SIMPLIFIED CFD MODELLING OF TIDAL TURBINES FOR EXPLORING ARRAYS OF DEVICES

Submitted by
Mulualem Gebregiorgis Gebreslassie
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ABSTRACT

The status of marine current tidal energy technology is currently in the research and development phase, with a few deployments and tests of prototypes under-way in some countries. There is a huge pressure for tidal farms to be of Gigawatt scale in order to have a real, economically viable impact on renewable energy utilization targets outlined for 2020. A route to achieving this is the large scale energy farm philosophy, similar to wind farms, based on very large numbers of unit current tidal stream devices. However, this emerging technology development raises different research questions which lead to further problems in the practical implementation of tidal stream devices. Thus, the aim of this study was: (i) to develop a new, computationally cheap computational fluid dynamics (CFD) based model of the Momentum-Reversal-Lift (MRL) tidal turbine, and (ii) to perform a detailed calculations of the flow field of single and multiple turbines using the developed model to investigate the flow features such as, downstream wake structures, dynamics of the free surface, wake recovery, and the influence of wake interactions on the performance of individual devices.

A new CFD based Immersed Body Force (IBF) model has been developed to represent the MRL turbine. The IBF model was developed based on the concept of actuator disc methodology by incorporating additional geometric features that induce energy absorption from the flow which also lead to a downstream wake structure intended to reflect more closely those of the real turbines than simple momentum sink zone models. This turbine model was thoroughly used to investigate the performance of the MRL turbine and the associated flow characteristics and proved its capability in analysing several issues relating to this design of tidal turbines.

Several calculations have been carried out and a full range of operating points of the MRL turbine was formulated. A maximum power coefficient of, $C_p = 0.665$, was obtained with a blockage ratio of, $B = 0.016$. However, the performance of the turbine was improved at a higher blockage ratio both in a single and tidal stream farm investigations. The power coefficient of a single turbine was improved by about 3% when simulated with a blockage ratio of, $B = 0.029$, and even a higher value was obtained in a tidal stream farm containing three turbines configured in the spanwise direction which reached up to, $C_p = 0.761$, with a global blockage ratio of, $B = 0.027$. These power coefficients are higher than the Lanchester-Betz limit of $C_p = 0.593$ obtained at $B = 0$, which is mainly due to the tidal turbine operating in a constrained environment, high blockage ratio, that increases the thrust force on the device. The power coefficient of the IBF model showed consistently higher values compared to experiments and a detailed CFD model results. This indicates that the power coefficient calculated using the IBF model includes some other losses within the turbine region, such as losses due to viscous, shear etc.

Investigations on the influence of closely packed clusters of turbines in a tidal stream
farm showed that a laterally close configuration of turbines improved the performance of individual turbines due to the blockage effect, which is created by the array of turbines in the span-wise direction. In contrast, a small longitudinal spacing between turbines inflicted a massive energy shadowing that affects the performance of downstream turbines. However, a tidal stream farm with a staggered turbine layout can reduce the longitudinal spacing by about 50% with a minimum of 6D lateral spacing compared with a regular turbine layout due to the advantage of using an accelerated bypass flows.

**Keywords:** MRL, IBF model, Wake interaction, Power extraction, LES
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Contents

1 INTRODUCTION 1
  1.1 General Informal Introduction ...................................... 1
  1.2 Conventional Tidal Turbines ........................................ 3
    1.2.1 Axial flow tidal turbines ...................................... 3
    1.2.2 Cross flow tidal turbines ...................................... 4
  1.3 New Generation Tidal Turbines ..................................... 6
    1.3.1 Transverse Horizontal Axis Water Turbine ....................... 6
    1.3.2 Momentum Reversal Lift Turbine ................................ 7
    1.3.3 Tradewind Turbines ............................................. 9
  1.4 Motivation and Significance of the Research Findings .......... 10
  1.5 Research Objectives ................................................ 14
  1.6 Thesis Layout ..................................................... 14

2 COMPUTATIONAL METHODS 17
  2.1 Introduction ...................................................... 17
  2.2 Turbulence Modelling ............................................. 18
  2.3 Large Eddy Simulations ........................................... 19
    2.3.1 LES Governing Equations ..................................... 20
    2.3.2 LES Sub-Grid Scale Models ................................... 21
      2.3.2.1 Smagorinsky .............................................. 22
      2.3.2.2 One-equation eddy viscosity ............................ 22
  2.4 Reynolds Averaged Navier-Stokes ................................ 23
    2.4.1 RANS Governing Equations ................................... 23
  2.5 Volume of Fluid Method ........................................... 25
  2.6 Turbine Modelling ................................................ 26
    2.6.1 Detailed Modelling Method ................................... 26
    2.6.2 Actuator Disc Method ......................................... 26
    2.6.3 Immersed Body Force ......................................... 28
## Contents

2.6.3.1 Limitations of the Immersed Body Force model  
2.6.3.2 IBF model parameter  

2.7 Model Set-up  
2.7.1 CFD Software Package  
2.7.2 Geometry and Mesh Generation  
2.7.3 Inflow Conditions  
2.7.3.1 Inlet velocity  
2.7.3.2 Turbulent kinetic energy  
2.7.4 Fluid Properties  
2.7.5 Wall Treatment  
2.7.6 Time Step Control  

2.8 Data Post-processing Methods  
2.8.1 paraFoam  
2.8.2 Wavelet Transforms  

2.9 Comparison of the Computational Models  
2.9.1 Computational Set-Up  
2.9.1.1 Computational domain  
2.9.1.2 Implementation of boundary condition  
2.9.2 Flow Field Analysis  
2.9.2.1 Comparison of LES and RANS  
2.9.2.2 Comparison of LES Sub-Grid Scale Models  

2.10 Summary  

3 CALIBRATION OF ENERGY EXTRACTION  
3.1 Introduction  
3.2 Performance metrics  
3.2.1 Coefficients of Thrust and Power  
3.2.2 Energy Flux  

3.3 Computational Set-Up  

3.4 CFD Results and Discussions  

VI
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.4.1 Preliminary Analysis</td>
<td>61</td>
</tr>
<tr>
<td>3.4.1.1 Mesh resolution and convergence</td>
<td>62</td>
</tr>
<tr>
<td>3.4.1.2 Dynamics of free surface</td>
<td>62</td>
</tr>
<tr>
<td>3.4.2 Performance of the MRL Turbine</td>
<td>66</td>
</tr>
<tr>
<td>3.4.2.1 Thrust Analysis</td>
<td>67</td>
</tr>
<tr>
<td>3.4.2.2 Power Analysis</td>
<td>68</td>
</tr>
<tr>
<td>3.4.3 Blade Positions</td>
<td>70</td>
</tr>
<tr>
<td>3.4.4 Side Plates</td>
<td>73</td>
</tr>
<tr>
<td>3.4.5 Comparison of the Annular and Blade approaches of the IBF model</td>
<td>75</td>
</tr>
<tr>
<td>3.4.6 Blockage effect</td>
<td>75</td>
</tr>
<tr>
<td>3.5 Validation of the IBF Model</td>
<td>78</td>
</tr>
<tr>
<td>3.5.1 Comparison with Experiments</td>
<td>78</td>
</tr>
<tr>
<td>3.5.1.1 Experimental set-up</td>
<td>78</td>
</tr>
<tr>
<td>3.5.1.2 Computational set-up</td>
<td>79</td>
</tr>
<tr>
<td>3.5.1.3 Discussions</td>
<td>80</td>
</tr>
<tr>
<td>3.5.2 Comparison with Detailed CFD model</td>
<td>83</td>
</tr>
<tr>
<td>3.5.2.1 Computational set-up</td>
<td>84</td>
</tr>
<tr>
<td>3.5.2.2 Flow field analysis</td>
<td>85</td>
</tr>
<tr>
<td>3.5.2.3 Power analysis</td>
<td>85</td>
</tr>
<tr>
<td>3.6 Summary</td>
<td>87</td>
</tr>
</tbody>
</table>

4 THE WAKE CHARACTERISTICS OF A SINGLE MRL TURBINE

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1 Introduction</td>
<td>91</td>
</tr>
<tr>
<td>4.2 Computational Set-Up</td>
<td>92</td>
</tr>
<tr>
<td>4.3 Results and Discussions</td>
<td>92</td>
</tr>
<tr>
<td>4.3.1 Comparison of the Two IBF Modelling Approaches</td>
<td>92</td>
</tr>
<tr>
<td>4.3.2 Sensitivity Analysis</td>
<td>95</td>
</tr>
<tr>
<td>4.3.2.1 Mesh sensitivity</td>
<td>95</td>
</tr>
<tr>
<td>4.3.2.2 Wall boundary proximity to the turbine</td>
<td>99</td>
</tr>
<tr>
<td>4.3.2.3 Body force loading</td>
<td>105</td>
</tr>
</tbody>
</table>
4.3.2.4 Ambient turbulence intensity ........................................ 110
4.3.3 Turbine Designs With and Without Side Plates ..................... 115
4.3.4 Free Surface Deformation ................................................ 120
  4.3.4.1 Comparison of the surface deformation by the two designs122
  4.3.4.2 Comparison of the surface deformation at different turbine positions relative to the free surface .......... 124
4.3.5 Velocity Deficit at Different Cross-Sections .......................... 124
4.4 Summary .............................................................................. 129

5 INVESTIGATING THE WAKE INTERACTION OF MULTI-TIDAL TURBINES 131
  5.1 Introduction ............................................................................ 131
  5.2 Related Studies ...................................................................... 132
  5.3 Computational Set-Up ............................................................... 136
    5.3.1 Base Turbine Computational Domain ................................. 136
    5.3.2 Two Turbine Configuration ............................................. 137
    5.3.3 Three Turbine Configuration ......................................... 138
    5.3.4 Seven Turbine Configuration .......................................... 139
  5.4 Base Case Turbine ................................................................. 140
    5.4.1 Flow Field Analysis ...................................................... 141
    5.4.2 Thrust and Power Analysis ........................................... 144
  5.5 The Influence of Lateral Turbines ........................................... 145
    5.5.1 Flow Field Analysis ...................................................... 146
    5.5.2 Thrust and Power Analysis ........................................... 156
  5.6 The Influence of Upstream Turbine ....................................... 158
    5.6.1 Flow Field Analysis ...................................................... 158
    5.6.2 Thrust and Power Analysis ........................................... 166
  5.7 The Influence of Surrounding Turbines .................................. 167
    5.7.1 Flow Field Analysis ...................................................... 168
    5.7.2 Thrust and Power Analysis ........................................... 177
5.8 Execution Time of the Simulations ........................................ 179
5.9 Summary ........................................................................... 181

6 CONCLUSIONS AND FUTURE WORK ........................................ 183

6.1 Conclusion ......................................................................... 184
   6.1.1 CFD based IBF model .................................................. 184
   6.1.2 Performance of the MRL turbine .................................. 185
   6.1.3 Flow Field Features ..................................................... 186
   6.1.4 Limitations of this Research ........................................ 187

6.2 Future Work ....................................................................... 188
   6.2.1 Experiments ............................................................... 188
   6.2.2 CFD Direction ............................................................ 189
   6.2.3 Analytical Modelling ................................................... 190

A List of Publications .............................................................. 211

A.1 Journal Papers ................................................................. 211
A.2 Conference Proceedings .................................................. 211