Bilbao Marine Energy Week 2015

Impact of Tower Top weight on the cost of the support structure

Túpac Canosa Díaz
Solute Ingenieros

Tower Top Mass Impact on Support Structure Cost

Reducing the mass of the components on the tower top **not only influence** the cost of the component it self, but also elements like tower or foundation/substructure will receive a big impact on their cost as well.

So, not only the generator's weights are at stake.

Tower Top Mass Impact on Support Structure Cost

An important issue to bear in mind is the resonance frequency for the system in principle the mode 1 frequency of the system shall be above the rotor frequency by a factor of about 20 %

The increase of tower top weight reduces the frequency.

If we have two turbines with the same power, the same rotor and the same operational conditions and different drive trains one heavier than the other, the heavier one will require a heavier tower in order to keep the frequency constrain.

For example: 10 MW, rotor radius of 190m, rated rotor speed of 8,5 rmp

Tower top mass 1: **1064 Ton**

Tower top mass 2: **1167 Ton**

Frequency constrain: 0,17 Hz

Tower and sub structure Mass 1: **1070 Ton**

Tower and sub structure Mass 2: **1210 Ton**

Tower Top Mass Impact on Support Structure Cost

		TT mass [Ton]	
		1167	1064
		0%	-9%
Tower Mass 1 [Ton]	1210	0%	
Tower Mass 2 [Ton]	1070		-12%

Influence of tower top mass on the inertial loads acting on the tower and foundation/substructure

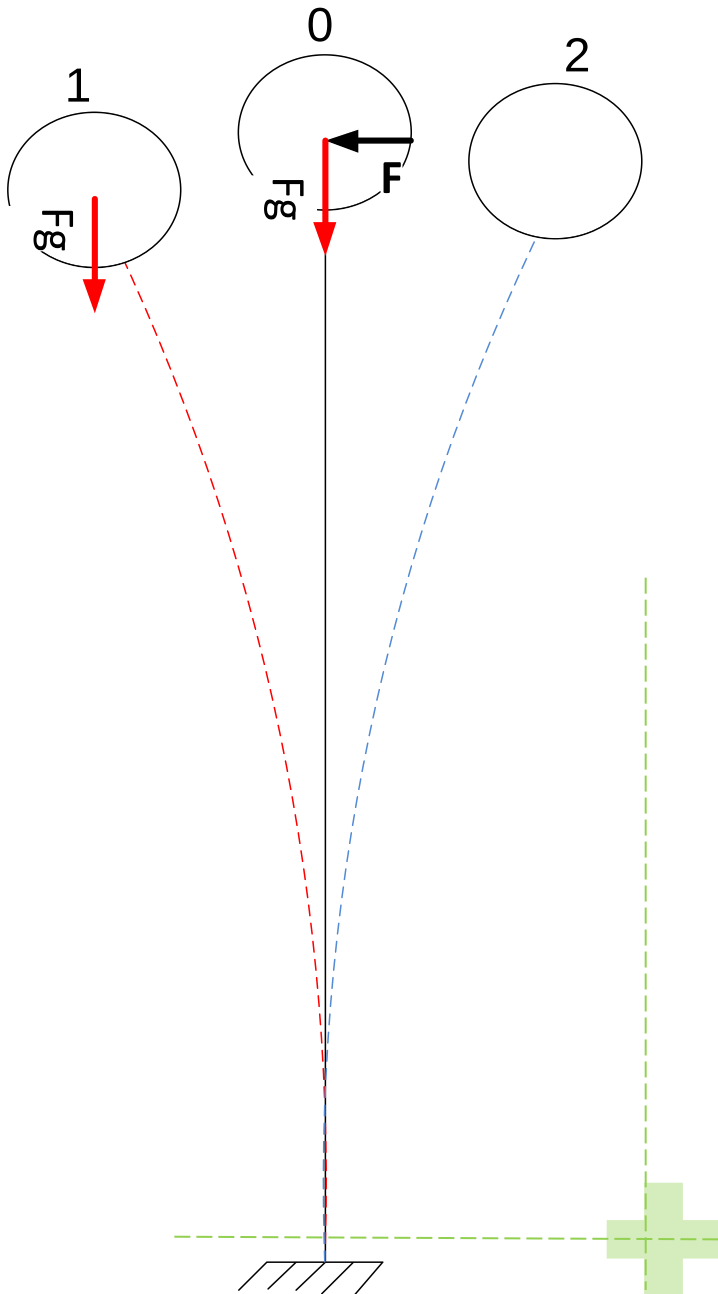
The bigger the tower head mass the bigger the tower and foundation mass

Tower Top Mass Impact on Support Structure Cost

Simplifying the problems to the limits:
We have a kind of pendulum that under the load F will bend backward.

If the load F is removed suddenly the head will accelerate forward crossing the point 0 and following to point 2. Stopping the head mass on 2 requires a big load on tower, the bigger the head mass the bigger the loads.

Moreover: once the body is off center, the gravity starts producing extra bending moment.



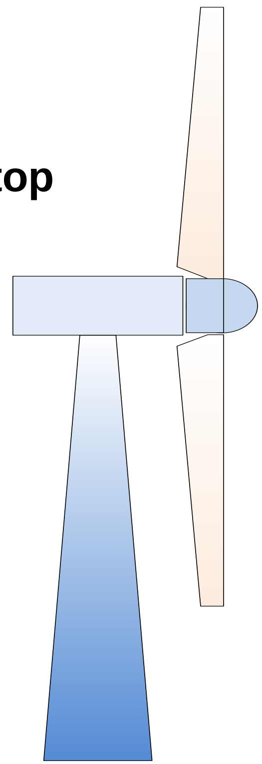
Tower Top Mass Impact on Support Structure Cost

We will illustrate the idea trough some examples:

Estimate the loads at tower bottom for three different towers with the same top mass and under the same circumstances:

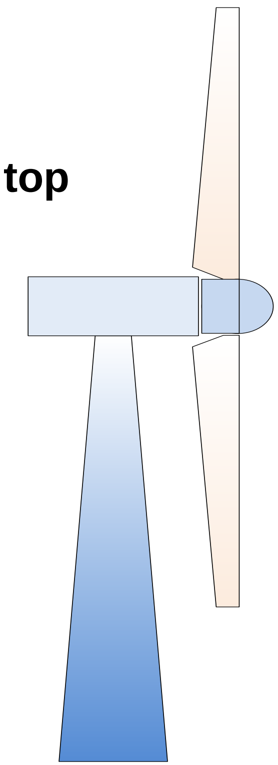
Operation at 14 m/s wind and an emergency stop

Tower top mass:
500 t



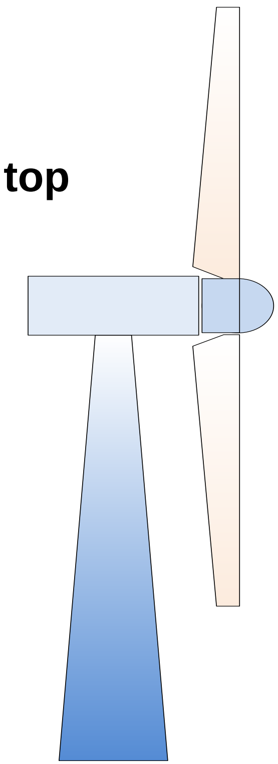
Tower 1:
heaviest

Tower top mass:
500 t



Tower 2:
lighter

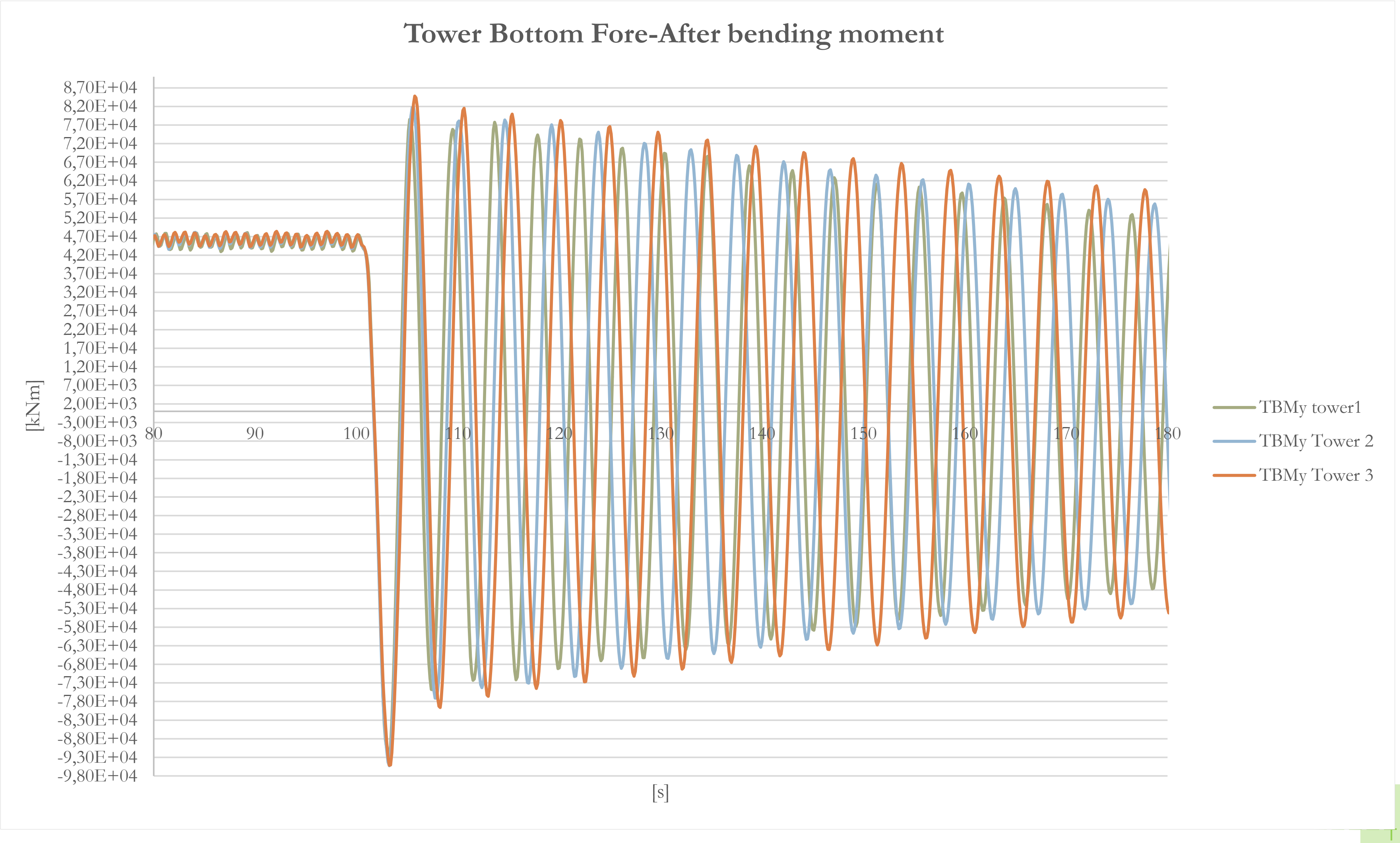
Tower top mass:
500 t



Tower 3:
lightest

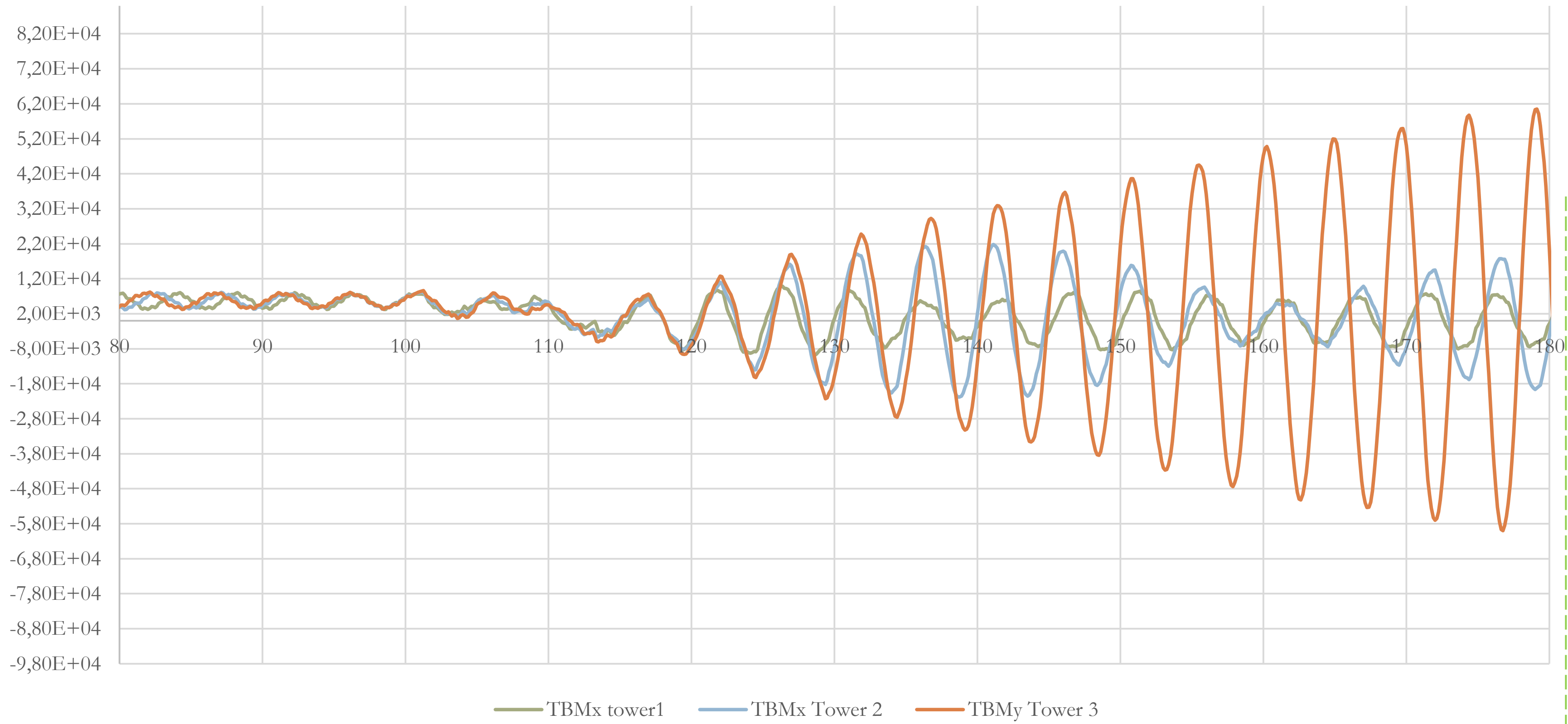
Tower Top Mass Impact on Support Structure Cost

The simulation shows that the loads will rise when the tower weight is reduced. So in principle we cannot reduce the tower weight without reducing nacelle mass. The reason is in this case are the inertial loads due to the movement of the tower head.



Tower Top Mass Impact on Support Structure Cost

Tower Bottom Side to Side bending moment



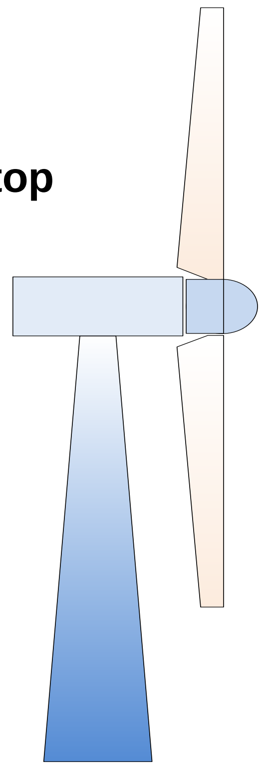
Tower Top Mass Impact on Support Structure Cost

We will illustrate the idea trough some examples:

Estimate the loads at tower bottom for the same towers with different top mass and under the same circumstances:

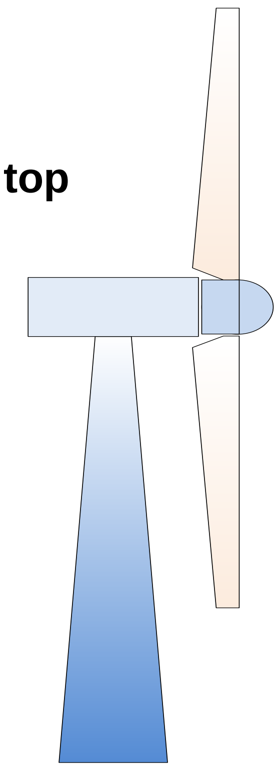
Operation at 14 m/s wind and an emergency stop

Tower top mass:
500 t



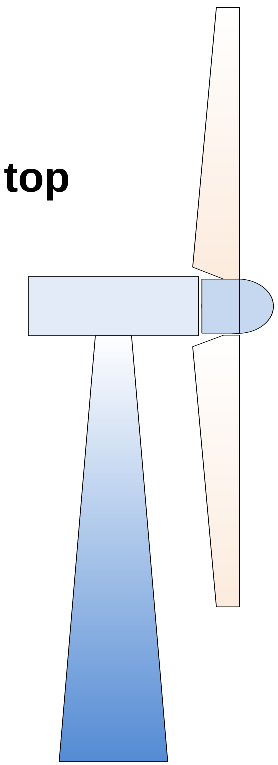
Tower 3:
lightest

Tower top mass:
450 t



Tower 3:
lightest

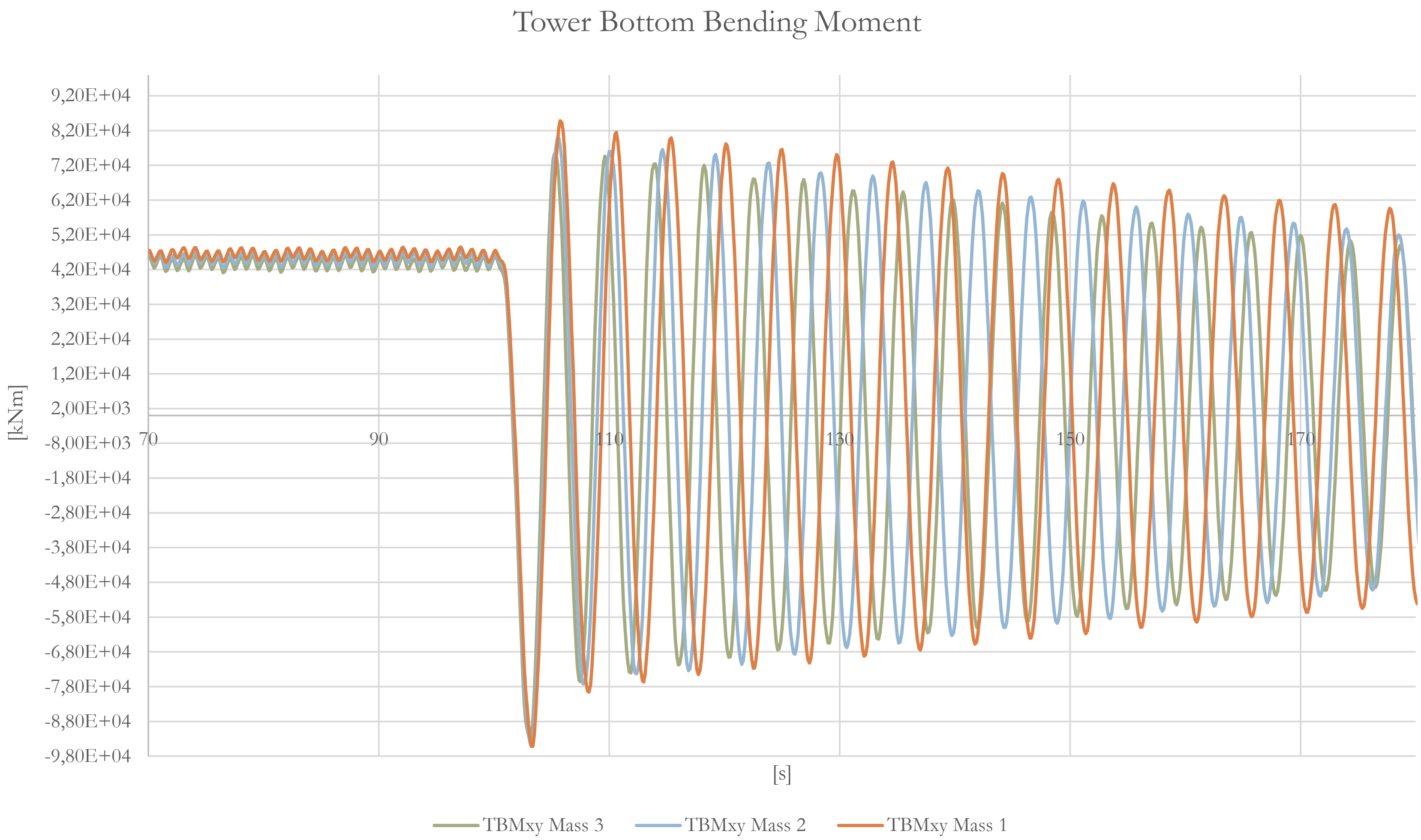
Tower top mass:
400 t



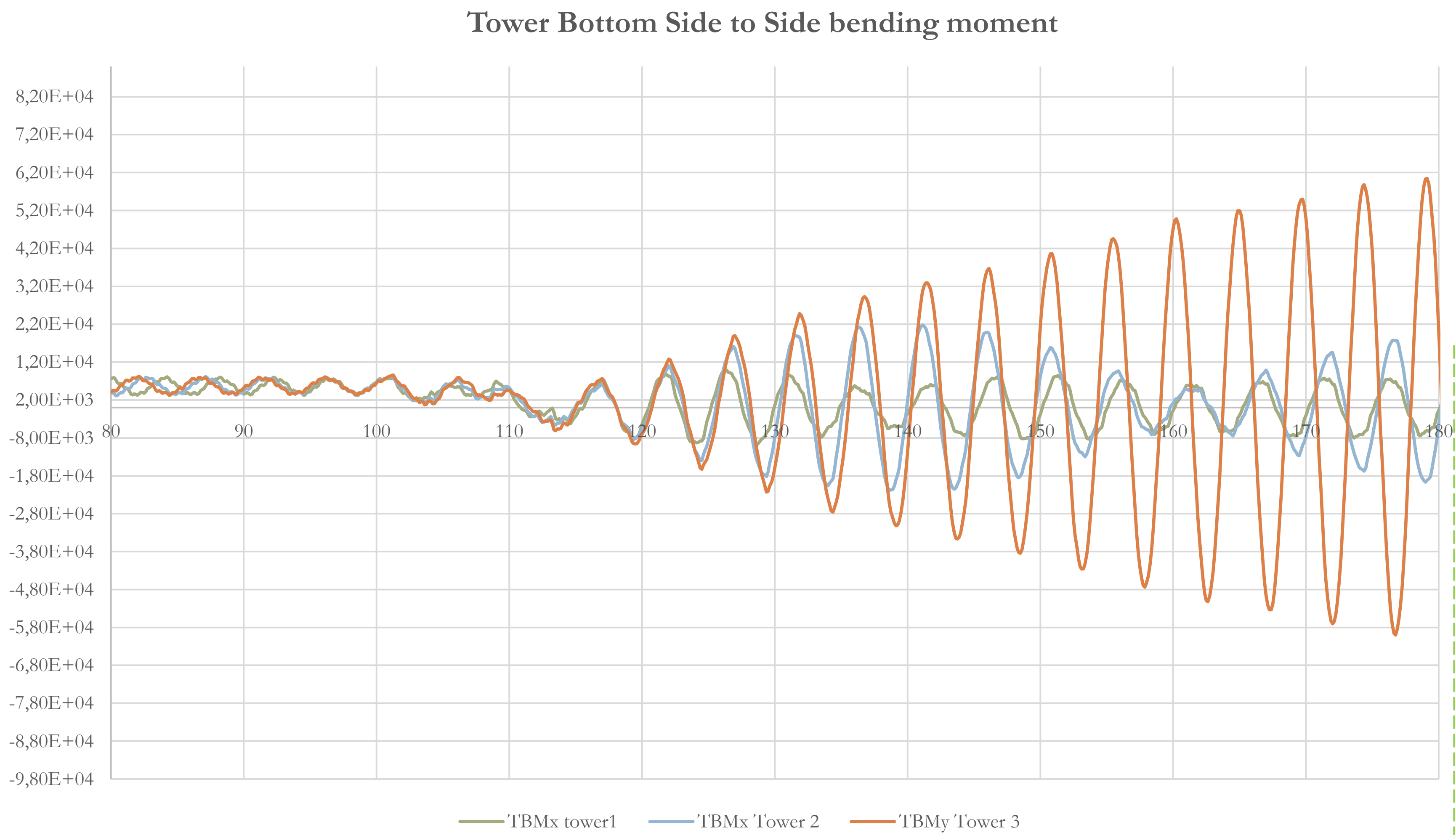
Tower 3:
lightest

Tower Top Mass Impact on Support Structure Cost

The simulation shows that in order to use the lighter tower we need to reduce the head mass significantly



Tower Top Mass Impact on Support Structure Cost



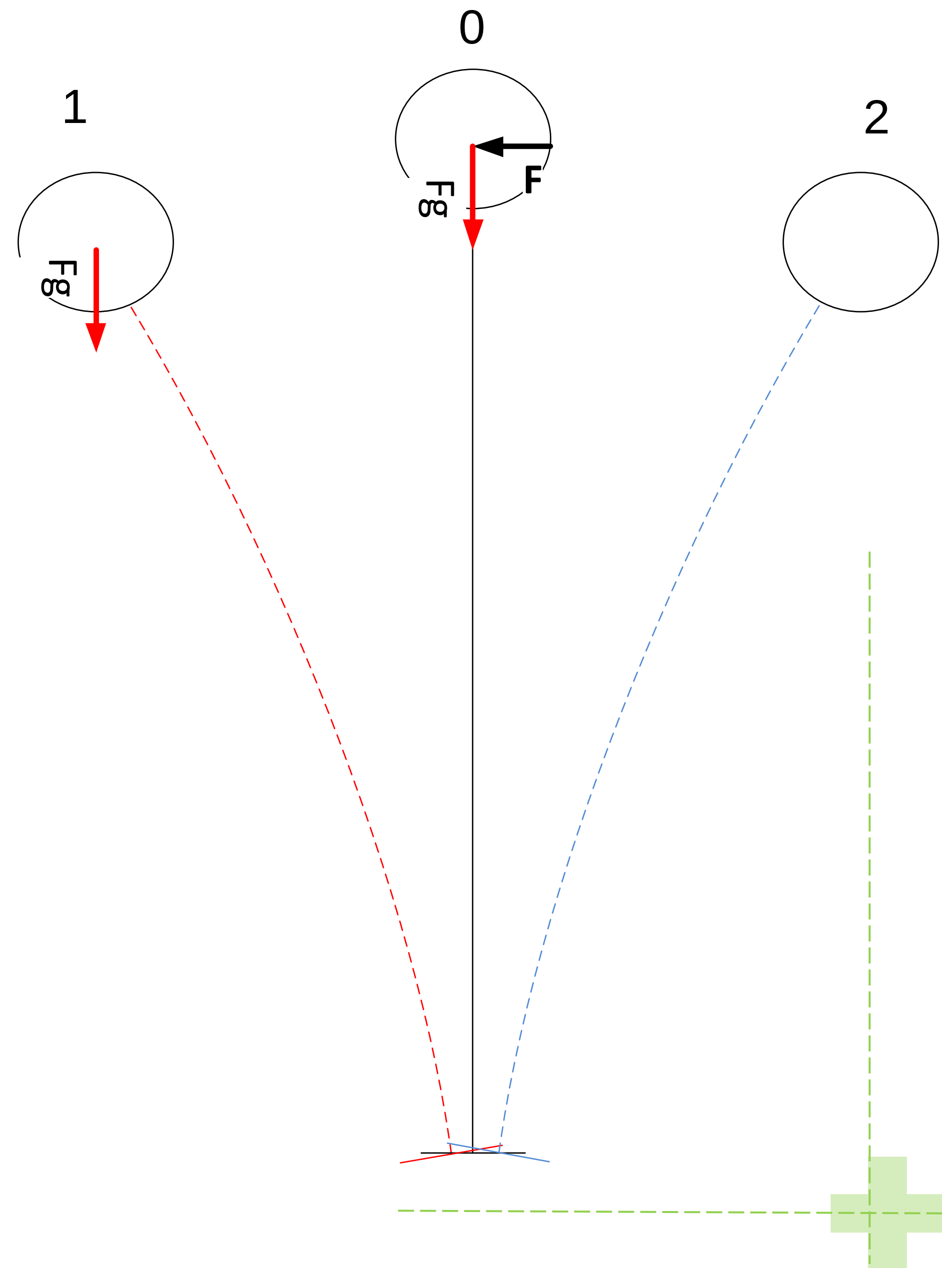
Tower Top Mass Impact on Support Structure Cost

Tower Weight ratio	TT mass		
	1	0.9	0.8
1	0		
0.85		-15%	
0.76			-24%

Tower Top Mass Impact on Support Structure Cost

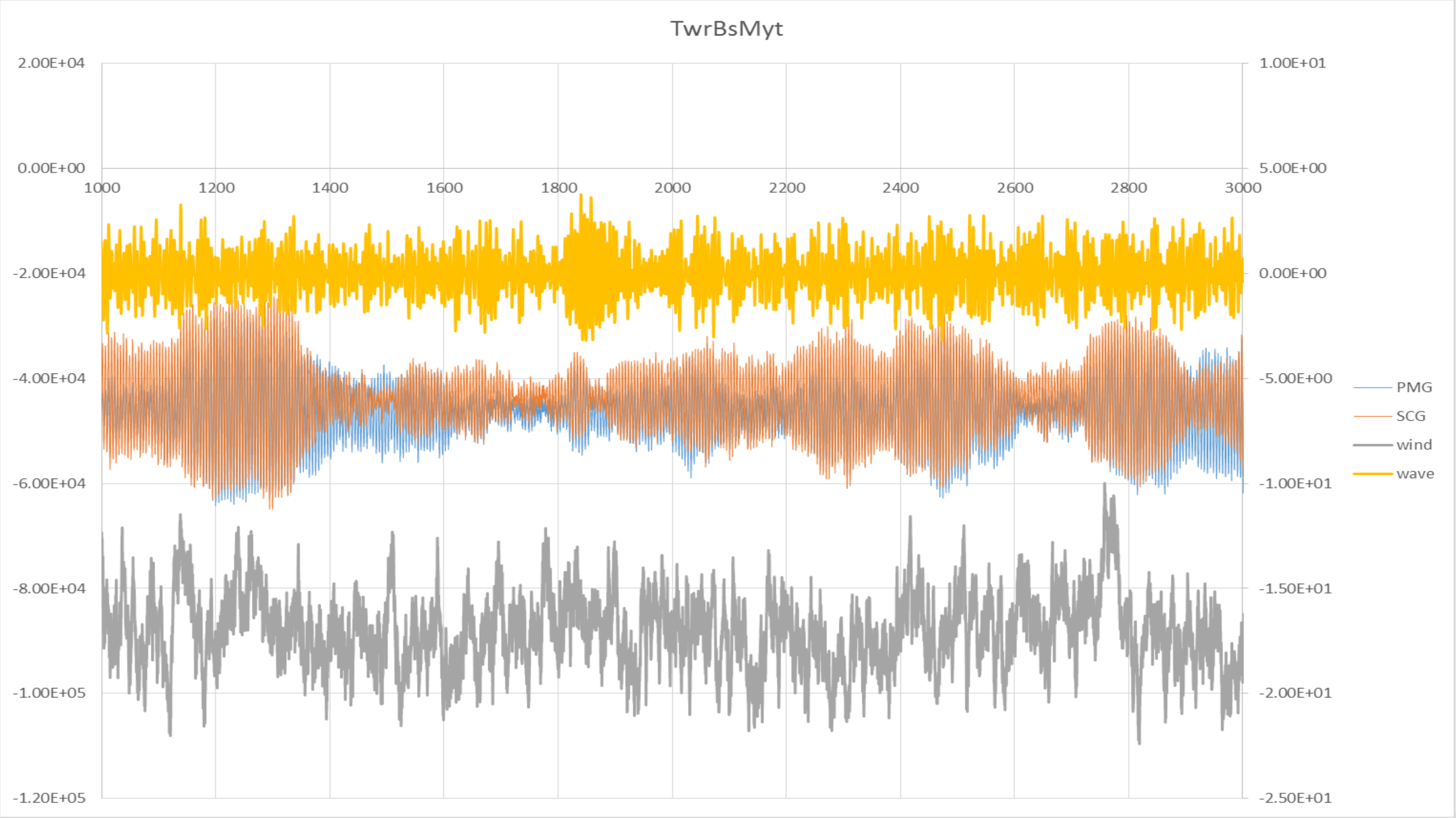
The problem is even worse when the foundation is not "rigid" but a floating kind

Here the oscillation will not only come from the tower bending but also from the sea movements, Increasing the amplitude of the deviation from equilibrium center, though magnifying the impact of the tower top weight on the tower and support structure.



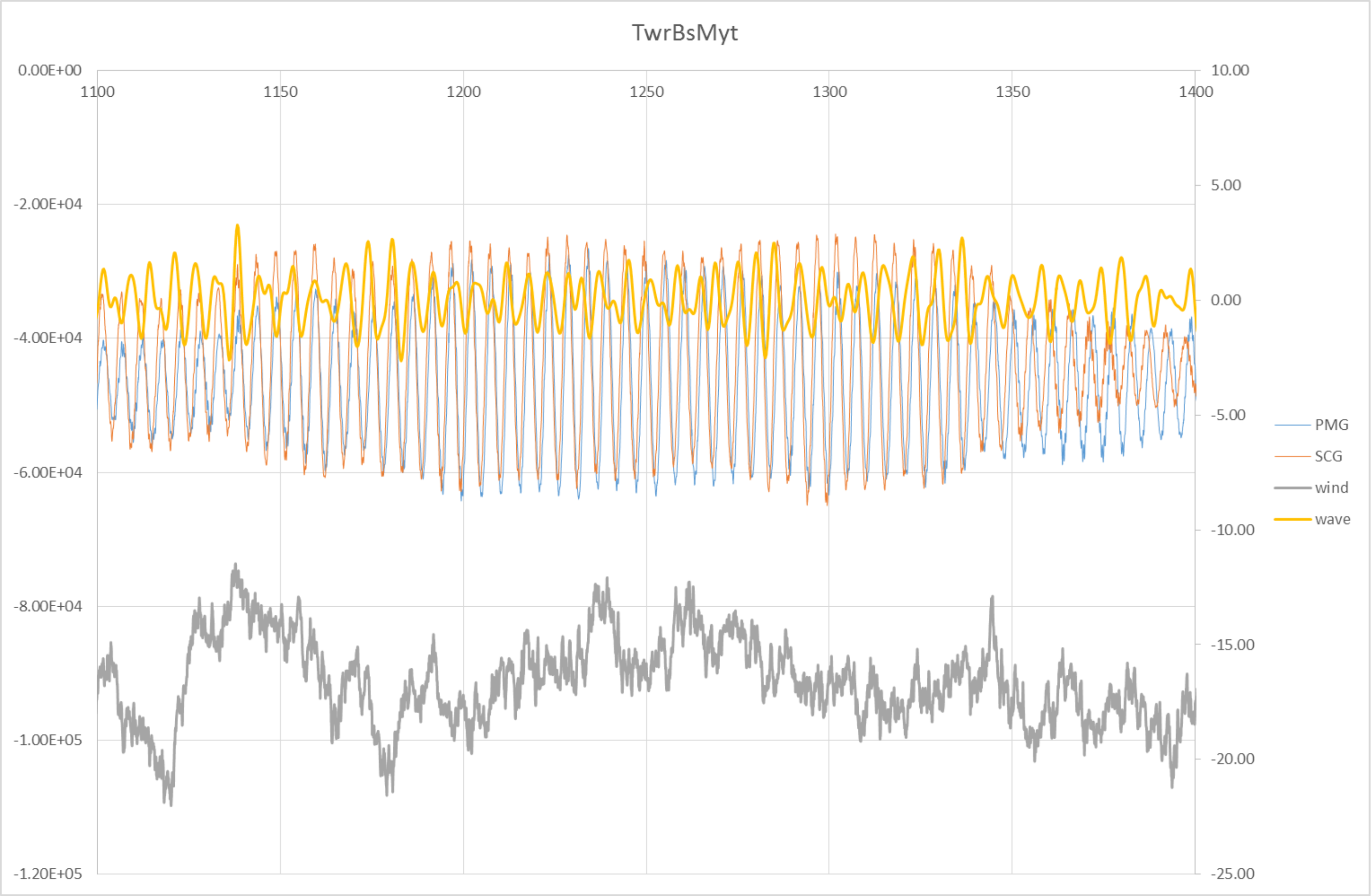
Tower Top Mass Impact on Support Structure Cost

Simulation with two different system with different ttop mass and different towers but equal mode 1 frequency (1.2 times rated rotor speed), matching with sea wave frequency:



Tower Top Mass Impact on Support Structure Cost

Simulation with two different system with different ttop mass and different towers but equal mode 1 frequency (1.2 times rated rotor speed), matching with sea wave frequency (detailed):



Tower Top Mass Impact on Support Structure Cost

Simulation with two different system with different ttop mass and different towers but equal mode 1 frequency (1.2 times rated rotor speed), matching with sea wave frequency (detailed):