WIND POWER PLANT CONTROL

Grid support and load redistribution | W.P. Engels
WIND POWER PLANT CONTROL

What is it?
- Non-default setpoints for individual turbines in the plant
  - Power
  - Yaw
  - Minimum pitch angle

Used for:
- Power optimisation of the whole plant (not today)
- Derating of wind power plant for grid support services
  - E.g. produce X MW, or produce Y% of max production
- Maximise *value* of wind energy

If RE penetration ↑
this will increase
WIND POWER PLANT CONTROL

✦ Currently:
  ✦ Uniform deregulation

✦ Opportunity:
  ✦ Redistribute loads in farm to:
    ✦ spread accumulated load evenly
      ✦ ‘plan’ failures
  ✦ reduce total load accumulation
    ✦ extend overall lifetime/reduce maintenance

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Wind Power Plant Control

Production

- Full energy
- Partial reservation

Value

- Full energy
- Partial reservation

Spare
Production

Value

- O&M
- Balancing & Ancillary Services
- Energy
So how do we do this?

- Not: control dynamics @ WT level
- PI control on power output
- Calculate ‘cost’
- Distribute control action based on lowest ‘cost’/kWh

Need:

- Loads
  - Accumulated load/damage estimation → online load calculation (unbinned cycle counting)
  - Load rate estimation → approximate, based on load-cycles
  - Calculated/estimated by wind turbine controller
- Production estimate (wind speed)
Wind farm control

- Setpoint
- PI
- Distribute
- Loads
- Power
WIND POWER PLANT CONTROL

Does that work?

- 3 wind turbines, waked set-up
- Simulations with FastFarm (NREL)
- Control relative plant output, using relative wind turbine setpoints
  - Change the power curve below rated

3 scenarios:
- Flat reduction rate, open loop (NoPC)
- Flat plant rate, closed loop (CPC)
- Load balanced plant control (LBPC)
  - Cost function based on weighted sum of:
    - Accumulated load and load rate
    - Blade and tower moments
Farm power

Power production [kW]

Time [sec]

NoPC
CPC
LBPC
RESULTS

Tower accumulated fatigue

Tower fatigue rate

0 100 200 300 400 500 600 700 800
Time [sec]
CONCLUSIONS

- Load redistribution wind power plant control works

- Using wind farm plant simulations + full wind turbine model + full wind turbine control simulations is essential

- ‘Correct’ overall power estimation? (Depends on time scale)
TO DO

- WPP and WT power setpoints vs relative setpoints
  - Take coupling-effects into account, e.g. (marginal):
    - Power turbine 1 ↓ → turbulence @ turbine 2 ↓ + power @ turbine 2 ↑
    - Better estimation of available power
  - Explore:
    - Different cost functions
    - Controller gain settings/strategies
    - Local vs. global optima
  - Combine with:
    - (scanning) LIDAR
    - wind farm power optimisation
THANK YOU FOR YOUR ATTENTION

TNO.NL/ECNPARTOFTNO
ONLINE FATIGUE LOAD ESTIMATION

- Problem:
  - Fatigue load calculated by rainflow counting and binning
    - Highly non-linear
    - Attribution in time problematic
      (1\textsuperscript{st} high load cycle occurrence gets all cost assigned)
    - Time derivative discontinuous

- Current workaround:
  - Use quadratic norm of loading
    - Too little weight on drops in load
    - Normal cyclic loading over emphasized
ONLINE FATIGUE LOAD ESTIMATION

- Fatigue load/damage:
  \[ L = m \sqrt{\sum_i n_i L_i^m} \]

- Consider no binning:
  \[ L = m \sqrt{\sum_i L_i^m} \]

  - Sum over load cycles as they occur
  - Still problem with assignment in time
  - Closely resembles official fatigue damage

- Fatigue ‘rate’ signal:
  \[ L' = L_i^m \]

  - Can be implemented such signal is ‘continuous’
  - Equal cycles = equal cost
  - Filter for smoother behaviour