



British Power International - the award-winning power sector design consultancy

Offering a complete 11kV to 400kV design service for substation, renewables and overhead lines

A technical review of the Protean, POC-MAST system, battery technology, aerial survey technology and an alternative foundation design.





Design Services



Aerial Survey

We use the latest LiDAR technology



Battery Storage Integration

BPI provides a complete design service for energy storage integration



Cable Systems

BPI provides cable system design specialisation



Civil and Structural

We provide a complete substation design



New Connections

We undertake detailed designs and submissions



Overhead Lines

Providing a complete overhead line design service covering 11kV, 33kV, 66kV, 132kV, 275kV and 400kV



Plant Services

Providing HV and LV plant design



Power Systems

Performing the expert evaluations needed to plan, design and operate a power network



Protection Systems

Ensuring that your protection system safeguards assets and ensures uninterrupted supply

Products



POC-MAST

The award winning cost effective solution for connecting to the network



Protean

The alternative to wood poles



Protection panels

Bespoke panel production



Awards & Accreditations





Introductions

- Ms Danielle Tile - Business Development Coordinator
- Mr Bob Ford - Managing Director





Today's presentations

- The main aim of today is to provide an 'interactive session' to discuss in detail each of the systems from a design, installation and operational view point.
- Please feel free to ask any questions at any time.
- We value your feedback.





Development of the Protean system

1. The changing landscape of generation for power transmission and distribution.
2. The Holford rules and recommendations for OHL routing and design.
3. The current transmission and distribution system.
4. New applications and processes available to us for new OHL designs.



Changing landscape of generation

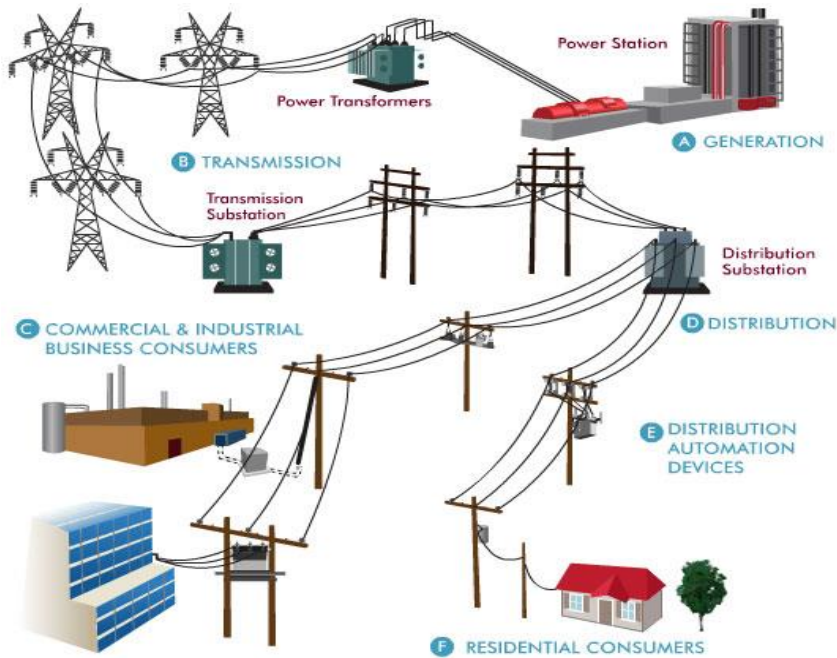
1. UK generation has changed considerably over the past 10 years with the significant increase in renewable generation.
2. The majority of the generation is from PV and wind in remote locations.
3. Connections are predominantly made on the 11–33–110–132kV network.
4. There are also a number of large 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.



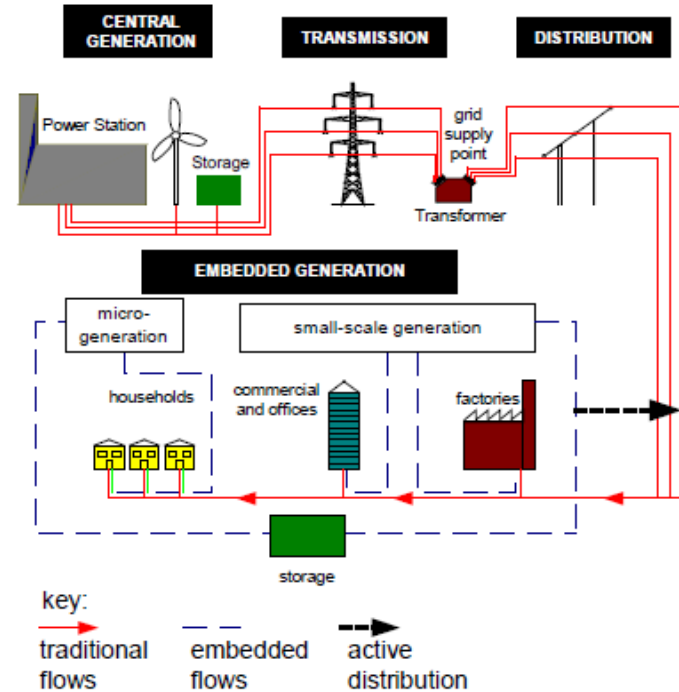


The changing landscape of Transmission & Distribution

All generating plant requires a distribution or transmission system - either cable or 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'.

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.

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 500mm²
- Can be used for new OHLs or refurbishing existing OHLs with minimal outages, ideally on the existing route
- Must be installed with minimal access modifications
- Must be compliant 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
- A basic span in excess of 250m
- There must be a complete supply chain for all elements





What's currently available in the UK

- 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



To summarise the limitations of wood poles and lattice towers

The 11–33-132kV 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 farm land which large machines need passing access
- The market availability of suitable size wood poles
- The requirements for stays to support transverse loads
- The recycling limitations of the treated wood pole



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 design and structures

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 OHLs

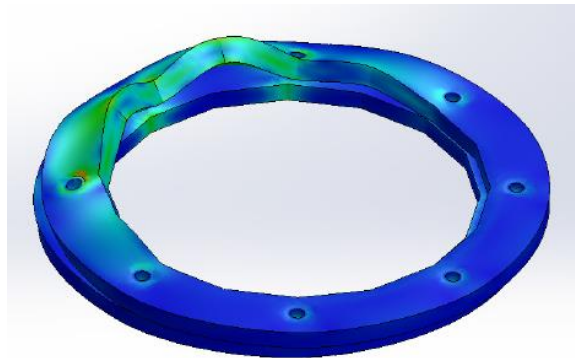
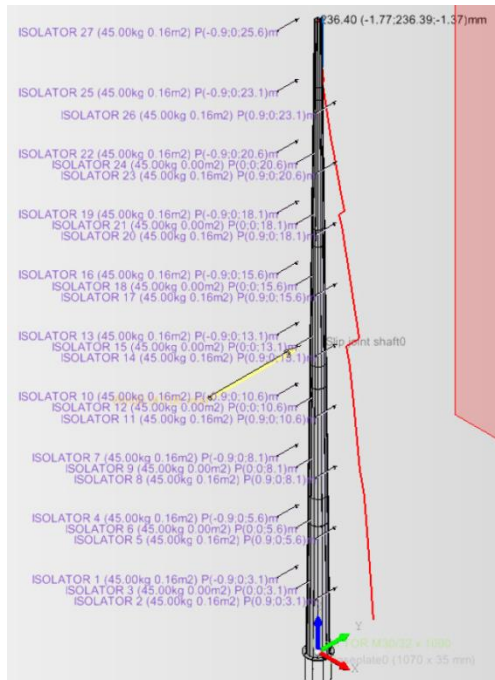
1. There has been significant advancement in 3D CAD technology for visual.
2. This enables both planners, designers and all stakeholders to produce a design to best fit the environment.
3. The following photo montage was produced for an HV connection with the POC – MAST based on a simple Google image.





Using technology and new processes for OHLs

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.



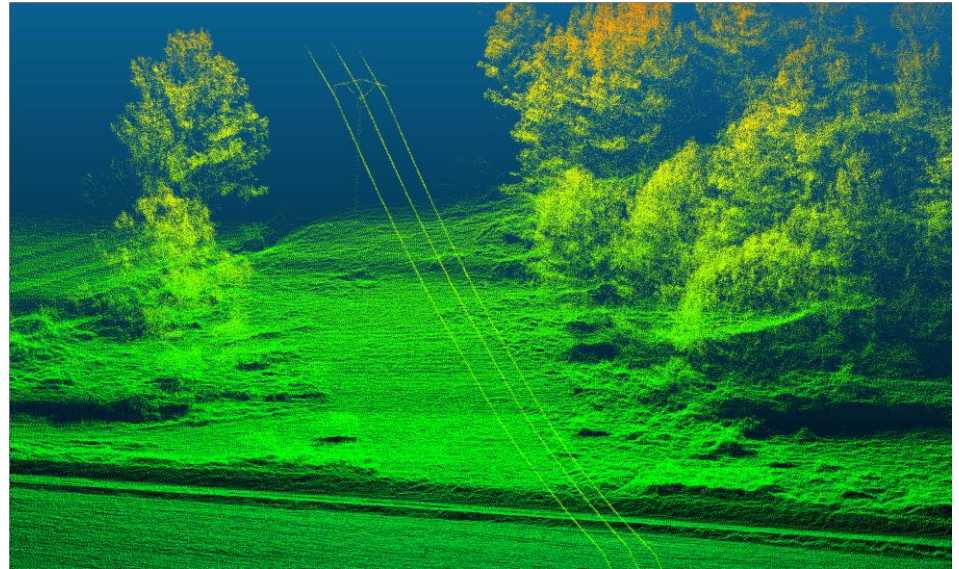


Using technology and new processes for OHL design

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



LiDAR data capture



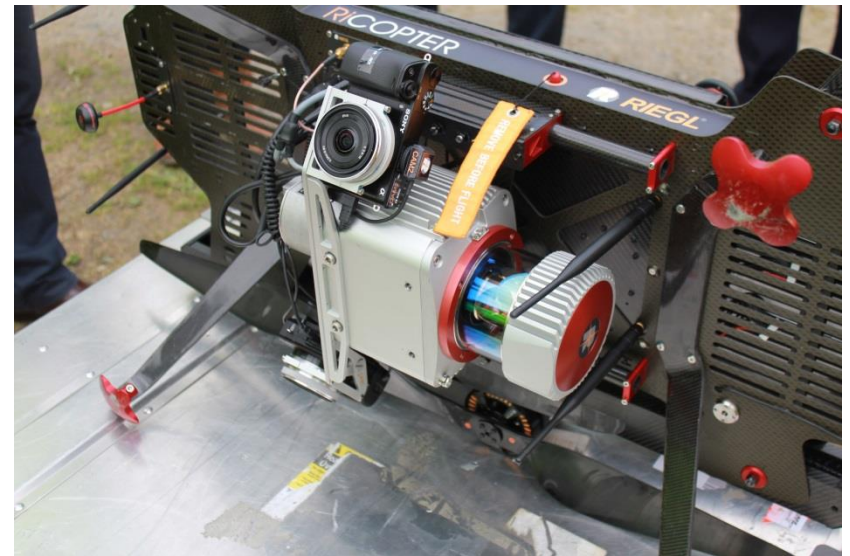
LiDAR data post - processing



Using technology and new processes for OHL design

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 has conducted a full trial





Using technology and new processes for OHLs

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

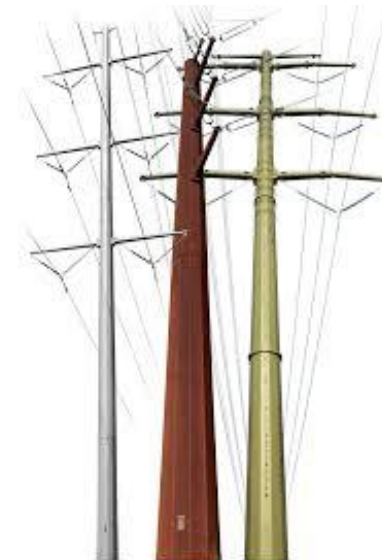




Using technology and new processes for OHLs

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

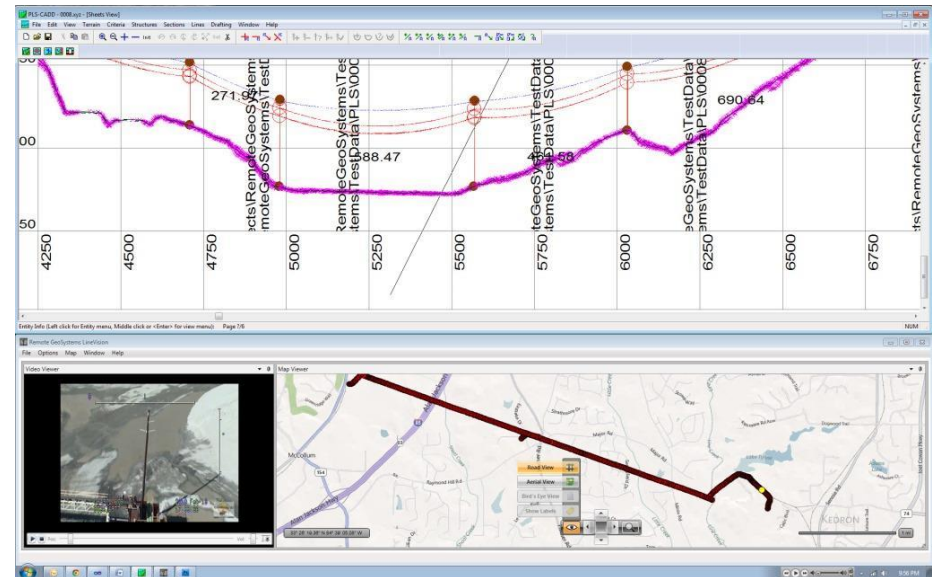




Using technology and new processes for OHLs

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 is output
- A clearance schedule to all features is output





A quick round up!

1. The changes with renewable generation throughout the UK.
2. The national energy policy for generation and transmission.
3. The challenges for the transmission and distribution system.
4. The Holford rules and how they affect the NEW T&D system.
5. Applying the latest technology to the requirements of the new T&D system.





The Protean design approach for 11–33–132kV

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 have 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



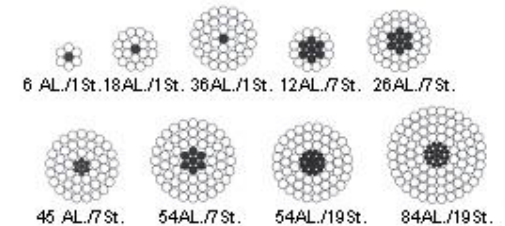


A radical alternative design approach

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.
- Once we have the transverse, longitudinal and vertical loads we can size and rationalise each of the structures.



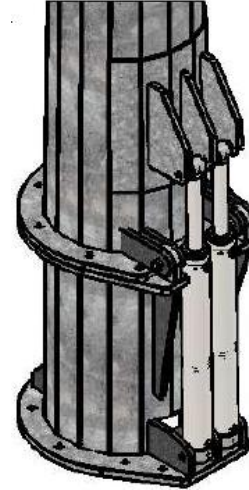
A radical alternative design approach

- 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 to support the structure based on the strength of the soil and its characteristics.



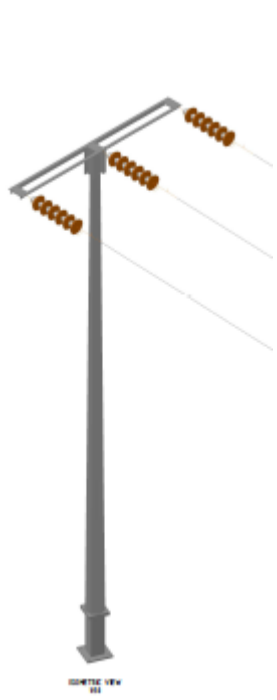
The Protean main components

The design is undertaken in a 3D CAD environment.

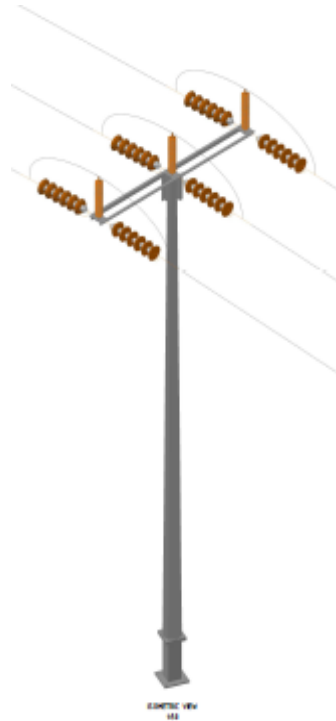




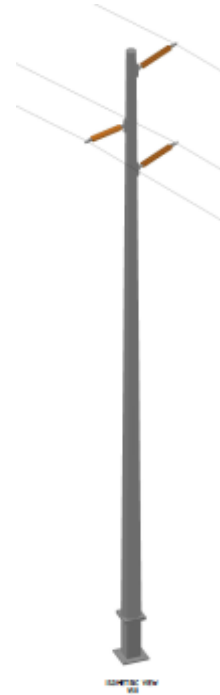
The Protean structure types



Terminal



Angle



Intermediate



Intermediate



Foundation failure





Foundation failure





Foundation failure the cause

There are a number of causes for foundation failure:

- Lack of knowledge that a wood pole requires a properly designed foundation
- Very poor Site geo-technical investigation
- Very little research in to the causes of settlement/movement
- One size foundation fits all
- The mechanical loads produced from wind and ice loadings
- Poor quality installation, incorrect back filling with poor soil compaction
- No innovation to develop new systems
- Cost is all that matters, we need to look at value



The Protean intermediate pole foundation

BPI have reviewed the current OHL foundation design and worked with foundation specialists to develop a replacement to the current timber baulk design.

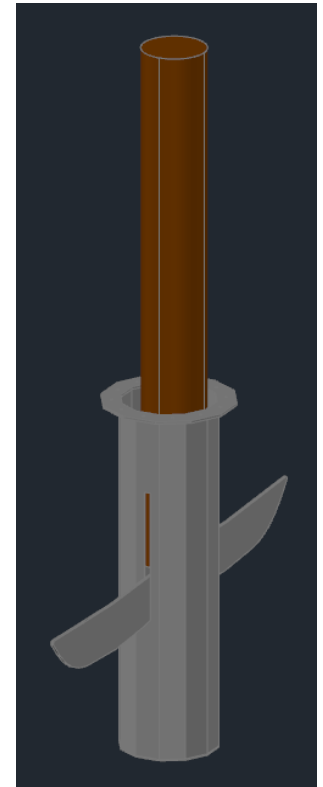
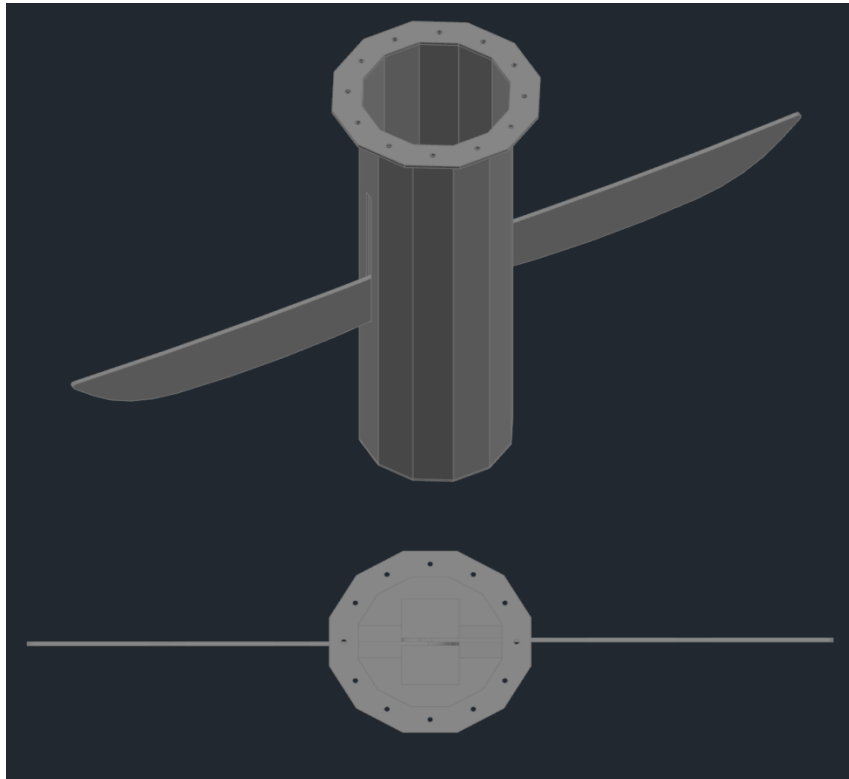
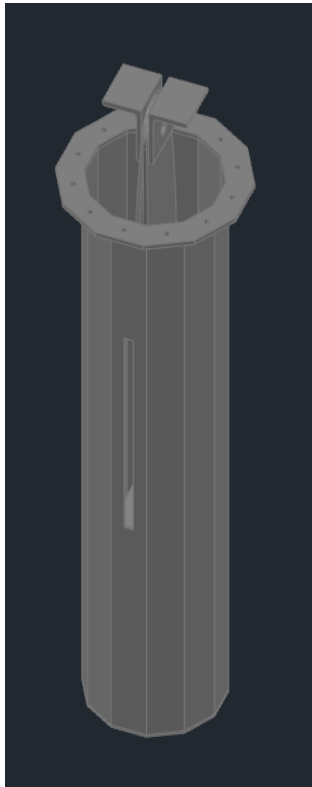
The new foundation is significantly stronger on paper and is planned for load testing in the next month.

The new foundation is under a patent design and will be used with the Protean system (intermediate) and traditional wood poles.



The Protean intermediate pole foundation

The new design provides at least 50% more transverse load capacity.





The Protean intermediate pole foundation

In brief:

- The new foundation design is made from 6–8mm galvanised steel plate.
- The foundation is inserted using Vibro foundation equipment.
- The blades are inserted using a simple rotating attachment.
- The foundation can support both steel and wood poles.
- The foundation void is filled with an expanding agent.
- The foundation can be used for weak to firm soils.
- The foundation is guaranteed for 40 years service.
- In the case of wood poles the creosote protected pole will not be in contact with the surrounding ground.
- The foundation is at least 50% increase in capacity for transverse loads.



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 and manufacture

- 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.
- Each structure is provided with ACD, climbing and fall arrester.





The Protean main components

The structure cross arm 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



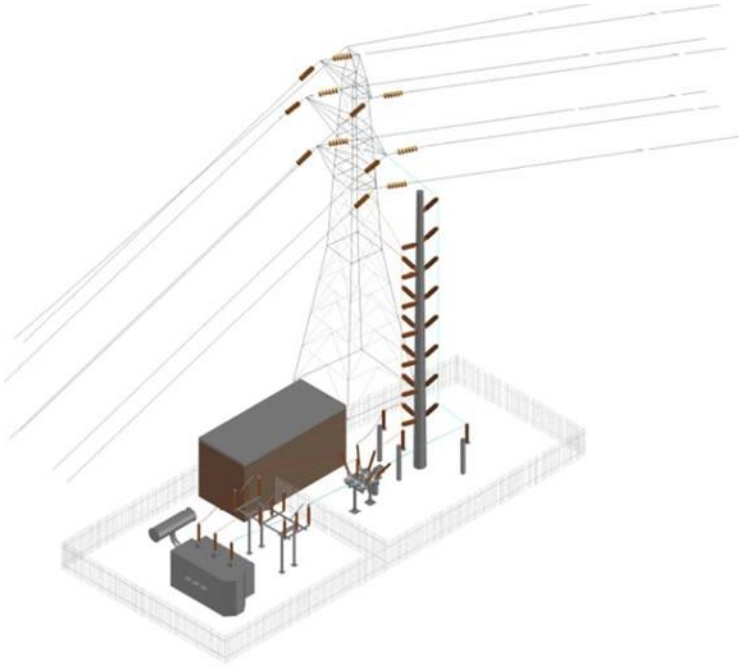
Folded steel extended to a POC design

- 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 in to the existing OHL structure.



Folded steel extended to a POC design

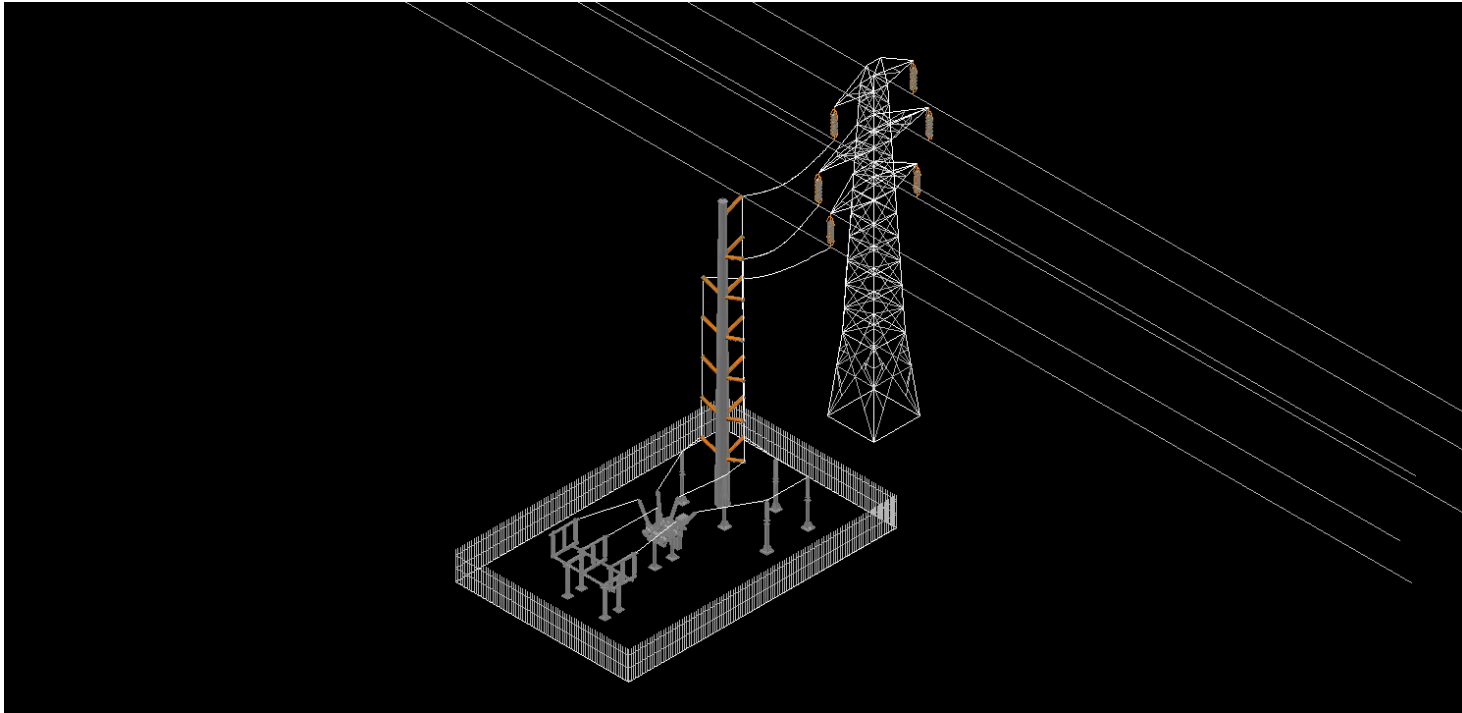
The POC-MAST can be used for both a **Tap in** or **Loop in Loop out** permanent connection





Folded steel extended to a POC design

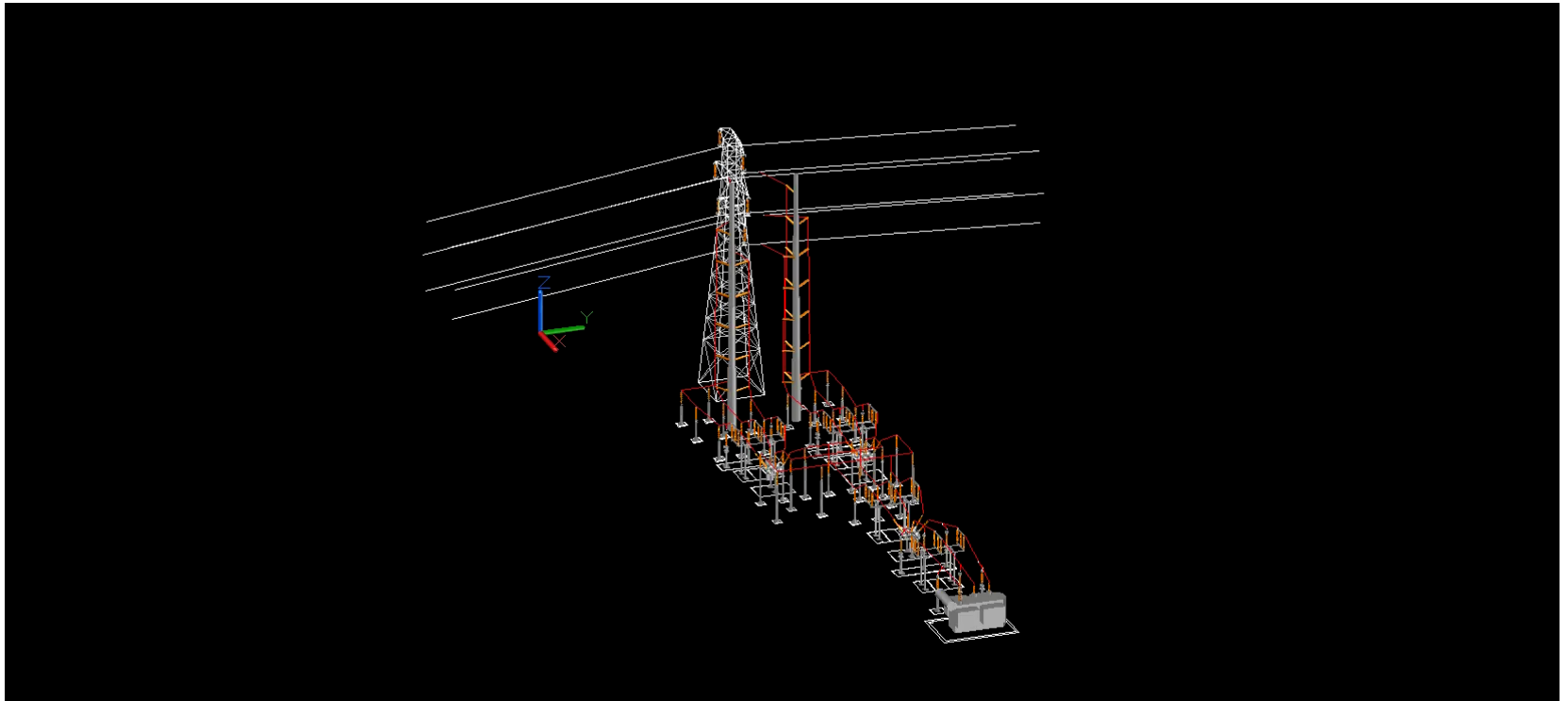
The POC-MAST can be used for both a **Tap in** or **Loop in Loop out** permanent connection





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

1. There is **no need** for specific protection for a POC-MAST. It simply needs to be securely earthed.
2. The mast is the physical apparatus providing a means of connecting the power cable leads between the overhead line and the new connection. Hence it requires no more protection than would a standard overhead line tower (or indeed a post insulator within a substation).
3. The protection requirements are no different to that for any other type of connection. The protection zones of the new connection will cover the leads teeing off from the overhead line.
4. For example, for a new generation point this could be covered by the G59 protection and for a feeder it would be covered by whatever protection is being installed.





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 route and location.
- The screw–anchor/tube foundations are designed to meet the soil bearing capacity.
- The Protean foundation can be installed under line for OHL rebuilds without an outage.
- The Protean and POC–MAST can be installed with the hydraulic hinge in minimum outage time.





Helicopter LiDAR and UAV drone technology

- BPI has already completed in excess of 1000km of OHL aerial survey in the UK for the design of 11–33–132kV.
- Detailed OHL designs were developed from the LiDAR data.
- The main advantages of LiDAR data capture over traditional OHL surveys are as follows.





Helicopter LiDAR and UAV drone technology

Traditional methods

- There are very few OHL survey companies in the UK.
- The land owner must be managed for access, which can affect program.
- A traditional ground survey for new lines provides at best 0.75 km/day.
- A traditional ground survey for existing lines provides at best 1.0 km/day.
- The output is feature and XYZ coordinates only. There is limited structure information.
- Any re-routing would require another site survey.
- Data collection for the conductor is very limited.

Aerial survey technology

- Over 100,000km flown to date.
- Full compliance with Aviation Authority.
- Data capture accuracy and quality checks.
- 120km/day to an accuracy of +/-50mm.
- Rate of data capture and post processing and return 6 weeks.
- Feature categorising along the OHL route.
- Data interchange and interface with PLS and Optimal.
- Data capture point cloud intensity 250,000pt /second.
- Forward and vertical facing lasers.
- Forward and vertical facing 16 megapixel digital cameras.
- Forward and vertical facing HD videos.



UAV drone technology

BPI undertook a UAV drone test flight in June, with positive results.



The latest drone technology



The drone LiDAR output

Below is an example output of the LiDAR data captured by the on-board laser scanner mounted on the UAV.





Battery technology in the UK

- BPI provides a battery integration design service.
- There are a number of battery manufacturers offering their systems in the UK.
- There are few companies offering the integration in to the existing power infrastructure.
- The main contracts have been for EFR (Emergency Frequency Response).
- BPI has already completed a 50MW modular building design.

So what are the challenges once you have decided on the battery technology?

- A container or building solution
- Connection in to the grid
- The building design



A container or building solution

- To date there seems to be very limited guidance from the DNOs on the specification of the container or building.
- The most recent enquiries over 20MW are looking for a building solution.
- So what does the audience consider to be the advantages and disadvantages of the container vs building?



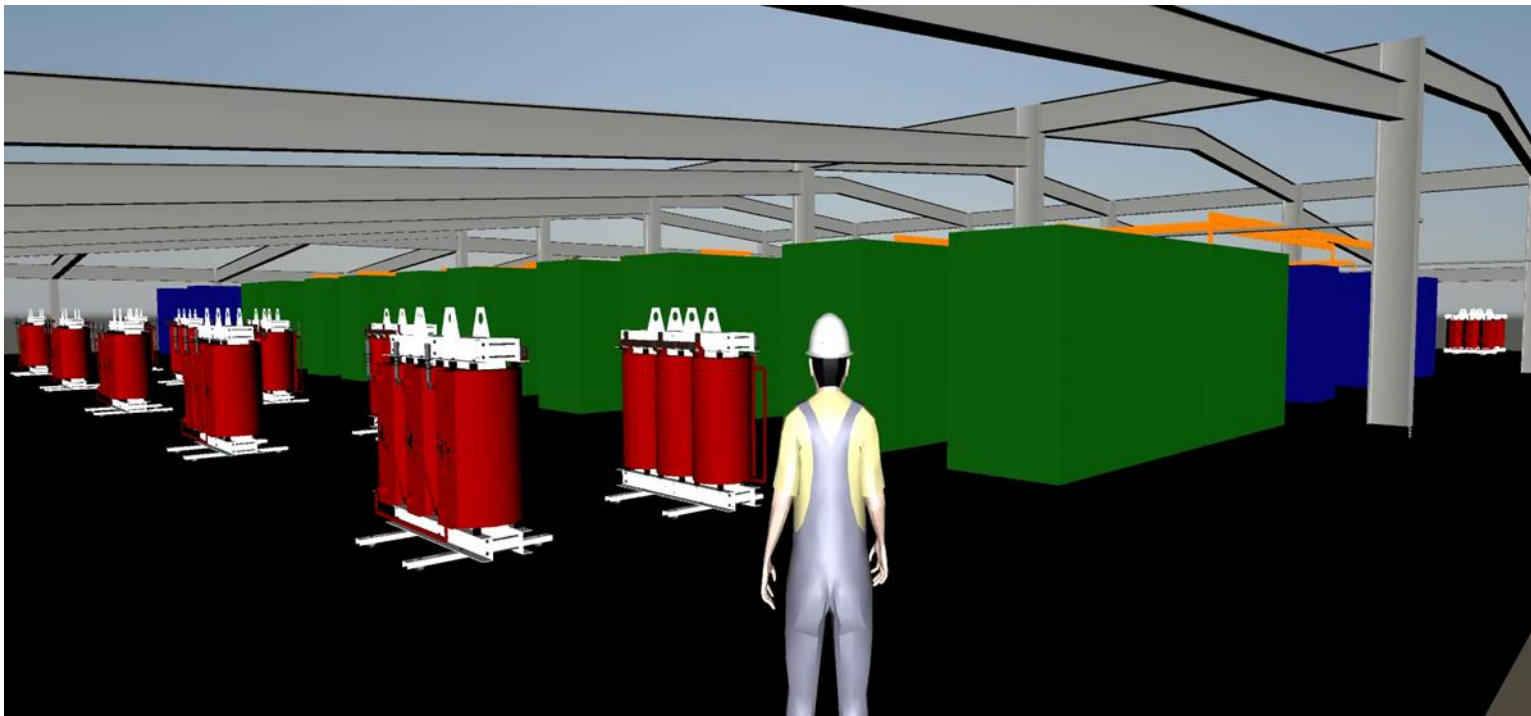
A building solution

- BPI has developed a modular/scalable battery building design.
- The main additional plant components are the switchgear, transformer and bus-bars.
- The cable connections.
- Offices and washrooms.
- SCADA control.
- Lighting and ventilation.
- The screw-anchors are ideal for the foundation, minimising concrete and curing time.
- A steel frame design for speed of assembly.
- Working with specialist cladding companies for planning and temperature control.
- Working with fire protection suppliers to meet all fire regulations.



A building solution

The latest Prim-tech software is ideal for providing highly detailed designs





Thank you