FarmConners

Public Workshop 10th December 2020 Certification, Standardisation, and other Regulatory Issues of Wind Farm Control

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Certification, Standardisation, and other Regulatory Issues of Wind Farm Control

Summary of Position Paper Deliverable D2.1

Overview

- Regulatory Landscape
  - Certification Schemes, Standards
- Wind Farm Control Functionalities
  - State-of the-art WFC, Novel WFC Strategies, Integration of WFC in WPP
- Wind Farm Control Economics
  - Market Structures, Economic Potential, Ancillary Services
- Challenges for Wind Farm Control Commercialisation
  - Turbulence and wake effects, grid requirements, wind turbine components
- Proposed Solutions
  - Temporary project certification, Risk based certification, Regulatory sand-box approaches

Regulatory Landscape

Regulatory Landscape

- Advanced Wind Farm Control strategies will have a characteristic influence on the loading profile of each individual turbine and the additional **load effects need be kept within the defined component design limits**

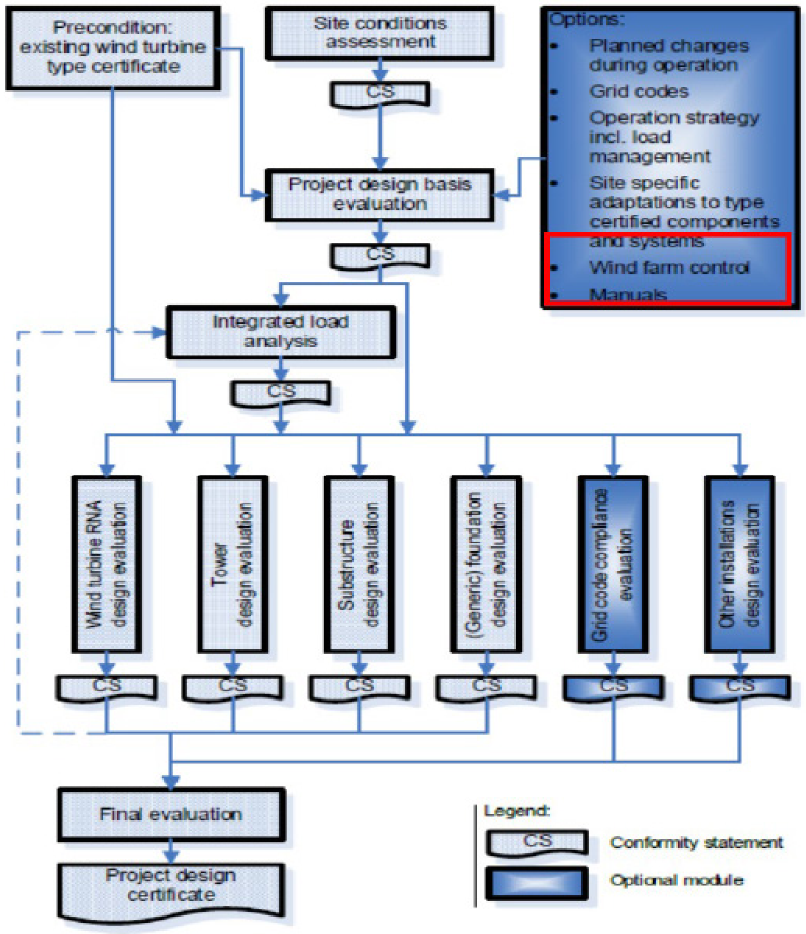
- Design limits are typically defined by a type certificate
  - Rotor-Nacelle Assembly (RNA)
  - Project certificate (for site specific support structures or a wind farm).

Regulatory Landscape

Two Certification Schemes found for WFC

IECRE standards OD-501 Ed. 2.0, 2018-05-24 for type testing and OD-502 Ed. 1.0 2018-10-11 for project certification

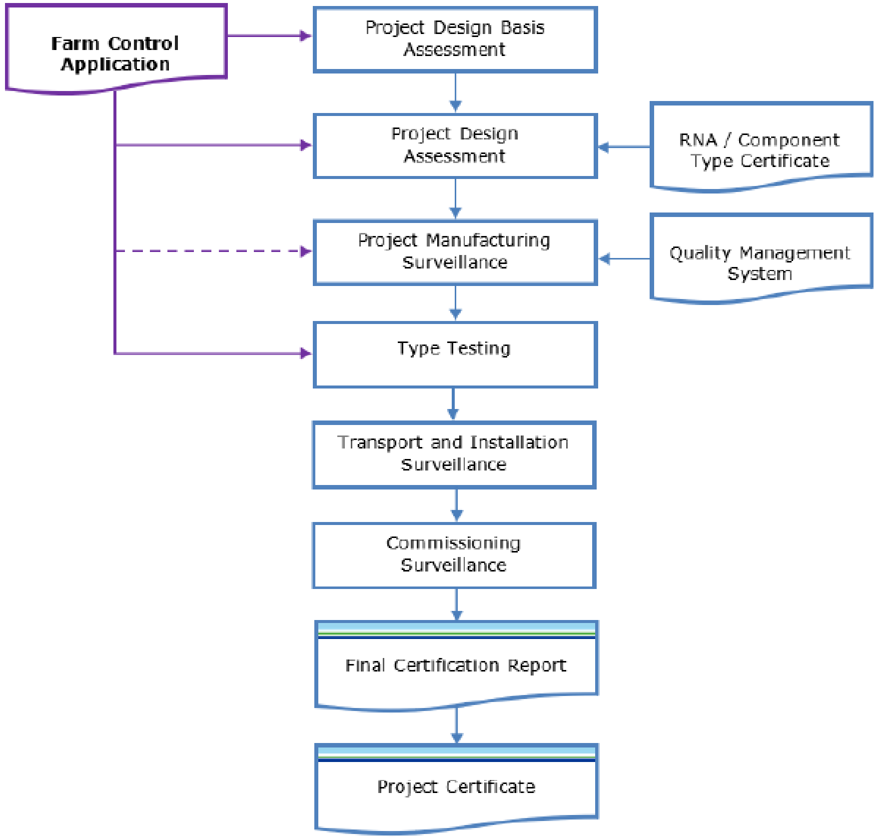
- Both IECRE standards make a provision to include wind farm certification, but with **no clear guidance about how this should be performed**



Regulatory Landscape

DNVGL service document SE-1090 Ed. December 2015 for the project certification of wind power plants.

- Within **DNVGL-ST-190 update** to be published 2020 the **wind farm control is considered** by performing a "Site-Specific Design Assessment (SSDA)".
- Wind farm is considered as a power plant and during design it is optimised as a whole
- The site-specific design assessment includes as a minimum analysis and review of:
  - Wind conditions at the site
  - Wind farm influence (site description/layout) / wake analysis (highest loaded wind turbine)
  - Site complexity analysis
  - Site-specific extreme loads



Regulatory Landscape

Identified standards and guidelines

- Existing standards in practice **do not cover the wind farm control case explicitly**.
- Still an individual approach will be needed, based on general requirements of standard wind turbine control systems, as far as applicable.

Table 3 Wind engineering standards and service documents

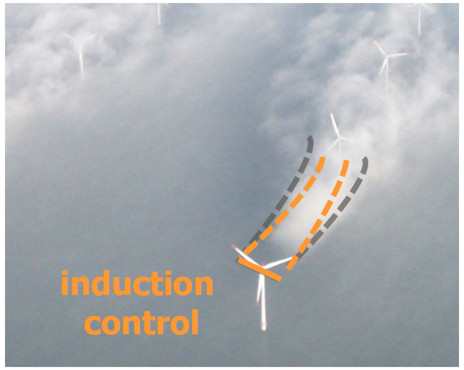
Group	ID	Revision	Description
IEC 61400 series	IEC 61400-1 [5]	Ed.3.0, 2005-08	Wind energy generation systems Part 1: Design requirements
	IEC 61400-1 AMD1	Ed. 3.0, 2010-10	Wind turbines – Part 1: Design requirements, Amendment 1
	IEC 61400-1 COR1	Ed. 3.1, 2014-04	Wind turbines – Part 1: Design requirements, Corrigendum 1
	IEC 61400-1	Ed. 4.0, 2019-02	Wind turbines – Part 1: Design requirements,
	IEC 61400-13	2015	Wind turbines - Part 13: Measurement of mechanical loads
	IEC 61400-3-1	2019	Wind energy generation systems – Part 3-1: Design requirements for fixed offshore wind turbines
IECRE system	IECRE OD-501	Ed. 2.0, 2018-05-24	IEC System for Certification to standards relating to Equipment for use in Renewable Energy applications (IECRE System), Type and Component Certification Scheme
	IECRE OD-502 [3]	Ed. 1.0, 2018-10-11	IEC System for Certification to Standards relating to Equipment for use in Renewable Energy applications (IECRE System), Project Certification Scheme
	IECRE OD-501-4	Ed. 1.0 2017-04-06	IEC System for Certification to Standards relating to Equipment for use in Renewable Energy applications (IECRE System), Conformity Assessment and Certification of Loads by RECB's
DNV GL service documents	DNVGL-SE-0073	Edition January 2018	Project certification of wind farms according to IEC 61400-22
	DNVGL-ST-0438 [6]	Edition April 2016	Control and protection systems for wind turbines

Wind Farm Control Functionalities

Wind Farm Control Functionalities

There exist different novel control approaches that can be used. The main strategies are:

- **Axial Induction:** modification of the energy harvest of either upstream or downstream turbines so that the effect of wake interaction can be mitigated. Derating upstream turbines is the **most popular in literature but comes with it challenges**. For example, wind tunnel tests and field tests call static induction control into question regarding wind farm power increase
- **Wake Steering:** redirecting the wake from the upstream turbine so as to avoid or modify its impingement in the downstream turbine, therefore reducing the wake interactions within the wind farm. Another concept with **yaw misalignment** one of the **promising techniques that has attracted significant attention, having been tested in real wind farms**

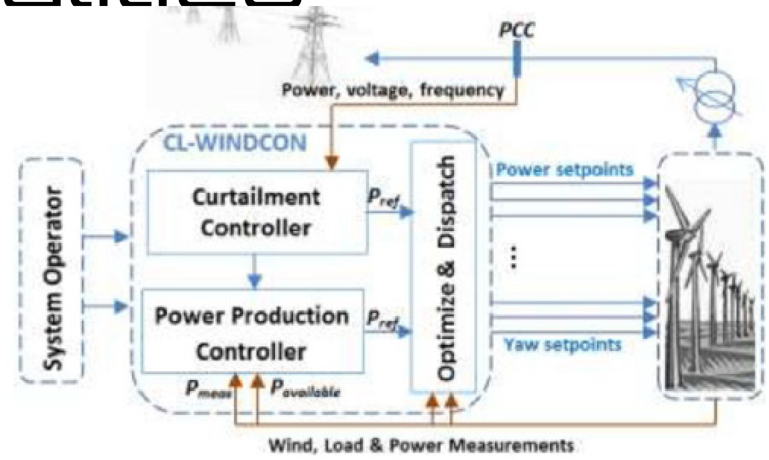


Wind Farm Control Functionalities

Integration of WFC into Existing WPP

So far in **research has largely focused on simulation** and little information has been published on how these functionalities can be implemented and certified.

- **Hierarchical design requirements proposed** for WFC from certification perspective **where trade-offs** between several design goals be **need found at the different levels**
  - Load reduction against the maximised energy yield
  - Operational costs reduced while it appears desirable to extend the features of the wind farm to market ancillary services
  - Certification mainly addresses aspects of safety, structural and electrical integrity of the wind farm



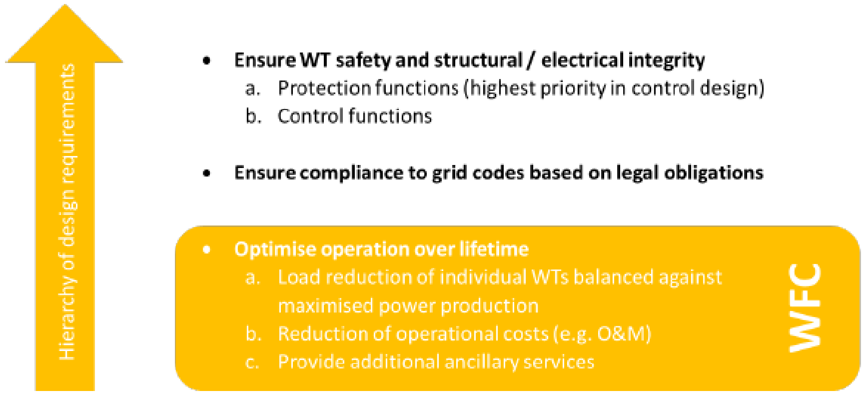


Figure 9 Hierarchy of design requirements applying WFC from certification's perspective

Wind Farm Economics

Wind Farm Economics

Electricity Markets

- Access to the electricity markets **will depend on robust WFC** that can
  - Coordinate the control actions within the windfarm
  - Adhere to the market participation rules
  - Abide under the grid codes and the normal operation of the wind farm.
- **Two recent developments are worth noting** as evidence of a significant change in the way TSOs procure ancillary services
  - Power Available (PA): increasing the visibility on active power generation headroom from wind power plants in system operation control rooms and therefore, allow them to participate in balancing mechanisms (BM).
  - Auction Trials: on-going trial for a live market structuring the provision of frequency support services, open to wind power operators, and running on a weekly basis, as an intermediate step towards a participation of wind power in day-ahead markets

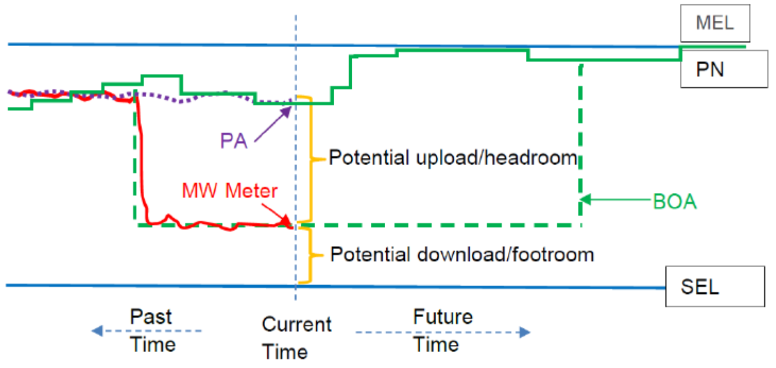


Figure 22 PA signal and WPP module frequency support during BM window(NationalgridESO)

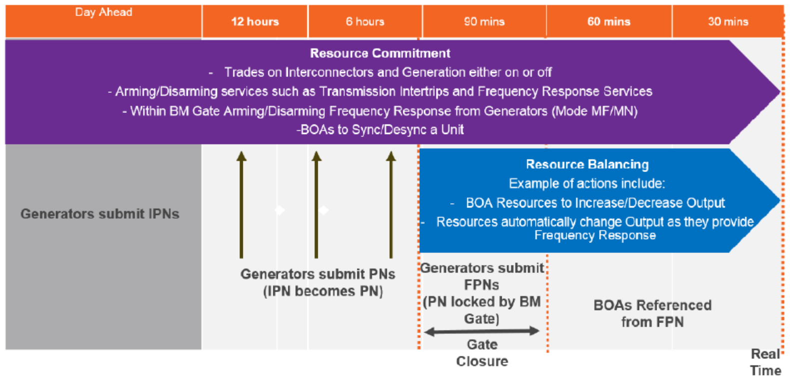


Figure 23 Resource commitment and balancing from day-ahead to real-time [81]

Wind Farm Economics

Economic Potential of WFC

A **feasibility analysis of wind farm control** implementation with **active wake steering** has been performed **from the economic point** of view based on control (**CL-Windcon)**

- Wake steering slightly improved the availability of the wind farm and increased the OPEX and the energy production
- Wake steering economically viable with revenue from power production gains with the averaged EPEX electricity spot price.
- The gain during the whole lifetime is around € 26.88 million, which represents the 1.10% of the whole project costs (in present value)
- Wind farm yaw wake steering control reduces slightly the LCOE from 31.55 €/MWh to 31.35 €/MWh.

Table 4 Main economic lifetime comparison Farm-wake-steering-control / Individual-control

Concept	Absolute (EUR)	Relative (%)
Increase in LCC (Present Value)	€ -3,592,100	-0.15%
Increase in Net Energy sales (Present Value)	€ 30,479,236	0.79%
Net differences	€ 26,887,136	1.10%

Table 5 Main project economic results Farm-wake-steering-control vs Individual-control

SCENARIOS/Concepts	Units	Yaw control	Individual
Total Present Value Costs	€	2,451,886,907	2,448,294,807
Total Energy Produced (Non discounted)	MWh	114,448,000	113,556,000
Total Energy Produced (Present Value)	MWh	78,212,726	77,603,141
Total incomes sales of energy (50€/MWh)	€	3,910,636,301	3,880,157,065
Average Cost (Present Value) per MW	€/MW	3,064,859	3,060,369
Total Net Energy Production (NPV)	MWh/MW	97,766	97,004
LCOE	€/MWh	31.35	31.55

Challenges for WFC Commercialisation

Challenges for WFC Commercialisation

Turbulence and Wake Effects

Increase energy yield has to be accompanied by the **guarantee that the structural integrity of the wind turbines** constituting the wind farm **is preserved**.

- The mostly used model in the industry is based on the **Frandsen turbulence model not detailed enough to cover the complexity in the wake physics** as this is empirically reduced to an increase of the turbulence intensity.
- **IEC standard still follows** the philosophy of the **verification of the single turbine** exemplary for the whole wind farm. **For large offshore wind farms**, common **practice is to separate into clusters** and perform load analysis for representative turbines for each cluster
- This approach, **however, would not be suitable** for the identification of critical turbine locations **using variable farm control strategies** where the full loading picture of the wind farm is needed

Challenges for WFC Commercialisation

Frandsen to Dynamic Wake Meandering Model

- **Frandsen models** also presents **some significant limitations** as there is no explicit way **to estimate partial wake effects**
- The **Dynamic Wake Meandering (DWM)** approach in IEC 4th edition provides an **alternative method** as this **captures the key features** of the wake with regards to wind turbine loads and power production, while maintaining sufficient computational speed for design calculations
- **In spite of the aforementioned methods** specified in the standards, its application to specific **projects faces challenges such as how to calculate wake effects at all positions** and the effect of the wind farm controller with pre-determined methods that don't account for closed loop control scenarios
- **Simulation tools already have enhanced capabilities** to model dynamic wake and meandering effects, **but it is still a challenge to perform full wind farm simulations** including wind farm control activities.

Challenges for WFC Commercialisation

Risks for Wind Turbine Components

Control actions may need further attention and possible amendments of standards. It is recommended to **extend the existing standards and develop criteria and requirements for the certification tasks (CL-Windcon)**

- Requirements for the wind turbine safety system (highest priority) in combination with farm control access to turbine manoeuvres such as blade pitch, yaw and torque
- Requirements to the redundancy of the farm controller and definition of possible “fall back” situations
- Load case amendments for the wake steering control approach and wake mitigation technique

** Find the full list of recommendations in the report

Proposed Solutions

Proposed Solutions

Temporary/conditional project certification

- This approach is presently developed by DNV GL (DNVGL-SE-0190) and **modifies the conventional Site-Specific-Design-Assessment (SSDA) to include additional inputs with wind farm control strategies.**

Risk based Certification

- To help assess safety concerns, **risk assessment for wind farm control can be carried out with certificates issued out**.

Regulatory 'sand-box' approaches

- To help ease regulatory barriers, **sand-box approaches which provide companies with an exemption from the obligation to comply with existing regulations** can be used

Thank you for your attention!

Further Questions?