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Computational Modelling of a Tidal Stream Turbine

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ABSTRACT

As one of the signatories of the Kyoto Protocol the United Kingdom is committed to reducing its emissions of greenhouse gases by 12.5% relative to the 1990 level by 2012. Whilst it is likely to achieve this goal, a reduction of 15.3% [1] had been achieved by the end of 2005, the government had also stated an intention to achieve a 20% reduction in carbon dioxide emmisions by 2010. This second target is unlikely to be achieved as the reduction stood at 6.4% at the end of 2005 and emissions had increased by around 2% since the Labour Party came to power. The main contributors to this recent increase arose from transportation and primarily from energy generation. To achieve any long term reduction in CO_2 emissions these two areas, which together accounted for 59% of emissions in 2005, need to be addressed. Exploitation of renewable energy sources offers a potential solution to achieve these aims. Certainly to achieve the goverment's stated desire to reduce CO_2 emissions by 60% by 2050 there is necessity to invest in research and technology associated with energy generation with low or zero carbon footprints.

The United Kingdom has a number of natural resources that should allow a much greater portion of its energy usage to be generated through renewal resources. Whilst solar and geothermal resources may be limited or expensive to exploit there is an abundance of both wind and water. Currently the United Kingdom generates around 2% of its energy from hydroelectric, 1.5% from wind and 0.8% from other renewal resources [2]. Consent has been provided to build further wind farms that potentially will provide a further 3.3% of the requirement but this will still leave the government short of its 10% target by 2010. One area that has not been exploited to the same level as wind is the generation of power from tides. One approach to harness the available energy in the tides is to use a device that resembles the standard wind turbine. The advantage of tidal power generation is that it is a predictable resource. Whilst the turbine will generate no power at the changing of the tides, probably for around 30 minutes every 6 hours, the device will be operational for the remainder of the time. Although the tidal flows are much slower than wind currents the extra density of water over air means the available energy in the tide is much greater. The disadvantages are mainly associated with installation and maintenance.

The work described in this contribution derives from one strand of a collaborative project between 7 groups at Swansea and Cardiff Universities and sponsored by the Welsh Energy Research Centre. The

brief of the project is to examine all aspects related to the installation of tidal stream turbines. These aspects range from determining the process necessary to reach consensus regarding installation of the device, surveying techniques necessary to obtain site related data through to numerical modelling. The numerical modelling is performed by 3 groups each concentrating on a different geometric scales which aim to predict the effects on the scale of the Bristol Channel, the interactions between devices when they are installed close together and the detailed modelling of an individual device. This contribution concentrates of the modelling of a single device.

The first stage in the modelling of the turbine is the prediction of its interaction with the tide and the energy generated by the device. These calculations have been performed both using time averaged momentum sources [3] and a moving mesh method. The prediction of the power extracted from the tide is consistently predicted by the two methods as well as the large scale fluid flow. They differ in the vicinity of the blade where the moving mesh method identifies the transient nature of the flow over the moving turbine blades. As a consequence the time averaged method, which is the computationally more efficient method, has been used in further simulations associated with large scale phenomena such as scouring and sedimentation and the moving mesh method has been used where effects local to the blade are important, such as the calculation of temporal loads on the structure.

One of the major concerns about tidal stream turbines is their environmental impact. These concerns cover both the effect of the device on the surrounding sea bed and with respect to any marine life present both on the bed and in the water column. Simulations have been performed to predict the scouring effects on the sea bed resulting from the presence of a support structure for the turbine. These simulations have investigated the effect of the shape of the support and mechanisms that may be used to reduce the effects of scouring. The current target area for installation of a turbine is the Bristol Channel. This waterway has a significant amount of sediment, mainly silt, suspended in the water column. Numerical studies have been performed to determine whether the presence of the turbine has any significant effect on the transport of the sediment and its distribution within the column. The questions related to damage to marine life are harder to resolve through simulation. Whether a device will attract or repel specific types of marine life is a psychological question rather than mathematical. What simulations can show are potential areas where damage may occur to marine life if they are present. Two measures have been developed, firstly to identify volumes where marine life will pass through the blades and secondly to identify where there is potential for pressure change related damage to occur.

The next stage of analysis of the turbine will concentrate on the loads on the device itself and the interactions of the structure back into the fluid. For these simulations the moving mesh technology will be employed so that the variation of load on the structure can be analysed. Obviously as a blade passes in front of the supporting structure there will be a shadow effect with respect to the flow and the load will be reduced. This will cause periodic motion of the structure and the associated disturbance to the flow field. The significance of these perturbations will be investigated with respect to the structural requirements of the supporting structure and to identify the potential for low frequency noise emissions which are thought to repel cetaceans.

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