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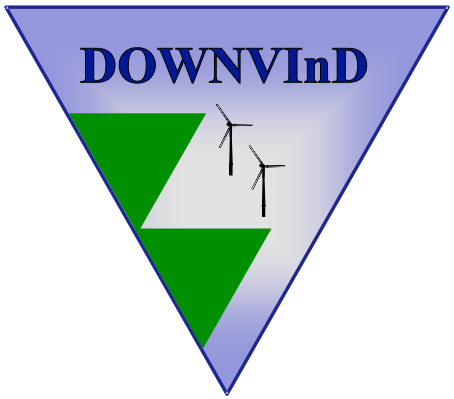
Electrical System Design for the Proposed 1GW Beatrice Offshore Wind Farm

Dr. Graham Ault



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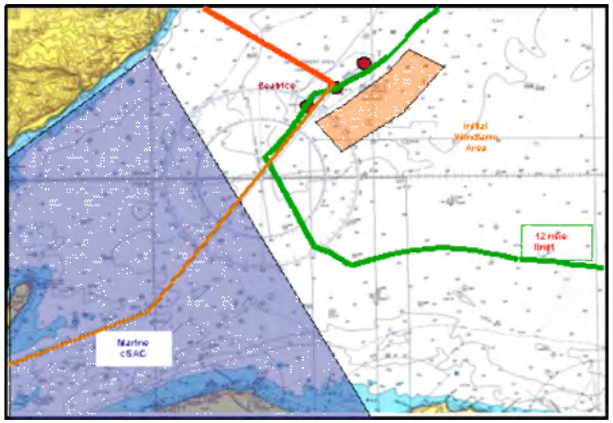
Outline

- Background
- Drivers
- Electrical system conceptual designs
- Design issues
- Design approach
- Conclusions

Beatrice Offshore Wind Farm Background

- Demonstrator programme will install 2 x 5MW RePower wind turbines
- Existing platforms to be used to connect demonstrator wind turbines and infrastructure can be used for full scale 1GW wind farm
- Research programme includes:
  - Environmental
  - Wind turbines and structures
  - Operation and maintenance
  - Electrical



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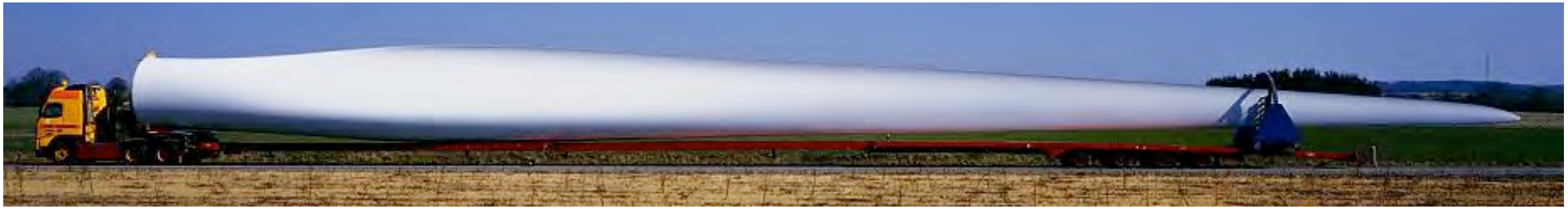
Specific Drivers for Beatrice Wind Farm

- Existing offshore infrastructure
- Desire to go deeper offshore
- Philosophy of very large-scale harnessing of energy (cf. oil & gas) and renewables
- UK renewables incentives
- EU, DTI and Scottish Executive support



Beatrice 2 x 5MW Demonstrator Wind Farm

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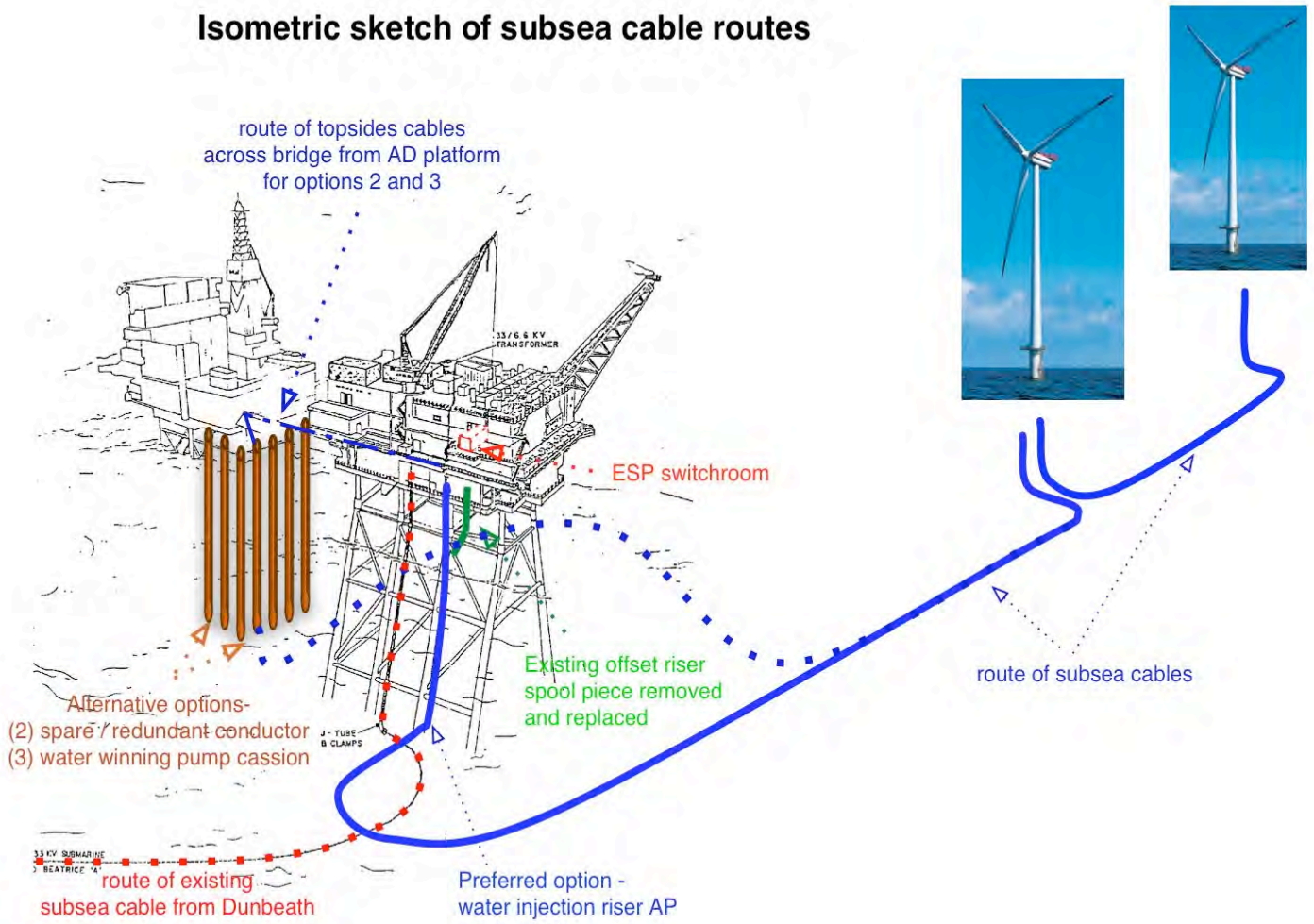

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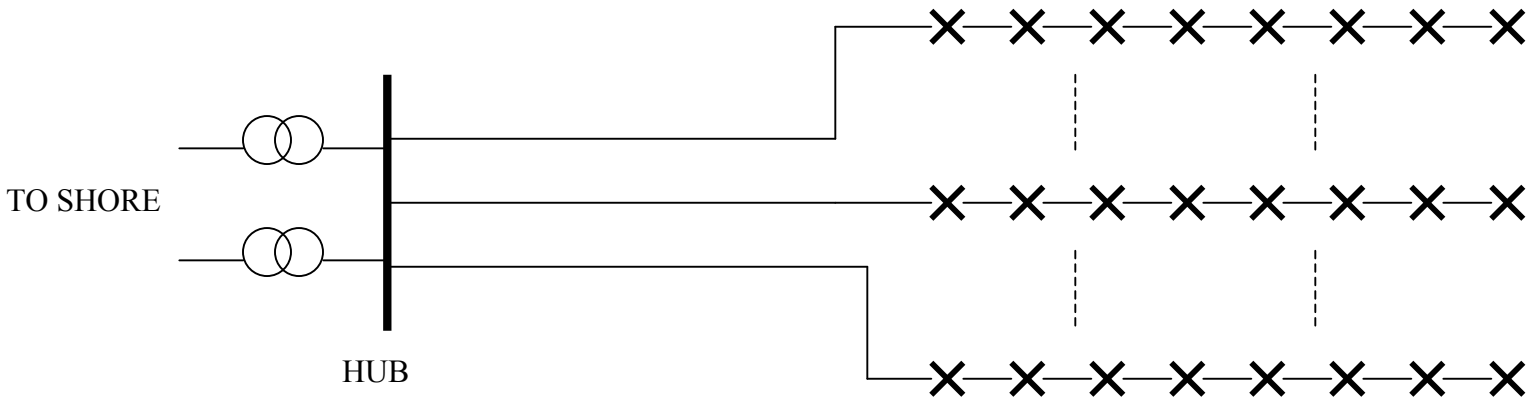
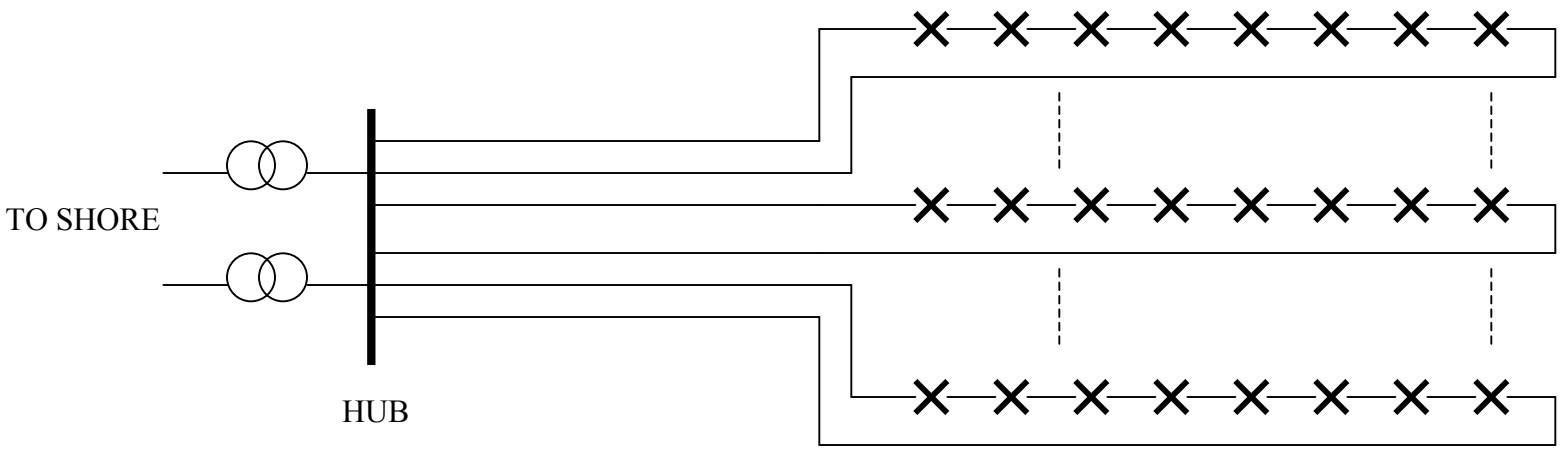
Offshore Collector System Conceptual Designs

‘Radial’ clustered wind turbines connected to single hub



- Simple control
- Relatively inexpensive
- Poorer reliability
- Switchgear more straightforward

‘Single sided ring’ clustered wind turbines connected to single hub



- Ring operated in open configuration
- More expense in cabling (run length plus loss of tapering)
- Greater security

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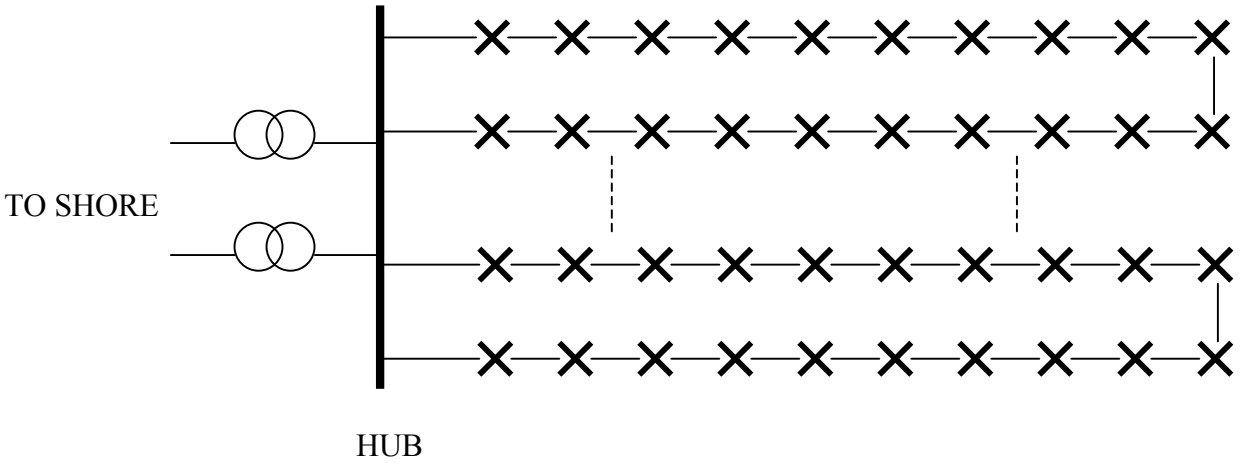
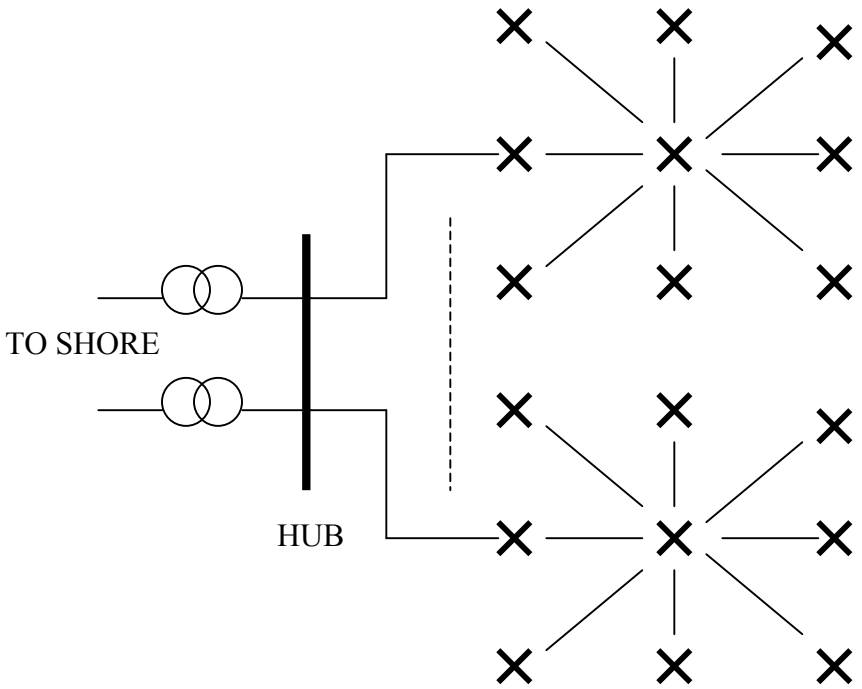
‘Double sided ring’ clustered wind turbines connected to single hub



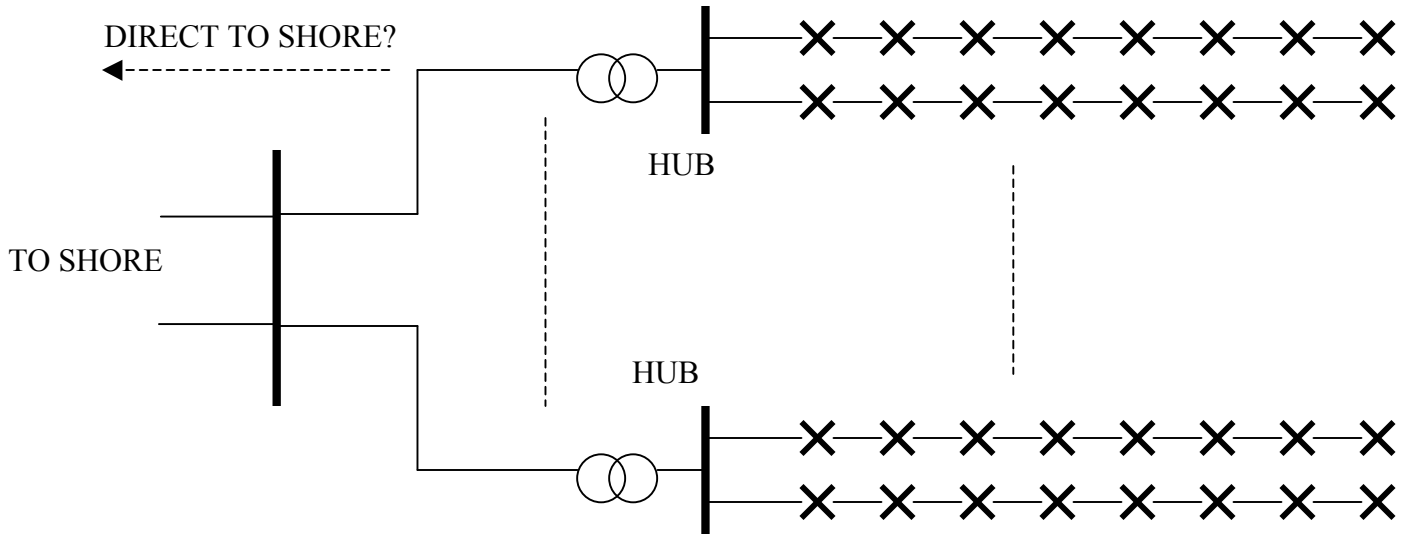
- Ring operated in open configuration
- More expense in cabling (possibility of partially rating cables)
- Greater security
- Upper limit on cable ratings a possible constraint

‘Star’ clustered wind turbines connected to single hub



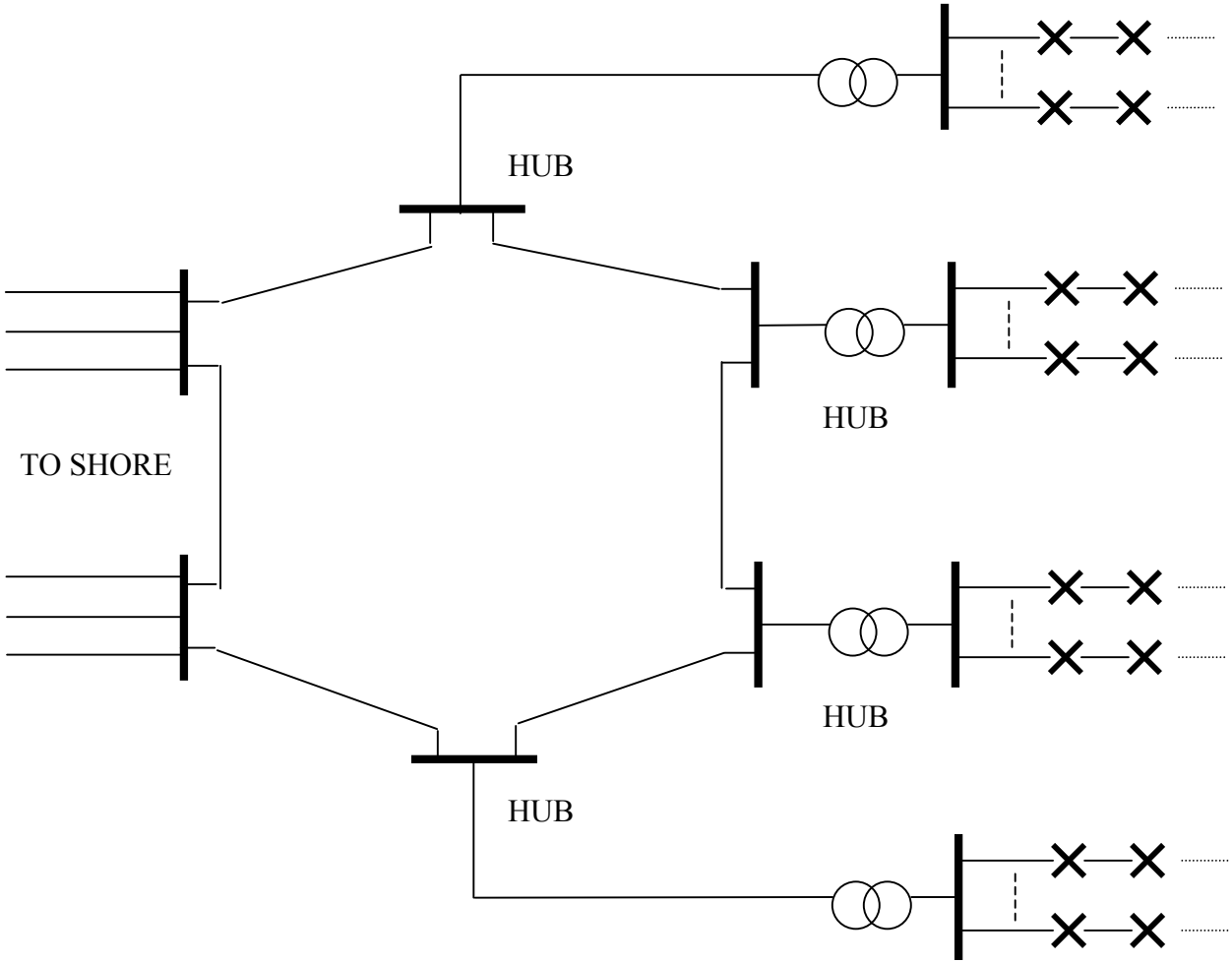
- Reduced cables ratings (and expense)
- Good security
- Good voltage regulation
- Switchgear arrangement more complex and expensive

‘Multiple hub’ arrangement with radial clustered wind turbines



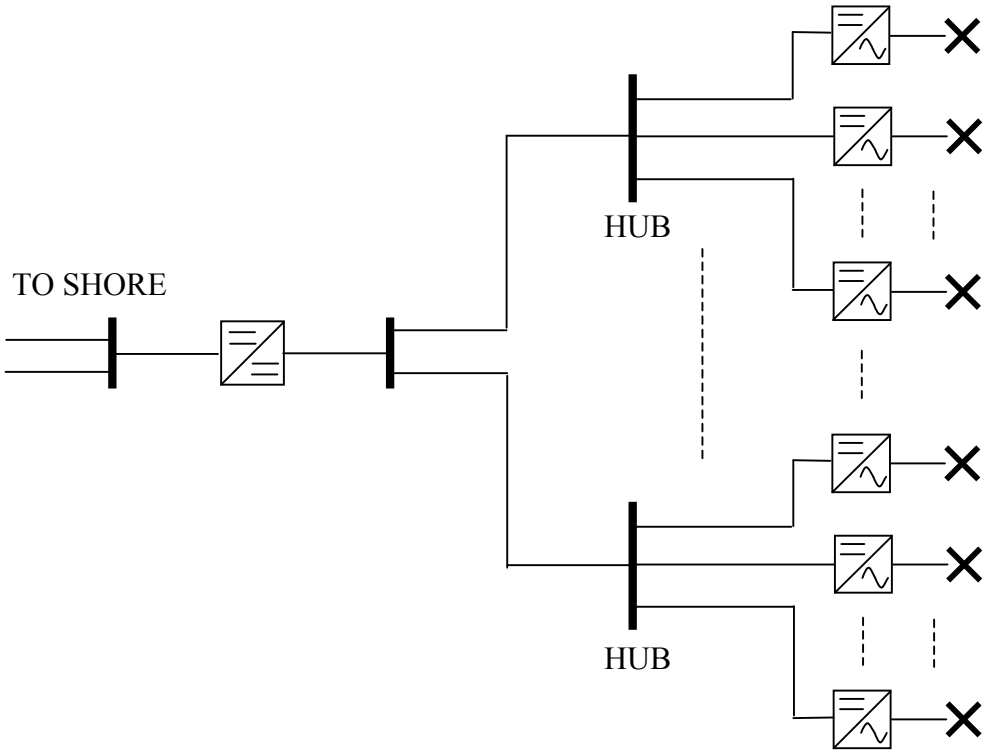
- Lower losses through higher voltage collection
- More expensive EHV cables?
- Multiple hubs provides greater security but more cost

‘Multiple hub ring’ arrangement with radial clustered wind turbines



- Enhanced collector system security
- Greater operational flexibility
- More expense in multiple hubs and higher voltage collection
- Tried and tested in onshore distribution and sub-transmission

DC collector system arrangement with radial clustered wind turbines



- Fits with future fully converted turbine generators
- Less expense in HVDC transmission to shore
- Costs within collector system unclear?
- More costly DC switchgear

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Electrical Collector System Design Issues

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Beatrice 1GW Wind Farm Design Issues

- Turbine generator technology: FSIG, DFIG, Fully converted
- Number of turbines per cluster and cluster formation
- Electrical cabling: length, runs, capacity, voltage level
- Hub design: number, plant required
- Reactive compensation requirement
- Operational Regime
- Protection and control
- Plant physical characteristics

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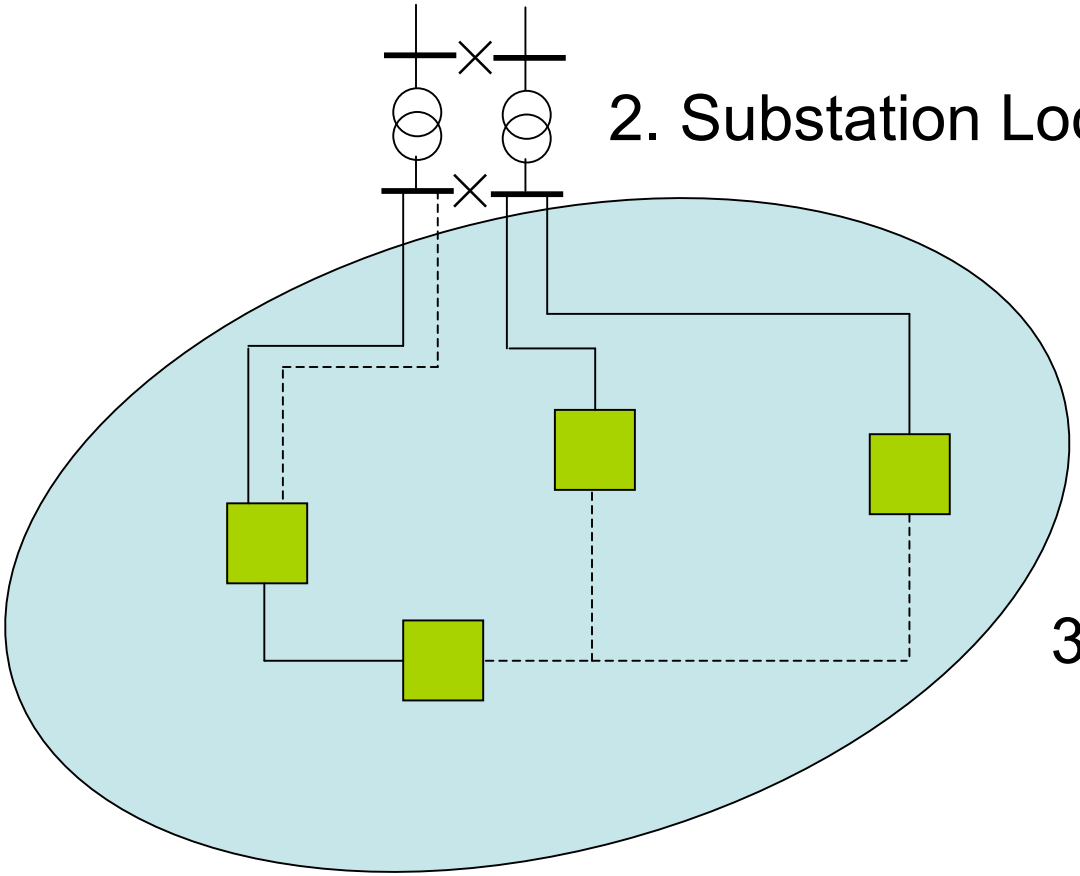
Beatrice 1GW Wind Farm Design Criteria

- Collector system security
- Power flows, voltage regulation and losses
- Fault currents
- Stability
- Power quality
- Operational restrictions
- Economics

Optimal Network Planning: Demand

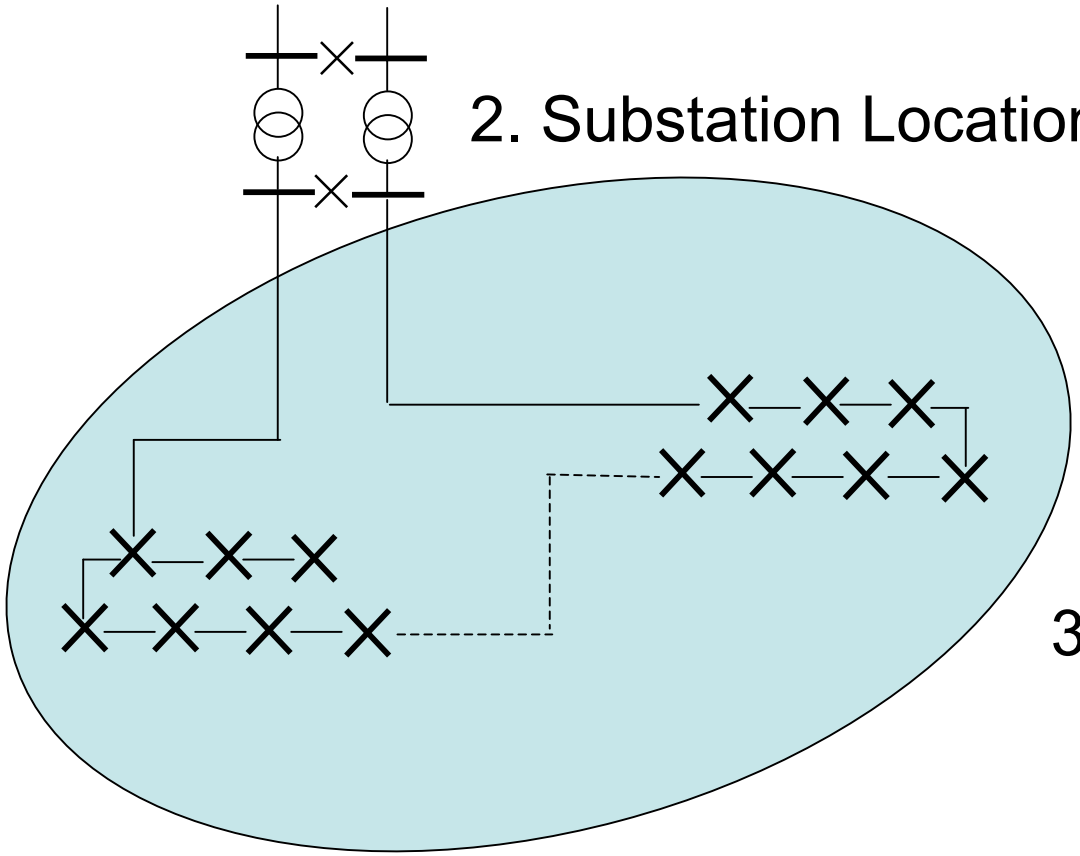


2. Substation Location & Rating

3. Cable Routing & Rating

1. Area Demand Assessment

Optimal Network Planning: Generation



2. Substation Location & Rating

3. Cable Routing & Rating

1. Area Resource Assessment

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Optimal Collector System Planning

- Distribution networks main drivers are demand security and adequacy
- Offshore collector system drivers are different:
    - Economy
    - Availability
- Resource assessment is very different from load demand
- Unit costs for substations and circuits are different

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Conclusions

- Downvind demonstrator programme and research programme underway
- General electrical collector system conceptual designs identified
- Design optimisation for 1GW wind farm in formulation
- Power system analysis programme now initiated
- Initial results show serious challenges for 1GW collector system