SUMMARY

This thesis presents the development of a comprehensive optimization routine tailored for the design of mooring systems in floating offshore wind turbines (FOWTs). With floating wind expected to unlock deeper offshore wind resources, mooring systems play a critical role in ensuring platform stability, safety, and cost-effectiveness. The thesis is structured into four main parts, each designed to logically build toward the creation, validation, and application of a robust and versatile mooring design optimization tool.

The first part, Context and Foundations I, sets the stage. Chapter 1 introduces the global and European energy context, where the decarbonization push and spatial and technical limits of bottom-fixed turbines drive attention toward floating solutions. The challenges and opportunities of floating platforms are outlined, with mooring systems emerging as a critical subsystem due to their influence on both capital costs and overall system performance and safety. Chapter 2 reviews the existing literature on mooring system design, highlighting the absence of integrated approaches that bring together cost modeling, physical constraints, extreme environmental conditions, a broad design space, reliability considerations, and a holistic design perspective. This gap motivates the core objective of the thesis: to create an optimization methodology that is both cost-aware and performance-driven.

The second part, Modeling and Methodology II, begins in Chapter 3 by establishing the numerical framework. To support the optimization, detailed models of floating wind systems are developed, covering hydrodynamics, aerodynamic loading, platform motions, and mooring mechanics. Both frequency-domain and time-domain approaches are used, allowing flexibility in balancing computational effort and modeling fidelity. Each numerical model, distinct in its formulation and complexity, is tailored to a specific purpose: time-domain models are employed for dynamic analyses and validation, while frequency- or spectral-domain models are used during the optimization process due to their lower computational cost and faster evaluation, making them well-suited for iterative design exploration.

Chapter 4 is the heart of the thesis; it introduces the optimization routine itself. The routine is built around a multiobjective genetic algorithm and integrates modules for defining design variables, environmental conditions, and constraints. It includes a spectral domain quasi-static simulation engine to estimate mooring loads and platform motions under various sea states. Feasibility checks ensure compliance with technical criteria, while a detailed cost model calculates the mooring cost based on line materials, anchor types, and installation needs. A graphical user interface supports user interaction. The optimization produces a Pareto front of design options, balancing cost against platform motion.

Part three, Results and Validation III, moves from theory to application. Chapter 5 presents an experimental campaign where a scaled floating wind turbine and mooring system are tested in a wave tank under a wide range of sea states. These experiments are

used to assess the accuracy of the numerical models by comparing their predictions with physical measurements of motion response and mooring line tension. Once validated and deemed trustworthy, these models serve as a benchmark for the next stage.

Chapter 6 then expands the scope, using the optimization tool in a variety of simulated scenarios to demonstrate its flexibility and scalability. Sensitivity analyses are conducted on seabed type, bathymetry, constraints, mooring line characteristics, wave and wind conditions, and different damping identification methods. The results show how optimal mooring configurations change in response to environmental and design constraints. This chapter also includes a thorough verification of the optimization outcomes against the validated time-domain models. By re-analyzing optimized configurations using high-fidelity dynamic simulations, the consistency between the fast, quasi-static optimization model and the time-domain results is assessed. This cross-check verifies the quality of the optimized solutions and reinforces the trustworthiness of the optimization routine as a reliable tool for practical design and early-stage project planning across a wide range of offshore conditions.

The last part of this thesis, Implications and Future Directions IV, brings the work to a close. Chapter 7 reviews the main contributions, namely, an experimentally verified and in-depth understanding of how mooring-line properties, platform hydrodynamics, environmental inputs, and optimisation settings interrelate to shape the cost-vs-performance landscape. This new knowledge is embodied in a modular, cost-efficient optimisation framework that practitioners can apply to floating offshore wind and other moored structures. While the software itself is a practical outcome, the genuine contribution to knowledge lies in the systematic methodology, the sensitivity insights, and the design guidelines distilled from the research. The chapter concludes by outlining future development paths.

The structure of the thesis tries to be as linear and interconnected as possible: the context motivates the need for optimization; the modeling provides the technical backbone; the optimization routine is the core innovation; experimental validation ensures reliability; and broad application proves the tool's utility.