Refind modeling&simulation of large-scale wind farm

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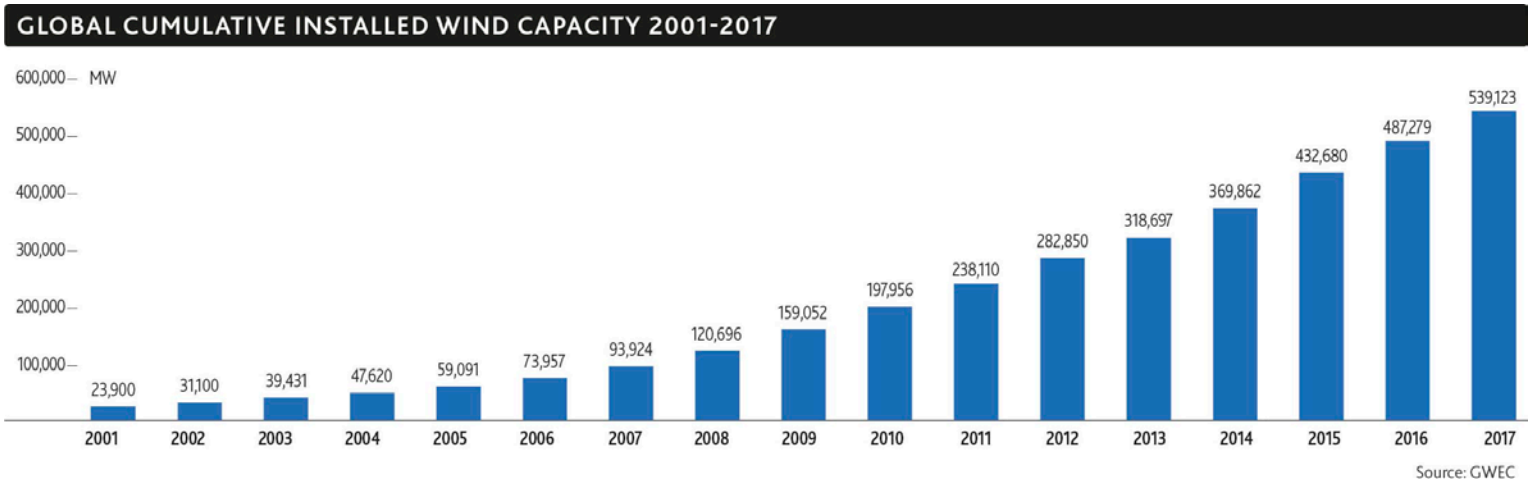
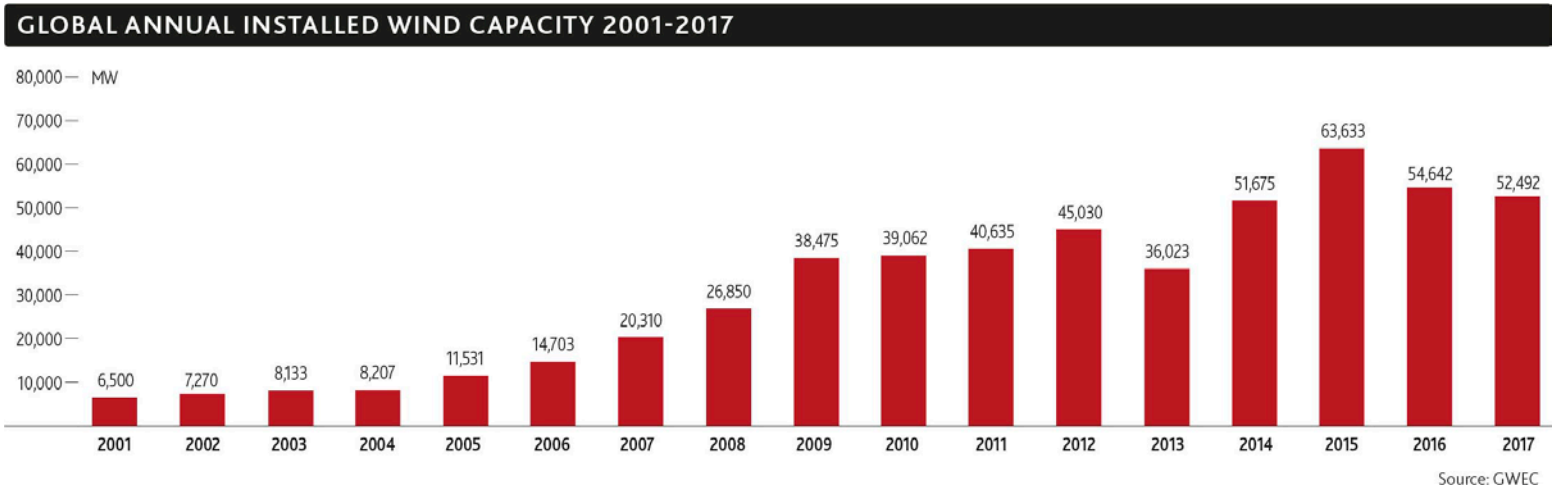
01 Introduction

Development of wind power in recent years

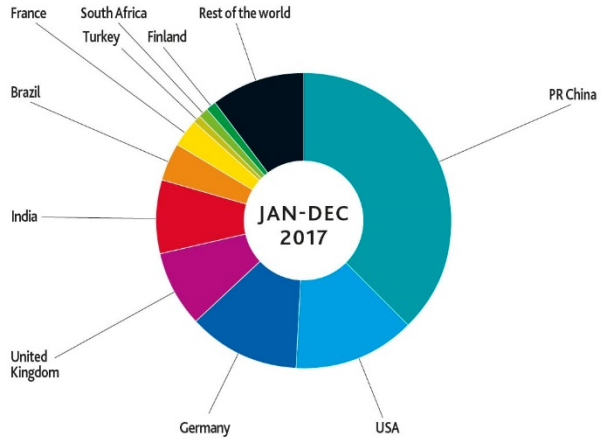




01 Introduction

Cumulative capacity of wind power

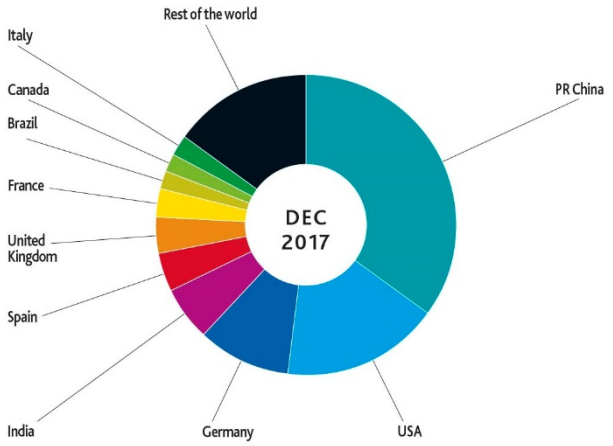
TOP 10 NEW INSTALLED CAPACITY JAN-DEC 2017



Country	MW	% Share
PR China	19,660	37
USA	7,017	13
Germany	6,581	12
United Kingdom	4,270	8
India	4,148	8
Brazil	2,022	4
France	1,694	3
Turkey	766	1
South Africa	618	1
Finland	535	1
Rest of the world	5,182	10
Total TOP 10	**47,310**	**90**
World Total	**52,492**	**100**

Source: GWEC

TOP 10 CUMULATIVE CAPACITY DEC 2017



Country	MW	% Share
PR China	188,392	35
USA	89,077	17
Germany	56,132	10
India	32,848	6
Spain	23,170	4
United Kingdom	18,872	4
France	13,759	3
Brazil	12,763	2
Canada	12,239	2
Italy	9,479	2
Rest of the world	82,391	15
Total TO P10	**456,732**	**85**
World Total	**539,123**	**100**

Source: GWEC

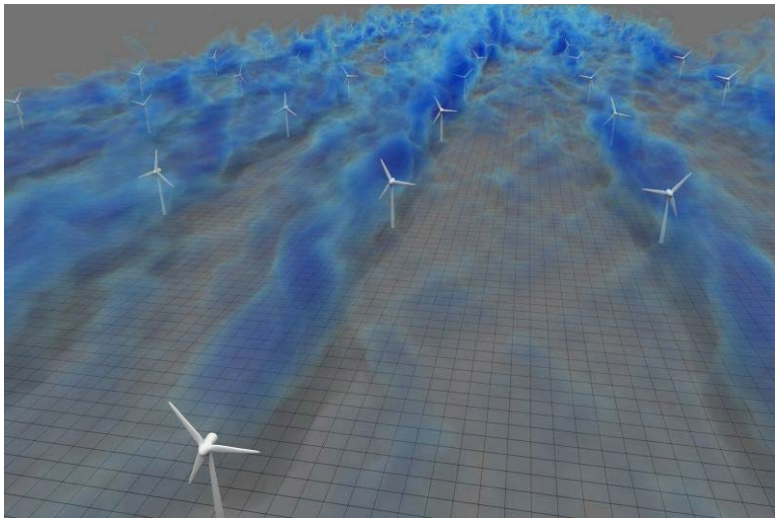
Characteristics of modern wind power integration

- Large-sacle

  (Wind farm cluster)
- High-level penetration
- High controllability and flexiblity

01 Introduction

Complete refined wind farm modeling



- Single wind turbine modelling
- Wind farm collection system modelling
- Wind farm control (SCADA)

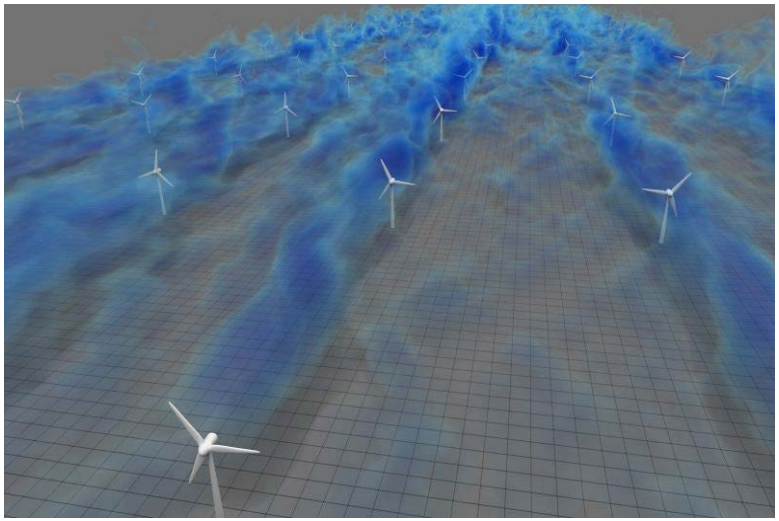
  Active/reactive power dispatch

  Ancillary service
- Wind filed modeling

  Interactions considered: wake effects, shadow effects, shear effects

01 Introduction

Complete refined wind farm modeling



- Single wind turbine modelling
- Wind farm collection system modelling
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  Ancillary service
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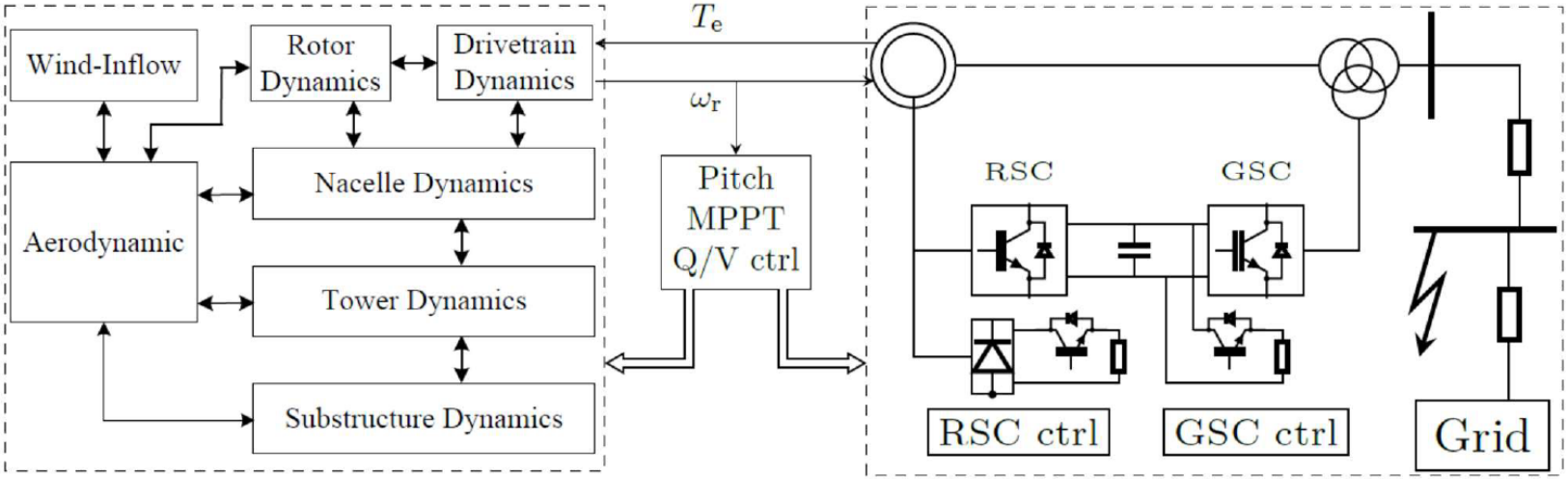
02 Modeling

Single Wind Energy Conversion System (WECS)



WECS: Multi-coupling, complex dynamic system

State of the art:

Simplified WECS for different study purpose

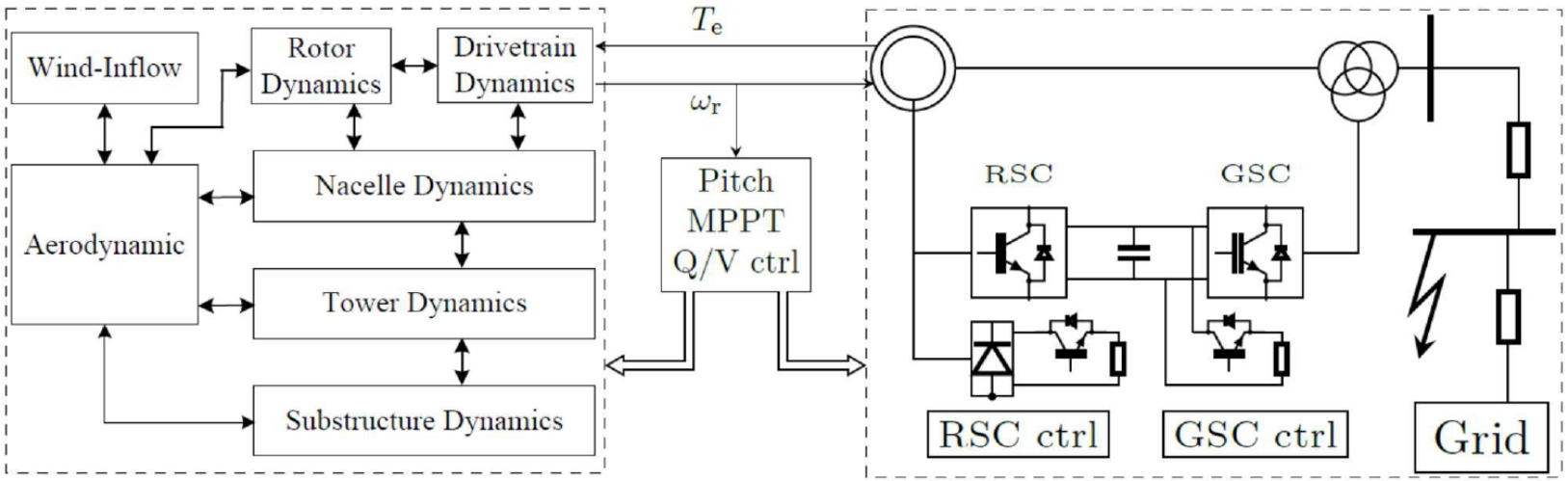
- **Power system study: simplified aerodynamic, mechanical parts**
- **Mechanical study: simplified electrical parts**

Single Wind Energy Conversion System (WECS)

Proposed co-simulation platform

Features: Refined, Real-time

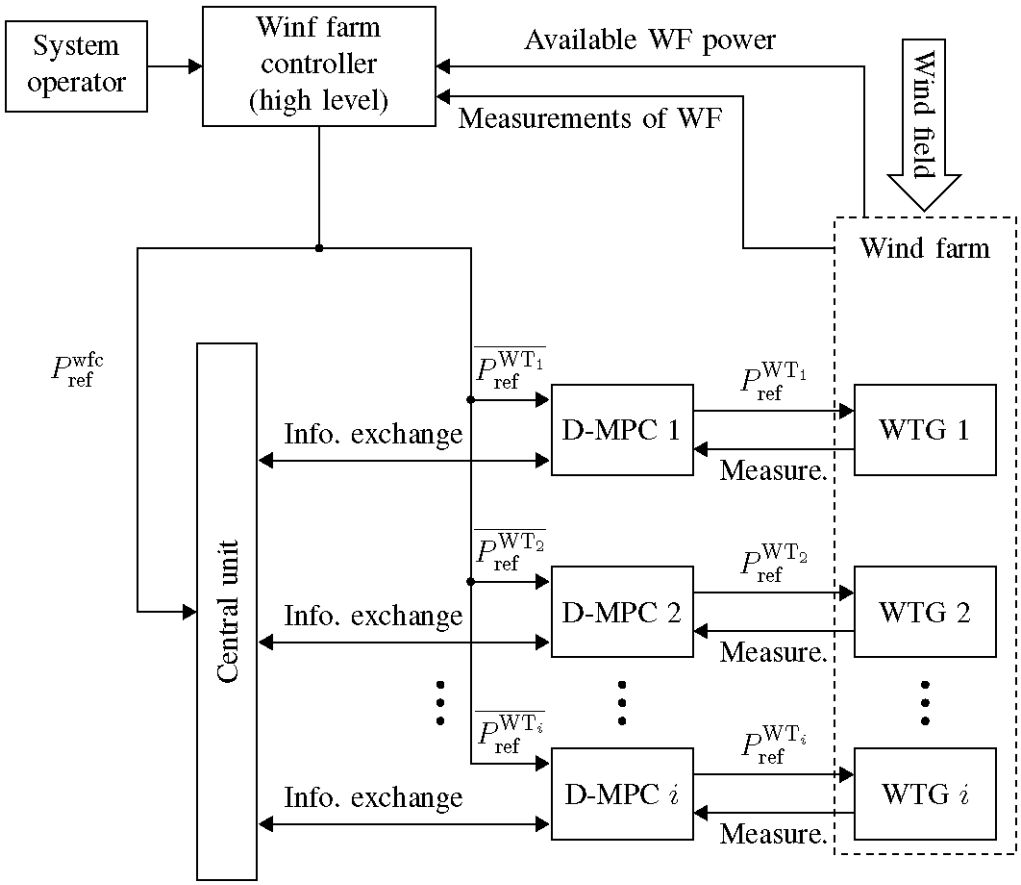
- **OpenFAST by NREL**
- **RTDS**
- **Real-time operating system (RTOS)**
- **Real-time networking (RT-net)**



OpenFAST in RTOS

RTDS

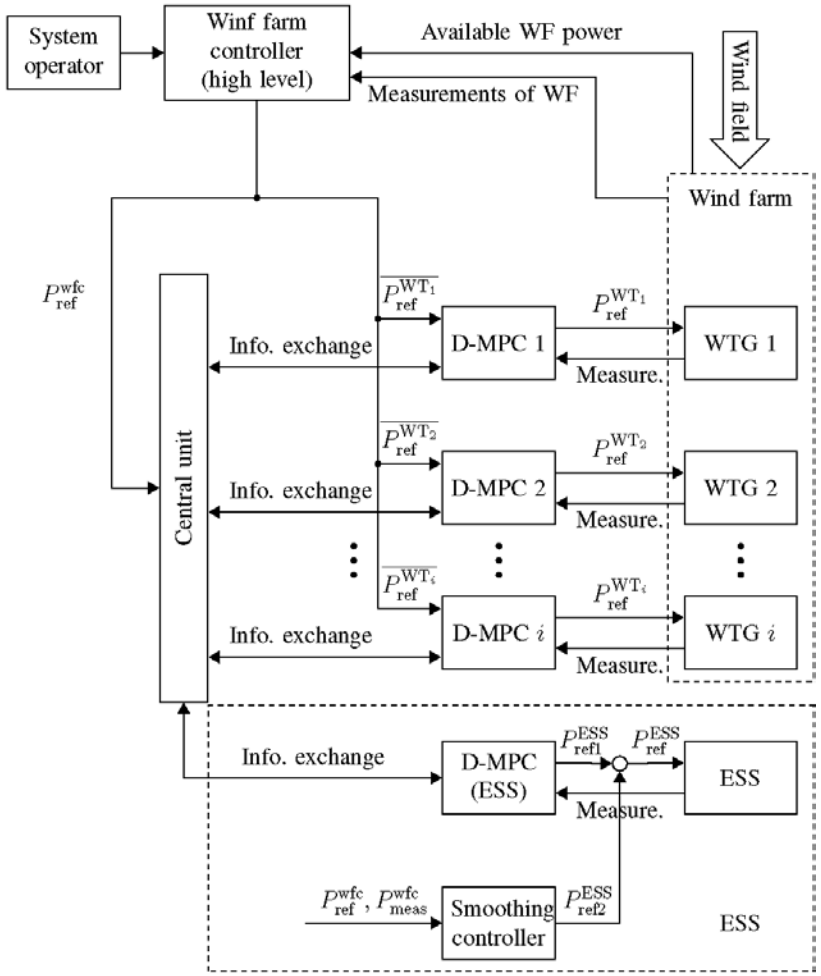
Wind Farm Control-Optimal P Control (D-MPC)



Case: Without Energy Storage

- Different form conventional proportional dispatch
- Guarantee the power demand from system operator
- Largely reduce the fatigue load
- Distributed structure, suitable for large-scale application
- Easy to be implemented and updated based on the present control structure

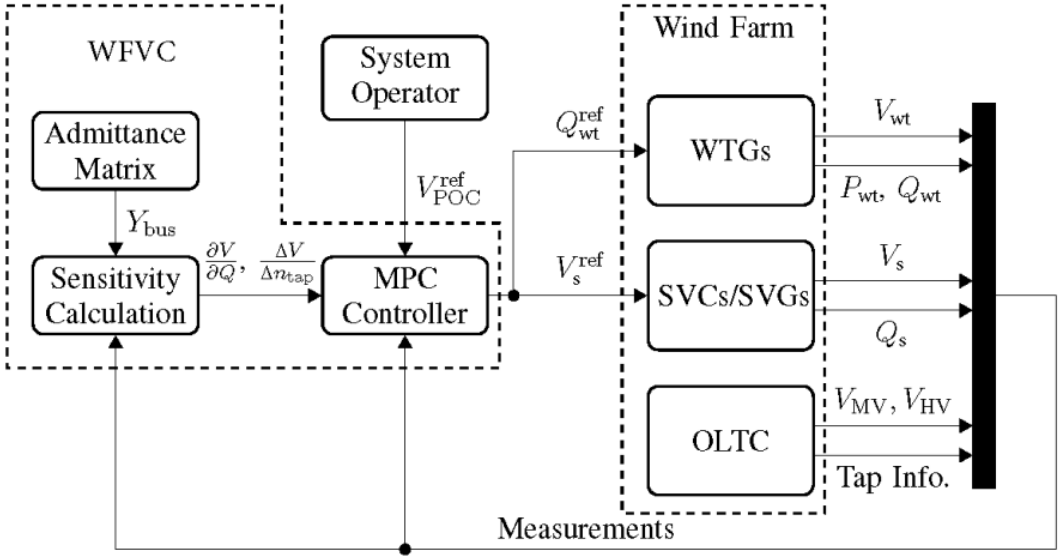
Wind Farm Control-Optimal P Control (D-MPC)



Case: With Energy Storage

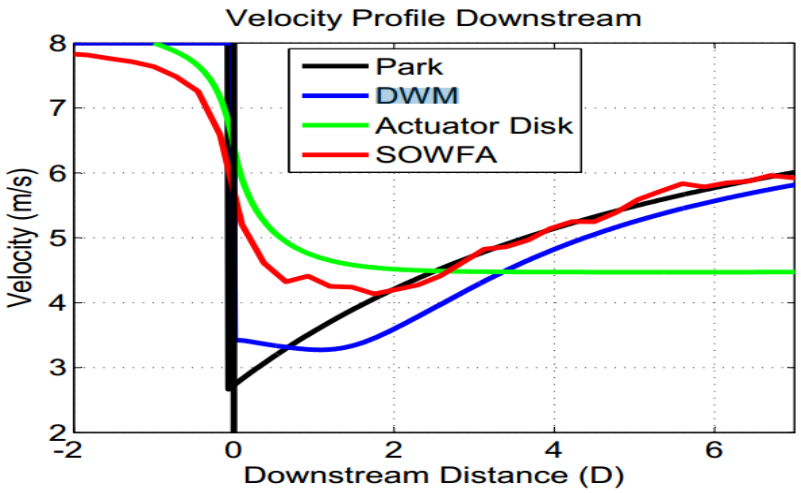
- **Energy storage involved**
- **Role of energy storage**
  - **Improve the power tracking performance**
  - **Improve the controllability**

Wind Farm Control-Optimal Q Control (Sensitivity based MPC)



- **Fulfill Q requirement of system operator**
- **Consider coordination of all Volt/Var compensation devices (WT, SVG/SVC, OLTC)**

Wind Field Modeling



Model	Computation Time	Turbine Model
Park Model	5 seconds	One-dimensional
DWM	8 minutes	Actuator Disk
Actuator Disk	25 seconds	Actuator Disk
SOWFA	30 hours	Actuator Line

- **Development based on DWM model for real-time application**

03 Experimental Setup and Simulation

For single WECS:

- **RT-OpenFAST**

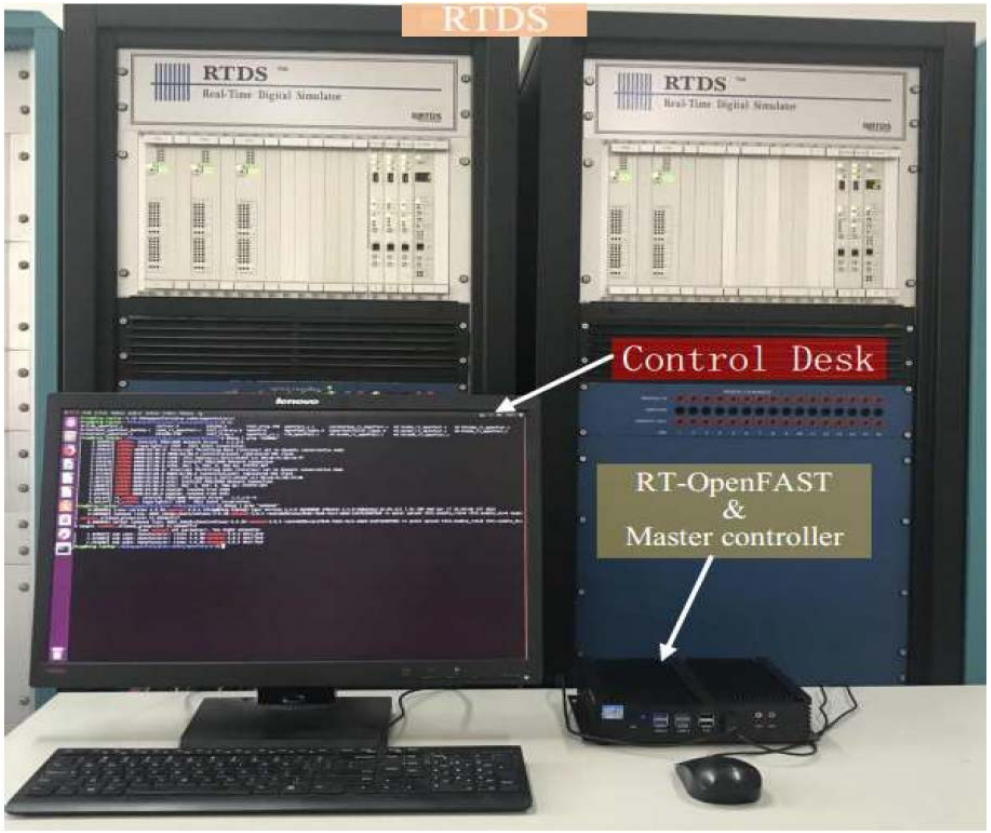
Real-time version of OpenFAST

- **RTOS**

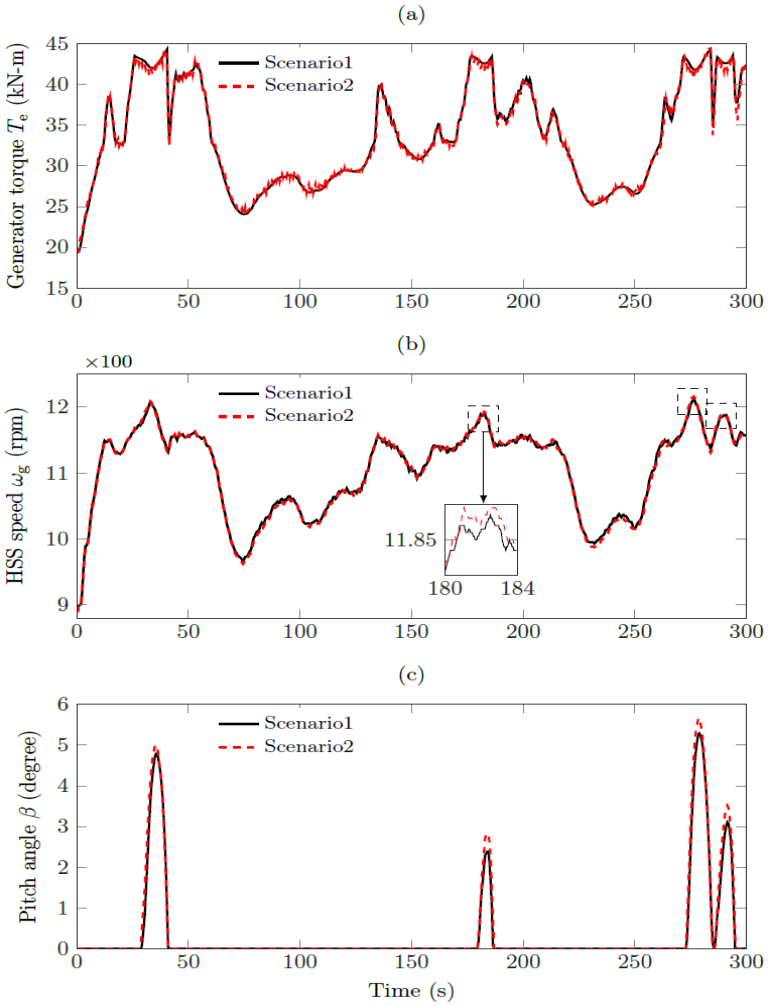
Implemented by Xenomai

- **Communication**

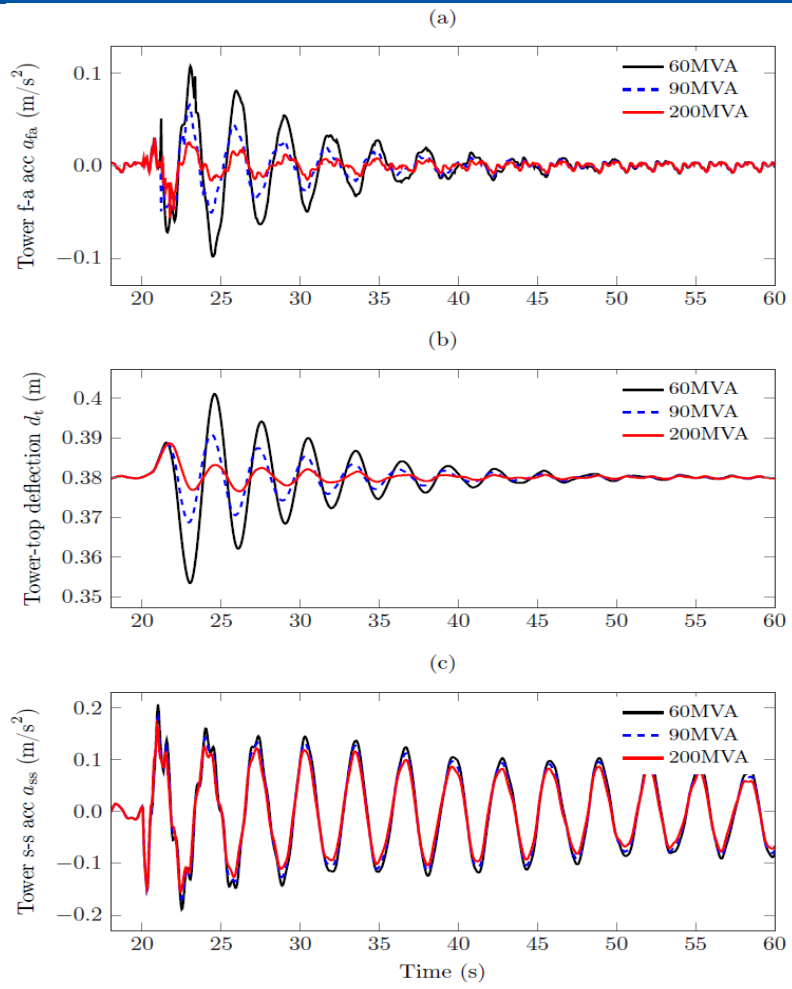
Implemented by RTnet



03 Experimental Setup and Simulation



Comparison of OpenFAST offline simulation and co-simulation



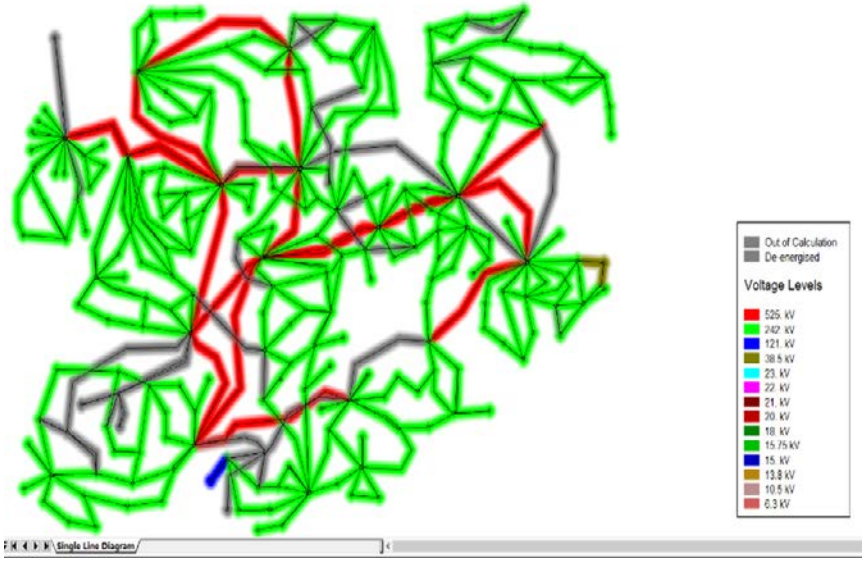
Tower vibration under different grid conditions

04 Outlook

- **Real-time co-simulation platform for wind power integration into large-scale power systems is in construction**
- **Features: Refined, Real-time, Large scale**

Refined wind farm modeling

Large-scale power system modeling



04 Outlook

Key technical problems

- **Refined wind farm modeling**

(hundreds of wind turbines)

  - **Single wind turbine model**

    (proposed RT-OpenFAST + RTDS/RT-Lab)

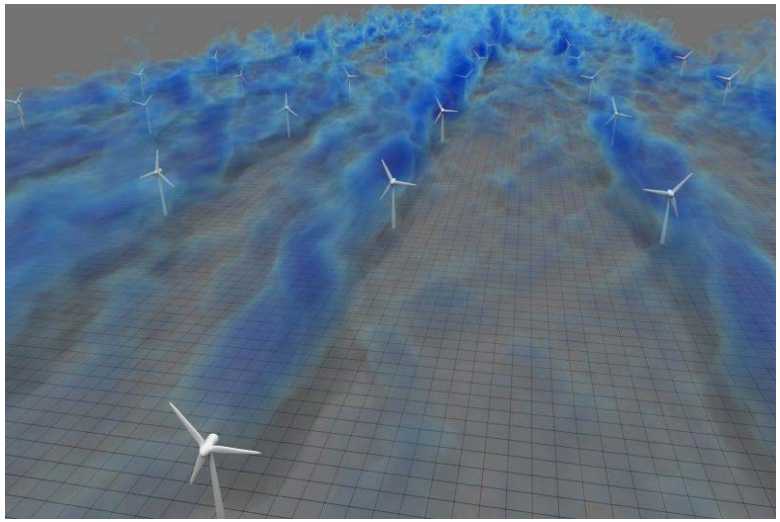
  - **Wind farm control (SCADA)**

    (Optimal control: multi-objective)

  - **Wind filed modeling**

    (Dynamic, interaction: wake, shear, shadow effects considered)

  - **Verification**



04 Outlook

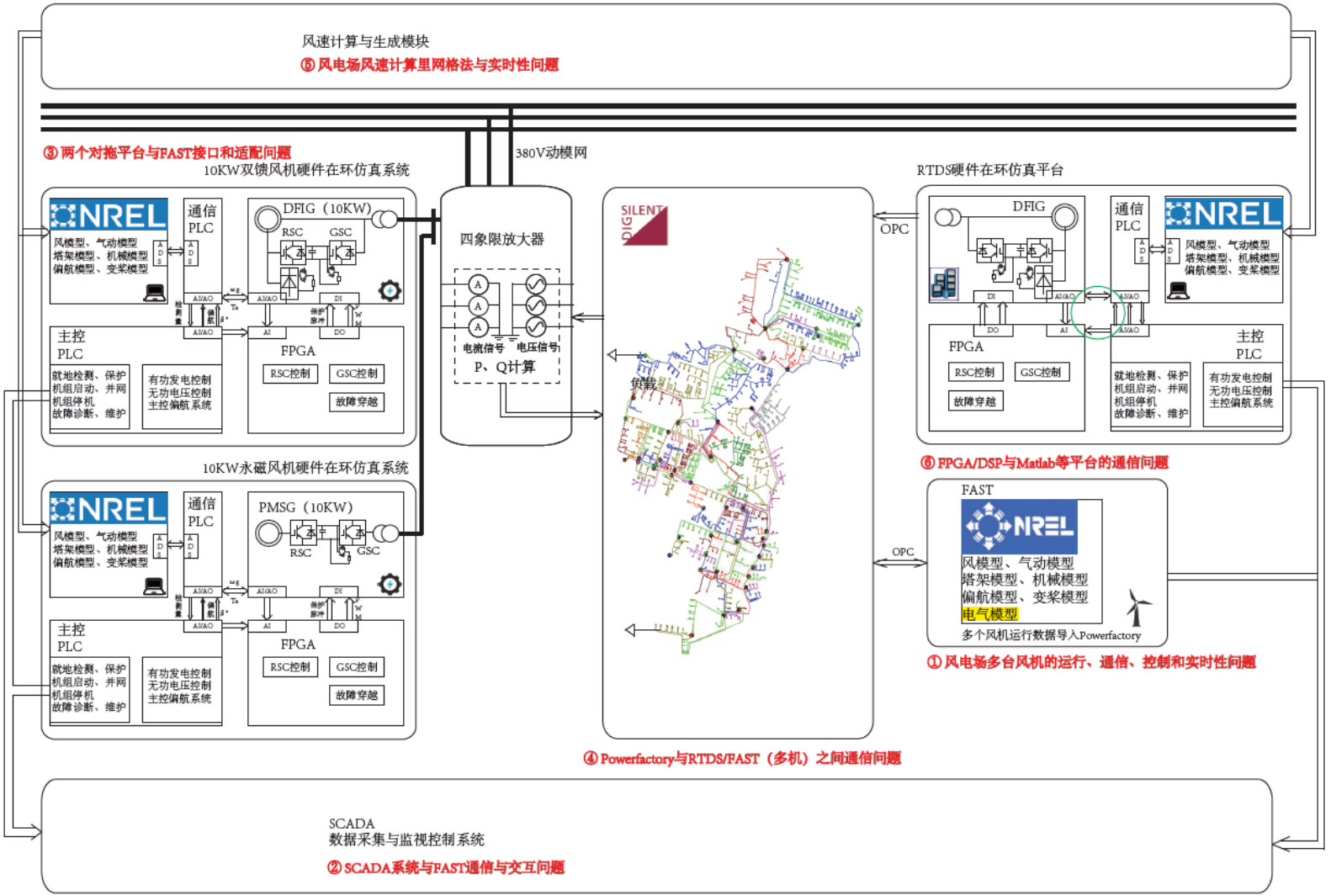
Key technical problems

- **Large-scale power system modeling (thousands of nodes)**
  - Real-time (RMS or EMT?)
  - Analysis capability for different aspects (small-signal, short-circuit, contingency analysis,…)
  - Verification

- **Interconnection between wind farm and grid**
  - Co-simulation interface implementation
    (RMS: grid EMT: wind farm)
  - Verification

04 Outlook

Proposed plan



05 Application scenarios

Individual wind turbine study

- Wind turbine controller design
- Fault ride-through

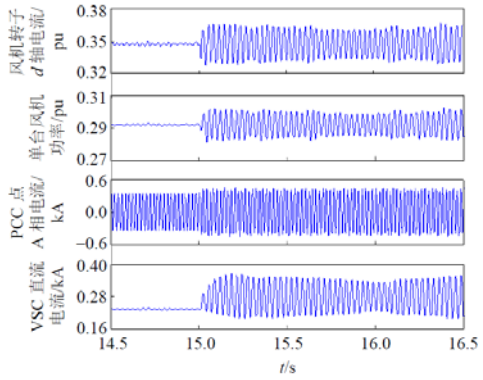
Wind farm study

- Optimal wind farm control design and verification (P/Q, inertial control)
- Potential ancillary service provided by wind farm

Power system study

(with large-scale wind power integration)

- Stability problems
- Power system operation problems



Thank you for your attention!
Questions?