SERIOUS CONSEQUENCES DUE TO EXCESSIVE ICE ACCUMULATION ON A TYPICAL WIND TURBINE

Winterwind 2014 INTERNATIONAL WIND ENERGY CONFERENCE

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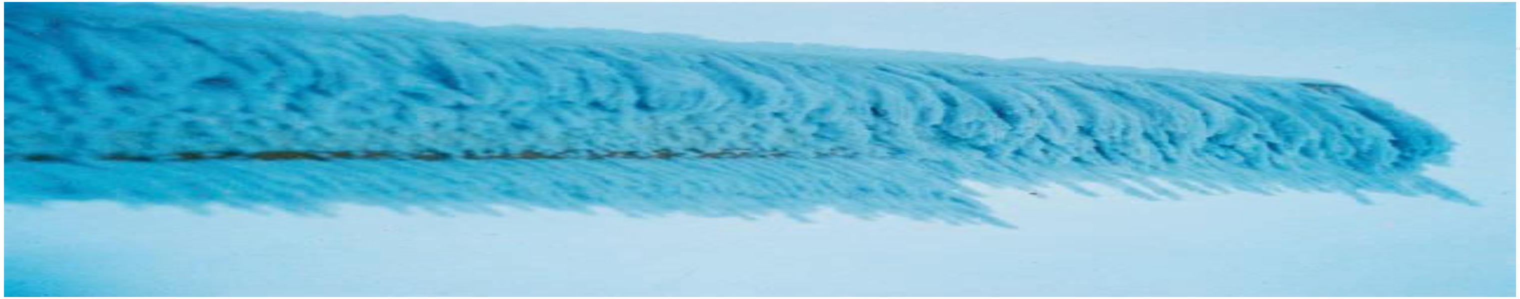
Objectives

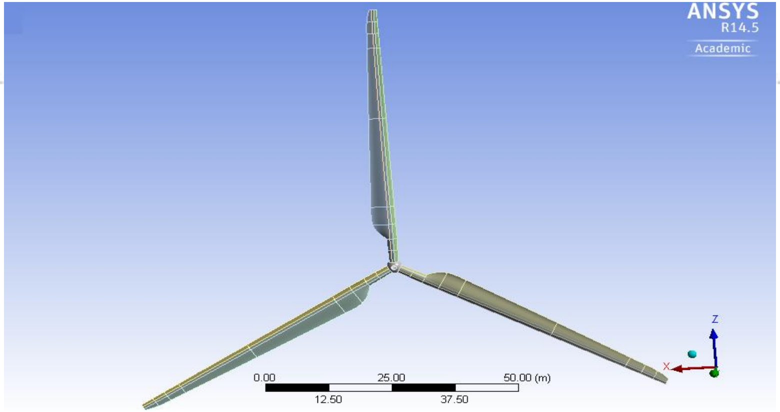
- Construct the assembled NREL 5-MW model with three blades and the hub.
- Use ANSYS to analyze the assembled model and extract first three natural frequencies.
- Three different icing scenarios are considered , one moderate (R5) and two heavy scenarios (R8) and (R9).
- Analyze the effect of icing by considering three assumed icing scenarios to investigate the vibrational behaviour due to atmospheric icing.

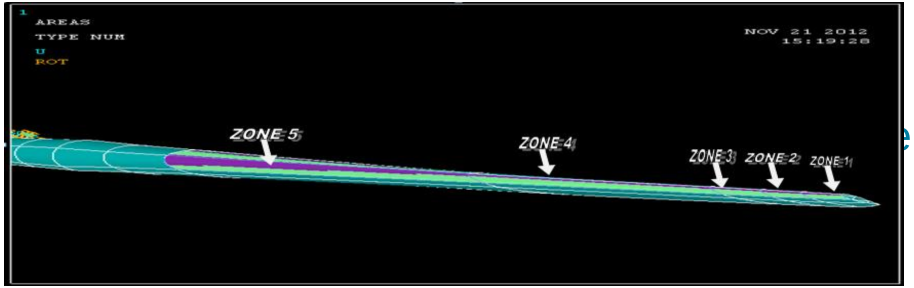
Introduction



- Wind turbines operating in cold regions or at high altitudes are frequently facing icing conditions during winter operation.
- Large amount of ice is accreted on the exposed objects of the wind turbines. Accreted ice represents additional load on turbines.
- More accumulated ice will lower the natural frequencies to values closer to the first resonance frequency.
- Lower natural frequency will associate with the first natural frequency of the tower of the wind turbine and so approaching to the self excitation region.

The Assembled Rotor

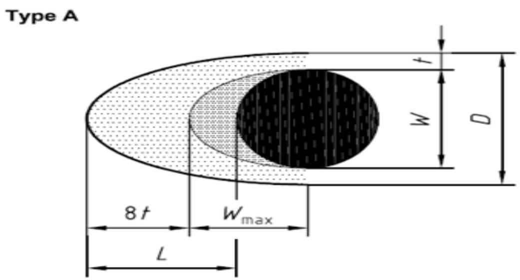




e Assumed Icing Zones

Ice Load Calculations

- The ISO 94242 International Standard has been adopted to be reference for ice load calculation
- Type A of The Standard reference, as shown in Figure 4 will be used to estimate ice load on the wind turbine blades.
- In the same Figure 6, a section of the 5-MW modelled blade is illustrated.
- Where *t* is the ice thickness, *W* is width of the object; *L* is length of ice vanes, and *D* is the total rime accreted diameter
- gest distance which



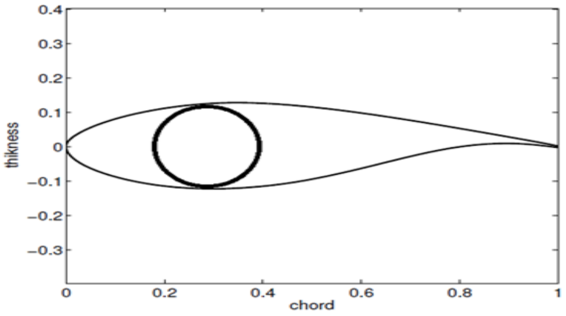


Table 3:Accreted Ice Dimensions and Masses for Large, Round Objects (ISO 2001)

Cross-sectional shape of object: Large, rounded objects							
Object width, mm			300	500	1 000	3 000	5 000
IC	Ice mass	Ice length, L (mm), and mass, m (kg/m)					
	m, kg/m	L, all dim.	m	m	m	m	m
R1	0,5	4	0,5	0,9	2,0	6,2	10,5
R2	0,9	8	0,9	1,7	3,6	11,2	18,9
R3	1,6	14	1,6	3,0	6,4	19,9	33,5
R4	2,8	24	2,8	5,2	11,1	34,9	58,7
R5	5,0	42	5,0	9,2	19,9	62,3	105
R6	8,9	76	8,9	16,5	35,3	111	186
R7	16,0	136	16,0	29,6	63,5	199	335
R8	28,0	217	28,0	49,7	104	321	538
R9	50,0	344	50,0	84,4	171	515	859
R10	To be used for extreme ice accretions						

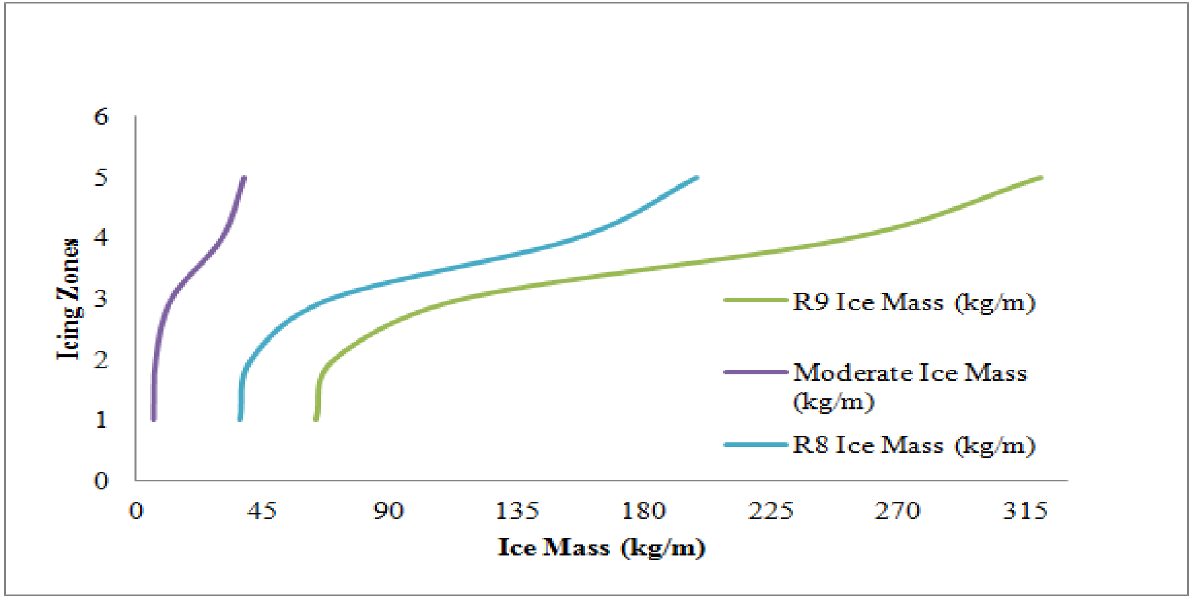
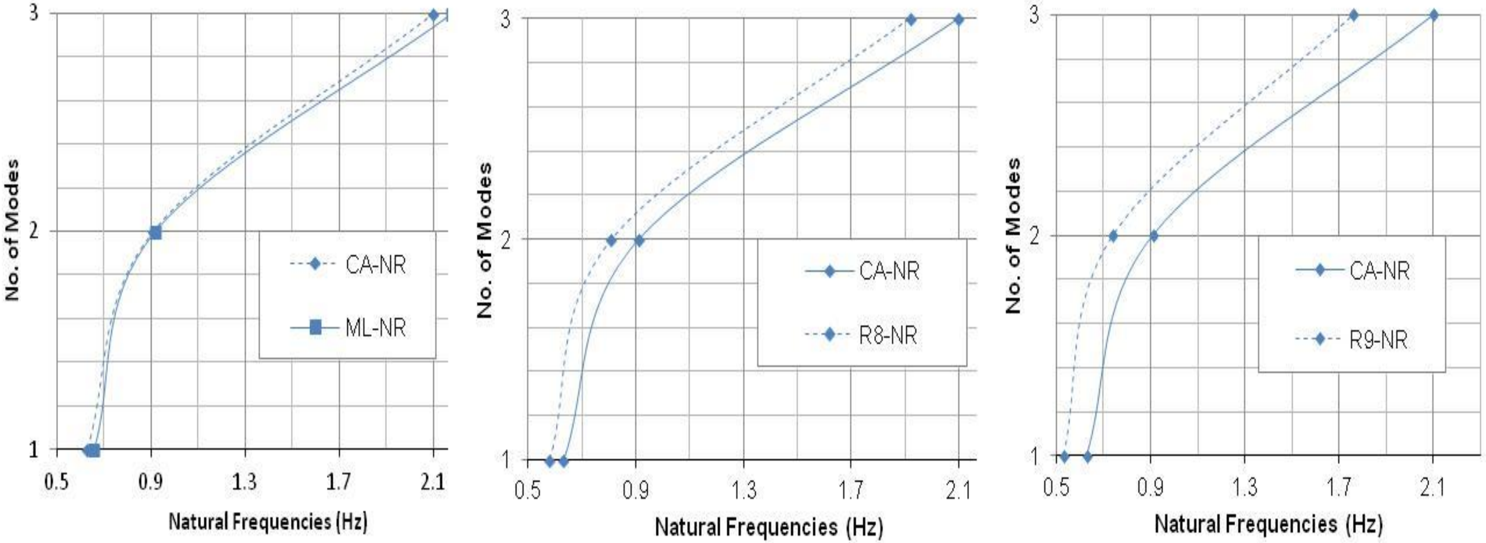


Figure 8: Accreted Ice Mass Per Unit Length for the Three Assumed Scenarios



- Figure 10: Reduction in Natural Frequencies Due to icing for the Three Assumed Scenarios

Findings

- Larger amount of ice is accumulated in both R8 and R9 cases comparing to that in moderate icing case in R5.
- A reduction in the first mode of natural frequencies of 5% for Moderate icing case and 17% for heavy icing scenario R8 and 24% for severe icing case R9.
- The wind turbine under R9 and R8 cases will not stand the vibrational sequences because of the low value of first natural frequency due to heavy ice load on blades.
- It's found that the value of 0.5 Hz is the resonant frequency at which the blades will experience continuous amplitude enlarging leading to destructive consequences.
- Moderate scenario can be accepted but both R8 and R9 scenarios are pushing first natural frequency to lower values towards resonance frequency, and according to current research they should be excluded

Publications

- [1]Alsabagh, Abdel Salam Y., et al. "A Review of the Effects of Ice Accretion on the Structural Behaviour of Wind Turbines." *Wind Engineering* 37.1 (2013): 59-70.
- [2] Abdel Salam Y. Alsabagh, Yigeng Xu, Muhammad S. Virk and Omar Badran, “Effects of Atmospheric Ice Accretion on Vibrational Behaviour of a Wind Turbine Blade”, (2013) (revision submitted to Journal of Wind and Structure)

Conferences

- [1]Abdel Salam Y. Alsabagh, Yigeng Xu, Muhammad S. Virk and Omar Badran, “Serious Consequences Due To Excessive Ice Accumulation on a Typical Wind Turbine”, (2014) Winterwind 2014, (12-14 Feb. 2014), Färentuna, Sweden.
- [2]Badran, O., Ahmad, S., A., A-Adwan, I., Abu Rahma, T., Alaween, A. and Alsabagh, A. S. (2013). Experimental Study on The Performance of Diesel Engine Using Different Alternative Fuels. The Fourth World Conference for Renewable and Energy Efficiency for the Desert Regions - GCREEDER 2013. Amman-Jordan on 12-14 September 2013.
- [3] Abdel Salam Y. Alsabagh, W. T. a. M. S. V. (2011). Effect of Atmospheric Ice Accretion on the Dynamic Behaviour of Wind Turbine. the Sixth International Conference in Multiphysics (MULTIPHYSICS 2011) Barcelona, Spain on 15-16 December 2011.
- [4]Mohamad Y., M., Abdel Salam Alsabagh, Muhammad S., Virk, M Moatamedi & B., C., Ewan (2011). Design of Water Shock Wave Tube for Testing Composite Shell Structures High North Conference 2011 - New Northern Strategy, 14-15/11/2011 Bodø, University of Nordland, Norway.

Thank You For Your Attention.