

# Communication based Power System Modeling for Online Security Detection

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#### Cyber physical systems

- Inverter based renewable energy integration (intermittent, highly dynamic, no inertia, ...)
- Information and communication network (real-time measurements, PMU, smart meters, data analysis, ...)

#### **UIC** Offshore Wind Power Integration

#### European Commission FP-7 Program "TWENTIES" project





## **UIC** System level – Integrated system security

How to maintain security of integrated system??

- Ensure power balance between generation and consumption
- Online detect system stability

**Online stability detection** 

- Time scale of dynamics ranges from milliseconds to minutes or even hours
- Lyapunov method. Hard to find the energy function for large systems.
- Numerical method. Hard to develop appropriate model that meets accuracy and computational requirements.

# **Power system dynamic model**

0 = g(x, y, z)(1)  $\dot{x} = f(x, y, z)$ (2)

- Algebraic equation (1): phasor model (network equations), e.g., V = X \* I
- Differential equation (2): a wide variety of controls ranging from short-term dynamics (e.g., generators) to long-term dynamics (e.g., tapchanging transformer)
- Full time-scale simulation deals with both equations, resulting in computational burden
- Accuracy-speed tradeoff





# **JIC** Quasi steady-state (QSS) approximation

 Rely on time-scale decomposition: fast phenomena are represented by their equilibrium conditions instead of full dynamics





 Assuming x<sub>0</sub> is infinitely fast and replacing corresponding differential equations by algebraic equilibrium equations, then

$$0 = g(x, y, z)$$

$$\dot{x} = f(x, y, z)$$
   
(3)

$$\dot{x_1} = f_1(x_0, x_1, y, z)$$
 (4)

in which f has been decomposed into  $f_0$  and  $f_1$ , corresponding to fast and slow parts, respectively.

### System Level - AC/DC System Security



- Turn complex DC circuits to virtual AC impedance circuits
- Applications: fault location, long-term frequency/voltage stability, load shedding, etc
- L. He and C.-C. Liu, "PMU-based circuit model for HVDC-connected offshore wind generators," *IEEE Trans. on Power Systems*, vol. 29, no.2, March 2014.



#### UK August 2019 blackout

### Worst over a decade

- About a million homes went dark(London and the South East, the Midlands, the South West, Yorkshire, the North East, Cornwall and Wales.)
- Chaos across much of Britain's transport network
- Possible reasons
- Little Barford gas-fired power plant(740MW) and Hornsea offshore wind (HVAC&HVDC/1.2GW now and planned 6 GW) went offline due to a fall in frequency
- Risk of high penetration of renewable energy, such as wind
- Solutions
- Online monitoring& Online modeling

#### England and Wales power cut

Customers affected in each electricity supply area





From <The Telegraph>

# **UIC** Selected Papers

- •L. He and C.-C. Liu, "PMU-based circuit model for HVDC-connected offshore wind generators," *IEEE Trans. on Power Systems*, vol. 29, no.2, March 2014.
- •L. He, C.-C. Liu, A. Pitto, and D. Cirio, "Distance protection of AC grid with HVDC- connected offshore wind generators," *IEEE Trans. on Power Delivery*, vol. 29, no.2, April 2014
- •L. He and R. Voelzke, "Effects of Pre-insertion Resistor on Energization of Compensated Lines," 2016 IEEE PES General Meeting, Boston, MA, July 2016. (Best Paper, Top 5%)
- •L. He, "Effects of pre-insertion resistor on energization of MMC-HVDC stations," 2017 IEEE PES General Meeting, Chicago, IL, Jul. 2017.
- •L. He and C.-C. Liu, "Effects of HVDC connection for offshore wind turbines on AC distance protection," 2013 IEEE PES General Meeting, Vancouver, BC, Canada, July 2013.
- •L. He and C.-C. Liu, "Impact of LVRT capability of wind turbines on distance protection of AC grids," 2013 IEEE PES Innovative Smart Grid Technologies (ISGT), Washington DC, Feb. 2013.
- •L. He and C.-C. Liu, "Protection coordination between a HVDC offshore wind system and AC grid," 2011 CIGRE Symposium "The Electric Power System of the Future", pp. 1-8, Bologna, Italy, Sep. 13-15, 2011.
- •K. Bell, D. Cirio, A.M. Denis, L. He, C.-C. Liu, C. Moreira, and P. Panciatici, "Economic and technical criteria for designing future offshore HVDC grids," 2010 Europe IEEE Innovative Smart Grid Technologies (ISGT Europe), Sweden, Oct. 2010.
- •E. Ciapessoni, D. Cirio, A. Gatti, A. Pitto, A.M. Denis, L. He, C.-C. Liu, C. Moreira, and B. Silva, "Impact of HVDC grid on AC system stability and operation," *2014 CIGRE*, Paris, France, Aug. 2014.