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Methods for predicting seabed scour around marine current turbine

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ABSTRACT

Marine energy sources are able to make significant contributions to future energy demands. Marine current has huge potential to supply renewable energy as compared to the other energy sources. Marine environment is harsh for the installation and operation of marine current turbine (MCT). Seabed scour around marine current turbine is induced when the flow suppression occurs at the seabed. Seabed scour is widely recognised as a difficult engineering problem which is likely to cause structural instability. The study found that the previous works mainly focus on the bridge piers, wind turbines and ship propeller jets induced scour. Little information to date was found to predict the MCT induced scour. The current paper proposes the potential equations to predict the MCT induced scour. The study also recommends the consideration of the rotor into the existing equations for future research.

Contents

1. Introduction

The installation of marine structures leads to the changes of flow patterns around the structures. The contraction of flow commonly occurs when the flow passes through a narrow area of structure. The formation of horseshoe vortex can happen in front of a monopile structure, whereas the formation of lee-wake vortices (with or without vortex shedding) can happen behind a structure. The generations of turbulence, wave reflection, wave diffraction and wave breaking are associated with flow passing through a marine structure. These flow phenomena cause the instability and liquefaction of soil leading to excessive sediment transport and seabed scour [1,2].

The impact of a marine structure to seabed is an essential environmental study at the planning stage for an engineering project [3]. The interaction between the flow and structures may

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cause scouring at the seabed leading to the structural instability [4–6]. Marine current turbine (MCT) is a rotating device designed to harness the kinetic energy of marine current and generate electricity. It consists of a number of blades connected to a supporting structure and it either rotates about a horizontal axis or vertical axis [7]. The installation of a monopile structure for marine current turbine gives no different effects from other offshore structures. The presence of MCT structure changes the flow pattern. The flow contraction accelerates the flow in its vicinity and leads to the local scour around the structure [8,9].

Climate change is one of the most challenging problems that humans have to deal with in the 21st century [10]. Most countries such as those in the European Union (EU) start to increase the electricity generation from renewables as part of their climate strategy [11]. Each renewable source has its own positive and negative attributes such as availability, affordability and environmental impacts [12]. The electricity generation from marine current sources is more predictable compared to the other renewables such as solar power and wind energy [13]. Marine current resource is therefore a vital natural resource to harness in order to secure the cleaner future energy supply [7]. Structural safety due to the seabed scour is one of the main considerations to take into account when considering the applicability of marine current renewables.

The foundation of MCT should be protected in order to prevent failure due to seabed scouring. The consequence of foundation failure may lead to the collapse of the entire MCT. The inclusion of a protection unit to prevent seabed scouring is important at the initial stage of design. The cost involved for scour and scour protection is considered as one of the highest contributors to the total cost of the entire offshore project. For instance, the cost of foundation for wind turbine can be up to 30% of the total cost when the scour protection is included [1].

The study of scour for marine current turbine is important to make marine current energy to be economically viable. The scour study can be started by understanding the previous studies on other marine structures such as piers and piles. The fundamental theories of scour are well-documented in the books of Whitehouse's “Scour at Marine Structures” [6] and Sumer and Fredsøe's “The Mechanics of Scour in the Marine Environment” [4]. The flow pattern and the scour process around the piers and piles have been previously investigated by using analytical methods, experimental tests and numerical modelling [1]. However, the study on mechanics of scour and scour protection method for marine current turbine has not been thoroughly studied. Little information to date was found to discuss the protection of the foundation of MCT. The engineering equations have not been summarised to provide a simple tool to investigate the seabed scour of MCT. The current study uses the experiences of induced scour due to wind turbines, ship's propeller jets and bridge piers as references for the scour study of MCT.

2. Seabed scour for support structures

2.1. Support structures of marine current turbine

Marine current turbine is generally divided into horizontal axis marine current turbine and vertical axis marine current turbine [14]. The technological development of the horizontal type does seem more mature compared to the vertical type due to its high promised performance. The established commercial turbines of Seaflow and SeaGen are both horizontal axis marine current turbines. The development of marine current technologies includes the design of an effective support structure to hold the turbines safely. The support structure for horizontal axis turbine can be categorised into four main types as shown in Fig. 1 [7]:

(1) Gravity structure: The gravity structure is a concrete or steel structure to hold the turbine by its self-weight to resist overturning.
(2) Monopile structure: The monopile structure is a large steel beam with a hollow section penetrating to a depth of seabed between 20 and 30 m for a soft seabed. The processes of predrilling, positioning and grouting are required for the seabed condition of hard rock.
(3) Tripod/piled Jacket structure: The tripod Jacket structure anchors each corner of the basement to the seabed by using steel piles. These steel piles are driven in between 10 and 20 m into the seabed to hold the structure firmly. Tripod Jacket structure is a well-established technology in the application of oil and gas industry.
(4) Floating structure: Floating structure is suitable for the application of deep water. The floating device appears at the surface of the water to hold the submerged turbine structure in the water. The submerged structure is locked to the mounting device at the seabed by using chains, wire or synthetic rope.

2.2. Seabed scour

Rambabu et al. [16] stated the fluid flow, geometry of foundation and seabed conditions are the governing factors for the seabed scouring. The characteristics of fluid flow include the current velocity, Reynolds number of model and Froude number of flow. The abovementioned four types of foundations have different areas of contact to the seabed. The selection of support structures lead to different flow patterns occurring at the foundation with different formation of flow-induced vortices in the vicinity of support structures. Different scouring patterns are induced by different geometry of foundation.

The gravity structure is most susceptible to seabed scouring due to its large contact area with the seabed compared to the other three types of foundation. The determination of geometry size and seabed preparation is required in order to implement the gravity structure as the foundation of MCT. The scour of monopile is less susceptible compared to gravity structure due to its low contact area with the seabed [7]. The scour development of piled jacket structure is more complicated compared to the aforementioned due to its footing shape [17]. McDougal and Sulisz [18] stated the floating structure gives lowest impact on the seabed scour due to the low area of contact between the structure base

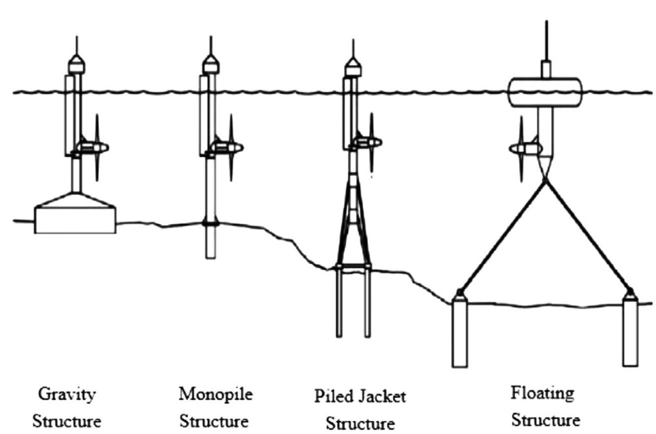

Fig. 1. Different types of support structures with horizontal marine current turbines [15].