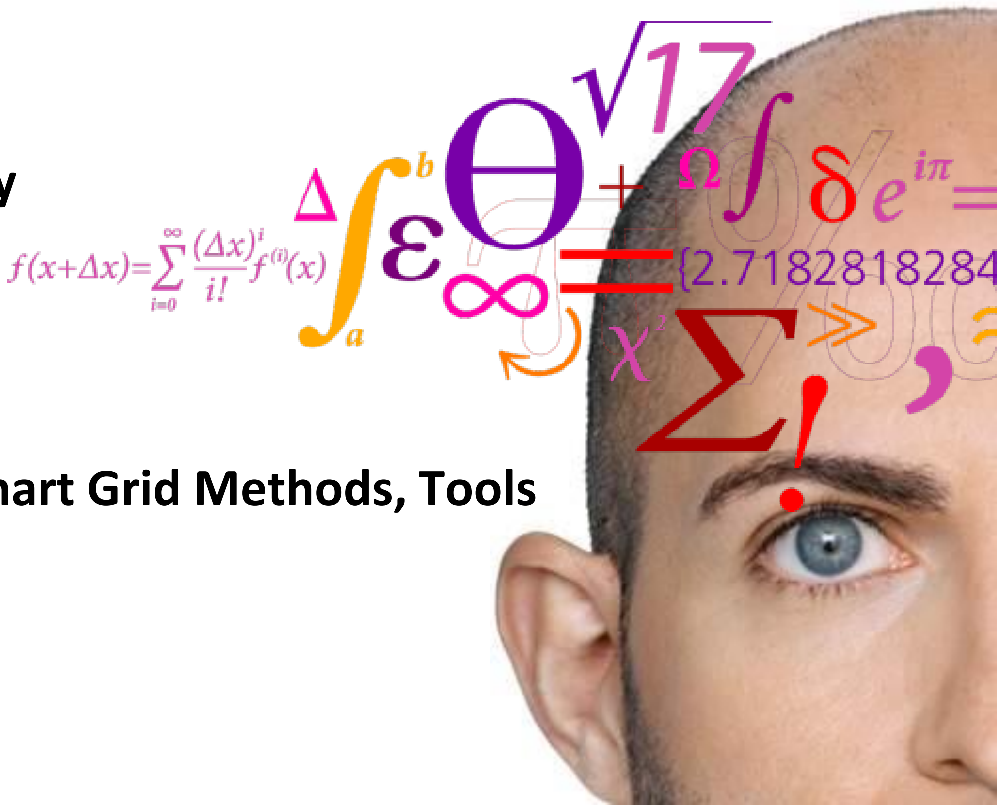
Optimal control strategy of wind farm

Haoran Zhao

Center for Electric Power and Energy

Technical University of Denmark



6th July 2017

2nd International Symposium on Smart Grid Methods, Tools and Technology, Weihai, China

Biography

Education

Work experience

Outline

1. Background
2. Optimal active power control
3. Optimal reactive power control
4. Combined active and reactive power control
5. Conclusion and future work

Background

- Fast development of wind power (12% electricity usage by 2050, IEA).
- Variability and uncertainty of wind ⇨ new challenges ⇨ stringent requirement by TSO.
- Fast development of power electronics ⇨ regulation flexibility (active and reactive power) ⇨ fulfil the requirement.

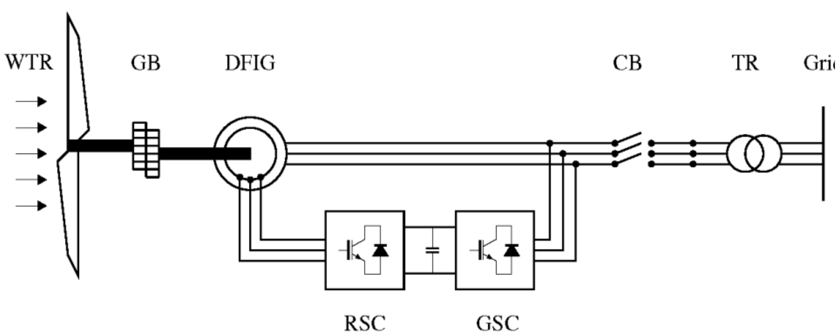


Fig. Structure of Type 3 WTG

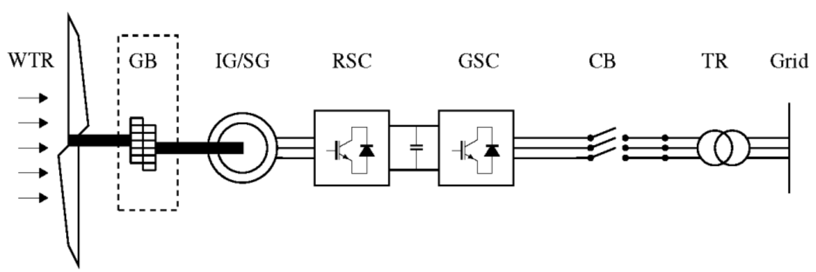


Fig. Structure of Type 4 WTG

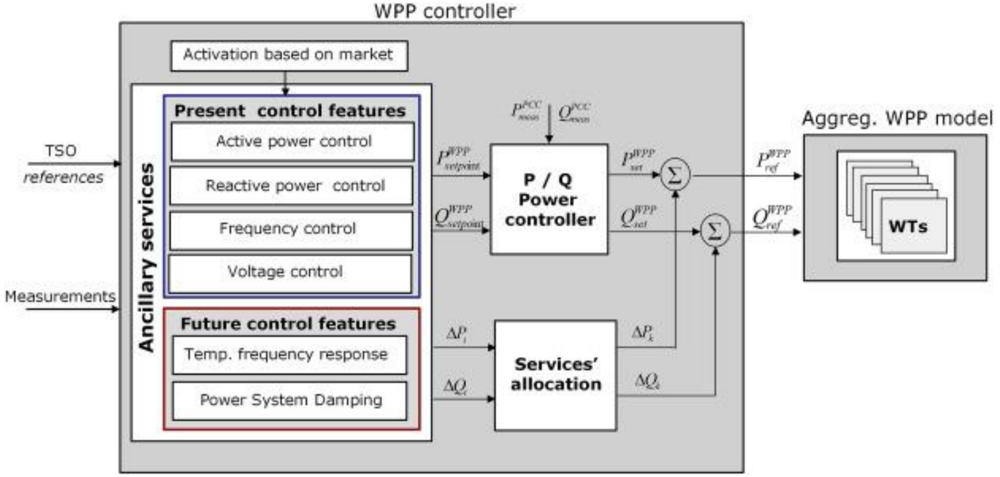
Background

For active power control

- ❑ **Track power reference by TSO (Primary control objective)**

For reactive power (voltage) control

- ❑ **Maintain the voltage of Point of Connection (POC)**
- ❑ **Maintain the voltages of wind turbine terminals**



Optimal active power control

- Control purpose

❑ Track power reference specified by TSO.

❑ Reduce fatigue loads (alleviation of shaft torque of drivetrain/ thrust force of tower)

- Optimal control problem

❑ Multi-objective control (optimal power distribution to wind turbines)

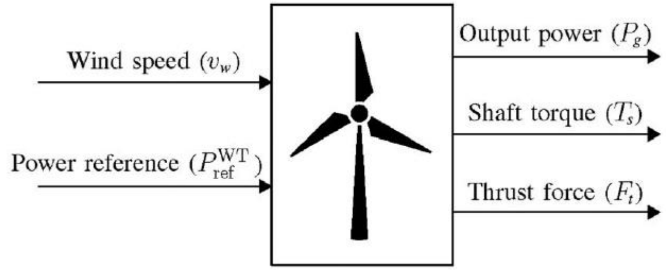


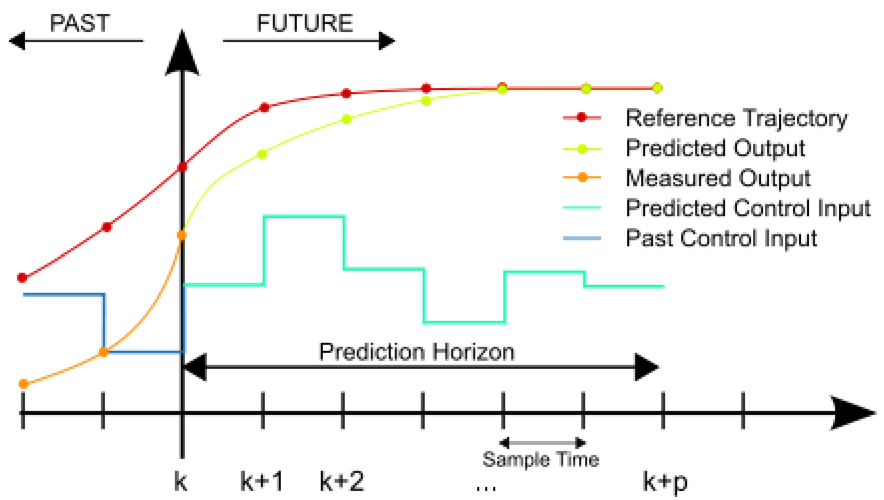
Fig. Power controlled wind turbine

Optimal active power control

- **Potential method- Model Predictive Control (MPC)**

  Receding horizon principle

  Consider input/output constraints



- **Solution of MPC**

❑ **Centralized manner (C-MPC)**

  Heavy computation burden

  Detailed wind farm model required

❑ **Distributed manner (D-MPC)**

  Parallel calculation: Reduced computation burden

  Iteration among the WTGs required ⇨ communication burden

  ⇨ improve convergence (Fast dual method)

Optimal active power control

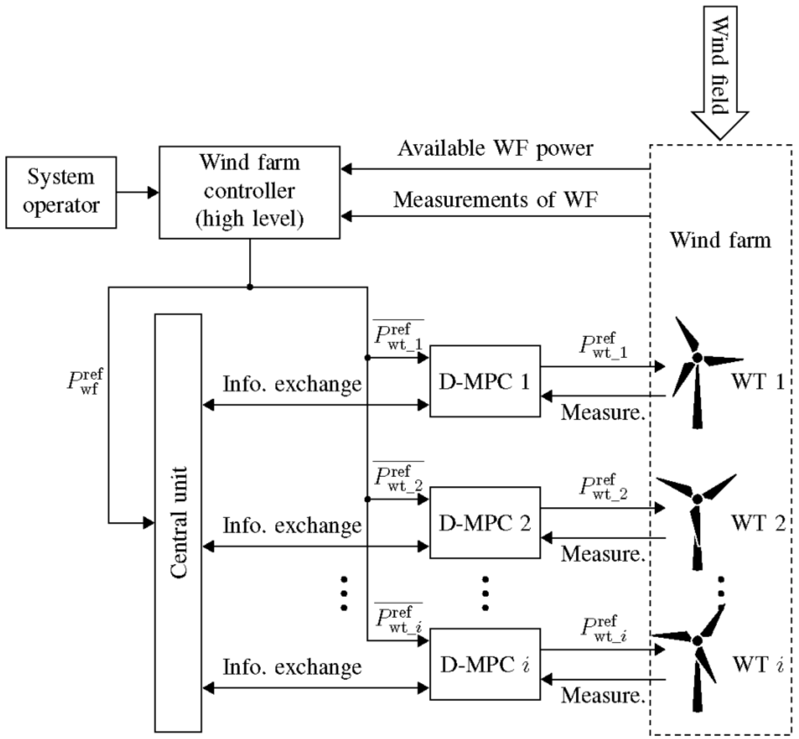


Fig. D-MPC based wind farm control (without ESS)

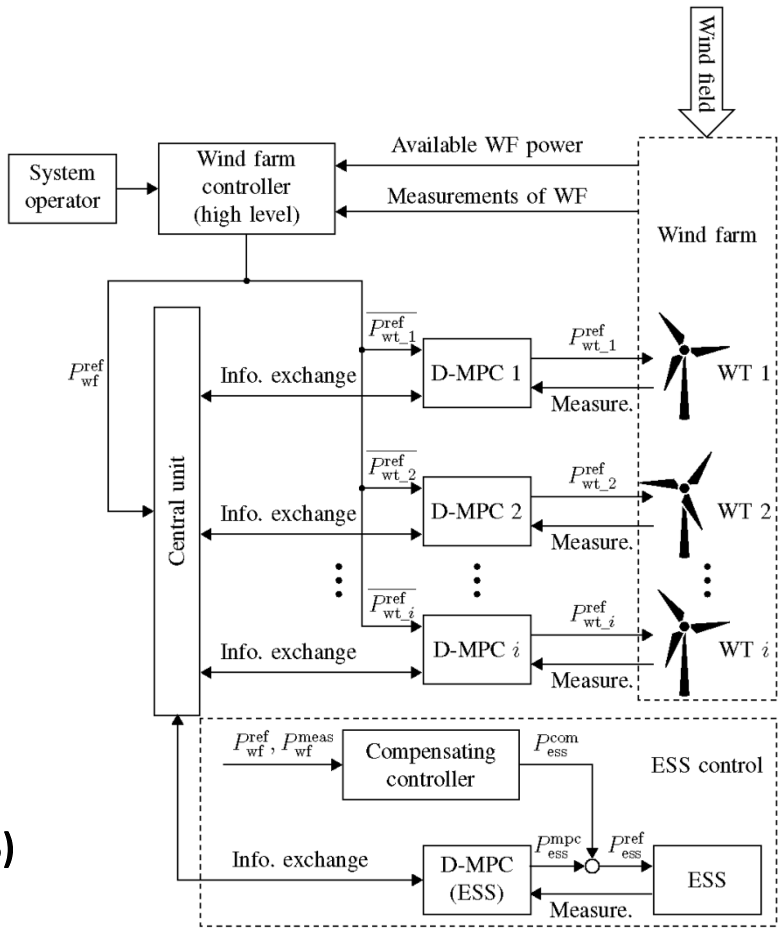


Fig. D-MPC based wind farm control (with ESS)

Optimal active power control

Simulation results

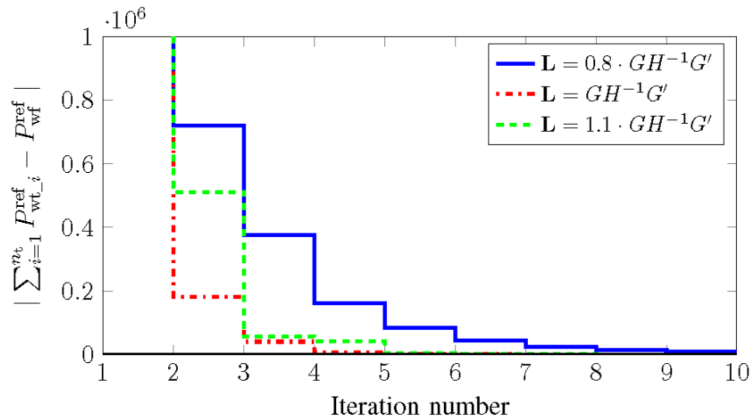


Fig. Convergence performance with fast dual gradient method

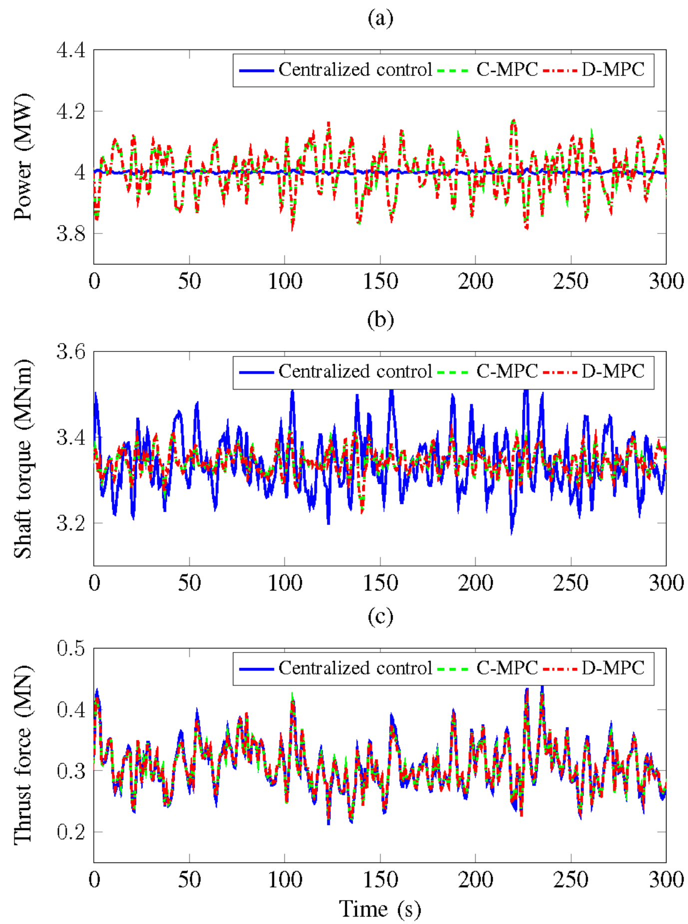


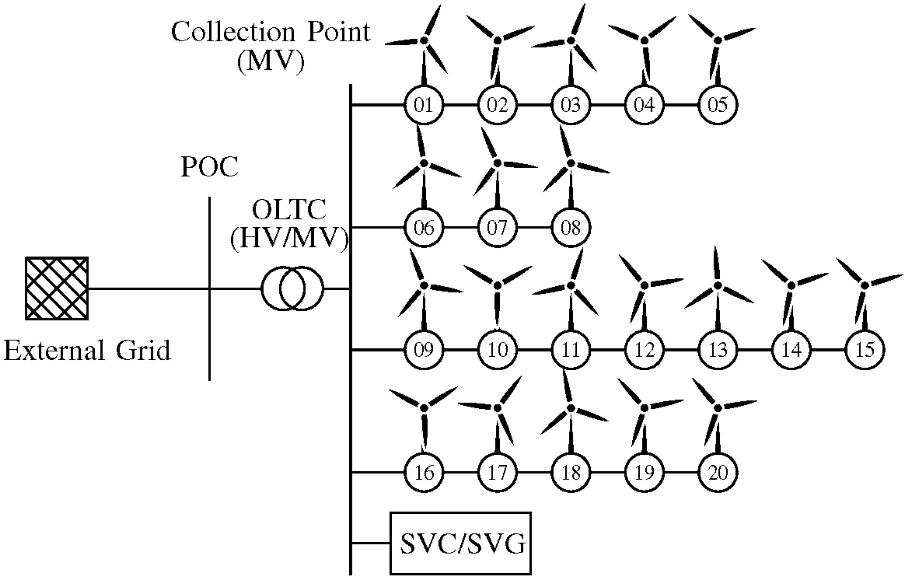
Fig. Simulation results under high wind condition

Optimal reactive power control

- **Control purpose**

❑ **Minimize the voltage deviation of POC**

❑ **Minimize the voltage deviations of wind turbine terminals**



- **Operation modes**

❑ **Normal operation mode (No voltage violation)**

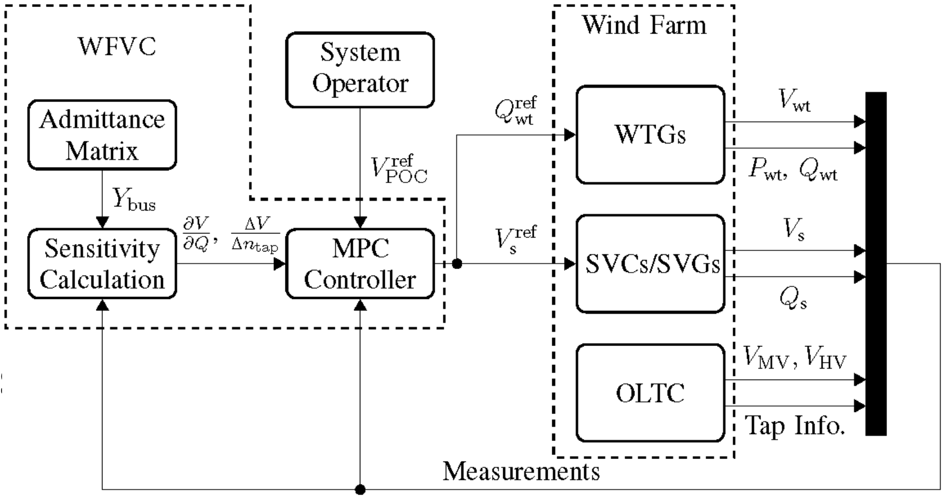
❑ **Emergency mode (Voltage violation occures)**

Optimal reactive power control

- **Optimal control problem**

❑ **Coordinate various Var/Volt devices (Wind turbines, SVC/SVG, OLTC)**

❑ **Network topology: voltage sensitivity of different wind turbine**
(Analytical method calculation)



- **Potential method- Model Predictive Control (MPC)**

Receding horizon principle

Consider input/output constraints

Optimal reactive power control

Simulation results

Events*: t*=20 s: Voltage drop
***t*=50 s: Voltage step**

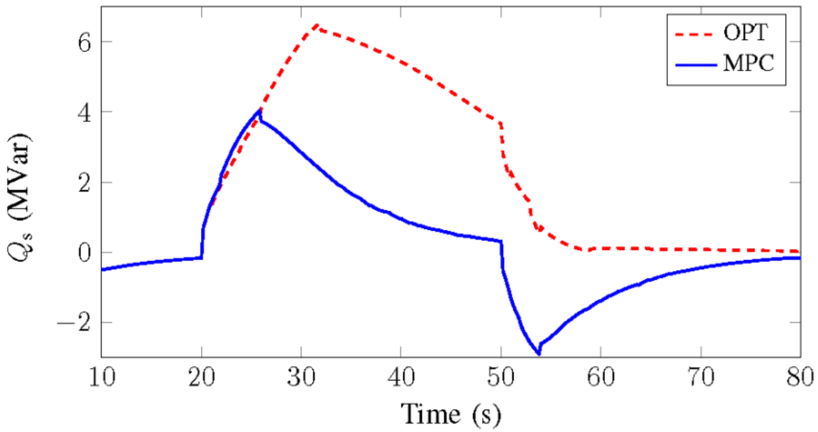


Fig. Var output of SVG (emergency mode)

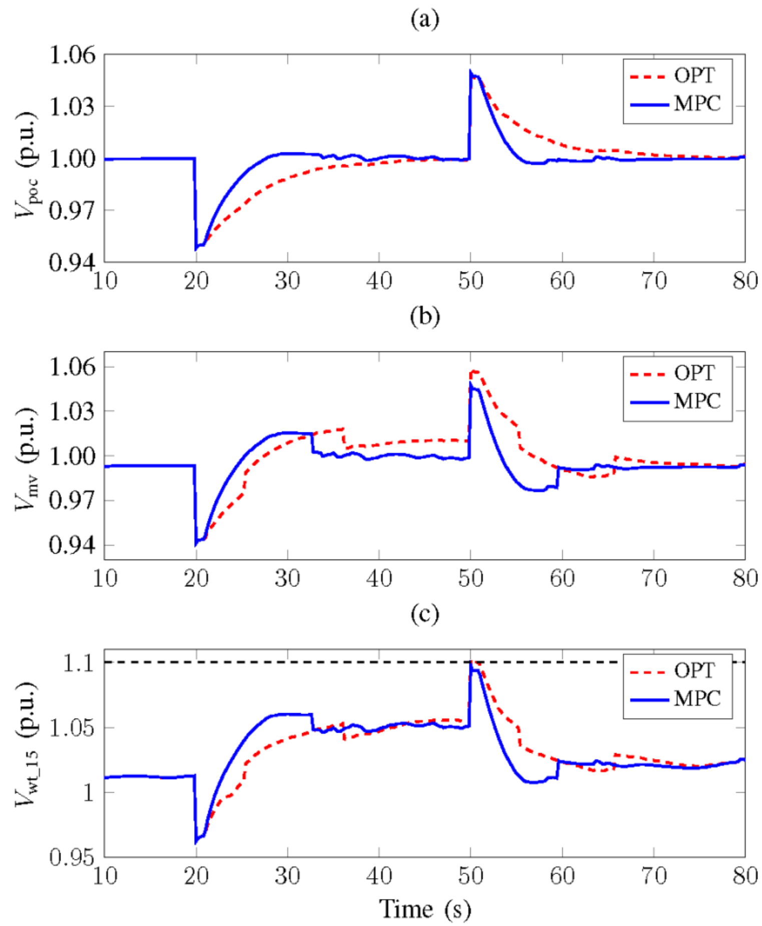


Fig. Voltage of presentative buses (emergency mode)

Combined active/reactive power control

- Conventionally, active and reactive power control are decoupled.

- Two facts are ignored

❑ Low *X/R* ratio ⇨ impact of active power (*P*) on voltage

⇨ limited voltage controllability

❑ Var capacity of modern WTG is dependent on the voltage and *P*.

⇨ Var capacity decreases significantly when WTG operates full load.

Combined active/reactive power control

- **Operation modes**

❑ **Normal mode**

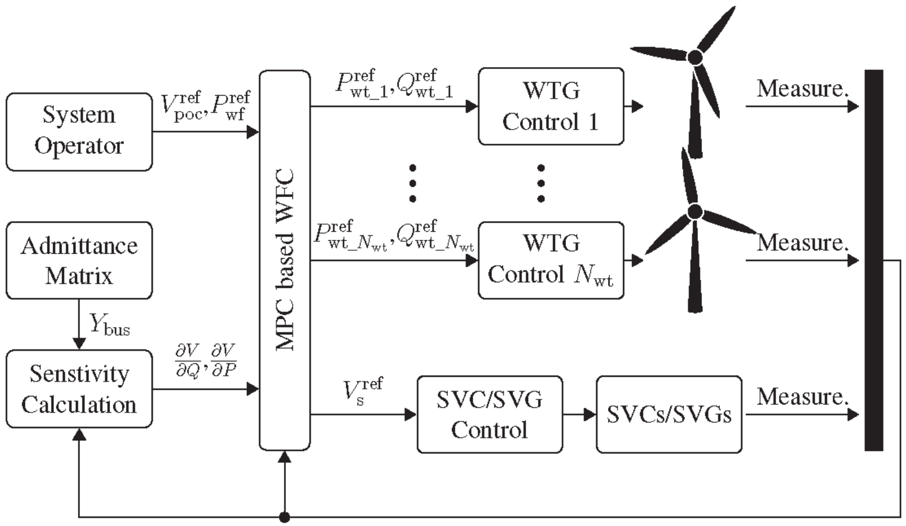
Guarantee the *P* control performances

Coordinate *P* and *Q* optimally to minimize the voltage deviation

❑ **Emergency mode**

Explore the potential of *P* and *Q* for the voltage support

Accelerate the voltage recovery & improve the voltage controllability



Combined active/reactive power control

Simulation results

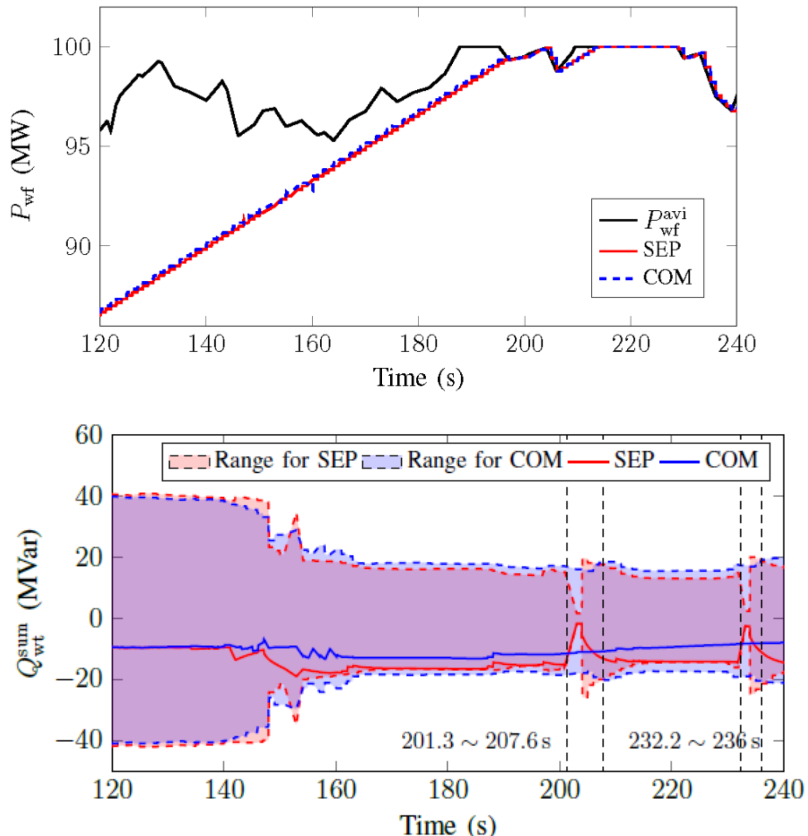


Fig. Var capacity of WTGs

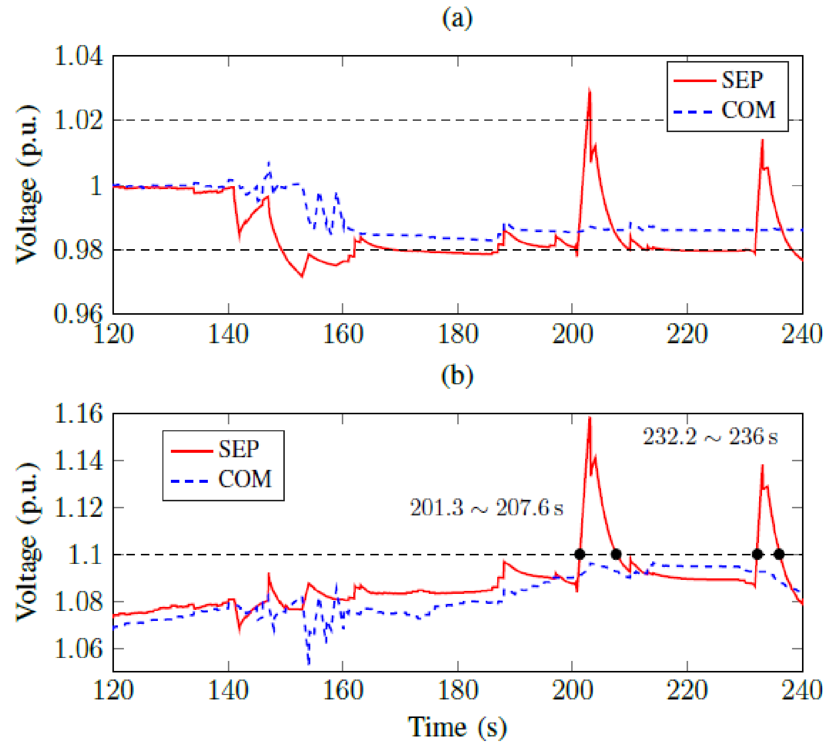


Fig. Voltages at POC and WT15 for high power production

Conclusion and future work

- Make use of flexible *P* and *Q* regulation of wind turbines, wind farm control problem can be formulated as a multi-objective control problem.
- MPC is an effective solution to solve the optimal wind farm control problem.

Potential research work in future:

- Stability problems of MPC for optimal wind farm control.
- Influence of communication delays on control performance.
- Decision of weighting factors for multi-objective control.

Thank you for your attention!

спасибо 谢谢
GRACIAS
THANK YOU
ありがとうございました MERCI
DANKE धन्यवाद
شُكراً OBRIGADO