Dynamics and vibration design of the Ringhals Motor-Generator set

Energiforsk - Seminar

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Functionality

The motor-generator set (MG-set) at Ringhals 2 supplies the control rods drives with power. For redundancy reasons, two parallel MG-sets are used, one of which is dimensioned to be able to supply all control rod drives with power.

- Convert 50 Hz to 60 Hz power
- When the generator spin speed drops from N1=1800rpm to N2=1605rpm during a time period of 1sec the minimum change rate of the kinetic energy stored in the spinning flywheel should be P=100kW

Factory Acceptance Test

Dynamic design requirements for assembled and installed MG-set

Vibration and structure integrity

- Dynamics and structural integrity should be checked in steady state conditions as well as transient conditions caused by start-up or electrical failure such as 2-phase and 3-phase short circuit.
- Primary Stress
- Lateral resonances
- Torsional resonances
- The design of the standing frame of the MG-set shall take into account the dynamic stiffness of the floor on site.

This shall apply for all allowed temperature and load ranges!

Primary Stress

Dynamic Requirements

	Yield strength $R_{p0,2}$ [MPa]	Fracture strength R_m [MPa]	Torsional strength τ_{sv} [MPa]
Static parts	240	360	-
Rotating parts	270	490	190

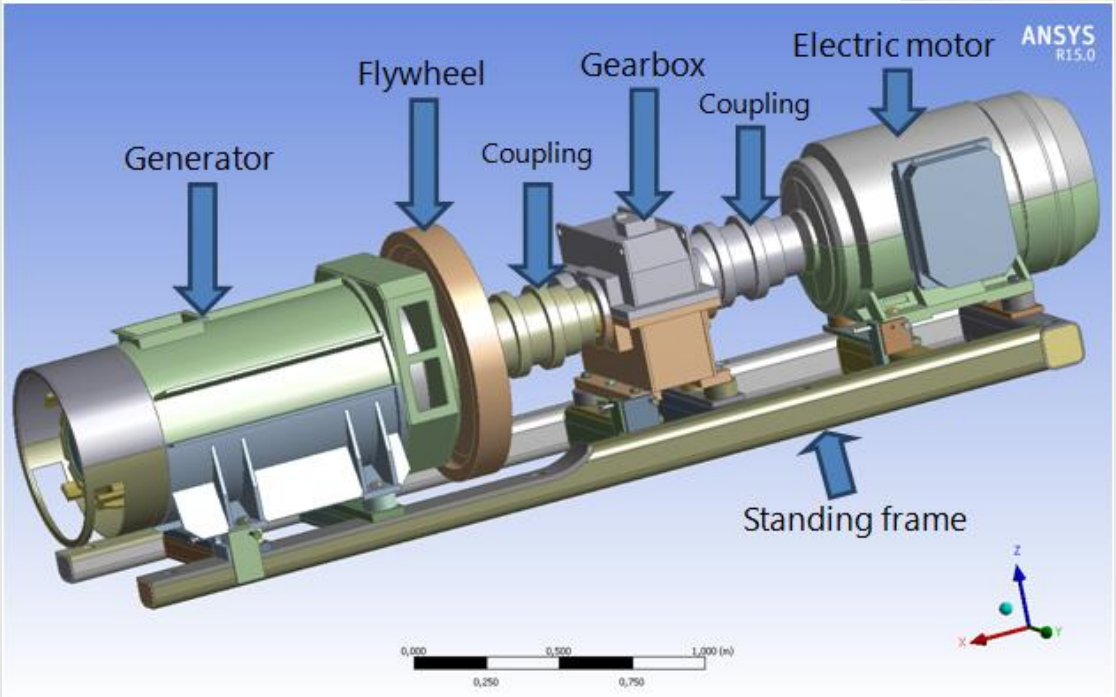
Table 1: Material properties for unknown materials

Start up and Fault Cases (2-phase and 3-phase short circuit)

- $S_f = 1,5$ for all parts

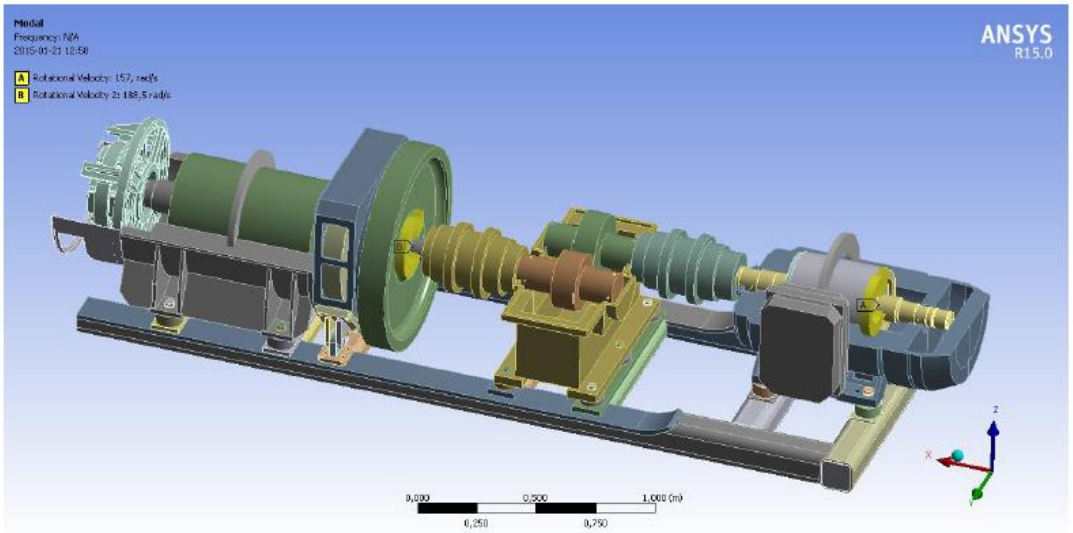
*The torsional yield strength used is **126MPa**, where a safety factor of 1.5 is considered.*

MG-set design



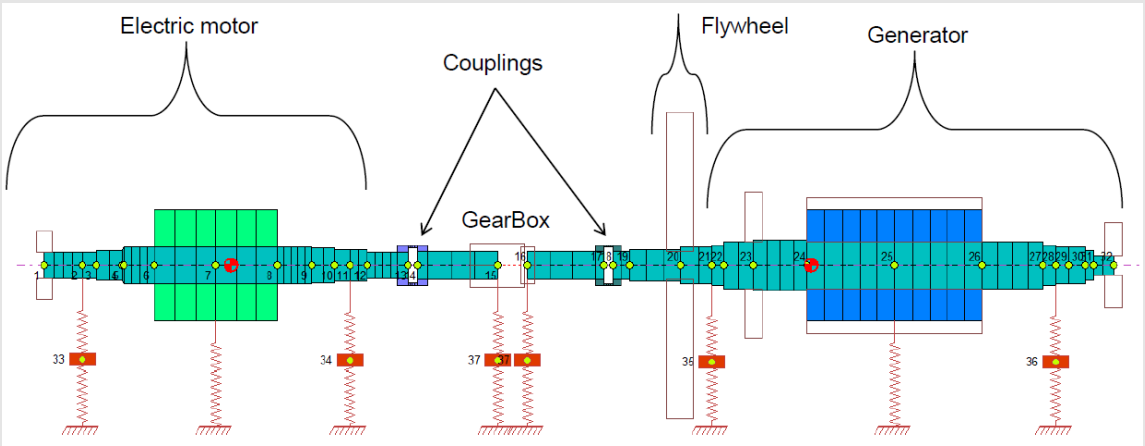
Simulation

Modal analysis: Ansys work bench as 3D models
Torsional analysis: DyRoBeS



Cut view MG-set

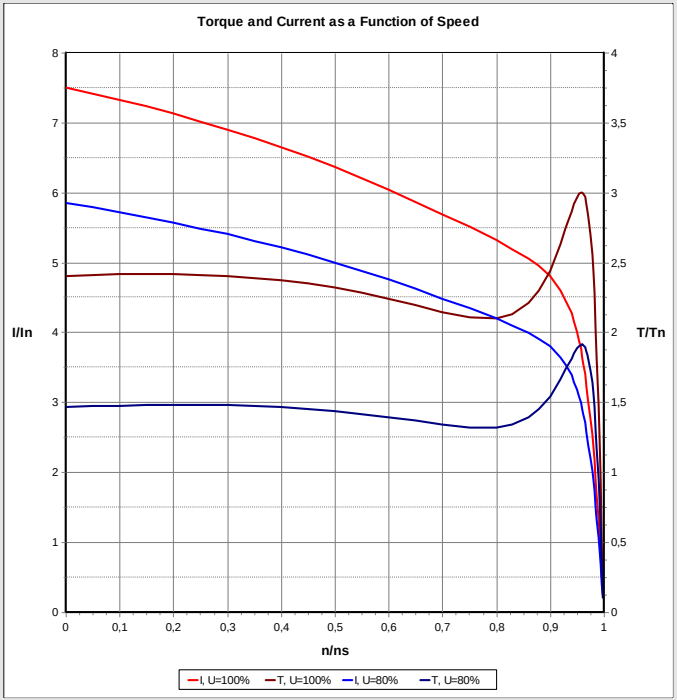
DyRoBeS: Rotordynamic modelling of MG-set



- The upper springs in represent the stiffness of the used SKF bearings,
- The lower springs represent the stiffness of the standing frame.
- The springs connected to station 7 and 25 represent the magnet pulling forces modelled with negative spring constants.
- Station 33 to 37 represent the weights of motor stator, gear box housing and generator stator.

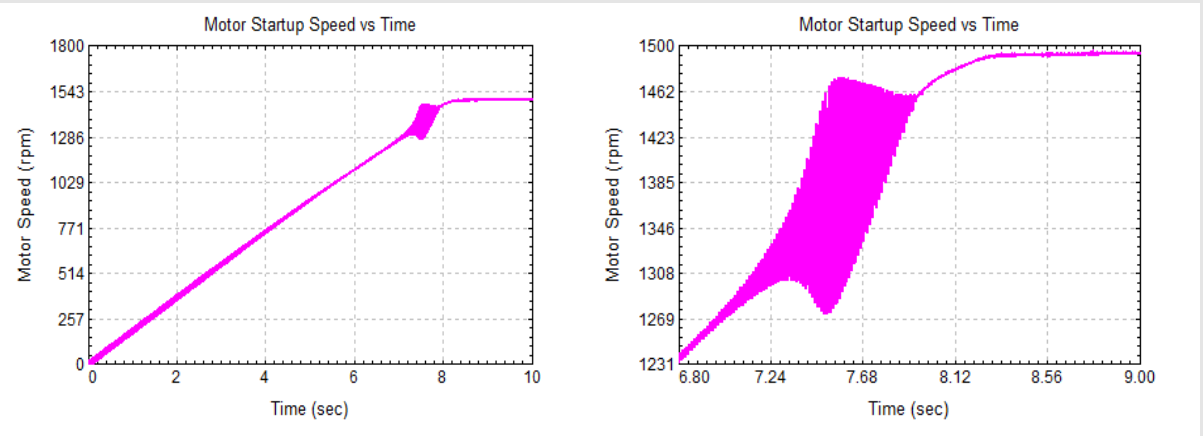
Torque Start-up curve

Induction motor torque as function of speed



T = 3 x Tn
was used in transients start-up simulation.
Tn = 846Nm.

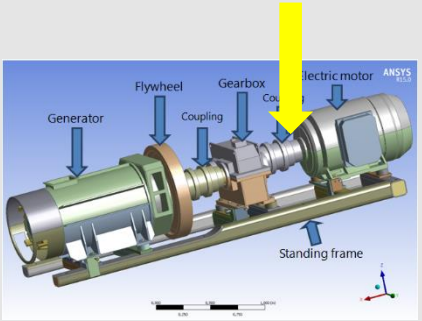
Motor speed as function of time



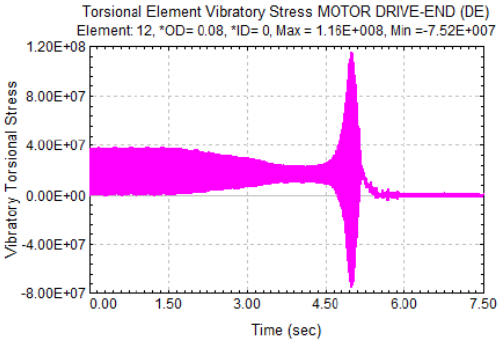
Large fluctuations in rotor speed occur about **7.5 seconds** after start.

Results – Start-up
torsional stress

OK: 116 Mpa < 126 MPa



–Maximum stress (116MPa) occurs in the Motor Drive End (DE)



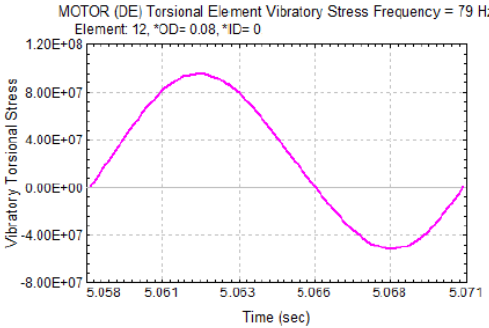


Fig. 7: (a) At about 5 seconds after start, the vibratory stresses in motor drive end reach a max value of 116MPa. (b) Frequency content of the vibratory motion is 79Hz (the inverse of the period time T≈ 0.0127 sec)

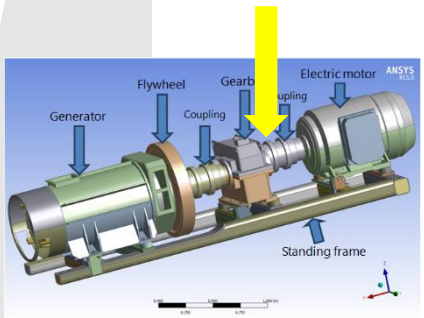
Results Start-Up
vibratory torque

Almost 15 times higher amplitude

magnitude torque (12520 Nm) than nominal (846 Nm) =

an important design parameter for selecting gear box!

–Maximum torque (12520Nm) occurs in the Gear box incoming axel (MOTOR SIDE)



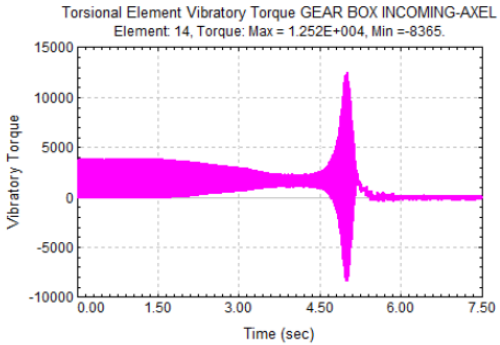
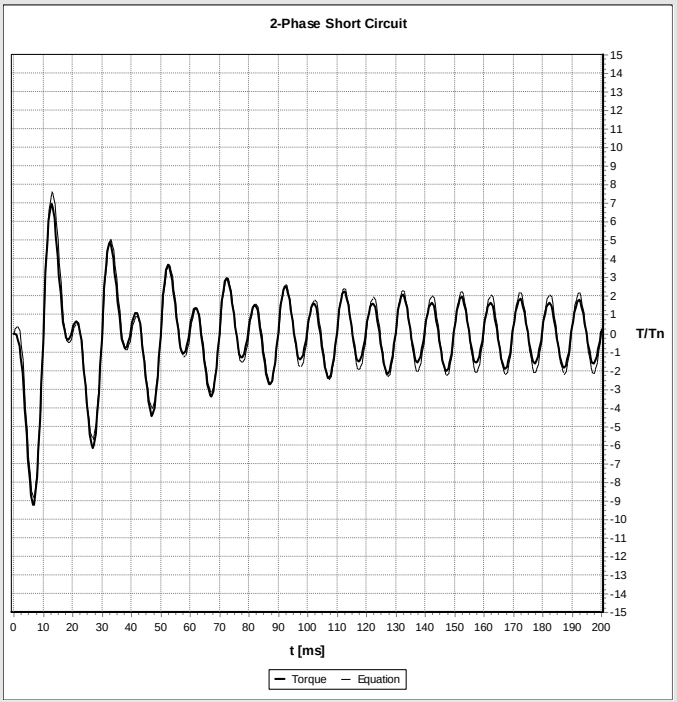


Fig. 8 At about 5 seconds after start, the vibratory torques in Gear box incoming axel reach a max value of 12520Nm

2-Phase short circuit excitation torque as a function of time

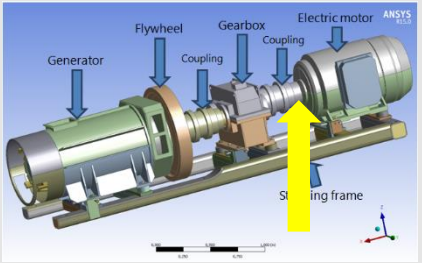
Induction motor torque as function of time



T = 9 x Tn
was used in transients start-up simulation.
Tn = 846Nm.

Results – 2-phase short circuit

OK: 120 MPa < 126 MPa



–Maximum stress (120MPa) occurs in the Motor Drive End (DE)

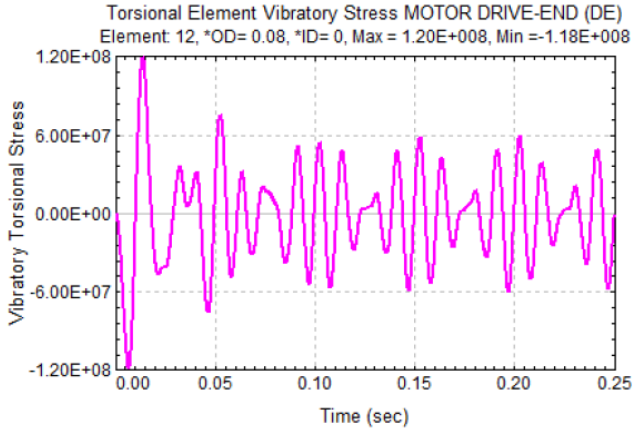
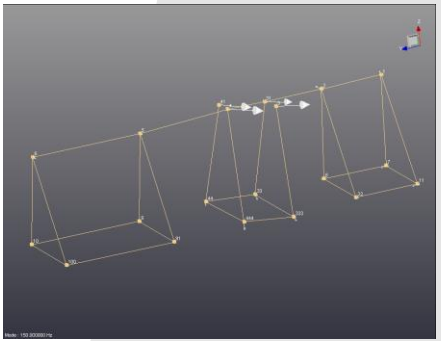


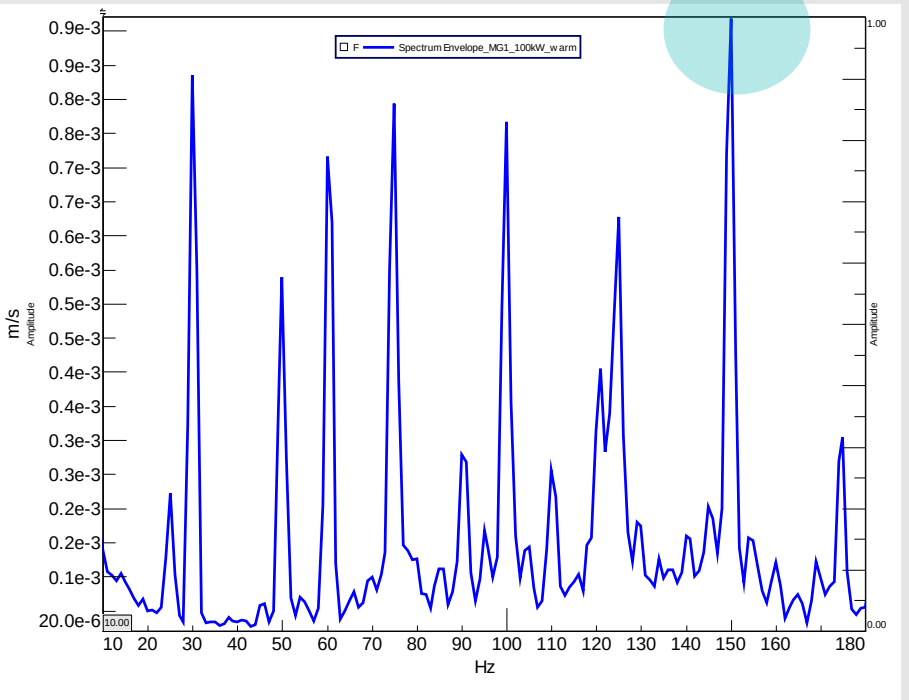
Fig. 12 The vibratory stresses in motor drive end reach a max value of 120MPa

ODS of running MG1 – spectrum envelope of 20 measurement points in x y z direction

All points below 0.9 mm/s rms < requirement 2.8 mm/s rms



ODS animation at
f= 150 Hz



Test verification was performed with LMS Test.Lab

What we learned!

- Large electrical machines must be treated in a special way during design phase. Don’t miss to check transient conditions caused by start-up or electrical failure such as 2-phase and 3-phase short circuit.
- Material input data is not easy for a supplier to declare for the components i.e. steel of shaft etc. Define your own material requirements in purchase requirements!
- Nominal torque for a motor start-up for the individual motor component may be scaled up couples of magnitudes when motor is assembled in a large machine.
- …….AND A LOT MORE!!!!