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Recommendations for wake loss calculation for offshore wind farms.

Status March 2019 by Per Nielsen, EMD International Ltd.

In windPRO 3.2 manual, EMD introduced a fully formula-based Wake Decay Constant (WDC) calculation from Turbulence Intensity (TI), and following recommendations:

	DTU recommendations:		EMD recommendations 3.2 manual:	
	N.O.Jensen(PARK1)	PARK2	PARK 1	PARK 2
Offshore	0.05	0.06	WDC = TI x 0.4	WDC = TI x 0.48
Onshore	0.075	0.09		

The EMD windPRO 3.2 recommendations do not comply well with several test cases offshore.

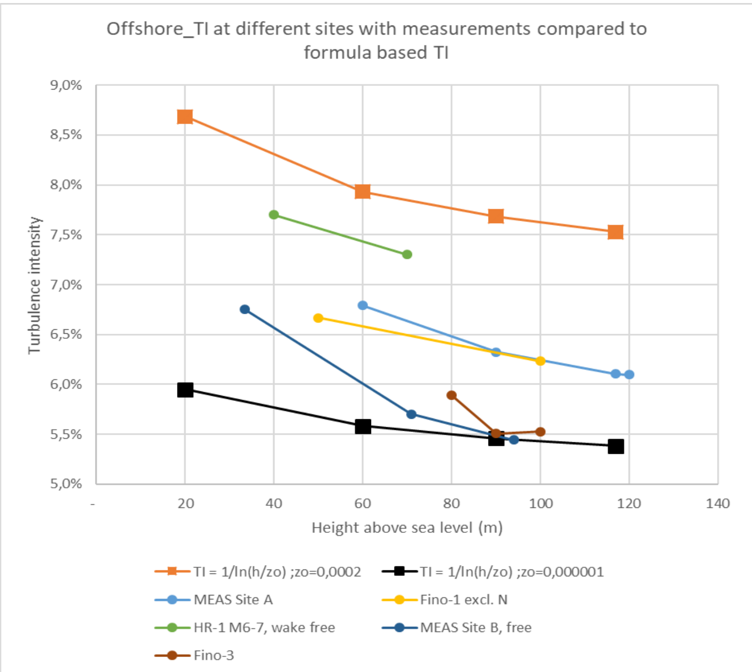
For PARK 2 is seen at HR-1 that WDC = TI x 0.8 do the job perfect. We thereby (also based on other offshore test sites) revise the offshore recommendations so 0.8 replaces 0.48 for PARK-2, and the 20% lower PARK-1 values thereby changes the factor on TI from 0.4 to 0.67, see example tables below.

	PARK-1	PARK-2
High TI	TI:	7,50%
Factor	0,67	0,8
WDC	0,050	0,060

	PARK-1	PARK-2
Low TI	TI:	6,00%
Factor	0,67	0,8
WDC	0,040	0,048

Worth to mention is that historical (before ~2017), DTU has always recommended WDC = 0.04 for offshore and PARK-1. Why has this changed? Primarily based on Horns Rev-1(HR-1) wind farm, which has been the main test farm for model calibration. The special about HR-1 site is that it has relative high TI for offshore, round 7.5% (70 m hub height).

That TI is deciding the wake loss is documented in numerous papers. To give good recommendations for offshore calculations therefore require good knowledge about the TI.



EMD has collected TI measurements (5-15 m/s where wake loss appears), from more different offshore sites to illustrate which "band" of TI can be expected.

The formula, that give a rough idea about TI, is illustrated in figure above. This is not that useful, when it comes to offshore locations, while it is extreme sensitive to the roughness length, and what is this offshore? Zo = 0.0002 is normally used, while this can be extrapolated from shear measurements. But also Zo= 0 is seen used in other contexts. If 0 is entered in formula, a division by 0 is seen, and this will not work. But lowering to Zo= 0.000001, show that the TI is lowered much. The sensitivity to roughness lengths offshore in the TI formula is probably the reason for that the fully formula-based concept with WDC = 0.4 x TI (see TI formula below); introduced in windPRO 3.2, not work well for offshore locations. Stability although also play a role.

$TI = A*k/\ln(h/z_o)$

Where;

- A = 2.5
- k=0.4
- h = calculation height
- z_o = roughness length

The measurement shown in graphic, indicates partly the "band" TI is within, but also how it changes with hub height.

For new 8+ MW offshore turbines hub heights 100-120 m will be seen. Here the TI could probably vary from 5.5% to 7.5%, depending on specific location.

Our recommendation for a simplified approach will be to go with 6% TI and thereby the mentioned WDC values for the two PARK variants shown in the table below:

	PARK-1	PARK-2
	TI:	6,00%
Factor	0,67	0,8
WDC	0,040	0,048

This is supported by e.g. Ørsted, that operates most large offshore wind farms, and claims that PARK-1 with WDC = 0.04 handles the wake losses very well in all their offshore windfarms.

This leads also to this updated recommendation in windPRO 3.3:

	DTU recommendations:		EMD recommendations 3.3 manual:	
	N.O.Jensen(PARK1)	PARK2	PARK 1	PARK 2
Offshore	0.05	0.06	WDC = TI x 0.67	WDC = TI x 0.8
Onshore	0.075	0.09	WDC = TI x 0.4	WDC = TI x 0.48

For a typical offshore wind farm, with wake loss ~10%, the modification will lower the calculated wake loss round 2 percent point.

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