New Concept for Wind Turbine Testing Rig

INNOWIND Forschungsgesellschaft mbH
in cooperation with
University of Applied Sciences, Saarbrücken and
Fraunhofer Institute for Wind Energy, Bremen

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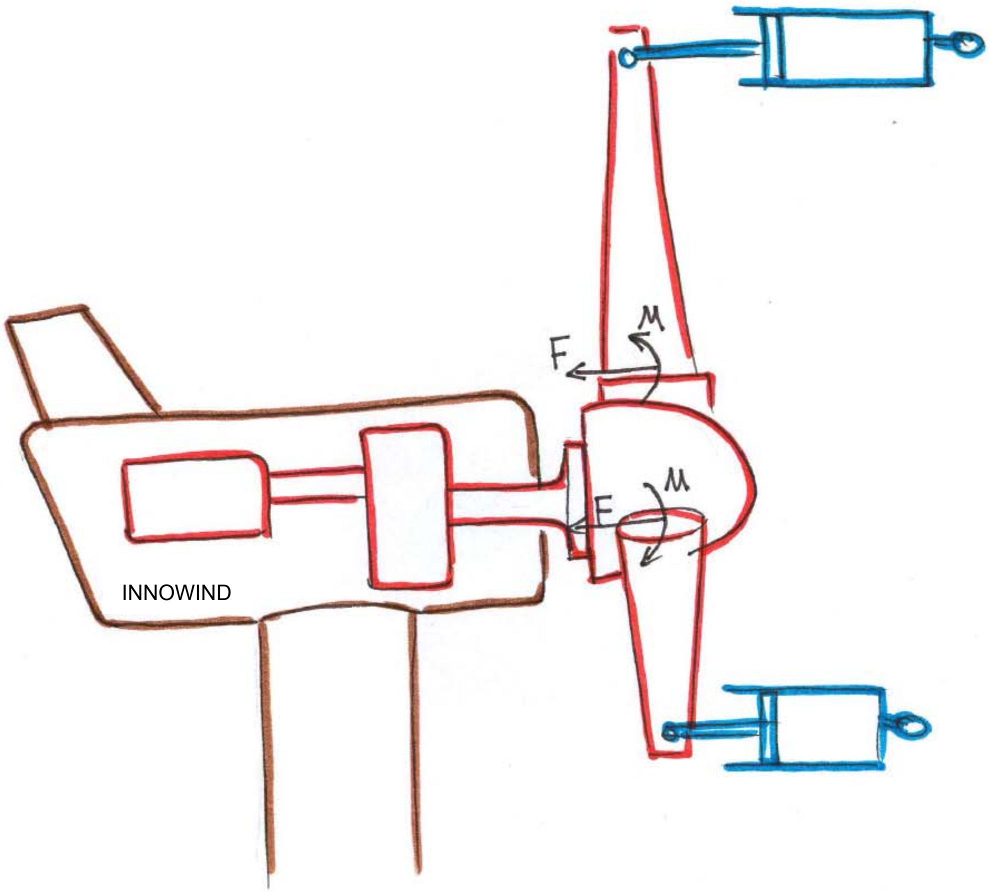
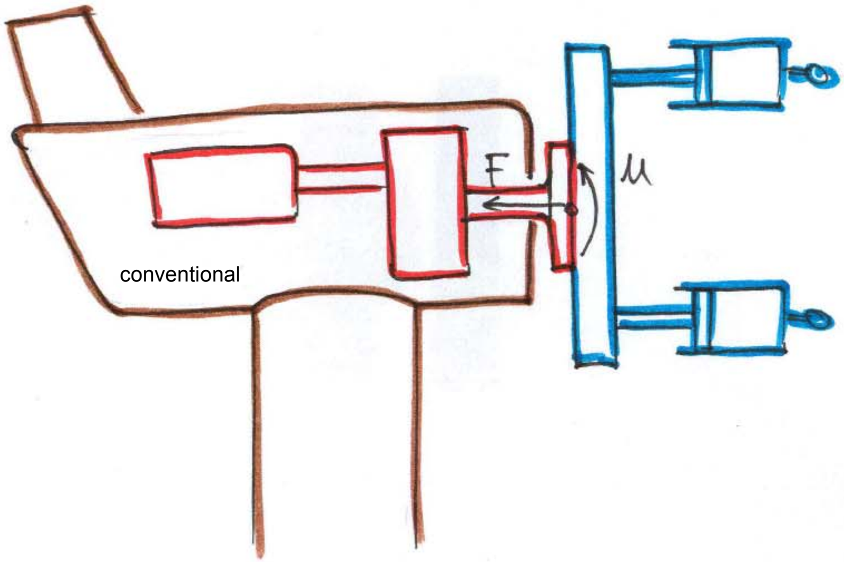
Summary: Strong need for fatigue testing of wind turbines

- Wind turbine are exposed to fatigue loads.
- 10^9 load cycles within 20 year life time
- In spite of computer simulation total loss of wind turbine is possible.
- existing testing rig are cost-intensive and power consuming
- new INNOWIND concept needs low energy input
- Includes testing of rotor hub, pitch bearings and pitch drives
- operates in open air
- uses remote parameter control techniques

INNOWIND Concept compared to existing Concepts

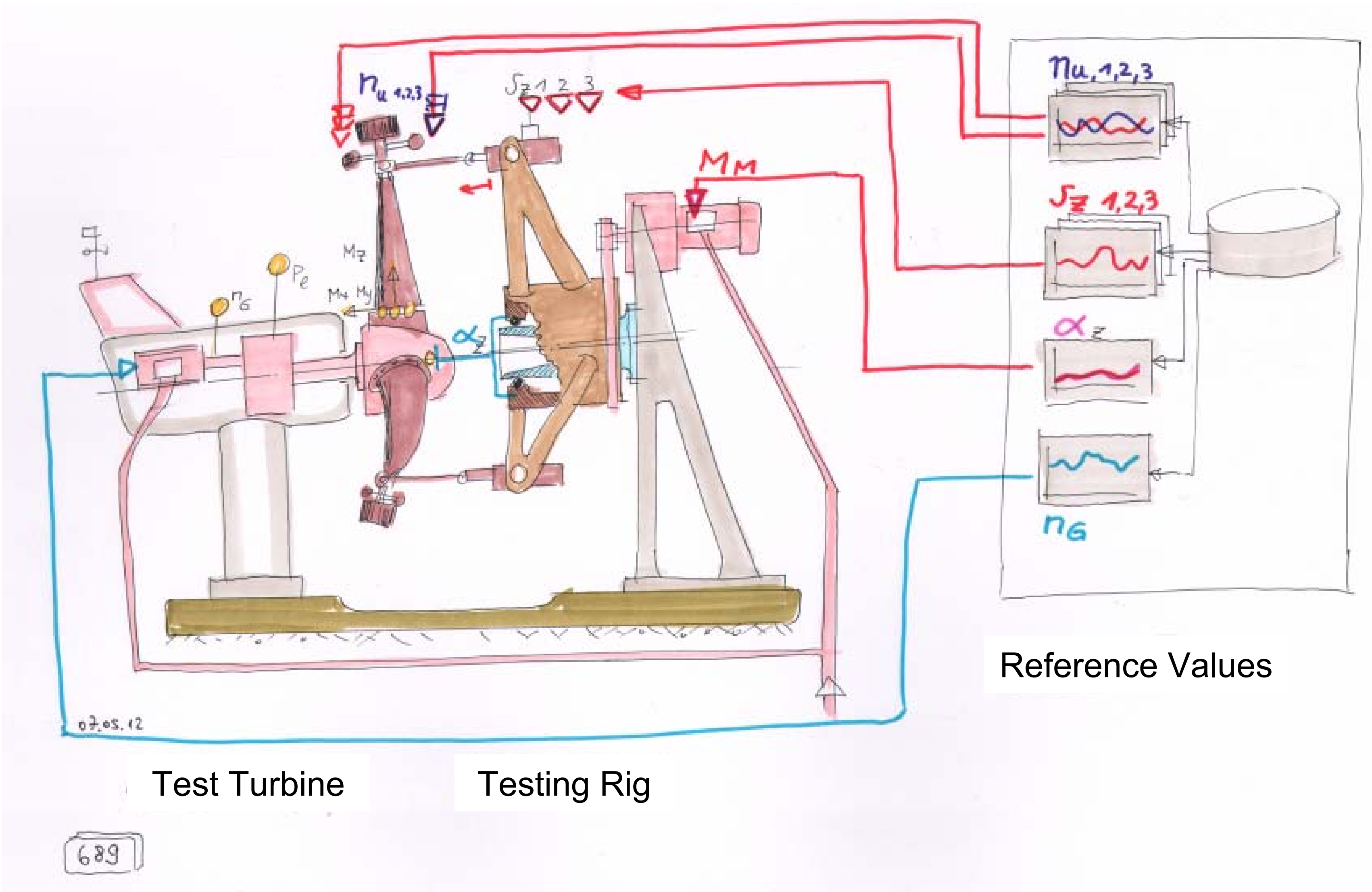




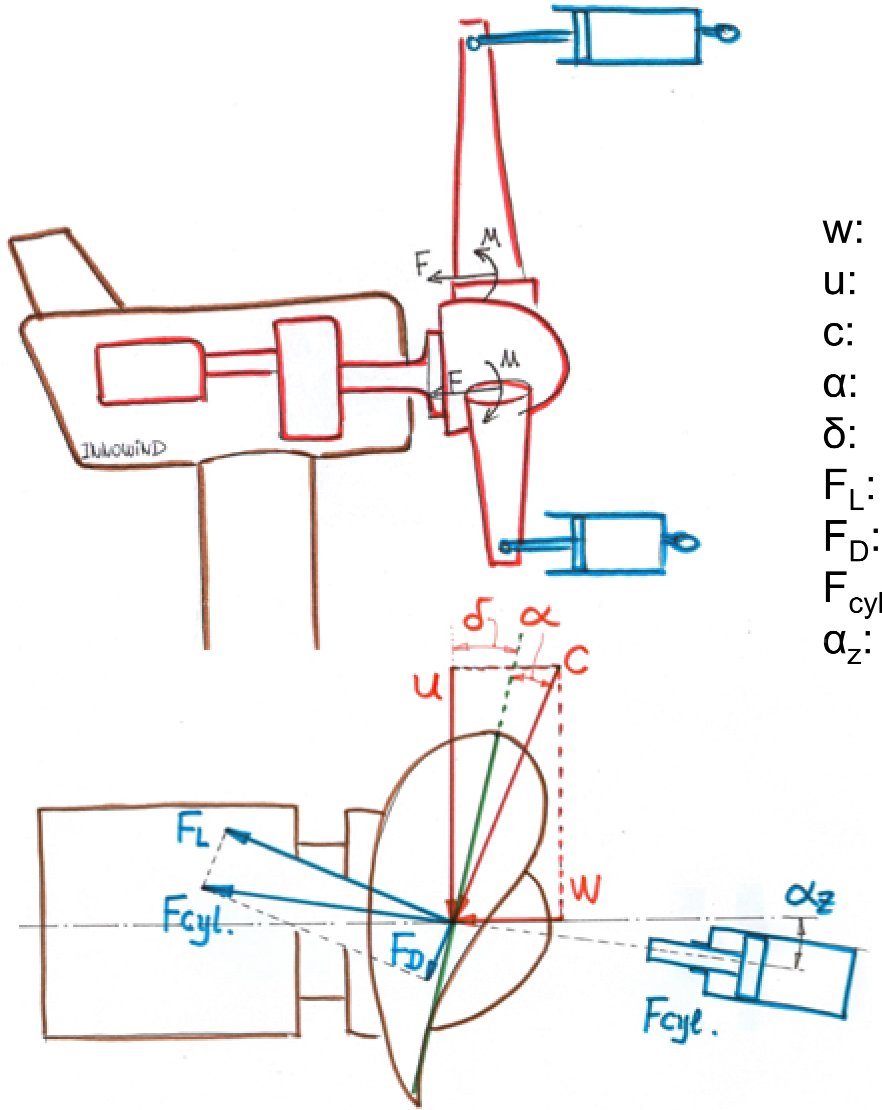
Load Introduction at 3 blades

Load Introduction on shaft end

Testing Strategy: Simple Configuration with Load Introduction at Blade Roots



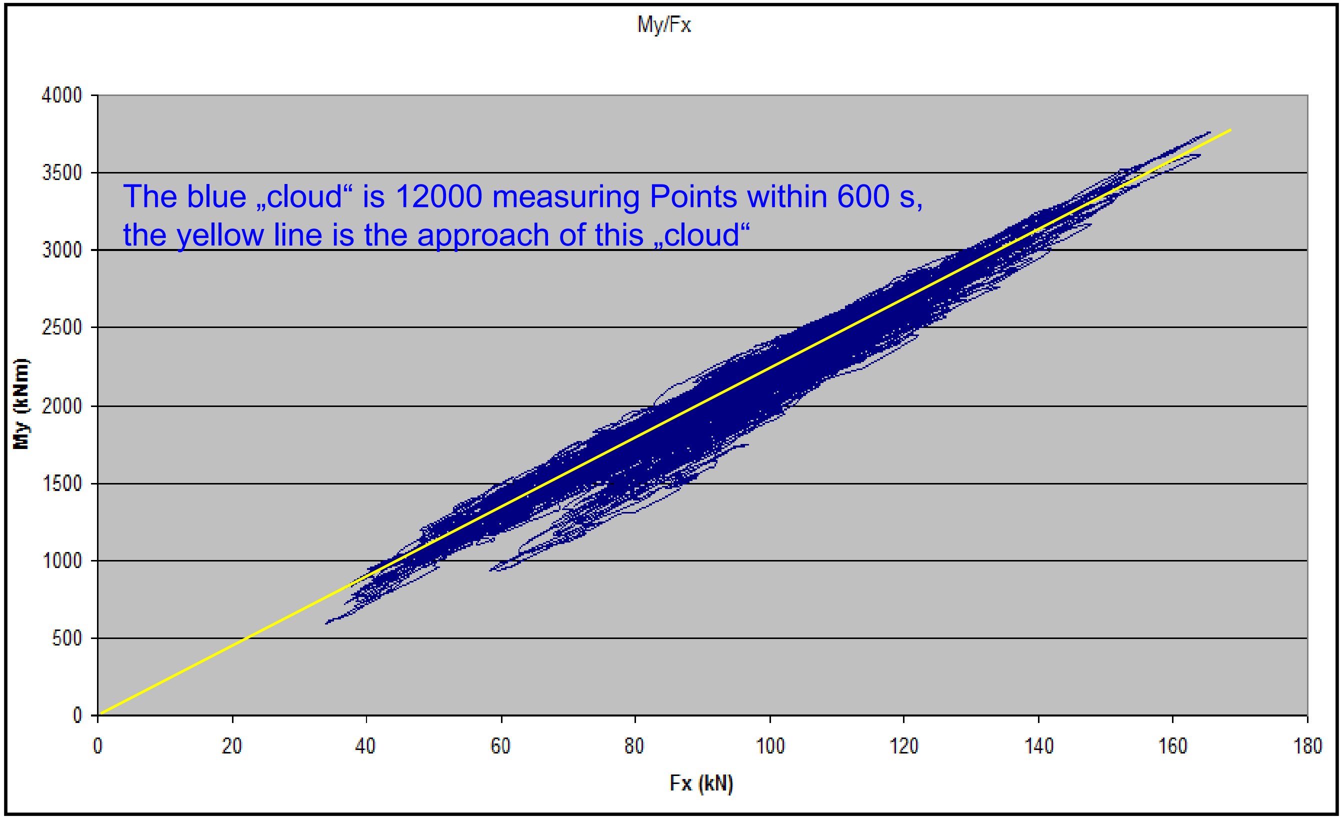
Speeds and Forces at blade segment

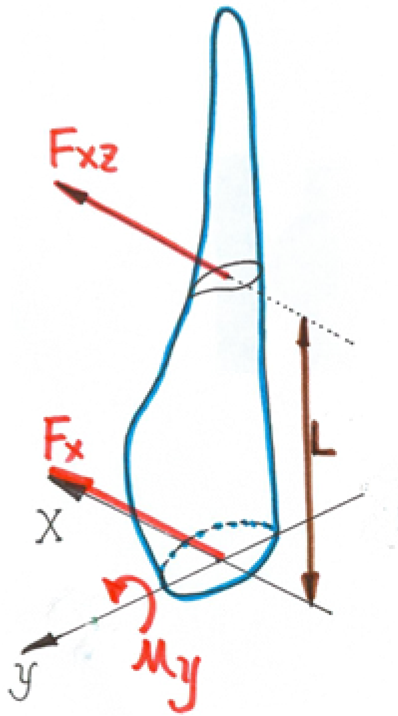


w:	Wind speed
u:	rotation speed
c:	resultant of w and u
α:	Angle of attack
δ:	Angle of setting
F_L:	Lifting force
F_D:	Drag force
F_{cyl}:	actuator force, resultant of F_L and F_D
α_z:	angle between cylinder and wind direction

Only one Force F_{xz} per Blade at Distance L

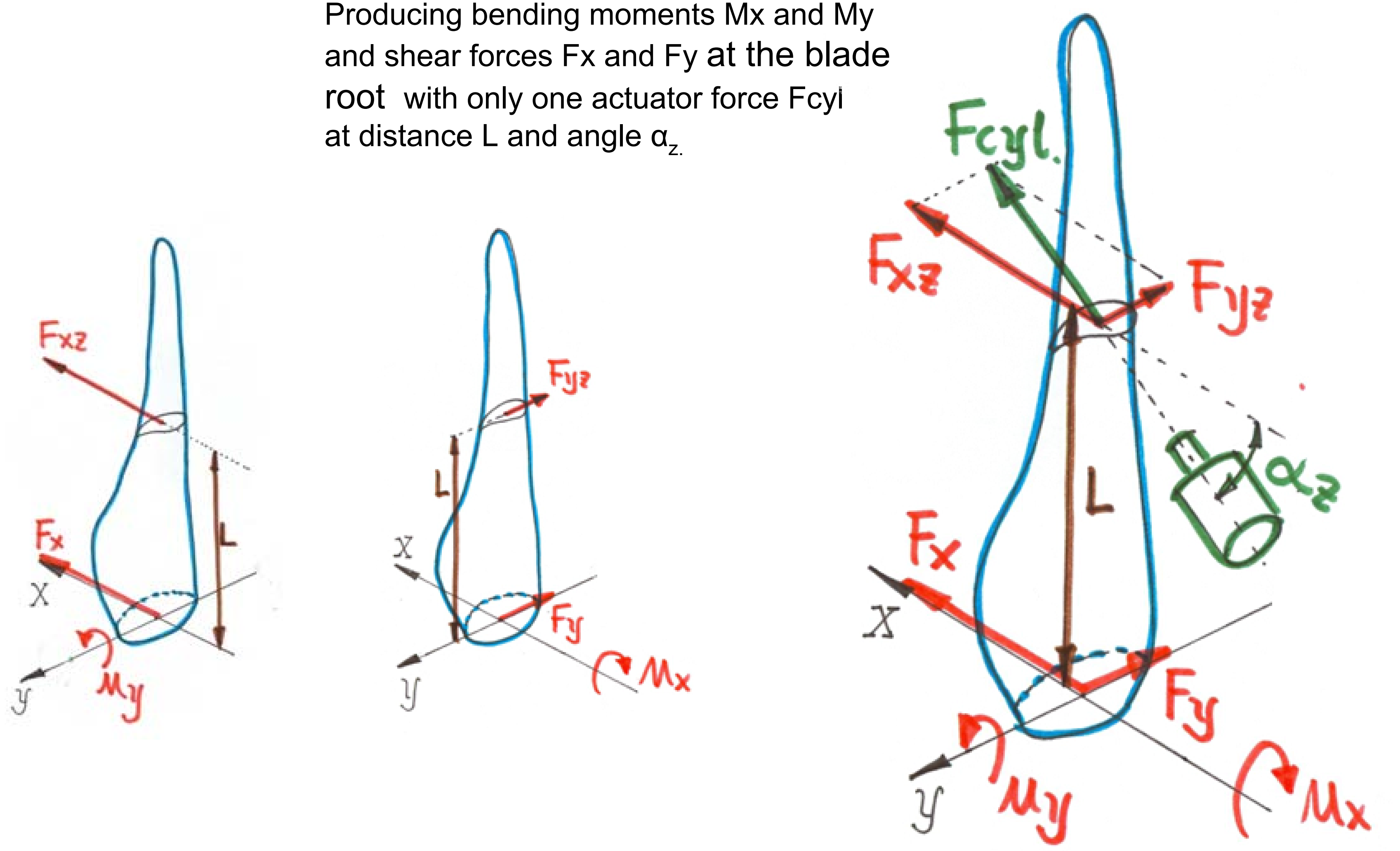
Production Loads My versus Fx at the Blade Root for a 2.5 MW Wind Turbine with 103 m Rotor Diameter at 10 m/s Wind Speed.



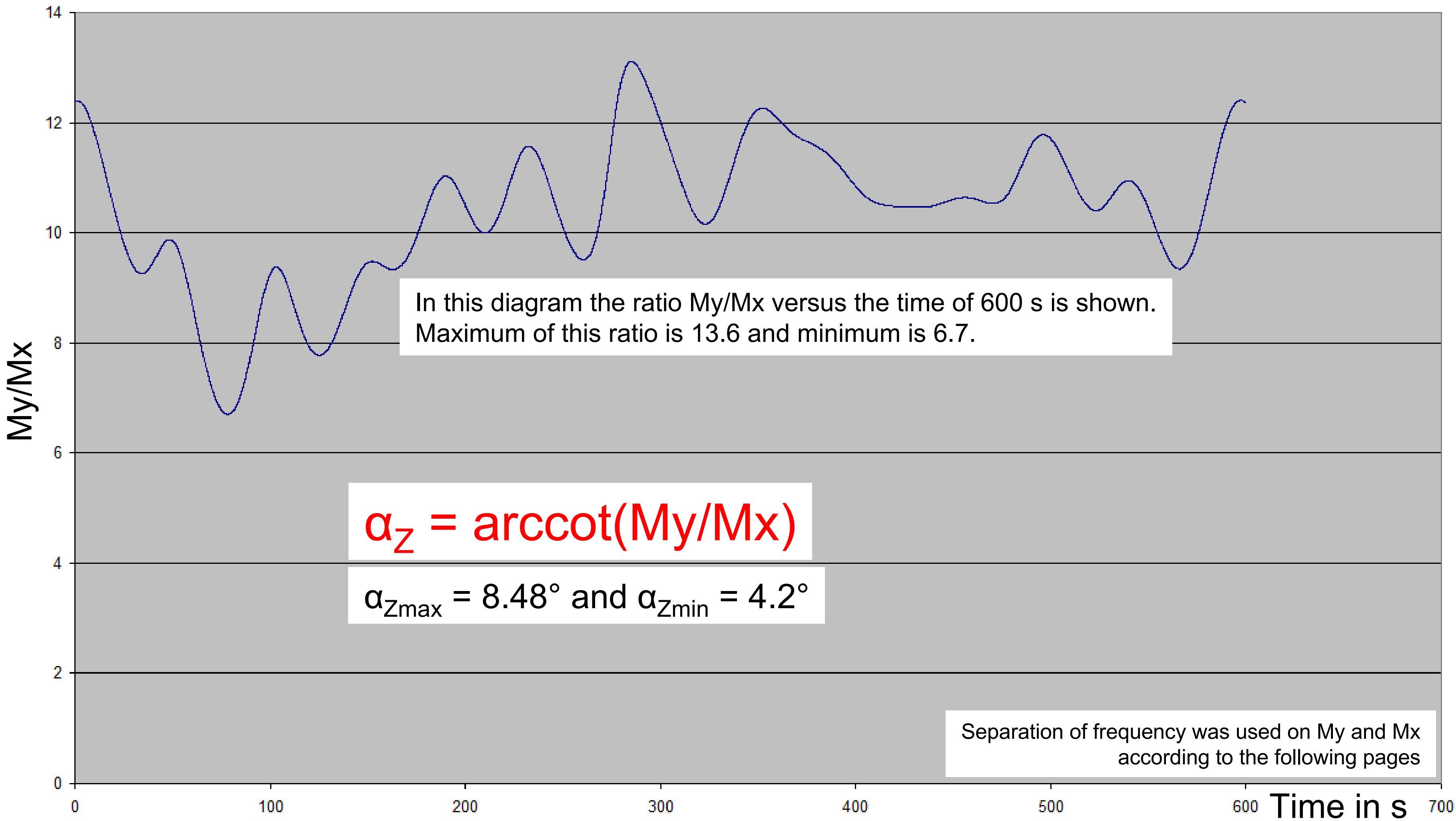


Only one actuator at distance L

Producing bending moments Mx and My and shear forces Fx and Fy at the blade root with only one actuator force Fcyl at distance L and angle α_z.

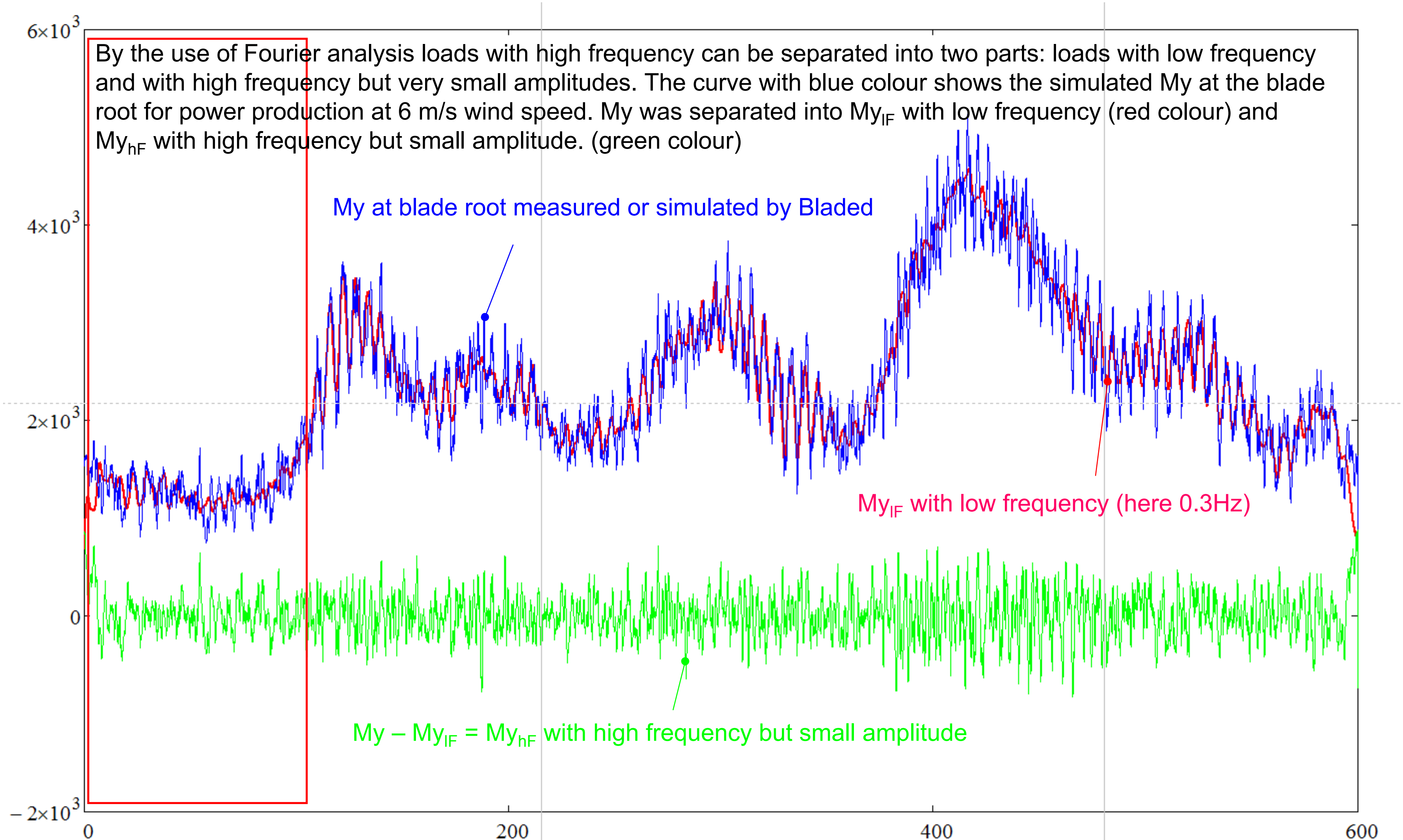


Ratio My/Mx at the Blade Root

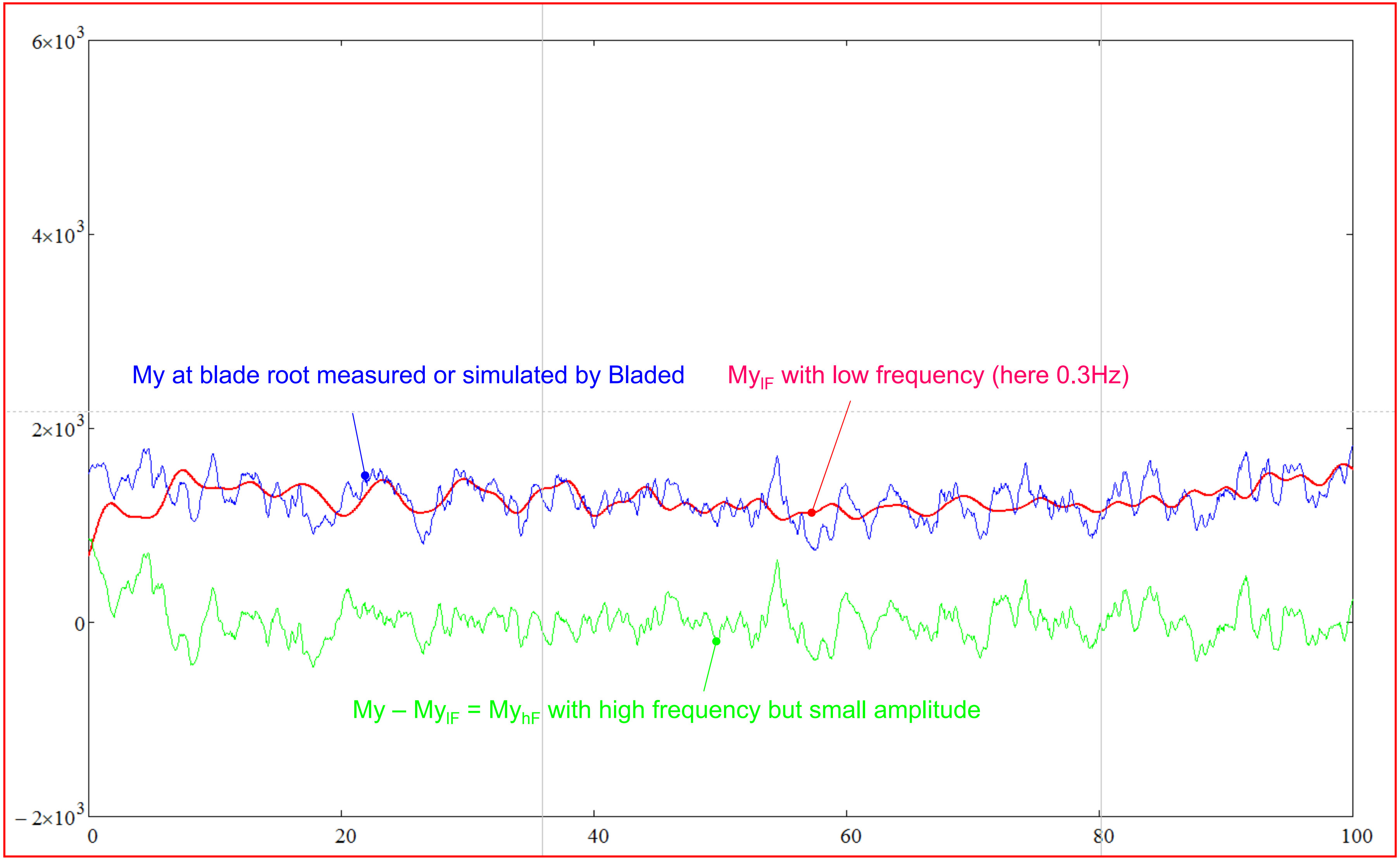


Separation My by frequencies

By the use of Fourier analysis loads with high frequency can be separated into two parts: loads with low frequency and with high frequency but very small amplitudes. The curve with blue colour shows the simulated My at the blade root for power production at 6 m/s wind speed. My was separated into My_{lF} with low frequency (red colour) and My_{hF} with high frequency but small amplitude. (green colour)



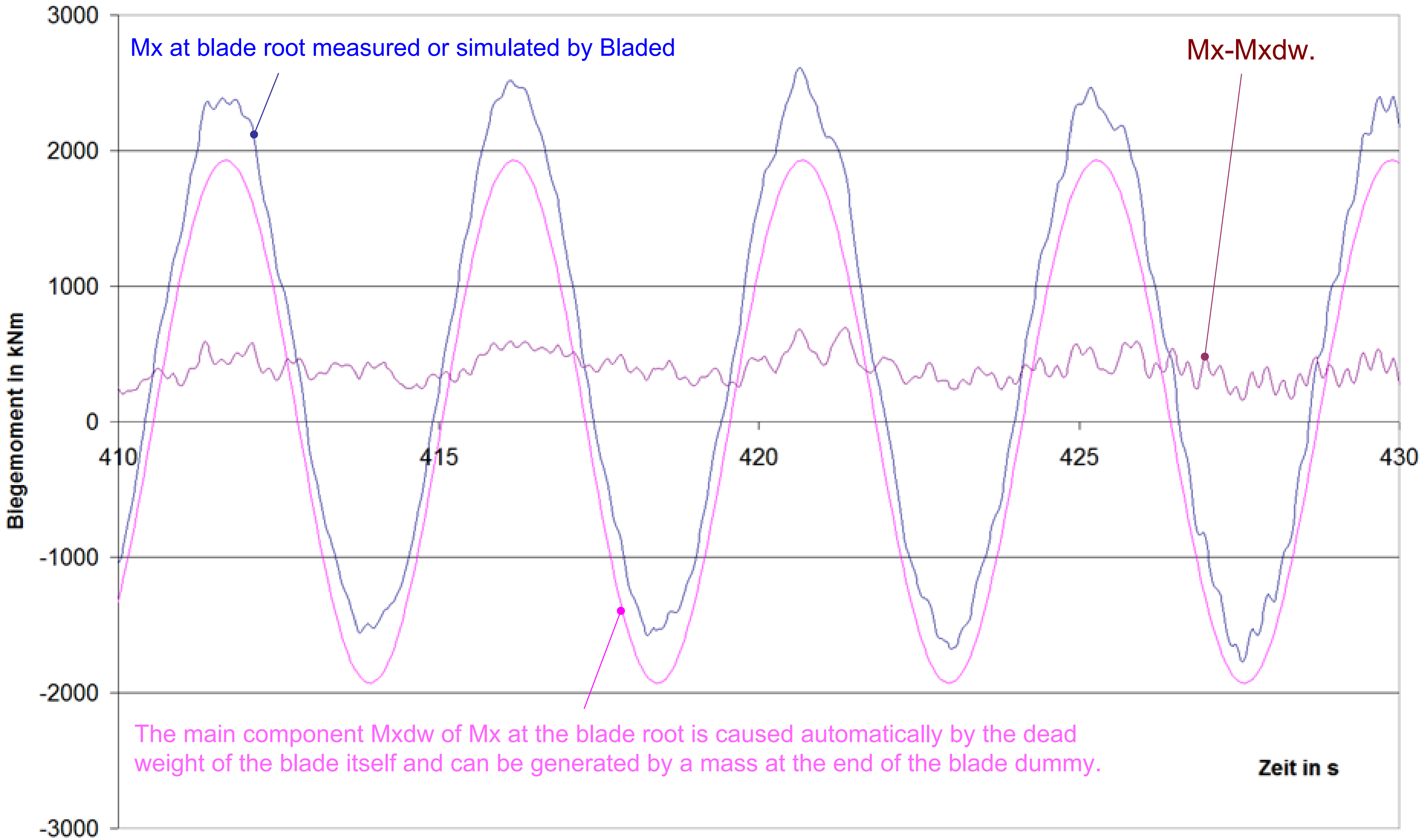
Separation My by frequencies



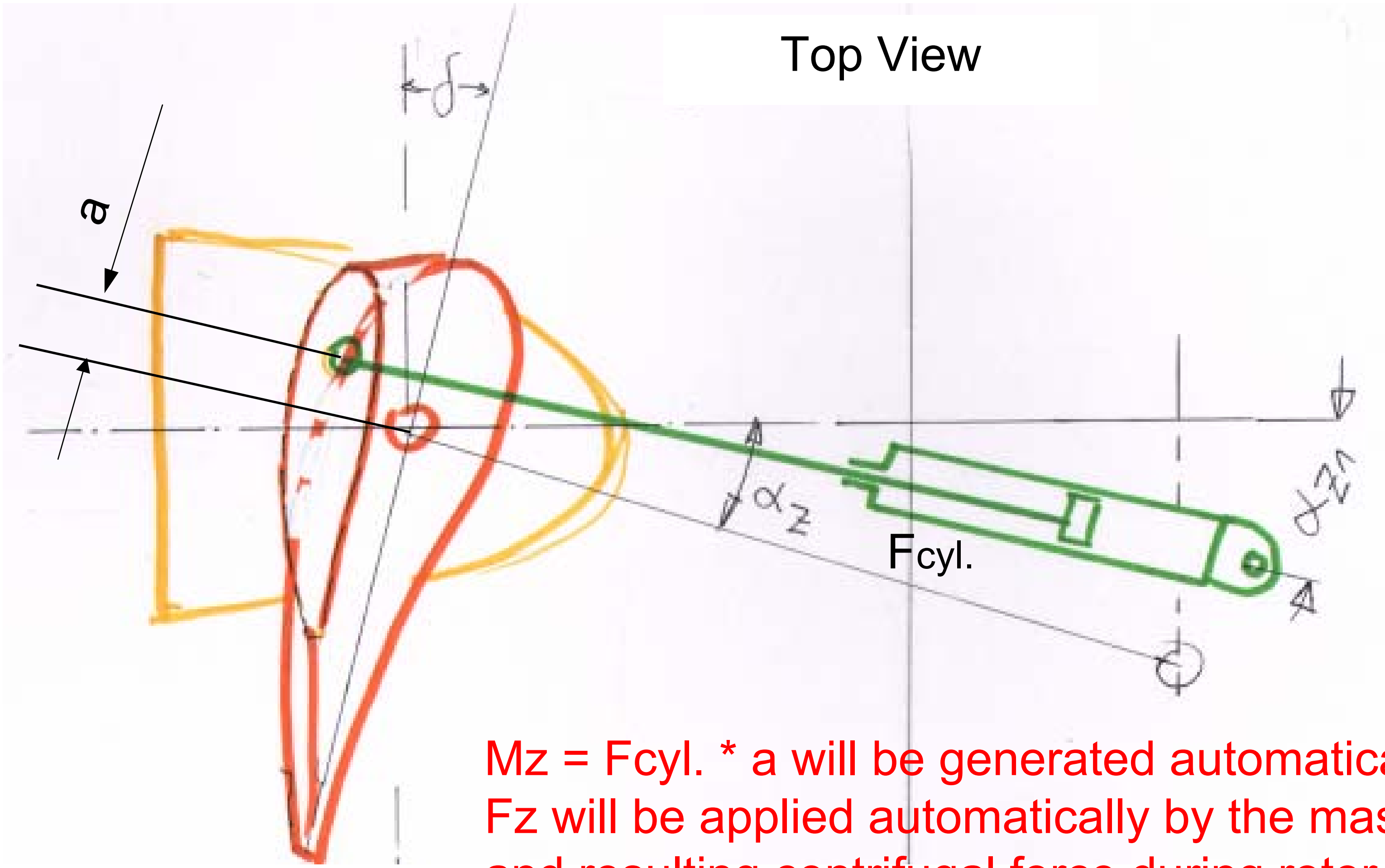
Separation Mx by frequencies

The curve with blue colour shows Mx at the blade root for power production with 6 m/s wind speed.

Separation Mx by frequencies

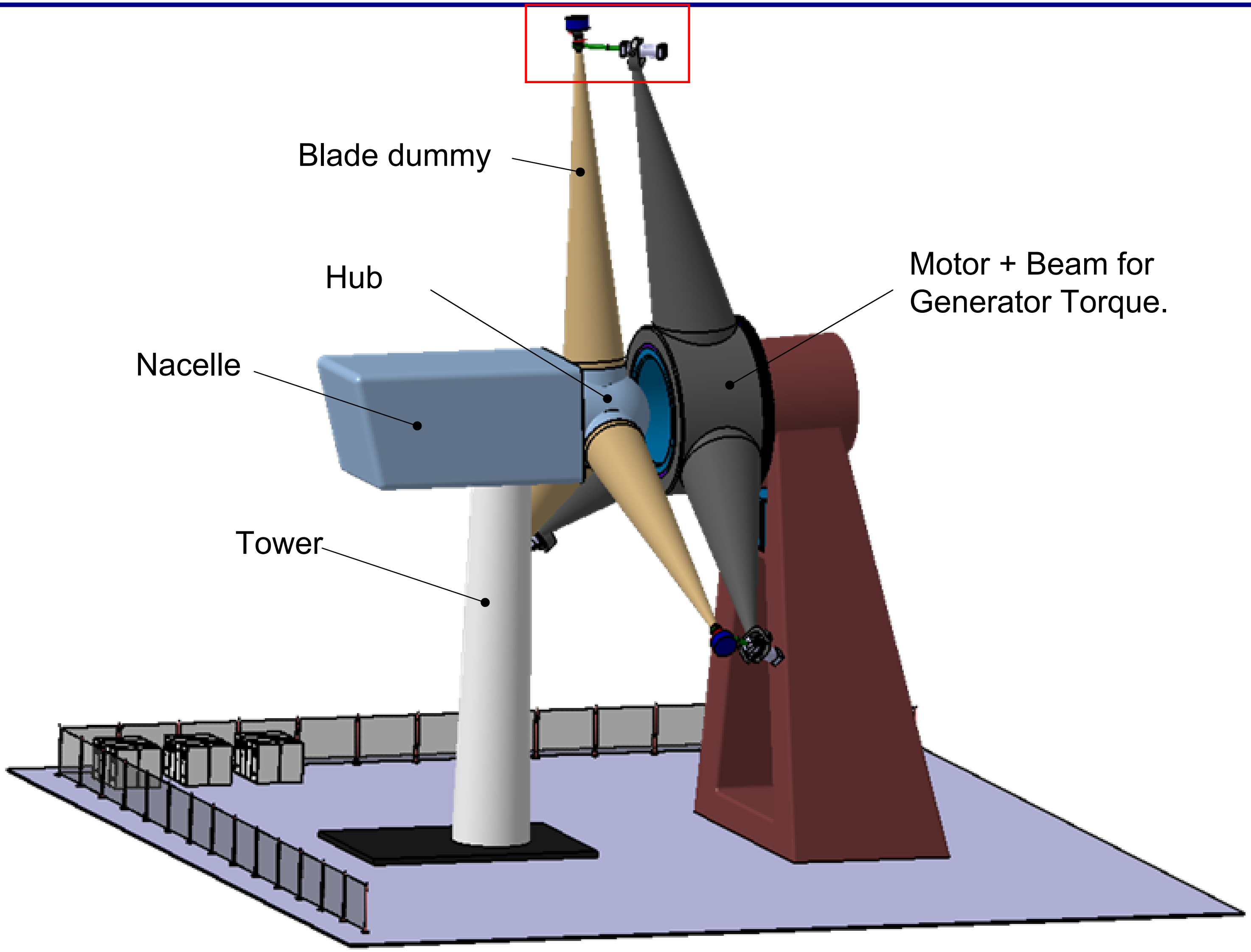


Generation Fz and Mz at the blade root



Mz = Fcyl. * a will be generated automatically
Fz will be applied automatically by the mass
and resulting centrifugal force during rotor rotation

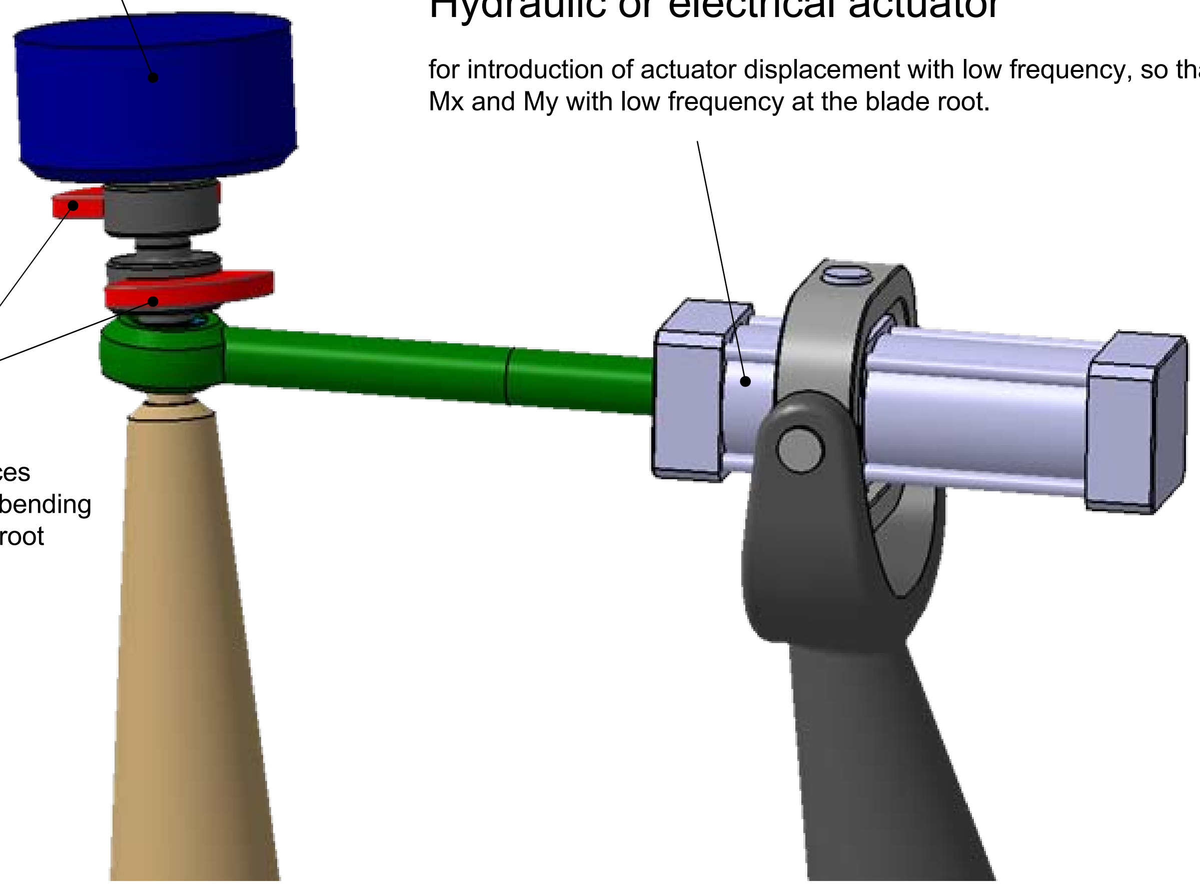
Testing Rig Configuration



Load Introduction on Blade Dummy

Mass

Generate together with blade dummy Mxdw at the blade root



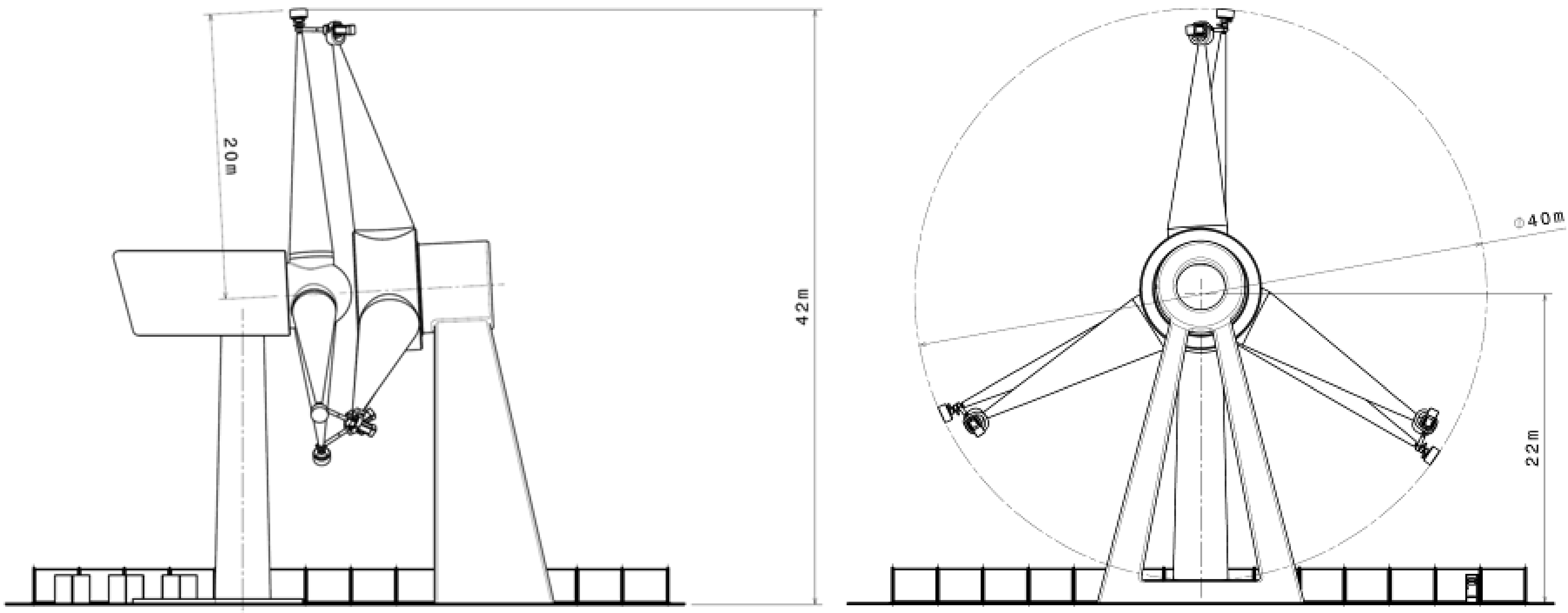
Hydraulic or electrical actuator

for introduction of actuator displacement with low frequency, so that also Mx and My with low frequency at the blade root.

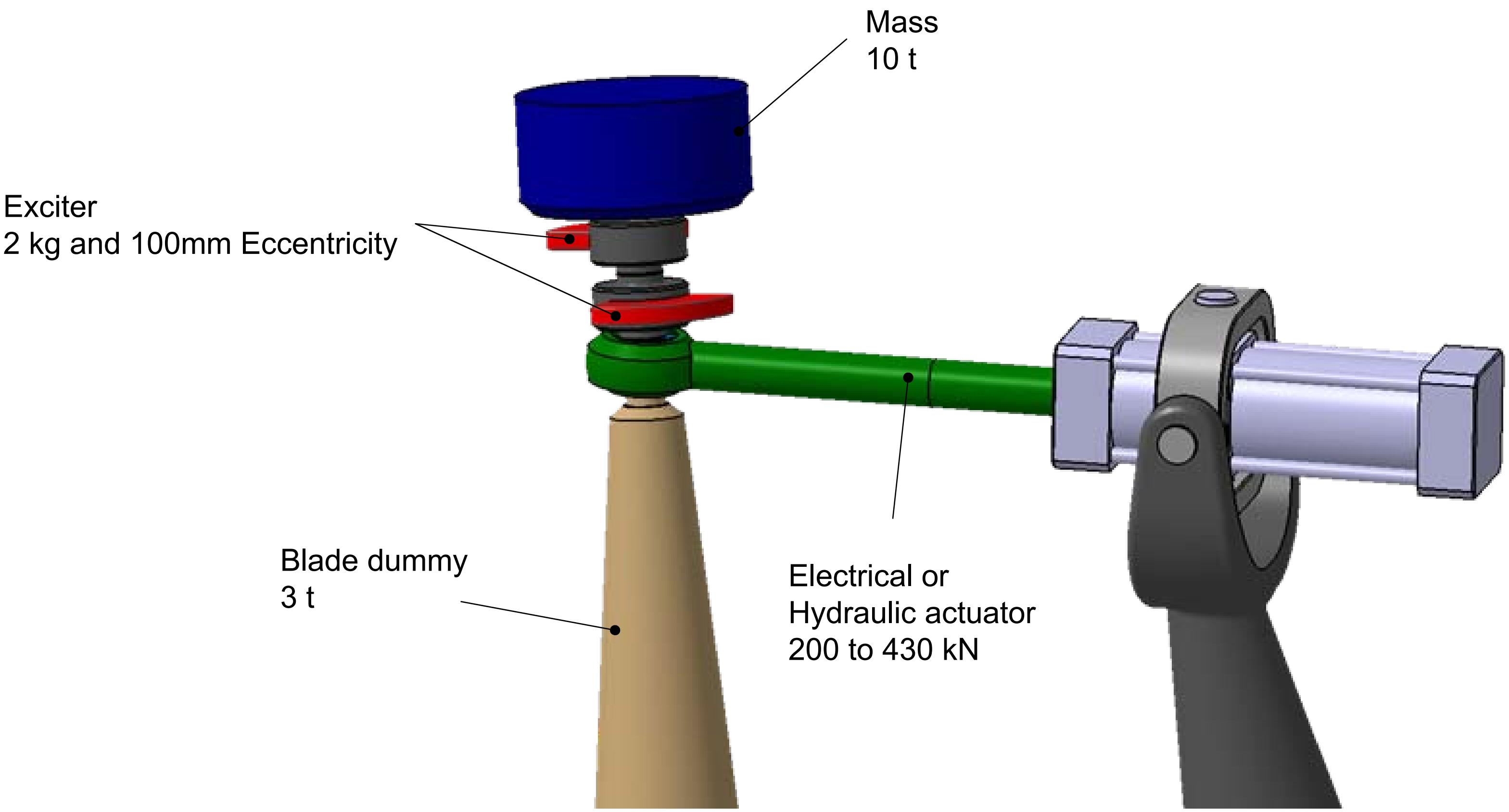
Exciter

For introduction of stochastic forces with high frequency, so that also bending moment Mx and My at the blade root with high frequency.

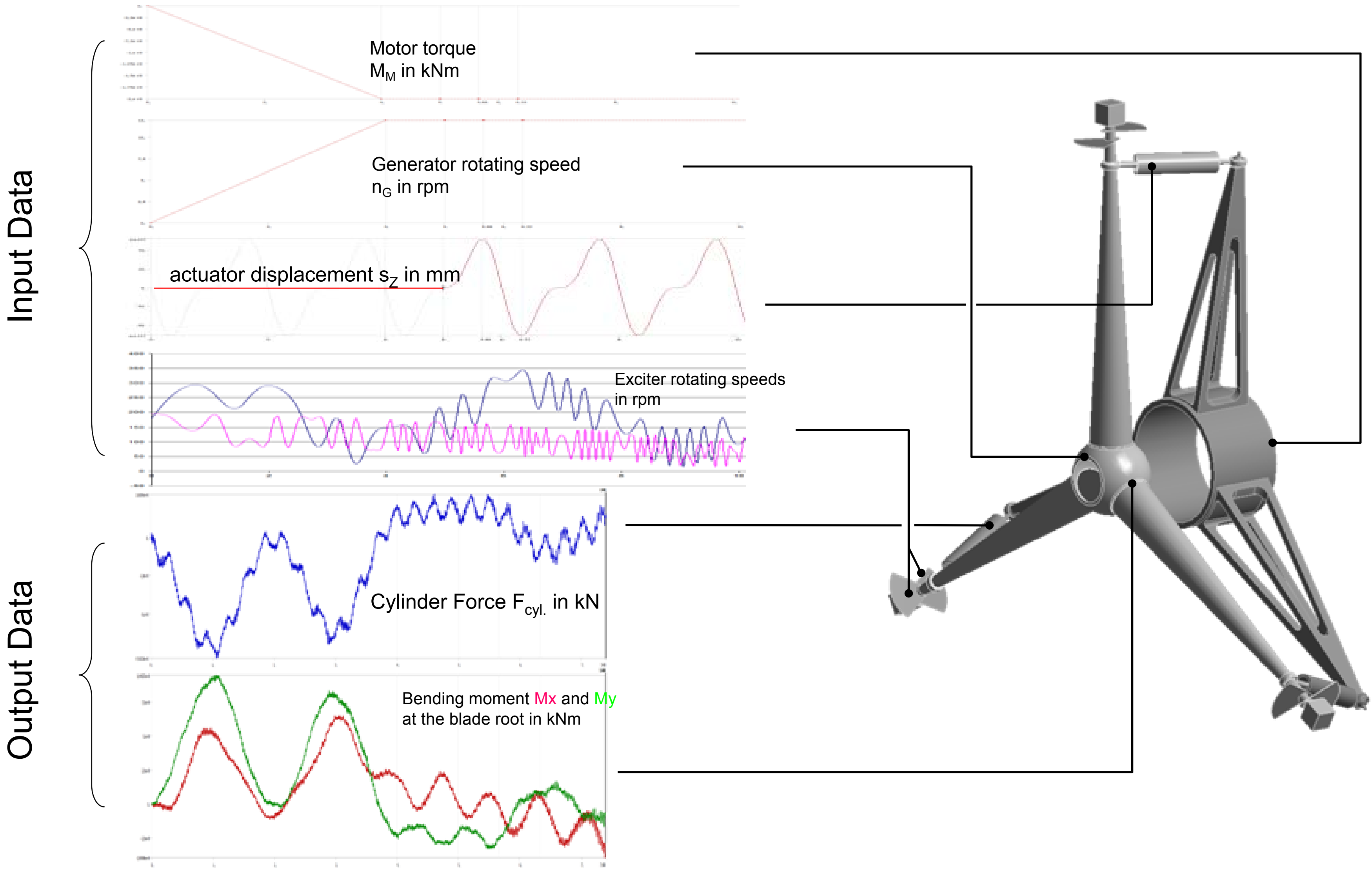
Dimension of the testing rig for 2,5 bis 4 MW



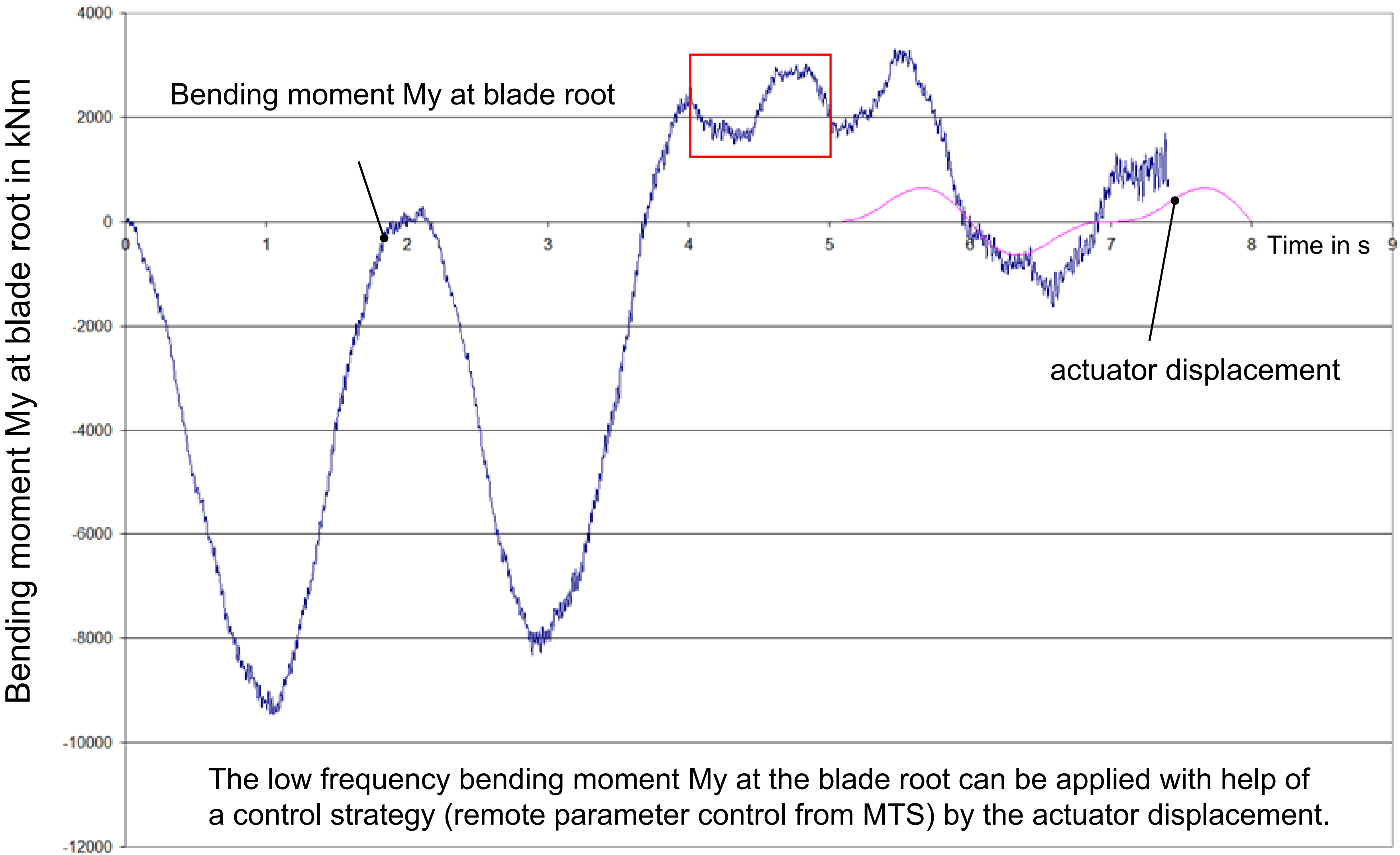
Masses


Mass
10 t
Exciter
2 kg and 100mm Eccentricity
Blade dummy
3 t
Electrical or
Hydraulic actuator
200 to 430 kN

Input and output data for the testing rig simulation

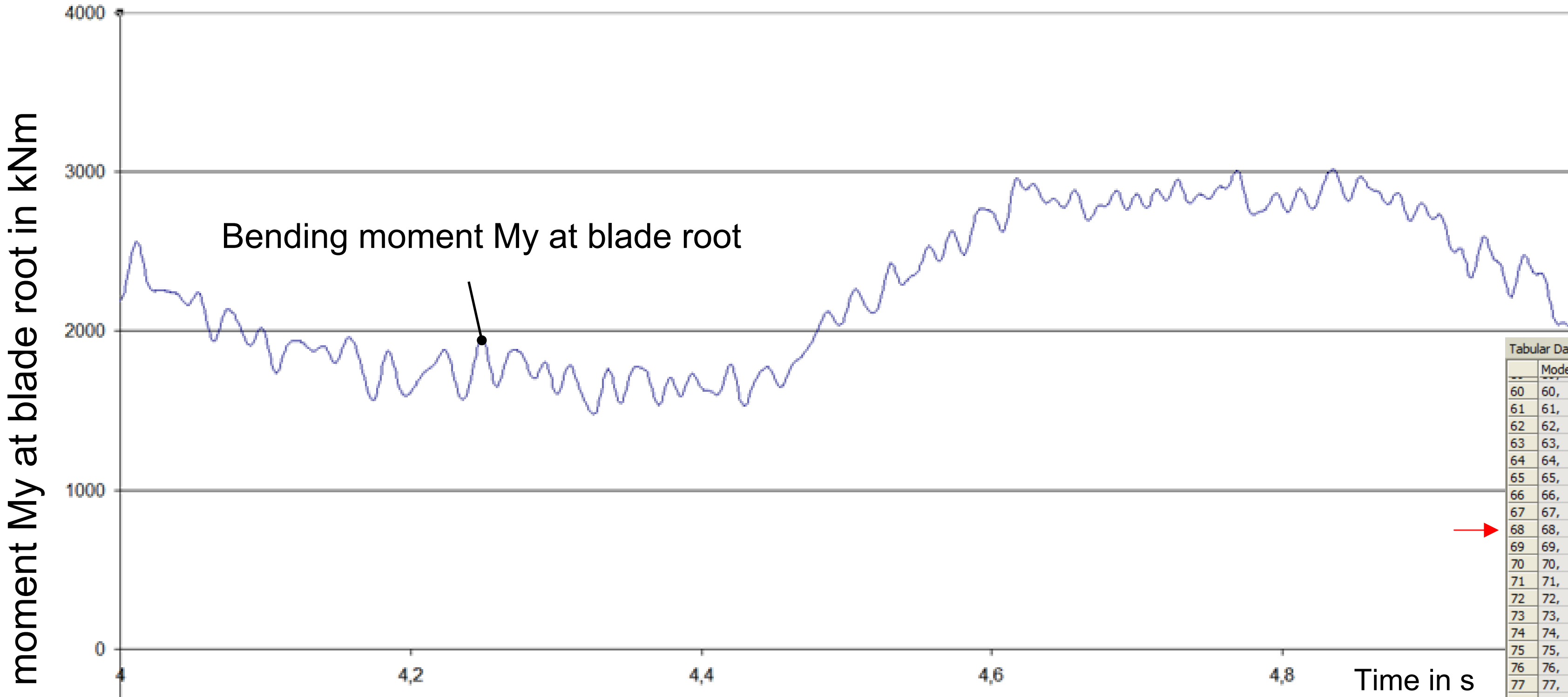


Simulation with actuator displacement +/- 140 mm and exciter excitation – output data



The low frequency bending moment My at the blade root can be applied with help of a control strategy (remote parameter control from MTS) by the actuator displacement.

Simulation with actuator displacement +/- 140 mm and exciter excitation – output data



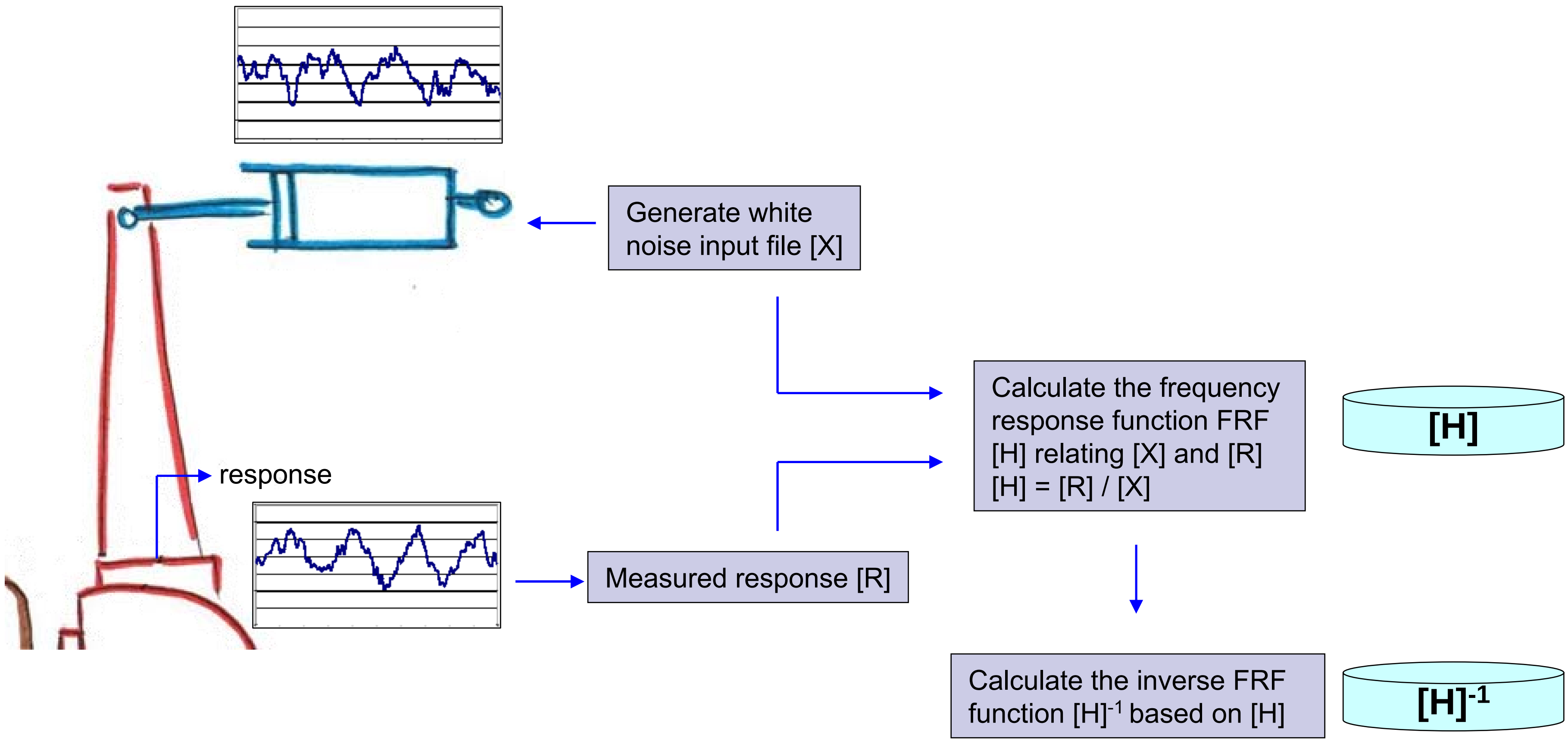
The bending moment My with high frequency has a frequency of 57 Hz, which complies with the 68th Eigen frequency of the whole testing system. (see red arrow)

It was introduced by the exciter and the frequency by the Eigen frequency of the whole testing system.

Tabular Data

	Mode	Frequency [Hz]
60	60,	43,479
61	61,	44,865
62	62,	45,001
63	63,	45,996
64	64,	46,628
65	65,	47,399
66	66,	49,295
67	67,	54,847
68	68,	57,225
69	69,	57,918
70	70,	63,426
71	71,	63,821
72	72,	64,25
73	73,	69,337
74	74,	74,863
75	75,	75,641
76	76,	75,875
77	77,	75,954
78	78,	76,368
79	79,	78,647
80	80,	79,674
81	81,	80,505
82	82,	81,824
83	83,	82,101
84	84,	82,128
85	85,	83,209
86	86,	83,23
87	87,	83,893
88	88,	84,712
89	89,	86,815
90	90,	86,841
91	91,	87,26
92	92,	87,455

System identification using Remote Parameter Control*

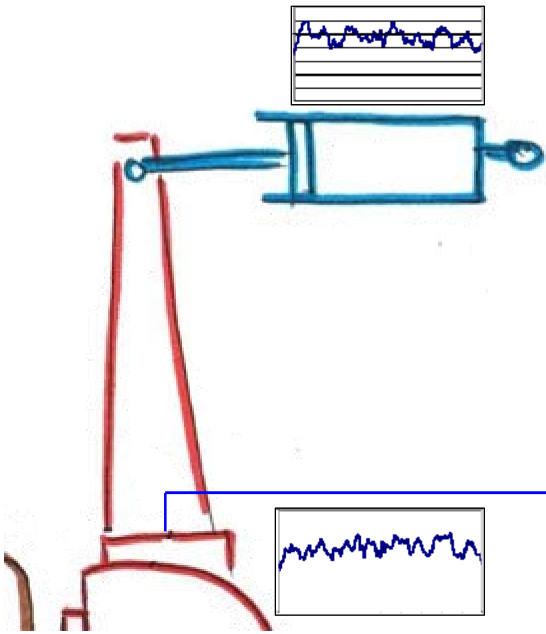


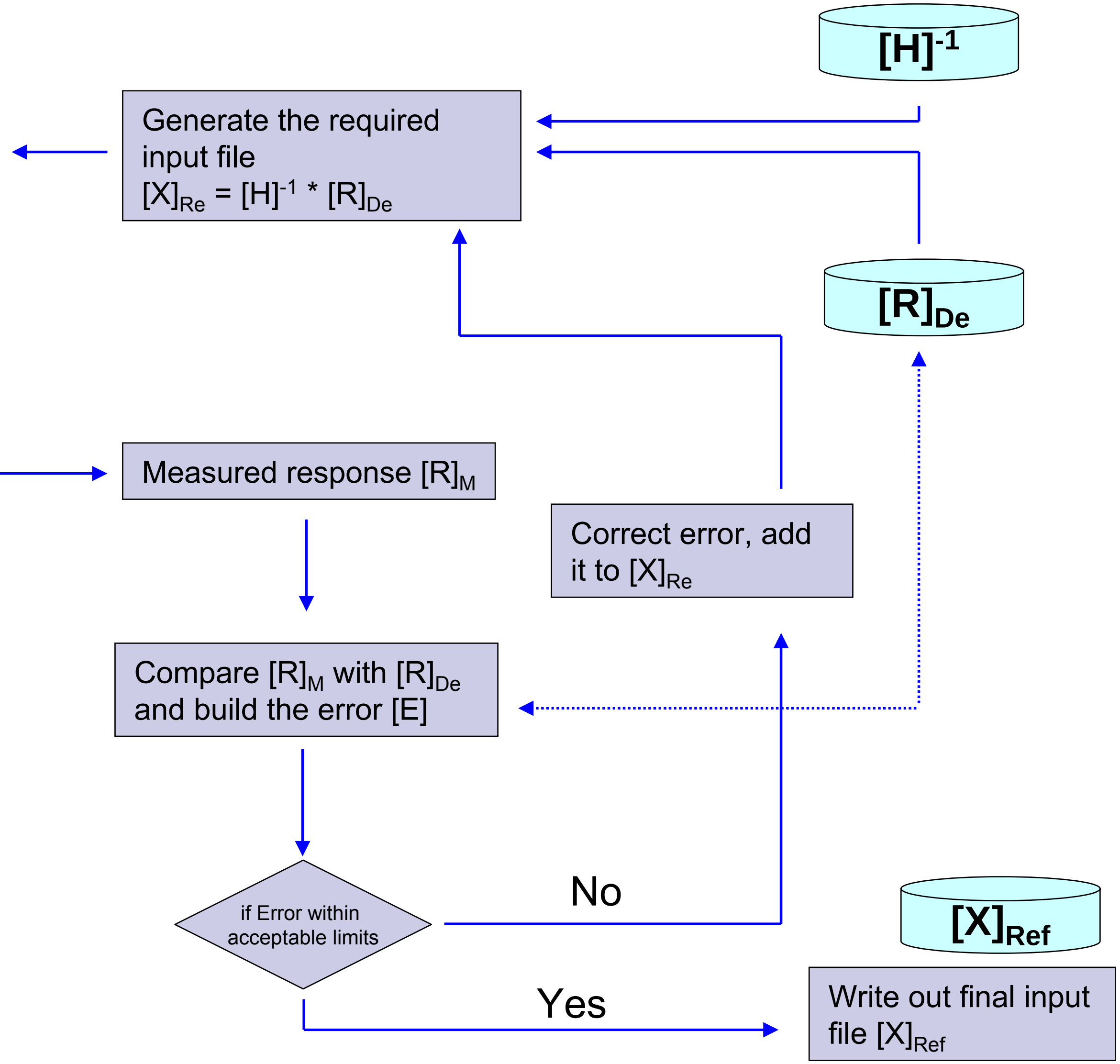
*: trade mark by

MTS systems corporation

Minneapolis USA

Iterative Generation Reference input Values with remote parameter control RPC*





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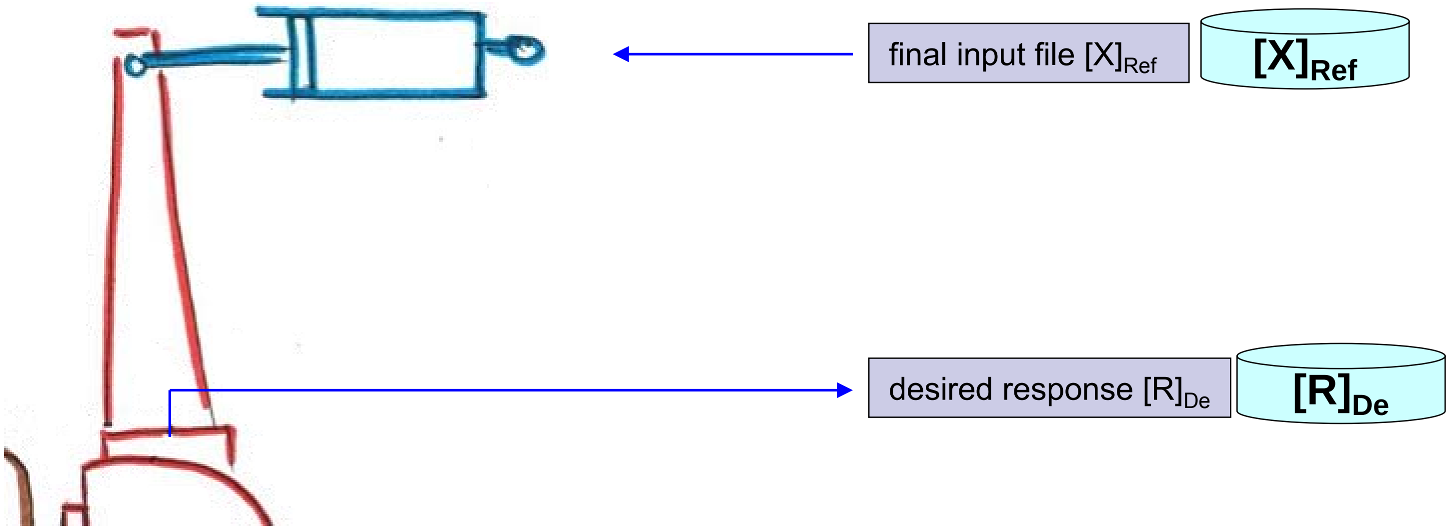
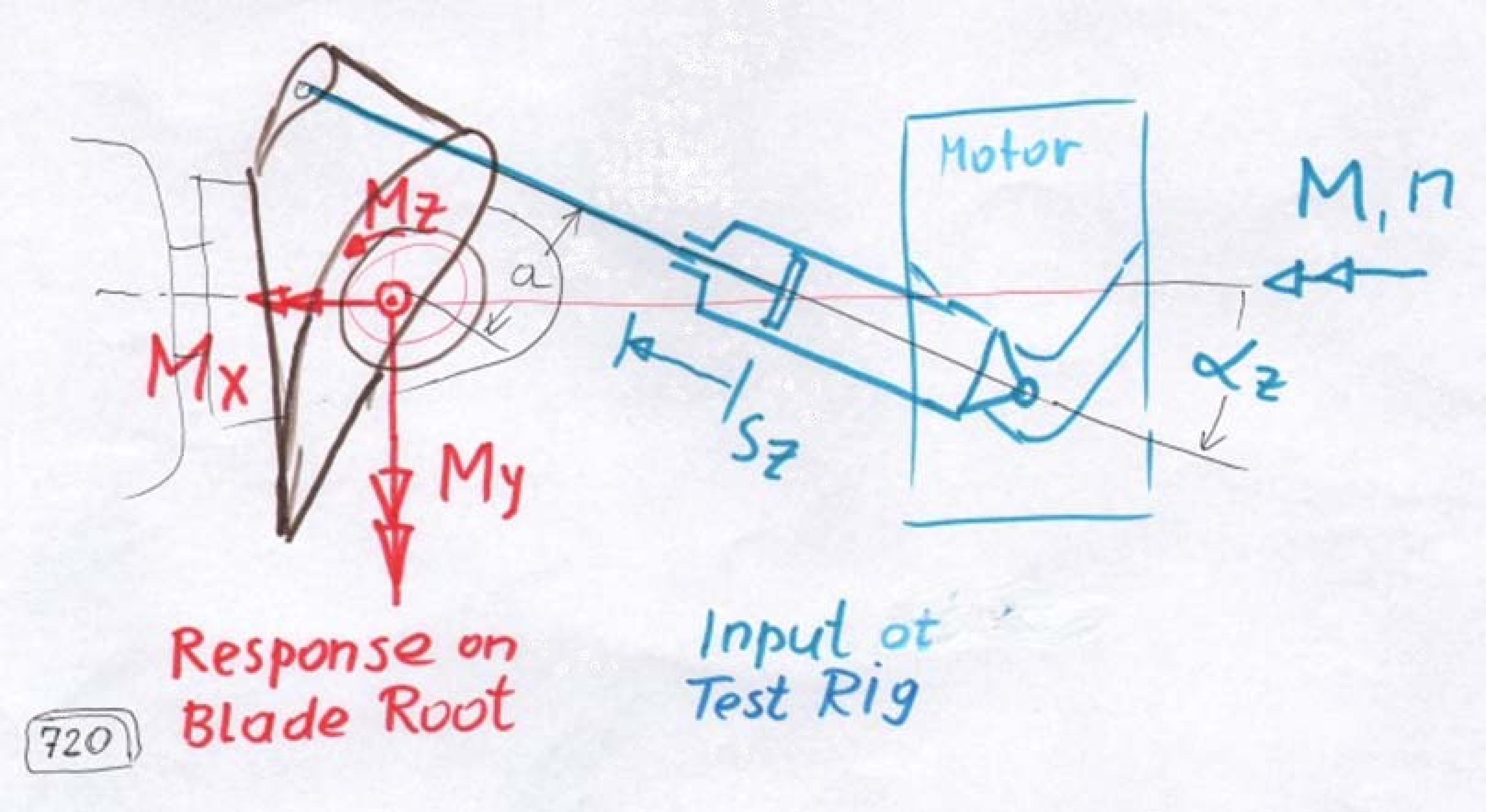
Drive the testing rig with input file $[X]_{Ref}$

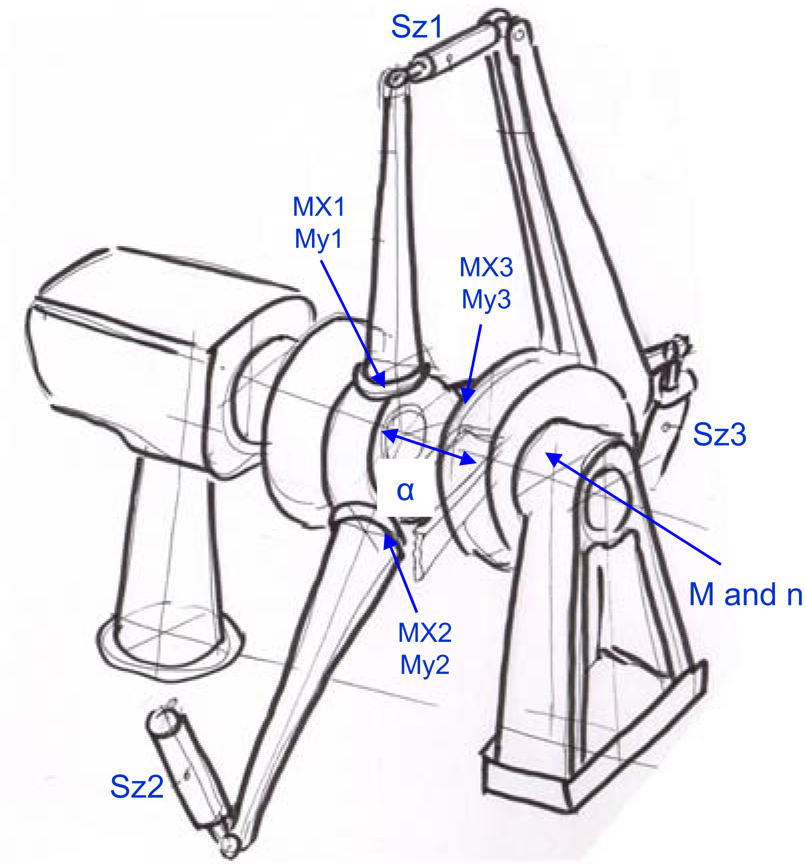


The final input file $[X]_{Ref}$ is used to perform the test by reproducing loads for several design load cases and repeating according their occurrence in the turbine life time.

Input and response Data for the turbine testing rig



Generation of reference values for input files [X] with inverse transfer functions $[H]^{-1}$



Required Input file [X]

Desired Response [R]

	Sz1	Sz2	Sz3	M	n	α_Z
Mx1	H_{11}	H_{12}	H_{13}	H_{14}	H_{15}	H_{16}
My1	H_{21}	H_{22}	H_{23}	H_{24}	H_{25}	H_{26}
Mx2	H_{31}	H_{32}	H_{33}	H_{34}	H_{35}	H_{36}
My2	H_{41}	H_{42}	H_{43}	H_{44}	H_{45}	H_{46}
Mx3	H_{51}	H_{52}	H_{53}	H_{54}	H_{55}	H_{56}
My3	H_{61}	H_{62}	H_{63}	H_{64}	H_{65}	H_{66}

transfer functions [H]

$Sz1 = Mx1 * H_{11}^{-1} + My1 * H_{21}^{-1} + Mx2 * H_{31}^{-1} + My2 * H_{41}^{-1} + Mx3 * H_{51}^{-1} + My3 * H_{61}^{-1}$

Sz2=…..

…

…

Generation Reference Values from field measurements