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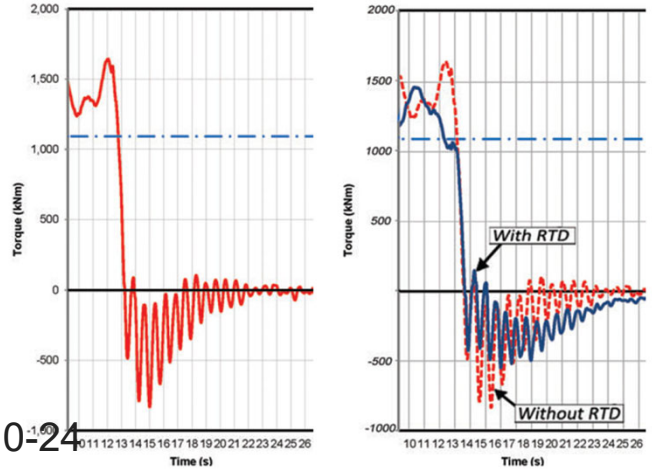
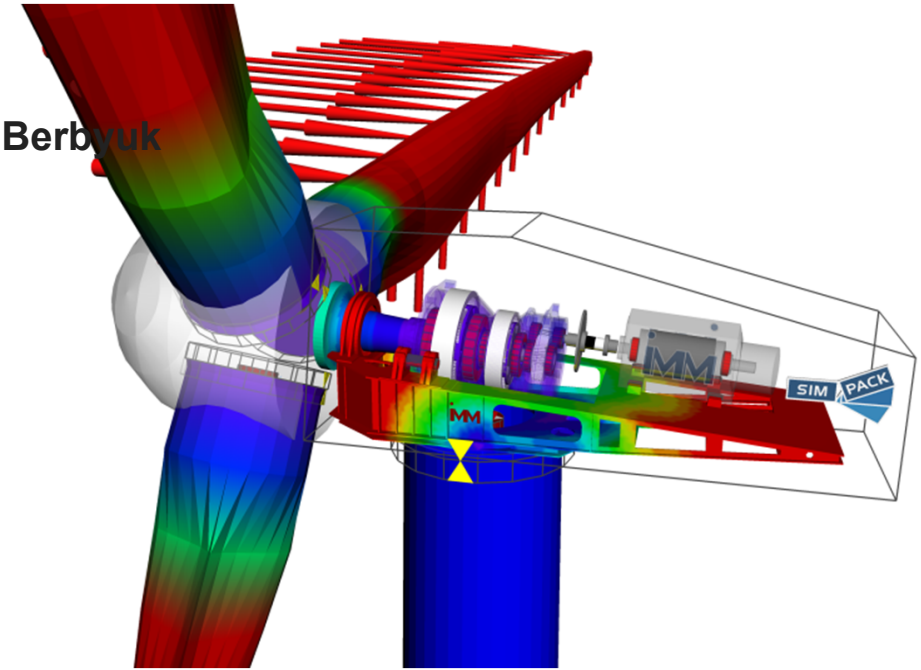
Transient torque reversals in wind turbine drivetrains: occurrence, consequences and mitigation

Saptarshi Sarkar, Håkan Johansson and Viktor Berbyuk

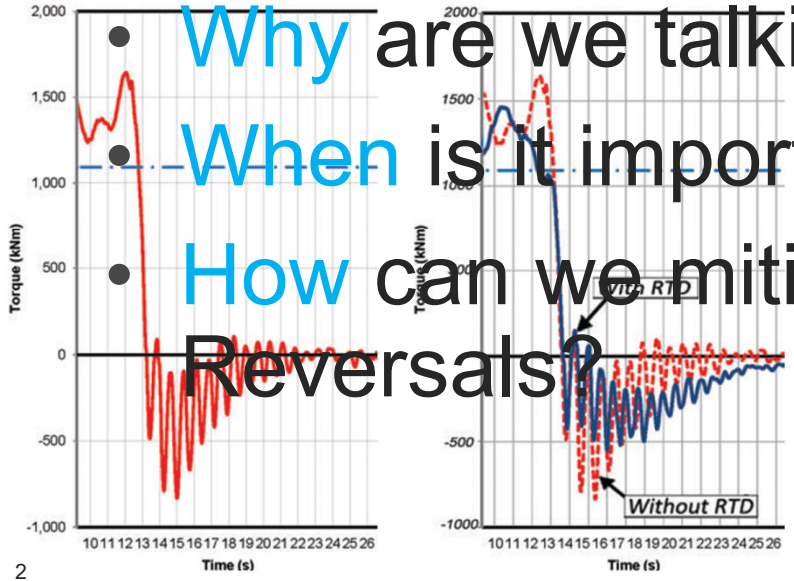


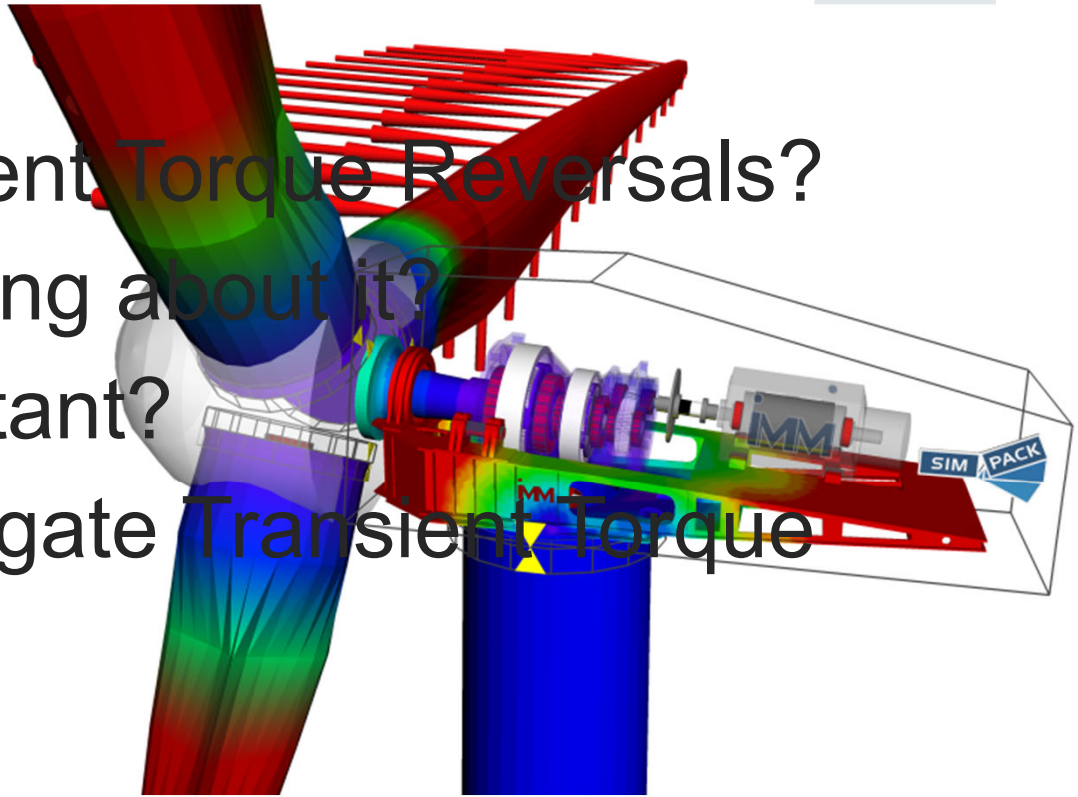


2022-10-24

Content

- What are Transient Torque Reversals?
- Why are we talking about it?
- When is it important?
- How can we mitigate Transient Torque Reversals?





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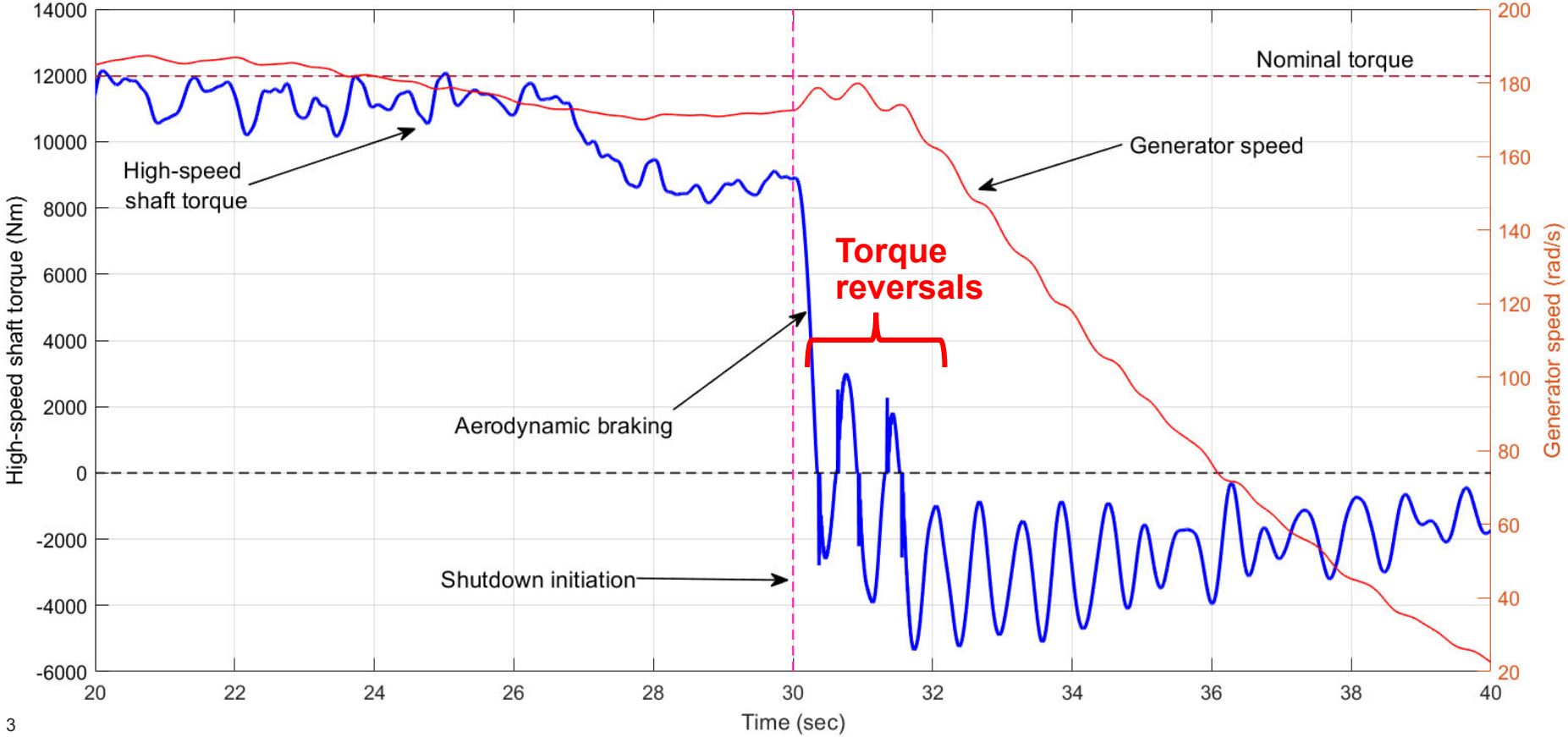
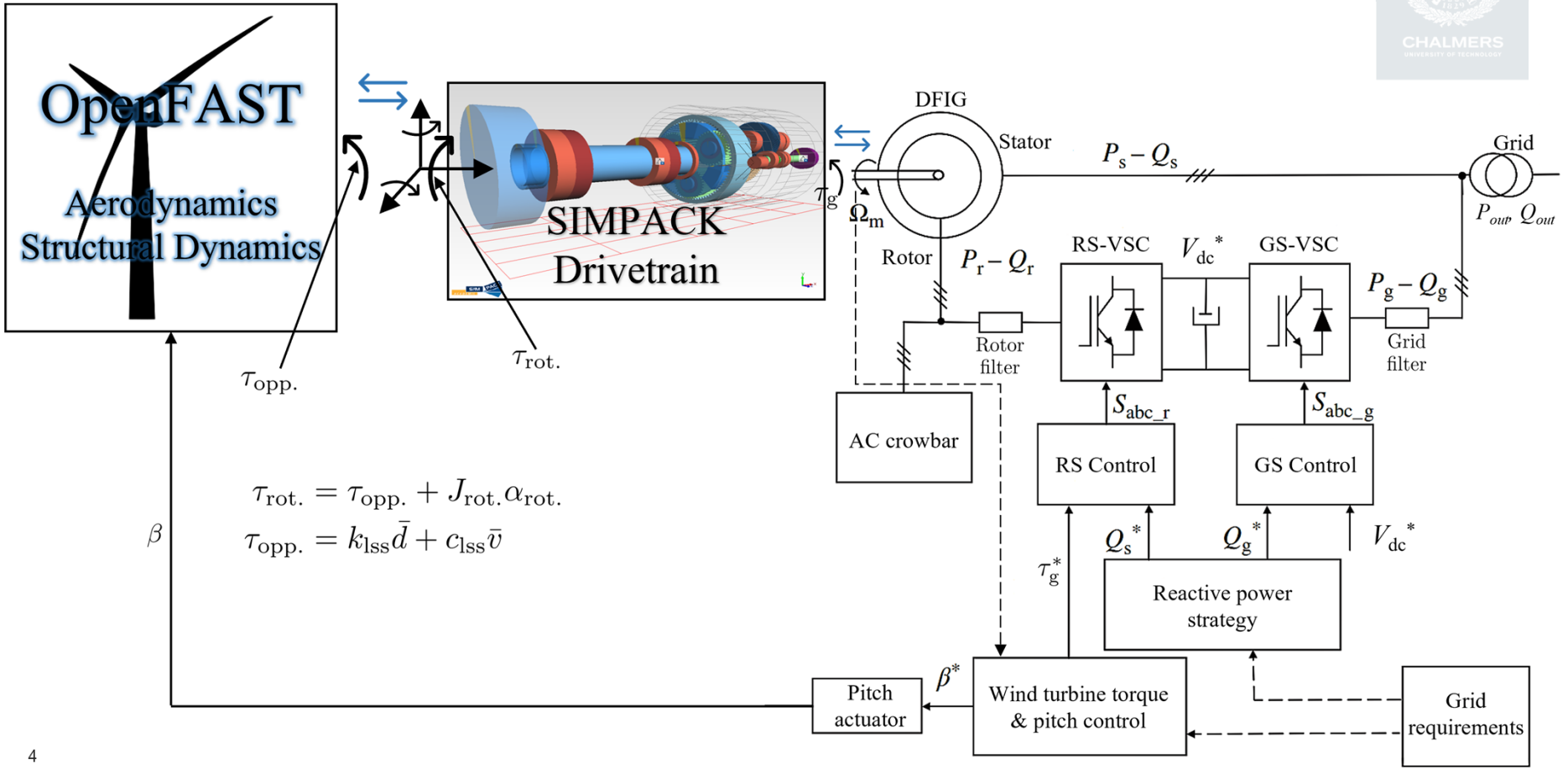
What?

High-speed shaft torque during an emergency shutdown



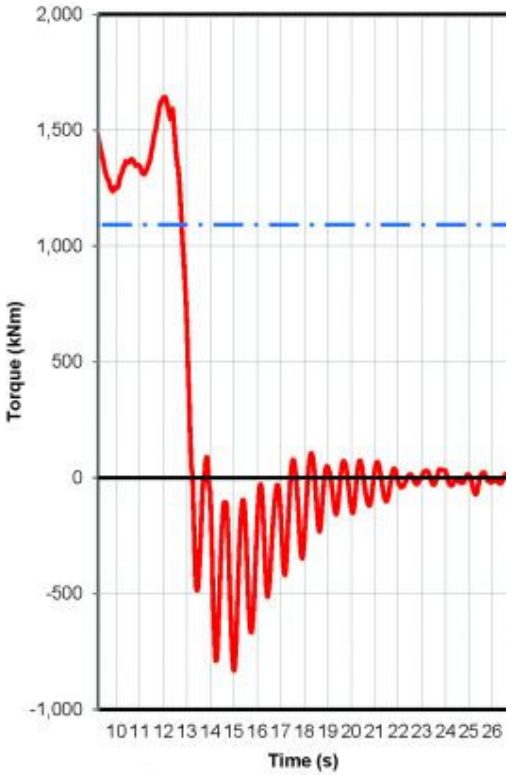
A quick side note

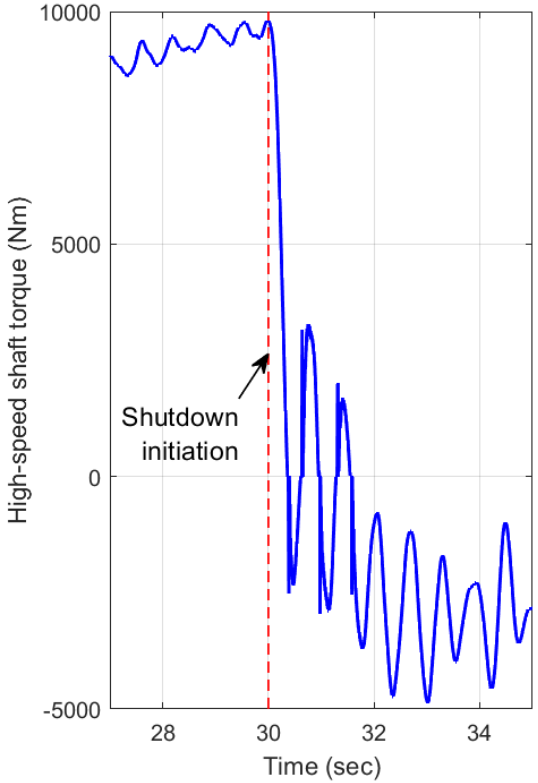


What?

Field measurements show similar behaviour

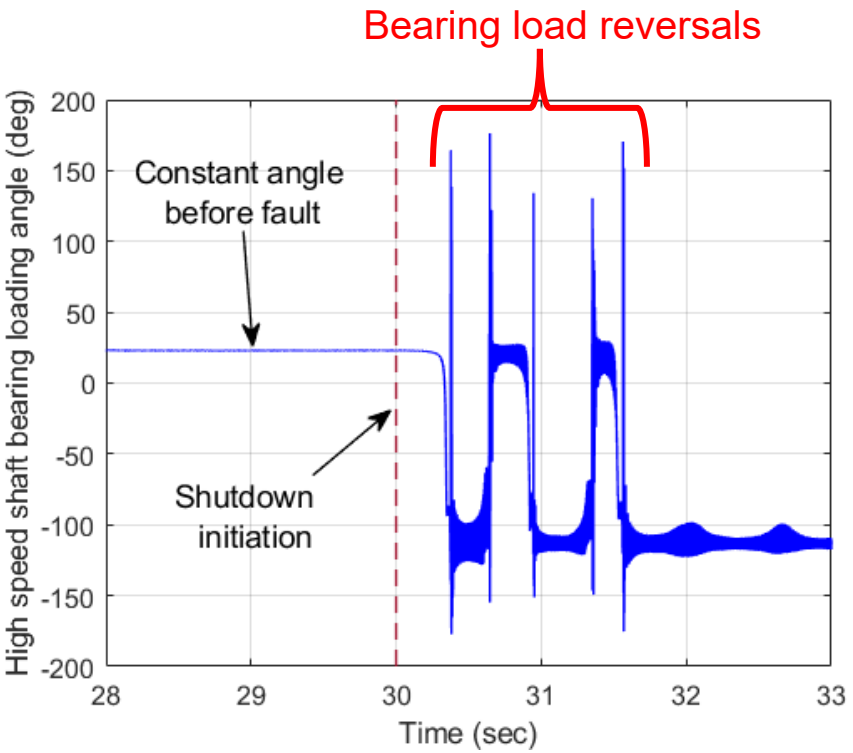
Aero braking only on a 1.65-MW turbine, as recorded by ***AeroTorque***

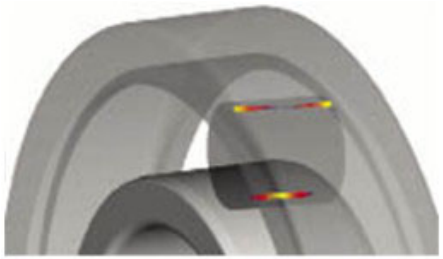


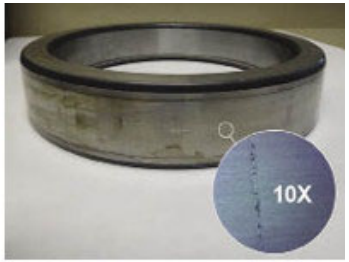


Ref: Eatherton S, Moroz E, Sadler D, Heidenreich D. The Mitigation Value of Reverse Torsional Damping of Transient Torsional Events in Wind Turbines, Using a Failure Modes and Effects Analysis Approach. URL: *https://www.aerotorque.com/sites/default/files/AeroTorque%20FMEA%20White%20Paper%20Final.pdf*. Accessed: 2022-10-12.

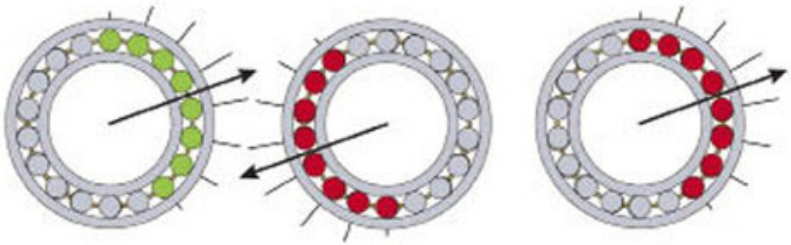
What?



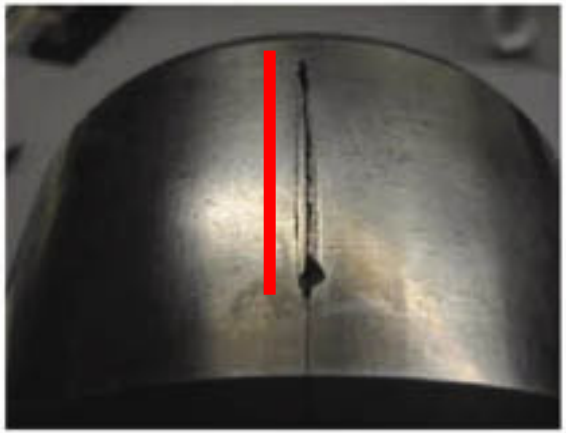




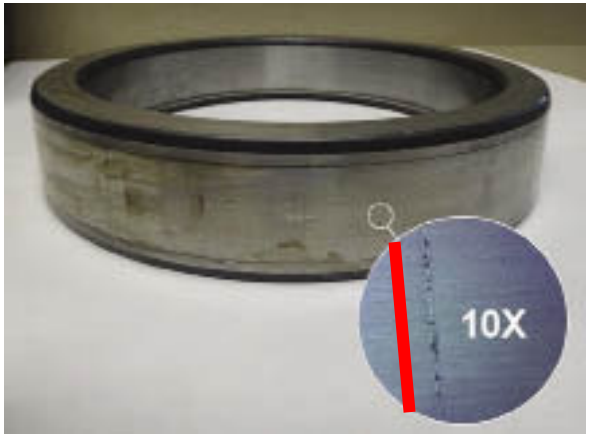
Rapidly reversing bearing load zones



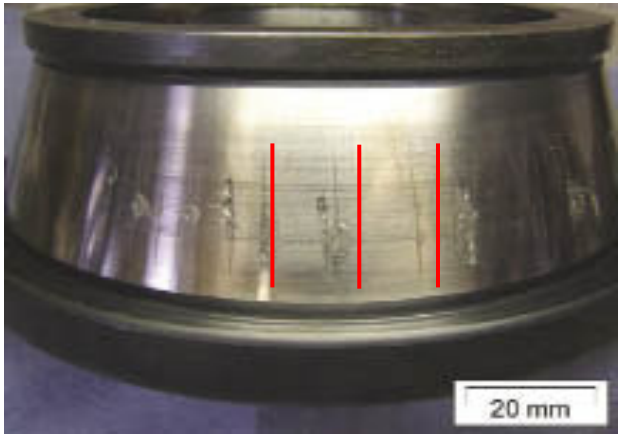
Why?



A single axial crack has propagated completely through the inner ring



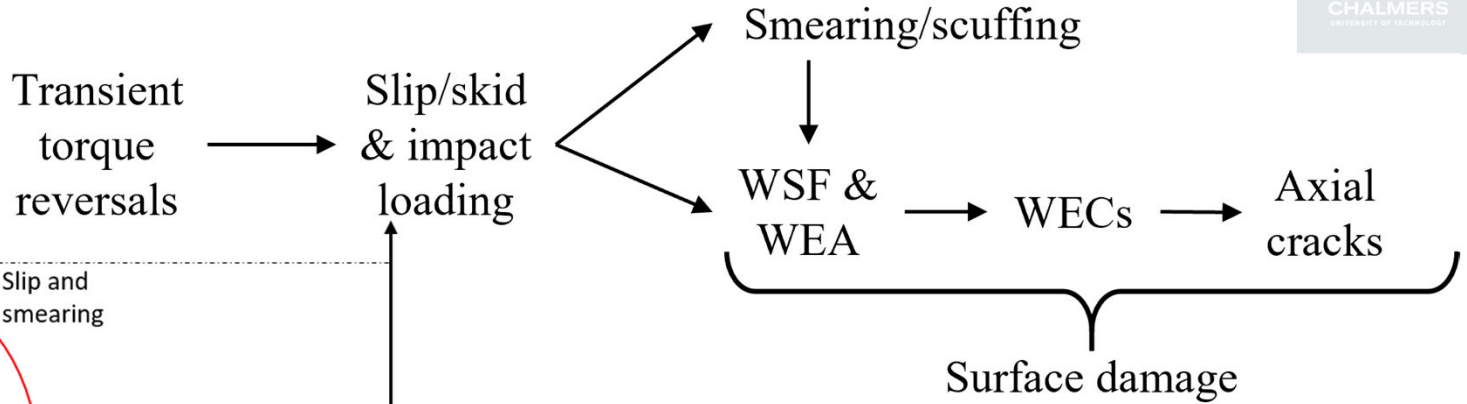
The early stages of multiple axial cracks appear on the inner ring

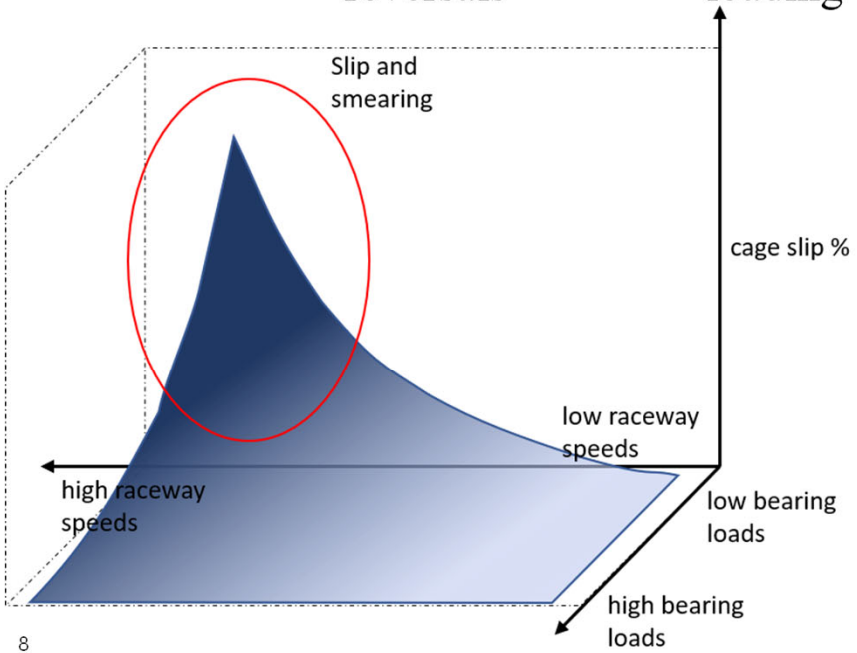


White Etch Cracks and White Surface Flaking appear on the inner ring of a tapered roller bearing.

Ref: Sharpley N. Understanding the root causes of axial cracking in wind turbine gearbox bearings. URL: https://www.windpowerengineering.com/understanding-root-causes-axial-cracking-wind-turbine-gearbox-bearings/ Accessed: 2022-10-12.

Why?





"Slip risk duration"

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When?

IEC 61400-1

DLC	Situation	Assessment	Simulation setup							Occurrence of TTRs
			Length (s)	Wind (m/s)	Yaw	Turbulence	Shear (α)	Gust	Fault description	
2.1	Power production + Grid fault	Extreme - normal event	25	12	0°	NTM	Vertical; 0.2	None	90% symmetrical voltage dip @ 15 s	Yes
2.2 a	Power production + Pitch system fault	Extreme - abnormal event	50	12	0°	NTM	Vertical; 0.2	None	One blade operating at minimum pitch angle	No
2.2 b	Power production + Pitch system fault	Extreme - abnormal event	50	12	0°	NTM	Vertical; 0.2	None	@ 25 s collective pitching towards minimum pitch angle at the maximum pitch speed	No
2.2 c	Power production + Yaw system fault	Extreme - abnormal event	50	12	15° to 345° with steps of 15°	NTM	Vertical; 0.2	None	Yaw system fault	No
2.3	Power production in EOG + Grid fault	Extreme - abnormal event	25	25	0°	None	Vertical; 0.2	EOG: Equation (17) [ref]	90% symmetrical voltage dip @ 15 s	Yes
3.2	Start up during EOG	Extreme - normal event	50	25	0°	None	Vertical; 0.2	EOG: Equation (17) [ref]	None	No
3.3	Start up during EDC	Extreme - normal event	50	25	0°	None	Vertical; 0.2	ECD: Equation (21) [ref]	None	No
4.2	Shut down during EOG	Extreme - normal event	50	25	0°	None	Vertical; 0.2	EOG: Equation (17) [ref]	None	No
5.1	Emergency shut down	Extreme - normal event	50	25	0°	NTM	Vertical; 0.2	None	shutdown @ 25 s; without mechanical brake	Yes
6.2	Parked 50-year extreme wind + loss of electrical network	Extreme - abnormal event	50	V50	300°	11%	Vertical; 0.11	None	abnormal yaw error due to loss of electrical network connection	Yes
6.3	Parked 1-year extreme wind + yaw system error	Extreme - normal event	50	V1	20°	11%	Vertical; 0.11	None	idling rotor with yaw system fault	Yes

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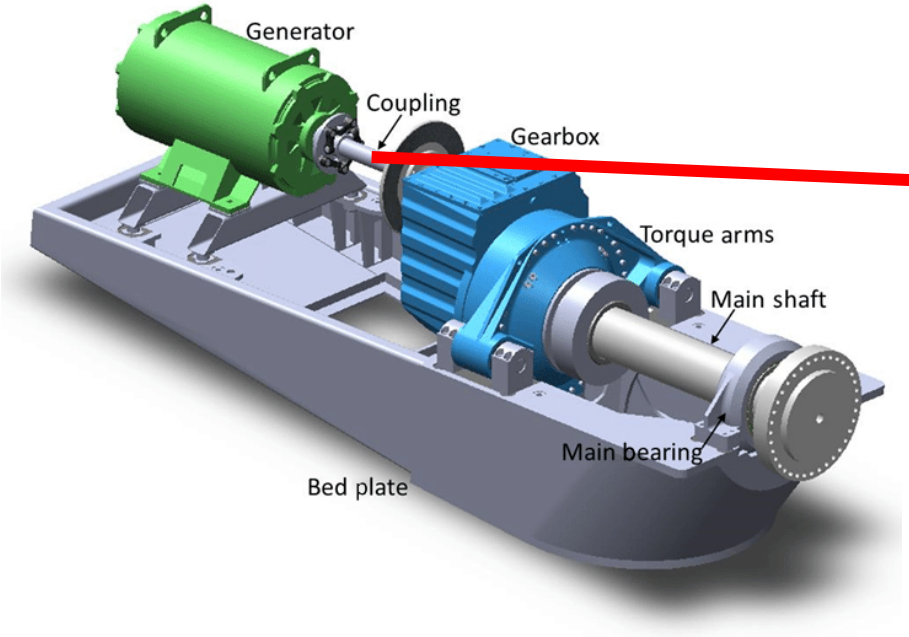
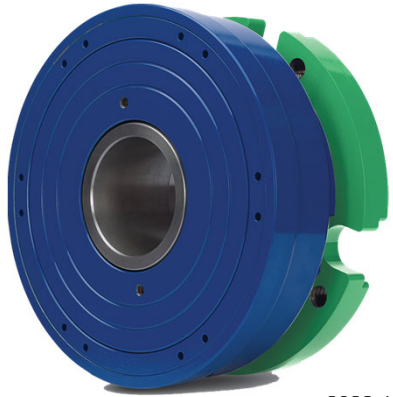
How to mitigate?





Tuned mass damper (mechanical dampers…)

Reverse Torsional Damper, by AeroTorque

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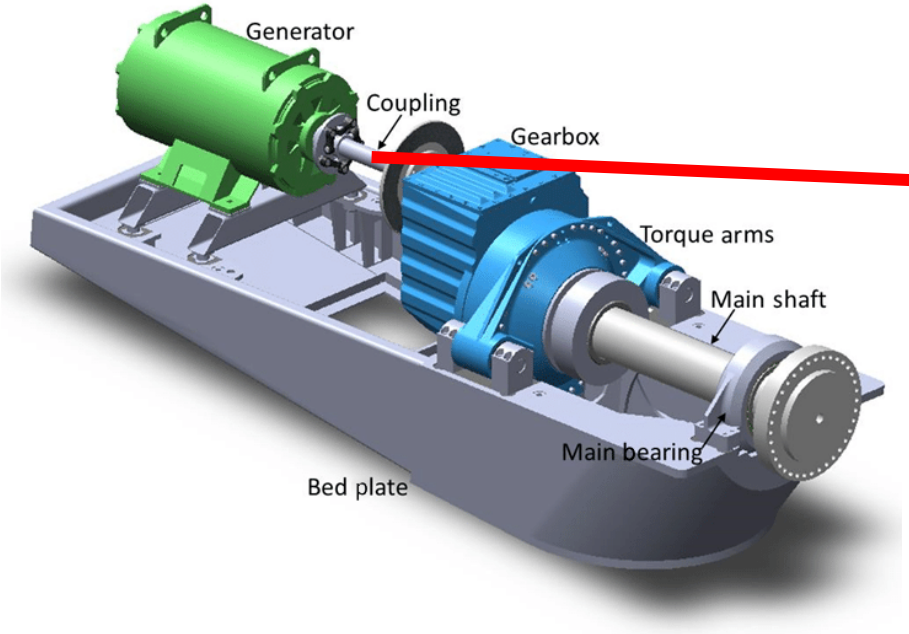
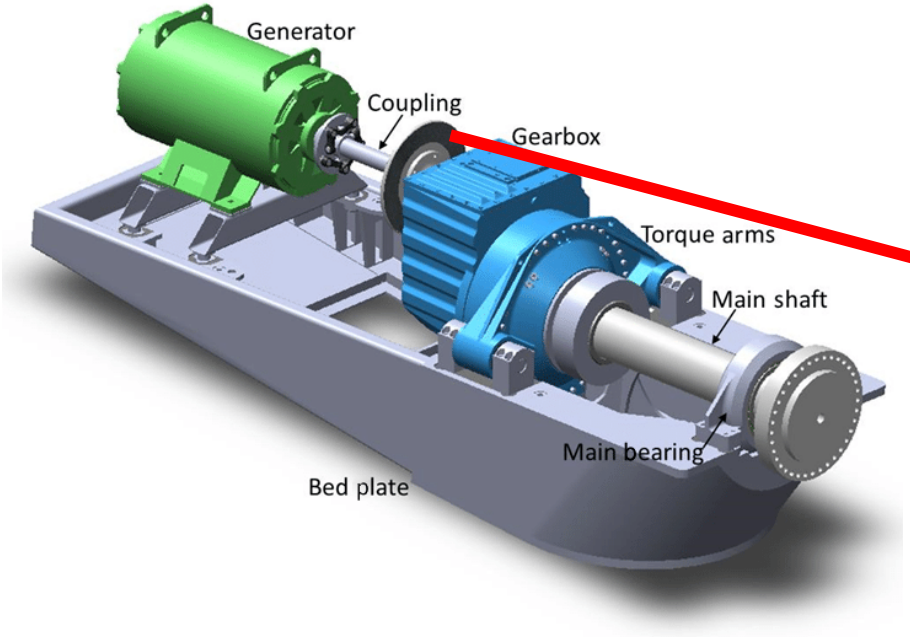
How to mitigate?

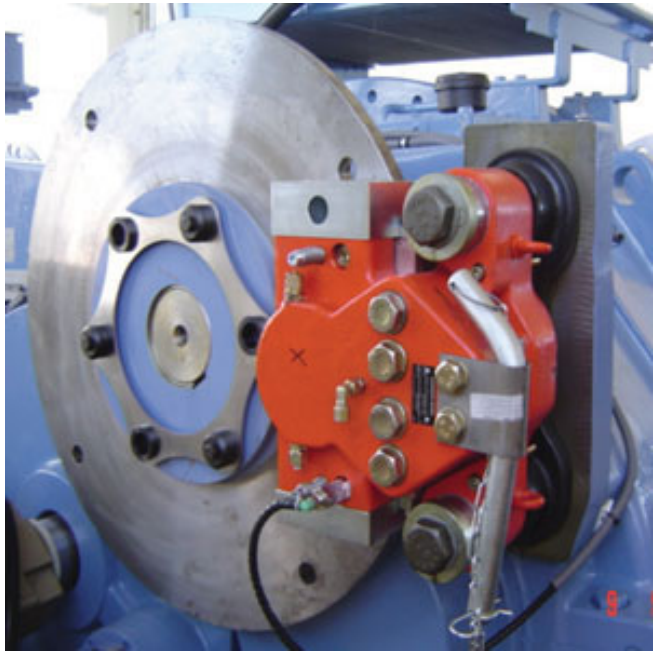


Asymmetric torque limiter (friction clutch devices…)

Spring torque limiter

How to mitigate?

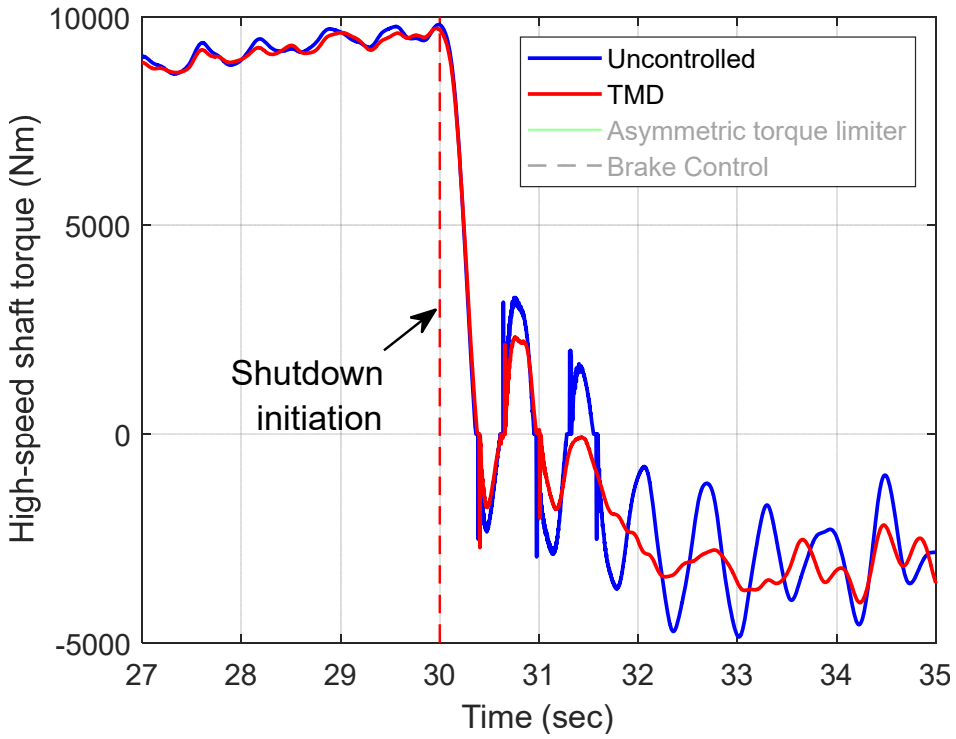


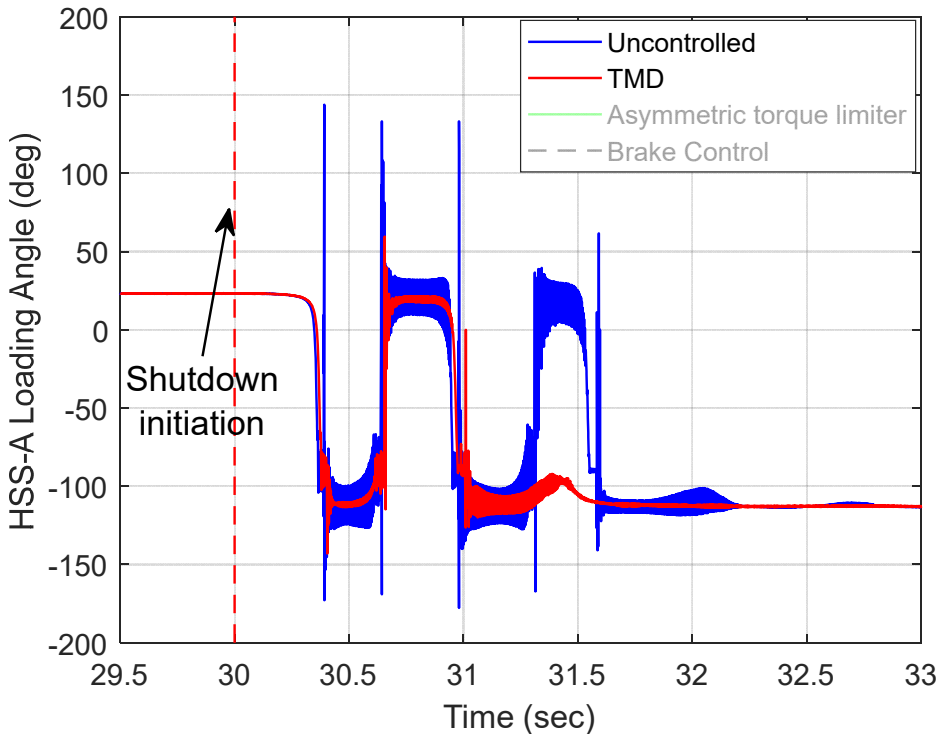


Proposed active control of high-speed shaft brake

How to mitigate?

Tuned mass damper

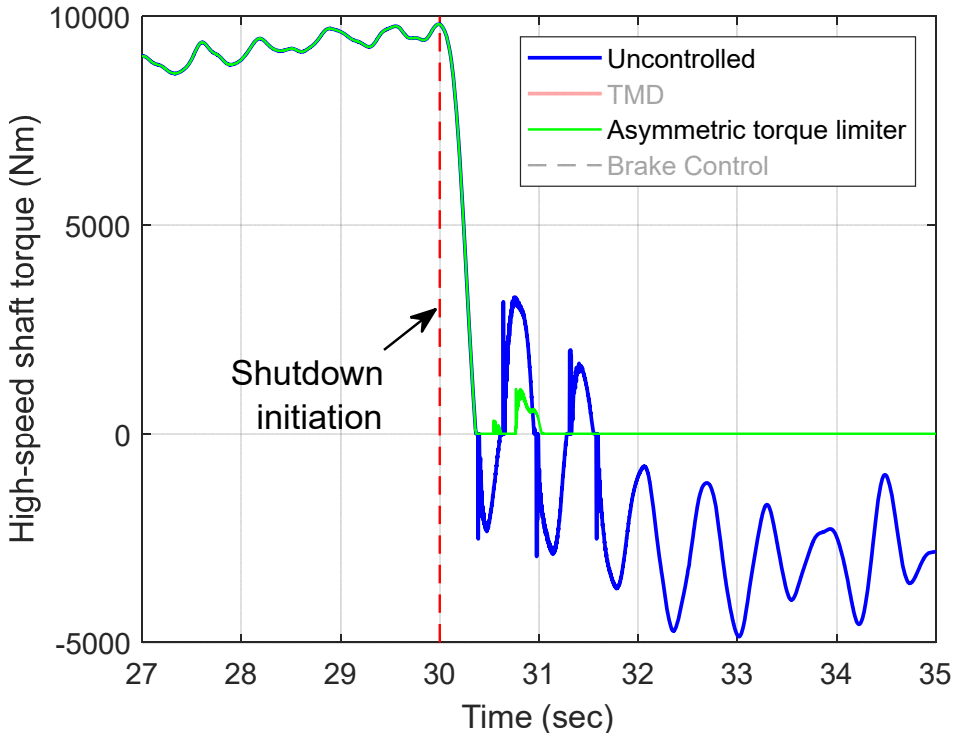


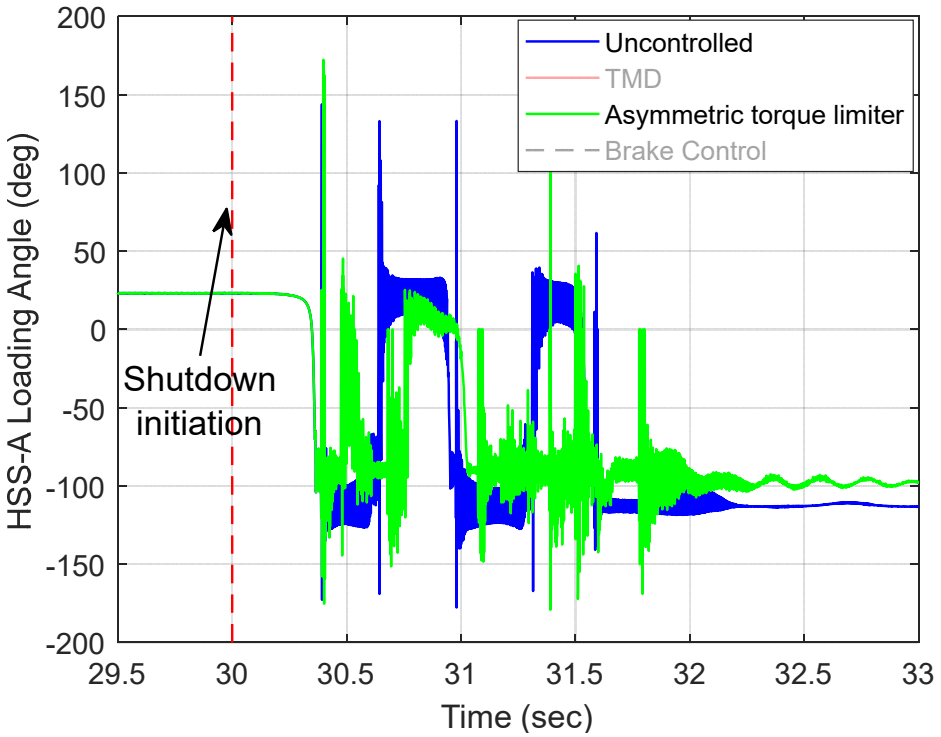


Emergency shutdown

How to mitigate?

Asymmetric torque limiter

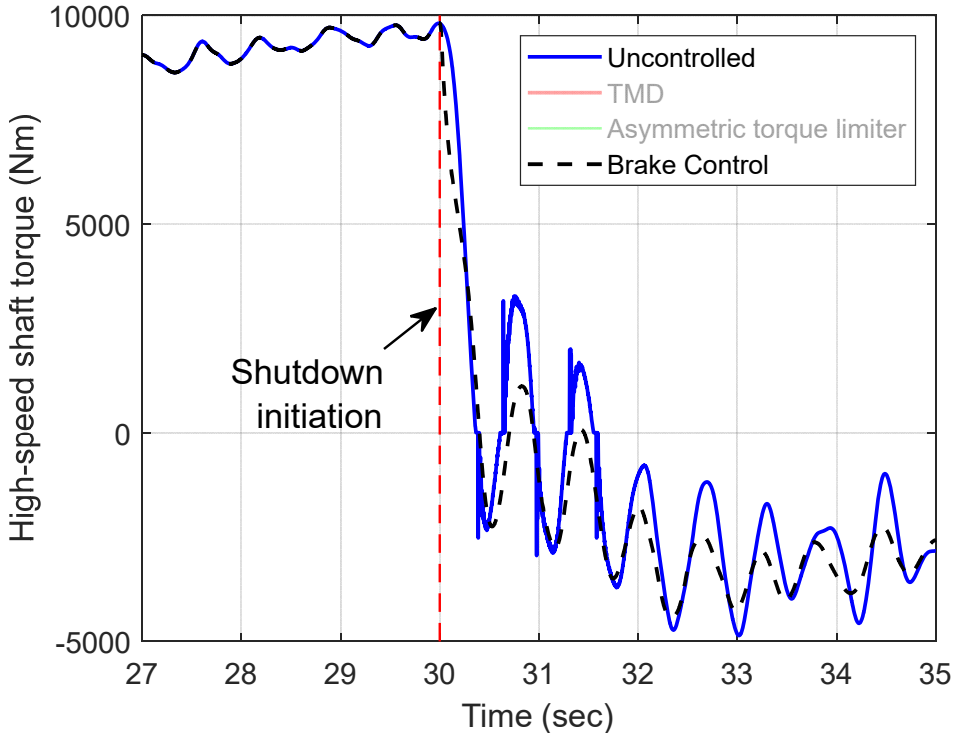


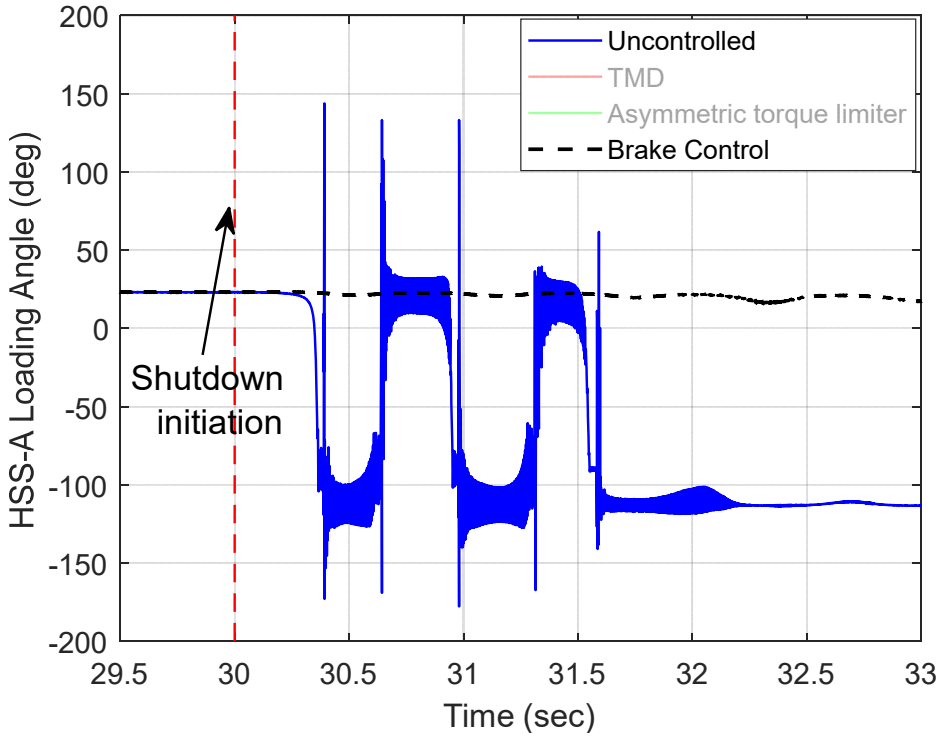


Emergency shutdown

How to mitigate?

HSS Brake Control (proposed by us)

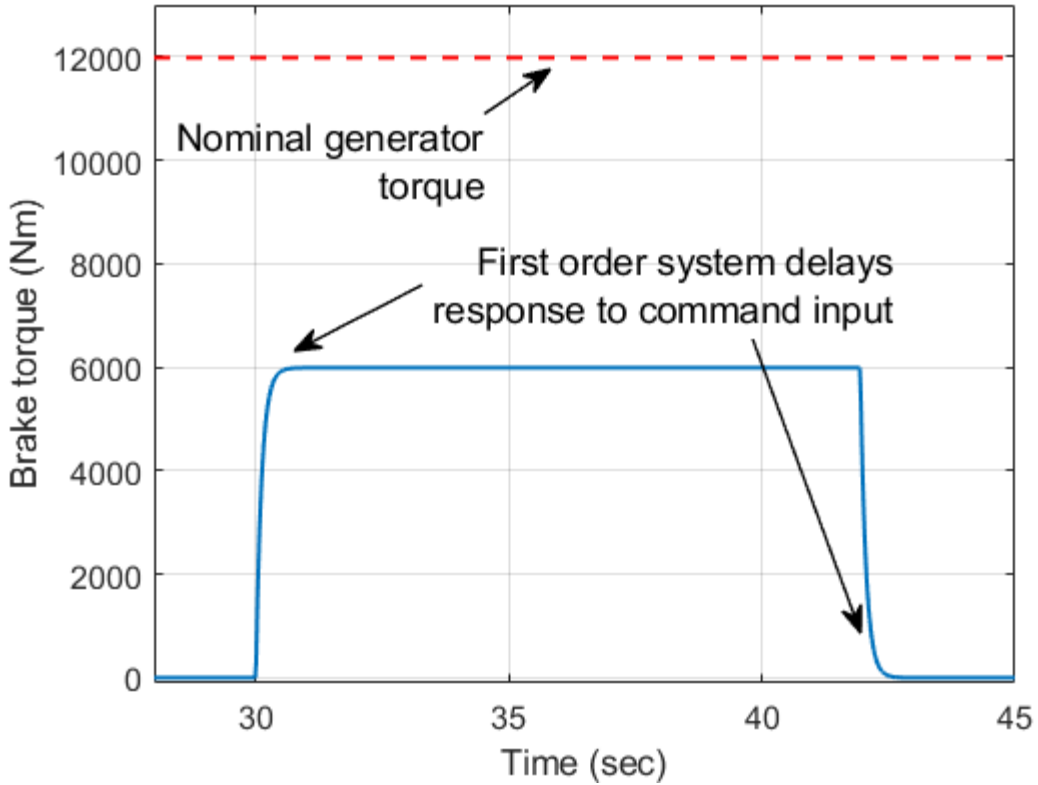




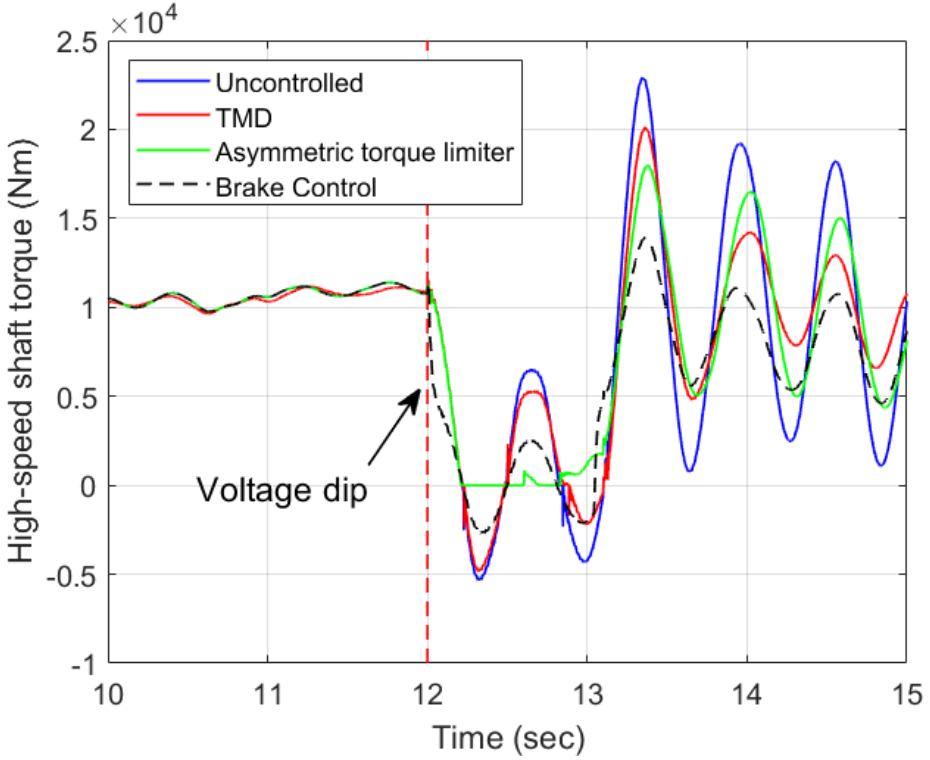
Emergency shutdown

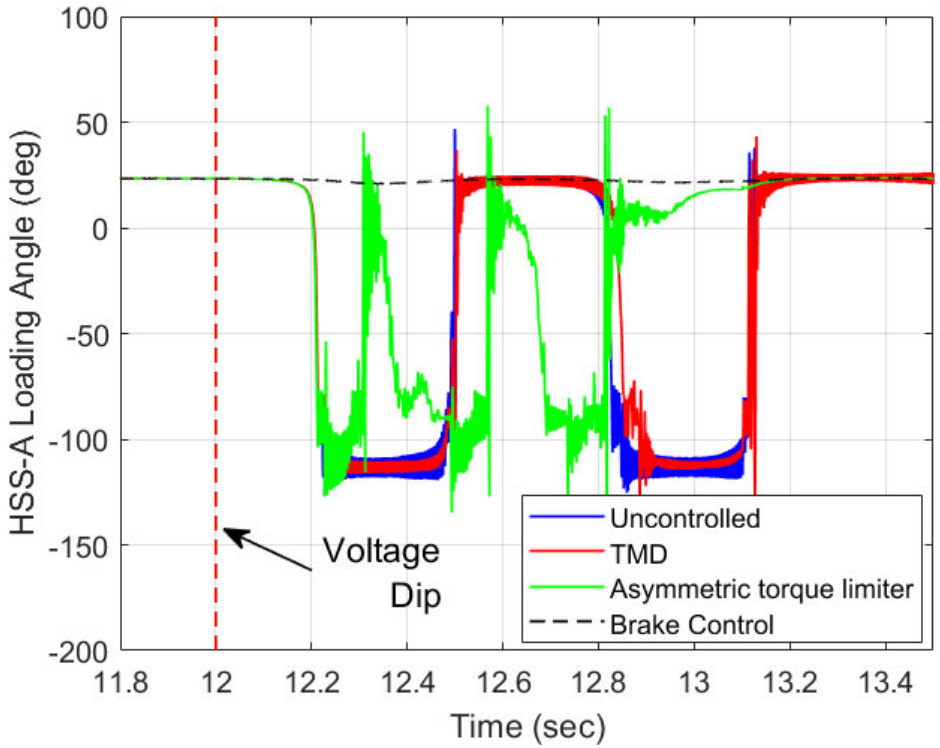
How to mitigate?

The brake torque



How to mitigate?





Symmetrical voltage dip

Thanks for listening! Questions?

Email: ssarkar@chalmers.se

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