Presentation PDF version:

Guidelines for Cluster-based Control Development in Floating Offshore Wind Farms

H. del Pozo Gonzalez, J.L. Domínguez-García and J.I. Rapha

This presentation was hold in **Wind Energy Science Conference** and is available at:

https://zenodo.org/communities/corewind/

BibTex:

```
@Misc{gonzalez2023guidelines,
    Title   = {Guidelines for Cluster-based Control Development in Floating Offshore Wind Farms},
    Author  = {Hector del Pozo Gonzalez, Jose Luis Domínguez-García and Jose Ignacio Rapha},
    Journal = {Wind Energy Science Conference},
    Year    = {2023},
    City    = {Glasgow}
}
```

COST REDUCTION OF
FLOATING WIND TECHNOLOGY

Shaping Energy for a Sustainable Future

Guidelines for Cluster-based Control Development in Floating Offshore Wind Farms

24th May 2023

corewind.eu

Héctor del Pozo González   Jose Luis Domínguez-García   Jose Ignacio Rapha

Objectives & Outline

- What is Cluster-Based Control and which are the benefits?
- Clustering techniques for floating wind farms
  - Hierarchical Algorithms
  - Partitioning Algorithms
- Clustering a 42 FOWT Farm
  - Wind-Wave Directions
  - Wake Effect
- An Example of Cluster-Based Controller
  - Decentralized Control for PCC Power Tracking + Fatigue Load Reduction

Why Cluster-Based Controls?

- Problems of Centralized Controls in large FOWF
  - Modern FOWF require large number of state information, increasing the computational burden
  - Requires:
    - Expensive communication networks
    - High computation power
    - Reduces the overall system resiliency, being too sensitive to the status of the communication link
  - Means: Low reliability of ensuring real-time control with a centralized scheme
- Benefits of Decentralizing the Controls of FOWF
  - Reduction of the communication links and computational costs
  - Combine online and offline computations to reduce the solving time
  - Robustness under communication faults

Clustering: Basics and Algorithms

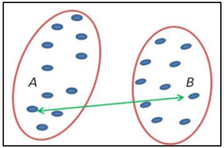
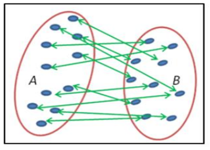
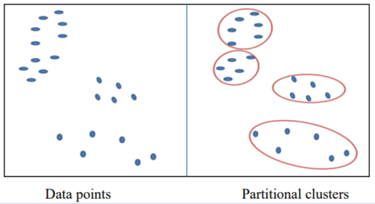
- ## Clustering Basis

Clustering can be represented as a set of S of subsets $S_1, S_2, \ldots, S_k$, such that:

$$S_1 \cap S_2 \cap S_3 \ldots \cap S_k = \Theta$$

This means that any instance in $S(S_1 \ldots S_k)$ belongs to exactly one subset and does not belong to any other subset.

- ## Types of Clustering

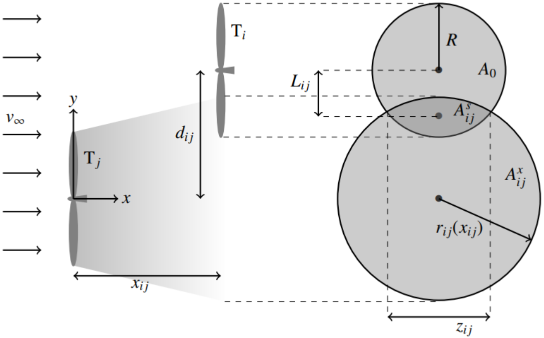
Hierarchical Algorithms	Partitional Algorithms
 	

corewind

IREC

Shaping Energy for a Sustainable Future

Clustering a FOWF:
A Wake-Based Algorithm



$$\epsilon_{ij} = \left|\frac{R}{r_{ij}(x_{ij})}\right| \frac{A^s_{ij}(x_{ij})}{A_0}$$

A Partitioning Algorithm

Objective 1:

Minimize the edges between different partitions, by maximizing the couplings among the FOWTs due to the wake propagations*:*

$$J_1 = \sum_{l \in K} \sum_{i \in V} \sum_{j \in K} (\varepsilon_{ij} + \varepsilon_{ji}) \gamma_{il} \gamma_{jl}$$

Objective 2:

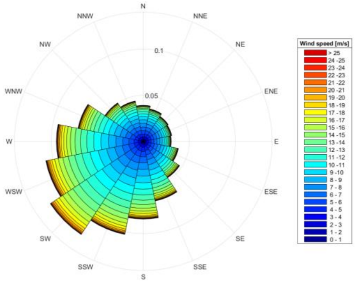
Minimize the distance among the FOWTs belonging to the same partition:

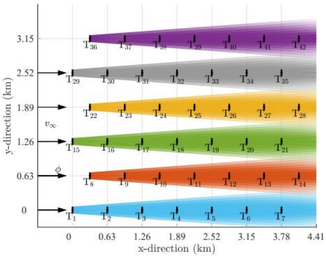
$$J_2 = \sum_{l \in K} \sum_{i \in V} \sum_{j \in K} d_{ij} \gamma_{il}$$

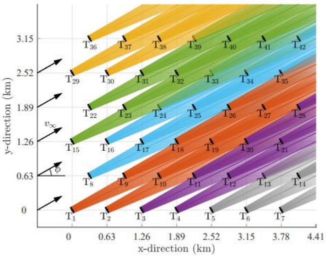
Therefore, the optimal partitioning is given by:

$$\min_{\gamma_{il}} \sum_{m=1}^{2} \omega_m J_m(\gamma_{il})$$

COREWIND Location I: West of Barra







P1 = {1, 2, 3, 4, 5, 6, 7}, (7)
P2 = {8, 9, 10, 11, 12, 13, 14}, (7)
P3 = {15, 16, 17, 18, 19, 20, 21}, (7)
P4 = {22, 23, 24, 25, 26, 27, 28}, (7)
P5 = {29, 30, 31, 32, 33, 34, 35}, (7)
P6 = {36, 37, 38, 39, 40, 41, 42}. (7)

Validity: $-5 \leq \Theta < 25$

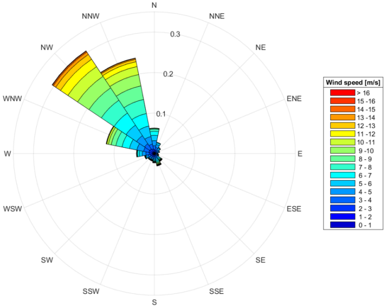
P1 = {8, 16, 17, 24, 25, 33, 34, 35, 42}, (9)
P2 = {1, 2, 9, 10, 18, 19, 26, 27}, (8)
P3 = {15, 22, 23, 31, 32, 39, 40, 41}, (8)
P4 = {29, 30, 36, 37, 38}, (5)
P5 = {5, 6, 7, 13, 14}, (5)
P6 = {3, 4, 11, 12, 20, 21, 28}. (7)

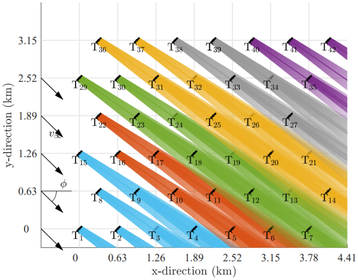
Validity: $25 \leq \Theta < 55$

corewind

IREC Shaping Energy for a Sustainable Future

COREWIND Location II: Morro Bay





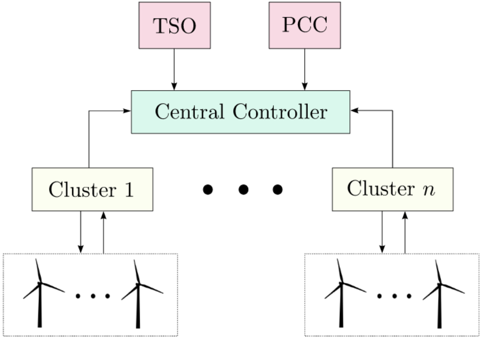
P1 = {1, 2, 3, 8, 4, 8, 9, 15}, (8)
P2 = {5, 6, 10, 11, 16, 17, 22}, (7)
P3 = {7, 12, 13, 18, 19, 23, 24, 29, 30}, (9)
P4 = {14, 20, 21, 25, 26}, (5)
P5 = {27, 33, 34, 38, 39}, (5)
P6 = {35, 40, 41, 42}. (4)

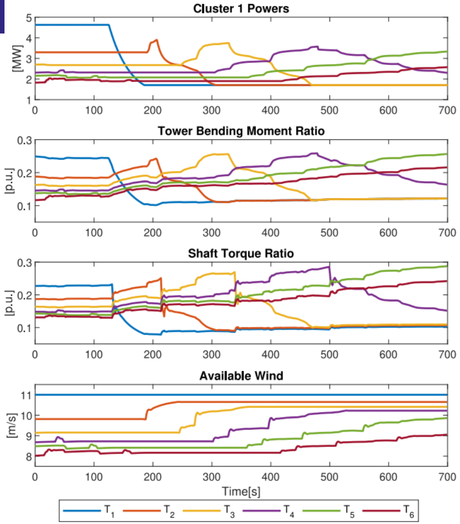
Validity: 115 ≤ Θ < 145

corewind

IREC
Shaping Energy for a Sustainable Future

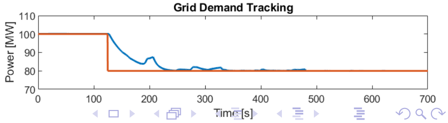
A Controller Example: Decentralized Control for PCC Power Tracking + Fatigue Load Reduction





	Centralized	Cluster-Based
Solver	0.1 s	0.005 (CLC) 0.03 (CC)
Benefit	0%	70%

$$\Delta t_s = \frac{t_s(CC) - t_s^{tot}}{t_s(CC)} \cdot 100\%$$



Conclusions

- Clustering algorithms can divide large wind farms into several disjoint partitions in order to ease the massive information exchange between the FOWTs and the wind farm central controller.

- An optimal set of partitions can be founded in function of the wake propagation through the floating wind farm.

- Cluster-based controls (decentralized) reduces consistently the computational costs compared to a centralized strategy, increasing the suitability for real-time applications.

Thanks for your attention

corewind

IREC Shaping Energy for a Sustainable Future