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Reliability Modeling of Wind Turbines: Exemplified by Power Converter Systems as Basis for O&M Planning

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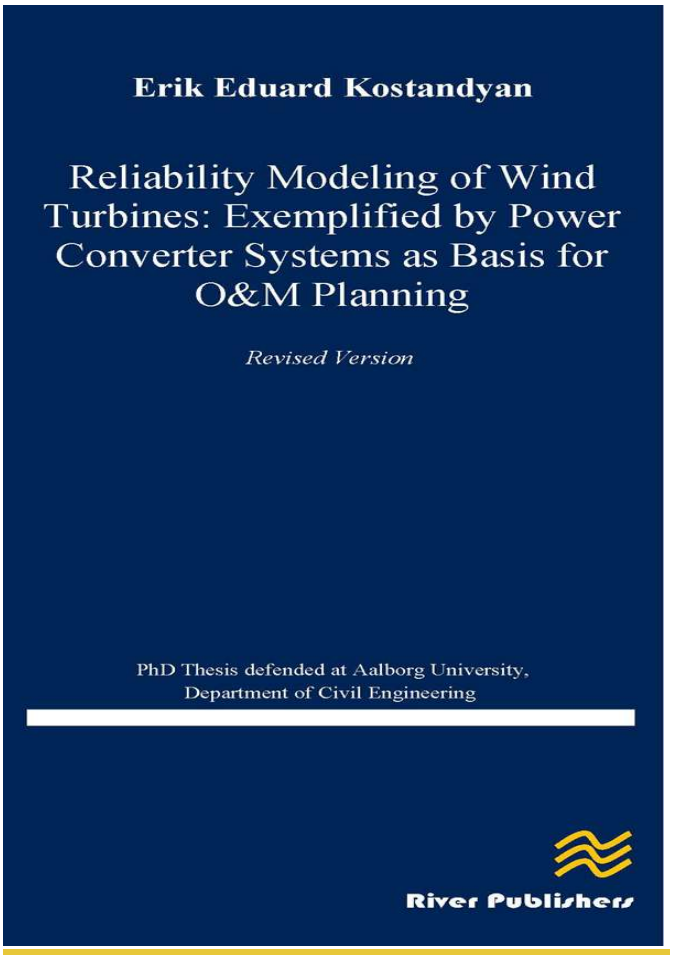
Cost reductions for offshore wind turbines are a substantial requirement in order to make offshore wind energy more competitive compared to other energy supply methods. During the 20 – 25 years of wind turbines useful life, Operation & Maintenance costs are typically estimated to be a quarter to one third of the total cost of energy. Reduction of Operation & Maintenance costs will result in significant cost savings and result in cheaper electricity production. Operation & Maintenance processes mainly involve actions related to replacements or repair. Identifying the right times when the actions should be made and the type of actions requires knowledge on the accumulated damage or degradation state of the wind turbine components. For offshore wind turbines, the action times could be extended due to weather restrictions and result in damage or degradation increase of the remaining components. Thus, models of reliability should be developed and applied in order to quantify the residual life of the components. Damage models based on physics of failure combined with stochastic models describing the uncertain parameters are imperative for development of cost-optimal decision tools for Operation & Maintenance planning. Concentrating efforts on development of such models, this research is focused on reliability modeling of Wind Turbine critical subsystems (especially the power converter system). For reliability assessment of these components, structural reliability methods are applied and uncertainties are quantified. Further, estimation of annual failure probability for structural components taking into account possible faults in electrical or mechanical systems is considered. For a representative structural failure mode, a probabilistic model is developed that incorporates grid loss failures. Further, reliability modeling of load sharing systems is considered and a theoretical model is proposed based on sequential order statistics and structural systems reliability methods. Procedures for reliability estimation are detailed and presented in a collection of research papers.



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