Performance Prediction and Structural Integrity Assessment of 50-kW Tidal Turbine Using Unidirectional FSI Method

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ABSTRACT

This research represents the results of performance prediction and structural safety evaluation of 50-KW tidal turbine rotor assembly. Unsteady CFD simulation of the rotor assembly was performed to predict the performance of rotor assembly, and a cavitation model was applied with consideration of underwater operating conditions. Flow analysis result showed that the average power was 47.87kW at an extreme tidal velocity of 6 m/s. Moreover, creations and destructions of rotating cavitations were also observed near the blade. The structural safety of the rotor assembly was evaluated by unidirectional FSI method. The analysis results showed that the minimum safety factor of the rotor assembly was 3.76. From the result, it was concluded that the rotor assembly had sufficient structural safety at an extreme operating condition.

KEY WORDS: Tidal turbine blade, Performance analysis, Structural integrity, CFD(Computational Fluid Dynamics), FSI(Fluid Structure Interaction)

INTRODUCTION

The Ocean energy sources with high potential for utilization are seawater temperature, wind, waves, tide and currents. Among them, power generation utilizing currents is less sensitive to changes in weather conditions (wind, waves, etc.), and as it is possible to accurately predict changes in the flow velocity and flow direction, it is possible to calculate annual energy production to analyze economic efficiency relatively accurately. However, problems caused by the special installation and operating conditions of the tidal turbine (waterproofing, anti-rust, seabed installation) may become major reasons for increased costs of installation and maintenance as compared to other types of power generation. Development of ocean energy converters and field test projects are actively carried out in Europe, and particularly EMEC (European Marine Energy Center) has developed and is diffusing the technical guideline for design, energy resource evaluation, performance evaluation, grid connection, environmental impact assessment and certification system in provisions against commercialization of ocean energy converters.

During certification and design evaluation of tidal current plants, whether the ultimate strength and fatigue strength of power plants are designed safely enough for operating conditions is intensively examined, and the tidal current plants will receive the final certificate after going through additional procedures like tests, quality system evaluation, factory inspection and installation and construction inspection. IEC TC114 working group is working on international standardization of the tidal current power generation system, but no standardized design evaluation method and procedure for various kinds of systems are available yet. When it comes to horizontal axis ocean current turbines similar to wind turbines, for load calculation essential in the design evaluation process, BEM-based hydro-elastic analysis codes like GL-Garrad Hassan’s GH-Tidal can be directly applied or aero-elastic codes used in the field of wind power can be partially modified and applied. However, they cannot be applied to new types of power plants like vertical axis type. Accordingly, for extreme load calculation of such non-standardized vertical axis tidal current plants, state-of-the-art CAE techniques like FSI (fluid structure interaction) need to be applied to establish the structural integrity evaluation procedure.

W. M. J. Batten, et al conducted researches applying the BEM method for performance evaluation of tidal turbines, and Mark Francis, et al conducted normal-state CFD analysis for performance analysis of floating-type tidal current plant blades. M. E. Harrison, et al conducted CFD analysis to study the wake characteristics of horizontal axis tidal current power farm. Most of these researches presented analysis results of BEM and CFD to examine the wake impact for performance analysis of the horizontal axis tidal turbine or optimal design of the tidal current power farm, but they seldom deal with results related to structural integrity evaluation. Accordingly, this study applied the unidirectional FSI analysis technique to evaluate the power performance and ultimate strength of non-standardized vertical axis tidal turbines in the steady and extreme flow velocity condition.

TYPE OF OCEAN CURRENT TURBINE

This study selected the vertical tidal turbine installed and operated in...