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Predictive Rating Models for Wind Farm Export Cables

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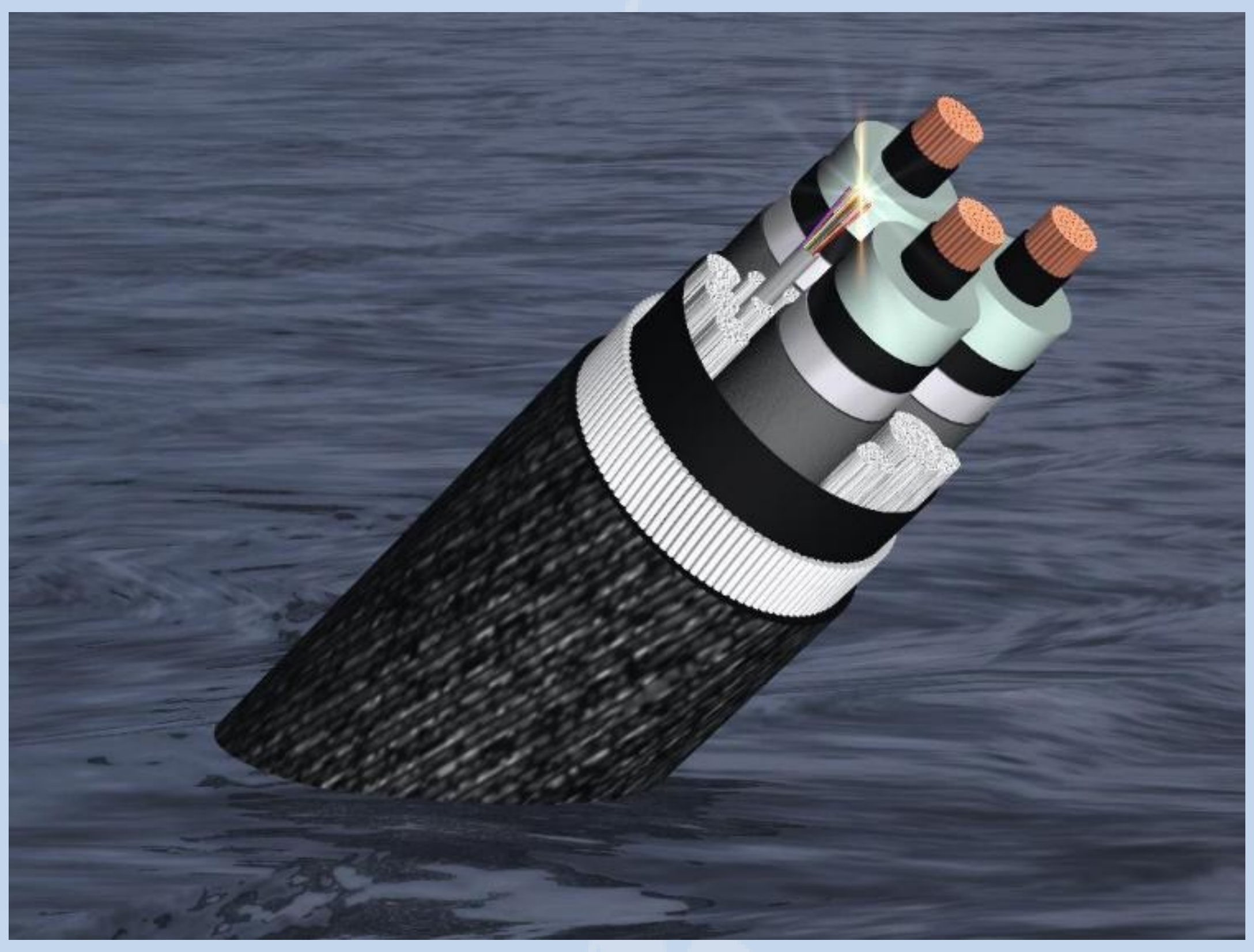
DEFINITION OF RESEARCH PROBLEM

Reasons for using Predictive Rating Models for Wind Farm Export Cables

- The power output of wind farms fluctuates with wind speed, so it is not constant. For the majority of the time, the output is below the nameplate level.
- Conventional rules for calculating cable ratings use thermal models based on steady state conditions with maximum load.
- This approach often leads to cables being oversized compared to real requirements, leading to poor asset utilisation.
- Using predictive rating modelling to assess cable requirements more accurately, should result in a smaller and (therefore cheaper) cable; thus reducing the cost of connecting wind farms to the grid.



http://subseaworldnews.com/2012/05/15/russia-to-get-submarine-fiber-optic-cable-in-far-east/

Research / Economical concerns

Economically oriented

- Improve wind farm cable asset utilisation
- Reduce costs in connecting offshore wind farms to the electricity grid, resulting in consumer savings

Research oriented

- Improve the existing method for rating wind farm export cables
- Incorporate wind forecast out-turn performance to achieve a better rating method

New modelling techniques can achieve both economical and research oriented concerns

EXISTING RATING METHOD FOR WIND FARM EXPORT CABLES

- At present, the IEC60287 international standard is generally used to rate AC wind farm export power cables:

$$I=\left[\frac{\Delta\theta-Wd[0.5T1+n(T2+T3+T4)]}{RT1+nR1(1+\lambda1)T2+nR(1+\lambda1+\lambda2)(T3+T4)}\right]^{0.5}$$

- The heat source in DC cable installation is generated only in conductors because when a cable is energized by DC voltage, the power frequency becomes zero; therefore, there are no losses due to skin and proximity effects on the conductor, no dielectric losses in the insulation, no eddy current losses in the sheath, no hysteresis losses in the armour and no circulating current in the sheath, armour and conductor.
- For DC cable, the equation is simplified from the main IEC 60287 equation by removing dielectric losses and sheath losses from the AC rating formula, although its applicability is restricted to MV installations:

$$I=\left[\frac{\Delta\theta}{R\prime(T1+T2+T3+T4)}\right]^{0.5}$$

- *T*1: Thermal resistance of the dielectric, *T*2: Thermal resistance between metallic screen/sheath and armouring. (This layer also includes bedding layers under the armouring), *T*3: Thermal resistance of the outer sheath (serving) over the armouring, *T4*: The accumulated thermal resistance between the buried cable and the sea floor (for buried submarine power cables the heat flow continues through the sea floor sediments).

CONCLUSION AND FUTURE WORK

- The asset utilisation of existing wind farms could be greatly improved by deploying probabilistic rating techniques.
- It may be possible to reduce cable size (and hence cost) through using such techniques.
- Accurate wind forecasting data would need to be combined with thermal data to produce accurate rating distributions.
- Work within this project is combining finite element modelling techniques with monte carlo simulations to determine the likely benefit to the industry of moving to such an approach.

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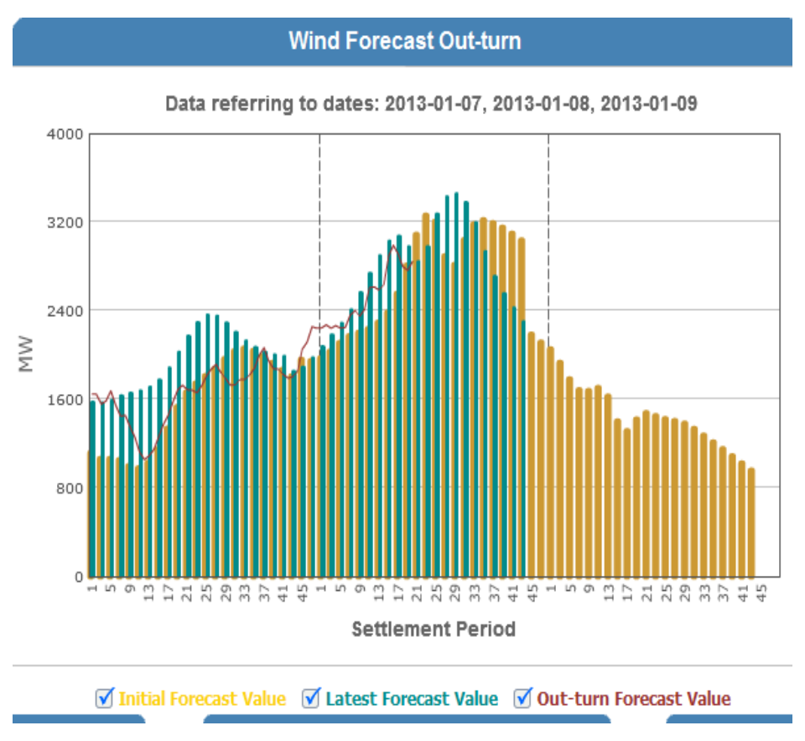
DEVELOPMENT OF PROPOSED PREDICTIVE RATING MODEL FLOWCHART

Proposed Flowchart for 500KV cable

Wind Forecast Out-turn Power Output Data



Data obtained from National Grid and Elexon Neta electricity summary

Convert wind farm input power data to load current on individual cables

Current Distribution

Load duration curves are obtained by calculating the percentage of time for which the wind farm power supply exceeds a particular value and plotting this against supply.

Weather Data

Burial Depth (m)	**SW of UK, Winter**	**SW of UK, Summer**
0 - 50	10-12	16-18

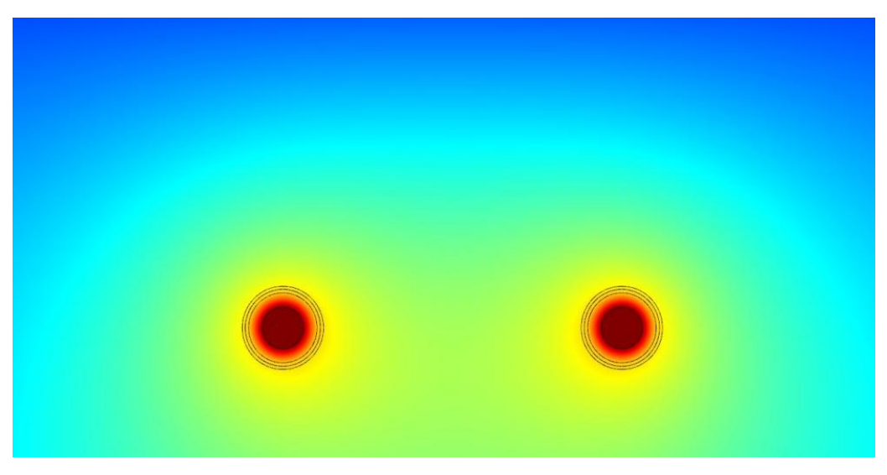
Burial Depth (m)	**NW of UK, Winter**	**NW of UK, Summer**
0-50	9-12	12-14

Data obtained from: http://chartingprogress.defra.gov.uk/feeder/Section_3.2_Temperature_and_Salinity.pdf

Ambient Temperature Distribution

The cumulative frequency distribution of ambient temperature is first determined, and from this, the cumulative probability distribution of ambient temperature can be obtained. From these probability distribution curves, information regarding the probability of certain values of ambient temperature occurring, can be obtained.

Thermal Analysis of a Cable System



Example of 2D FEA cable model

Sensitivity Coefficient Evaluation

Provides a simpler method to predict the conductor temperature for small parameter variations and will afford substantial savings in computer resources and time.

Piece-Wise Equation

In situations where there are changes in more than one parameter (which is usually the case), conductor temperature can be considered to be a piece-wise multi-dimensional linear function of thermal parameters. The individual effects of conductor temperature of each parameter change can be summed up to give the overall change in conductor temperature.

Monte Carlo Simulation

Provides a much simpler method to obtain the required probability densities of conductor temperature. This method generates independent random numbers and uses them to draw parameter values from the corresponding parameter probability distribution curves.

Probabilistic Rating

Cable temperature is evaluated in each random parameter values and stored in a corresponding histogram.