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The Use of Sub-Arrays in Tidal Farms

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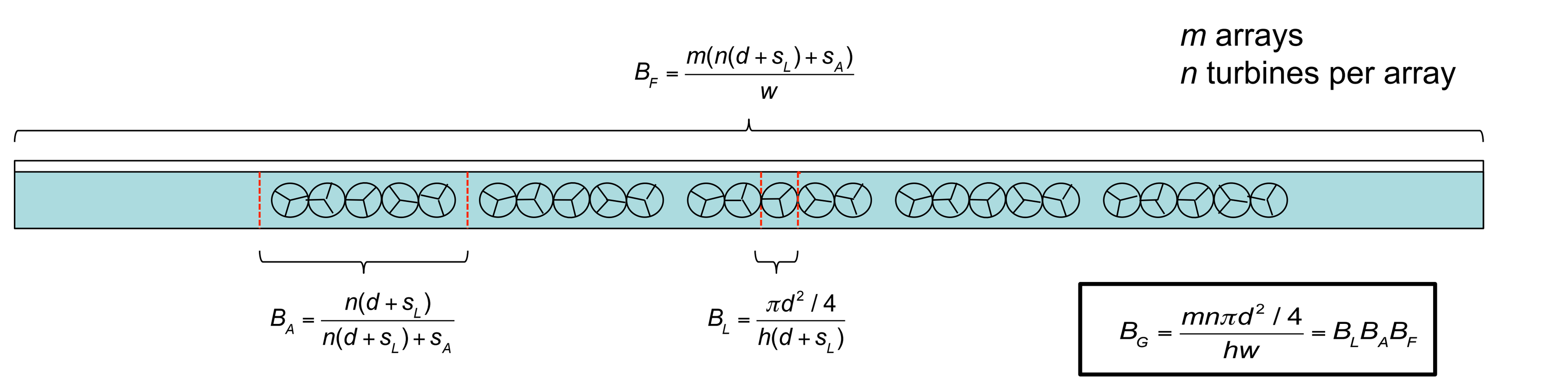
INTRODUCTION

This poster describes the development of an analytical actuator disc based model for a single row farm of tidal turbines containing multiple sub-arrays. This scenario may be of interest where bathymetry and economic constraints mean that multiple short arrays of closely spaced turbines are preferable to a single long array.

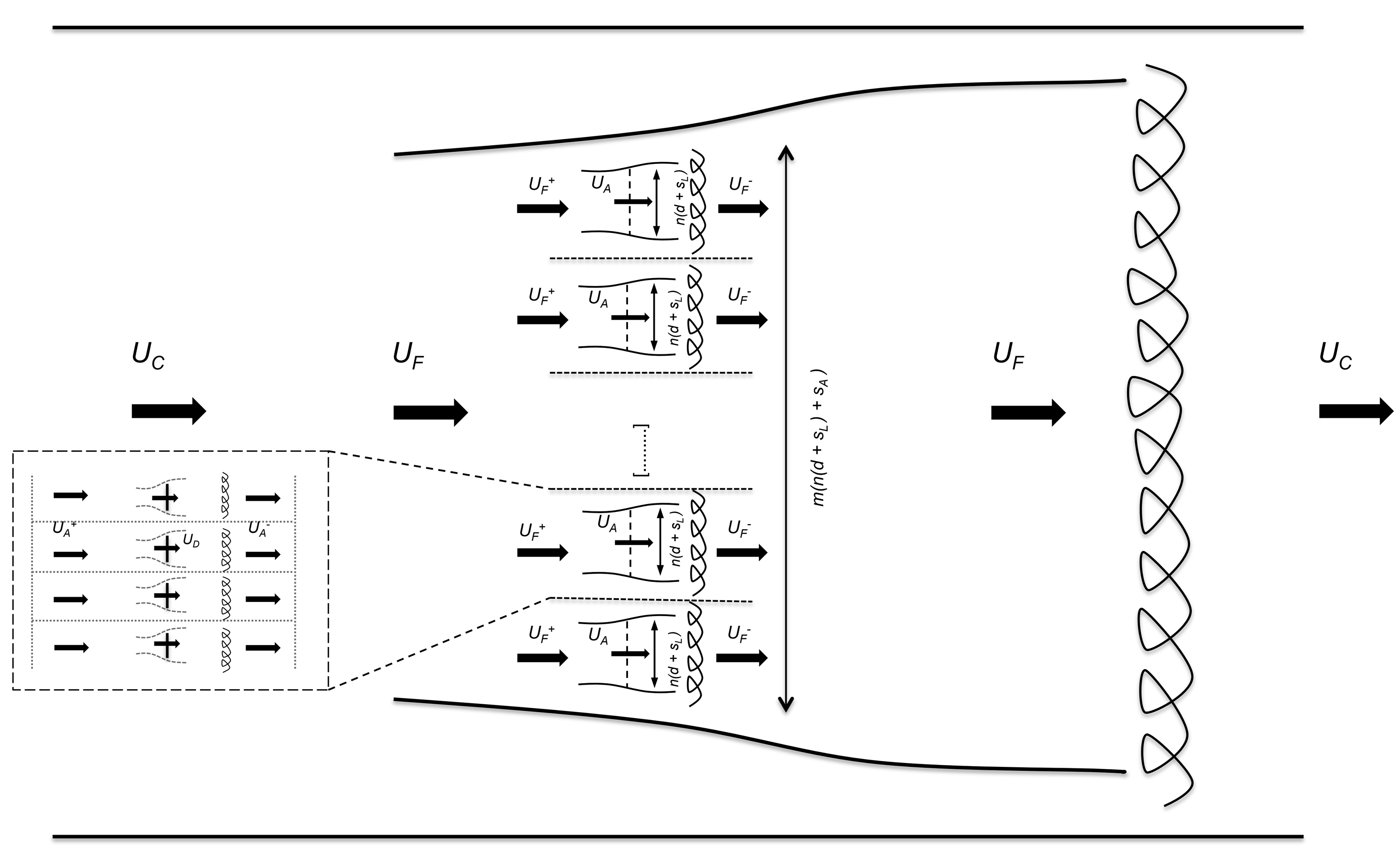
The new model builds on work by Nishino & Willden [1] modelling a single partial array, which introduced a scale separation between device and array, allowing the governing equations to be applied separately at each scale, with dynamic and kinematic matching between scales. The new model extends this with an additional scale separation to consider multiple partial arrays side by side, stretched across a wide channel. The new model has been used to investigate the effect of varying blockage ratios on available power and basin efficiency.

TIDAL FARM MODEL

Analytical model based on the partial fence model [1] which introduces scale separation between local device wake and array wake for a single row array. This scale separation is then applied again to create an outer 'farm' scale for a row of multiple sub-arrays.

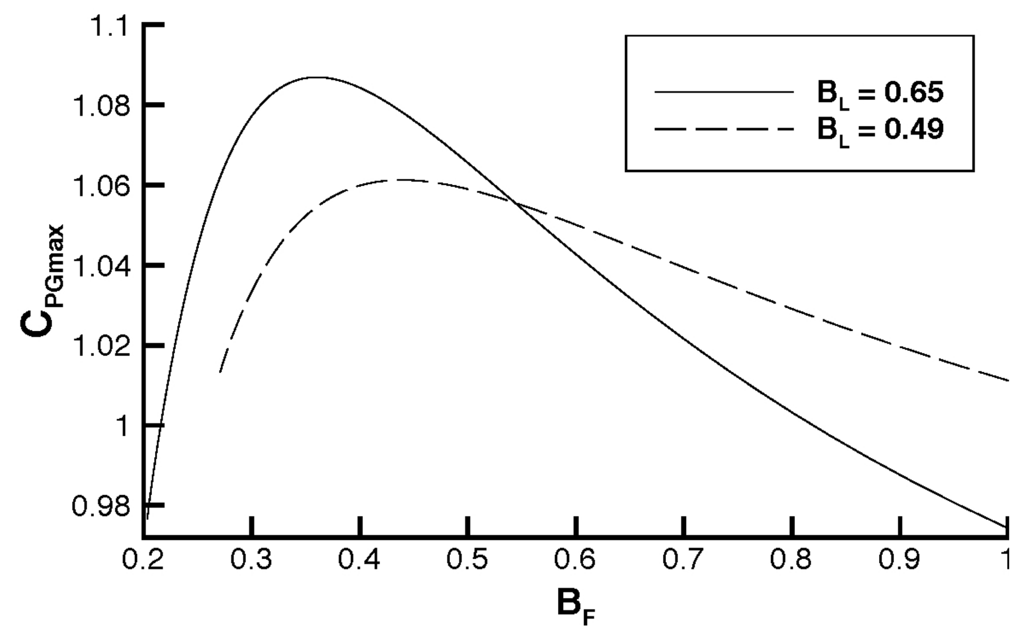


Blockage ratios ($0 < B < 1$) are defined at each scale, with global blockage ratio, B_G, defining total device frontal area to channel cross-section. B_L is local blockage (device to local flow passage area), B_A is array blockage (width of array to array flow passage), B_F is farm blockage (width of farm to channel).

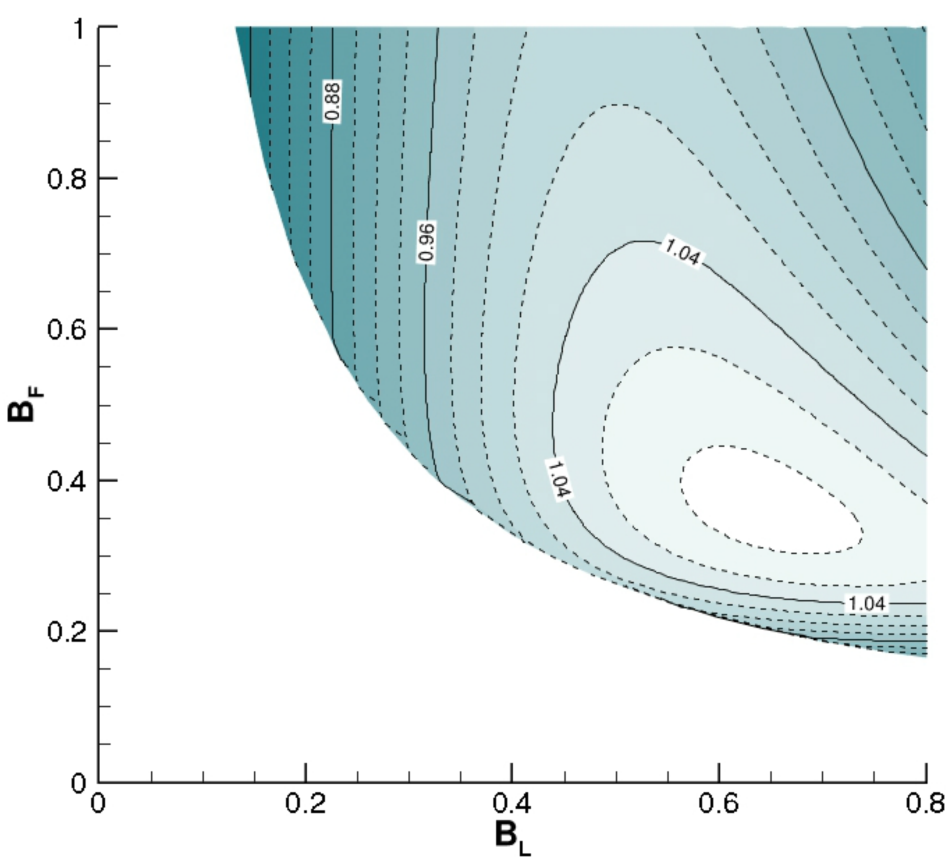


RESULTS: EFFECTS OF BLOCKAGE

For given B_L, i.e. local intra-turbine spacing at fixed depth, spreading out sub-arrays to occupy more of the channel width (increasing B_F) can increase maximum power available, C_{PG}.

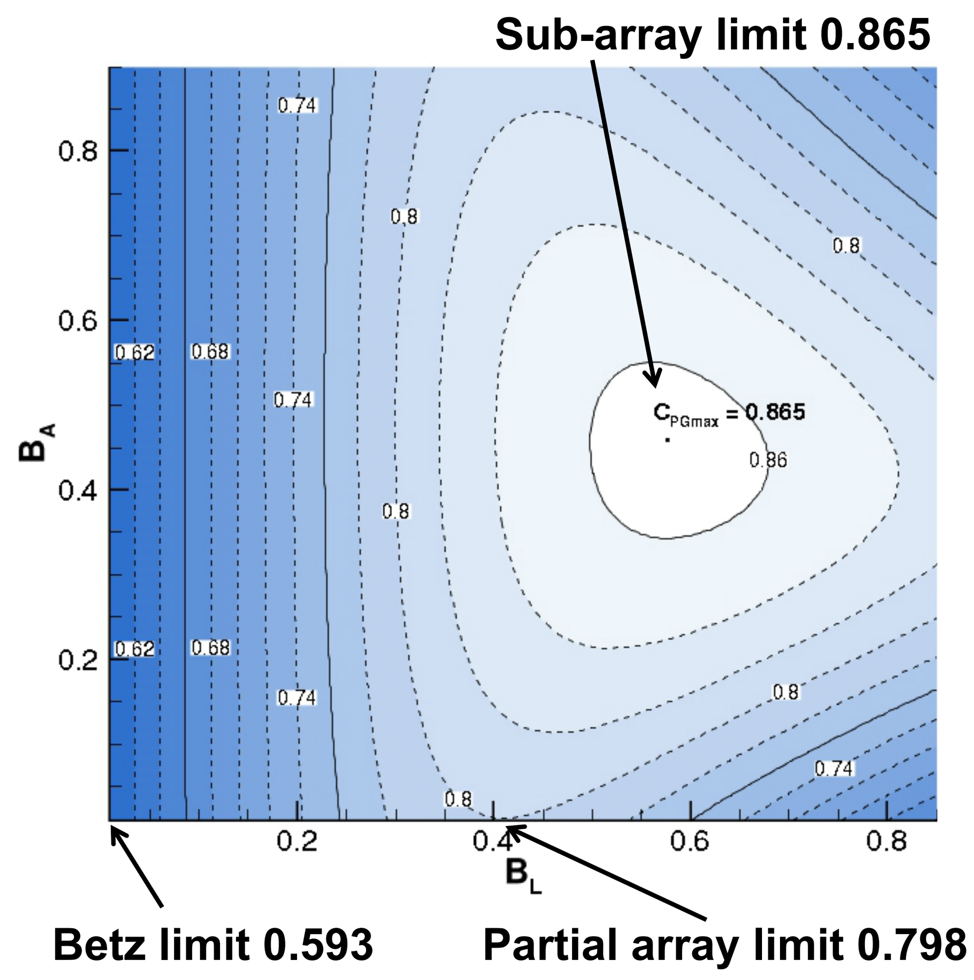


For constant B_G, i.e. total number of turbines held constant (here we take $B_G = 0.131$ as example), an increase in C_{PG} is achievable for sub-arrays with higher B_L (> 0.3).



Increased C_{PG} comes with decreased basin efficiency, η (ratio of generated to removed power). However, η_{min} is not at exactly same point as C_{PGmax} so it is possible to tune operating point to balance between maximizing power production and minimizing energy losses.

For the infinite channel width case ($B_G \to 0$), the power available to a single turbine fence is greater than the Betz limit and tends to $C_{PGmax} = 0.798$ at optimal local blockage conditions [1]. Splitting the single array into sub-arrays allows further performance enhancement to a new limiting power coefficient of $C_{PGmax} = 0.865$.



This analytical model has some inherent limitations: no array end effects are included, and for smaller numbers/sizes of sub-arrays, scale separation will become less well-defined.

CONCLUSIONS AND FUTURE WORK

Splitting up long row arrays of tidal turbines will not necessarily harm their performance if done with consideration of blockages, and may in fact offer a new method of increasing available power for very large arrays.

Further development of the model and potential for supporting porous disk experiments being considered.

REFERENCES

T Nishino & RHJ Willden (2012), The efficiency of an array of tidal turbines partially blocking a wide channel. *J Fluid Mech* 708, 596-606.