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Potential scour for marine current turbines based on experience of offshore wind turbine

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Abstract. The oceans have tremendous untapped natural resources. These sources are capable to make significant contribution to our future energy demands. Marine current energy offers sustainable and renewable alternative to conventional sources. Survival problems of Marine Current Turbines (MCTs) need to be addressed due to the harsh marine environment. The analogous researches in wind turbine have been conducted. Some of the results and knowledge are transferable to marine current energy industry. There still exist some gaps in the state of knowledge. Scour around marine structures have been well recognised as an engineering issue as scour is likely to cause structural instability. This paper aims to review different types of foundation of MCTs and potential scour and scour protection around these foundations based on the experience of offshore wind turbine farm.

1. Introduction

In 1987, the term “sustainable development” has been coined by the United Nations in the Brundtland Report. Sustainable development refers to the development that meets our today generations’ needs without compromising those future generations. As the human population increased dramatically in recent years, the energy consumption has been raised up sharply as well. It is not possible to meet future energy demands without risking serious damage to the environment either through continuing to burn the fossil fuels or through placing increasing reliance on nuclear power [1].

In order to achieve sustainable development, exploration of renewable energy becomes highly vital. The oceans have tremendous untapped natural resources. These sources are capable to make significant contribution to our future energy demands. There are several types of ocean sources have been defined as potential sources to generate energy, which include tidal barrage, marine current energy, wave energy, ocean thermal energy and salinity gradient energy [2].

Tidal energy is more predictable compared to wind and wave energy. The tidal sources are easier to be quantified and predicted [3,4]. The marine environment is harsh for the installation and operation of Marine Current Turbines (MCTs). Extreme sea conditions have to be considered for the structural stability of MCTs under marine environment. Scour around marine structures have been well recognised as an engineering issue where scour is likely to cause structural instability. The information regarding the seabed scour around MCTs’ foundation is limited in the existing literature. Relevant

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research has been done in the field of offshore wind farm. There still exist some gaps in the state of knowledge. This paper reviews the seabed scour concerns around MCTs' foundation and potential scour protections.

2. Different types of foundations of marine current turbines

The support structure of MCTs is of significant importance in the overall marine current energy system. Prior assessment of the support structure of MCTs was carried out before approaching the seabed scour around foundation of MCTs. Based on the current status of MCTs, four basic support structures for MCTs have been described in the following [5]:

1) Gravity structure: This gravity structure is made up of large steel or concrete base column. It is able to resist overturning by its self-weight. The steel component of this gravity structure adds some advantages to itself, such as ease of production, transportation, and installation.
2) Monopile structure: This type of structure is made up of a large-diameter hollow-steel beam. The beam is penetrated approximately 20-30 m into seabed while the seabed conditions are soft. If the rock is harder, pre-drilling, positioning and grouting may be the methods to install this structure.
3) Floating structure: Floating structure provides the optimum solution for the placement of devices in deeper water conditions. This type of structure is made of mounting device and floating vessel which is moored to the seabed using chains, wire or synthetic rope.
4) Tripod/Piled Jacket structure: Each of the corners of the structure's base is anchored to the seabed by using steel piles. The steel piles are driven approximately 10-20 m into the seabed depending primarily on the seabed conditions. This type of structure is well understood since it has been widely used in the oil and gas industry. Compared to other structures, this type of structure has lighter structural loading. All the aforementioned support structures have shown in Fig.1[5].

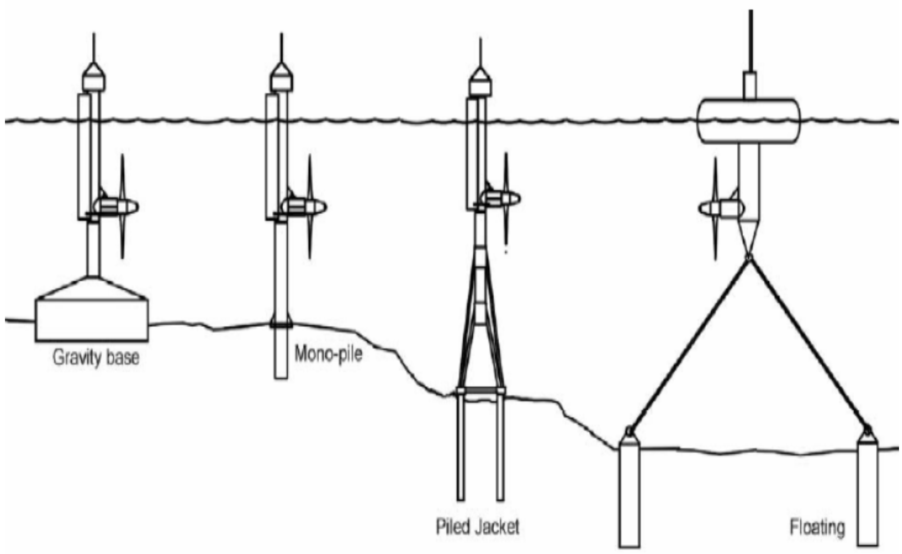

Figure 1. Different types of support structures with horizontal marine current turbines

Horizontal axis and vertical axis MCTs are the two groups of hydrofoil-shaped blades applied in marine current energy devices [6].Horizontal axis MCTs is the most common to-date devices, and they rotate at a horizontal axis which is parallel to the current stream [7]. On the other hand, vertical axis MCTs rotate about a vertical axis which is perpendicular to the current stream [8]. There are many novel prototypes has been invented in the industry to harness the kinetic energy from marine current. Rourke et al. [5] reviewed some of the prototypes in detail which including their dimensions, features and status of development.

3. Potential seabed scour around foundation of marine current turbines

In this section, the local scour around the MCTs foundation is discussed. Scour around marine structures have been well recognised as an engineering issue where scour is likely to cause structural instability. Seabed protection for the foundation of marine structure is required [9-11]. Seabed scour issues have to be taken into account for a sound design of MCTs and their support structures. However, the researches relevant to seabed scour of MCTs foundation are insufficient. The seabed development around MCTs is based on the experience of offshore wind turbine farm.

Whitehouse developed a conceptual model of scour sensitivity which includes full range of marine sediment types [12-13]. According to Whitehouse, as the susceptibility of sediments to erosion reduces, the scour is expected to decrease for both coarser and finer soils. Moreover, muds and clays have more uncertainties regarding the response of scour due to their formation history and degree of compaction. Besides, cyclic loading by waves may result in scour due to pore pressure built up in the soil. Hence, wave-induced liquefaction may occur and it could decrease the strength of soil. [12-13].

In extreme events, the hydraulic force increases whilst the scouring depth of some sediment increases. On the contrary, some sediment waves may result in a decrease of scour depth. In addition, the events either with high energy for erosion occurrence or in long duration increase the rate of scour. Nevertheless, the scour response of the seabed in time-limited event depends on the sensitivity of the seabed to increased shearing force on seabed, and the severity of the event [9]. Due to the intrinsic nature of sea state, sea environment is harsh and extreme events occur frequently, such as hurricane, typhoon, tsunami and storm. The extreme events could bring along extreme wave and strong wind so that the extreme event may causes substantial erosion and scouring around the foundation of MCTs. The scour around the foundation of MCTs may result in instability of the support structure of MCTs.

Whitehouse et al. [13] assessed scour problem at several offshore wind turbine farms and summarised the site characteristics of each farm with description of sediment type and other governing factors such as wave and current conditions. The largest value of scour depth observed was S/D=1.47 (S stands for scour depth, D stands for pile diameter). However, the peak current speeds at these sites are small which not more than 2 m/s. Charlier [14] stated that the marine current sites have a current velocity of 2.5 m/s or more are considered as high energy resources so that seabed around foundation of MCTs may has larger scour depth.

Besides, the type of support structure of MCTs may lead to different impacts on benthic habitats. Byrne and Houlsby [15] reviewed different foundation design for offshore wind farms. The study found that the gravity base foundations require substantial seabed preparation and are susceptible to scouring. The scour protection is installed below the level of the surrounding seabed [5, 15]. On the other hand, the monopile structure does not require seabed preparation [5]. It means monopile structure is less susceptible to scouring during its operational life. Therefore, an appropriate foundation design of MCTs integrated with seabed condition could enhance the structural stability of MCTs.

4. Potential seabed scour protection

Sour protection could be placed around the MCTs' foundation in order to stabilize the support structure of MCTs. Whitehouse [13] reviewed numerous approaches for mitigating scour around foundations. These methods are geotextile containers/sandbags, concrete amour units, concrete block mattress, grout bags/mattresses, gabions/gabion mattresses and flow inhibitors, where rock amour is the most common scour protection in offshore wind farm industry [14]. These scour protection technologies are transferable to MCTs. However, the appropriateness of these sour protections for MCTs has to be identified in further researches.

5. Conclusion

Seabed scour development around offshore wind turbine foundations has been studied extensively. Some of the results and knowledge are transferable to marine current energy industry. However, surrounding environment where MCTs operates is differs from wind marine. MCTs face more challenging problems compare to wind turbine. Some other survival problems MCTs may face during its operational life such as cavitation, high axial force and access of installation and maintenance. The developers of marine current energy have to overcome all the survival problems in order to harness kinetic energy from MCTs and to generate designed electricity.

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