Numerical and Experimental Analysis of the Transient Behavior of Wind Turbines When Two Blades Are Simultaneously Struck by Lightning

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***Abstract*— Wind turbines (WTs) are one of the most promising sources of sustainable energy. However, they are frequently subjected to lightning strikes resulting in downtime of WTs and loss of numerous megawatts of power generation. Studying the transient behavior of a WT when two blades are struck simultaneously by lightning is the main contribution of this article. Although the simultaneous hitting of two blades of the same WT is not occurring frequently, it is more severe than striking a single blade. Hence, assessing the transient behavior of WTs during this phenomenon is important for proper lightning protection system design. The variation of induced overvoltages across the WT during the strike is calculated using a simplified numerical model. The equivalent circuit of WT is represented in the time domain, including various WT parts starting from the blades up to the grounding system. Then, the continuous time-domain circuit is converted to a discrete time-domain circuit, and the system nodal equations are written to calculate the transient response. For checking the validity of the numerical model, a small-scale WT model is connected with an impulse generator to simulate the lightning strike in the laboratory. The measured overvoltages across the small-scale WT are found to be very close to the numerical ones at different grounding resistances, which proves the correctness of the numerical model.**

***Index Terms*— Grounding system, lightning strikes, overvoltage phenomena, transient analysis, wind turbines (WTs).**

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NOMENCLATURE

Abbreviations

IEC	International Electrotechnical Commission.
LPS	Lightning protection system.
NRMSE	Normalized root mean square error.
WT	Wind turbine.

Latin Symbols

C_h	Capacitance of bearing system.
C_{bs}	Capacitance of down conductor segment.
c	Speed of light.
f_{lm}	Lightning channel maximum frequency.
g	Thickness of tower cylinder.
h_{tc}	Height of tower cylinder.
i_{C}	Capacitor current.
i_{R}	Resistance branch current.
i_{RL}	Resistance–inductance branch current.
i_{s}	Lightning current source.
I	Matrix of node current sources.
L_{bs}	Inductance of the down conductor segment.
L_{tc}	Inductance of the tower cylinder.
l_{bs}	Length of the down conductor segment.
n_{s}	Number of time samples.
q_{s}	Down conductor surface resistivity.
R_{h}	Resistance representing the slipping contact and brushes.
R_{C}	Equivalent resistance of the capacitance