

# Clemson University Charleston - SC

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**Utilisation of controllable grid emulator for multi-turbine  
testing for advanced power system services**

**DONG**  
energy

# OUTLINE

- DONG Energy Wind Power: an overview
- Test of multiple WTs connected to CGI
  - Motivation
  - System description
  - Targeted tests
  - Offline test results
  - Way forward

# This is what we do

*London Array Offshore Wind Farm*

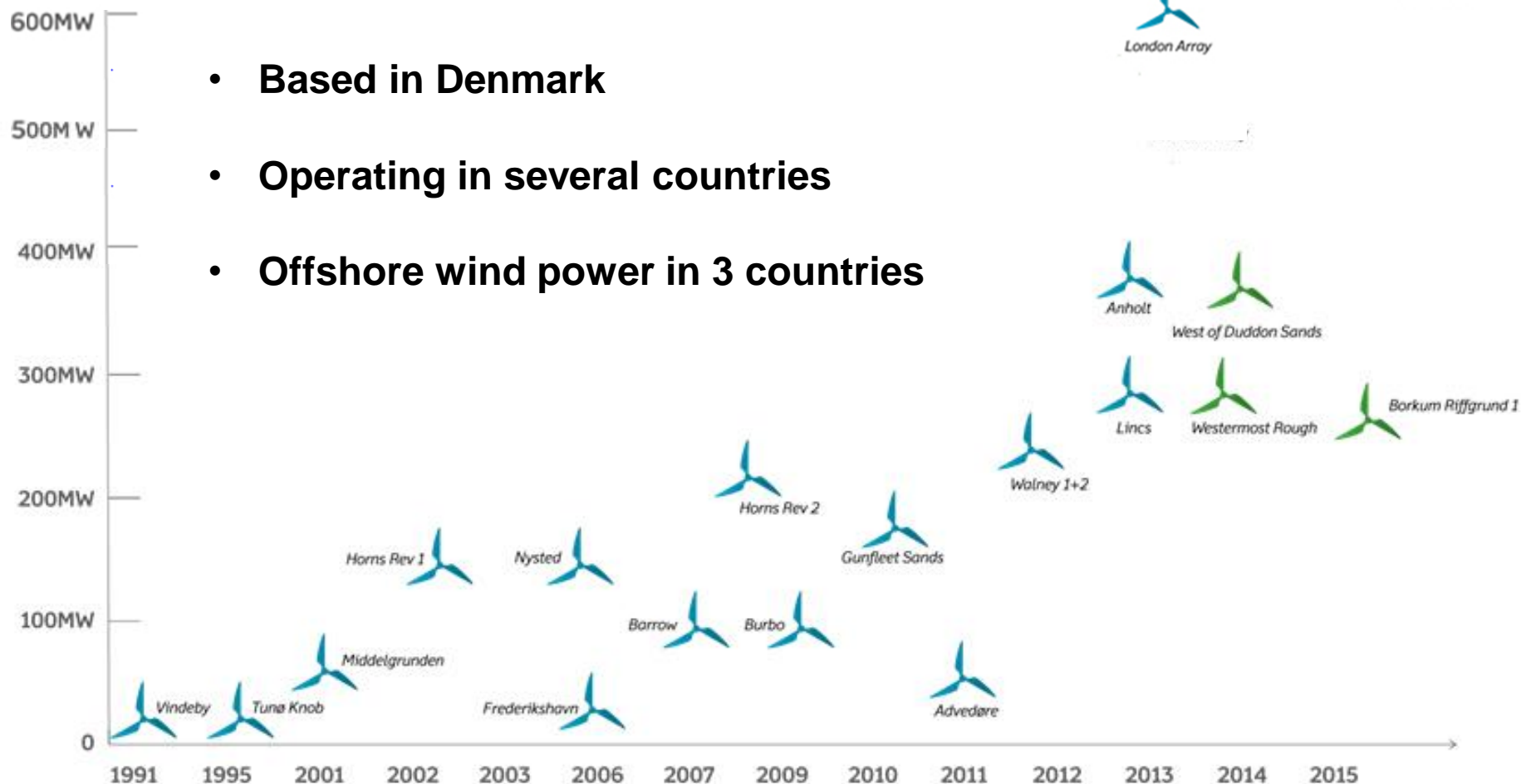
**630MW**

**2 years**

**EUR 2.2 bn**

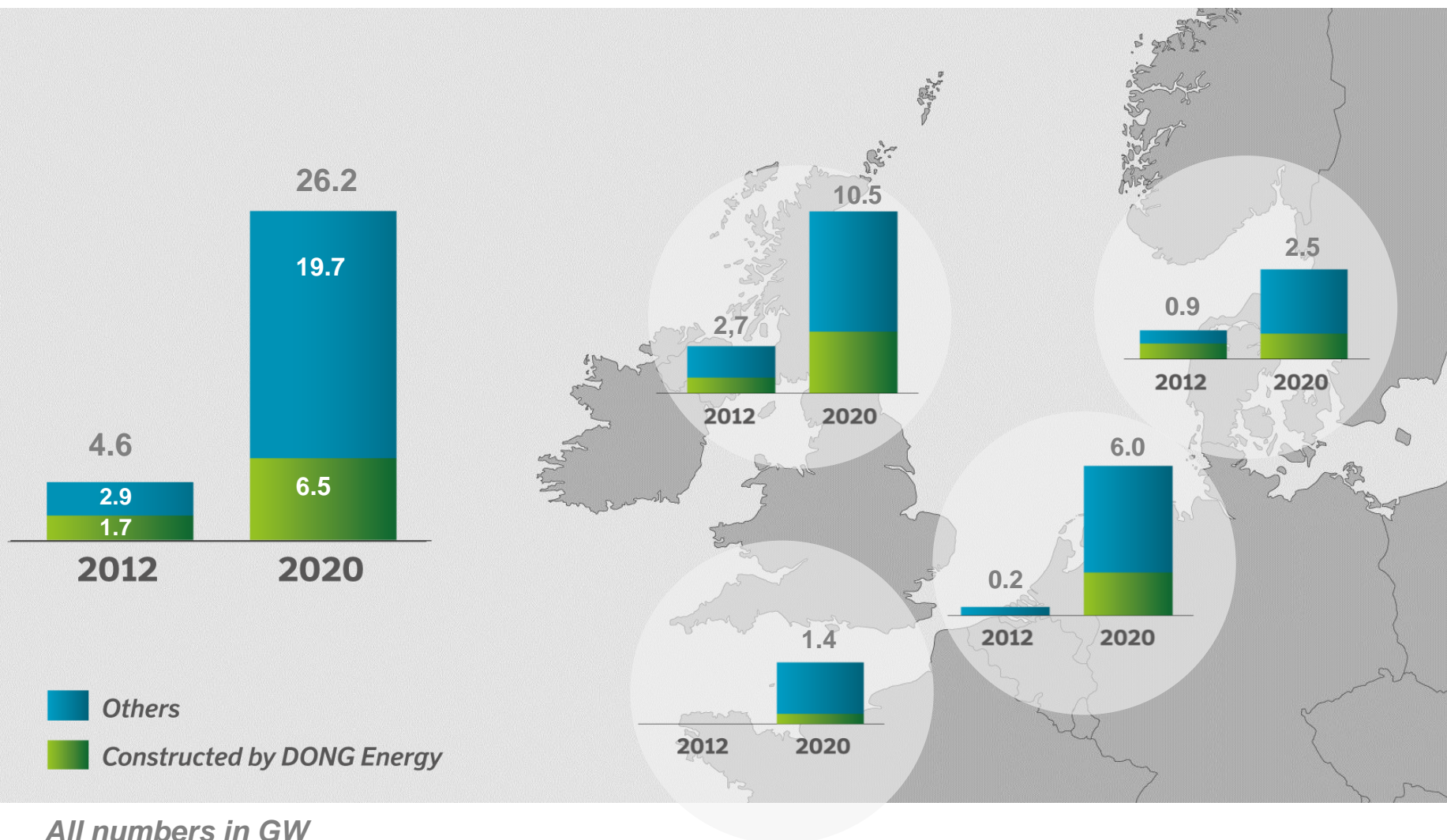
# 25 years of experience

- Based in Denmark
- Operating in several countries
- Offshore wind power in 3 countries





# Outlook and installed offshore wind capacity for Europe



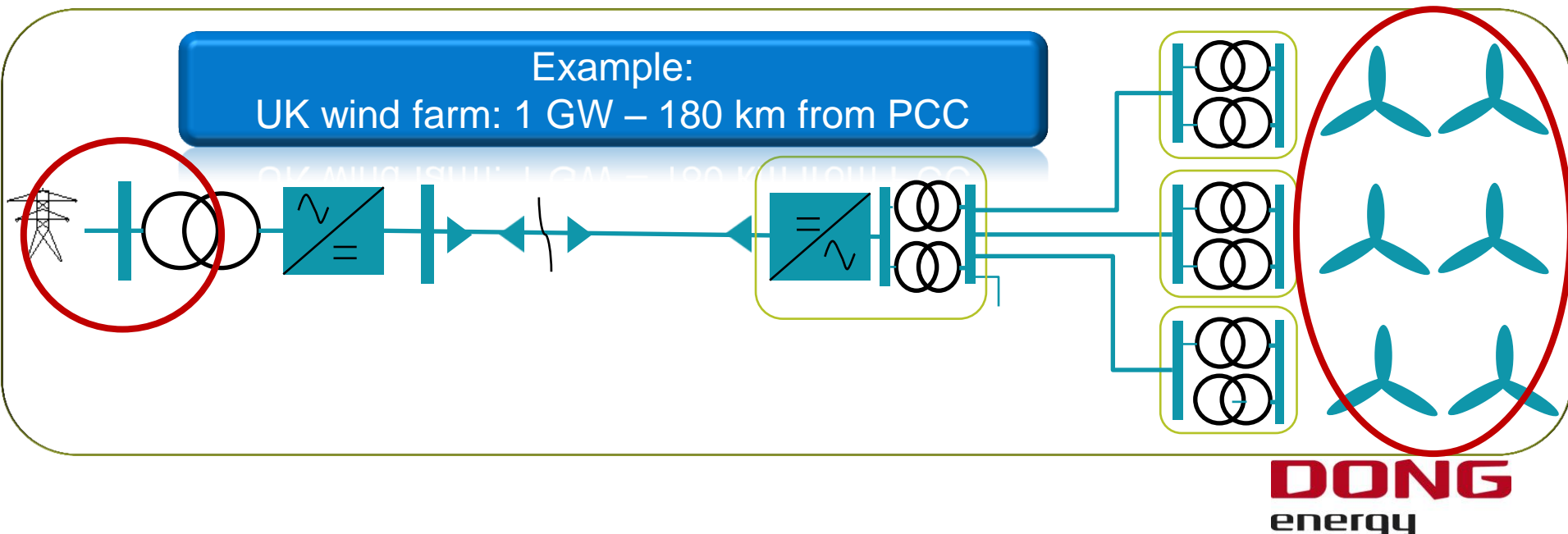
*All numbers in GW*

*Based on October 2013 figures – may change*

# The connection of offshore wind and grid code compliance

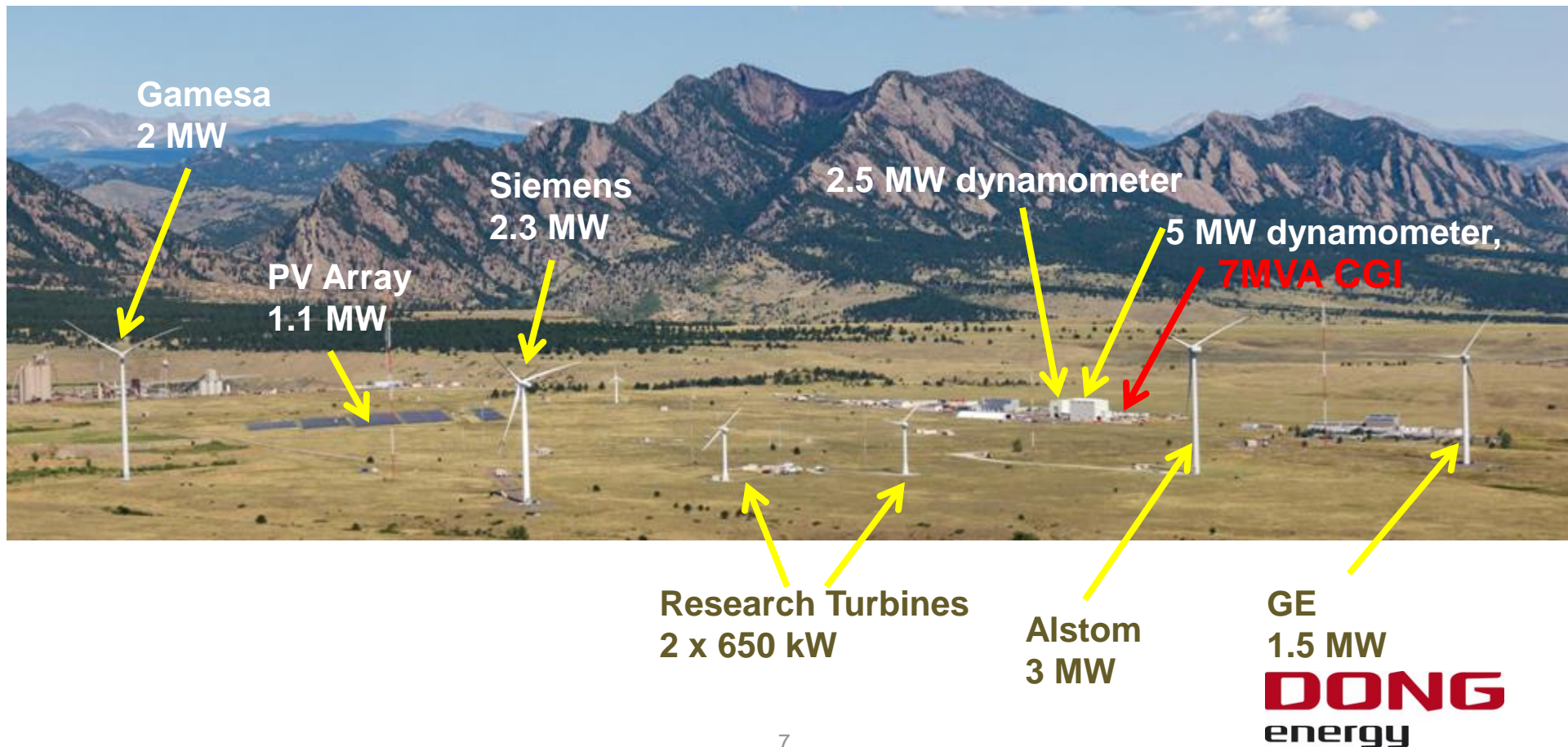
## Why is the multi-turbine testing interesting?

- HVDC technology may become attractive
- Grid code compliance to be guaranteed at onshore PCC
- System services might be required (FC and POD)
- Wind farm layout
  - Nowadays: single manufacturer
  - Future:
    - Multiple manufacturers?
    - Clustering with existing wind farms?



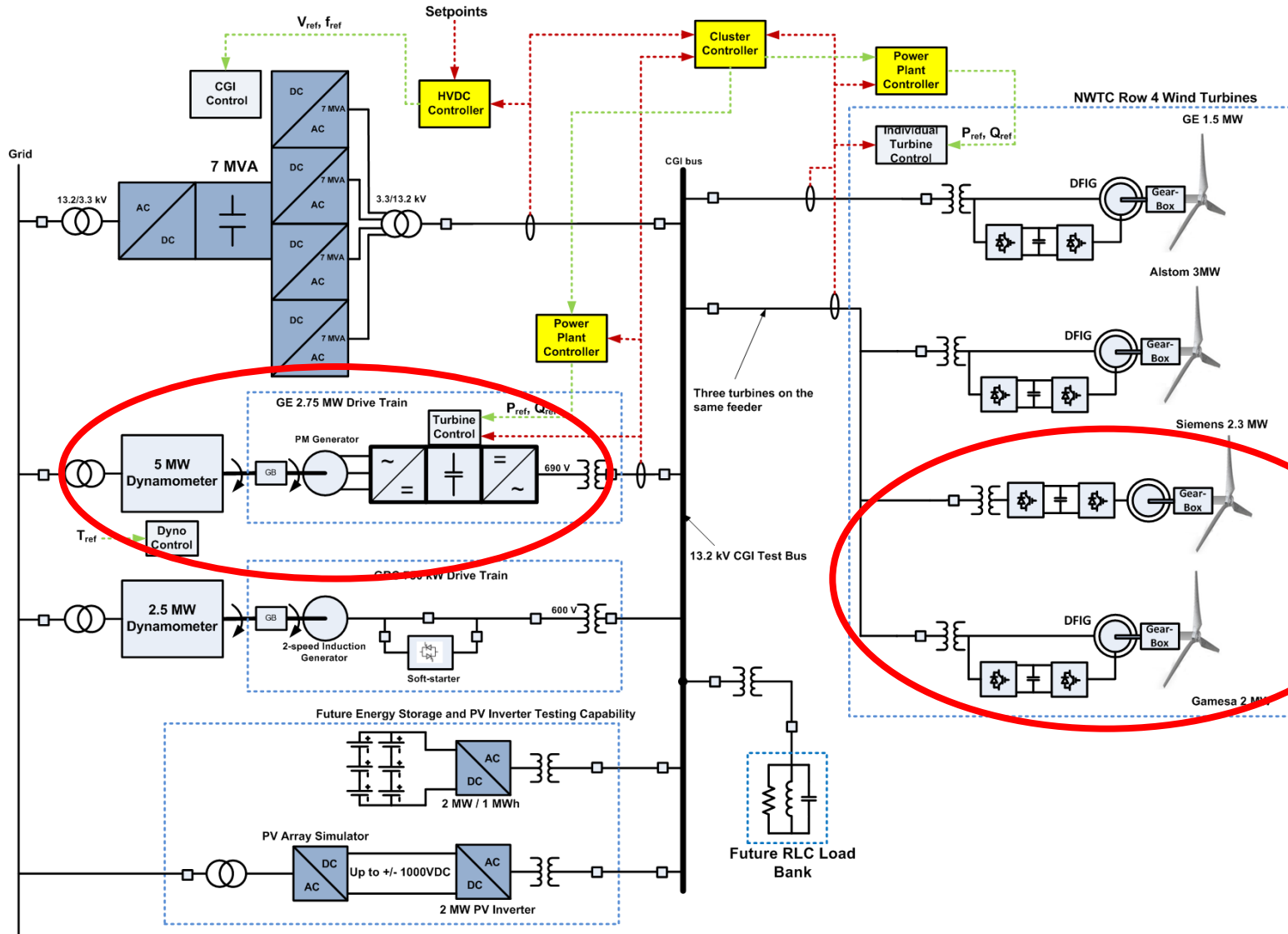
# NREL NWTC Test Site

- Total of 11 MW variable renewable generation currently at NWTC test site
- There are many small wind turbines (under 100 kW) installed as well
- 2.5MW and 5 MW dynamometers
- **7 MVA Controllable Grid Interface (CGI): grid compliance and system integration testing**
- Multi-MW energy storage testing capability under development





## Multi-turbine testing: hardware and software setup



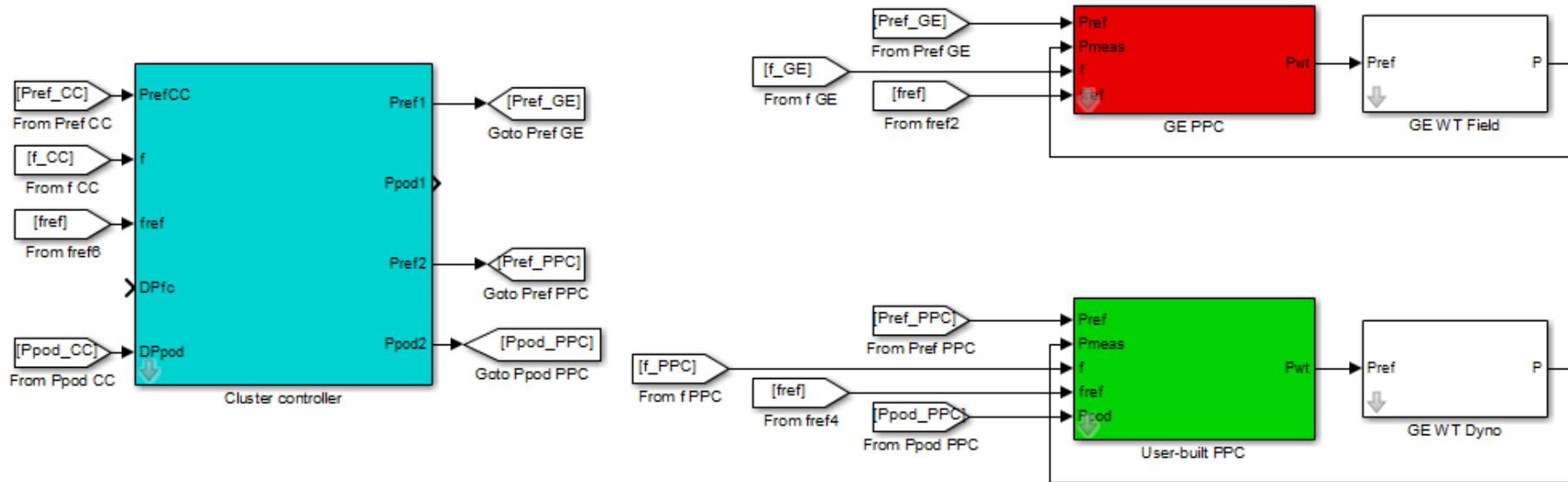


# Multi-turbine test: scope of work

- Characterisation of response of WTs and plant controllers in terms of advanced system services provision
  - Frequency control - SOA
  - Power oscillation damping – outlook
- Comparison to user-built plant control
  - Where are the limitations?
  - Can commercial products improve?
- Gain experience on coordination of multi-vendor clusters
  - Guarantee stability, avoid conflicts and operate according to grid codes
  - Operate generation facilities as lumped power plant
  - Favour competition
  - All the above to **lower cost of electricity**

# Multi-turbine test: sample preliminary simulation results

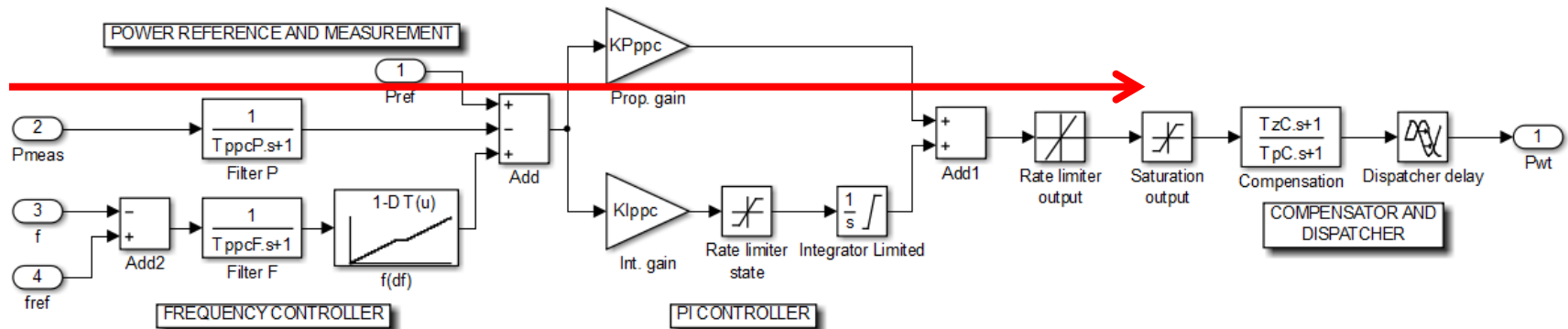
## Power Oscillation Damping



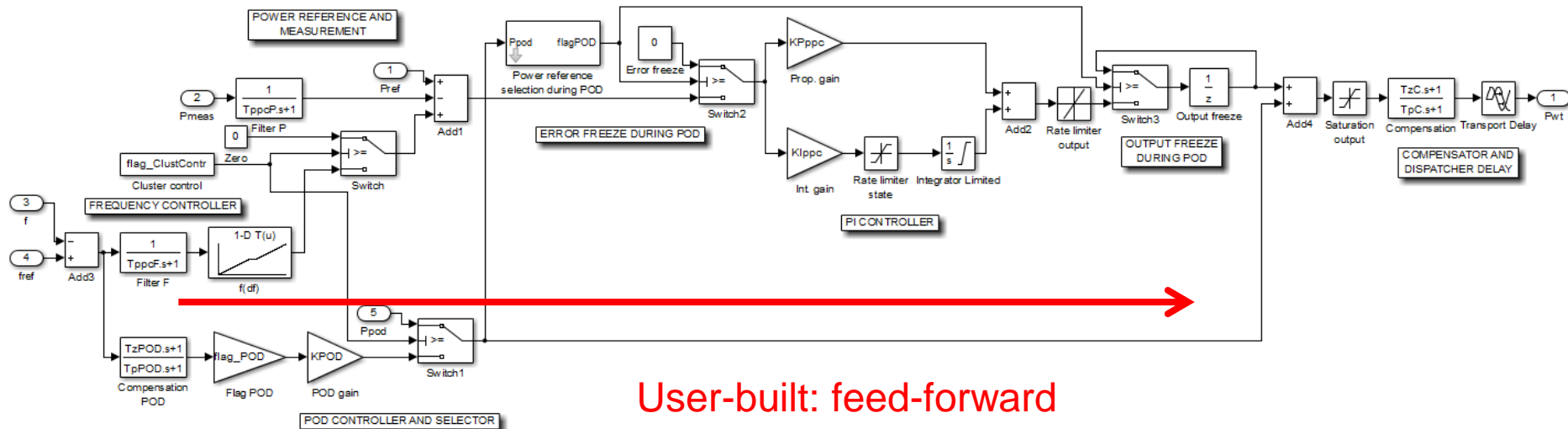
- Cluster control receives/generates reference signals
- Dispatch to plant controllers
  - Commercial plant controller → red colour
  - User-built plant controller → green colour
- Sub-dispatch to WTs

# Plant controllers comparison

## Power Oscillation Damping



Commercial: through PI controller



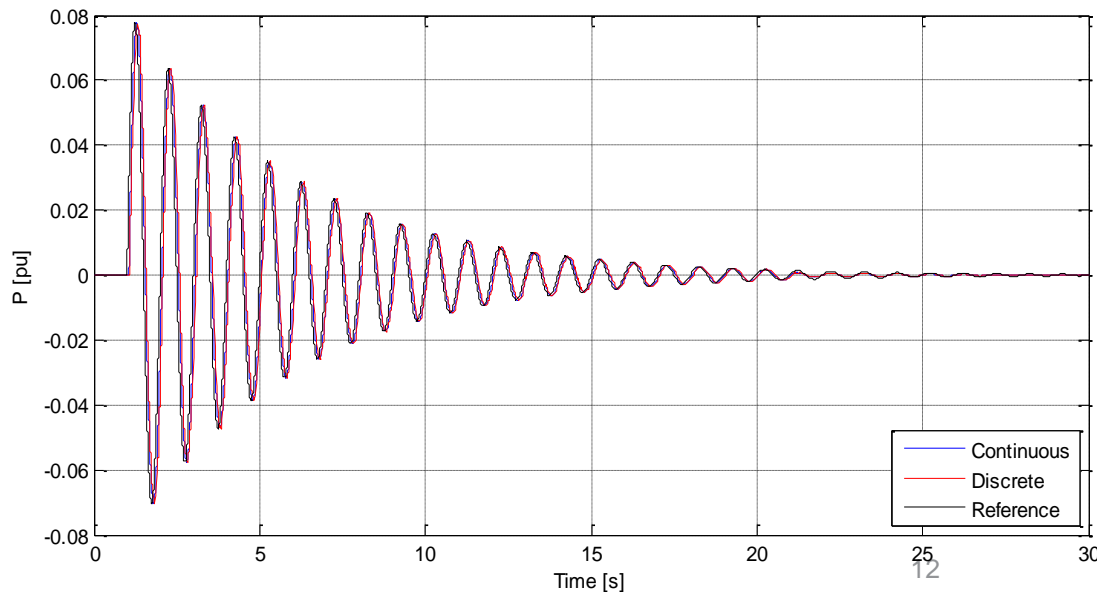
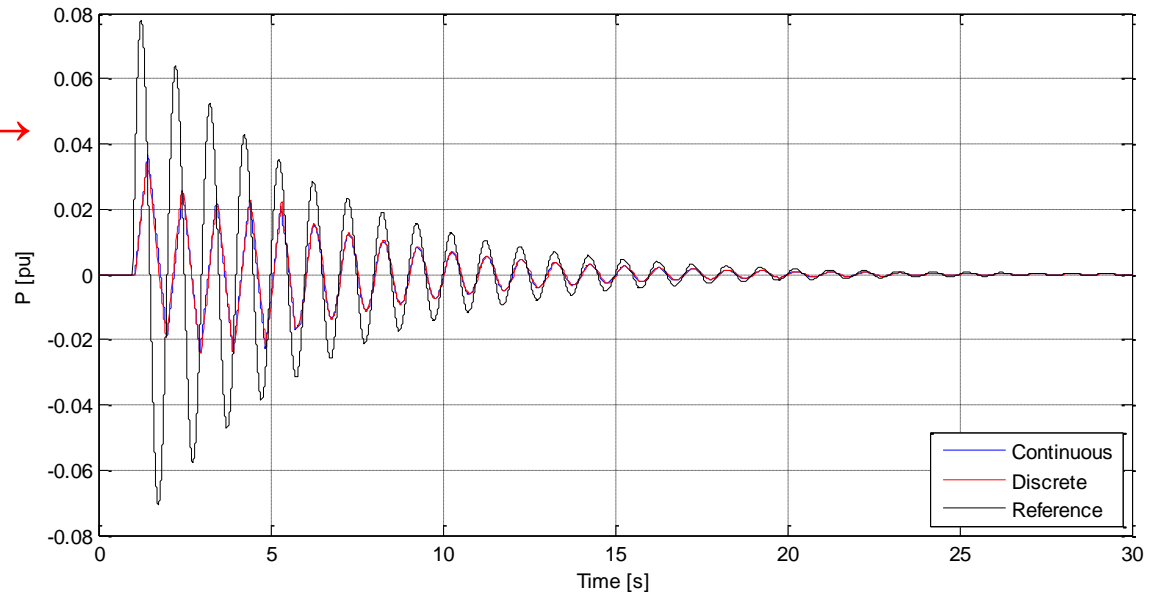
User-built: feed-forward

# Multi-turbine test: preliminary simulation results

## Limiting factors for POD

**Commercial** →

- Example: ramp-rate limiter
- Other limiting factors:
  - sample time: at high frequency
  - other delays
  - PI control parameters variations

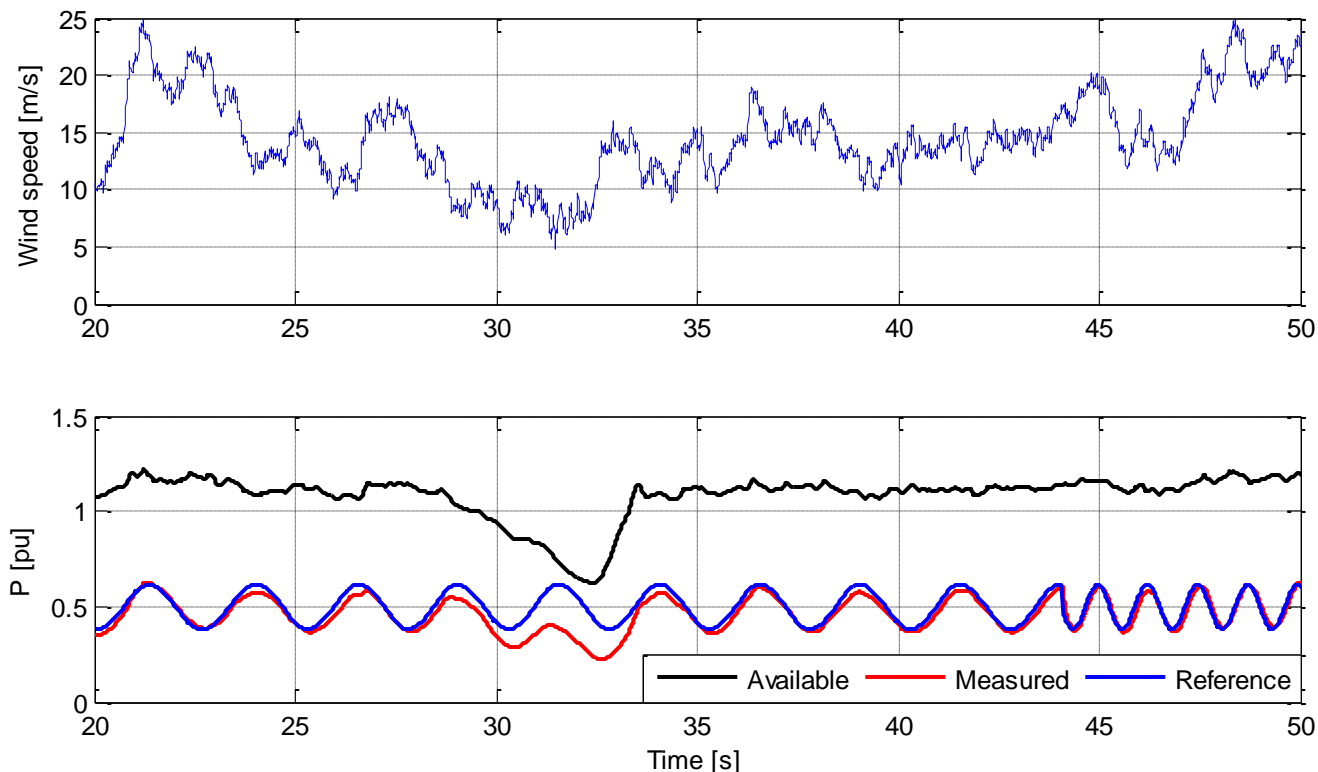


← **User-built**



# Multi-turbine test: preliminary "real-time" simulation results

- Connection between NI real-time controller and simulation model on computer
- LAN communication tested successfully
  - Synchronisation time down to 10 ms: sufficient for the scope
  - Stable and deterministic communication delay
- Turbine model responds well to power reference tracking



# Multi-turbine test: next steps

- Connection of real-time controller to dyno-driven machine
- Connection of field machines to CGI
  - Challenges:
    - Lack of availability of realistic plant control → difficult comparison with user-built control
    - Possibly low Pref update rate → limited frequency spectrum of testable POD
- Test of Pref steps and validation of models
- Test of multi-turbine response to advanced service event



**THANKS FOR YOUR ATTENTION! Any questions?**  
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