Dynamic characteristics analysis of wind turbine transmission chain

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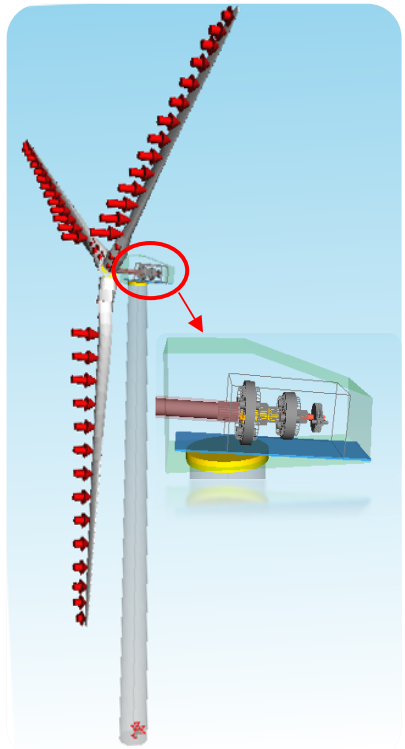


1. Team Profile

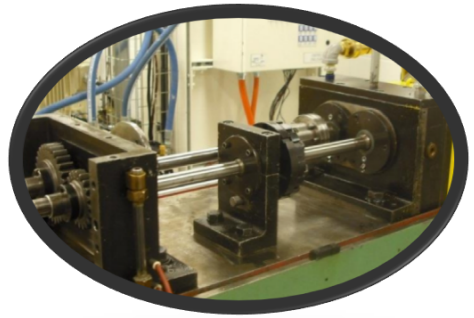
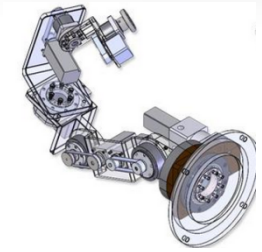
2. Works in the dynamic analysis of wind turbine drive-train

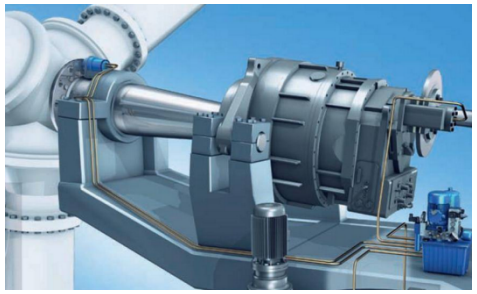
3. Future work

1. Team profile

Research fields:

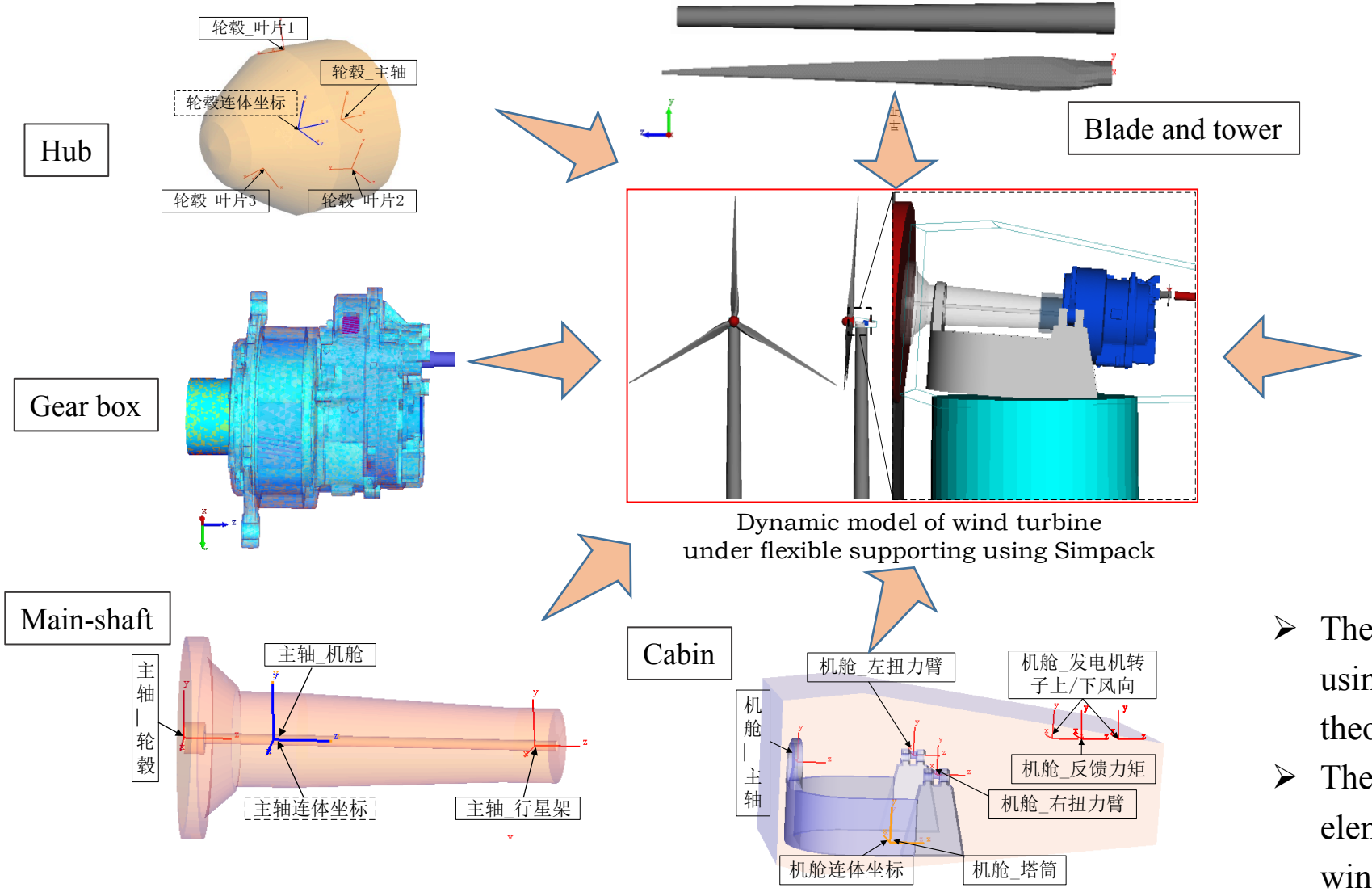
- fundamental research and application of gear transmission
  - contact and lubrication of gear
  - fatigue and strength of gear
  - experimental study of gear transmission
- research on the new precise gear transmission
  - cycloidal-pinwheel RV precise transmission
  - beveloid gear RV precise transmission
  - down-angle gear transmission
- research on the high-speed and heavy-duty gear transmission
  - Gear transmission of wind turbine
  - Gear transmission of vessel

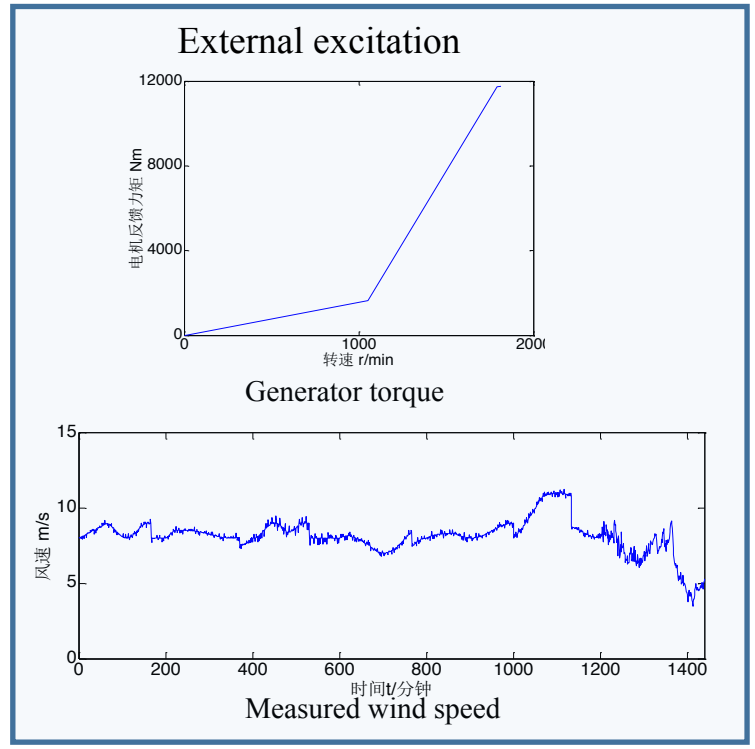







2. Works in the dynamic analysis of wind turbine drive-train

2.1 The dynamic analysis of wind turbine drive-train considering flexible supporting





- The dynamic modal of wind turbine is developed using Simpack based on muti-body dynamic theory.
- The load on blade is calculated using blade element momentum(BEM) based on measured wind speed.

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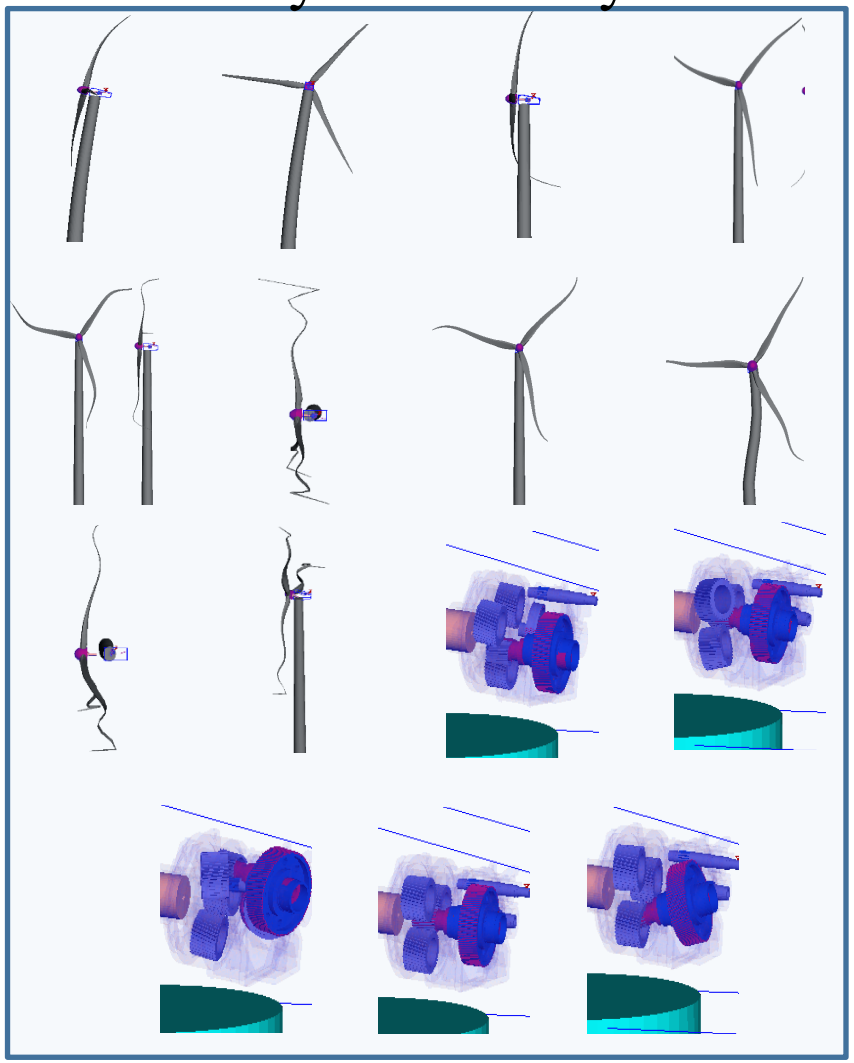


Figure 1. The first 15 order mode shape

Natural frequency analysis

Table 1. The first 15 order natural frequencies

order	Frequency (Hz)	order	Frequency (Hz)	order	Frequency (Hz)
1	0.405	6	10.084	11	379.747
2	0.405	7	12.76	12	532.196
3	0.863	8	19.188	13	660.919
4	1.627	9	78.829	14	1049.061
5	3.617	10	193.197	15	1188.202

2. Works in the dynamic analysis of wind turbine drive-train

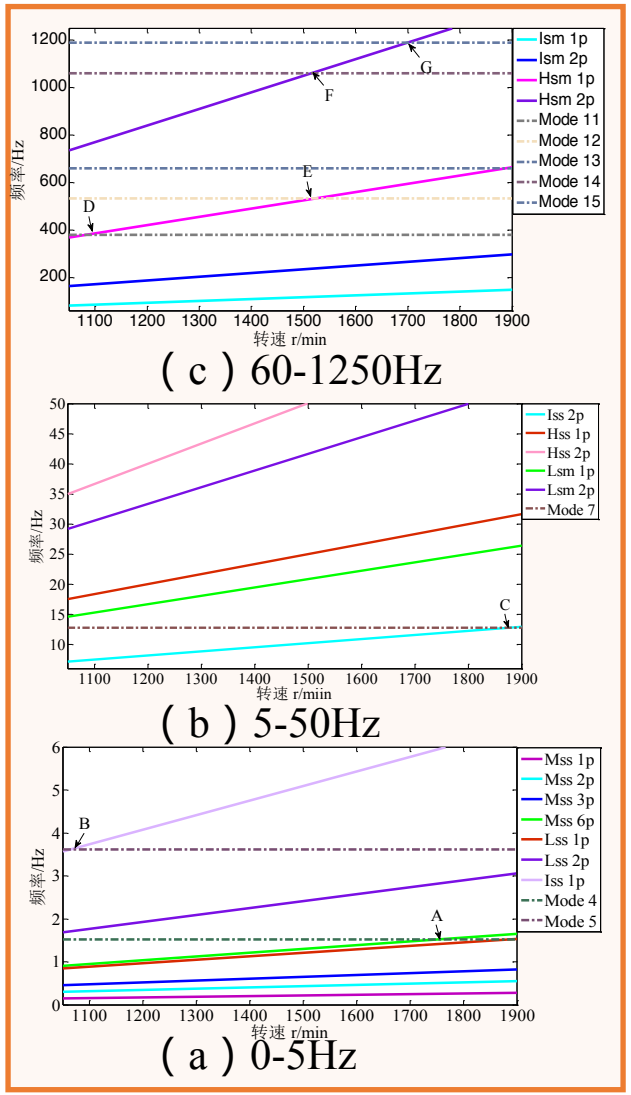
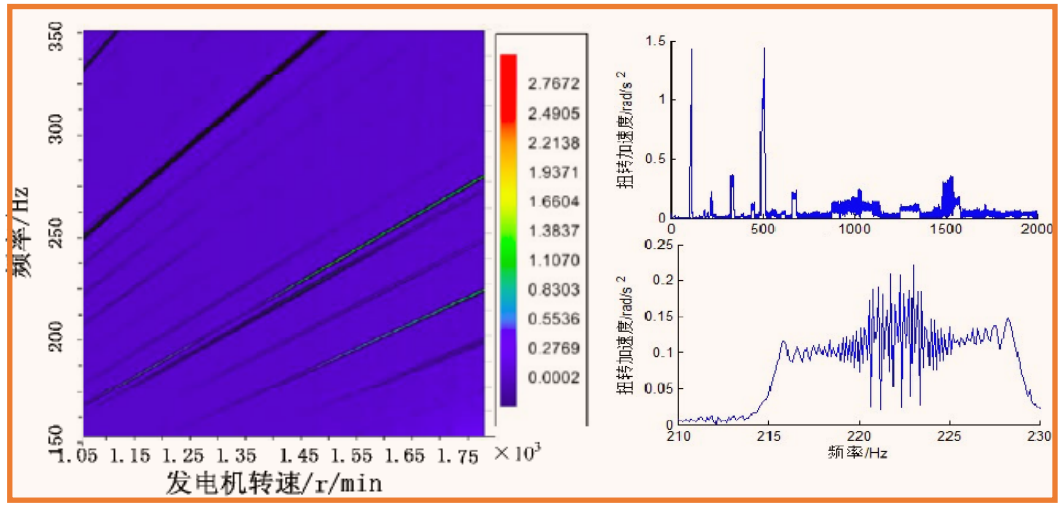


Figure 2. Campbell chart

Screening



- The intersections of excitation frequency and natural frequency are the potential resonance, there are seven intersections(A、B、C、D、E、F and G)as shown in Campbell chart which should be identified.。
- We eliminate these potential resonance by frequency sweep analysis.

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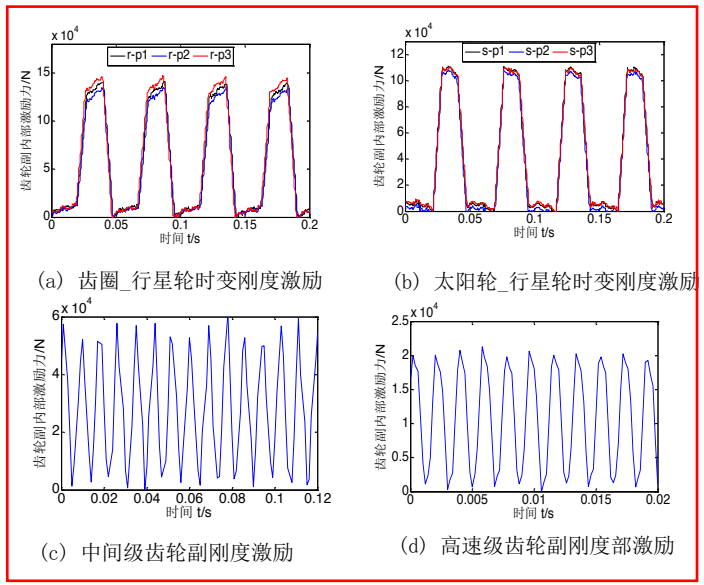


Figure 3. Internal excitation

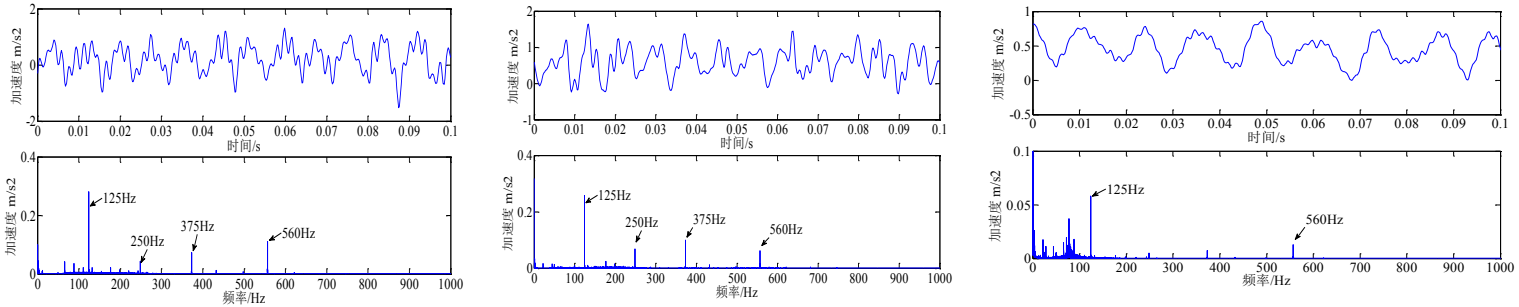


Figure 4. Vibration acceleration of main-shaft at Time domain and frequency domain(X-,Y-,Z-direction)

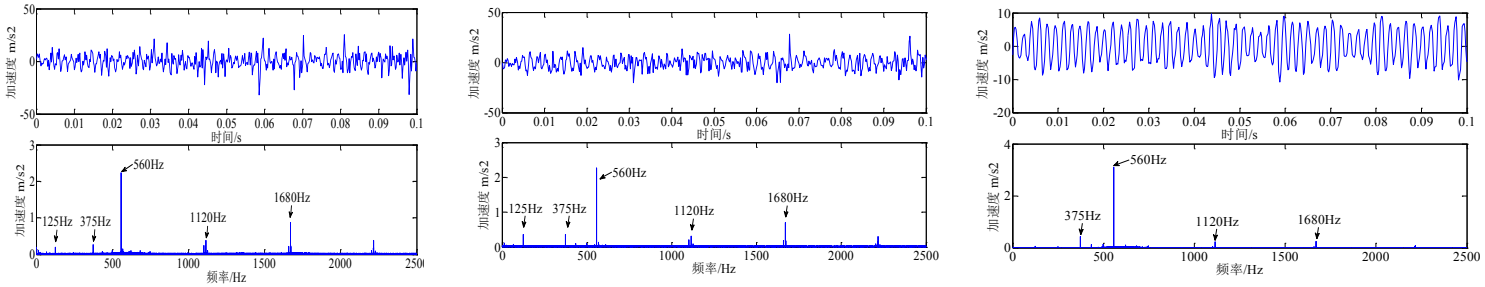


Figure 5. Vibration acceleration of high-speed shaft at Time domain and frequency domain(X-,Y-,Z-direction)

- The vibration is main concentrated in high-speed shaft of gear box

2. Works in the dynamic analysis of wind turbine drive-train

$$a_{effw0} = \sqrt{\frac{1}{T_0}\int_0^{T_0} a_w^2(t)dt}$$

The standard of VDI 3834

Table 2. Effective value of vibration acceleration (m/s2)

components	Frequency range	X-direction	Y-direction	Z-direction
Main-shaft	0.1~10Hz	0.027	0.026	0.015
Carrier	0.1~10Hz	0.121	0.092	0.169
Torque arm	10~2000Hz	1.697	1.629	1.317
High-speed shaft	10~2000Hz	5.156	5.38	3.861
Generator fotor	10~5000Hz	---	1.421	---

- The Effective value of vibration acceleration of drive train components locate in region I/II according to standard of VDI 3834, which means the drive train can stability operation.

2.2 The dynamic analysis of wind turbine under emergency shutdown

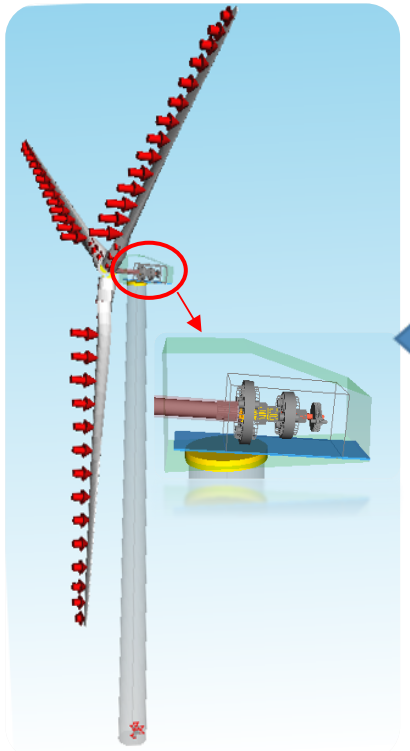


Figure 7. The aero-servo-elastic Dynamic model of wind turbine

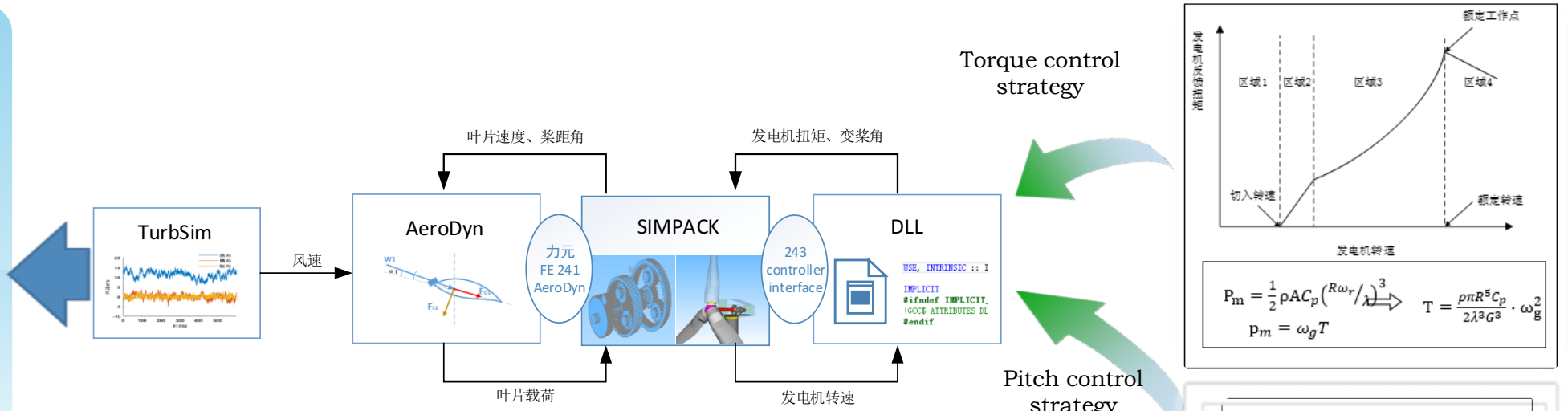
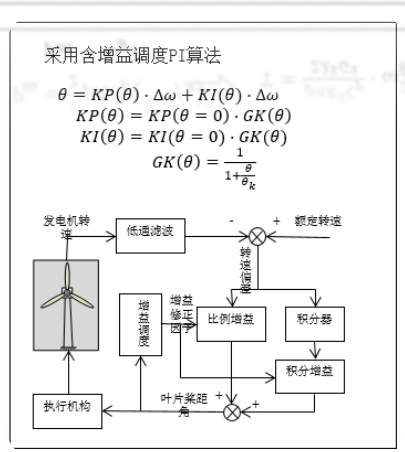


Figure 6. The flow chart of aero-servo-elastic dynamic model of wind turbine



- The aero-servo-elastic dynamic model of wind turbine is developed by Simpack considering the flexibility of tower and bladed, the stochastic loads of wind, the gear mesh features as well as the control strategy

2. Works in the dynamic analysis of wind turbine drive-train

2.2 The dynamic analysis of wind turbine under emergency shutdown

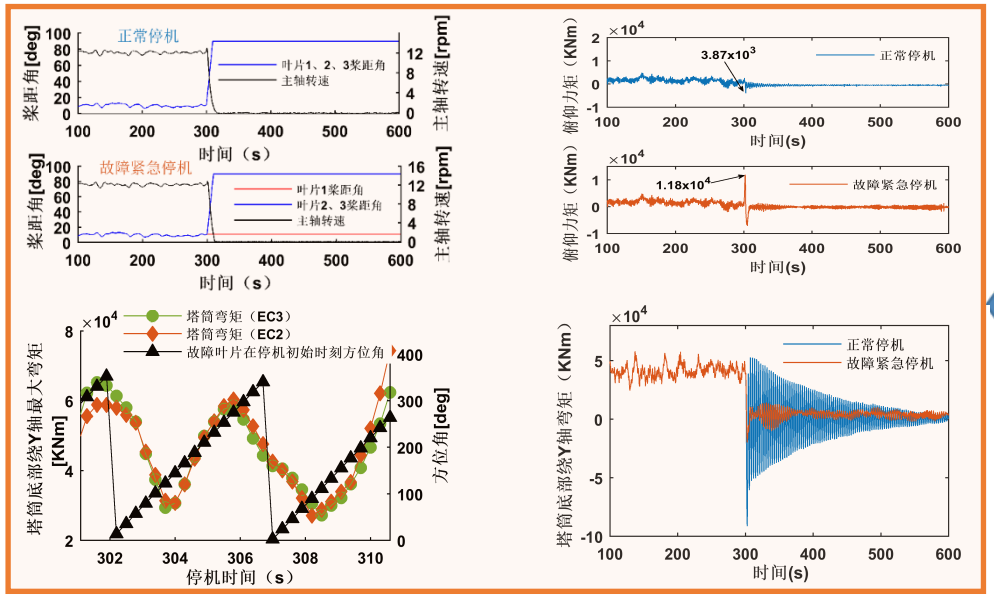
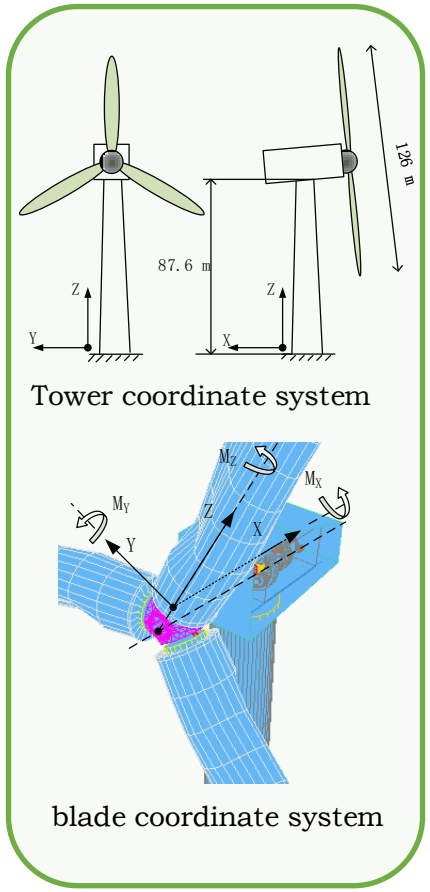


Figure 8. The dynamic response of wind turbine under emergency shutdown due to a stuck pitch actuator



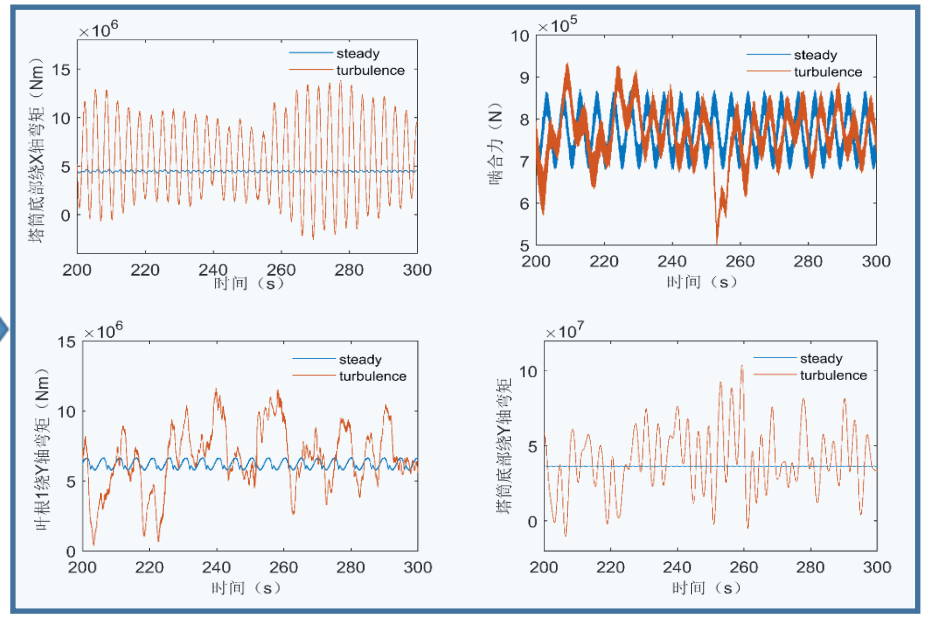


Figure 9. The influence of turbulence on dynamic response of wind turbine

- the tower-bottom suffer large impact load during emergency shutdown process, and the maximum bending moment of tower-bottom varies cyclically with the fault blade azimuth
- The turbulence have great influence on dynamic response of wind turbine, it is better to consider this factor during load calculation

3. Future works

Future work: The fatigue damage analysis of offshore wind turbine drive train considering stochastic load effect

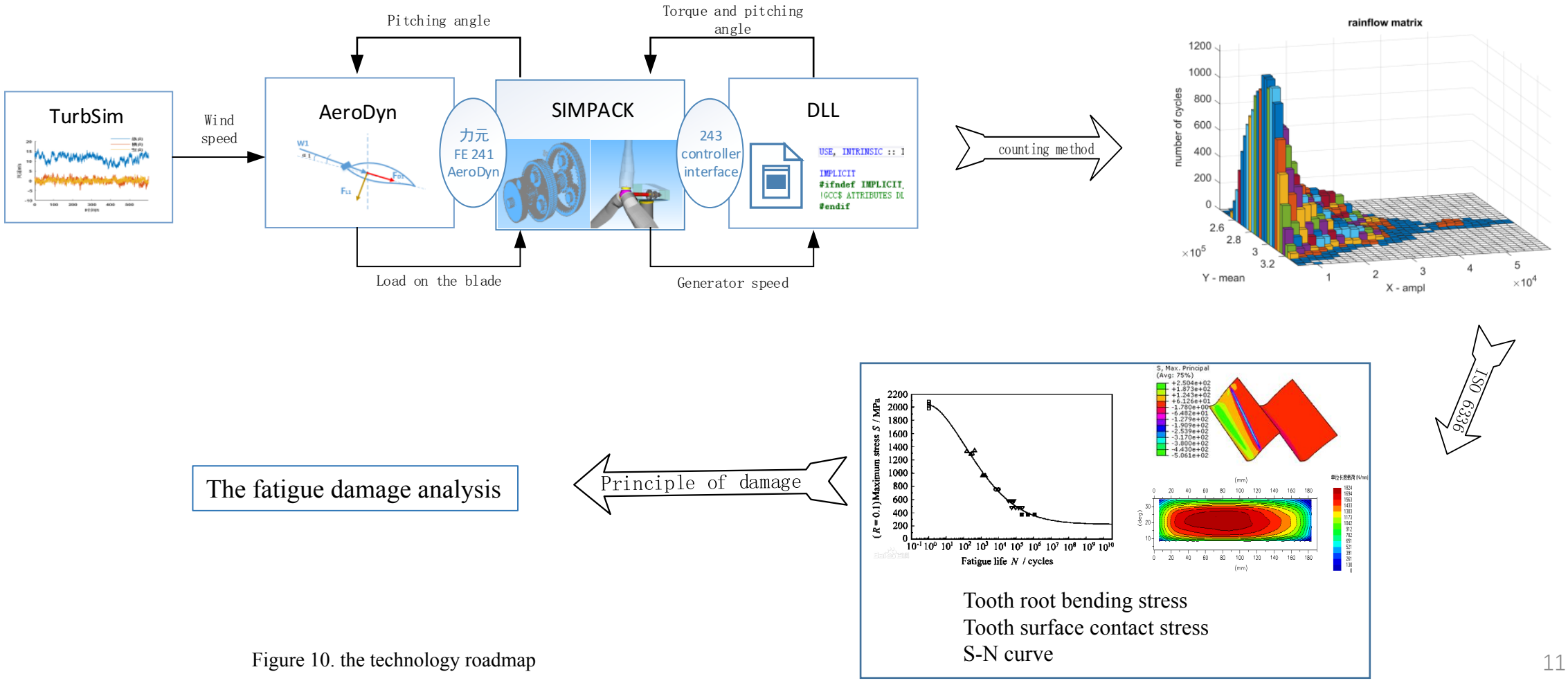


Figure 10. the technology roadmap

Thanks!