Study Committee B2
OVERHEAD LINES
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Affordable overhead lines towers compaction using aerospace-borrowed lattices

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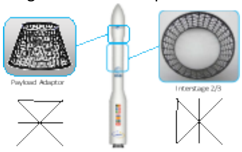
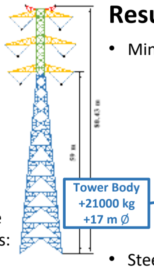
Motivation

- Improve social acceptance and reduce project cost.
- OHTL towers compaction reduces visual impact (less corridor width & improved aesthetics), but it may be uneconomical and environmentally unfriendly (more materials & CO_2 release).
- Here, we optimized several aerospace-borrowed grid topologies to reduce material utilization, improve aesthetics, and facilitate the assembly of a new lattice design intended to replace conventional lattice towers:



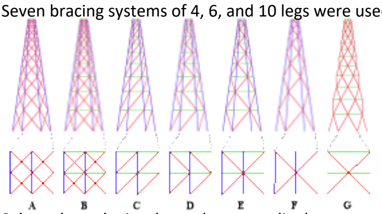
These earth and space mono-layer lattices that can be generated by repeating the pattern along the axial and hoop directions



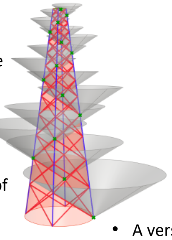
Already applied to OHTLs in Oka river towers one century ago by the Russian engineer and architect V. Shukhov

Tower body geometry

- Seven bracing systems of 4, 6, and 10 legs were used.



- Selected topologies do not have any diaphragm or sub-bracing to deliberately increase (visual & wind) transparency, simplicity, and aesthetics.
- To assist design, detailing, and assembly, only a single node geometry is required since all diagonals share the same cone angle and the curvature is constant.

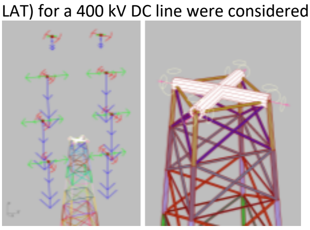


Node positions (green dots) are determined from the intersection points between the cone (grey) from previous level and next leg (blue)

- CHS tubes (EN10210-1 steel S275 and S355) instead of usual angles to further reduce weight and wind drag.

Simulation

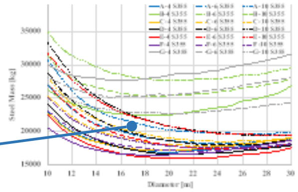
- All practical bracing angles and base diameters were simulated by FEA (2nd order theory)[1]. Cross-sections were optimized and conform Eurocode (EN1993.1.1).
- Conductor loads were translated to applied at a single point at tower body top and injected as forces & torques into the structure using rigid and massless bars (white). All load cases in the Spanish norm (ITC-LAT) for a 400 kV DC line were considered.



- Only the highest (59 m) tower body (blue) was utilized to simplify the comparison.
- A similar optimization was performed for an equivalent tubular steel pole design.

Results

- Minimum mass vs. base diameter and topology:

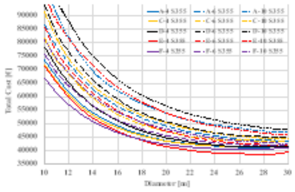


- Steel poles (unstiffened) are 3-4 times heavier:

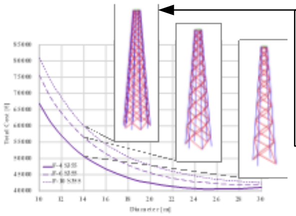
Steel		Displ	Base		Cost		
Type	Mass	Max.	Diam.	Thick.	Steel	Found.	Total
[-]	[kg]	[cm]	[mm]	[mm]	[€]	[€]	[€]
S275	65442	182	2230	31	100781	67862	168643
S355	63403	261	1930	35	108419	68824	177243
S275	86637	100	2610	35	133421	67082	200503
S355	99088	100	2430	43	169441	66767	236207

*CHS steel pole (59 m) modelled as 100 equal finite elements. Foundations cost is computed using the linear regression for slab foundations in normal soil [2]. The steel cost is 1.71 €/kg for S355 and 1.54 €/kg for S275 (a 10 % lower). Overturning is 25-26 kN·m and buckling factors 8-20.

- Simple cost model elaborated based on tubes and nodes steel (wrt. max. loads), foundations (market data & up-lift[2]), and land footprint. Cost vs. diameter:

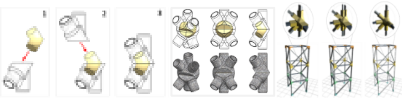


- 4-legged F-topology is the most cost-effective, but bar lengths (10 m) & weights (500 kg) difficult assembly:

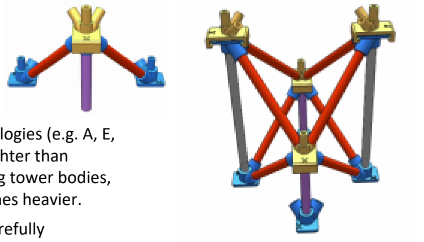


10-legged F topology utilizes 5 m & 100 kg tubes, but costs 20 % more

- A versatile rigid connection system based on nodes[3] was identified for cost-effective manufacture:



- Assembly concept was virtually validated:



Conclusions

- Whereas several topologies (e.g. A, E, or F) are up to 20% lighter than standard cross-bracing tower bodies, steel poles are 3-4 times heavier.
- A tradeoff must be carefully considered between project expenses, compaction, and manufacturability.
- A standardized connection system based on rigid nodes must be developed to enable cost-effective fabrication.

References

[1] Preisinger, C. (2013), Linking Structure and Parametric Geometry. Architectural Design, 83: 110-113.
[2] Working Group 22.09 CIGRE. "Foundation Cost Study" (Electra number 165 April 1996 pages 36-51)
[3] López Blanco, José Ramón. (2017). Node elements, kits, and methods. European patent No. 3545144 B1.

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