Storm Control Strategy

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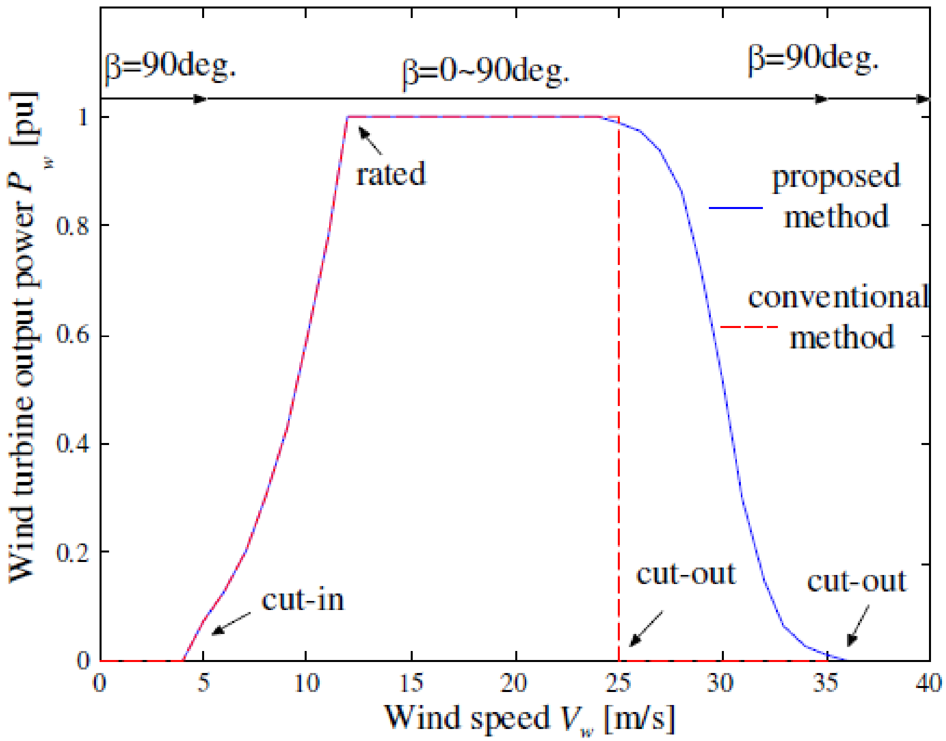
Why operation in strong wind conditions?

- **High quality, reliable and robust power production demanded**
  - Fast increase of installation
  - Bigger share in the whole electricity production
  - Higher impact on the electrical gird

- **Traditional wind turbine operation**
  - Normally run at a wind speed between 5 m/s to 25 m/s
  - When exceed the cut-out speed, shut down and cut off from grid
  - Introduce sudden changes to the grid, may destabilize it and cause problems to power supply.

- **Operation in strong wind conditions**
  - Run wind turbines at very high wind speed up to 40 m/s
  - Generally decrease the rotational speed and power output
  - Avoid sudden changes to the grid and lower the impact

Existing Storm Control Strategies



Control strategies for wind turbine in storm conditions, such as shown in above figure had been investigated in literature [1-2] and applied in industry [3].

[1] H. Markou H and T.J. Larsen, "Control strategies for operation of pitch regulated turbines above cut-out wind speeds", in: Proceedings of EWEC 2009 (Marseilles, France, 16-19 March, 2009)

[2] J. Feng and W.Z. Shen, "Control of variable speed pitch-regulated wind turbines in strong wind conditions using a combined feedforward and feedback technique", in: Proceedings of Torque 2012 (Odenburg, Germany, 9-11 Octerber, 2012)

[3] http://www.enercon.de/en-en/754.htm

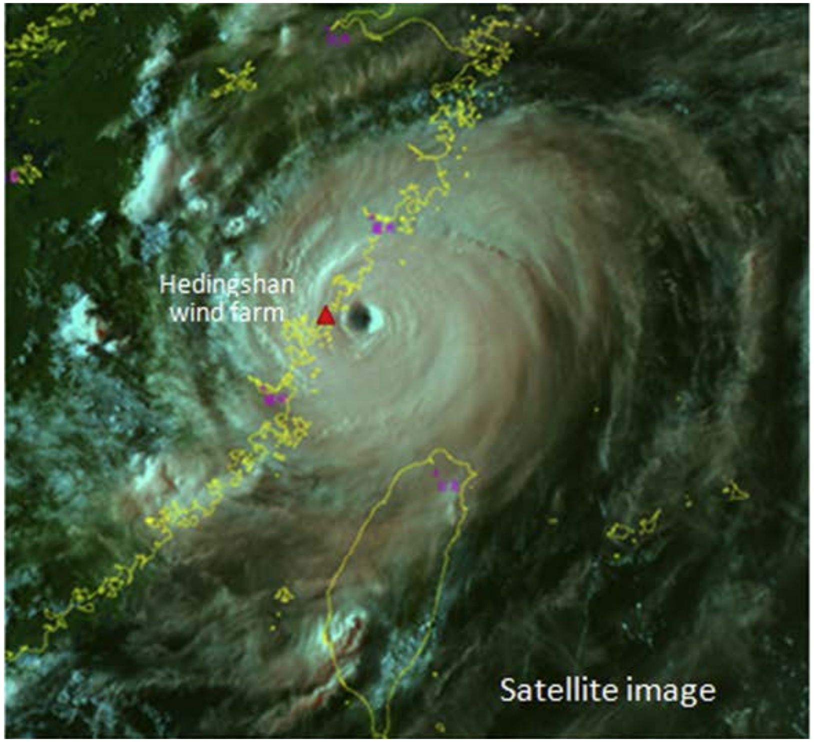
How about even higher wind speed?

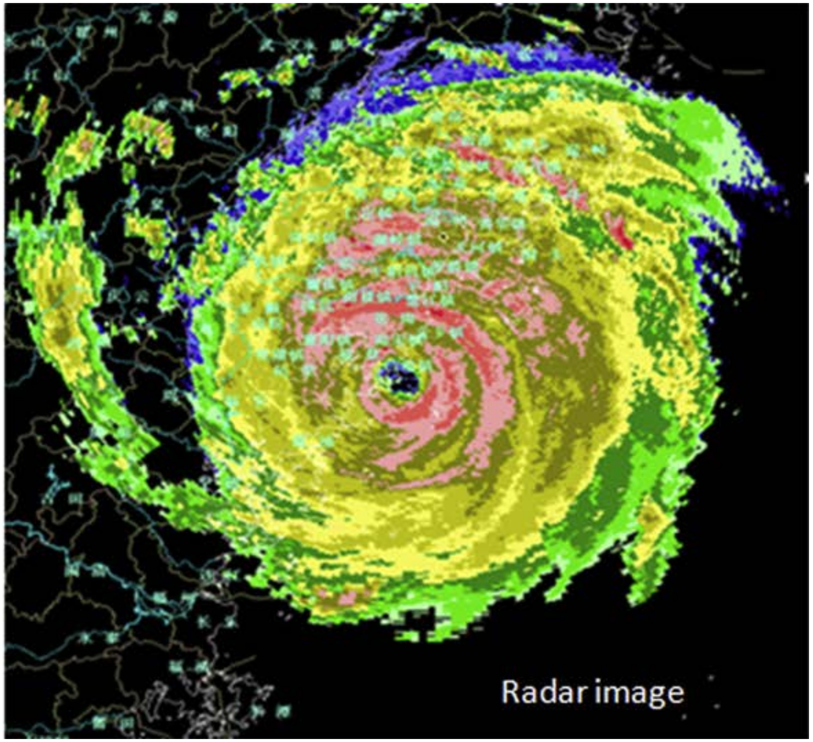
Like those wind turbines in Typhoon condition,

What will happen?

A Valuable Lesson from a Real Case *:

Hedingshan Wind Farm under Super Typhoon Saomai in 2006

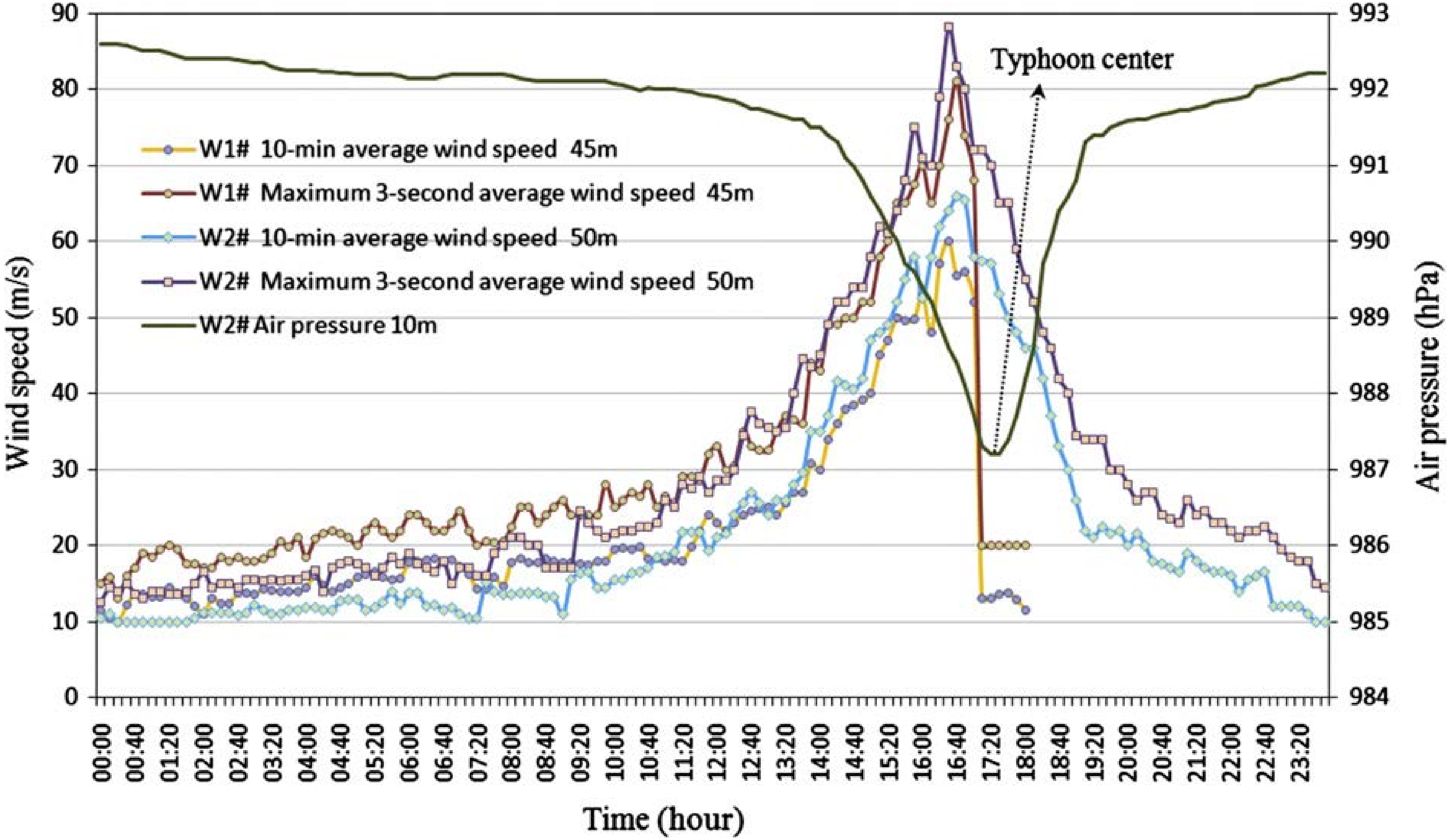




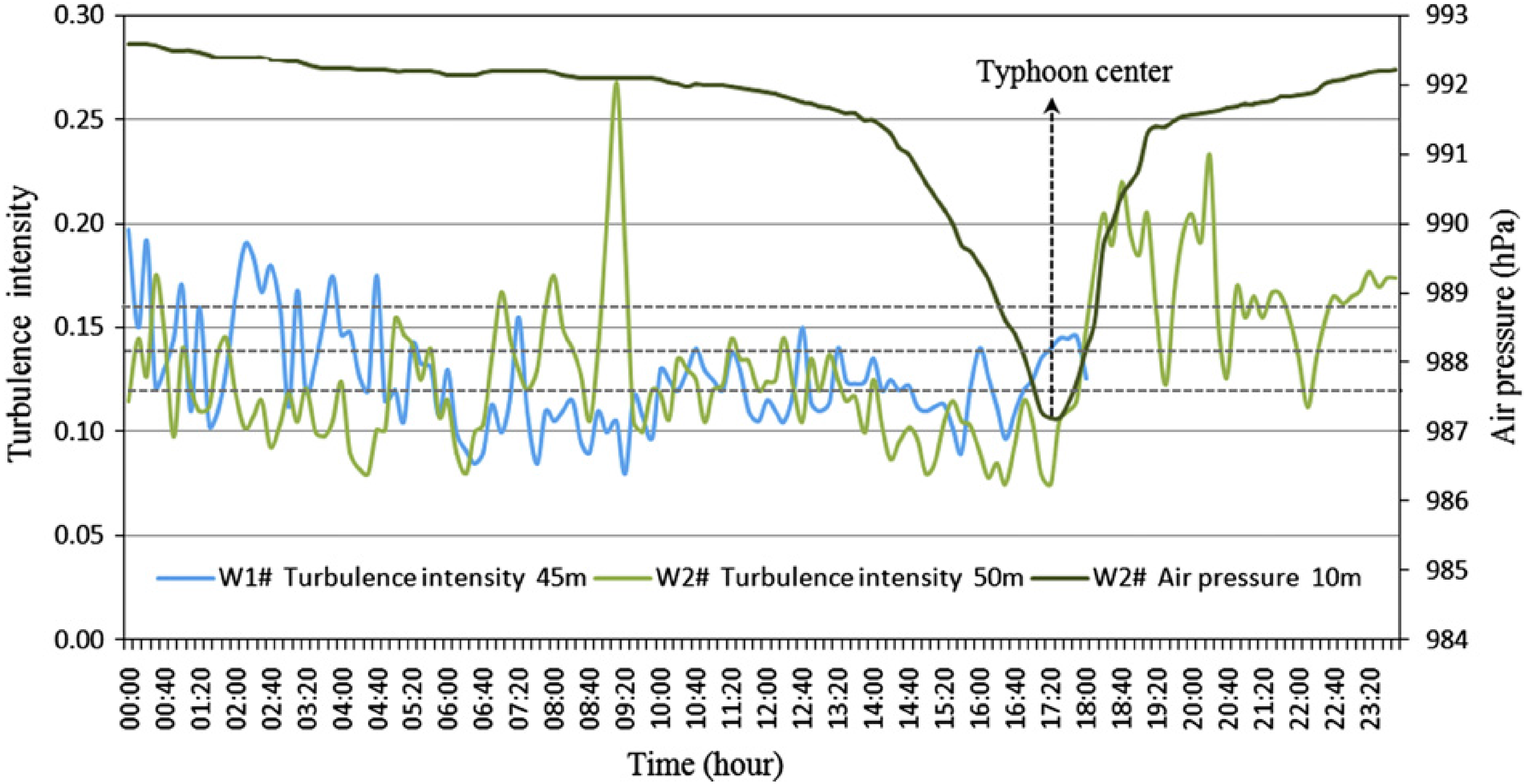
Satellite and Radar images of super typhoon Saomai before landing in 2006

** This wind farm located in Zhejiang, China, the figures and data about this case are mostly from:*

[4] Z.Q. Li, S.J. Chen, H. Ma, T. Feng. "Design defect of wind turbine operating in typhoon activity zone", Engineering Failure Analysis 2013; 27: 165-172



Wind speed variations from two meteorological wind towers during super typhoon Saomai moving



Turbulence intensity variations from two meteorological wind towers during super typhoon Saomai moving

According to standard **IEC 61400-1:2005**, wind turinbe classes are defined as in following table:

Table 1 – Basic parameters for wind turbine classes[1]

Wind turbine class		I	II	III	S
V_{ref}	(m/s)	50	42,5	37,5	Values specified by the designer
A	I_{ref} (-)		0,16		
B	I_{ref} (-)		0,14		
C	I_{ref} (-)		0,12		

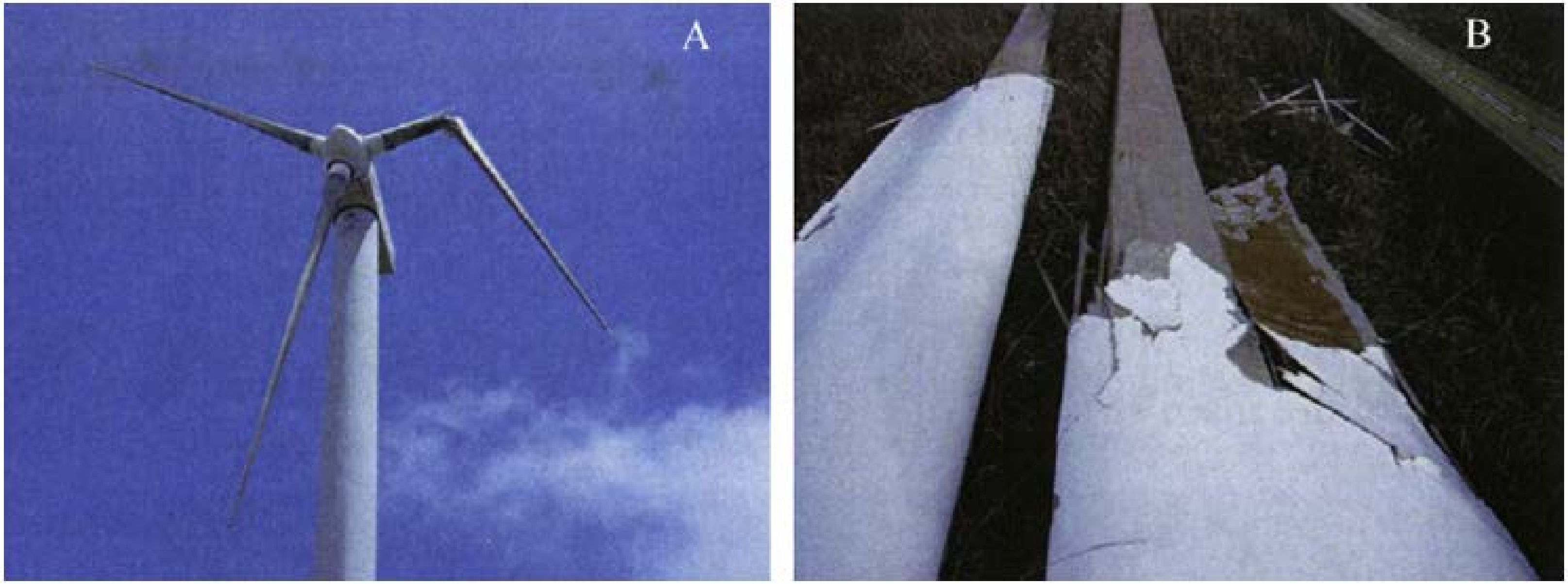
- In Hedingshan wind farm, they chose class II C type wind turbines
- During Saomai, the maximum wind speed (10-min average) > 60 m/s
- the extreme wind speed (3-second average) > 80 m/s

- So, Big disaster to this wind farm was the result.

Wind Turbine Tower Collapse

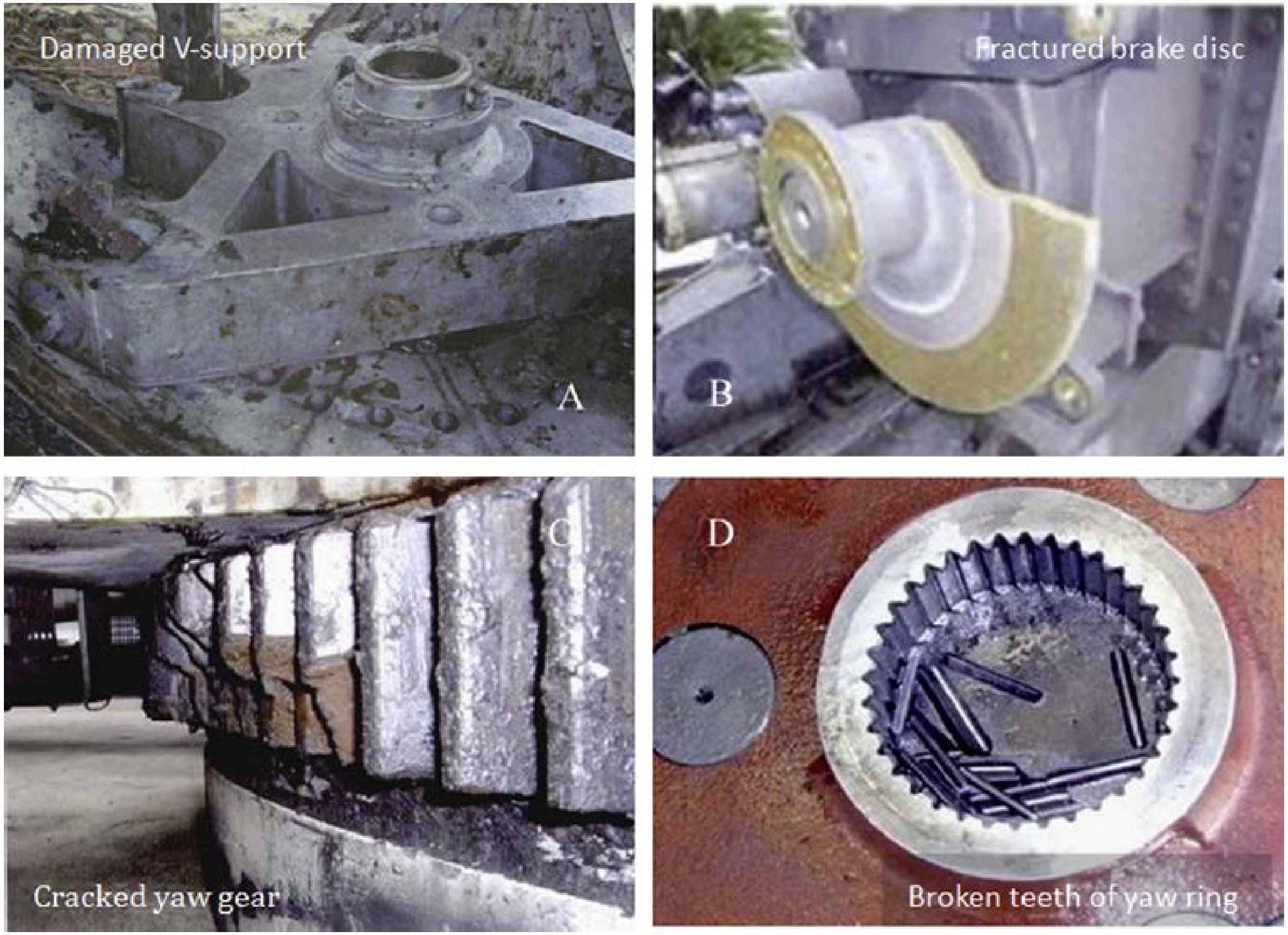
- 5 towers cllapsed down. (Fix-pitch WTs showed better performance of resisting typhoon)

Blade Crack and Break

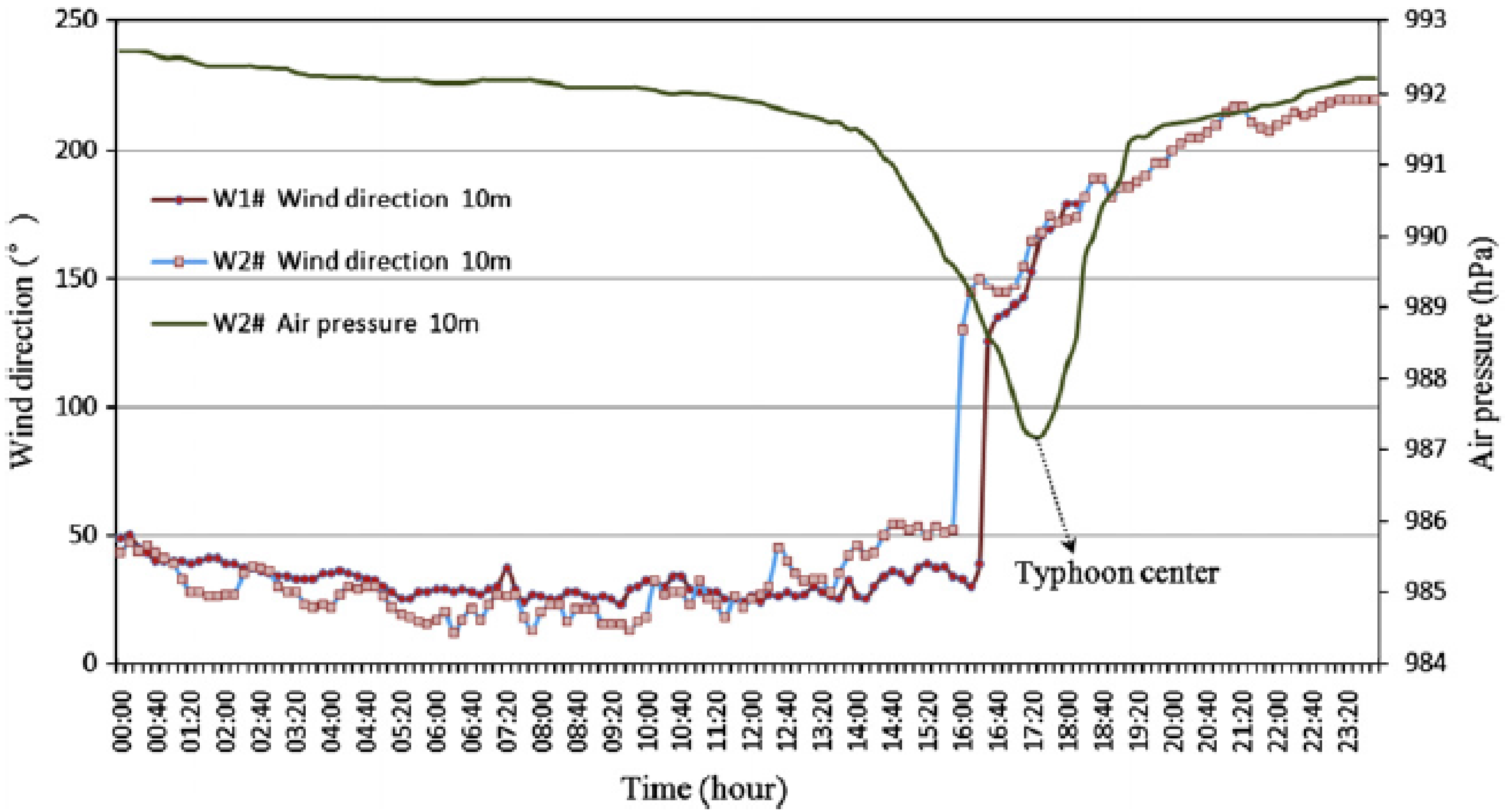


- 33 blades were damaged (excluding the blades of the 5 collapsed towers)

Pitch Control System and Yaw System



- Yaw system using hydraulic brake mechanism survived
- Damaged yaw systems are those using slider brake mechanism.



Abrupt change of wind direction

All WTs were in automatic braking-stop state because of the violent wind and intense turbulence.

Yaw control were inactive since the power grid failed during typoon.

What to do about this?

- Some constructive think form the authors [4]:
  1. *Independent design of WT tower*
  2. *Appending standby power for WT*
  3. *Upgrading blade manufacture technology*
  4. *Improving other components*

What else can be done?

Yaw control and pitch control?

What if there is no power?

Downwind turbine?

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Thank you for your attention!