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Cyclic Load Derivation For The Rating Of Offshore Wind Farm Cables

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Abstracts

By its nature, the power generated by offshore wind farms varies substantially with time. Despite this fact, the cable systems which connect such wind farms back to the onshore grid are typically sized on a maximum, continuous current rating. In order to develop techniques by which the sizing of such cable connections might be optimized, this paper presents a method for deriving equivalent cyclic load curves from realistic, time variant generation data. These cyclic load profiles may be used with the conventional IEC 60853-2 cable rating calculation [1], allowing the cable to be sized for a more realistic duty cycle. The example calculations presented show that this reduction in conservatism permits the use of smaller cable sizes, helping to drive down project costs. The implications of using such methods are discussed, highlighting the trade off between cost and conservatism.

Methods

The method will be demonstrated by carrying out the initial sizing of the export system for a hypothetical 300MW offshore wind farm. Wind speed data shall be obtained from a meso-scale model and converted into a time series of the wind farm power output using a generic wind turbine power curve with an appropriate number of turbines assumed. Finite element analysis will be used to determine a low load threshold and this shall be equated to a wind speed. These thresholds will be used to determine the load durations.

SYSTEM CONSIDERED

A sketch of the wind farm transmission architecture is shown in figure 1, below.

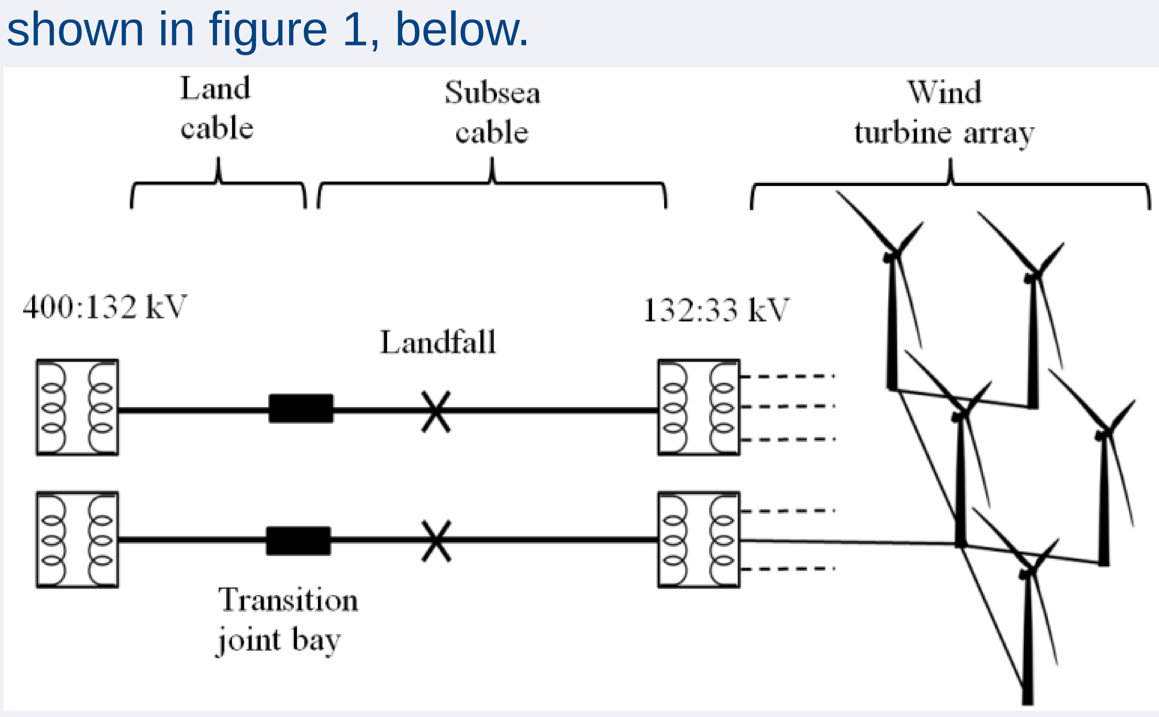


Figure 1: Transmission system architecture.

This study considers a wind farm export system with two export cables which consist of 132kV 3 phase XLPE insulated SL type cables with 1000mm2 conductors. The three phases are protected and held together by layers of PE and steel armour wires. A cross sectional illustration of the cable layout is presented in figure 2.

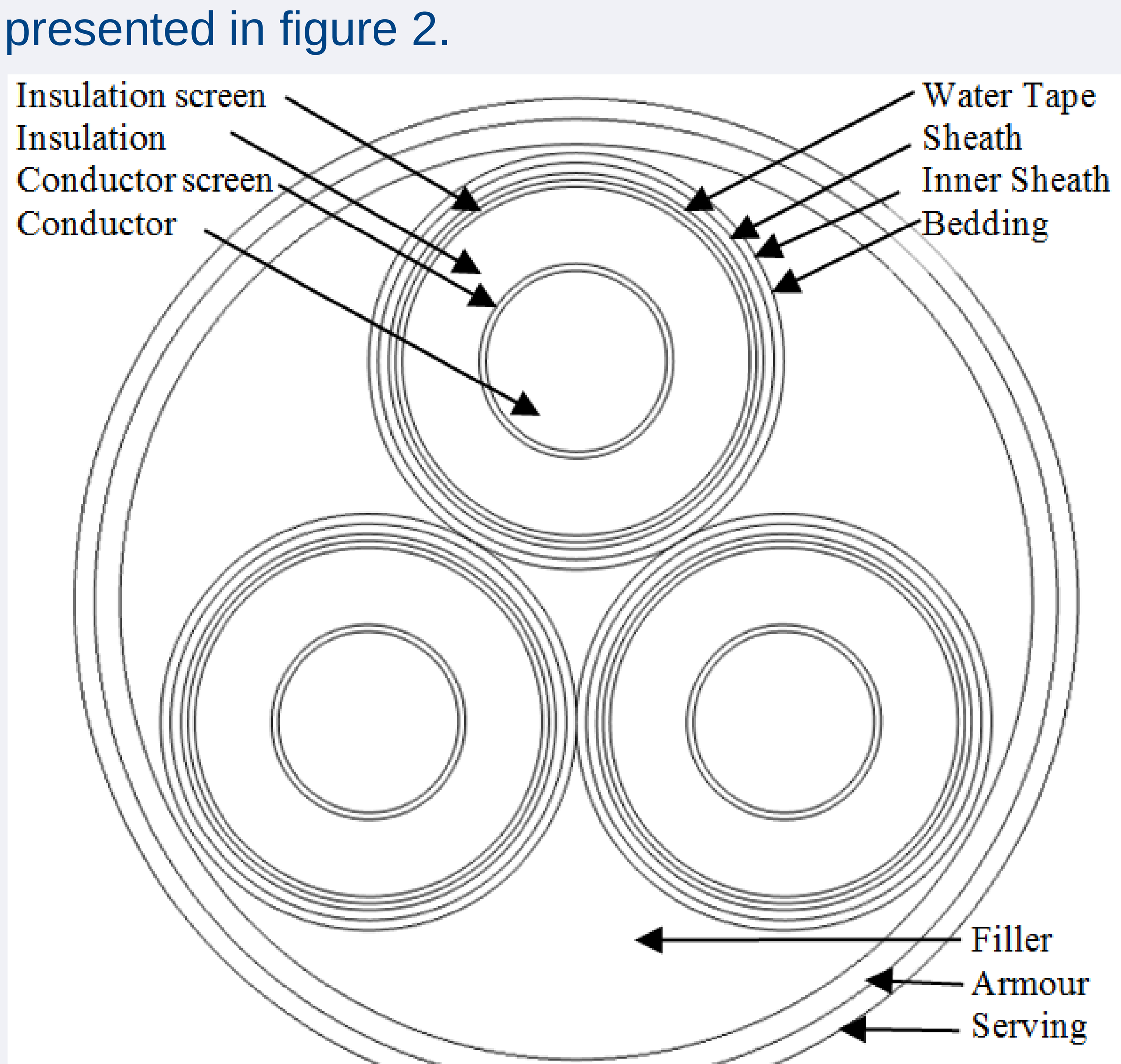


Figure 2: Single cable load as a function of wind speed.

INPUT DATA

A time series of the current at the landfall was obtained by modelling the power output from a large array of wind turbines with respect to an 11 year wind speed and direction time series. Estimates of wind speed variation across an offshore wind farm site on an hourly time resolution were obtained through the use of the Weather Research & Forecasting (WRF) Mesoscale Model. The variation of current with respect to wind speed is shown in Figure 3. The maximum output sets the typical value of current used to size the cable system under the conventional steady state assumptions.

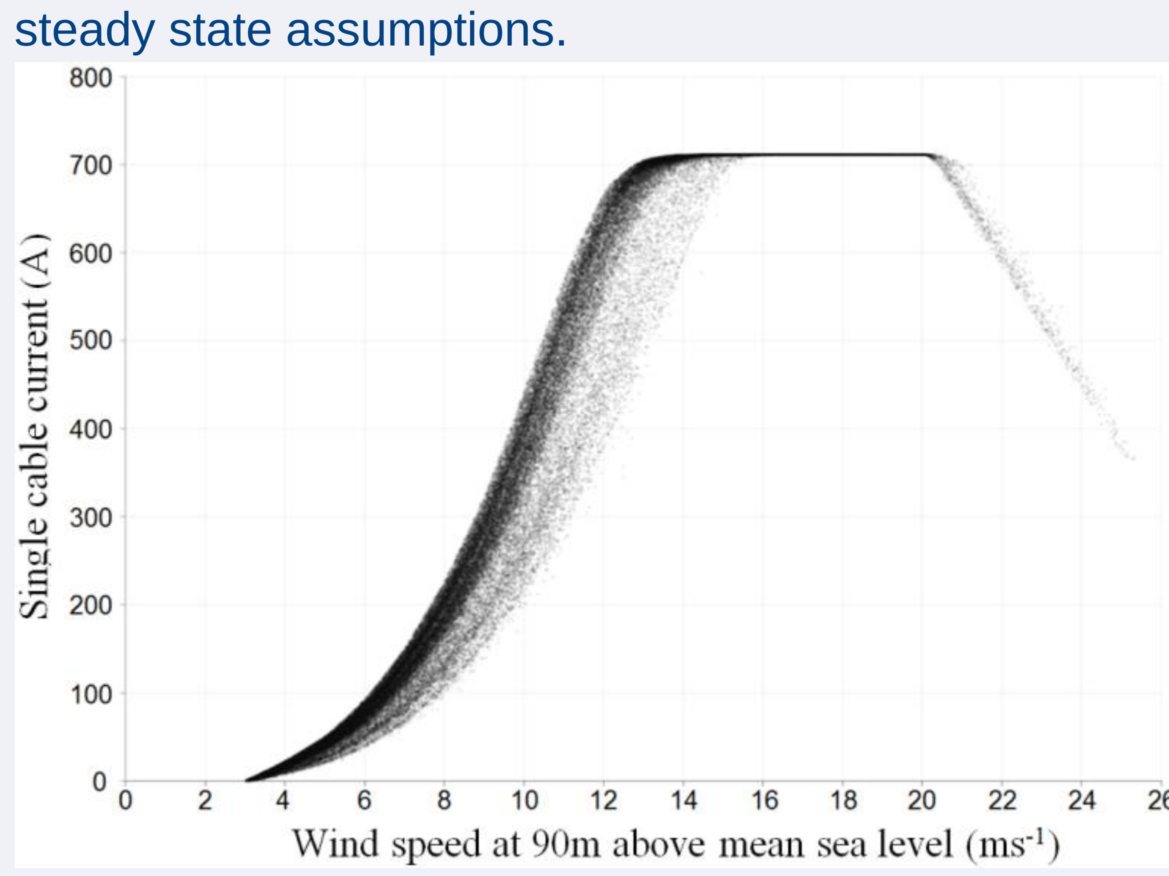


Figure 3: Single cable load

CYCLIC LOAD DERIVATION

A cyclic load is characterised by the ratio of time spent at high power to low power and the magnitude of the high and low loads, as illustrated in figure 4.

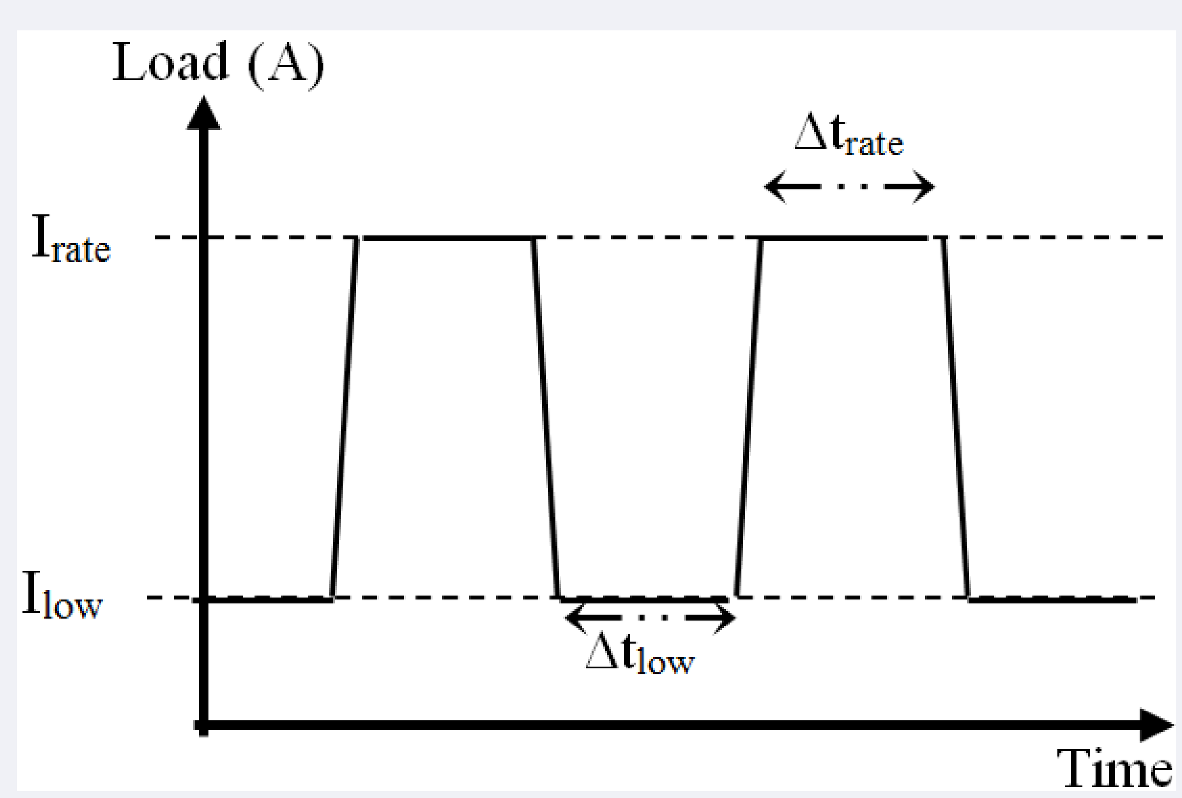


Figure 4:Generic cyclic load profile

A threshold for separating the high loads (I_{rate}) and low load (I_{low}) was determined through calculation of the steady state temperature rise in a cable over a range of currents. I_{low} was initially determined by calculating the load on the 1000mm^2 cable which produces a steady state temperature of 30ºC, which corresponds to a current that is mainly heating the cable and not having a significant impact on the temperature of the burial environment, this is demonstrated in figure 5.

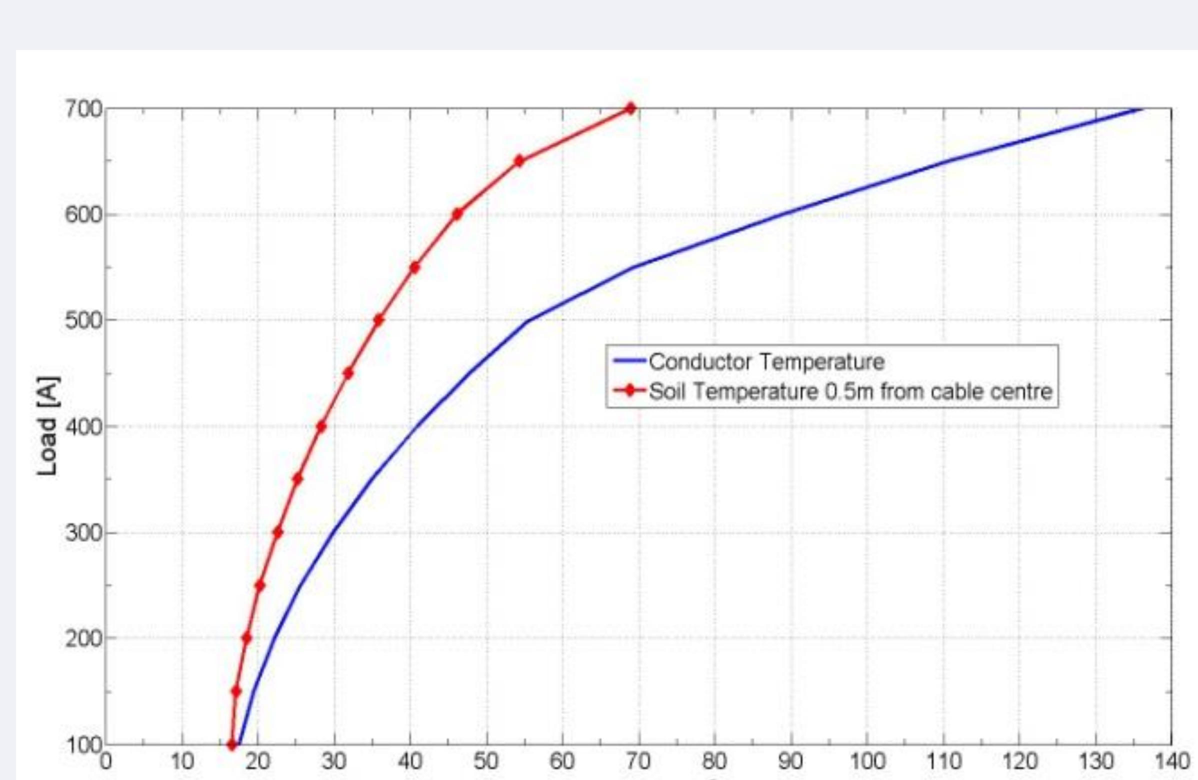


Figure 5: Circuit load variation for conductor temperature

The duration for which I_{rate} and I_{low} loads are likely to persist was determined through a simple analysis of the long term wind time series and the amount of time spent within and without a 9 to 25ms^{-1} range. Wind speeds below 9ms^{-1} resulting in $I_{low.}$ In addition to basing this analysis on the hourly wind speed data from the WRF model, the use of a rolling average filter to smooth the wind speeds by removing short term fluctuations before assessing persistence was investigated. Carrying out a persistence analysis on each of the time series returned high and low load durations with the characteristics detailed in table 1.

Filter Length (hr)	Persistence of periods inside 9-25 ms^{-1} range		Persistence of periods below 9 ms^{-1}	
	Mean length (hr)	Max length (hr)	Mean length (hr)	Max length (hr)
1	13.62	191.00	13.58	293.00
3	21.44	259.00	21.49	387.00
6	28.83	333.00	29.03	448.00

Table 1: Distribution of wind speed with different filter lengths

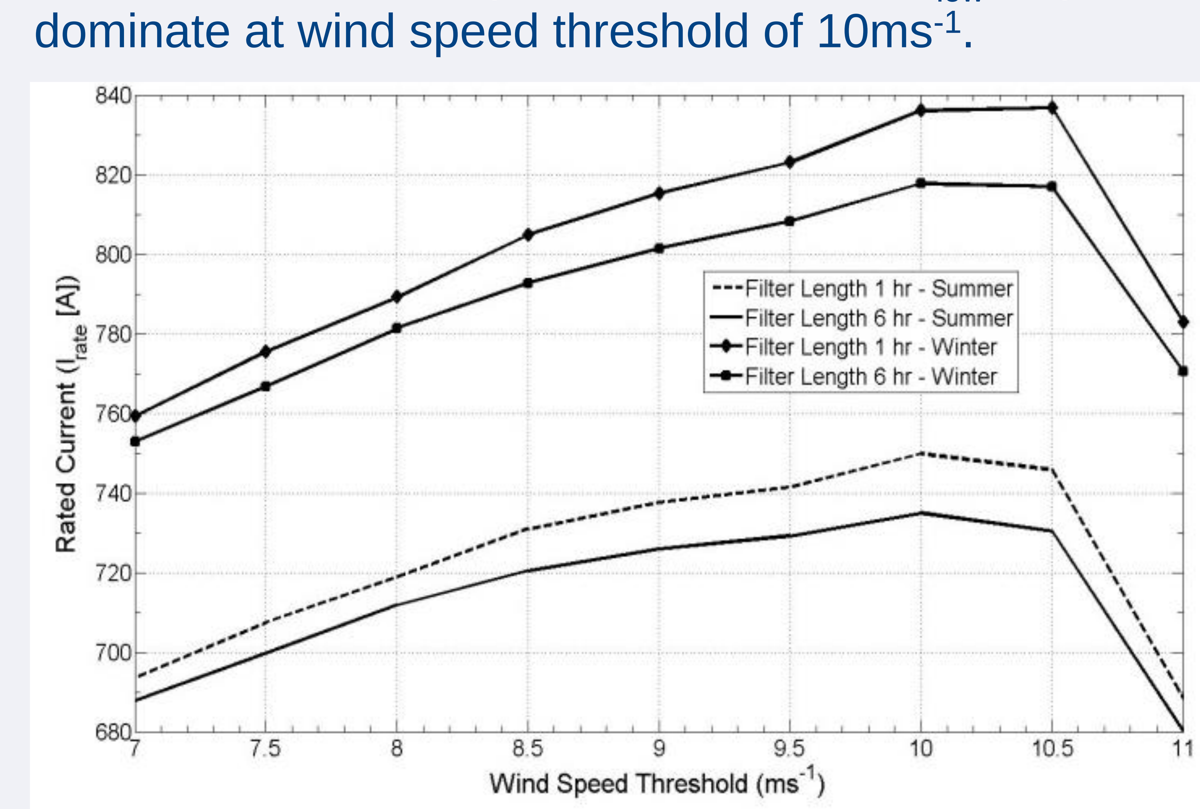
Results

The rating of the cable was found using the IEC60287 [2] method and compared with those obtained from IEC60853 and Finite Element Analysis.

Filter length (hr)	Summer Rating, I_{rate} (A)		
	IEC 60287	FEA	IEC 60853
1		762	738
3	604	745	728
6		735	725

Table 2: Comparison of different rating methods

The wind speed threshold, which is derived from I_{low}, effects the value of I_{rate}. This is shown in figure 6. I_{rate} increases with wind speed threshold until I_{low} begins to dominate at wind speed threshold of 10ms^{-1}.



Conclusions

A method for sizing offshore wind farm export cables based on the expected load has been presented. A comparison between the steady state and cyclic rating have been shown. Good agreement was found between results obtained through IEC60853 and 2D finite element analysis. Use of the cyclic rating method resulted in an increase in rating of up to 22%, compared to a traditional continuous rating method. Although the use of this method has clear benefits due to the reduced conductor size requirement it must be noted that a suitable curtailment strategy must be in place to mitigate the risk that a period of high power generation could be longer than predicted.

References

[1] Calculation of the cyclic and emergency current rating of cables. Part 2: Cyclic rating of cables greater than 18/30 (36) kV and emergency ratings for cables of all voltages, IEC60853-2, 1989

[2] Electric cables - Calculation of the current rating - Part 1-1: Current rating equations (100 % load factor) and calculation of losses - General, IEC60287-1-1, 2006.