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Novel Control Parameter Setting for Rotor Speed of Spar-type Floating Offshore Wind Turbine-Generator System

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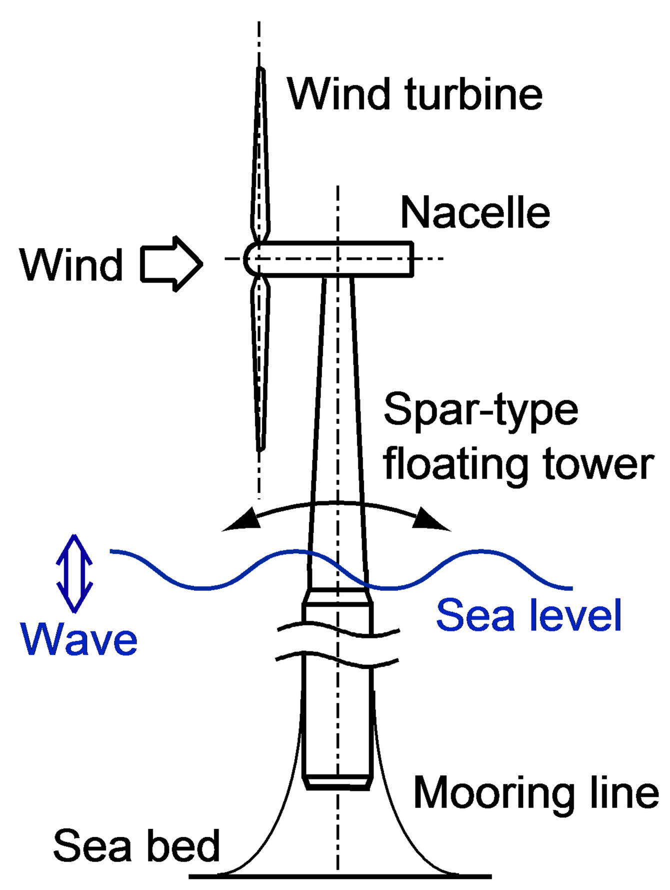
Abstract

Floating offshore wind turbine-generator systems are expected to install in areas that have very deep waters. Although these systems require a cost reduction, sufficient strength design, and platform stability for commercial use, the establishment of the platform stability by a control approach contributes considerably to satisfaction of the other requirements. Therefore, the present study develops a novel control parameter setting for a conventional feedback control of the rotor speed based on collective blade pitch angle manipulation to reduce the power output fluctuation as well as the platform motion. The development is conducted through a numerical analysis of a spar-type floating offshore system using the aeroelastic simulation model (FAST), observed high wind speed data, and irregular sea waves. The proportional-plus-integral action of the collective blade pitch angle manipulation is employed for the rotor speed control. The numerical analysis found a novel control parameter setting for the rotor speed of the spar-type floating offshore system, which can reduce both the power output fluctuation and platform pitching motion. This good reduction is achieved by the high damping of the control loop to prevent the negative damping effect, and the high natural frequency to improve the control performance of the rotor speed.

Spar-type Floating Offshore Wind Turbine-Generator System



Wind turbine-Generator:
NREL 5-MW baseline machine
Floating platform:
OC3-Hywind spar-buoy model

System Operation Control

- Variable speed operation at low wind speeds
  - Generator torque manipulation in response to rotor speed variation
- Constant speed operation at high wind speeds
  - **Generator torque** manipulation
  - **Collective blade pitch angle** manipulation

Dynamic Simulation Model

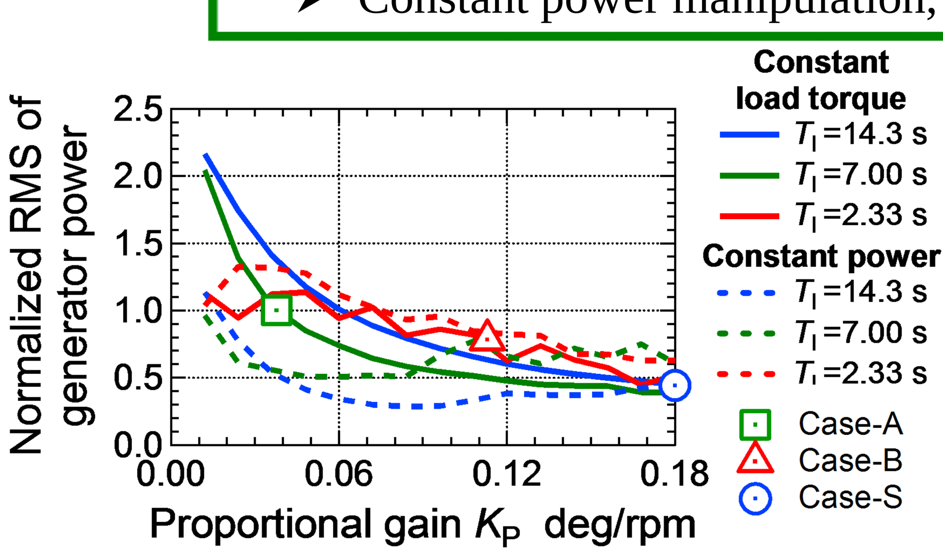
FAST: NREL aeroelastic simulator

- Wind turbine: ***Blade element and momentum theory***
- Controller:
  - ***Blade pitch angle manipulation***: PI action based on rotor speed error
    Gain scheduling
  - ***Generator torque manipulation***:
    ① Constant generator torque
    ② Constant power manipulation
- Rotor–Drivetrain: ***Equivalent shaft model (lumped system)***
- Floating platform: ***6 DOF (lumped system)***
- Solution method: ***Predictor-corrector method***

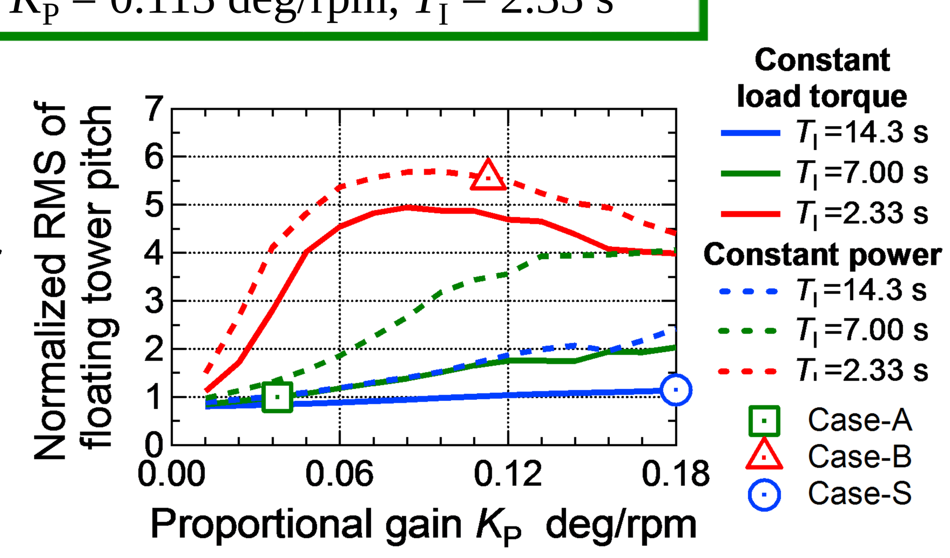
Dynamic Behavior Analysis at High Wind Speeds and under Irregular Waves

Baseline controller settings

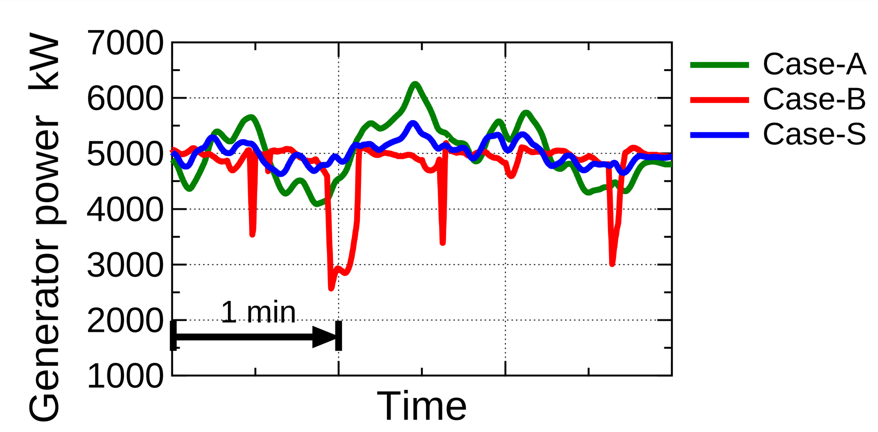
- **Case-A**: Parameter setting for NREL off-shore system
  - Constant generator torque, K_P = 0.038 deg/rpm, T_I = 7.0 s
- **Case-B**: Parameter setting for NREL on-shore system
  - Constant power manipulation, K_P = 0.113 deg/rpm, T_I = 2.33 s



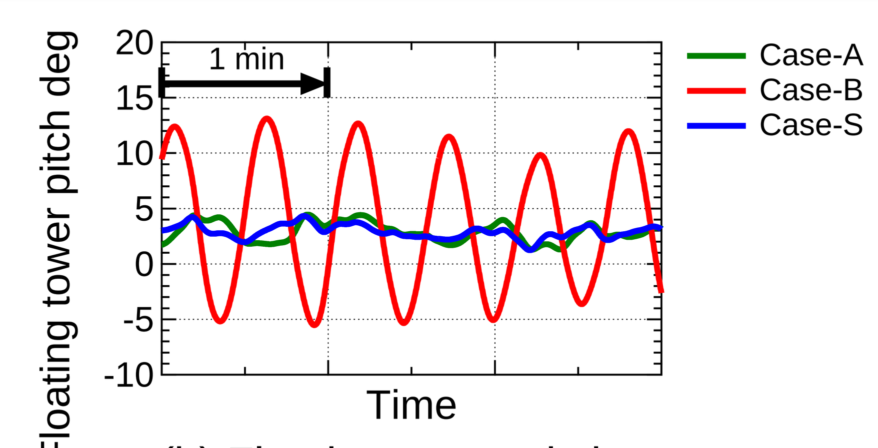
(a) RMS of normalized generator power



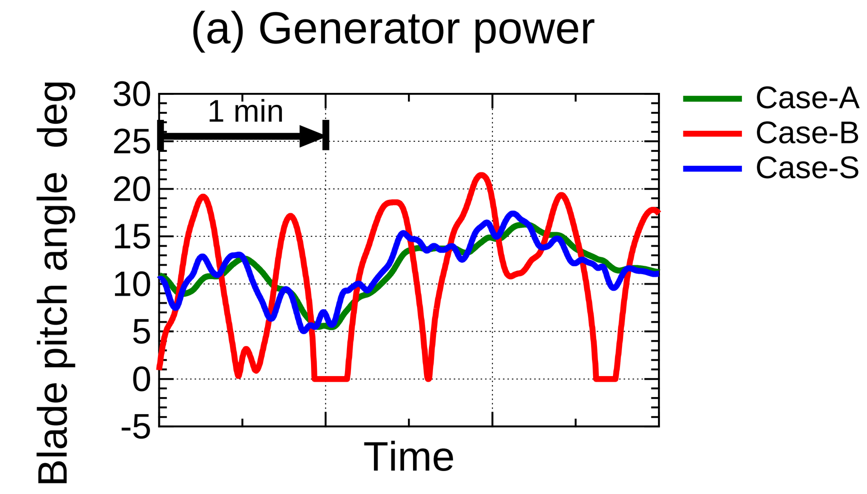
(b) RMS of normalized floating tower pitch



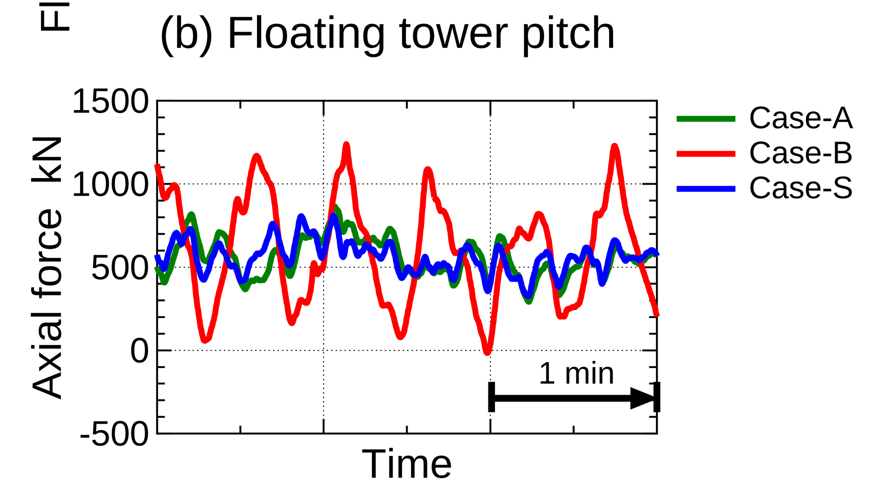
(a) Generator power



(b) Floating tower pitch



(c) Blade pitch angle



(d) Axial force to tower

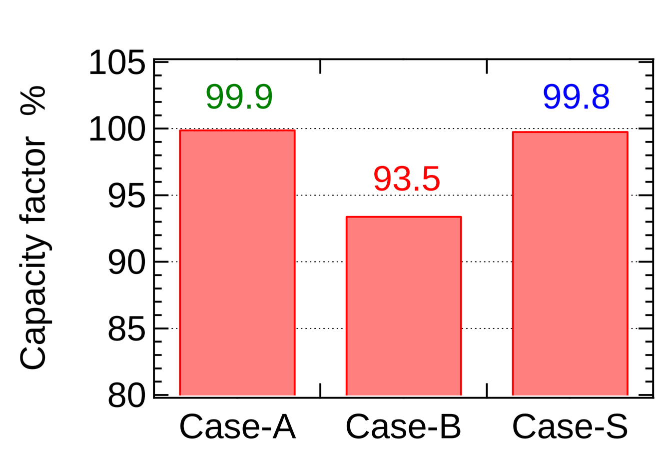
Novel controller setting

- **Case-S**: Constant generator torque, K_P = 0.18 deg/rpm, T_I = 14.3 s

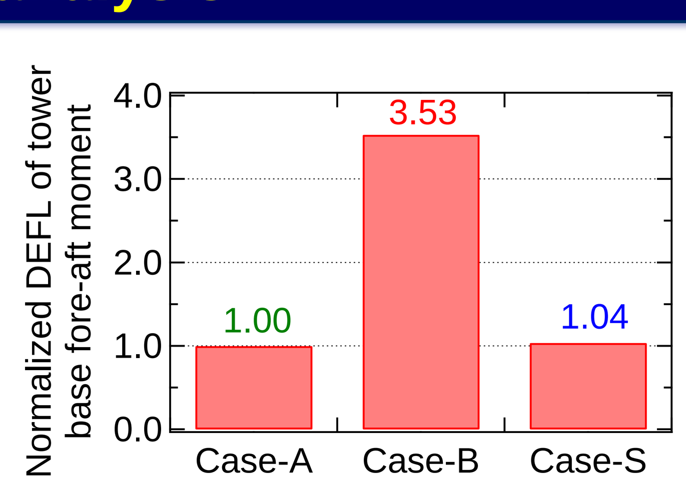
Dynamic behavior in Case-S

Small manipulation of blade pitch angle reduces negative damping effect to platform

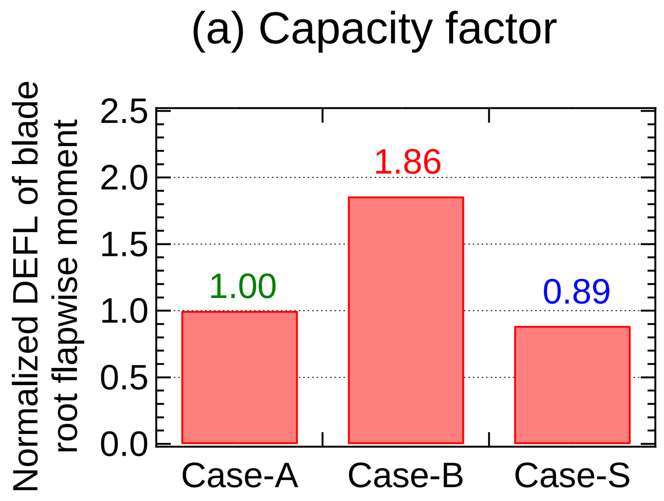
Performance analysis



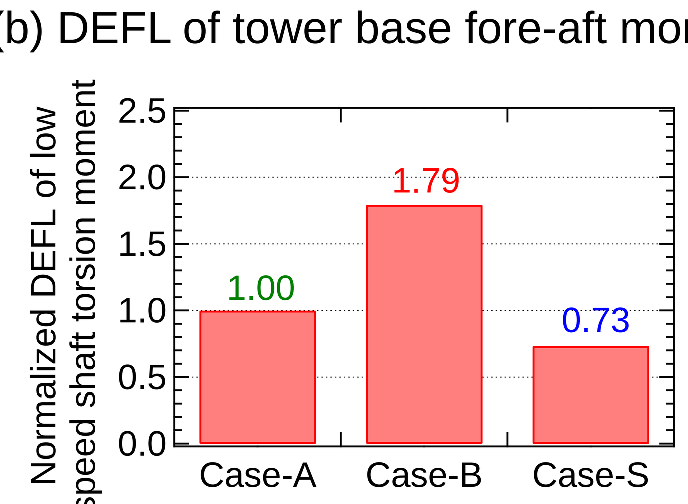
(a) Capacity factor



(b) DEFL of tower base fore-aft moment



(c) DEFL of blade root flapwise moment



(d) DEFL of low speed shaft torsion moment

Damped oscillation characteristics of control loop

Equilibrium operating point: Inflow wind speed of 15 m/s

	Case-A	Case-B	Case-S
Natural frequency Hz	0.031	0.093	**0.047**
Damping coefficient	0.682	0.682	**2.13**

Natural frequency of floating tower pitching : 0.034 Hz

Conclusions

- A novel control parameter setting for the rotor speed of the spar-type floating offshore system (Case-S), which can reduce both the power output fluctuation and platform pitching motion, was found through the dynamic behavior analysis.
- The good reduction is achieved by the high damping of the control loop to prevent the negative damping effect, and the high natural frequency to improve the control performance of the rotor speed.