THE PROTEAN AND POC-MAST DESIGN

Introduction

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An OHL Designer/Engineer for 35 years, working on a number of international and UK projects during this time.

Contents

The changing landscape of generation

1. The UK generation has changed considerably over the past 10 years, with the significant increase in renewable generation.

2. The majority of the generation is from PV and wind in remote locations.

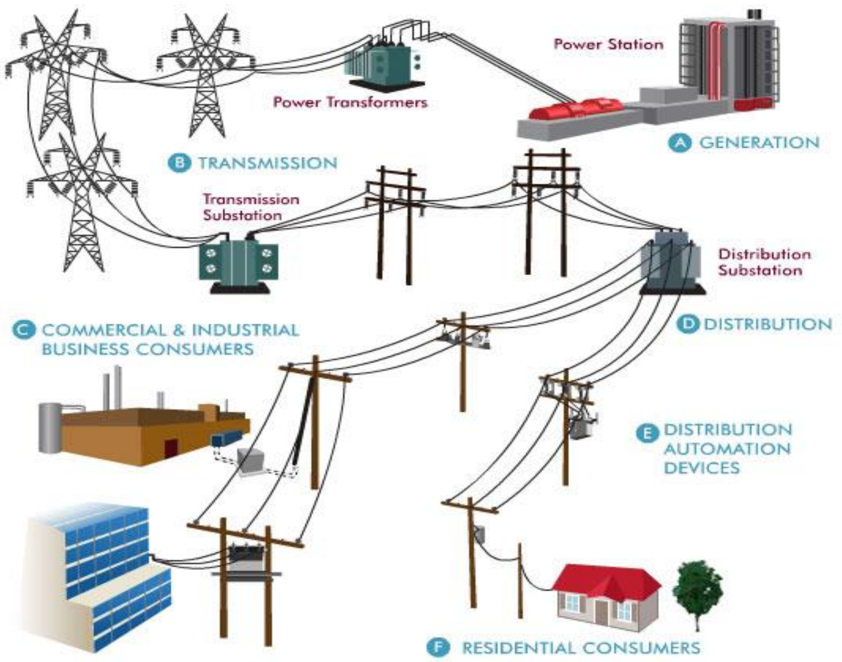
3. The connections are predominantly made on the 11–33–132kV network.

4. There are also a number of large battery projects on the horizon, all awaiting a secure connection to the 11–33kV network.

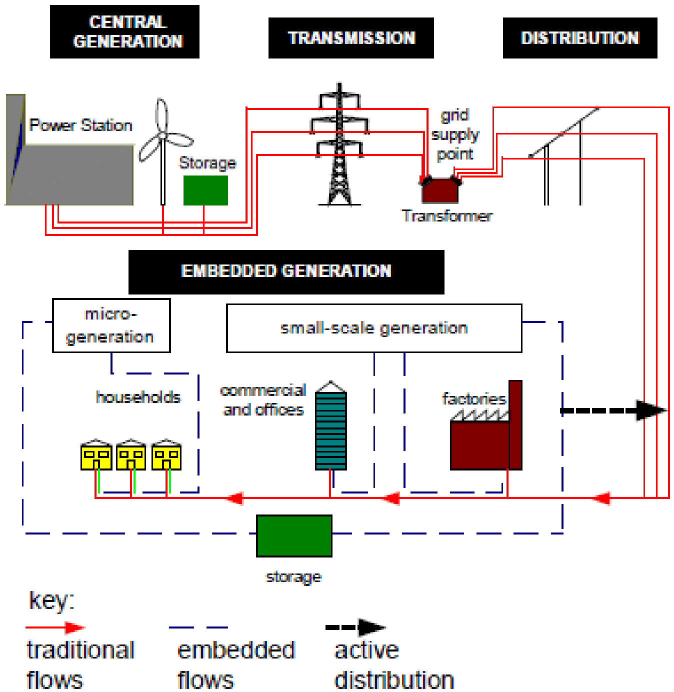
5. The UK is working towards a 15–20% energy supply from renewables by 2020. We are well on the way, with more energy battery storage projects.

The changing landscape of Transmission & Distribution

All generating plant requires a distribution or transmission system - either cable, overhead line, or a combination of both.



The traditional UK T&D system



The new T&D UK system

Challenges of the new T&D system

National Policy Statement for Electricity Networks Infrastructure (EN-5)

Part 1 Introduction

1.1 Background

1.1.1 The new electricity generating infrastructure that the UK needs to move to a low carbon economy while maintaining security of supply will be heavily dependent on the availability of a fit for purpose and robust electricity network. That network will need to be able to support a more complex system of supply and demand than currently and cope with generation occurring in more diverse locations.

Challenges of the new T&D system

- The wood poles and lattice towers have served the UK distribution and transmission system well over the past 70 years. A large majority need replacement.

- The thermal capacity of a majority of the existing overhead lines will be severely challenged with the change in generation and increased capacity.

- The majority of the embedded generation is being restricted by the capacity and location of the existing ageing 11-33kV distribution system.

- A large majority of current designs are based on wood poles, with a limited number of conductor sizes below the required capacity for the increased generation.

Challenges of the new T&D system

- A number of new generators are in remote locations, with no OHL or the current system is inadequate
- The size and strength of wood poles is being compromised from the effects of global warming.
- Gaining planning permission for a new lattice tower line (L4m) can take several years.
- The UK has been very slow in taking up new innovations in the area of T&D, the L4M was designed in 1977. National Grid are only now developing the 'T Tower'.
- Many of the current OHL specifications are not compliant to the latest EURO codes.

The Holford rules and guidance

The Holford rules and recommendations were produced in 1959 and are still practiced for OHL routing. Let's take a quick tour!

Rule 1: Avoid altogether, if possible, the major areas of high amenity value, by so planning the general route of the line in the first place, even if the total mileage is somewhat increased in consequence.

Small foot print, low height

Rule 2: Avoid smaller areas of high amenity value, or scientific interest by deviation; provided that this can be done without using too many angle towers, i.e. the more massive structures that are used when lines change direction.

Small foot print, low height

Rule 3: Other things being equal, choose the most direct line, with no sharp changes of direction and thus with few angle towers.

Long basic span, low height

The Holford rules and guidance

Rule 4: Choose tree and hill backgrounds in preference to sky backgrounds, wherever possible; and when the line has to cross a ridge, secure this opaque background as long as possible and cross obliquely when a dip in the ridge provides an opportunity. Where it does not, cross directly, preferably between belts of trees.

Low height, visual impact

Rule 5: Prefer moderately open valleys with woods where the apparent height of the towers will be reduced, and views of the line will be broken by trees.

Low height, visual impact, colour

The Holford rules and guidance

Rule 6: In country which is flat and sparsely planted, keep the high voltage lines as far as possible independent of smaller lines, converging routes, distribution poles and other masts, wires and cables, so as to avoid a concatenation or 'wirescape'.

Low height, visual impact, colour.

Rule 7: Approach urban areas through industrial zones, where they exist; and when pleasant residential and recreational land intervenes between the approach line and the substation, go carefully into the comparative costs of undergrounding, for lines other than those of the highest voltage.

Low height, visual impact, colour, receive cable terminations, small foot print

Applying the modern T&D and Holford requirements to design

From a design perspective based on the new T&D requirements and the Holford recommendations, we need an OHL design with the following attributes:

- Supports a range of larger conductors up to 500mm^2.
- Can be used for new OHLs or refurbishing existing OHL's with minimal outages, ideally on the existing route.
- Must be installed with minimal access modifications.
- Must be complaint to the latest Euro specifications.
- Must be low in height and width for visual impact.
- Must take a small footprint for land usage, stays an option!
- Must be cost and value effective.
- There must be a complete supply chain for all elements.

What's currently available in the UK for T&D

- Traditionally the UK has used wood poles for 11–33kV OHL distribution system.
- At 132kV there is the 43-50 Trident wood pole.
- At 132–275 and 400kV the design is predominantly based on lattice towers.

11 -33kV

132kV Trident

132kV wood pole

132kV DC lattice

The limitations of wood poles and lattice towers

The 11–33 kV T&D system based on wood poles and lattice towers is limited by the following:

- The mechanical capacity of the wood pole
- The foundation design and mechanical capacity
- It is predominantly based on a single circuit
- The limitation of the conductor size (200mm)
- Short spans in agricultural farmland, with large machines needing passing access
- The market availability of suitable size wood poles
- The requirements for stays to support transverse loads
- The recycling limitations of the wood pole treated material

The limitations of wood poles and lattice towers

The transmission system based on lattice towers is limited by the following:

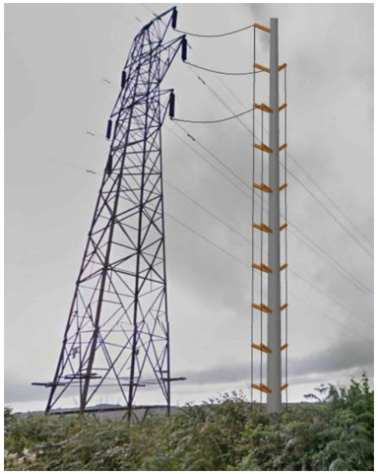
- The L4 (M) tower was designed in 1975
- The lattice towers are tall with high visual impact
- It can take more than 18 months to secure planning permission
- The tower construction requires panel assembly and working at height
- The foundations typically require open excavations
- Extensive access preparation is required for cranes and concrete mixing plant for safe access to site
- The L4 tower design is based on a double circuit tower
- There is limited flexibility to make a point of connection

Using technology and new processes for OHL’s

1. There has been significant advancement in 3D CAD technology for visual effects.
2. The use of Finite Element Analysis coupled with modern metal cutting and bending techniques enables complex structures to be constructed with high productivity.
3. The aerial survey LiDAR techniques provide high accuracy data capture for OHL routing and detailed design.
4. The development in ground anchor technology provides foundation systems capable of supporting high mechanical loads with minimal disruption to the ground and environment.
5. To reduce visual impact structures can be finished in various colours and textures to blend in to the landscape.
6. The use of the latest PLS-CADD software enables all structure mechanical loads to be calculated to the latest standards.

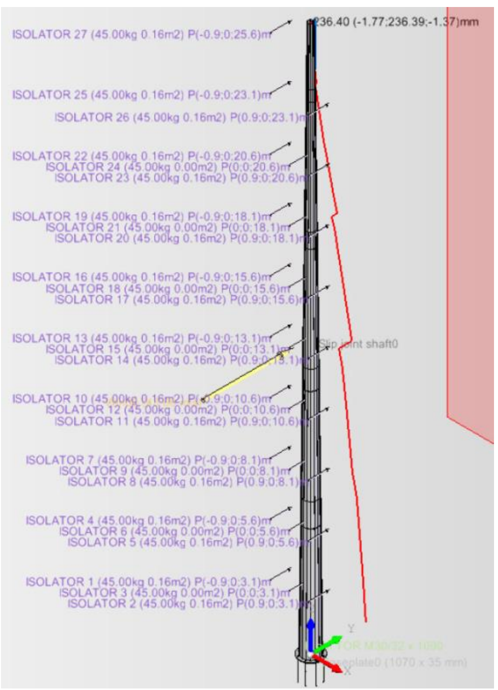
Using technology and new processes for OHL's

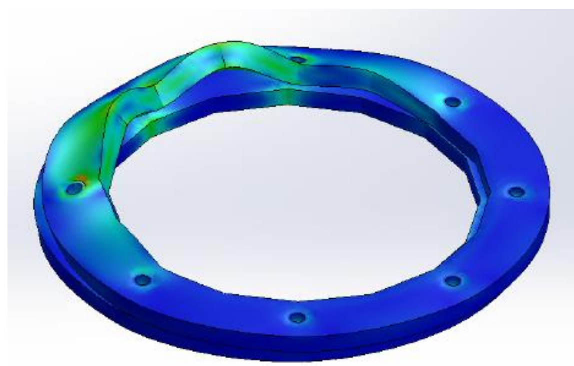
1. There has been significant advancement in 3D CAD technology for visual.
2. This enables both planners, designers and all stakeholders to produce a design to best fit the environment.
3. The following photomontage was produced for an HV connection with the POC–MAST based on a simple Google image.



Using technology and new processes for OHL's

1. The use of Finite Element Analysis coupled with modern metal cutting and bending techniques enables complex structures to be constructed with high productivity.
2. The UK manufacturer can produce in excess of 500 structures/month.

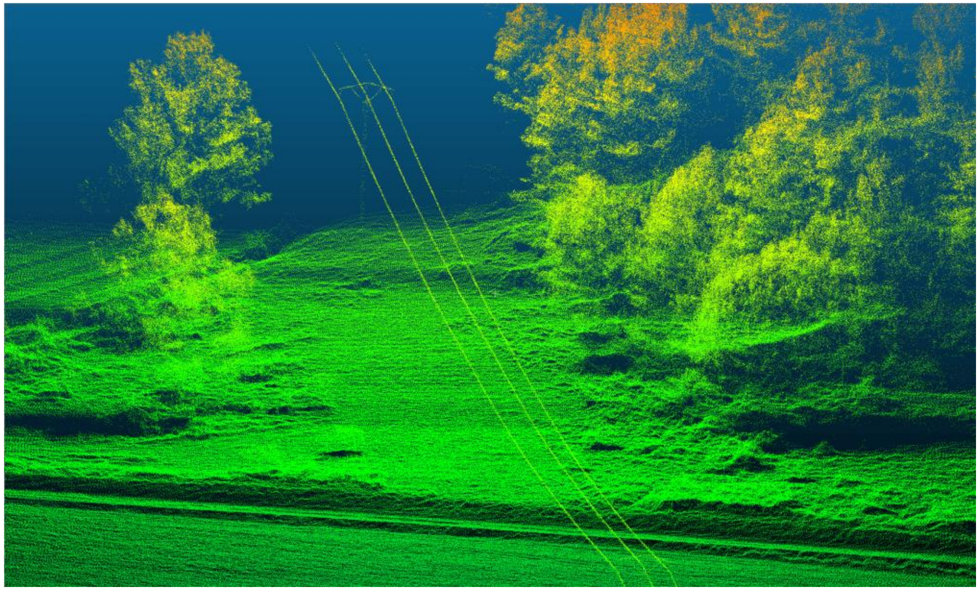




Using technology and new processes for OHL's

1. The aerial survey LiDAR techniques provides high accuracy data capture for OHL routing and detailed design, capable of surveying over 100km/day.
2. BPI have already completed over 1000km of UK survey and OHL design.

LiDAR data capture



LiDAR data post-processing

Using technology and new processes for OHL's

Aerial LiDAR data capture is now moving to a drone platform .

- The drone is a flexible platform
- A least cost option
- Low noise in sensitive areas
- BPI is conducting a full trial in June 2016

Using technology and new processes for OHL's

The development in ground anchor technology provides foundation systems capable of supporting high mechanical loads with minimal disruption to the ground and environment.

Using technology and new processes for OHL's

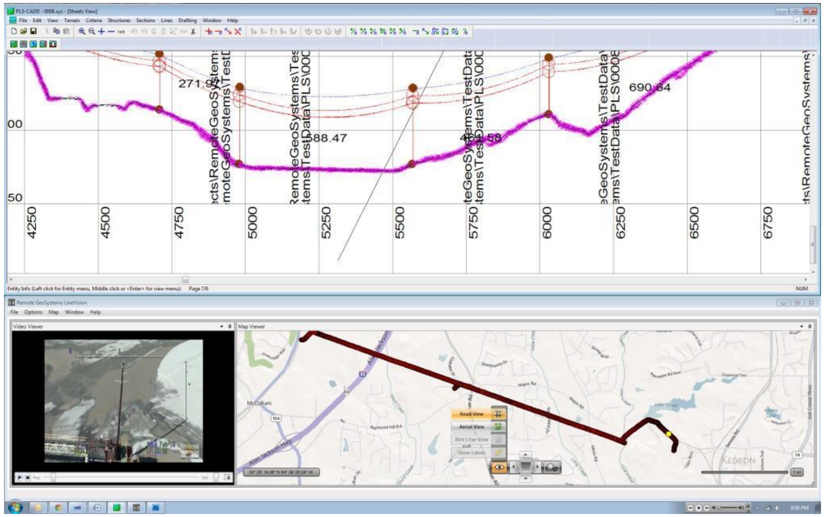
To reduce visual impact, structures can be finished in various colours and textures to blend in to the landscape.

- Structures can be galvanised to UK standards
- The colour of the structure can be user defined
- Using 3D CAD rendering techniques and variety of finishes can be explored

Using technology and new processes for OHL's

1. The use of the latest PLS-CADD software enables all structure mechanical loads to be calculated to the latest standards.
2. The mechanical loads provide the Protean pole size and the resultant foundation loads for the screw anchor design.

- **Profiles are produced from the LIDAR data**
- **All structure loads are automatically output**
- **All structure setting out coordinates are out**
- **A complete line fitting schedule is produced**
- **A complete set of route maps are output**
- **A clearance schedule to all features is output**



A quick round up!

1. Changes with renewable generation throughout the UK.
2. National energy policy for generation and transmission.
3. Challenges for the transmission and distribution system.
4. Holford rules and how they effect the NEW T&D system.
5. Applying the latest technology to the requirements of the new T&D system.

The BPI Protean OHL System

- Versatile
- Capable of assuming many forms
- Flexible
- Adaptable

A radical alternative design approach

The Protean design methodology is a revolution in the traditional thinking of UK OHL design.

- The number of circuits is user defined single or double
- The conductor size (MVA) can be up to 500mm
- The earthwire can be either OPGW or OPPC over or under slung
- There is no requirement for terminal or angle pole stays
- The Basic Span can be up to 250m
- The cross arm configuration is designed to provide the clashing model clearance

Once specified, the design can begin.

A radical alternative design approach

BPI has used folded steel for its Protean and POC-MAST design.
The Protean design takes the following open design approach:

- The number of circuits (single or double)
- It is based on the latest design codes
- The conductor size and thermal rating
- There is minimum working at height
- Unique structure lifting hydraulic hinge
- Small sections for ease of transport and assembly
- The basic span and maximum structure height
- No requirement for stays at angle or terminal structures
- The foundation type mass concrete or screw anchors
- Project defined failure containment
- The requirement for communications OPGW, OPPC
- Access limitations

A radical alternative design approach

Table 1
Electrical Properties of Conductor Systems

Conductor Configuration	Nominal Aluminium Area (mm^2)	Maximum Operating Temp.	DC Resistance at 20°C (Ohm/km)	Current Rating* (Amps)		Ratings in MVA (Summer Loadings)		
				Spring	Summer	11kV	33kV	132kV
Horse	70 ACSR	-	0.365	286	148	2.82	8.46	33.84
Oak	100 AAAC	-	0.282	384	307	5.85	17.55	70.19
Caracal	175 ACSR	-	0.1563	383	205	3.91	11.72	46.87
Jaguar	200 ACSR	-	0.1367	415	197	3.75	11.26	45.04
Lynx	175 ACSR	75°C	0.153	675	615	11.72	35.15	140.61
Upas	300 AAAC	75°C	0.0925	1000	915	17.43	52.30	209.20
Totara	425 AAAC	90°C	0.0665	1250	1140	21.72	65.16	260.64
Zebra	400 ACSR	75°C	0.0662	1180	1080	20.58	61.73	246.92
C^7	483 C^7	180°C	0.0583	2030	1170	22.29	66.87	267.50

*Current ratings are based on 50 Hz AC, 75°C conductor temperature, and 0.61 m/s (2 ft/s) wind, 0.5 coefficients of emissivity and absorption.

A radical alternative design approach

The traditional approach to OHL design used a range of 'look up tables' for wind and weight span calculations. There were crude calculations to satisfy the conductor uplift requirement.

There was typically very limited geotechnical data, which led to foundation failure through poor design.

- The Protean design uses the latest OHL design software coupled with accurate LiDAR data capture.
- On completion of the ground profile, the structures are spotted with the conductors under a range of stringing parameters for clearance and mechanical load checks.

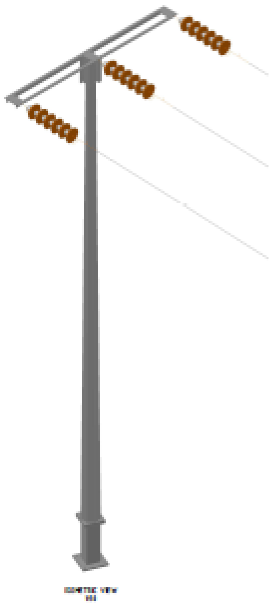
A radical alternative design approach

- The design is undertaken in a 3D CAD environment.
- On completion of the conductor stringing, the mechanical loads and structure heights are calculated.
- These loads are used to design the structure heights and sizes of the folded plate thickness and overall sizes.
- The resultant loads are then used to calculate the foundation loads, which determines the number, size and depth of screw anchors required.

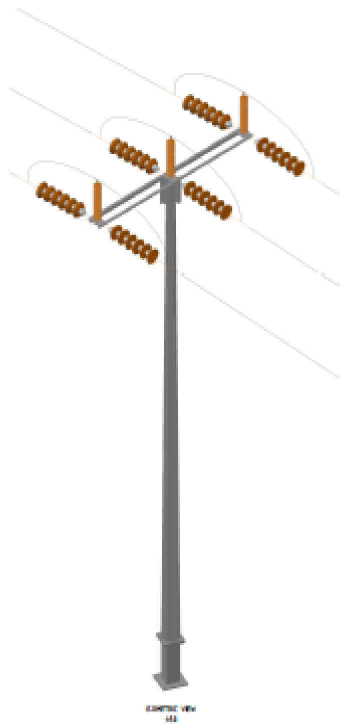
The Protean main components

The design is undertaken in a 3D CAD environment.

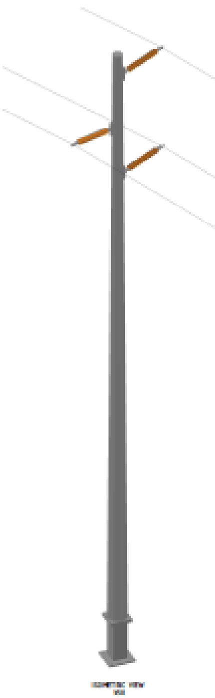
The Protean structure types



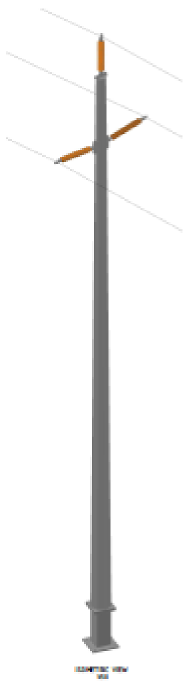
Terminal



Angle



Intermediate



Intermediate

The Protean main components

The foundation design:

- The screw anchors can be installed with minimal site set up and security.
- The screw anchors are guaranteed for 40 years maintenance-free operation.
- The screw anchors are designed specifically for each pole location and soil type.
- During installation each screw anchor torque measurement and depth is taken, to ensure the anchor provides the correct strength capacity.
- The screw anchor and pole hinge assembly adaptor plate enables each pole to be accurately plumbed.

The Protean main components

The structure design:

- The structure is designed to the latest OHL codes.
- The structure strength is based on the plate thickness, the butt and top diameter.
- Each structure is made in 3–5m section lengths.
- The sections are slotted together on site and compressed for a permanent interference fit.
- The structure is fully galvanised.
- The footprint can be reduced without stays.
- The structures are fully galvanised.
- Each structure is provided with ACD, climbing and fall arrester.

The Protean main components

The structure cross arm and insulator design:

- The cross-arm can be a polymeric insulator or folded steel, based on the applied loads.
- To reduce cost the cross-arm can be a polymeric insulator.
- The cross–arm arrangement is completely user definable.

Installing the Protean system

The Protean is designed for minimal climbing:

- The screw anchors can be installed with minimal headroom.
- The hydraulic hinge assembly is attached to the screw anchors.
- The structure is then assembled and attached to the hinge.
- The hydraulic ram is then fitted and the structure raised.
- Once installed, the ram is removed and replaced with anti–vandal fixings.

A complete design pack

The Protean system is supported with a complete design pack.

- Profiles and route maps - various scales
- Engineering compliance document
- Fixtures and fitting document
- General arrangement and erection drawings
- Erection sag tension document
- Foundation calculations and drawings
- Setting out coordinates
- Insulator and small piece drawings

Folded steel extended to a POC design

The folded steel design approach has been extended in to the POC–MAST system.

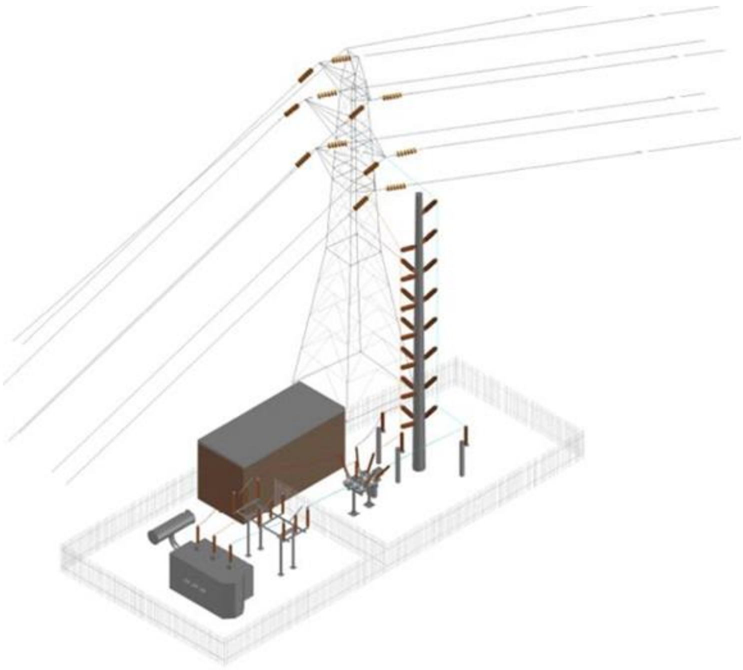
The POC-MAST provides a safe, economical and fast (4 hours) method of making an HV connection to existing overhead lines.

Unique to the POC-MAST design is the hydraulic hinge assembly, allowing the POC-MAST to be fitted with all insulators at ground level and raised with the hydraulic ram - minimising working at height.

The POC-MAST transmits negligible mechanical load into the existing OHL structure.

Folded steel extended to a POC design

The POC–MAST can be used for both a **Tap in** or **Loop in Loop** out permanent connection.



In conclusion

- The design approach enables the Protean OHL design system to meet the requirements of the generator T&D.
- The UK manufacturers can provide 500 structures per month.
- The Protean structures are designed for each location.
- The screw anchor foundation is designed to meet the soil bearing capacity.
- The Protean poles can be installed under line for OHL rebuilds without an outage.
- The Protean and POC–MAST can be installed from the hydraulic hinge in minimum outage time.