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Lateral distance effect on tidal turbine performance

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INTRODUCTION

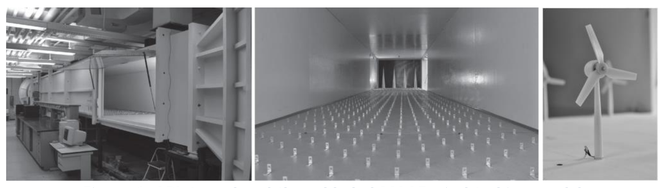
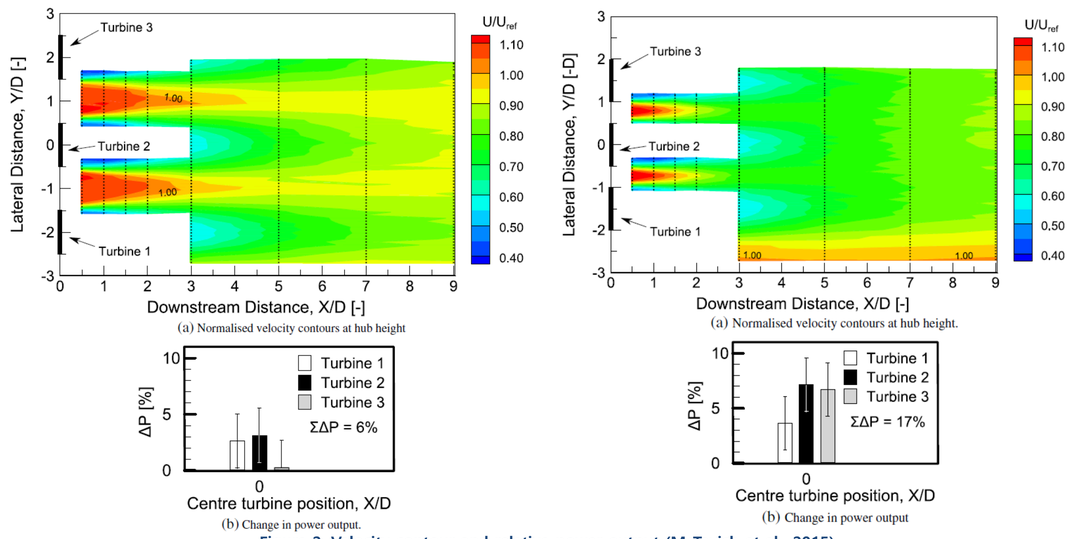


Figure 1. APL tunnel and three-bladed MAAE wind turbine model (McTavish et al., 2015)

- McTavish et al. (2015) conducted wind turbine interaction experiment
  - turbine diameter: 20cm (1/400 scale)
  - blockage: about 5%
  - turbine performance increased by lateral interaction



(a) Normalised velocity contours at hub height

(b) Change in power output.

(a) Normalised velocity contours at hub height.

(b) Change in power output

Figure 2. Velocity contour and relative power output (McTavish et al., 2015)

TURBINE DESIGN

- NREL S-series foil (S818, S830, S832) used for tidal turbine design
- 2D analysis applied to calculate lift and drag coefficients
- Number of nodes about 2,800,000

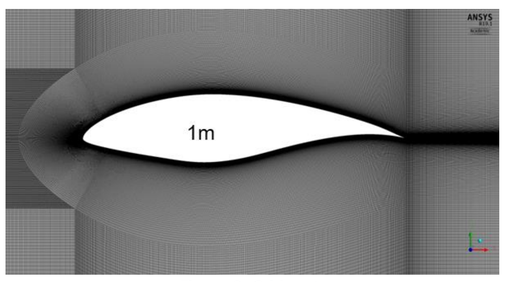


Figure 3. Grid system

Table 1. Analysis condition

Description	Analysis condition
Analysis type	Steady state
Inlet	Normal speed (14.9m/s, 11.6m/s, 4.4 m/s)
Side	Symmetry
Outlet	Average static pressure (0Pa)
Foil	No slip wall
Turbulence model	SST

- 1MW tidal turbine designed based on BEMT (blade element momentum theory)
- Design parameters ad per commercial tidal turbines developed by Simec Atlantis Energy

Table 2. Design parameters

Parameter	Value
Rated power	1MW
Turbine diameter	15m
Rated velocity	3m/s
Tip speed ratio	5
Number of blades	3ea

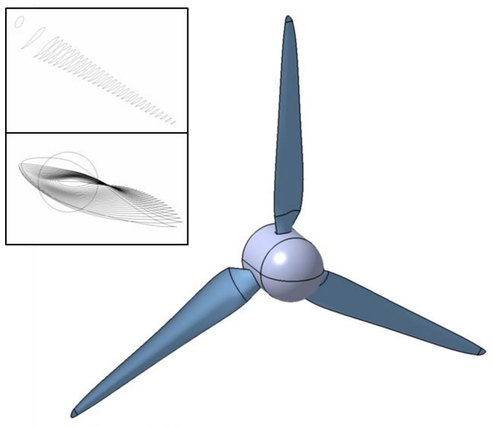


Figure 4. 3D model of designed tidal turbine

TURBINE PERFORMANCE

- Real sea condition assuming water depth of 3D
- Number of nodes : 4,200,000 (stationary domain), 3,300,000 (rotating domain)

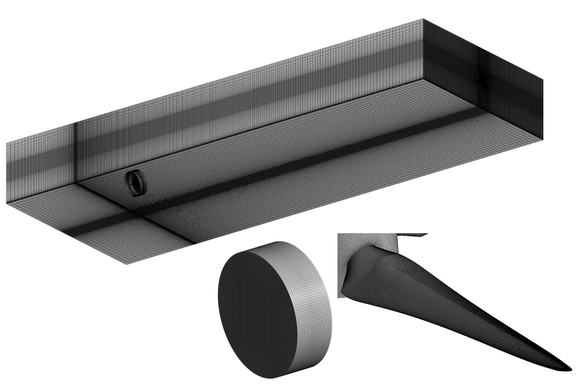


Figure 5. Grid system (performance analysis)

Table 3. Analysis condition (real sea condition)

Description	Analysis condition
Analysis type	Steady state
Inlet	Normal speed (3m/s)
Side boundary	Opening
Top boundary	Free slip wall
Bottom and turbine	No slip wall
Outlet	Average static pressure (0Pa)
Turbulence model	SST

- Maximum power coefficient: 47%
- Rated TSR = Design TSR
- Rated turbine power: 1.15MW
- Rated RPM: 19rpm

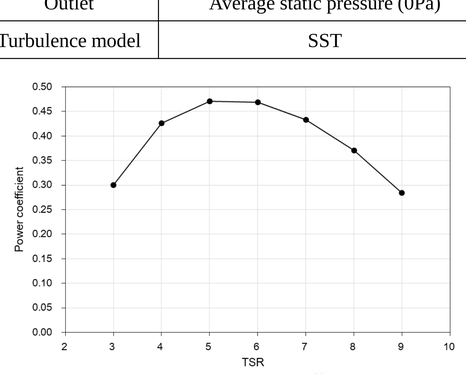


Figure 6. Power coefficient

TURBINE PERFORMANCE (OPEN WATER)

- Open water condition applied
  - depth enlarged and top and bottom boundaries set as opened neglecting blockage effect
  - water depth effect studied on turbine performance and lateral interaction
- Turbine performance increased by 1% due to blockage effect of water depth at rated TSR

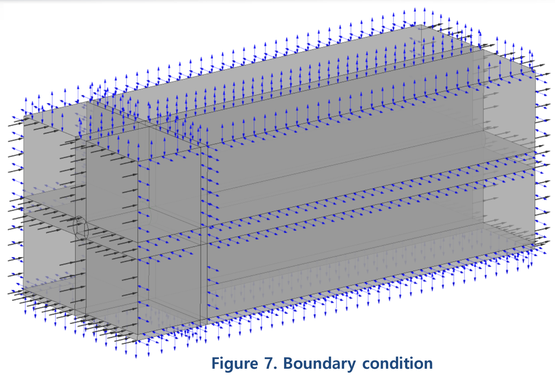


Figure 7. Boundary condition

Table 4. Comparison of turbine performance in each condition

Condition	TSR	Torque (Nm)	Power (MW)	Power coefficient
Real sea	4	650,686	1,041,098	0.426
	5	574,883	1,149,766	0.470
	6	477,272	1,145,453	0.468
Open water	4	643,464	1,029,542	0.421
	5	563,501	1,127,002	0.461
	6	462,170	1,109,208	0.454

LATERAL INTERACTION

- Interaction analysis based on performance study
- Lateral distance: 1.5D, 2D, 2.5D
- Actual sea and open water conditions considered

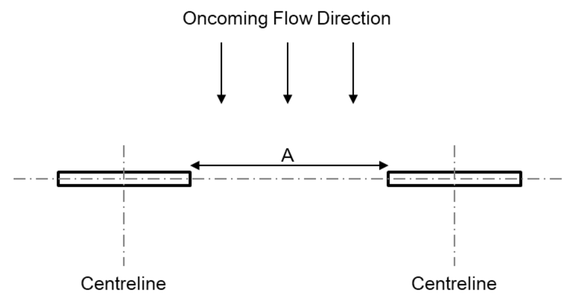


Figure 8. Lateral distance between two tidal turbines

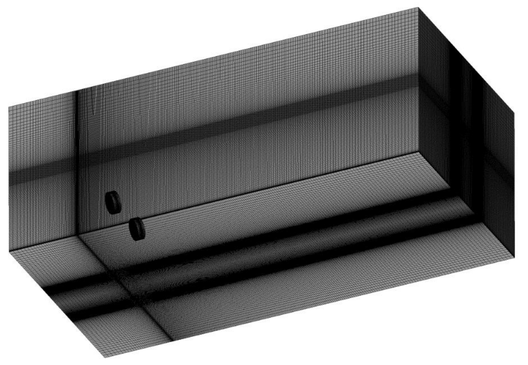


Figure 9. Grid system (interaction analysis, open water)

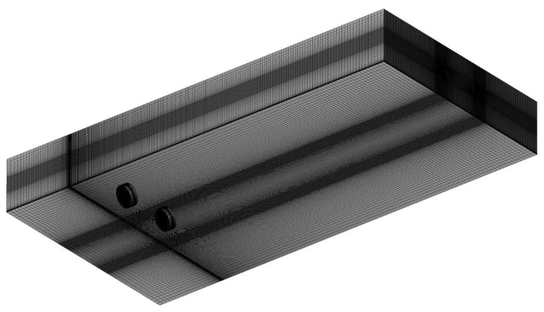


Figure 10. Grid system (interaction analysis, real sea)

- Turbine performance increased by lateral interaction
  - by 1% in actual sea condition
  - by 0.3% in open sea condition
- Turbine performance increased as lateral distance is closed.
- This phenomena caused by increased blockage due to lateral interaction of two turbines and bottom and top boundary effects

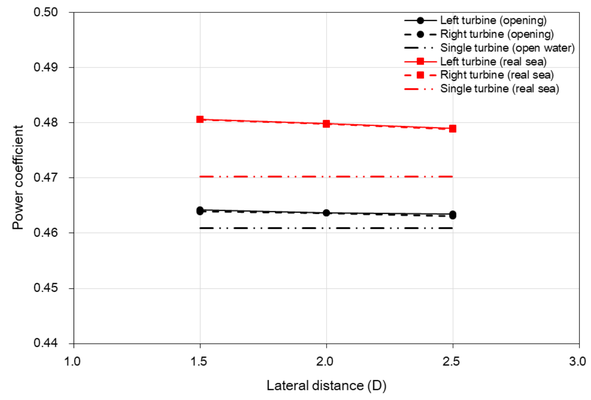


Figure 11. Power curves

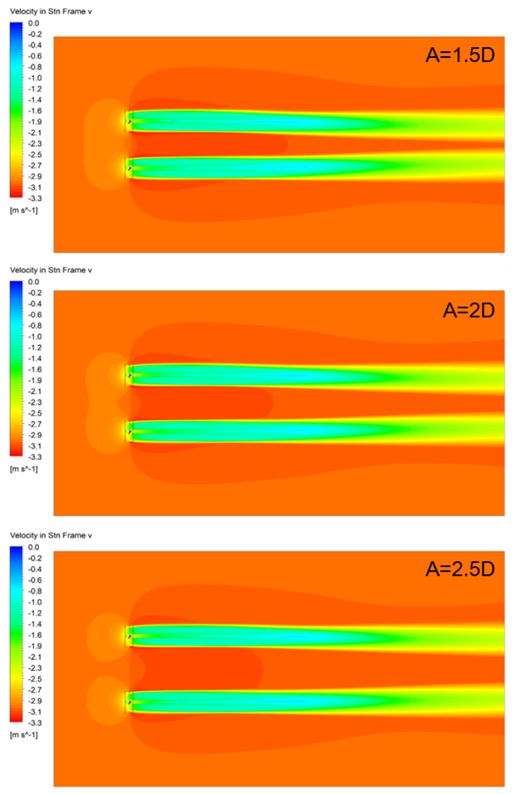


Figure 12. Axial velocity contour (real sea)

CONCLUSION

- A tidal turbine was designed and applied in the analysis to simulate the lateral interaction arrangemnet and to investigate the relationship between lateral distance and efficiency.
- Turbine performance is increased by 1% in actual sea condition and 0.3% in open water condition.
- This phenomena is caused by blockage which is increased by lateral interaction and boundary effect.

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