Power Line Systems

IT'S ALL ABOUT YOUR POWER LINES

2017 PLS-CADD Advanced Training and User Group

"May the wind be always at your back"

PLS-CADD helps meet the challenges and opportunities of wind energy in Ireland

by

Oisín Armstrong

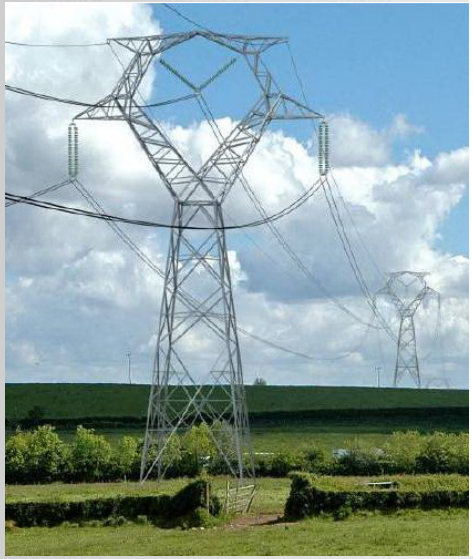
ESB International

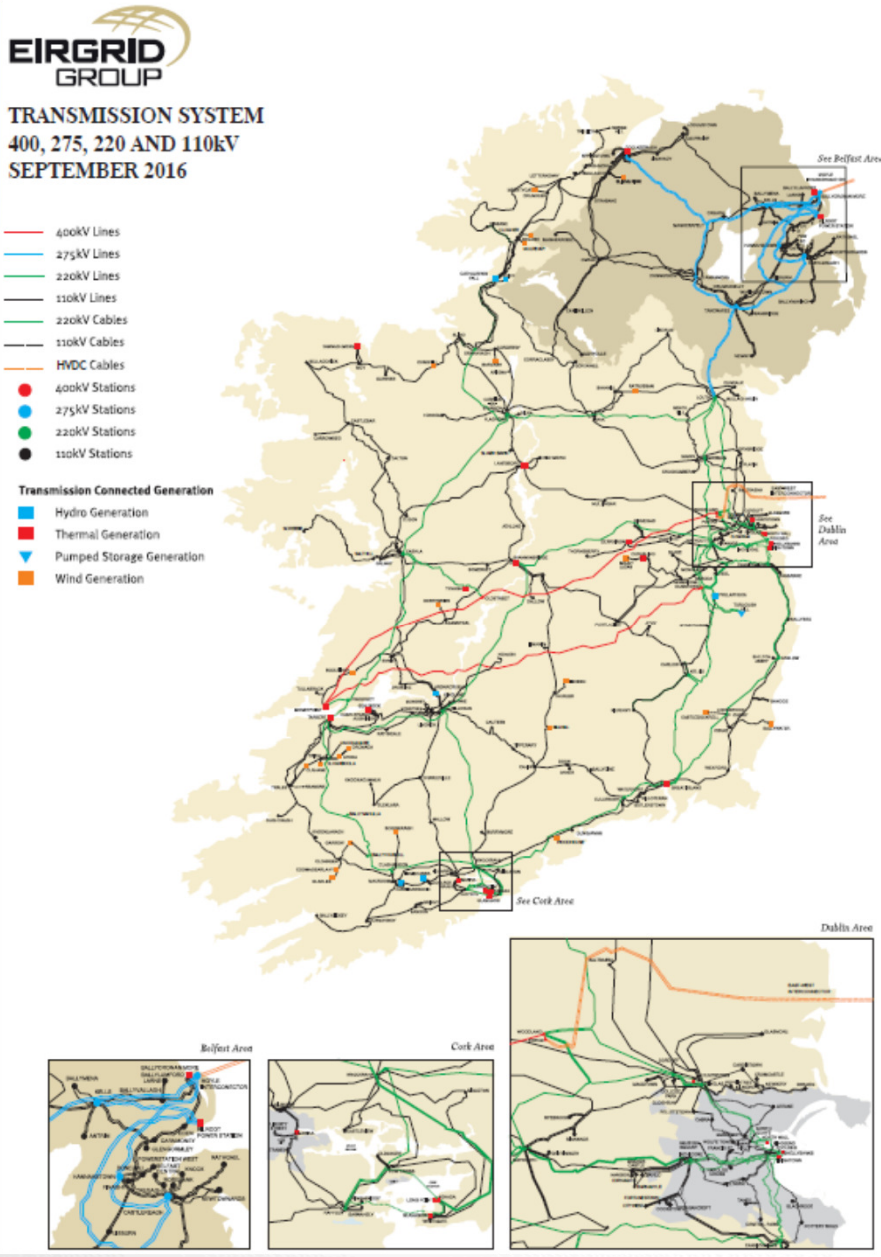
POWER LINE® SYSTEMS · INC ·

IT'S THE SOLUTION

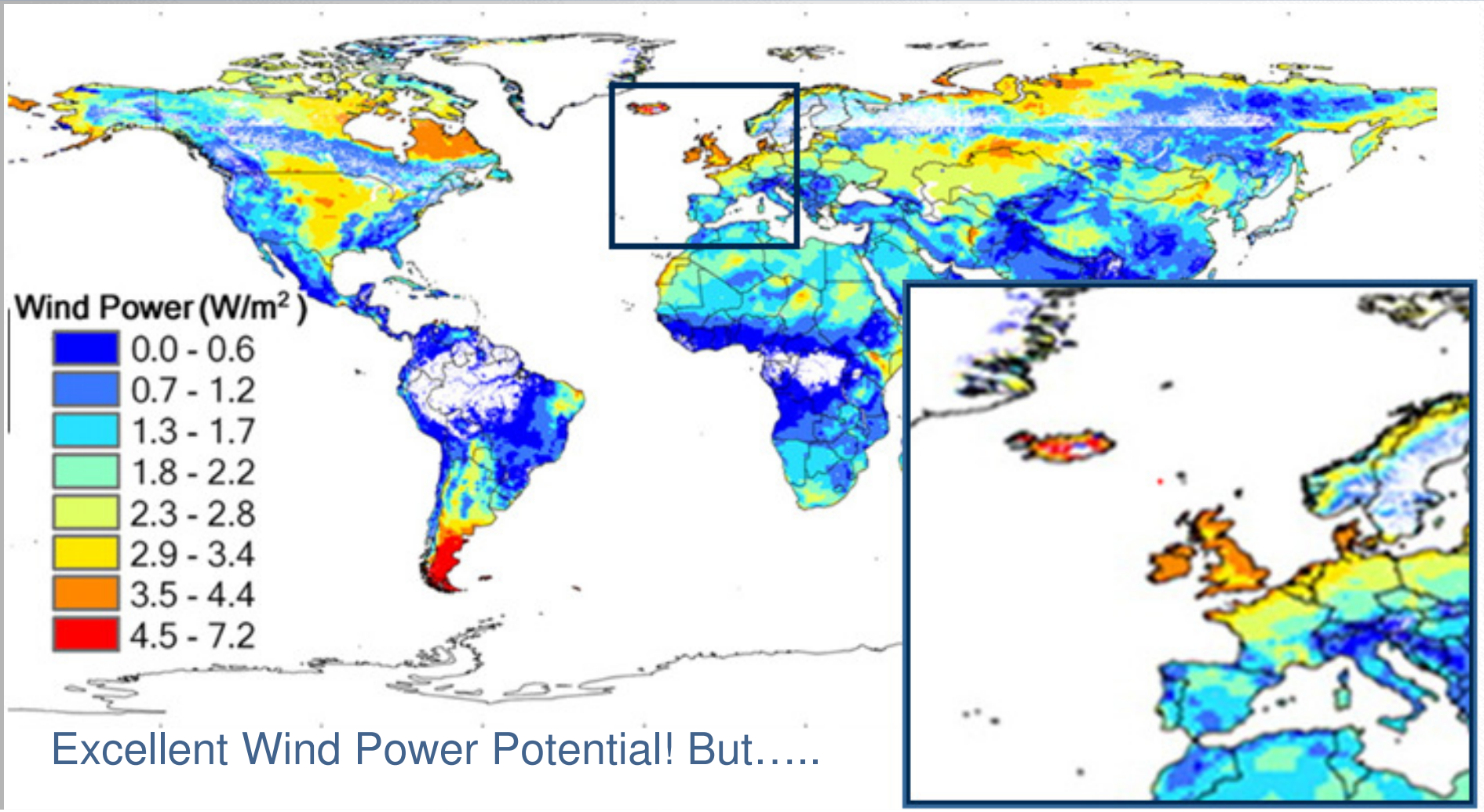
Ireland - Network

- **Ireland – Network Organisations**
  - **Grid Operator – EirGrid (Transmission)**
  - **Asset Owner – ESB Networks (T&D)**
  - **Network Design/Maintenance/Standards – ESB International**
  - **Network Development –, EirGrid, ESB , IPP's etc.**
- **Transmission Network**
  - 400 kV – 450 km (Steel Lines)
  - 220 kV – 1,900 km (Steel Lines)
  - 110 kV - 4,900 km (Wood Portal/Steel)
- **Distribution Network**
  - 38kV – 6,000 km (Wood Pole/Portal)
  - <20kV – 150,000 km (Wood Pole)





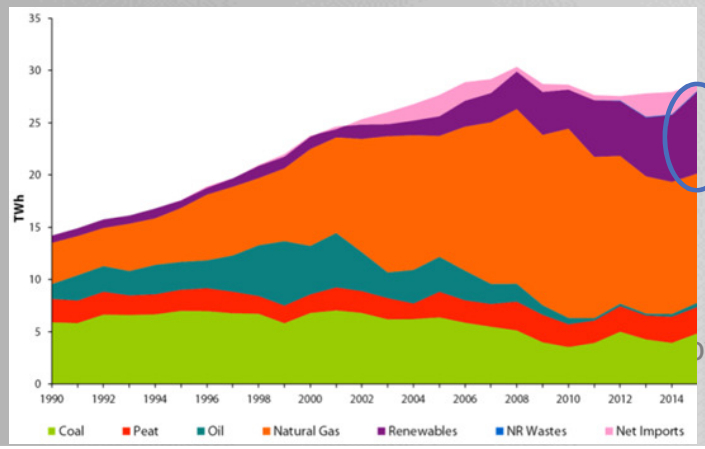
Ireland - Wind Power Opportunity



Excellent Wind Power Potential! But…..

Wind Energy In Ireland (2017)

- **Island of Ireland Figures (NI & ROI)**
- **Total No. of Windfarms = 272**
- **Installed Capacity = 3,736 MW**
- **Wind Generation Record = 3,071 MW at 18:45 on 25th Jan 2017**
- **Over 60% of total electricity usage at time**
- **Renewables in 2nd place after gas but ahead of coal**
- **Target of 40% for renewable energy (by 2020?) will require up to 6,000 MW of wind generation capacity installed**
- **21% of Ireland's electricity demand met from wind in 2015**

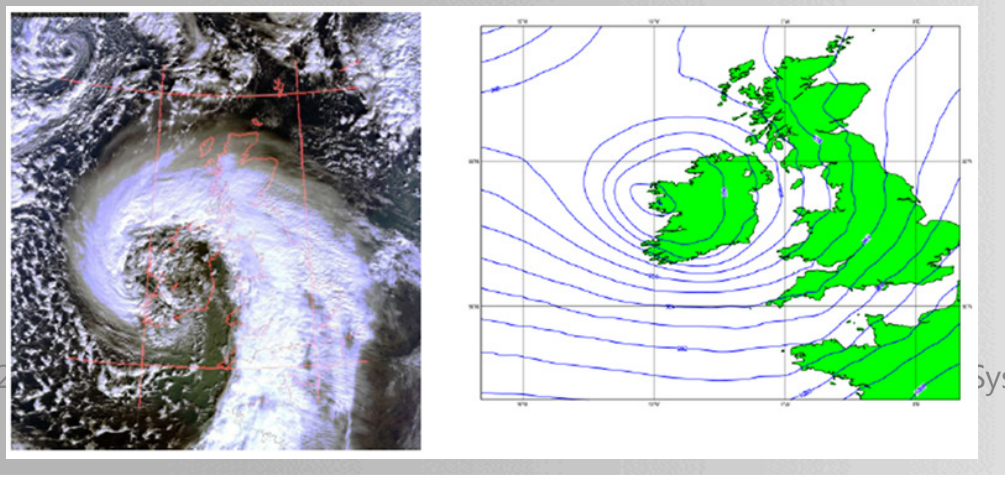


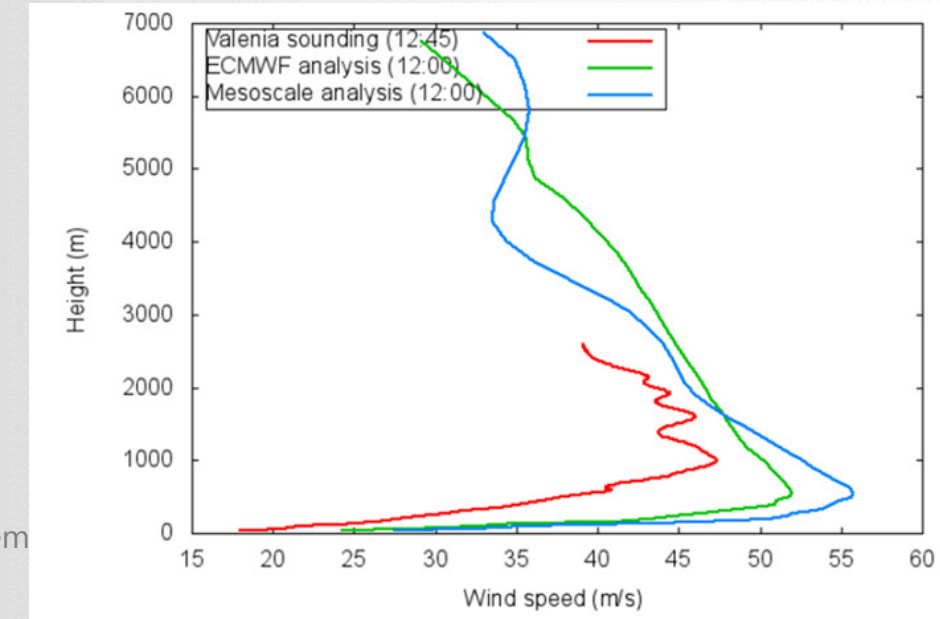
Generation – concentrated in NW and SW

Wind Energy Challenges

- Ireland is a windy (and sometimes stormy) location!
- Most Recent Example - Storm "Darwin" (12th Feb 2014)
- Worst of 9 storms in a two-month period
- One of 5 worst weather systems to hit Ireland in past 130 years
- Estimated that 1% of all forestry felled

Storm Darwin Video



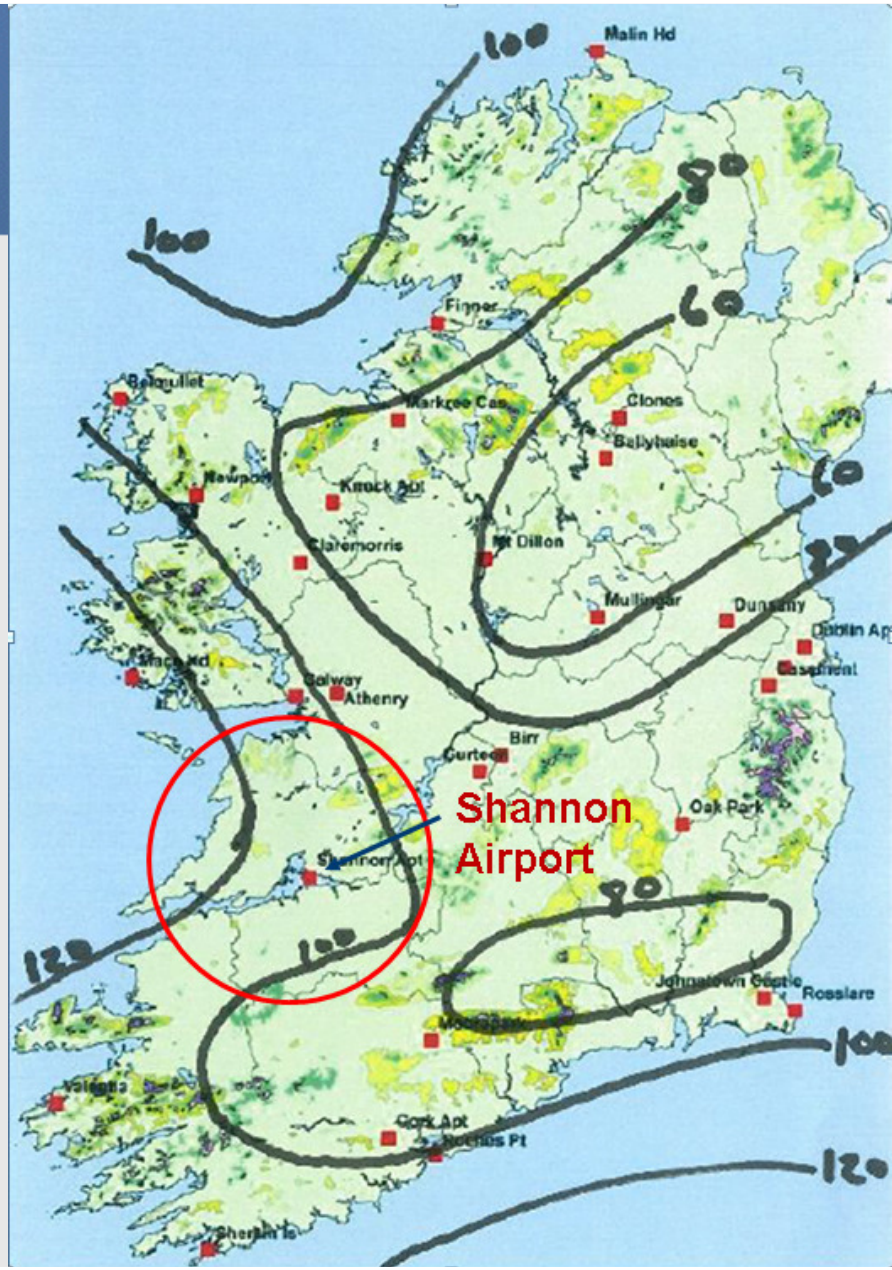


Storm Darwin Damage

- 260K customers out at peak (13% of Total)
- 25K individual network faults
- 10 days before all customers restored
- Widespread damage on distribution network
- 3 portal structure failures on 2 110kV transmission lines – poor ground, should have been stayed (guyed)
- Various other minor damage and faults on 110kV network
- Max. Sustained wind (10 min mean) of 120km/hr (> Cat 1 hurricane min of 118km/hr)
- Max Gust wind of 159 km/hr (98.7 mph) recorded (5th highest on record)

Storm Darwin Analysis

- Pressure drop of 39 hPa in 24 hrs
- A “Weather Bomb” since > 25 hPa drop in 24 hours
- Minimum of 955 hPa (28.20 inches)
- Peak wind speeds increasing rapidly with height to around 700m elevation (“Sting-jet”)
- A 1 in 20 year event but Met Eireann noted that in parts of Ireland could be “worst in living memory” event (1 in 50 years?).
- Area centred on Shannon Airport saw peak gust of 159km/hr (98 mph)
- Area also saw most damage to network, particularly transmission (designed for 100 mph wind).

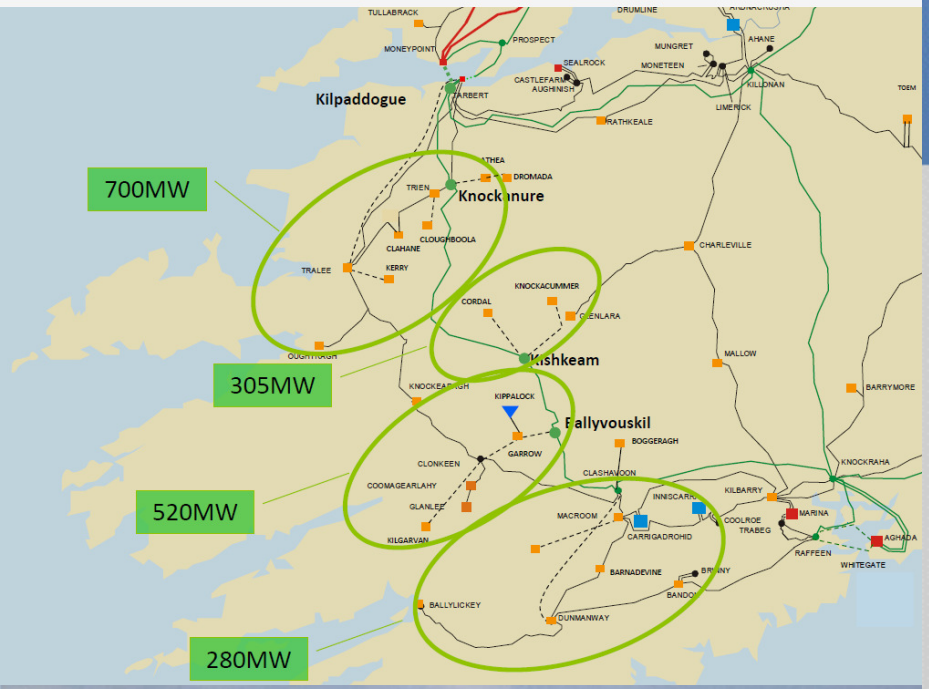


How Did it Compare?

- **Described as a violent storm but not exceptional**
- **Hurricane "Debbie" in 1961 - gusts of 130-160 km/hr generally and max of 181 km/hr**
- **Winter storms in 1997 and 1998 more intense (stronger gust winds recorded)**
- **"Night of the Big Wind" in 1839 is still without parallel - over 100 deaths**

Year	Date	Storm	Wind Force	Wind - 10 min	Wind - gust	ESB Impact
1839	6-7th Jan	"Night of the Big Wind"	Force 12	65-70 knots (Est.)	75-100knots+ (Est.)	NA
1903	26th-27th Feb	Winter Storm	Force 11+	NA	NA	NA
1961	16th Sept	Hurricane Debbie	Force 12	66 knots	98 knots	No data available
1974	27th Jan	Winter Storm	Force 11	62 knots	96 knots	241K customers out, 6732 Plant Items Damaged, Cost=€4.2M
1976	2nd Jan	Winter Storm	Force 11	56 knots	85 knots	148K customers out, 3662 Plant Items Damaged, Cost = €1.8M
1988	9th Feb	Winter Storm	Force 11	60 knots	93 knots	? Customers out, 3753 Plant Items Damaged, Cost = €2.6M
1997	24th Dec	Winter Storm	Force 11	56 knots+	88 knots	355K customers out, 10,877 Plant Items Damaged, Cost=€8.7M
1998	26th Dec	Winter Storm	Force 11	61 knots	96 knots	185K customers out, 6,479 Plant Items Damaged, Cost?
2014	12th Feb	Winter Storm "Darwin"	Force 12	65 knots	86 knots	280K customers out, 50001 Plant Items Damaged, Cost=€25M

GRID25 Network Development South

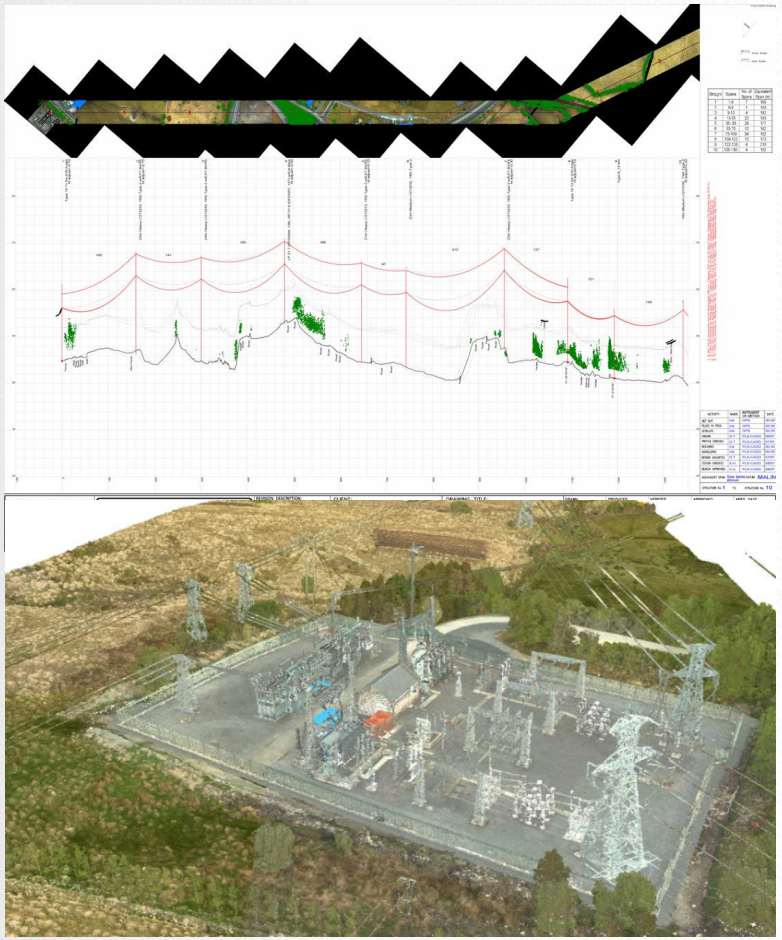


Wind Energy Developments

- **Transmission Network Development**
  - 1,150 km new lines (220 kV and 400 kV)
  - 2,300 km of line uprates 110 kV and 220 kV
    - 1,200 km at 110 kV
    - 1,100km of 220kV (70% of existing 220 kV
  - Multiple new generation connections to existing grid for Wind Generation – many in SW and NW Ireland
- **Overall Challenges**
  - Building new lines – planning/environmental
  - New technologies – conductor/towers etc.
  - Ensuring optimised solutions
  - Reuse of Existing infrastructure

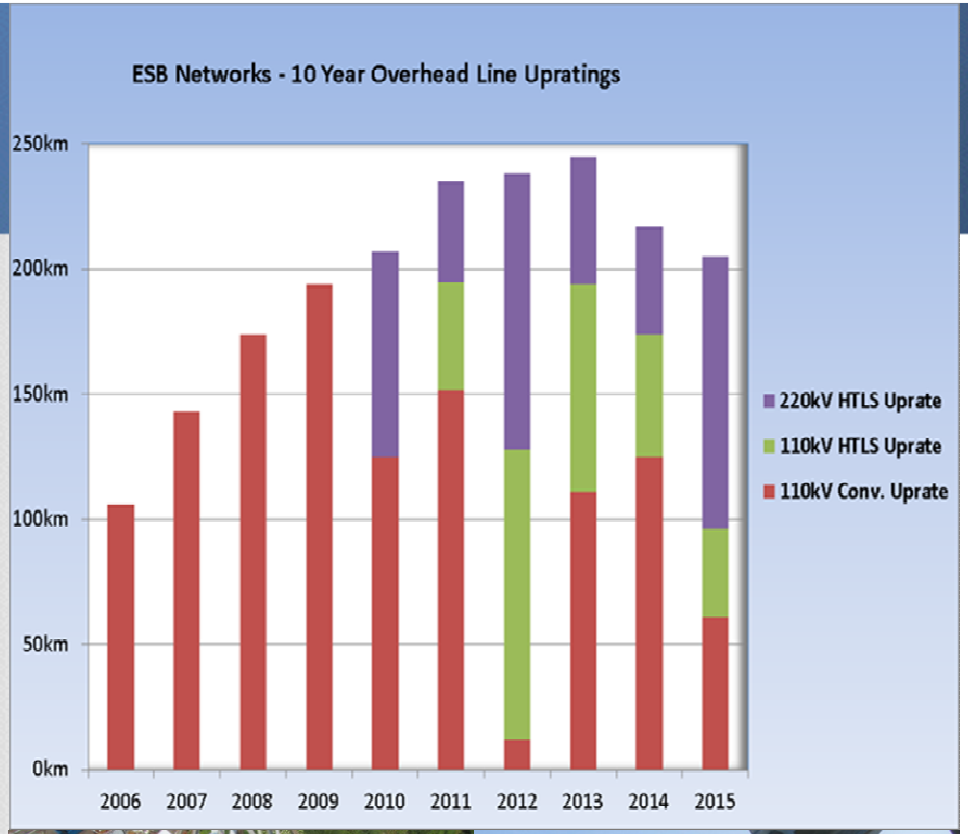
Project Delivery: PLS-CADD with Lidar

- **PLS-CADD Design System**
  - Introduced in 2003-4 / By 2005, all new designs utilising PLS-CADD
  - 75 PLS Licences (incl. 25 CADD, 18 POLE, 13 TOWER, 11 SAPS etc)
  - Full Materials Database, Structure Libraries etc.
  - In-House Applications (Excel-based)
    - Design Verification System (DVS)
    - Thermal Rating Data Manager (TRDM)
- **PLS-CADD with Lidar**
  - Lidar-based designs commenced in 2006
    - refurbishment and uprating designs
    - in response to new legislation on Safety Files etc.
  - Widespread acceptance of advantages of PLS-CADD with Lidar.
  - Since 2006, 3,000 line km of uprates, refurbs, new builds completed
  - 5 year lidar framework for up to 500 line km per year



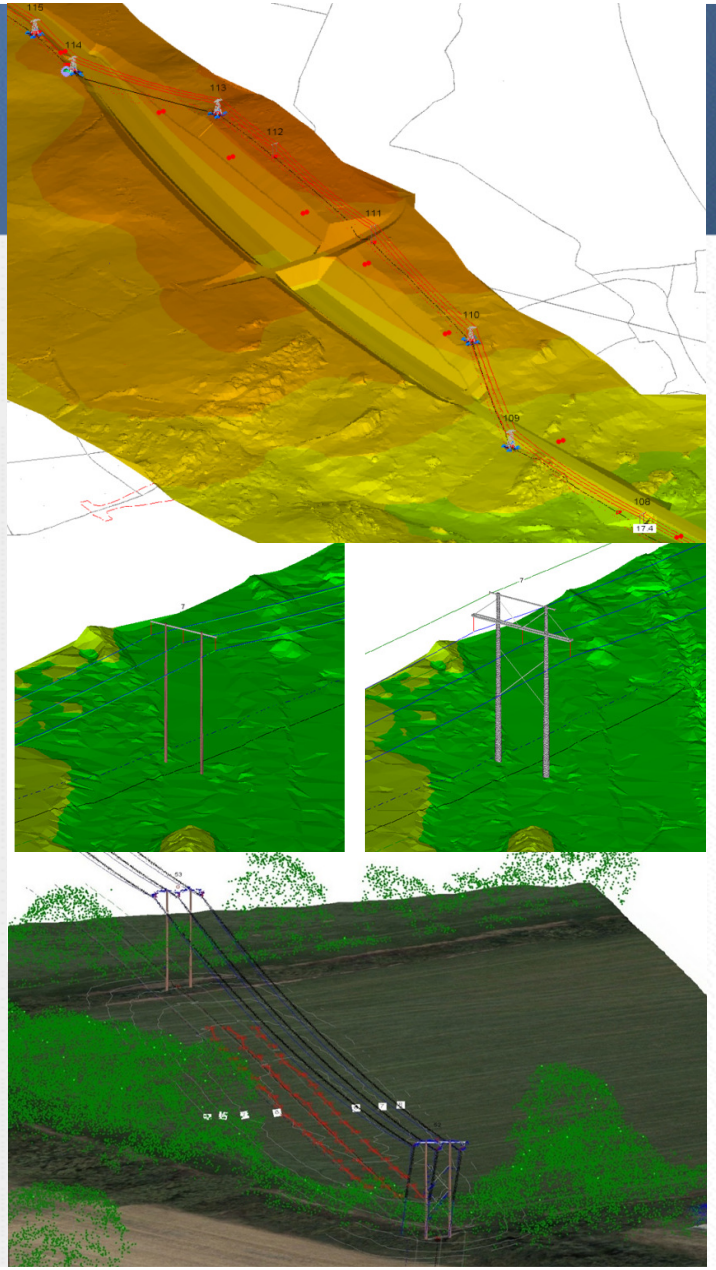
PLS-CADD Benefits!

- **Doubling of project delivery since 2006 on line uprates**
- **Changing nature of projects…**
  - HTLS (Gap-type) conductor widely deployed since 2010, particularly on 220kV Lines)
  - 750 line km HTLS Uprates installed since 2010
  - 500 km+ ACSR upgradings since 2010 on 110kV unshielded network with OPPC phase to replace phase wrap
  - Requirement to retain wrapped phase live during uprating works
- **Staff numbers unchanged since 2006…**
  - PLS-CADD w/ Lidar main driver of increased productivity
  - Staff age profile also a positive factor (in some senses!)



OHL Design Challenges

- **Maintenance Issues**
  - Composite poles to replace wood poles
  - Steelwork corrosion and replacement
  - Diversions/Alterations of Existing Circuits
- **Voltage Upgrades**
  - 110 to 220kV (composite pole portals)
  - 220kV to 400kV (composite crossarms)
- **Distribution Assessment w/PLS-CADD**
  - 38kV network lidar surveys and assessment (incl. fibre)
- **New Design Standards**
  - Application of new fully probabilistic design approach
  - Based on Wind/Ice Model for Ireland

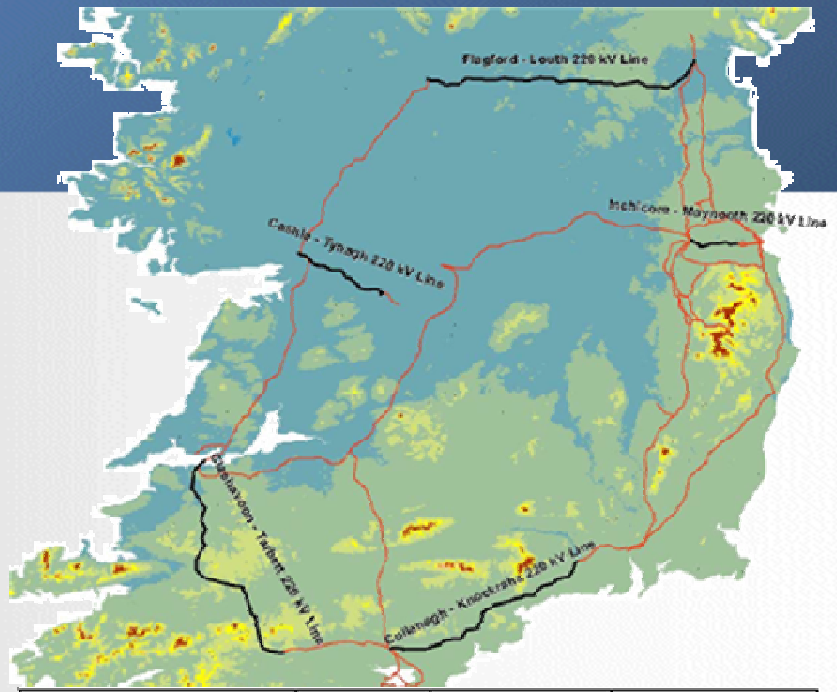


New Design Standards

- **Need to best utilise existing line assets**
  - How valid were original deterministic design standards?
    - Wind-only : 100 mph Wind (44.7 m/sec)
    - Ice-only : 40mm (1.57”) radial ice, 900 kg/m^3
    - Wind and Ice : 25.7 m/sec wind on 25mm (1”) radial ice, 900 kg/m^3
  - These ice values/densities seem excessive? Maybe not given some recent ice events!
  - Ice load increase with elevation?
  - Wind speed increase with elevation? Recall the Storm Darwin Wind Profile
  - Geographical Variation of wind/ice loads? Any need - Ireland is a very small island!

Wind/Ice Loading Assessment

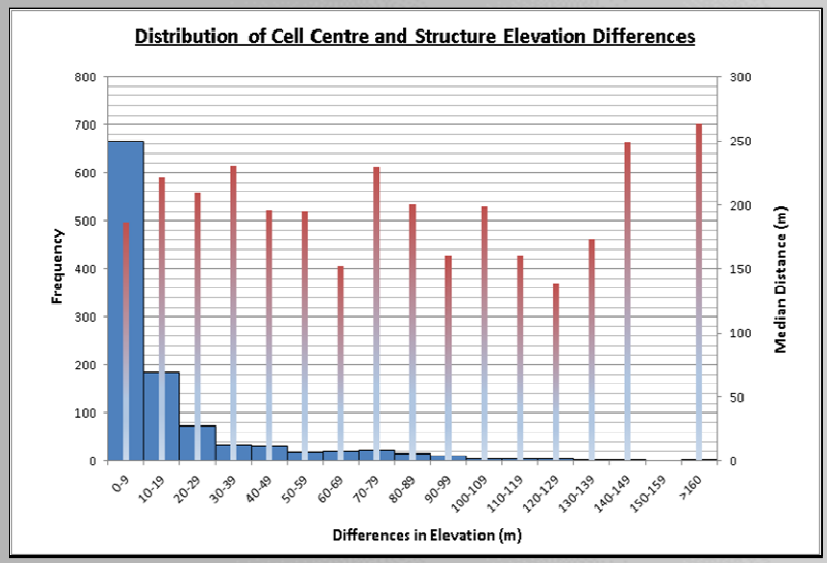
- Development of new Wind/Ice Model for Ireland (500m resolution) by EA Technology (UK)
- Use of New Model on Feasibility Study Project in 2015
- Follow-on study on sizeable existing network sample (5% or 400 line km – 5 no. 220 kV lines selected
- Sample Lines already fully modelled in PLS-CADD using Lidar Surveys
- 4 out of 5 uprated with Gap-type conductor (GZTACSR 586mm²)
- Assist with determining appropriate ice/wind values to use for new design approach….
  - For new Irish NNA to EN50341-1:2012
  - Will Ice/Wind Model loadings exceed deterministic? – if so, where?



Line	Length (km)	No. of Structures	Elevation Spread
Flagford-Louth 220 kV	110	321	24 m - 252 m
Inchicore-Maynooth 220 kV	19	72	42 m - 85 m
Clashavoon-Tarbert 220 kV	100	286	4 m - 288 m
Cullenagh-Knockraha 220 kV	86	290	8 m - 168 m
Cashla-Tynagh 220 kV	40	117	22 m - 111 m

Sample Lines Assessment

- PLS-CADD Staking Tables merged with Wind/Ice Cell Data (500m cells) in ArcGIS
- Spatial Join used to select ice/wind cell centres closest to each structure
- 90% of elevation differences between PLS-CADD structures and cells <30m
- No evident correlation with distance

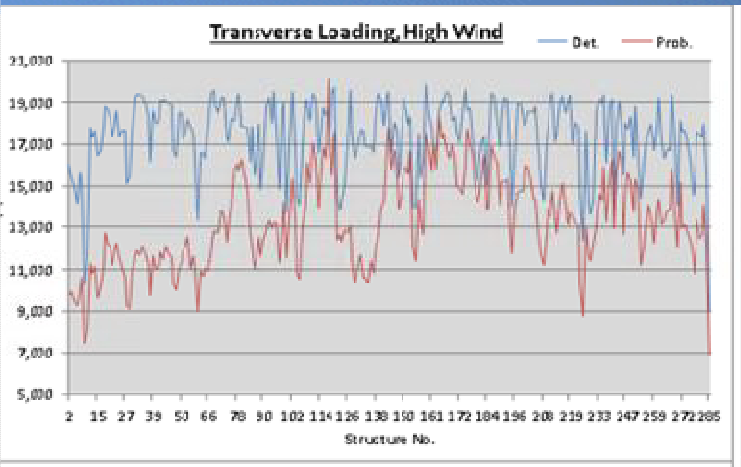


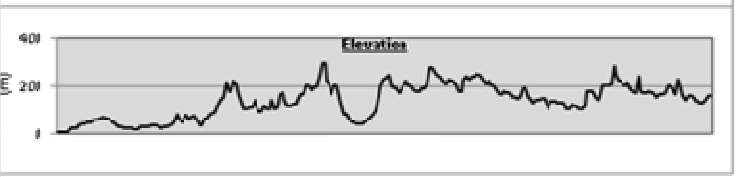
Deterministic Loads	Probabilistic Loads
High Wind Transverse	High Wind Transverse
Heavy Ice Vertical	Heavy Ice Vertical
Wind and Ice Transverse	HP* Wind LP* Ice Transverse
Wind and Ice Vertical	HP Wind LP Ice Vertical
Wind and Ice Transverse	HP Ice LP Wind Transverse
Wind and Ice Vertical	HP Ice LP Wind Vertical

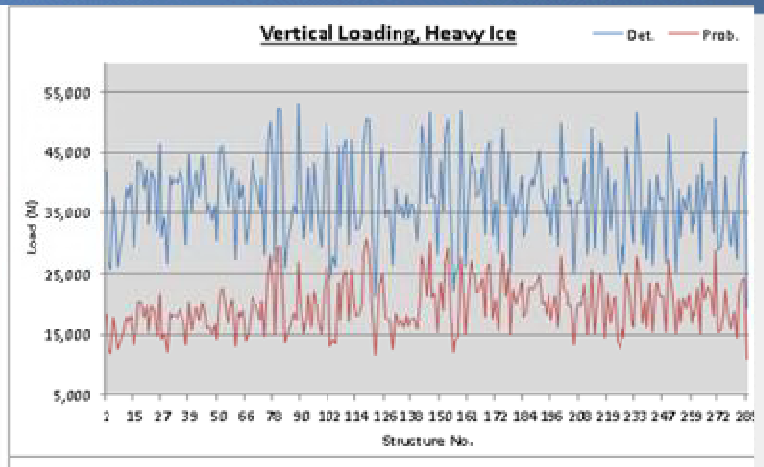
*HP = High Probability *LP = Low Probability

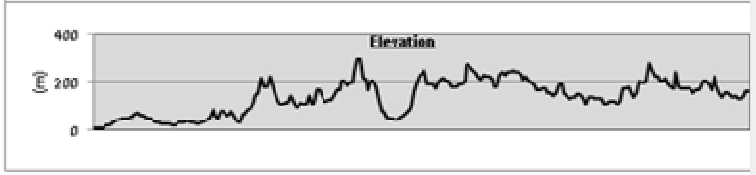
- Suspension (intermediate) structure loadings only considered – for simplicity
- Comparison of climatic loadings
- All structures treated as in-line suspension (>90%+ would be anyway)
- Ice/Wind Loading for Wind/Ice model data calculated using IEC 60826 approach

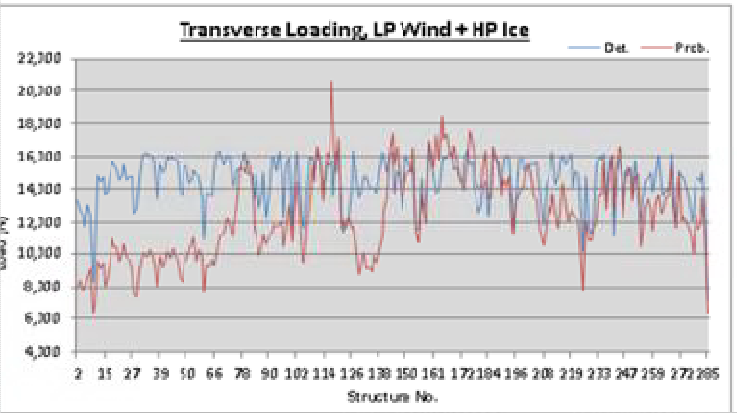
Clashavoon-Tarbert 220kV Line Example

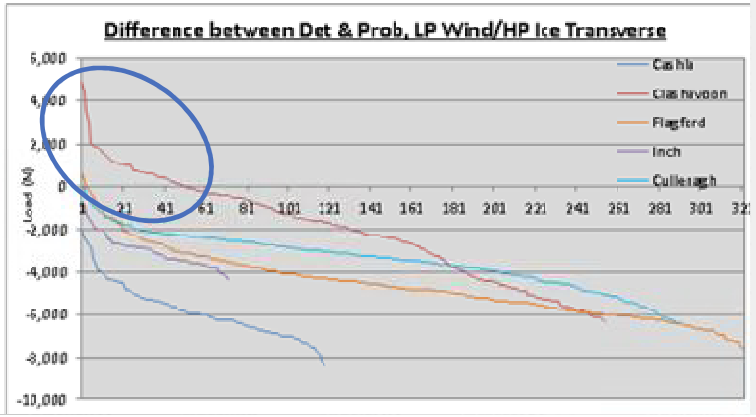


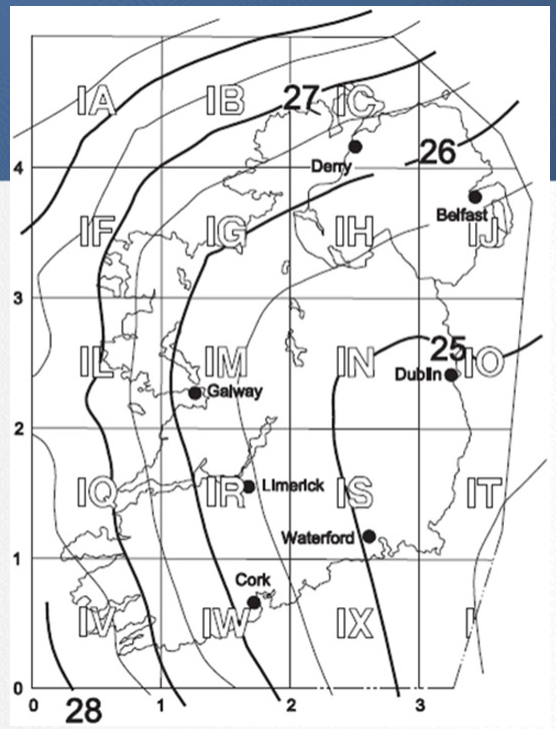










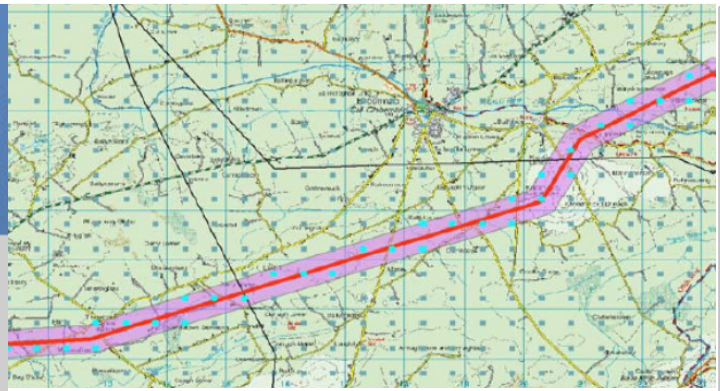


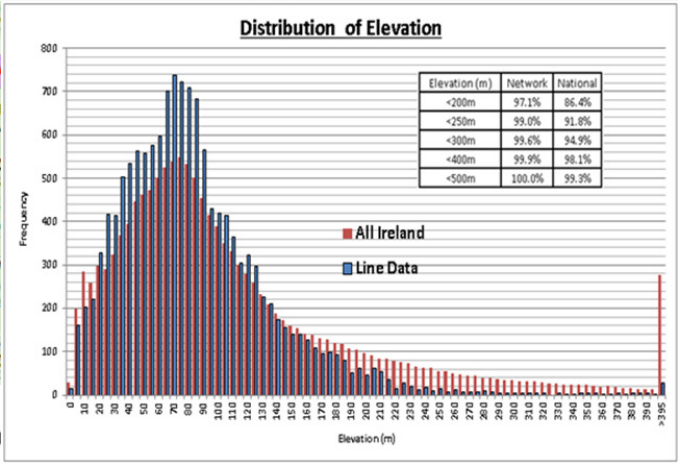
LP Wind/HP Ice Transverse Case : Ordered by magnitude of Loading Differences

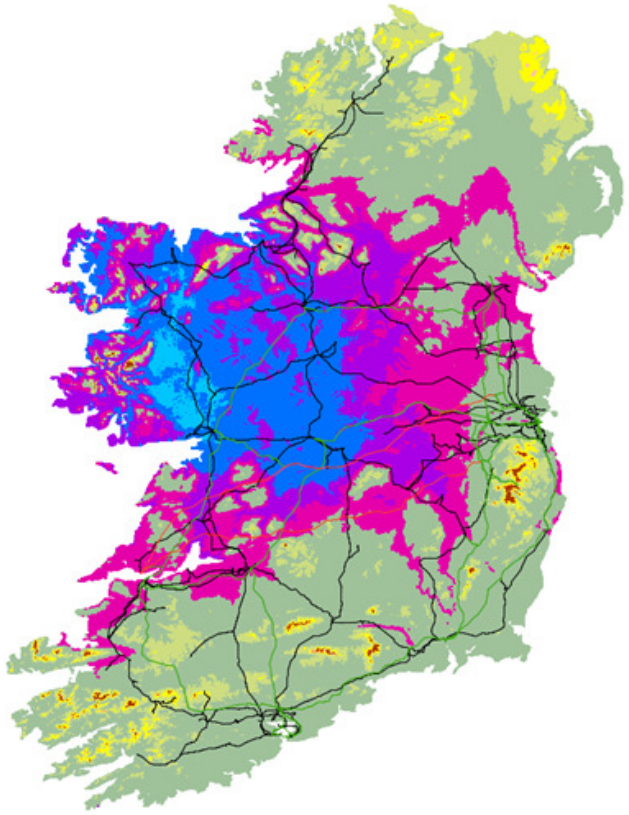
=> Shows that only Clashavoon-Tarbert line has numbers exceeding deterministic loadings

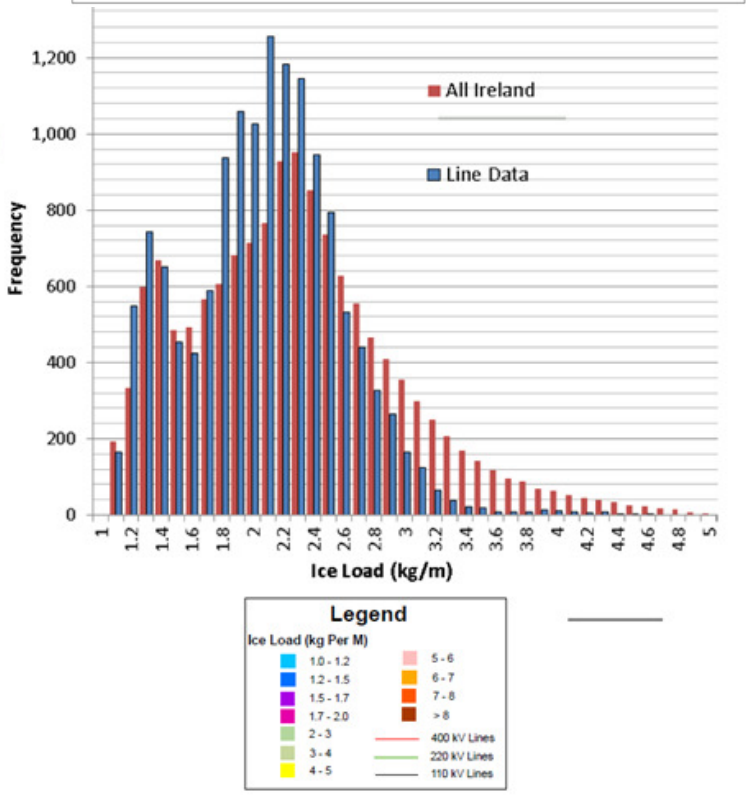
Ice Load Distribution

- Comparison of Wind/Ice Data between Existing Network
- Buffer Applied to extract 1 cell every 500m (or roughly 1 for every 2 structures)
- Compared against national wind/ice model
- Considered elevations and ice loads
- Network skewed towards lower elevations – lower ice and wind loads
- Lines follow valleys and avoid higher locations
- Two distinct ice zones identified but…not practical to consider geographical zone









Assessment Results

- **Consider elevation bands for Design Basis….**
  - **PLS-CADD structures assigned to loading groups by elevation**
  - **Standard families of structures (with wind/weight span limits based on band loadings)**
  - **Ice loads = within-band 95th percentile values**
  - **97% of existing network <200m elevation**
  - **Note: basis is national dataset => more conservative than existing network**
  - **Some existing and future wind farm connection lines up to 500m**
- **Alternatively…Could variable ice/wind values be assigned in PLS-CADD?**

Golagh 110 kV Wind Farm Connection, Donegal (120-330m)

Band	Elevation	Ice Load (Median)	Ice Load (95%)	Ice Load (99%)	Density	Elev. Adj. Wind Speed*
Band 1	≤100 m	1.8 kg/m	**2.5 kg/m**	2.9 kg/m	600 kg/m^3	29.7 m/s
Band 2	101 m – 200 m	2.4 kg/m	**3.0 kg/m**	3.5 kg/m		32.4 m/s
Band 3	201 m – 300 m	3.1 kg/m	**3.6 kg/m**	4.1 kg/m		35.1 m/s
Band 4	301 m – 400 m	3.6 kg/m	**4.1 kg/m**	4.5 kg/m		37.8 m/s
Band 5	401 m – 500 m	4.2 kg/m	**4.6 kg/m**	5.6 kg/m		40.5 m/s

* Wind speeds based on 27 m/sec at sea level (covers 95% of country)

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