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Supergen Offshore Renewable Energy

WEIGHTED DOUBLE-LOOPS CONTROLLER FOR PLATFORM STABILIZATION OF FOLATING TURBINES

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1. Introduction

Why floating offshore turbines?

- Access to stronger & more consistent wind with less shear.
- Possibility of constructing larger size wind turbines.
- Use of deeper water sites opens up new areas.

Fig. 1: Main categories of Floating Offshore Wind Turbines (FOWT)[Source: https://e360.yale.edu]

FOWT control system objectives:

- Maximise power (region 2) or regulates power and rotor speed (region 3),
- Increase fatigue life by reducing structural loads,
- Stabilizes FOWT platform.

2. Loop Weighting Controller

Proposed Controller Structure

Double-loop Control: PI control loop for platform pitch angle regulation in parallel with conventional power/rotor speed regulation loops.

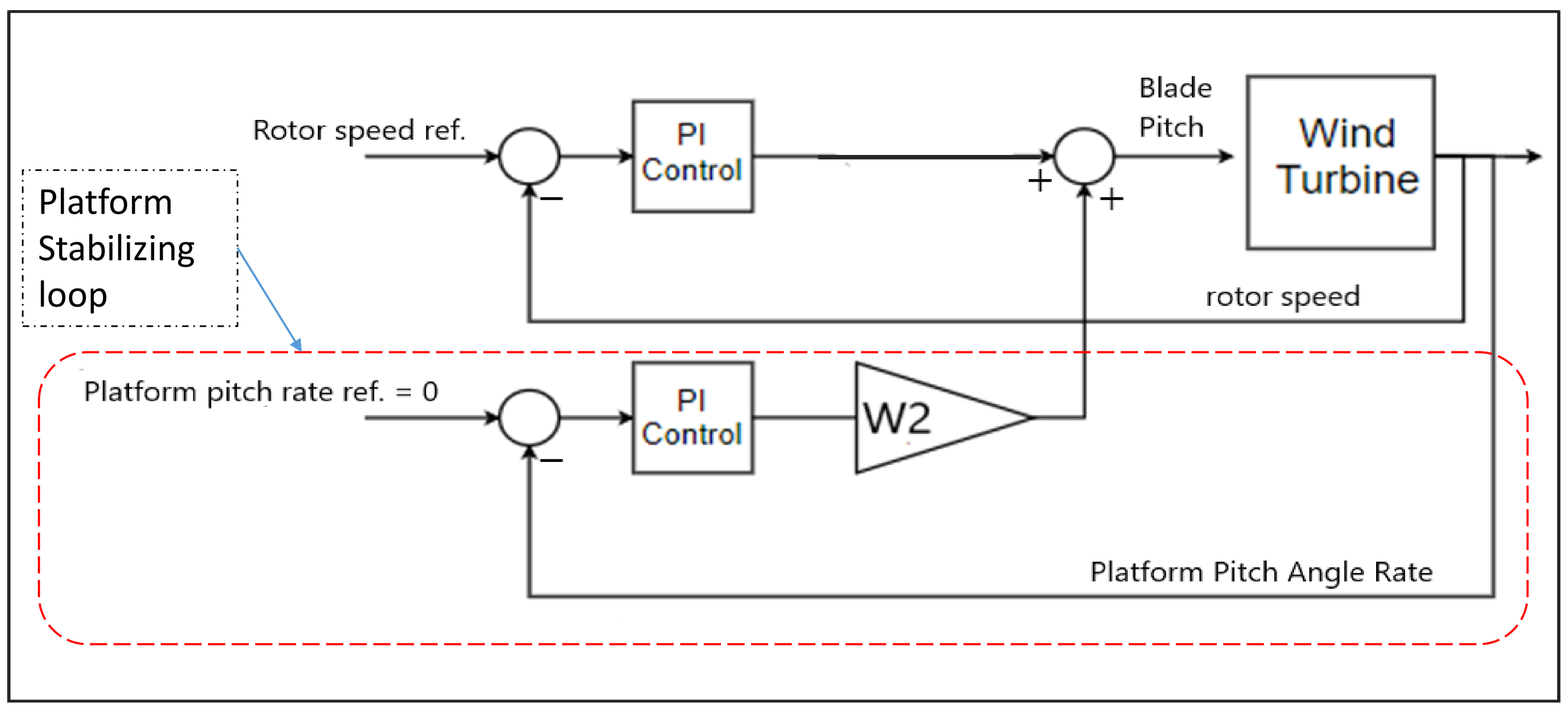


Fig. 2: Double-Loop weighted control system for FOWT

Loop weighting W2 is design parameter to tune FOWT performance in region 3 by balancing objectives (*Ramos, 2018*):

- Ensure stability of FOWT;
- Regulate rotor speed to its rated value 12.1 rpm;
- Reduce platform motion in pitch direction, to reduce loading on FOWT components: tower, blades, and platform,
- Minimise blade pitch actuation rate, to extend pitch actuator life-time.

3. Simulation & Results

i) Simulation Setup

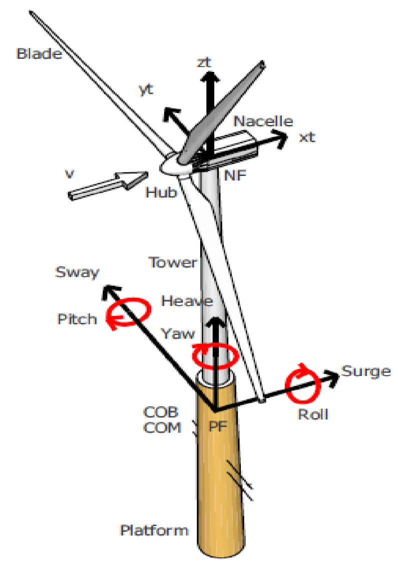
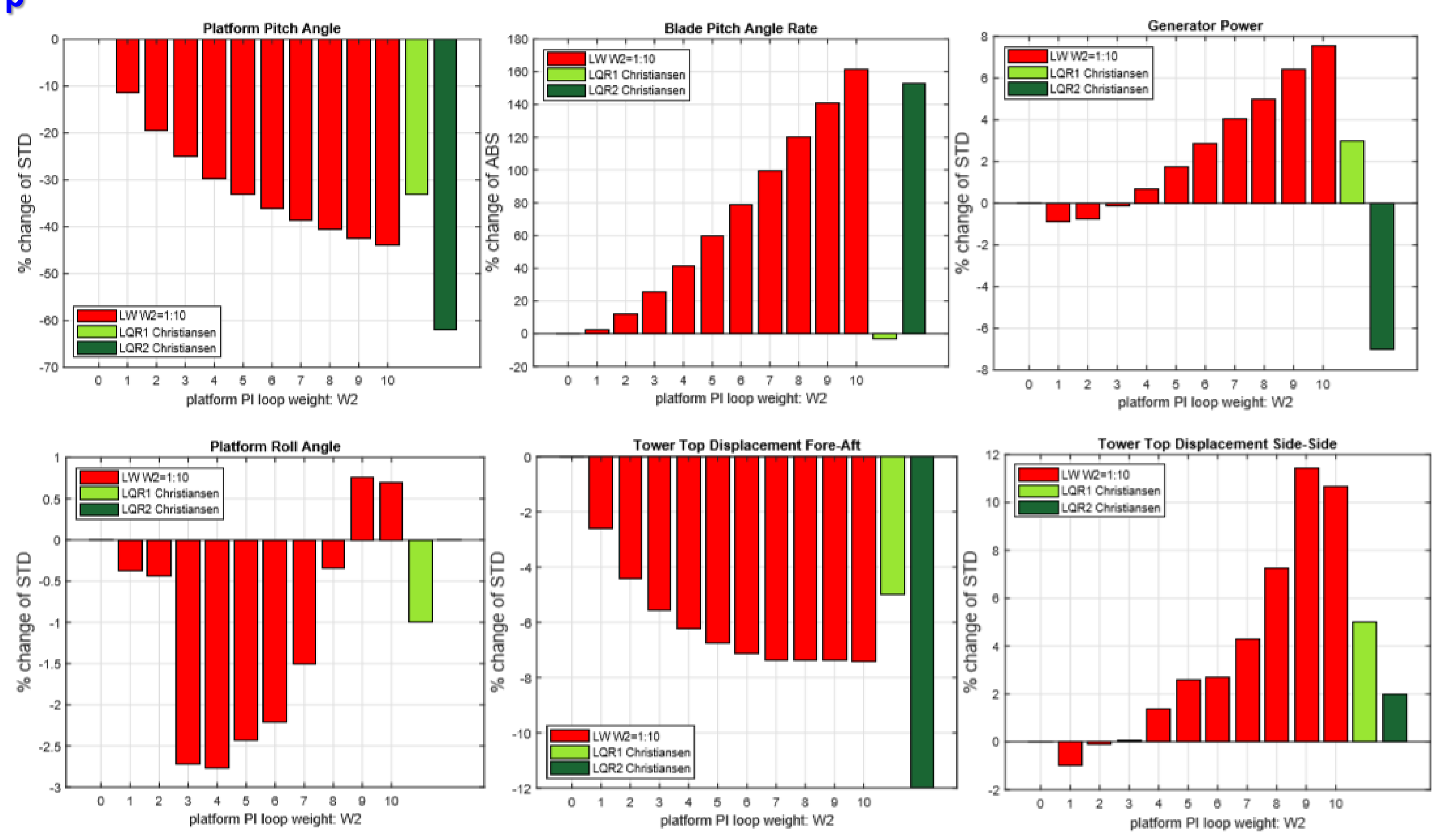


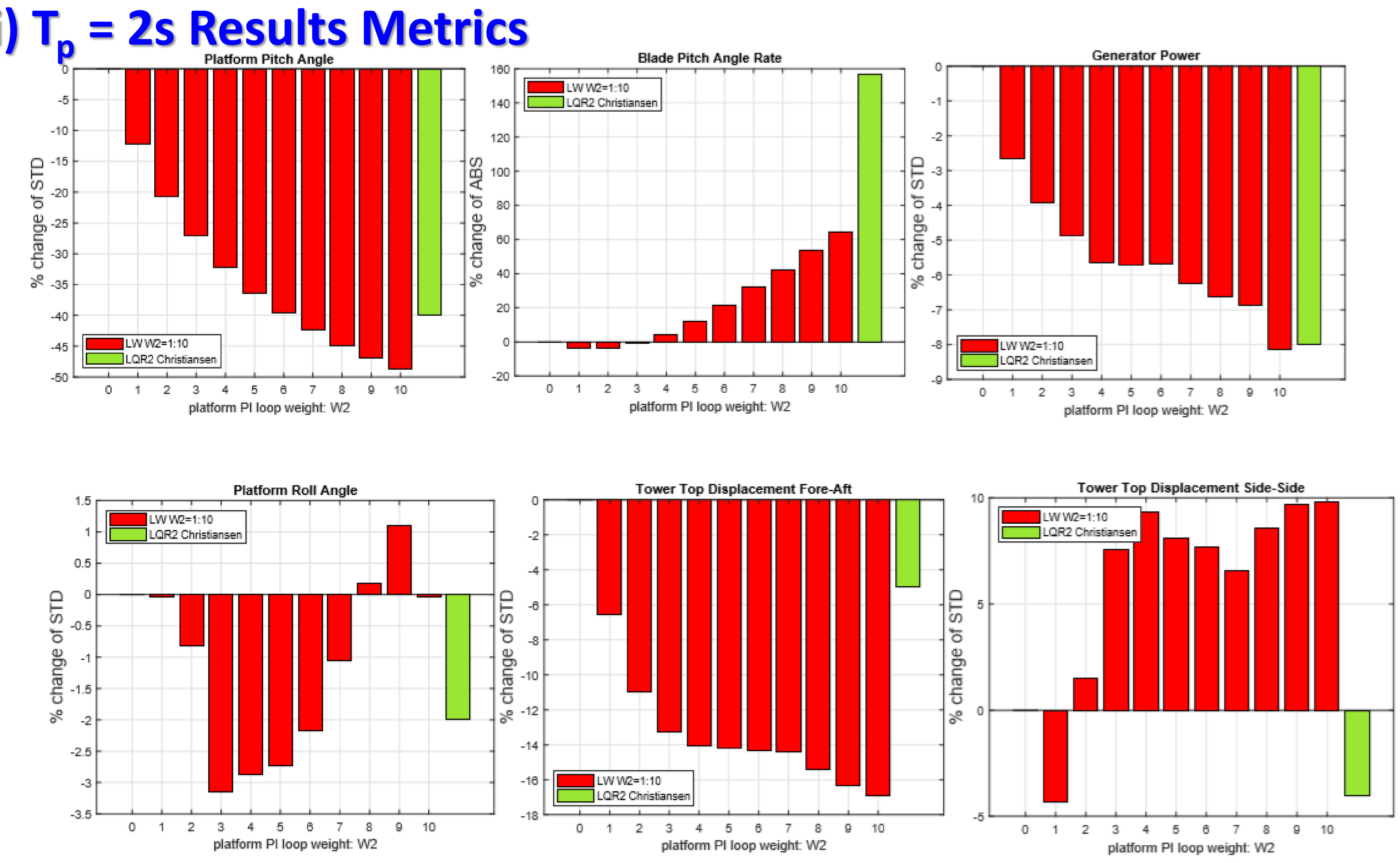
Fig3: OC3-Hywind FOWT illustration (Christiansen et.al. 2013)

- ✓ The controller is applied to OC3-Hywind FOWT and compared with advanced LQR control of (Christiansen et.al. 2013).
- ✓ Wind speed 18 m/s with turbulent 14.9% and irregular waves with significant wave height 6m and peak periods, T_p = 2, 5 and 10 s.
- ✓ Simulation in FAST in Matlab/Simulink environment.
- ✓ 6 metrics used for controllers comparison:
  - Platform pitch motion,
  - blade pitch angle rate,
  - power fluctuation,
  - platform roll angle fluctuation,
  - tower top for-aft motion and
  - tower top side-side motion.

ii) T_p = 10s Results Metrics



iii) T_p = 2s Results Metrics



- Double-loop control enhances platform stabilization for increasing W2.
- **At T_p=10s:** Double loop controller gives lower performance than LQR control. But is more flexible by enabling practical compromise between platform motion damping and pitch activities.
- **At T_p=2s:** Double loop control gives better performance than LQR in most metrics. For example, good performance is obtained by setting W2=5:
  - Platform pitch motion reduction by 40% for only 15% increase in blade pitch activities, compared with 157% increase in blade pitch activity for the same amount of platform motion reduction with LQR.

4. Conclusions & Future Work

- Proposed double loop control gives:
  - Flexibility in balancing conflicting control objectives
  - Simplicity of using familiar PI controllers
  - Better performance at short wave periods
- LQR control is superior at large peak period sea states. This may be due to long wave periods giving enough time for wave/wind estimators to get accurate results, supporting optimized control signal generation.
- Inspired by this, future work will evaluate double-loop control with wind/wave estimators.

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References

[1] Ramos, R. L. (2018). Linear quadratic optimal control of a spar-type floating offshore wind turbine in the presence of turbulent wind and different sea states. *J. of Marine Science and Engineering*, *6*(4), 151.

[2] Christiansen, S., Bak, T., & Knudsen, T. (2013). Damping wind and wave loads on a floating wind turbine. *Energies*, *6*(8), 4097-4116.