems optimization. The metric reflects the ratio of the annualized investment and operating costs and the average electricity yield during the evaluation period of a generation asset. It does not however, capture the location and time dependent monetary value of the generated energy and other services (e.g., capacity, operating reserves, reliability services) to the power system. Consideration of metrics that encompass the various system values of a technology, can have important consequences for wind energy systems optimization and design trade-offs. This presentation compares several

alternative competitiveness metrics, illustrates their relevance for wind energy systems engineering, and discusses challenges in the use of these metrics.

Biography:
Philipp Beiter is an Energy Analysis Consultant for the U.S. Department of Energy's National Renewable Energy Laboratory (NREL). His areas of expertise include financial modeling and economic analysis of offshore wind systems, electricity market design, and data analysis. He has advised government agencies and the private sector on cost, market, and valuation trends of the emerging U.S. offshore wind industry. Prior to joining NREL, Mr. Beiter worked at the Organization for Economic Co-operation and Development (OECD) and at the World Bank. He holds a Master's degree (M.P.A.) in Energy Management and Policy from Columbia University and the London School of Economics. Mr. Beiter has (co-)authored over 30 publications and journal articles.

Variance Reduction in Wind Farm Layout Optimization

Andrew PJ Stanley (Brigham Young University)

Abstract:
Wind is inherently a stochastic resource. Most wind farm optimization seeks to maximize some measure of the mean power production, while ignoring other statistics. In wind farm layout optimization, we have found that in addition to optimizing wind farms for high mean power, we can minimize the power variance with respect to the wind direction with no sacrifice to the mean power. The wind farm layout function space is unique in that there are many local solutions that are very similar in their mean power production. We exploit this multimodality, and find one of the solutions that results in high mean power production as well as low variance. For the cases we considered, we have been able to reduce the variance of an optimized wind farm by an average of 5-15%, while maintaining the optimal mean power.

Biography:
PJ Stanley is a 4^{th} year PhD Candidate at Brigham Young University. His research focuses on wind farm optimization, including heterogeneous turbine design in a wind farm, variable reduction of the wind farm layout problem, and new statistics and constraints in wind farm optimization. He spent a summer as a visiting researcher at the National Wind Technology Center at the beginning of his graduate studies, and has continued to collaborate with the researchers there in the years since. PJ received his BS from BYU in 2016.

Session II: What is Wind Energy Systems Engineering?

Session Chairs: Carlo Bottasso (TUM), Alessandro Croce (POLIMI)

Origins of Systems Engineering and MDAO for wind energy applications (wind turbine design)

Carlo Bottasso (TUM)

Abstract:
The design of wind turbines is a highly multi-disciplinary endeavor with strong couplings among aerodynamics (and hydrodynamics in the offshore case), structures, controls and on-board systems. Similarly, the design of wind farms involves several different coupled aspects, from the wind flow over complex terrain and vegetation, to logistics, building regulations,

impacts on the population and the environment and many others. Taking an even broader perspective, wind power plants do not work in isolation, but are part of the overall energy system. This is the classical situation of a system of systems, with strong internal and external multi-disciplinary couplings. The design of such systems is extremely challenging, and always involves the analysis of trade-offs and the satisfaction of constraints. This presentation will review the introduction in the wind energy field of systems engineering and MDAO and the progress achieved so far, with a specific focus on the design of wind turbines.

Biography:
Carlo L. Bottasso received a Ph.D. in Aerospace Engineering from Politecnico di Milano in Italy. Dr. Bottasso holds the Chair of Wind Energy at the Technical University of Munich, Germany, where he directs the Wind Energy Institute, and he currently serves as President of the European Academy of Wind Energy (EAWE). His research interests are in wind energy and rotorcraft technology, with particular reference to modeling and simulation, aeroservoelasticity and control. On these topics he has co-authored over 400 publications, including over 130 peer-reviewed journal papers.

Expansion of Systems Engineering in wind energy to plant design applications

Ewan Machefaux (Vestas Wind Systems A/S)

Abstract:
Wind energy is a growing and global market. The competitiveness of wind will continue to improve with market specific reduction between 23 % and 36 % expected by 2020 – 2030.

Following this rapid LCOE reduction trend, plants will become increasingly more complex to design with new renewables assets such as solar panels and batteries, more complex wind assets (advanced control operations, adaptive control, design envelop extensions), new plant level operational strategy (intermittent plant control, ancillary services, lifetime extension) …
Model based system engineering is essential to achieve LCOE reduction targets through technical and financial optimization of renewable plants, in its ability to model and optimize complex systems with multiple design variables, objectives and constraints.

Vestas has been developing over the last years a multi fidelity simulation environment platform. This computing platform integrates key components of a power plant into a model-based system engineering approach allowing modeling and validation across scales, leveraging on high performance computing, surrogate modeling, probabilistic design and advanced data analytics.

The key focus and challenge of MDAO plant design applications is to provide optimal technical and business solutions while remaining of practical relevance.

Biography:
Ewan have been working in the field of wind energy for 10 years. He holds a Master Degree in Wind Energy from the Technical University of Denmark, a PhD Degree in experimental and numerical analysis of wind farm flow fields from DTU Wind Energy Risø Campus. Following his PhD, he became a Post-Doctoral researcher in Wind Farm control and Optimization in the Aeroelastic design department of DTU Wind Energy.

He joined Vestas Wind Systems A/S 4 years ago as a Specialist in Wind power plant flow modeling at the Plant Siting and Forecasting department and recently extended his area of interest to Plant simulation and optimization using model-based system engineering at the Plant Hybrid modeling & Analytics department.

Re-thinking plant operation and control - maximizing profitability over the plant lifetime

Christopher Bay (NREL)

Abstract:
As installed capacity of wind generation continues to grow, wind farm manufacturers and operators are increasingly looking for ways to maximize their profitability while increasing the competitiveness of their respective services. An area of opportunity for improvement of wind plant operation exists in controls. However, to effectively leverage controls in the design of wind plants, computationally efficient and accurate models are needed. With such models, new control strategies and optimizations can be explored and evaluated at scale.

One promising control strategy is wake steering, or the method of adjusting a turbine's operation to deflect its wake away from downstream turbines. This has been shown in simulation, and more recently the field, to give an overall increase in a plants power production.

This talk will focus on how wake steering can be used in the design of a wind farm. We use a new and improved version of FLORIS to demonstrate layout optimization with all the relevant wake steering physics captured in a controls-oriented model. Additionally, work on incorporating loads into FLORIS to obtain better wind farm layouts without sacrificing AEP will be discussed.

Biography:
Christopher Bay is a research engineer at the National Wind Technology Center (NWTC) within the National Renewable Energy Lab (NREL). Christopher's background includes controls, building energy systems, and wind farm control. His studies focused in Mechanical Engineering, receiving his B.S. and M.S. from the University of Colorado Boulder, followed by his PhD at Texas A&M University. Christopher is currently focusing on distributed wind farm controls, integration of wind control systems with the grid, and co-design of wind plants bringing controls into the systems engineering process.

Session III: Application of Wind Energy Systems Engineering in Practice

Session Chair: Irene Eguinoa (CENER)

Vortex induced vibrations in high soft steel tubular towers

Javier Alonso (Siemens Gamesa Renewable Energy)

Abstract:
When facing the design of considerably soft Wind Turbine towers (high and flexible steel tubular towers) the unusual low frequencies of the whole structure result in several additional dynamic and control issues.

One of them, where this study focuses, is the effect of Vortex Induced Vibrations caused by the wind over the tower of a completely installed Wind Turbine Generator in standstill or idling condition. When the tower behavior, in terms of dynamic performance, is such that the tower

frequencies are significantly low, the 2nd eigenmode is susceptible to be excited up to critical levels.

The analysis of these critical wind speeds, Wind Turbine Tower movements and consequent loads are calculated for a specific real case. Moreover, the importance of certain parameters of the structure is identified in the analysis.

Based on such real case, the implementation of Vortex Generators has been evaluated and its effects measured for the correlation of simulation methods that will allow anticipate the behavior during tower design phases.

Biography:
Javier Alonso is a MSc Engineer specialized in support structures for wind turbines with more than 15 years of experience. His area of expertise is the design and calculation of towers and foundations and has been working in new developments of concepts and technologies to reduce costs and improve performance.

XXL Wind Turbine Challenges

Arantxa Esparza (Nabrawind Technologies)

Abstract:
For several years, the wind energy industry trend walks towards the development and installation of bigger wind turbines; higher hub heights, larger rotors and greater power, the so called XXL turbines. Associated with these XXL wind-turbines are many barriers that constrain their development and to which the wind industry should face; expensive, complicated logistics, very high assembly cost, expensive cost of energy. In this scenario, developments such as Nabrawind and Nabrajoint try to respond to the main challenges of XXL turbines

Biography:
Arantxa Esparza Zabalza is Project Manager in NABRAWIND TECHNOLOGIES, company dedicated to the development of advanced technologies for wind turbine components. During last year she has been devoted to coordinate the construction of the first Nabralift prototype (160 m height). She has 17 years of experience in the wind industry, as part of Gamesa and Acciona Windpower Engineering Department teams. She works as assistant professor at the Wind Energy MSc in the School of Engineering of the Public University of Navarra since 2006.

Breaking the ice for the MDAO ship

Sebastian Sanchez Perez-Moreno (Innogy)

Abstract:
Established wind farm development companies have had, for historical reasons, siloed geographically-dispersed mono-disciplinary design teams. This compartmentalization is known to hamper efficient collaboration, system optimisation and design automation. This talk will focus on the technical, organisational and cultural obstacles for introducing automated, collaborative and holistic wind farm design, as well as the key measures that help mitigate those obstacles and support the application of Multidisciplinary Design Analysis and Optimisation (MDAO) techniques. This story paints a before and after picture of the wind farm design process, fuelled by personal experience at a major player in renewable energy.

Biography:
Physicist at heart and passionate computer scientist, Sebastian Sanchez spent the last four years at the Delft University of Technology researching the application of Multidisciplinary Design Analysis and Optimization (MDAO) for wind farm design. This research led to the PhD dissertation "A guideline for selecting MDAO workflows with an application in offshore wind energy". Since 2015, Sebastian has been an active member of the IEA Wind Task 37 for Systems Engineering, co-leading the design of the IEA37 reference offshore wind farm. The speaker is now employed as an analyst at innogy SE, tasked with the holistic and automated design, analysis and optimisation of offshore wind farms, well aware of the risk of becoming a jack of all trades, master of none.

Hybrid Storage Systems in Renewable Energy Integration: Barasoain case study
Eugenio Guelbenzu (Acciona Energy)

Abstract:
Acciona is convinced that the future of the energy will be based on Renewables and Storage, and based on this conviction, in 2010 they incorporated a BES (Battery Energy Storage) to a commercial PV Plant. In 2016 they repeated the experience, but this time the Hybrid BES was associated with Wind energy.

This double experience, has allowed them to compare and verify the different dynamics between these two variable renewable energy sources and therefore their different Storage requirements. Today, they are presenting the Barasoain Hybrid Storage Project describing the structure, operation modes and implemented functionalities.

Biography:
Eugenio obtained his Bachelor Engineer in Power Electronics in 1973 from EPP Mondragon, in Spain. He also has an Engineering Degree in Control Engineering from "École supérieure d'électricité", in Paris and a Master in Electric and Electronics at Paul Sabatier University in Toulouse. With more than 40 years of experience, he passed 21 years in Technological Research Center holding different positions from Digital Control System Design Engineer to Research Unit Director. Over the last 17 years, he has been working for Acciona Energía holding different positions from Solar PV and CSP Project Manager, Hydrogen, Electric Vehicle & Energy Storage Program Manager to Innovation & Technology Project Director.

Session IV: Advanced Methods in Wind Energy Systems Engineering - Plant Controls (CL-Windcon)
Session Chair: Jan-Willem van Wingerden (TU-Delft)

Wind farm controller design and testing using LongSim
Ervin Bossanyi (DNV-GL)

Abstract:
LongSim is an engineering tool developed by DNV GL for wind farm analysis, both steady-state and dynamic, aimed at designing and testing of wind turbine and wind farm controllers. It is designed to run rapidly, to allow fast design iterations and long simulations. Turbine wakes are represented by a range of engineering models of wake deficits and added turbulence. The wakes are embedded into a realistic ambient flowfield which can be generated from site data.

This presentation explains how LongSim was used in the CL-Windcon project to design and test both wake steering and induction controllers for Sedini wind farm. The induction controller was then installed at Sedini, and field test results will also be presented.

Biography:
Ervin Bossanyi has a physics degree and a PhD in energy economics, and has been working on many aspects of wind energy in the academic, industrial and consultancy sectors since 1978.

Main contributions include development of advanced control concepts for commercial wind turbines, including individual pitch control and LiDAR, original development of the variable slip generator, detailed simulation modelling including development of the widely-used Bladed code, grid integration of renewables, and turbulence modelling. He is a co-author of the widely-used Wind Energy Handbook (Wiley, now in second edition), and is now senior principal researcher in renewables at consultants DNV GL, with a current focus on wind farm modelling and control. He was awarded the 2014 Scientific Award by the European Academy of Wind Energy, and has an honorary visiting professorship at Bristol University.

Towards closed-loop wind farm control under time-varying inflow conditions
Bart Doekemeijer (TU-Delft)

Abstract:
Wake formation in wind farms (WFs) leads to notable losses in the energy yield of downstream turbines. This talk will give an introduction to the concept of closed-loop wind farm control to address the issue of wake formation. In this work, a WF controller is synthesized leveraging the popular surrogate wind farm model FLORIS, which is actively developed by NREL and TU-Delft.

The novel controller proposed in this talk continuously estimates the inflow (supported by a theoretical notion of observability) and maximizes the energy yield of the farm through yaw-based wake steering. The controller is tested in high-fidelity simulations of a virtual 6-turbine wind farm using SOWFA. The WF controller is stress-tested by subjecting it to strongly-time-varying inflow conditions over 5000 s of simulation, in which the wind direction shifts several times over a region of 90 degrees. A time-averaged improvement in the energy yield of 1.3% is achieved compared to a baseline, greedy controller, with instantaneous energy gains of up to 10% for wake-loss-heavy situations. Note that this is the first WF controller tested at such fidelity and with such a time-varying inflow. This solidifies the WF controller as perhaps one of the first realistic closed-loop control solutions for yaw-based wake steering.

Biography:
Bart Doekemeijer is a PhD candidate at the Delft University of Technology on the topic of closed-loop wind farm control, in the group of prof. Jan-Willem van Wingerden. Over the past 3 years, Bart has taken a lead role in coordinating and executing the European CL-Windcon project, consisting of the development of the surrogate model FLORIS, devising static and dynamic wind farm control algorithms, extending high-fidelity tools for controller validation, and the controller design for the wake steering experiments at an onshore wind farm in Sardinia, Italy. In addition to CL-Windcon, he has collaborated with several prominent industrial partners on the topic of wind farm control. Most recently, Bart received an IEEE distinction for Outstanding Student Paper Award.

Overview of recent experiments in wind farm control using scaled models in a boundary layer wind tunnel

Carlo Bottasso (TUM)

Abstract:

The cooperative control of wind turbines is gaining acceptance as a mean to improve the way wind farms are operated. Notwithstanding its great promise, the problem remains extremely challenging due to the uncertain and variable nature of wind and wakes. In an effort to characterize the behavior of wind farm control strategies in a more controllable, known and repeatable environment, our group has developed a scaled wind farm that is operated in a large boundary layer wind tunnel. This presentation will review recent results obtained with this scaled facility. The setups considered include scaled wind turbines with pitch, torque and yaw control, operated by a farm-level super-controller and mounted on a large turntable that simulates wind direction changes. Some interesting conclusions are drawn on the effects of the accuracy of the flow models used for the synthesis of the control laws, and of the knowledge of the inflow conditions.

Biography:

Carlo L. Bottasso received a Ph.D. in Aerospace Engineering from Politecnico di Milano in Italy. Dr. Bottasso holds the Chair of Wind Energy at the Technical University of Munich, Germany, where he directs the Wind Energy Institute, and he currently serves as President of the European Academy of Wind Energy (EAWE). His research interests are in wind energy and rotorcraft technology, with particular reference to modeling and simulation, aeroservoelasticity and control. On these topics he has co-authored over 400 publications, including over 130 peer-reviewed journal papers.

Full scale testing of open-loop wind farm control approaches for reducing wake losses

Stefan Kern (GE)

Abstract:

In the context of the H2020 project CL-Windcon, full scale tests of open-loop wind farm control strategies are being tested on ENEL Greenpower's Sedini wind plant. The approaches tested include wake loss mitigation using induction control and wake steering on two separate turbine clusters in the wind farm. In both cases, look-up-tables of optimized operational setpoints as function of local wind conditions have been precomputed and deployed at site with a toggling strategy continuously alternating between baseline and optimized operation.

This presentation will provide an overview of the concept and setup of the tests executed at the Sedini site. The approaches used to estimate inflow wind conditions will be discussed as well as important aspects to quantify small performance deltas between operation modes along with some preliminary results.

Biography:

Stefan Kern is a senior aerodynamics engineer at GE Renewable Energy and leading the development and validation of wind farm control technologies to increase wind farm energy capture. He has worked on wind turbine and wind farm aerodynamics for over 10 years. His expertise covers modeling aspects from simple engineering models to high fidelity CFD based approaches, field measurement campaigns using state-of-the-art remote sensing technology and system optimization. Stefan Kern received a PhD in mechanical engineering from ETH Zurich, Switzerland.

Thursday, October 03rd, 2019	
8:30 am – 9:15 am	Keynote: Pedro Mayorga, EnerOcean
9:15 am – 10:25 am	**Session V: Advanced Methods in Wind Energy Systems Engineering - Design & Optimization** Chairpersons: Frederick Zahle, DTU, and Michael McWilliam, DTU Katherine Dykes, DTU Frederick Zahle, DTU Andrew Ning, BYU
10:25 am – 10:45 am	Coffee Break / Posters session
10:45 am – 12:15 am	**SESSION VI-Advanced Applications in Offshore Wind Energy Systems Engineering** Chairperson: Mario Garcia-Sanz, US DOE ARPA-E Mario Garcia-Sanz, US DOE ARPA-E Jose Azcona, CENER Joaquín Urbano, ESTEYCO Brandon Ennis, Sandia Labs
12:15 am – 1:15 pm	Lunch
1:15 pm – 2:45 pm	**SESSION VII-Standards and Data for Wind Energy Systems Engineering** Chairperson: Katherine Dykes, DTU Pietro Bortolotti, NREL Niels Jacob Tarp-Johansen, Ørsted Pawel Gancarski, CENER Elyoenai Egozcue, S21sec Nikolai Hille, DNV-GL
3:30 pm	**Visits: Barasoain experimental area (hybrid wind storage plant) & CECOER (Renewables Energy Control Center) - ACCIONA**

Keynote

W2Power: Twin-rotor floating wind platform development

Pedro M. Mayorga Rubio (EnerOcean)

Abstract:
The development of the W2Power solution from its conception in 2009 up to the sea testing at PLOCAN will be presented. The W2Power solution joins several innovations in order to make a cost efficient solution to exploit the wind resource at open sea in any water depth. The development of the W2Power has comprised a significant effort of engineering, and before its sea testing the concept was tested at 4 laboratories in three countries in eight testing campaigns. The 1:6 scale platform finally design, manufactured, assembled, installed and tested at open sea has become the first Spanish floating wind platform and the first multi turbine solution in the World to reach open sea testing. The challenging environment for a scale down version has allowed an accelerated test of its functionality, stability and survivability.

Biography:
EnerOcean S.L. Founder, President and Chief Technology Officer.
Engineer with more than 24 years of experience. He started as manufacturing and maintenance engineer at General Motors group and as renewable energy expert in a research center, before creating EnerOcean.

Founder of EnerOcean, the oldest Spanish company specialised in marine energy, Mr.Mayorga has led the development of W2Power since 2012, including design, tank testing, control and monitoring solutions and finally coordinating the project that has built the current scale prototype, first floating platform in Spanish waters and the first multirotor design to achieve this technological level. Associated Professor at Malaga University (Marine Energy). Member of several associations and committees.

Session V: Advanced Methods in Wind Energy Systems Engineering – Design & Optimization

Session Chairs: Frederick Zahle, Michael McWilliam (DTU Wind Energy)

Advanced MDAO for wind power plant design

Katherine Dykes (DTU Wind Energy)

Abstract:
Wind power plant optimization has evolved significantly over the last decade. This talk reviews the historic developments in systems engineering for wind power plants and also highlights some key current trends and future directions. The presentation is based on a recent wind turbine and power plant optimization chapter for a wind energy simulation book series that will be published in the fall of 2019.

Biography:
Dr. Katherine Dykes is the Head of Section for Loads and Controls at DTU Wind Energy where the team researches wind turbine and power plant aeroelasticity, controls and optimization for both land-based and offshore applications. Prior to this, she spent 8 years at NREL with a focus on multi-disciplinary design, analysis and optimization applied to wind turbine systems - leading a team engaged with studies ranging from individual component optimizations to full wind plant scale optimizations of layout and controls strategy. Katherine has a PhD from the Engineering Systems Division of the Massachusetts Institute of Technology where her thesis centered on the interplay between wind technology innovation and deployment. She is also a co-operating agent (along with representatives from DTU Wind Energy, Denmark and Sintef Energy Research, Norway) of IEA Wind Task 37 on systems engineering / integrated RD&D for wind energy.

High-fidelity wind turbine blade design enabled by adjoint techniques

Frederick Zahle (DTU Wind Energy)

Abstract:
Design of wind turbine rotors is commonly based on aerodynamics modelled with the blade element momentum (BEM) method, which is computationally very efficient and accurate. While these methods work very well for conventional blade designs, novel design features near the root and tip of the blade, or other types of rotor concepts require improved modelling fidelity. Additionally, to carry out a truly free-form design of a wind turbine blade in which both planform and cross-sectional shape are designed simultaneously, some kind of flow solver is needed.

In this talk we explore the perspectives of applying high-fidelity 3D computational fluid dynamics (CFD) to design the blade aerodynamically, which is enabled by the application of adjoint techniques that efficiently can handle hundreds of design variables. We present an large scale optimisation of a 10 MW rotor based on the IEA Wind Task 37 aerodynamic rotor design case study, and discuss future work needed to make this approach industrially relevant.

Biography:
Frederik Zahle completed his masters in aeronautical engineering at Imperial College, London in 2003, and earned a Ph.D. jointly from Imperial College and Risø DTU in the field of computational fluid dynamics (CFD) of wind turbines, which he completed in 2007. He is currently holding a position as a senior scientist in the Aerodynamic Design Section (AER) at the Department of Wind Energy, Risø Campus, DTU. His current research activities are within aerodynamics of airfoils and rotors, computational fluid dynamics, and multi- disciplinary design of wind turbines.

Large-Scale Gradient-Based Optimization for Wind Energy Systems
Andrew Ning (BYU)

Abstract:
This talk will highlight a range of wind farm and wind turbine projects in our research lab. By leveraging numerically exact gradients we explore larger-scale wind farm and wind turbine optimization problems. We are also developing techniques to optimize more effectively, improve aerodynamic fidelity, and capture tradeoffs in uncertainty.

Biography:
Andrew Ning is an assistant professor at Brigham Young University specializing in aerodynamics and optimization. Prior to joining BYU he worked on the wind energy systems engineering project at NREL. He earned his PhD in 2011 from Stanford University in Aeronautics and Astronautics.

Session VI: Advanced Applications in Offshore Wind Energy Systems Engineering

Session Chair: Mario Garcia-Sanz (US DOE ARPA-E)

Control Co-Design of Floating Offshore Wind Turbines: the ARPA-E ATLANTIS Program
Mario Garcia-Sanz (US DOE ARPA-E)

Abstract:
Starting in January 2018, the Advanced Research Projects Agency – Energy (ARPA-E), U.S. Department of Energy, began challenging the research and industrial communities to develop new and disruptive Control Co-Design (CCD) solutions for a large variety of applications. The new ARPA-E ATLANTIS program encourages the application of CCD methodologies to Floating Offshore Wind Turbines (FOWTs), integrating all relevant engineering disciplines at the start of the design process, with feedback control and dynamic interaction principles as the primary drivers of the design. The program seeks to design radically new FOWTs; build a new generation of computer tools to facilitate FOWT design; and collect real data from full and lab-scale experiments to validate the FOWT designs and computer tools. The program also proposes a new metric space that considers the specific swept-rotor-area per unit of total-

mass and the power generation efficiency of the FOWT, and guides the research across the resulting LCOE isolines.

Biography:
Prof. Mario Garcia-Sanz currently serves as Program Director at the Advanced Research Projects Agency-Energy (ARPA-E), U.S. Department of Energy, where he leads the ATLANTIS Program on Floating Offshore Wind Turbines and the NODES Program on Grid Control Technologies among other initiatives. Garcia-Sanz is also Professor at Case Western Reserve University. Previously, he was Professor at the Public University of Navarra, Research Scientist at CEIT, Professor at TECNUN, Visiting Professor at UMIST, Oxford University, NASA-JPL and the European Space Agency, and a NATO RTO Lecture Series Director. Garcia-Sanz has extensive private sector experience; he founded CoDyPower, a consulting firm specializing in robust control systems and energy innovation, and has worked as a Senior Advisor for wind energy companies, electrical utilities, corporations and space agencies. He holds over 20 patents, has written 3 books and published over 250 research papers, and has been the principal investigator of over 50 industry research projects.

SiL scaled hybrid testing in the design of floating wind turbines

José Azcona Armendáriz (CENER)

Abstract:
During the design process of a floating wind turbine, the concept has to be validated through scaled wave tank experiments that accurately represent the system dynamics, including wind and wave loading. This requires solving the scaling conflict between the hydrodynamic and aerodynamic forces. Software-in-the-Loop method (SiL) was developed as a hybrid testing method to sort out this conflict. The SiL method consists of a ducted fan that replaces the rotor and introduces a force representing the aerodynamic thrust. A simulation of the rotor, coupled in real time with the measured platform displacements at the basin, provides the rotor force introduced by the fan. This method has been applied on many test campaigns of semisubmersible, spar and Tension Leg Platforms (TLP) that support floating wind turbines.

The SiL hybrid testing method has shown to be an efficient, reliable and cost saving technology. Further developments of the method are being carried out to include the coupled rotor moments and to better characterize the band with response of the actuator.

Biography:
(PhD, MEng) Head of the Offshore business unit. He graduated in Industrial Engineering at the Universidad Pública de Navarra and obtained his PhD in Naval Engineering at the Universidad Politécnica de Madrid with the Extraordinary Doctorate Award. Has more than 15 years of research experience in the field of Renewable Energies. Since 2004 he has been working at CENER. He has experience in rotor design and loads calculation for wind turbines. He has taken part at the IEA annexes 23 and 30 on validation of integrated simulation codes and he has lead several tasks in European research projects (INNWIND.EU, IRPWind). He has developed the OPASS code for the dynamic analysis of mooring lines that he has validated experimentally and coupled with tools for floating wind turbines. He has developed the Software-in-the-Loop hybrid testing method for scales wave tank experiments of floating wind turbines. His main research topics are related with integrated simulation tools, mooring line dynamics and scale testing of floating wind turbines.

ELISA Technology: from numerical modelling to offshore installation

Joaquín Urbano (ESTEYCO)

Abstract:
Numerical modelling is, in general, an effective, cost-saving tool in almost any field of engineering. When referring to floating structures, motions and loads are assessed by means of numerical models, yielding precise enough results to ensure the expected behavior when carrying out the real operation. ELISA technology has been widely numerically analyzed, contrasted and calibrated against several tank testing campaigns and finally successfully transported and installed, showing that numerical calculations were accurate. This presentation aims to show some comparison between the numerical calculations, at different stages of the project, and some real data gathered from the platform instrumentation during transport and installation operations.

Biography:
Joaquín Urbano is a Senior Naval Architect specialized in the design of fixed and floating offshore structures and holds a MEng in Naval Architecture and Marine Engineering from Universidad Politécnica de Madrid (Spain). Over the last years, he has been working for ESTEYCO SA where has been involved in several offshore wind design projects at very different stages of maturity, from the very beginning concept development to the on-site construction and installation, going through the concept design, FEED and detailed design phases. He has been part of different renowned projects such as Kincardine Wind Farm, in UK, and the ESTEYCO's bottom fixed prototype recently installed in Spain, ELISA.

Engineering Judgment and Systems Engineering Perspective from Sandia´s Floating Offshore VAWT Project

Brandon Ennis (Sandia National Laboratories)

Abstract:
Sandia National Laboratories has recently completed a multi-year project to analyze the system levelized cost of energy (LCOE) for a vertical-axis wind turbine (VAWT) designed to access the vast wind energy resource at deep-water sites. At the large scales that will be common for offshore turbines, VAWTs have improved efficiencies over HAWTs. In addition, a significant portion of the LCOE for a deep-water offshore wind plant comes from the platform costs. Due to the lower drivetrain placement and center of gravity, VAWTs may have lower platform costs compared with HAWT designs. This talk will summarize the findings of this project and provide a discussion of the interdependencies on the system-level design for this floating offshore wind energy system, in addition to the necessary role of optimization and engineering judgment for design of these complex systems.

Biography:
Dr. Brandon Ennis joined the Wind Energy Technologies Department at Sandia National Laboratories in 2014. He was the aero-hydro-elastic lead for the offshore vertical-axis wind turbine project and was responsible for the structural design and aeroelastic loads analysis for the National Rotor Testbed project in which blades were designed and manufactured for testing at Sandia's experimental wind plant facility. Brandon currently leads the composite materials/structural optimization research at Sandia and has supported projects focused on rotor design, experimental loads analysis, and atmospheric data analysis. He led the system LCOE analysis of the floating offshore VAWT project which quantified the cost and performance tradeoffs of every component in the system.

Session VII: Standards and Data for Wind Energy Systems Engineering

Session Chair: Katherine Dykes (DTU Wind Energy)

Task 37 guidelines for integrated wind energy system modeling

Pietro Bortolotti (NREL)

Abstract:

This work reviews the state-of-the-art in the development of software frameworks for integrated wind turbine and plant design, analysis, and optimization, and proposes a classification system for the frameworks along dimensions of model fidelity and scope. Within each major wind turbine and power plant subsystem, a matrix is developed for the disciplines used and the fidelity levels with which each discipline can be modeled. The existing frameworks are then classified according to the matrix. Next, an ontology is proposed that allows for standardizing how data is transferred between the most common discipline-fidelity combinations used in the frameworks. A common representation of data creates the ability to 1) share system descriptions and analysis results or supporting more transparent benchmarking and comparison, and 2) integrate models together into workflows within and across organizations for improving the efficiency and performance of wind turbine and power plant design processes - ultimately leading to better overall wind energy system designs with high performance and low costs.

Biography:

Dr. Bortolotti is a research engineer at the National Wind Technology Center (NWTC) of the National Renewable Energy Laboratory (NREL) in Boulder, Colorado. Dr. Bortolotti obtained his PhD at the Technical University of Munich under the supervision of Prof. Dr. Carlo L. Bottasso. His research area is systems engineering for wind energy, with a focus on wind turbine rotor design. Dr. Bortolotti is part of the core development team of the systems engineering framework WISDEM.

Publishing FAIR data

Pawel Gancarski (CENER)

Abstract:

Findable Accessible Interoperable and Reusable (FAIR) data is a set of guidelines crucial for facilitating collaborative research. Following those guidelines, is the best way for implementing the Open Science and Open Data policies. It is also a necessary step in the advancement of digital science, infrastructures and data economy. To address the challenge of FAIR data, open source data conversion tool and naming conventions dictionary is being developed.

With wind energy suffering from both lacks of standards for emerging technologies, as well as incompatible or overlapping standards where multiple disciplines overlap, the challenge for the tools is not to promote any specific approach, but rather to offer support in the current, chaotic context and providing a structured environment where standards can naturally emerge.

The need for improvements in the quality of data standardization and documentation is well understood. Both industry and research community seems to be aware of the data bottleneck when it comes to extracting value from existing databases and the implementation of the latest data-related technologies such as Big Data, machine learning or IoT. Because of that, data quality becomes an important part of most of the newly defined projects. Unfortunately,

as it cannot be considered a “scientific research topic”, nor a commercial project, there are no projects solely focused on this aspect, large enough to facilitate community wide solution for preventing fragmentation.

Even though the long term impact of using unified data conversion tools is clear, the tools are not used if they imply additional work in short term. This is a result of data processing being performed on a project basis – with tight deadlines and budgets, and no resources reserved for research on data management aspects.

To address that, when introducing changes to the users workflow on data processing, the full data life-cycle needs to be analyzed and modified. Integrating the data conversion steps with data processing, analysis, archiving, documentation and publishing, ensures that time efficient work will only be achievable through serious treatment of standards.

Engagement of the whole community is of key importance, to prevent further fragmentation of efforts. To do that, the community needs more awareness of different efforts, and needs to respect parallel initiatives by building bridges between them, and merging them where possible.

Biography:
Dr. Pawel Gancarski, has a PhD in Computer Science from Trinity College, Dublin. He joined CENER in 2011 as an experienced researcher with the WAUDIT Marie Curie fellowship. He was involved in the model Verification and Validation, throughout the projects IEA Task 31 Wakebench, NEWA, EERA-DTOC, EERA-Avatar, EERA-IRPWind and OWAbench. He was a WP Leader in the IRPWind project, dealing with benchmarking of design codes for offshore wind turbines. He was also the lead developer of Windmesh, a meshing tool for CFD models for wind resource assessment in complex terrain. Currently his work is focused on best practices for data standardization, publishing and workflows.

Cybersecurity and wind energy

Elyoenai Egozcue (S21sec)

Abstract:
Key elements in which cyber security standards impact the design and operation of wind turbines and wind farms. Standards such as IEC 62443 and NERC CIP imposes a number of cyber security requirements at a component level and to wind farm architectures and operational procedures. During the talk, some of the key requirements to consider when designing key components such as controllers and local SCADA systems will be detailed. Likewise, two of the most relevant operational use-cases affected by cyber security requirements at a windfarm level, including remote access to a windfarm and its network segmentation will be reviewed.

Biography:
Mr. Elyoenai Egozcue received his M.Sc. in Telecommunications Engineer from the UPNA University of Pamplona, Spain undertaking his Master Thesis at the VUB University of Brussels, Belgium. He started his professional career as a cyber security researcher at S21sec Labs, dealing with open-source cyber intelligence, RFID security, Network security and biometrics. He is currently the head of cyber security services for industrial automation and control systems at S21sec and leads relevant projects in this field in sectors such as renewable power generation, power transmission and distribution, railway transportation, logistics, etc.

New wind power plant control in the framework of existing certification schemes

Nikolai Hille (DNV-GL)

Abstract:

Pressure on the economics of wind power plants is increasing. One way of improving the performance is the implementation of new control strategies to individual turbines and increasingly also to the whole wind farm considering it as a single power plant. Within the EU funded research project CL-Windcon these new control strategies for the wind power plant have been developed and demonstrated in simulation and onsite measurements.

Certification is an important independent quality assurance for large scale projects like a wind power plant. Basically, the economics of such projects is not the primary focus for certification. Structural integrity of the individual wind turbine as well as the dynamic interaction of all wind turbines within a wind farm and its connection to the electrical grid play the most important roles. The new outstanding features of the CL-Windcon control strategies are that mechanical loads as well as the energy output can be mitigated from one turbine to another. The benefits are a maximised total energy output of the whole wind power plant and an optimised distribution of the mechanical loads. By that the optimisation of each single turbine is given up to the benefit of an optimised wind power plant.

Certification of such novel control strategies is a challenge, as the assessment of the new design can only relate to existing standards. When these standards were written they considered the present state-of-the-art. In the best case the original purpose of the standards can be interpreted and applied for the new designs to aim for an adequate assessment. For more complex designs like the control strategies proposed with the CL-Windcon plant control this can be difficult.

Within the present project it was investigated up to which extend the proposed control strategies require an amendment of existing design requirements for Type and Project Certification to respond to additional risks of the new design. The new requirements shall be in good balance to the expected additional risks of the proposed technology with the intention to support the step from research level within CL-Windcon to the launch of commercial projects.

The presentation will give a short introduction to certification in the light of plant control. Then it will be evaluated to which extent amendments for the control system are necessary which will reflect the more complex control algorithms, additional sensors and optimisation algorithms.

The more complex plant control will in turn imply increased efforts within the calculation of design loads because the new control strategies will lead to operation of the turbines in conditions which are not assumed in conventional control, e.g. the permanent operation at increased yaw error. At the same time the application of new wind farm simulation tools is a challenge as long as they are not sufficiently validated. The presentation will highlight the most important impacts on the calculation of design loads.

Individual national requirements on grid code compliance need to be considered before the erection of a new wind power plant. The integration of additional power to a grid tends to be difficult because grids nowadays are often operated close to their limits for capacity. The presentation aims to identify amendments to existing standards for design and test to ensure a required grid code compliance.

Biography:
Nikolai Hille has a degree in mechanical engineering (Dipl. Ing.) from Braunschweig Technical University. He joined Germanischer Lloyd (nowadays DNV GL) in 2001. Since then he worked in the context of wind energy certification with different responsibilities as project engineer and project manager. Holding the position of a Senior Engineer for loads he took an active part in the development of a number of wind energy loads Standards and Recommended Practices. Being expert for LIDAR assisted control in certification he participates in the research project CL-Windcon and currently initiates a Joint Industry Project on LIDAR measured turbulence intensity at DNV GL Renewables Certification.

Visits

Barasoain Experimental Area (hybrid wind storage plant)

Located at Barásoain (Navarra, Spain), this experimental wind farm, owned by ACCIONA and set up in 2013, consists of five 3-MW wind turbines of different heights, tower types and rotor diameters. It is used for the ongoing testing of wind turbine components and the testing of new ones with a view to the continuous improvement of the turbine models that are launched in the market. Its experimental nature does not prevent it from sending a considerable amount of energy to the grid. It produces an average 34 GWh per year, equivalent to the electricity consumption of 12,000 homes.

CECOER (Renewables Energy Control Center)

The CECOER is the biggest control center for renewable facilities in the world. From its location in Sarriguren, on the outskirts of Pamplona in Spain, the center manages all the company’s electricity generation plants worldwide. This installation carries out real-time monitoring of the operation of renewable energy plants managed by the ACCIONA Group with more than 14,000 MW in total. The CECOER is manned by a skilled team of 80 people and it operates 24 hours a day, 365 days a year.

Friday, October 04th, 2019 – Tutorials	
9:00 am – 10:00 am	**BLADE OASIS/BASFF** Ainara Irisarri, Iñaki Nuin, CENER
10:00 am – 11:00 am	**WISDEM & FLORIS** Pietro Bortolotti, Garrett Barter, Christopher Bay, NREL
11:00 am – 11:45 am	Brunch
11:45 am – 12:45 am	**HAWTOpt2/Topfarm** Katherine Dykes, DTU
12:45 am – 13:45 pm	**Cp-Max** Luca Sartori, POLIMI

Tutorials

BLADE OASIS/BASFF

Ainara Irisarri (CENER), Iñaki Nuin (CENER)

Abstract:
(Blade Optimal Aero-Structural Integrated Solutions) is an in-house CENER tool to help in the design of rotor blades. It integrates both aerodynamic and structural modules, that cross-linked by an optimization algorithm from Dakota (public domain software developed by Sandia National Laboratories), achieve blade designs complying as much as possible with the optimization function defined by the user.

The aerodynamic module is based on BEM (Blade Element Momentum) approach. It mainly provides information related to the performance of wind turbine such us power curve, AEP (Annual Energy Production), TSR (Tip Speed Ratio), CP (Power Coefficient) and CT (Thrust Coefficient).

The structural module applies the fundamentals of CLT (Classical Lamination Theory) approach, EBT (Euler – Bernoulli Beam Theory) approach and TMBT (Thin-walled Multi-cell Beam Theory) approach. This module provides information of the blade deflection, strength and fatigue reserve factors according to the blade geometry, internal structure, lay-up and loads.

The workshop session dedicated to BladeOASIS/Bassf tutorial will go through the general overview of the tool, and will show two practical application cases. The first case will be an aeroelastic optimization case, while the second case will show how to move from the parametric structural design obtained with BladeOASIS to the detailed structural design.

Biography:

Ainara Irisarri is a Mechanical Engineer with experience on load calculation for certification under IEC and GL standards. Since October 2008 she works on blade design projects involving rotor optimization tools and blade concept analyses codes in the aerodynamics area within the Wind Turbine Analysis and Design Service, belonging to the Wind Energy Department of CENER. She has participated on FP7 projects like INNWIND and AVATAR relating multi-megawat offshore wind turbines. Ainara also collaborated on FP7 project WINDUR, on small VAWT rotor design.

Iñaki Nuin is a Mechanical Engineer with experience in the design of composite and metallic components. Specialized on rotor blades design and adhesives. Researcher on new analysis tools and new design methods for components optimization and reliability improvement. During seven years he was Consultancy Engineer for MSC Software focused on the automotive Industry at Analysis and Simulation, S.L. Since February 2006 he is working in the Mechanical and Structural Area within the Wind Turbine Analysis and Design Service, belonging to the Wind Energy Department of CENER.

WISDEM & FLORIS

Garret Barter, Pietro Bortolotti, Christopher Bay (NREL)

Abstract:

This session will present two NREL software models: 1) WISDEM, the wind systems engineering software, and 2) FLORIS, the wind plant wake and control modeling software. WISDEM, built on NASA's OpenMDAO software, integrates a full set of wind turbine and plant models for holistic system analysis. It includes modules turbine aerodynamics, component structural analysis, component costs, plant balance-of-station costs, plant operations and maintenance costs, financial models, wind plant layouts, and wind turbine aeroelastic simulations. This FLORIS framework is designed to provide a computationally inexpensive, controls-oriented modeling tool of the steady-state wake characteristics in a wind farm. The WISDEM presentation will be a tutorial lasting 40 minutes and include basic OpenMDAO building blocks and WISDEM highlights. For the best participation experience, please install Anaconda and WISDEM ahead of time using instructions at: https://github.com/WISDEM/WISDEM. The FLORIS presentation will be an overview of capabilities and code architecture, but no hands-on tutorial.

Biography:

Garrett Barter has a background in aerospace, systems engineering, and computational methods, receiving his degrees through PhD from MIT. From there, Dr. Barter worked at Sandia National Laboratories for 6 years conducting systems engineering and analysis studies that supported the Department of Energy Vehicle Technologies office and the Department of Homeland Security. After a 3-year stint in the private aerospace and defense sector, he returned to the national laboratories, this time at the National Renewable Energy Laboratory. In this position, Dr. Barter is the principal investigator for NREL's wind system engineering and offshore wind analysis programs.

Dr. Pietro Bortolotti is a research engineer at the National Wind Technology Center (NWTC) of the National Renewable Energy Laboratory (NREL) in Boulder, Colorado. Dr. Bortolotti obtained his PhD at the Technical University of Munich under the supervision of Prof. Dr. Carlo L. Bottasso. His research area is systems engineering for wind energy, with a focus on wind turbine rotor design. Dr. Bortolotti is part of the core development team of the systems engineering framework WISDEM.

Christopher Bay is a research engineer at the National Wind Technology Center (NWTC) within the National Renewable Energy Lab (NREL). Christopher's background includes controls, building energy systems, and wind farm control. His studies focused in Mechanical Engineering, receiving his B.S. and M.S. from the University of Colorado Boulder, followed by his PhD at Texas A&M University. Christopher is currently focusing on distributed wind farm controls, integration of wind control systems with the grid, and co-design of wind plants bringing controls into the systems engineering process.

HAWTOpt2/Topfarm

Katherine Dykes (DTU Wind Energy)

Abstract:

Over the last 10 years, DTU Wind Energy has been developing MDAO tools for both turbine and plant design optimization. This session will provide an overview of DTU Wind Energy system design and optimization capabilities with some examples of the latest developments for research and commercial applications.

Biography:

Dr. Katherine Dykes is the Head of Section for Loads and Controls at DTU Wind Energy where the team researches wind turbine and power plant aeroelasticity, controls and optimization for both land-based and offshore applications. Prior to this, she spent 8 years at NREL with a focus on multi-disciplinary design, analysis and optimization applied to wind turbine systems - leading a team engaged with studies ranging from individual component optimizations to full wind plant scale optimizations of layout and controls strategy. Katherine has a PhD from the Engineering Systems Division of the Massachusetts Institute of Technology where her thesis centered on the interplay between wind technology innovation and deployment. She is also a co-operating agent (along with representatives from DTU Wind Energy, Denmark and Sintef Energy Research, Norway) of IEA Wind Task 37 on systems engineering / integrated RD&D for Wind energy.

Cp-Max

Luca Sartori (POLIMI)

Abstract:

The development of next-generation wind turbines is a true multi-disciplinary challenge which must be addressed with suitable design algorithms (MDO).

In this tutorial, we present the design framework Cp-Max, a suite for the system design of wind turbines developed by Politecnico di Milano and TUM. We'll dig into the multi-level architecture of the code to understand how the complex multi-disciplinary design task is performed by a cluster of interfaced optimization loops. We'll then discuss the philosophy behind such an approach and how conflicting requirements about optimization scope, modelling fidelity and number of design variables are managed by the program. To complete the presentation, we'll briefly describe the main input required by the code and what is the sequence of operations in a typical design scenario.

Biography:

Luca Sartori is an aeronautical engineer from Politecnico di Milano (Polimi) with research interests in numerical optimization, lightweight rotors and innovative concepts in wind energy applications. In 2013 he completed his Thesis at ECN (now part of TNO), where he developed a free-form algorithm for the design of WT rotors. After his graduation Luca started a PhD in wind energy: his research project developed mainly around the topic of system-design of wind turbines. In this context, his effort was to implement new methodologies to support the design of next-generation very large rotors. This year he defended his doctoral thesis and now he is continuing as a post-doc. At present, Luca is investigating the impact of WF controllers on the aero-structural design of existing turbines.