Power Pylons of the Future: The Composite Pylon

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Introduction

- The European electricity grid is undergoing major expansions to accommodate the switch to renewable sources and more decentralised energy production. The European Network of TSOs for Electricity (ENTSOE) foresees a need for approximately 48,000km of new or upgraded extra high voltage routes over the next 10 years.

- The Future Pylon project aims at the development and demonstration of next generation design-driven transmission structures which fully harness perceived stakeholder acceptability of overhead line infrastructure through the deployment of disruptive designs and technologies. Utilising state of the art materials and manufacturing techniques to deliver compact, low level structures with reduced corona, electromagnetic fields and a full transmission or distribution engineering capability.
Looking back for a moment...

- Demand for energy outweighed any social and economic impacts
Why must green power mean a 160ft pylon looming over my house?

LIVING WITHIN 1 MILE OF A PYLON INCREASES YOUR CHANCE OF GETTING CANCER

FILL YOUR POCKETS SOMEWHERE ELSE!

SAVE OUR SCENERY!

DON'T BREAK THE HEART OF WALES
PUBLIC PERCEPTION OF LATTICE TOWERS

- Associated With Fossil Fuels
- Very Low Acceptance

...like grumpy old men (Erik Bystrup)
Public Acceptance

- Good or Bad housing development planning?
Public Acceptance

- Not only transmission ……its any shiny new infrastructure!

(Image taken from the ‘Save the Goring Gap’ Campaign Website in relation to the Great Western Electrification through the Chilterns.)
Public Acceptance

- Decision-makers and professionals have become increasingly aware of the influence that social impact and psychological effects may have on project acceptability and, consequently, on total costs (Goodland 1994 Goodland R. 1994. Environmental sustainability and the power sector. Rowan 2009 Refining the attribution of significance in social impact assessment.)

- However, communities often believe they are not engaged enough, or that their interests and concerns are not taken seriously in the decision-making process (Devine-Wright et al. 2010 Devine-Wright P, Devine-Wright H, Sherry-Brennan F. 2010. Visible technologies, invisible organisations: an empirical study of public beliefs about electricity supply networks.)


- Aesthetics are playing a growing part in these processes.
Visual Impact Assessment

Waterway

Road

Railway

Highway

High speed railway

400 kV overhead line
Mitigation - Aesthetic Design
More closer to home....
National Grid 400kV T-Pylon

- Competition Winning design
- *Implied* greater public acceptance
- Introduced new concepts and technologies
- Monopile foundations
- Compact structures
- Lower E-fields and EMFs
Composite Insulator Design

- Fundamentally a composite structure solution
- Opportunity to push the performance envelope
- Introduce new concepts and technologies
- Design, Engineering, FEA, Global Modelling, Testing
Composite Pylon Project

- Bystrup Architects (who were the Architects of the T-Pylon) are championing the cause.
- They saw this as the pinnacle of elegance for Transmission.
- Was a good fit for Allied following on from the composite insulator developments.
- Earlier project in Denmark Polymer Pylon of the Future PoPyFu
- Built on previous successful collaborations
- Takes design and manufacturing to a new level.
Preliminary Concept

Flatter construction profile and no earth wires
Which became.....Happier
Low Height - Acceptability

SIZE

- L13 Pylon
- T Pylon
- Composite Pylon

- Reduced Height
- Reduced Weight
- Reduced Price
CONVENTIONAL LINE

• Two Lines Each Carrying One 400 kV Circuit
Visual Impact Reduction

COMPACT LINE

- One Pylon Carrying Two 400 kV Circuits
Eurostars Project

- Eurostars supports international innovative projects led by research and development-performing small- and medium-sized enterprises (R&D-performing SMEs).

- Eurostars is a joint programme between EUREKA and the European Commission, co-funded from the national budgets of 36 Eurostars Participating States and Partner Countries and by the European Union through Horizon 2020.

- The role of SMEs for the economy has never been so important. Eurostars aims to bring increased value to the economy, higher growth and more job opportunities.

- Provides Grant funding (60%) for projects that are successfully meet the target thresholds.
Eurostars Project

- We successfully secured a Eurostars project for our ComPylon project.
- Collaboration between Bystrup, Allied & Norco Composites
- Project is to develop and test a fully working prototype of the Composite Pylon.
- Initially our aims were for a 400kV Pylon however we believe a 132kV would be more feasible and practical.

- There has to be significant challenges, uncertainly and risk in the project for it to qualify as R&D and satisfy the Eurostars process.
- The aim of the project is to quantify these unknowns and develop engineering solutions.
- Disruptive technology ........the Art of the Possible

Aim higher
The ComPylon Project
ComPylon Advantages

- Compact design (about half the size of a conventional lattice tower, and significantly shorter than previous design pylons made from steel)
- Lower lighting susceptibility
- Positive effect of the visual design (enabling advanced geometries not possible with steel)
- Capable of carrying 2x400 kV (unibody insulator with two cross arms each carrying 400 kV)
- Made from non-conductive materials, reducing corona noise and electrical field
- The pylon can be assembled on site and erected in one single day
Fully Composite Pylon Structure

- Designed in full compliance with EN 50341
- Managing Extreme loadings
- Resilient to environmental factors
- Can meet all prescribed testing standards and specifications
- Can offer a comparable lifetime of service
- Conductors can act like springs and offer resistance and stability
ComPylon Structure
Lightning Protection & Earthing

- One of the major challenges for the project
- Original theory was based on running without earthwires! Maybe radical on 400kV dual circuit lines but currently possible on single circuit 132kV wood pole lines.
- Depending on the importance of line, conventional towers use shielding angles between 10° and 35°.
- The fully composite pylon suggested design provides a negative shielding angle of 60° for the lightning protection system.
- The Composite structures are effectively ‘unearted’
Lightning Susceptibility

- Based on 400kV Comparisons

- Reduced Height
- Reduced Weight
- Reduced Price
Lightning Susceptibility using the Electro-geometric EGM Method

- If the leader reaches the area between A and B or A’ and B’, the lightning will attach to the earth wire. Lightning strikes outside these areas will terminate on the ground. As the lightning current increases, the distance between B and B’ decreases and for values above a specific current magnitude, the area between B, C and B’ will disappear and there will be an overlap between two points of B and B’ as shown in Figure 2-b.

![Diagram of striking distances of fully composite pylon](image)

Figure 2: Striking distances of fully composite pylon \((r_\alpha, r_\beta)\), a) for current below \(I_{MIC}\), b) for current equal to \(I_{MIC}\) (protected zones (grey area); unprotected zone (red area))

Minimum intersection current, \(I_{MIC}\)
Improved Lightning Performance

- Ground Flash Density - If a lightning strikes within the shadow area (collection width) it is attracted to the line.

\[ N_{\text{line}} = \frac{N_g}{10} \cdot (28H^{0.6} + D) \quad \text{[Flashes per 100 km-year]} \]

Estimated number of strikes to the lines

<table>
<thead>
<tr>
<th>Pylon Type</th>
<th>Flashes per 100 km-year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fully composite pylon</td>
<td>28.3</td>
</tr>
<tr>
<td>Eagle pylon</td>
<td>38.7</td>
</tr>
<tr>
<td>Donau pylon</td>
<td>36.7</td>
</tr>
</tbody>
</table>

Flashover from shielding failure \( I_c \)

- The critical current \( I_c \), lightning stroke current that will cause a flashover:

\[ I_c = \frac{2CFO}{Z_c} \quad \text{[A]} \]

- Surge impedance, \( Z_c \), of fully composite pylon is lower than Eagle and Donau pylons.
- Since \( I_c \) is larger than \( I_{MIC} \), therefore, theoretically no lightning current can strike the phase conductor.
- Therefore lower is better! Less attractive to Lightning
Electrical Requirements

- Basic electrical clearances & clashing model (CIGRE Galloping methodology)

(Note: Unearthed Flat Structure)
Electrical Requirements

- Electric field modelling & control
- The importance of the electric field distribution along a composite insulator has been recognized by the industry.
- Electrical field stresses on polymeric insulating materials such as silicone rubber shall be as low as possible to avoid tracking and erosion phenomena due to corona discharges.
- Also very high requirements for RIV & Corona Extinction due to increased visibility and lower height.
Mechanical Design to EN 50341

(Note: Unearthed Flat Structure)

- **Unbalanced Ice Loading**

- **Combined Wind & Ice**

- **Security Load (Broken Wire) ?**

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**Overhead Line Colloquium**

**Allied Insulators**

Safer, Stronger, Smarter Networks
Mechanical Design

- Torsion
- Tension Force
- Vertical Load
- Elasticity
- Lateral Force
- Bending Moment
- Buckling
- Shear Forces
- Global Stability
- Longitudinal
- Compression Loading
- Overturning Moment
- Bending Moment

Overhead Line Colloquium

Safer, Stronger, Smarter Networks
Crossarm Mechanical FEA Design

Unloaded

Wind

Unbalanced Ice

Wind & Ice
Ultra high strength requirements
Modular Interface – Critical Zones
Insulator Resilient joint requirements:

Based on the applied loads below (which are worst case and not every day loads) The torsion stress could be higher than the max failure stress of the GRP material. Hence we need something to transfer the torsion through the current flange to flange /flange joint or sit between the flanges.

Loads Applied

- >1000kN – Tension & Compression
- >200kNm Torsion
- >1350kNm Bending
Torsional & Shear Capability
Modular Crossarms - Hollowcore

Integrated flange technology

Conical FRP filament winding – Ultra high E-modulus
Novel Insulator Connections
Work Packages

- 36 Month Project
- (WP1) Project Management Scope
- (WP2) Specifications and preliminary design
- (WP3) Mechanical and Electric Calculations and Analyses
- (WP4) Production and Assembly of Prototype Pylon
- (WP5) Mechanical and Electrical Testing
- (WP6) Exploitation & Dissemination
Questions?