The University Of Sheffield.

Department Of Mechanical Engineering

Multibody Dynamic Modelling of Wind Turbine Gearbox to Investigate Bearing and Gear Loading Under Different Operational Conditions

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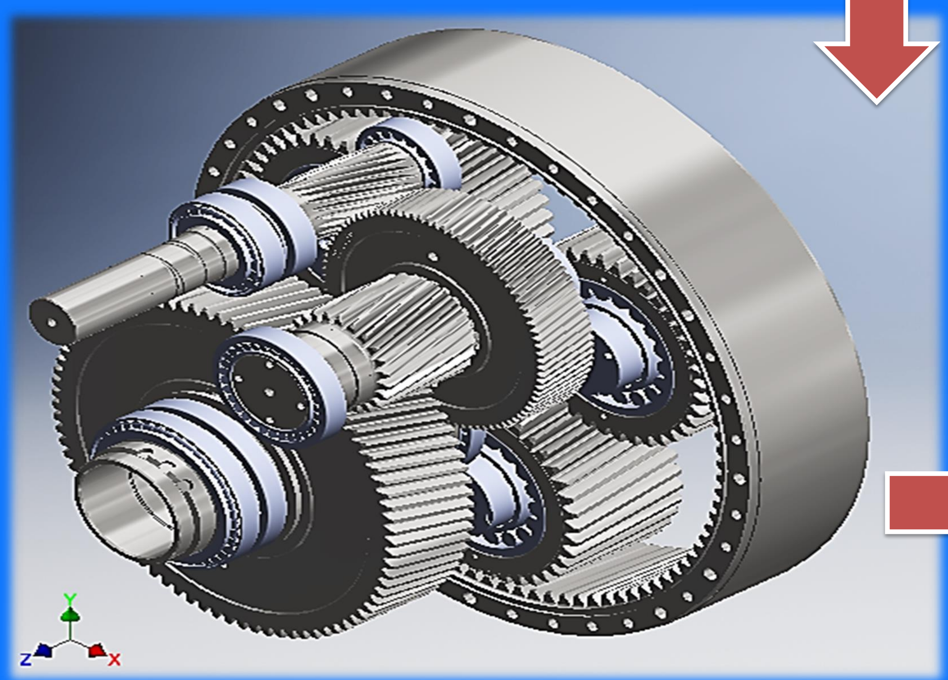
FAILURES OF WIND TURBINE GEARBOX BEARINGS AND GEARS

- Failures of gearbox components are responsible for more than 20% of the downtime of wind turbines [1].
- Real operational conditions are more complex when specified in IEC 61400-4 standard thus the real loading maybe under estimated in the design calculations.
- Common design practice reduces wind turbine drivetrain dynamic model to simple two or five degrees of freedom, resulting in restricted details in describing dynamic behaviour of internal drivetrain components under complex loading conditions [2].

3D Model for National Renewable Energy Laboratory (NREL) 750kW wind turbine gearbox has been created. The required parameters for modelling the gearbox have been calculated by using Autodesk Inventor Professional software and validated with that available in published literature.



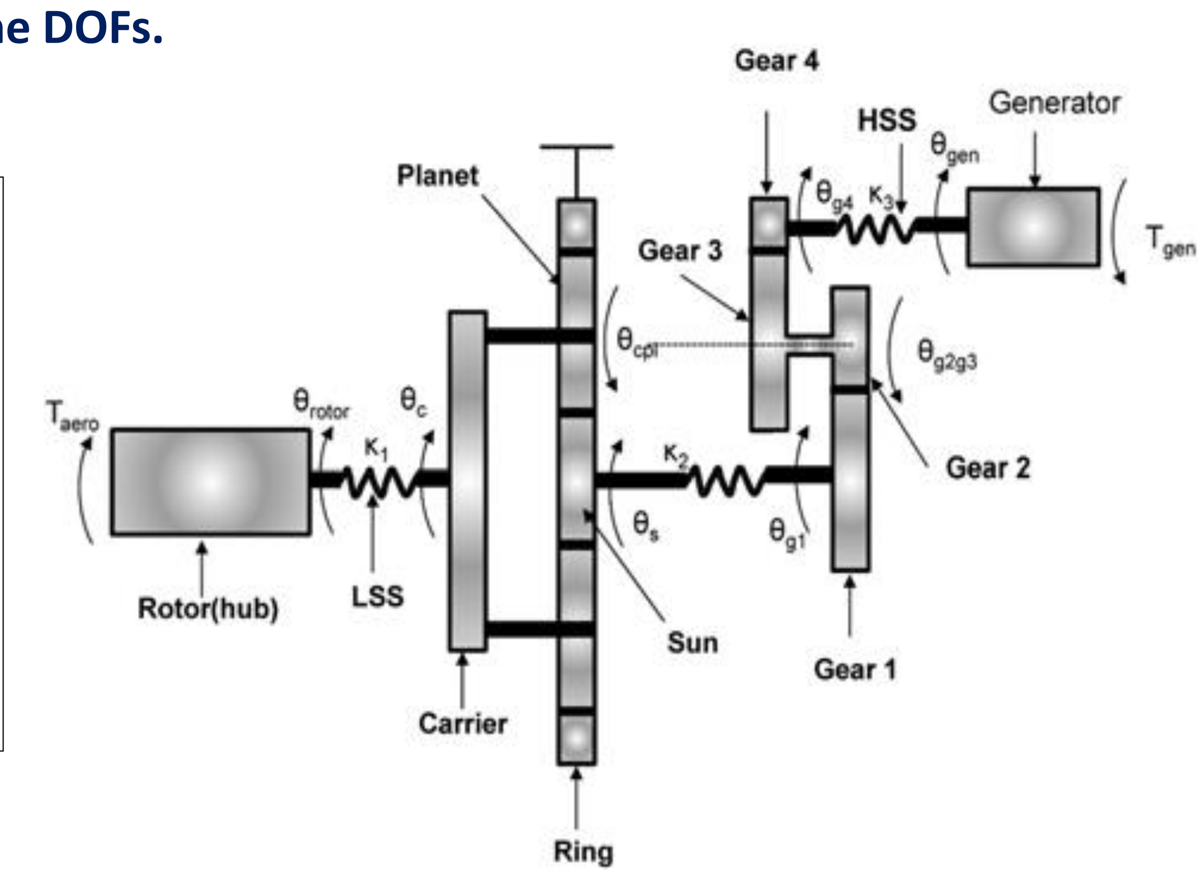
WIND TURBINE DRIVE TRAIN MODEL

- Pure torsional with lumped parameter dynamic model for 750kw wind turbine, one DOF per component, the overall dynamic model has nine DOFs.
- Lagrange's equation was employed to derive the equation of motion.

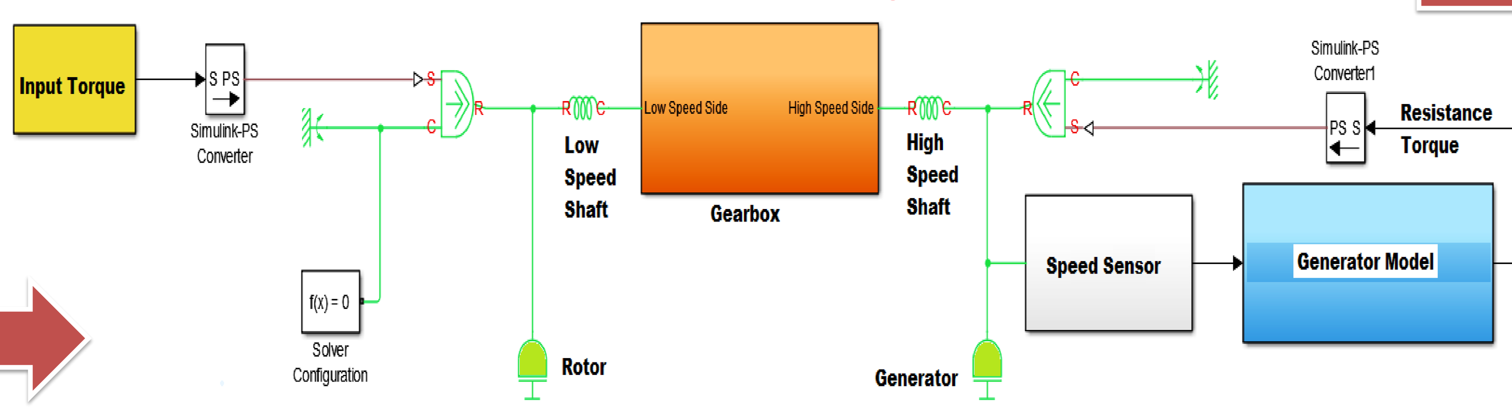
$$L=\frac{1}{2}[J_{rotor}(\dot{\theta}_{rotor})^2+\left(J_c+\sum_{i=1}^{3}m_p r_c^2\right)(\dot{\theta}_c)^2+\sum_{i=1}^{3}J_p(\dot{\theta}_{cpi}+\dot{\theta}_c)^2 +J_s(\dot{\theta}_s)^2+J_{g1}(\dot{\theta}_{g1})^2+J_{g2g3}(\dot{\theta}_{g2g3})^2+J_{g4}(\dot{\theta}_{g4})^2+J_{gen}(\dot{\theta}_{gen})^2]$$
$$-\frac{1}{2}k_1(\dot{\theta}_{rotor}-\dot{\theta}_c)^2-\frac{1}{2}k_2(\theta_s-\theta_{g1})^2-\frac{1}{2}k_3(\theta_{g4}-\theta_{gen})^2$$
$$-\frac{1}{2}\sum_{i=1}^{3}k_{rp}[r_r\theta_r-r_c\theta_c-r_p(\theta_{cpi}+\theta_c)]^2$$
$$-\frac{1}{2}\sum_{i=1}^{3}k_{sp}[r_s\theta_s-r_c\theta_c-r_p(\theta_{cpi}+\theta_c)]^2$$
$$-\frac{1}{2}k_{g12}(r_{g1}\theta_{g1}+r_{g2}\theta_{g2g3})-\frac{1}{2}k_{g34}(r_{g3}\theta_{g2g3}+r_{g4}\theta_{g4})^2$$
$$-\frac{1}{2}k_{tc}\theta_c^2-\frac{1}{2}k_{ts}\theta_s^2-\frac{1}{2}k_{tr}\theta_r^2$$

$$\frac{d}{dt}\left(\frac{\partial L}{\partial \dot{q}_i}\right)-\frac{\partial L}{\partial q_i}=Q$$

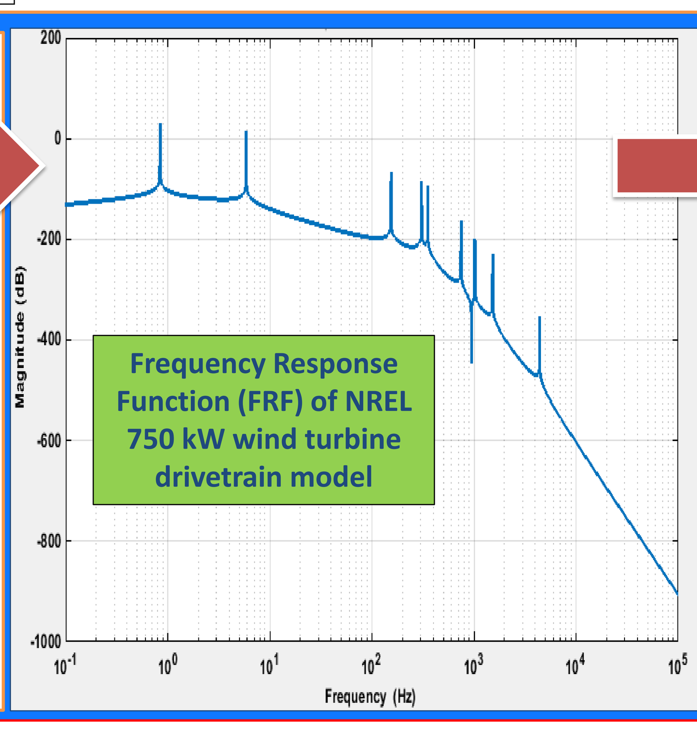
$$M\ddot{u}+Ku=Q$$

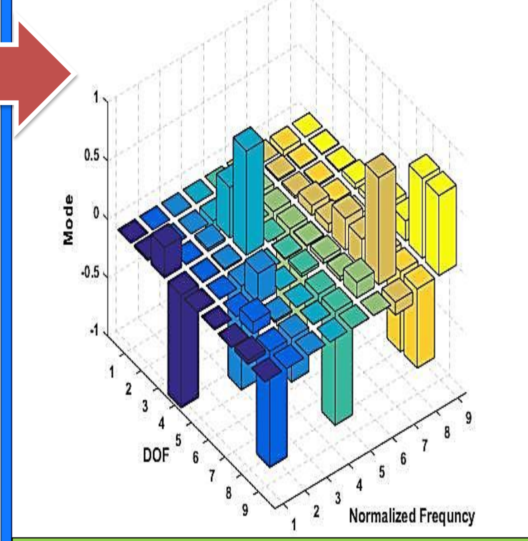


DEVELOPMENT OF A DYNAMIC WIND TURBINE DRIVETRAIN MODEL BY USING MATLAB/SIMDRIVELINE



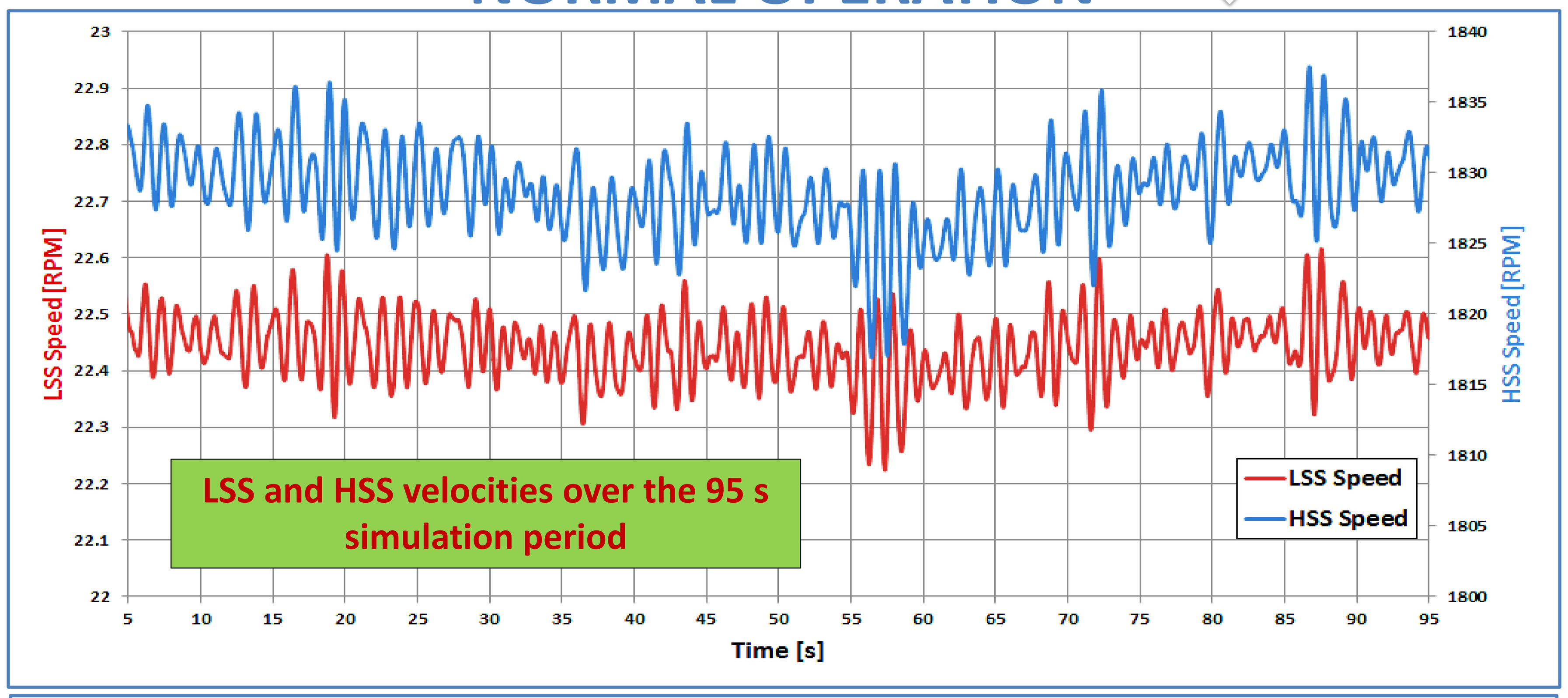
Pure torsional model of 9 DOFs for NREL 750kW wind turbine multistage gearbox consists of a planetary gear set and two parallel gear sets, with two intermediate shafts.

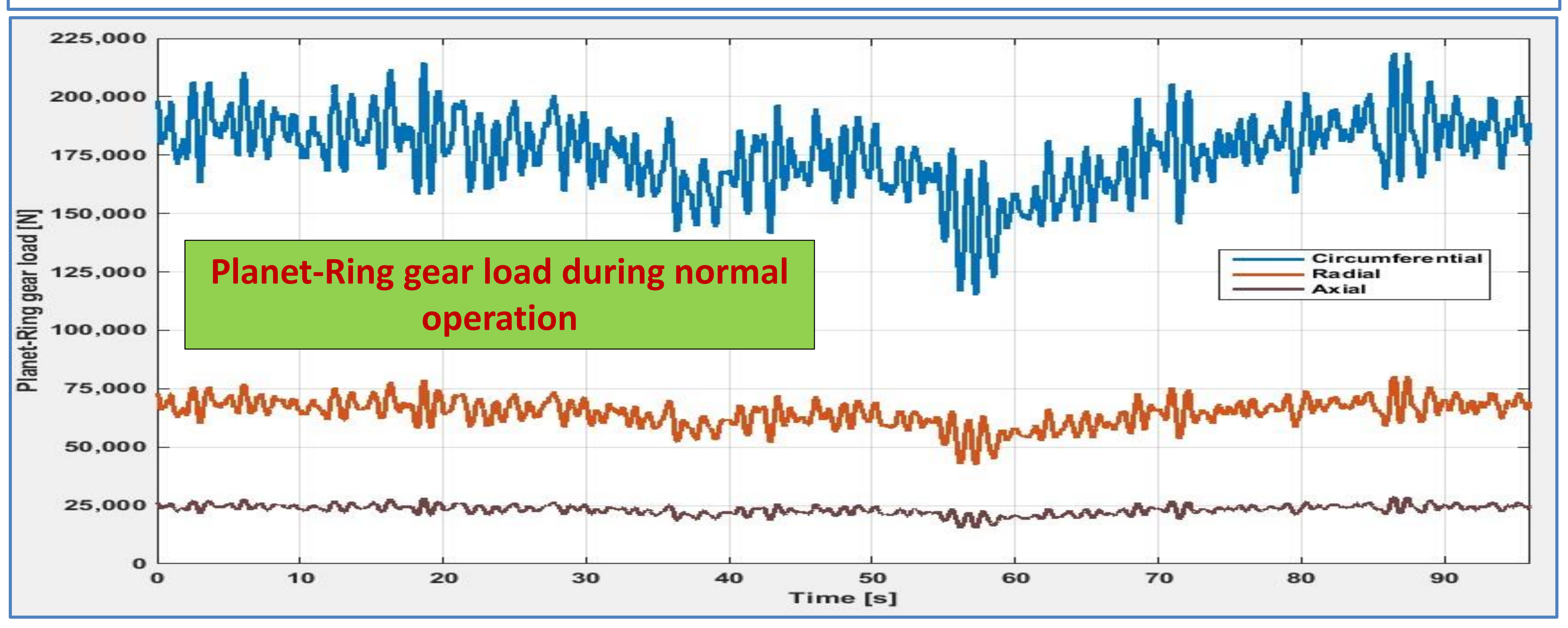


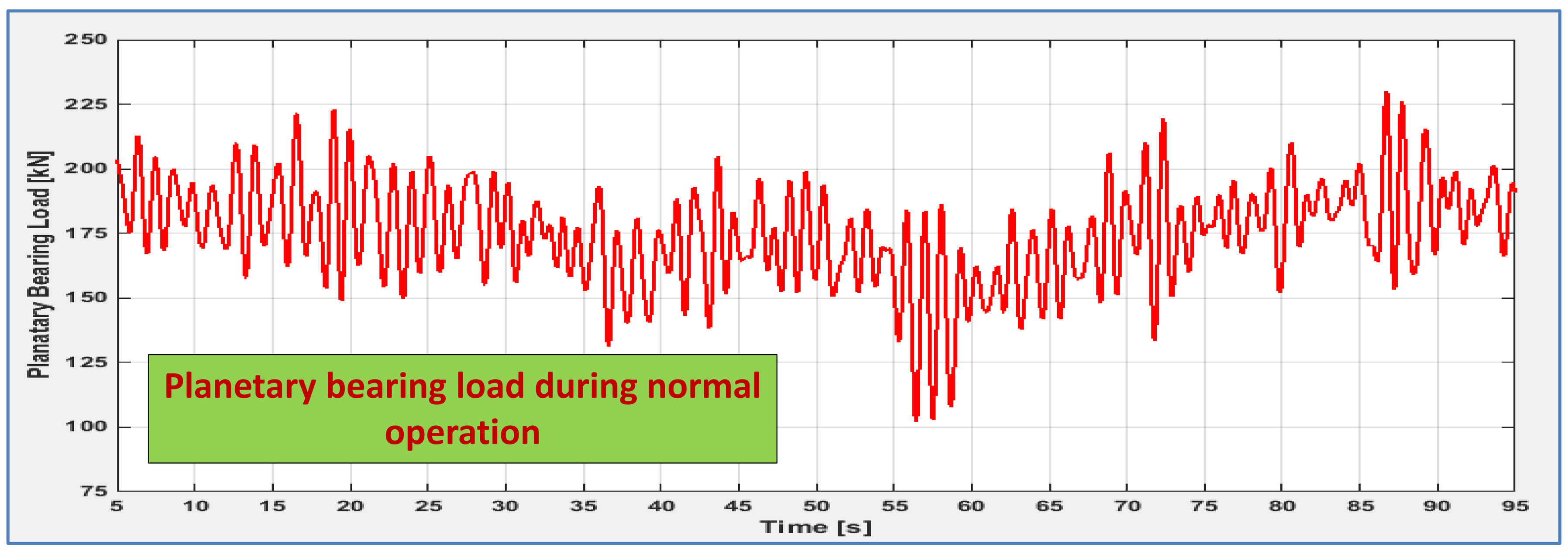


Mode shape of NREL750 kW wind turbine drivetrain model

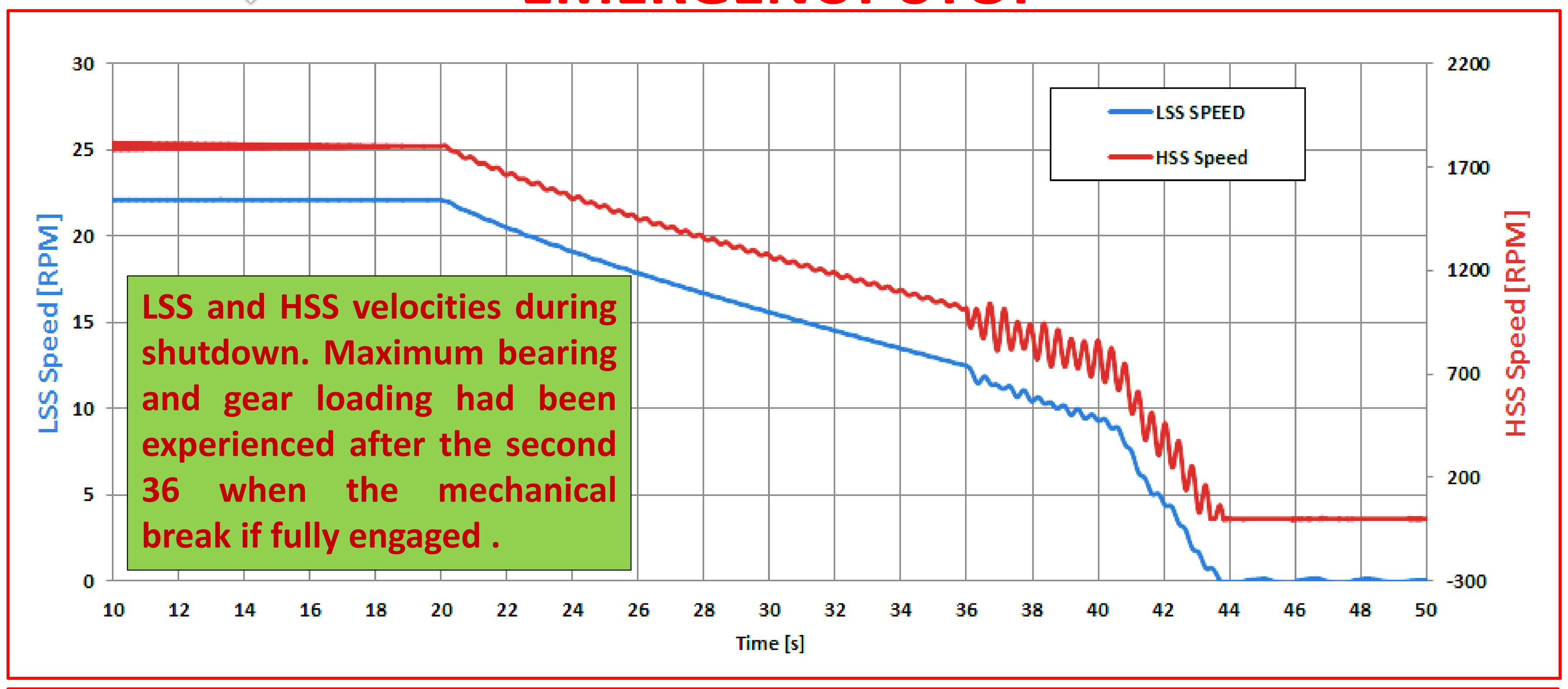
NORMAL OPERATION

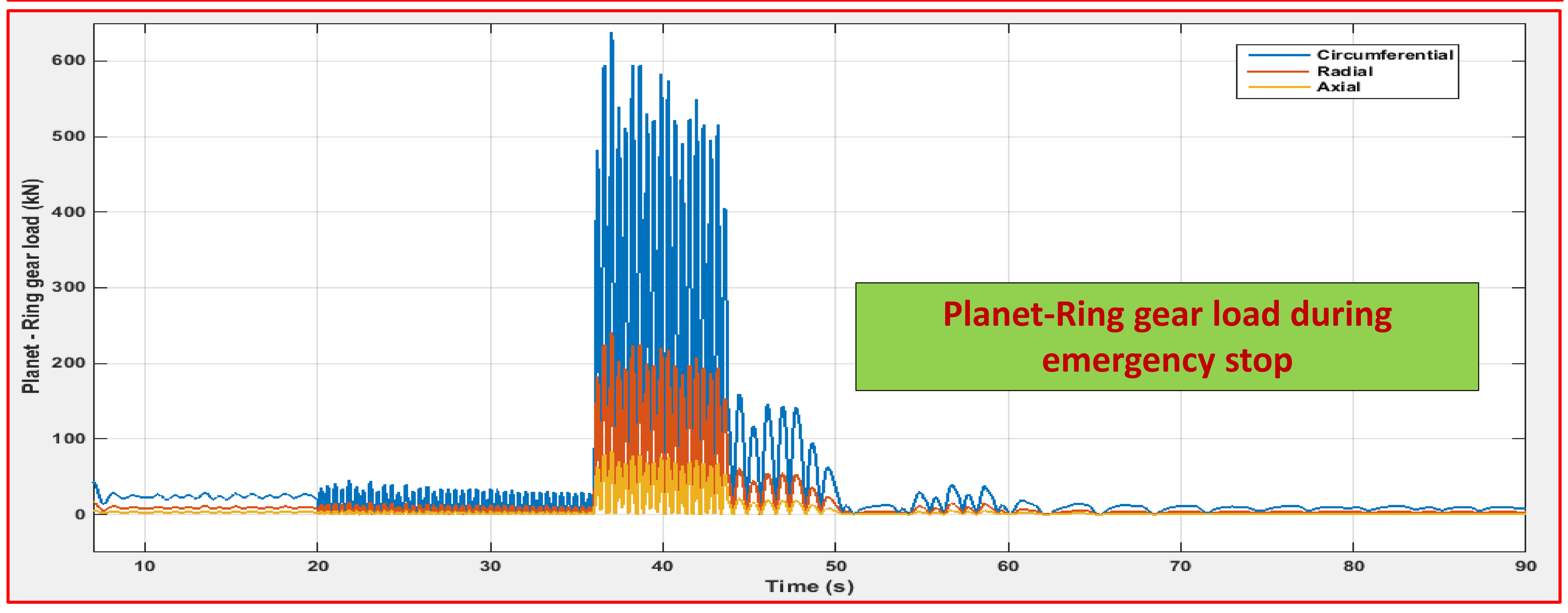


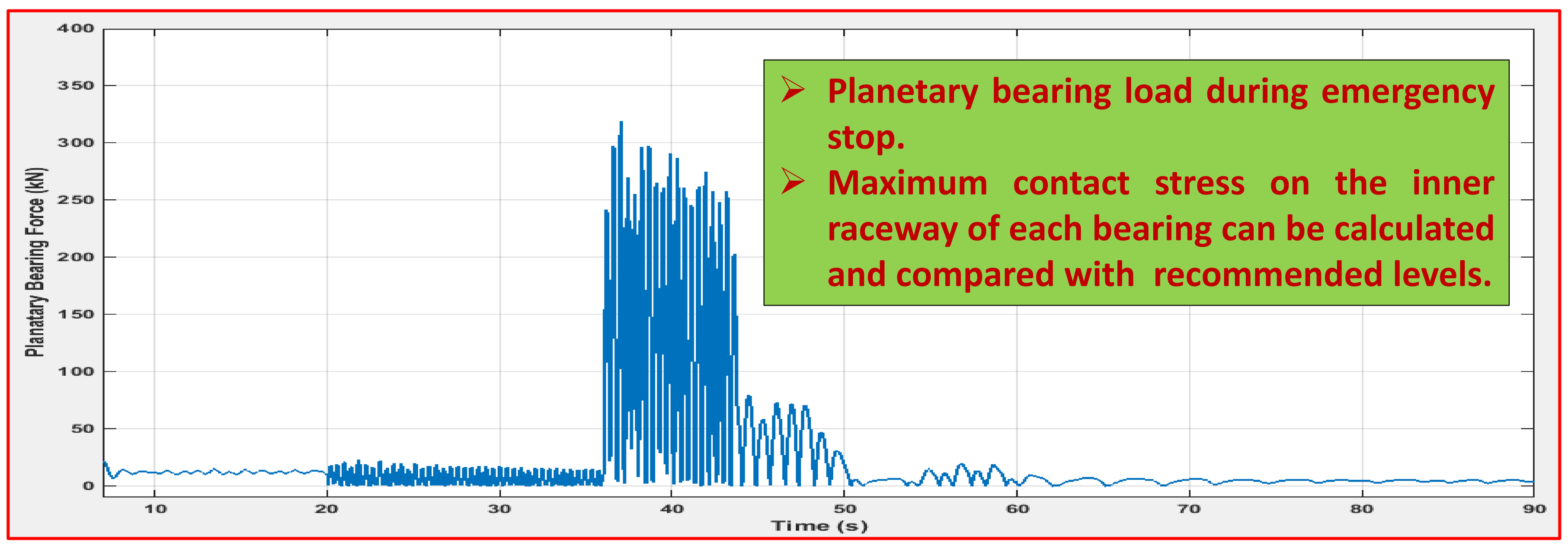




EMERGENCY STOP







CONCLUSIONS:

- A pure torsional dynamic model of a 750 kW wind turbine has been successfully developed by using MATLAB/SIMDRIVLINE, validated and used to simulate normal operation and manual shutdown operation of wind turbine.
- The model can be simulated under different operational conditions to investigate the drivetrain dynamic characteristics and behaviour, particularly predicting possible resonant excitations.
- The bearings and gears of wind turbine gearbox are subjected to high load levels during manual shutdown higher than that normal operating condition.

REFERENCES:

[1] *M. Singh et al., "Simulation for wind turbine generator—with FAST and MATLAB/Simulink modules," Nat. Renew. Energy Lab., Golden, CO, USA, Tech. Rep. NREL, 2013.*
[2] *J. Peeters, "Simulation of dynamic drivetrain loads in a wind turbine," Ph.D. dissertation, Dept. Mech. Eng., K.U. Leuven, Leuven, Belgium, Jun. 2006.*
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[4] *Scott, K.S., Infield, D., Barltrop, N., Coultate, J., Shahaj, A.: 'Effects of extreme and transient loads on wind turbine drive trains'. 50th AIAA Aerospace Sciences Meeting including the New Horizons Forum and Aerospace Exposition, 2011*