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Improved performance of Wells turbine power take-off for an oscillating water column wave energy converter

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INTRODUCTION

The Wells turbine is one of the most widely used self-rectifying air turbine technology used as a power take-off within oscillating water column (OWC) wave energy converters (WECs). A large body of research regarding the aerodynamic performance of Wells turbines has documented some common disadvantages that include relatively low efficiency and dynamic stall under certain operational characteristics [1, 2]. Numerical and experimental studies have found that some of the aforementioned disadvantages of Wells turbines can be minimized by adjusting rotor design parameters that include solidity, chord length, blade count, and by the inclusion of the guide vanes (stationary stator blades) upstream and downstream of the rotor [2, 3].

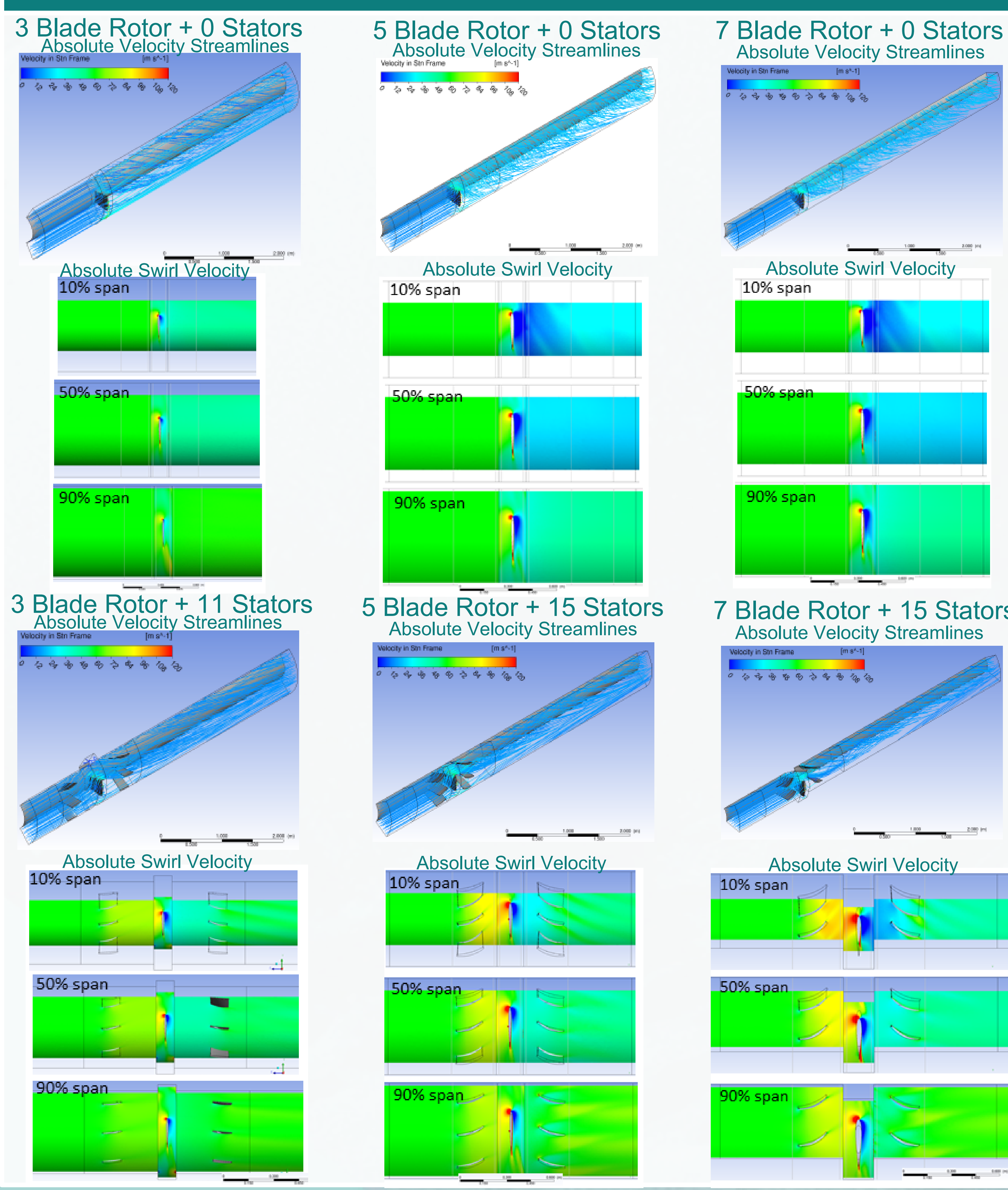
AIM

Design and improve the performance of a Wells turbine for use within the MARMOK OWC-WEC designed by IDOM corporation

Used iterative multi-fidelity numerical modeling approach

1. 1D analysis of scaling relationships and design variables (torque, thrust, solidity) to identify optimal concept and configuration
2. 2D analysis using turbomachinery design tools to target desired aerodynamic operating conditions and define rotor and guide vane blade geometries
3. 3D analysis using CFD modeling of blade designs to determine turbine performance
4. Iterate the multi-fidelity approach for multiple rotor and guide vane blade designs

RESULTS



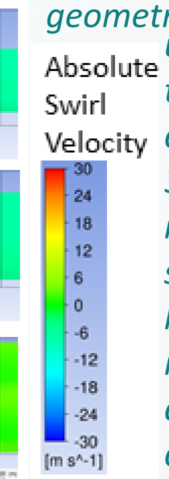


Figure 2. Plots of absolute velocity streamlines and absolute swirl velocity at 10%, 50%, and 90% constant span. Data for plots was extracted from CFD simulations of the aerodynamic flow field within draft tubes for the six (6) air turbine designs (3 blade rotor + 0 stators, 3 blade rotor + 11 stators, 5 blade rotor + 0 stators, 5 blade rotor + 15 stators, 7 blade rotor + 0 stators, 7 blade rotor + 15 stators). Steady CFD simulations were conducted using ANSYS CFX with the Shear Stress Transport turbulence model (inlet velocity = 14 m/s and RPM = 2122). Plots were produced using the ANSYS CFD-Post Software within the CFX modeling suite. Model geometry was produced using 2D turbomachinery design tools and 3D CAD modeling software. (Note: lines dissecting model geometry are where model domains meet.

METHOD

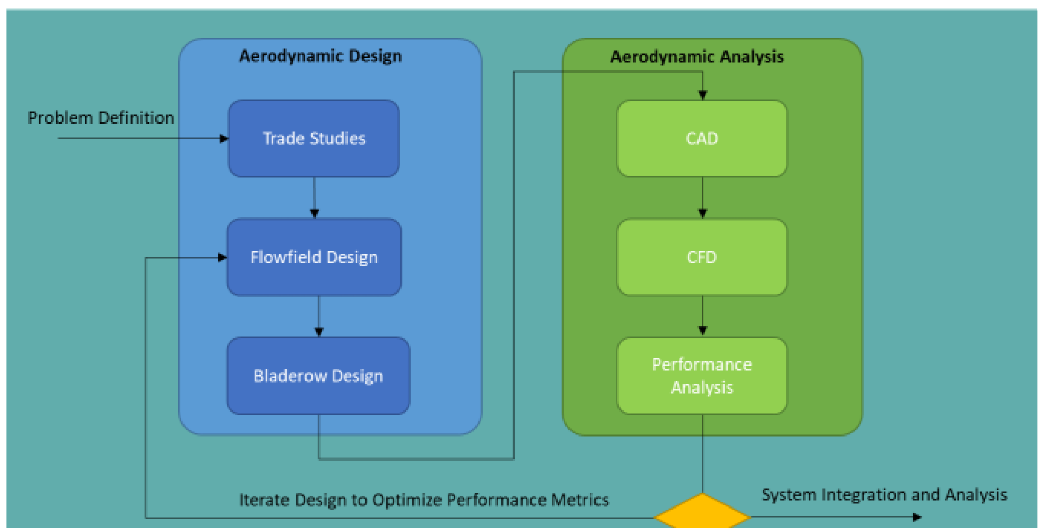


Figure 1: Workflow used in the iterative multi-fidelity numerical modeling approach used to design and improve the performance of the Wells turbine for use within the MARMOK-OWC.

CONCLUSIONS

- Design with 7 blade rotor and 15 stators is the optimal design
- Increasing the number of blades on a rotor increases the performance of the turbine
- Inclusion of stators/guide vanes reduces energy losses downstream of rotor-stator stage
- Inclusion of stators/guide vanes allows rotors to be installed in series because of aforementioned reduction in energy loss
- Efficiency of turbine designs ranges from 0.08 to 0.65
- Workflow illustrated here can be applied to other studies aimed at improving Wells turbines

ACKNOWLEDGEMENT

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