Comparison of Synchronous Condenser and STATCOM for Wind Farms in Weak Grids

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Presenter: Li Bao

Outline:

- Introduction
- Type-4 wind farm in weak grid
  - System model
  - Simulation results
- STATCOM
  - Operation structure
  - Simulation results
- Synchronous condenser
  - Working principle
  - Simulation results
- Conclusion

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Introduction

- The increasing penetration of renewable energy sources such as wind farms have caused some unexpected dynamic problems.
  - Subsynchronous oscillations have observed around the world in past decade.

- In order to enhance voltage stability, reactive power compensation is an effective method.
  - Synchronous condenser (SynCon) and static synchronous compensator (STATCOM) are two major categories among reactive power devices.
  - SynCon and STATCOM have the capability of increasing the transmission system stability and efficiency by absorbing or generating reactive power.

- This paper presents a comparison of SynCon and STATCOM under the condition of zero reactive power injection.

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System model

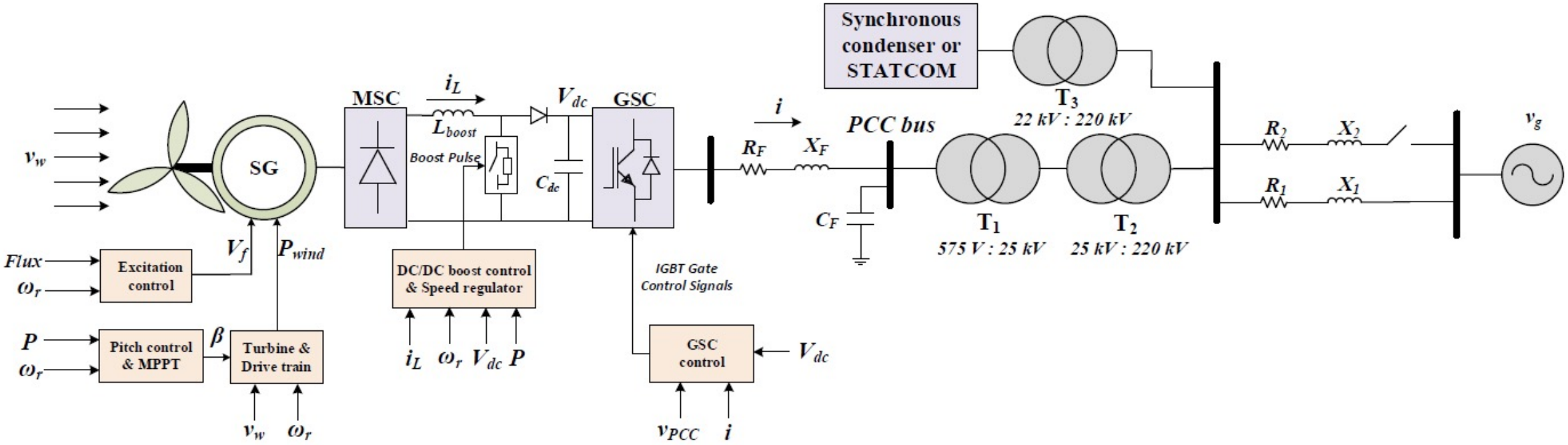

Figure 1. EMT testbed structure of a type-4 wind farm with reactive power devices.

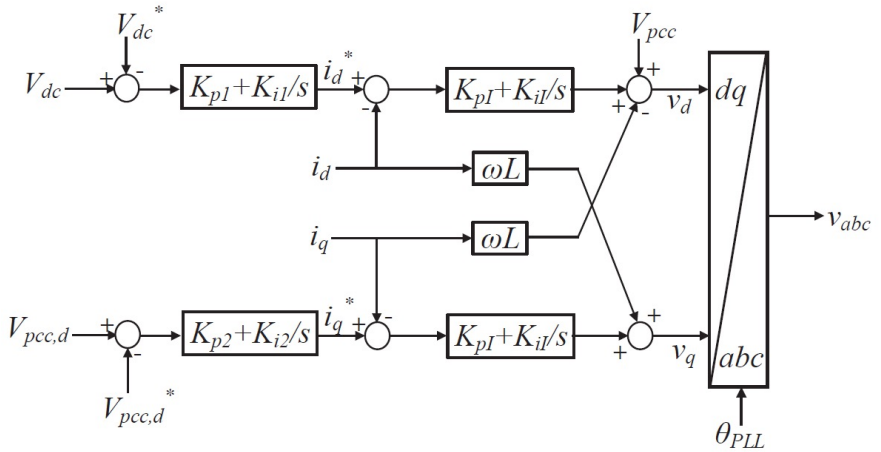

Figure 2: GSC control structure. The dc and ac voltage references are set at 1 pu.

Simulation results

- Transmission line impedance X_g is given a step change from 0.2 pu at 5 second to emulates a parallel line tripping events.
- The dynamic responses are compared when X_g changes to 0.41 and 0.42 pu.
- It can be observed that the system becomes unstable when X_g changes to 0.42 and keeps stable when X_g reaches to 0.41. So the marginal stable condition is X_g = 0.41 and oscillation frequency is about 9 Hz.

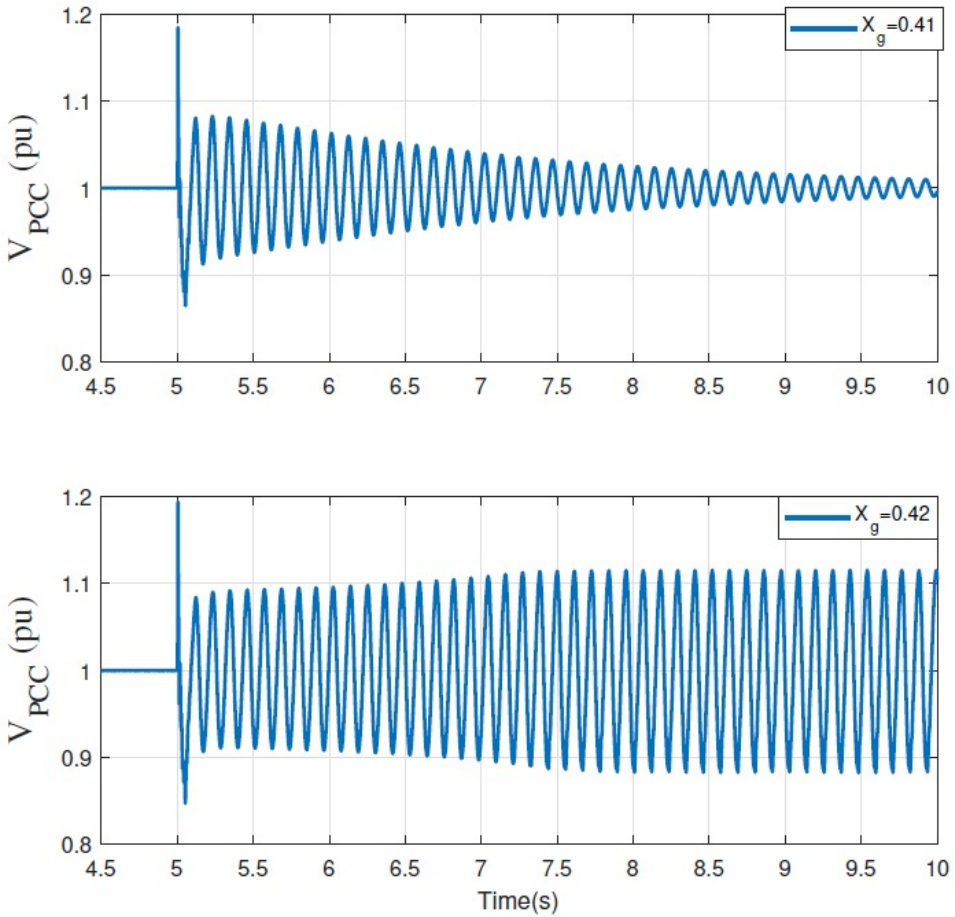

Figure 3: PCC voltage of wind farm.

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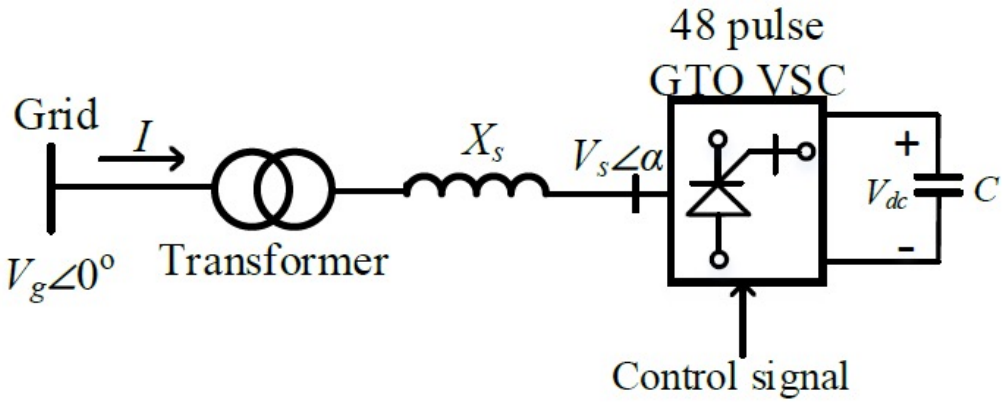
STATCOM model

- STATCOM consists of a DC capacitor and a voltage source converter, which is connected to a grid through a transformer.
- The transferred active power (P) and reactive power (Q) from the grid to the STATCOM are controlled by adjusting the output voltage of the converter:

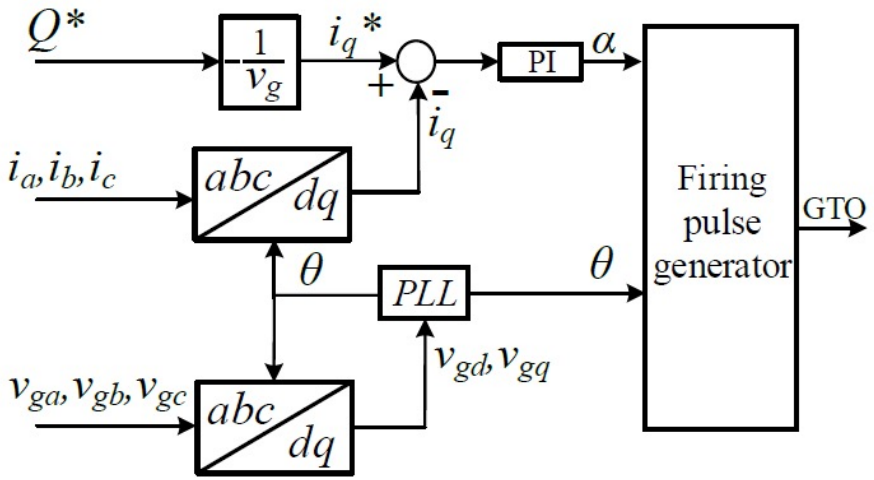
$$Q = \frac{|V_g|(|V_g| - |V_s|\cos\alpha)}{X_s}$$

$$P = |V_g||V_s|\frac{\sin(-\alpha)}{X_s}$$

- Line current i is decomposed into real and reactive current, and the reactive current i_q is compared with the reference reactive current i_q to produce an angle α.
- The reference reactive current is generated from reference reactive power.



(a)



(b)

Figure 4: (a) Single-line diagram circuit of STATCOM. (b) Control block diagram of STATCOM.

Simulation results

Two cases are simulated:

1. No active and reactive power transferred between the STATCOM and the power system.
2. STATCOM injects 0.1 pu reactive power into the system.

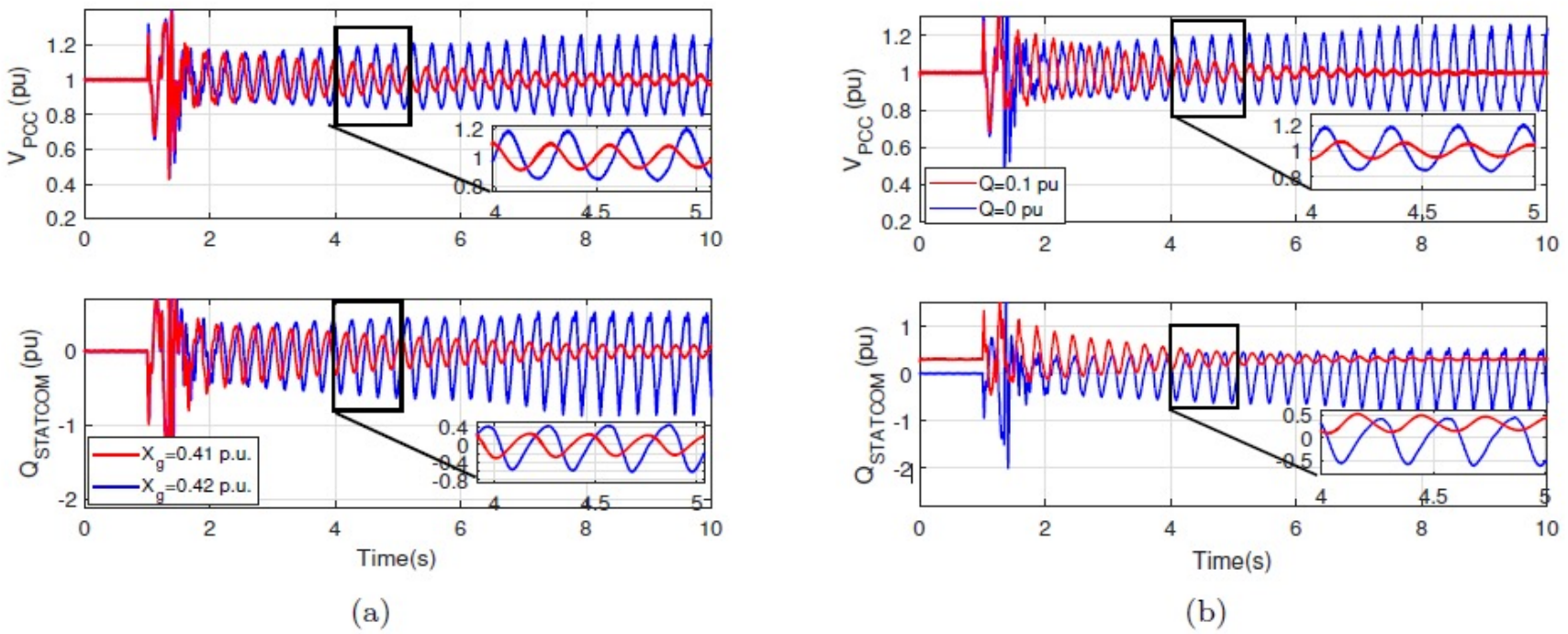


Figure 5. (a) Voltage at PCC bus and reactive power from STATCOM. (b) Voltage at PCC bus in wind farm system with STATCOM when X_g changes to 0.42 pu at 1 second, STATCOM injects 0 or 0.1 pu reactive power to system.

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Working principle

- Synchronous condenser is a synchronous generator without mechanical input, so it provides reactive power support and additional short circuit power capacity.
- An excitation system is used to provide excitation current and regulate the terminal voltage for the machine.
- According to IEEE standard, there are three dierent groups of excitation systems: DC type, AC type, and Static Excitation System (type ST).
- In this model, the SynCon is equipped with a DC2A excitation system.

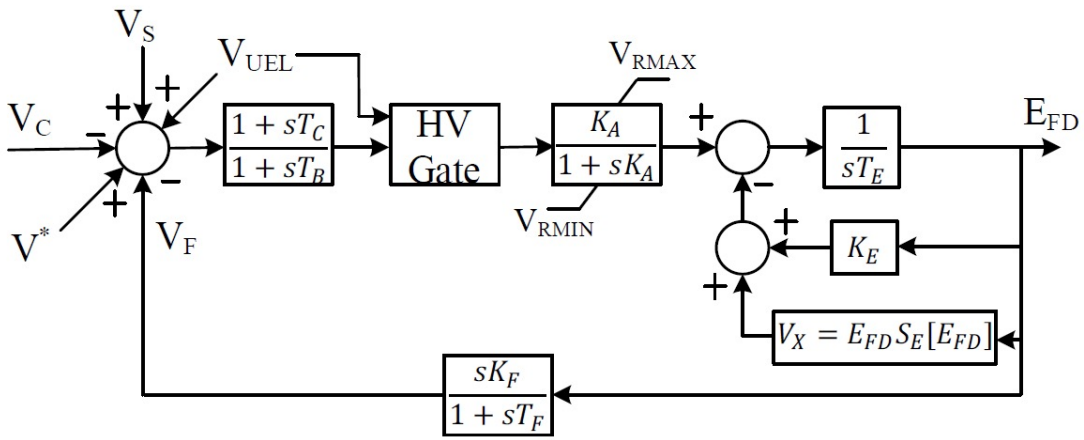

Figure 6. Synchronous condenser exciter model.

Simulation results

- In this case, the synchronous condenser is operated under no power condition.
- When X_g changes from 0.2 to 0.42 pu, the system recovers to stability after a short period of oscillations.
- To find out the marginal stability condition, the transmission line impedance is adjusted.

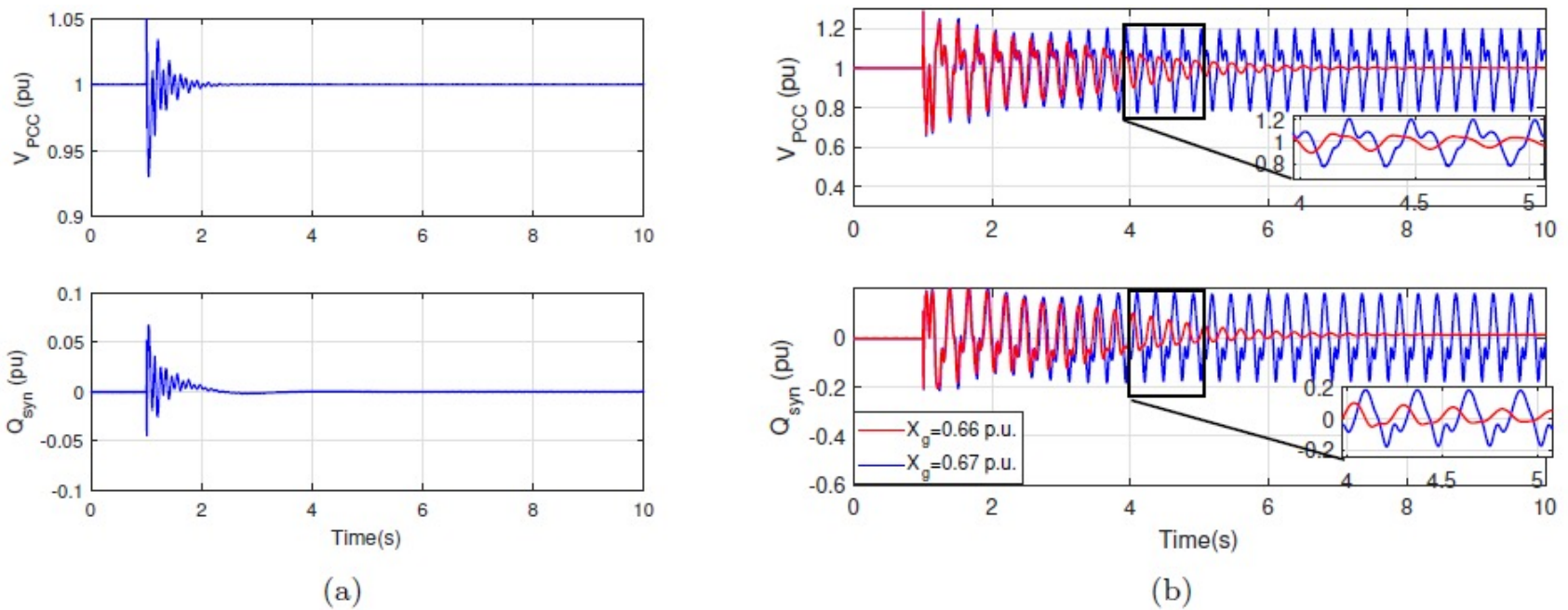

Figure 7: (a) Voltage at PCC bus and synchronous condenser reactive power in wind farm system when Xg changes from 0.20 to 0.42 pu. (b) Voltage at PCC bus and the reactive power from the SynCon for two additional cases: Xg from 0.20 to 0.66 and 0.67 pu.

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Conclusion

- As the mostly used reactive power devices, SynCon and STATCOM are implemented in a type-4 wind farm system to investigate their impacts on the overall stability of the system.
- The models of type-4 wind farm, STATCOM and synchronous condenser are presented.
- While the other literature mainly focus on the stability improvement by reactive power compensation, this paper presents a comparison of SynCon and STATCOM under the condition of zero reactive power injection.
- It is found that **SynCon is capable of stability enhancement while STATCOM does not have such capability**.

Thank you!