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Original Article

Marine hydrokinetic energy potential of Peninsular Malaysia by using hybrid site selection method

Nur Amira Nabilah, Cheng Yee Ng, Nauman Riyaz Maldar, Fatin Khalida Abd Khadir

Department of Civil and Environmental Engineering, Universiti Teknologi PETRONAS, Seri Iskandar 32610, Perak, Malaysia

* **Correspondence email:** chengyee.ng@utp.edu.my

Abstract

The exponential increase in global energy demand is a direct result of the rapid growth of the world's population and technological advancements. However, the use of fossil fuels to meet this demand has led to the issue of CO_2 emission and global warming, which prompting nations to undertake mitigation plans for minimize the negative impacts. Seeing the fact that extensive usage of the fossil fuel, which is non-renewable, as the energy source is the root cause of these negative effects, more renewable energies (RE) investigation has been conducted. On top of that, the implementation of RE is urgently needed to achieve a sustainable development. Peninsular Malaysia, which is surrounded by the Strait of Malacca and the South China Sea, has abundant of hydrokinetic energy source. This study aims to provide a comprehensive approach to identify the suitable locations for marine hydrokinetic energy extraction in Peninsular Malaysia, considering all essential factors that influence decision-making.

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1 Introduction

Renewable energy has become an increasingly important topic due to concerns over climate change and the finite supply of fossil fuels. According to International Energy Agency (IEA), renewable energy sources have grown to account for 26.2% of global electricity generation in 2018 [1]. This growth has been driven by improvement in technologies, decrease in costs, and government policies, aiming to address the issue of greenhouse gas such as CO_2 emissions [2,3]. In addition, renewable energy has the potential to bring economic benefits to regions that invest in it, creating jobs and spurring economic growth [4,5]. Renewable energy refers to energy generated from natural resources that can be replenished, e.g., sunlight, wind, wave, and geothermal heat. Solar energy is generated from the sun's radiation and can be converted into electricity using solar panels. It is a highly abundant and widely available source of energy. Wind energy is generated by the converting the wind kinetic energy to electricity. Such kind of energy is a highly scalable and cost-effective. Hydro energy is generated by the motion of water and can be harnessed by using hydropower plants or hydrokinetic turbines. It is a reliable and widely available source of energy Geothermal energy is generated by the heat within the earth's core and can be harnessed using geothermal power plants. It is a highly efficient and reliable source of energy. Biomass energy is generated by burning organic matter such as wood, agricultural crops, and waste. It is a highly versatile and widely available source of energy [6]. These renewable energy sources have been extensively investigated and developed in recent years, with significant advancements being made in their efficiency, cost-effectiveness, and scalability [7]. The importance of the RE is recognized as an alternative to the conventional fossil fuels to mitigate the climate change and energy security. [8-10].

Globally, about 70 % of the Earth's surface is covered by the oceans, which make the power extracting from ocean source is promising. According to IEA, marine renewable energy technologies include ocean thermal energy conversion, wave energy, tidal energy, and ocean current energy [1]. Marine renewable energy sector is in growing trend too as the world seeks to reduce dependence on fossil fuels and mitigate climate change. According to a report by the International Renewable Energy Agency (IRENA), the potential for wave and tidal energy alone is estimated to be 29,500 terawatt-hours per year [6]. Marine renewable energy has several advantages over other types of renewable energy sources. For instance, the ocean current flow velocity is predictable and reliable compared to solar and wind energy. Tidal and wave patterns can be accurately forecasted. Additionally, marine renewable energy sources are typically located near coastal populations, which is reducing the need for long-distance transmission line. This will minimize the losses during transmission. In general, marine renewable energy is promising and rapidly developing field with significant potential to contribute to global renewable energy goals.

Marine hydrokinetic energy is harnessed from kinetic energy of ocean current flow, which can be harnessed by hydrokinetic turbine (HKT). HKT has similar engineering operation mechanism like wind turbine, which convert the kinetic energy to mechanical and eventually electrical energy. HKT has proven the potential to be one of the sustainable alternatives to traditional large-scale hydropower such as dam. HKT installation, unlike dams and barrages, is cheaper and more environmental friendly. However, HKT have installed only to western countries, or particularly the industrialized regions. Nonetheless, the growing interest in this technology has prompted research institutes in several other nations, like Malaysia, to undertake decision analysis studies and anticipate new deployment sites for HKT [7,8].

The Exclusive Economic Zone (EEZ) of Malaysia covers an area of 334,671 km^2, along with a coastline of 4,675 km. On top of this, the country also has more than 200 rivers, in which 150 of which are located in the Peninsular Malaysia and the remaining in the East Malaysian states of Sabah and Sarawak. Considering these geographical features, Malaysia has an abundance of ocean energy sources. Furthermore, Malaysia government has announced the National Energy Policy 2022 – 2040, which the RE generation shall increase 20% by 2050. To achieve this goal, it is necessary to make consistent progress in identifying potential long-term solutions [9]. This research aimed to conduct a site selection analysis to identify suitable location for the deployment of MHKT. The methodology proposed in this study can be utilized to achieve a regional decision-making process for offshore current kinetic energy planning, as well as the study findings can also be used to build renewable energy source policies.

2 Methodology

The methodology for site selection analysis to identify suitable location for the deployment of HKT is explained herein. Firstly, ocean current resources analysis was performed by desktop study. The desktop study was conducted by collecting and compiling data from public domain resources. The data collection mainly focuses on published data by government departments and agencies e.g., Ministry of Energy, Science, Technology, Environment, Climate Change (MESTECC); Defense Ministry; Malaysia Marine Department; National Hydrographic Centre; and Centre for Coastal and Marine Department (CMER). In this study, the data collection is limited to ocean current velocity, flow direction, depth of velocity measurement. The data is processed by statistical analysis to obtain the maximum current speed, area distribution and other information. From the analysis, the ocean current performance is estimated and visualized. Finally, the potential site within Peninsular Malaysia is selected by using Google Earth Pro with the assistance of Microsoft Excel.

Literature has been reported that HKT required a minimum flow of 2 m/s to initiate the turbine rotation. In parallel to this paper, a design optimization for MHKT configuration is being conducted. This optimized HKT is targeted to be deploy within the Malaysia that the average current flow is recorded 1 m/s. To support the study, the first stage of selection is selecting sites with ocean current velocity greater than 1 m/s. The next stage of filtering includes the ship routes, pipeline, and underground cable, as well as territorial waters and area. Based on the second stage screening, the HKT farm analysis based on the micro-sitting method was taken place. Herein the number of turbines, their exact locations, and configuration were identified. The flow chart in Fig. 1 illustrated the methodology of the study as described.

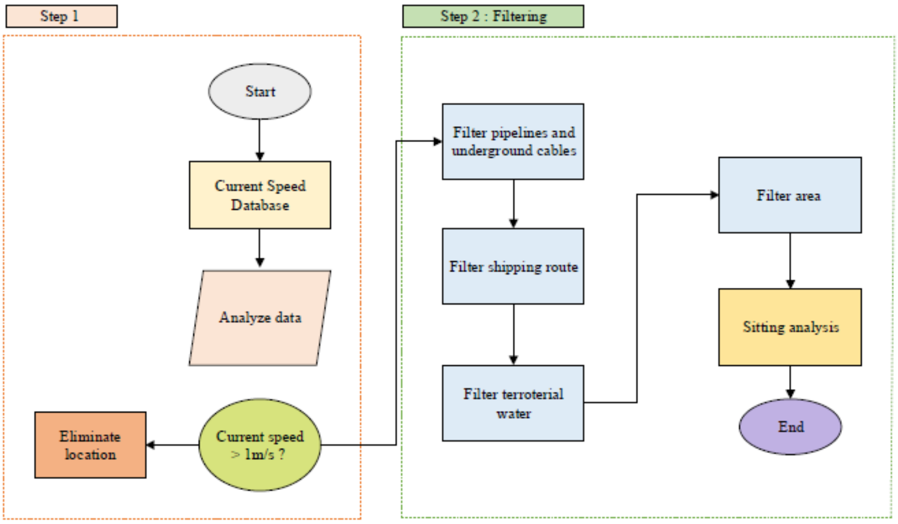

Fig. 1 Flow chart of the research methodology.

3 Results and discussion

3.1 Primary screening

Based on the data collected the ocean current velocity for the locations are tabulated in Fig. 2. 11 locations are having ocean current velocity between 0.5 m/s – 1 m/s and 2 locations below 0.5 m/s. Based on the screening, 6 locations that meet the requirement of the base case for ocean current velocity of 1.0 m/s, as illustrated in Fig. 3. As a summary, more than 61% of the locations across strait of Malacca had maximum current speed exceeding 0.5 m/s but less than 1 m/s.

3.2 Secondary screening

During the secondary screening, one of the key factors under consideration is the assessment of shipping routes. The Strait of Malacca experiences high vessel traffic density, rendering it a bustling region with a notable risk of accidents. Navigation safety is compromised as trade and vessel traffic through the chokepoint increase. Therefore, conducting a comprehensive study is essential before finalizing the location for deploying the HKT. The shipping routes for these six locations were sourced from the Marine Traffic Application. Fig. 4 to Fig. 6 illustrated the condition of the shipping routes near these regions.

The shipping route near Tanjung Pelepas is found to be very close to proposed coastal regions. It can be observed from Fig. 4, that ships are docking near the seashore in Tanjung Pelepas area. Next is Pusat Latihan Rekrut (Pularek), Pengerang area. As shown in Fig. 5, the shipping routes are thus far from each other and are not too congested. It can be reported that the area has not become a major concern for the placement of the HKT in the Pularek area. This makes the location partially suitable for the placement of HKT. Next, Pulau Pintu Gedong, as illustrated in Fig. 6, is also a low volume shipping routes region. This is mainly due to the narrow bay in the region. On top of that, the presence of neighboring ships docking is not quite affected by the area of the deployment of hydrokinetic turbine. However, the route near Belungkor is reported with a heavy maritime traffic due to the presence of oil tankers. Hence, it is categorized as not suitable for HKT deployment. Similarly, Southeast Point is also experiencing heavy maritime traffic due to the presence of cargo ships, tug and fishing activities.

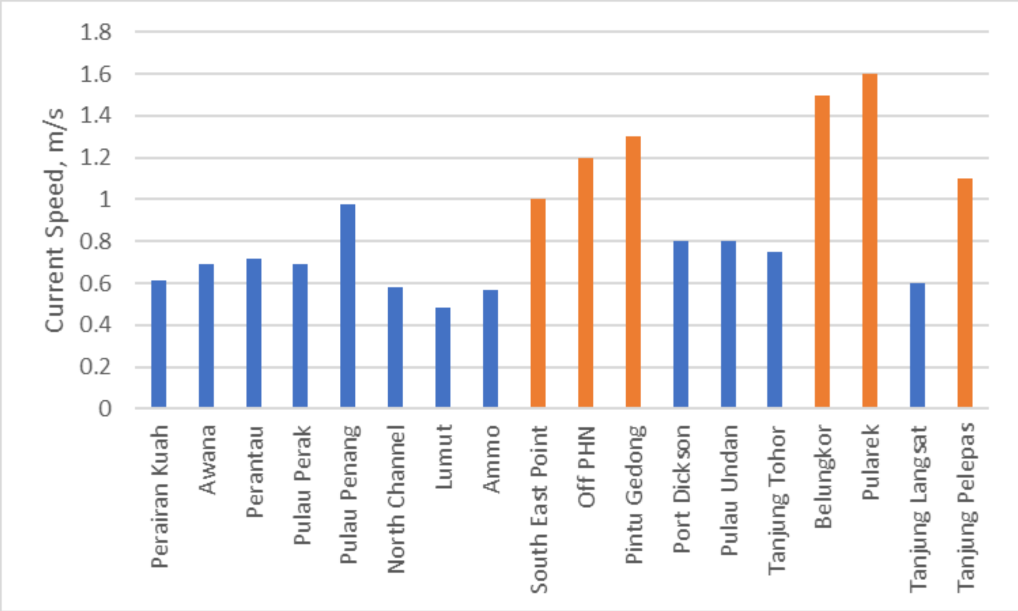

Fig. 2 Current speed for potential locations in Malaysia for MHKT deployment.

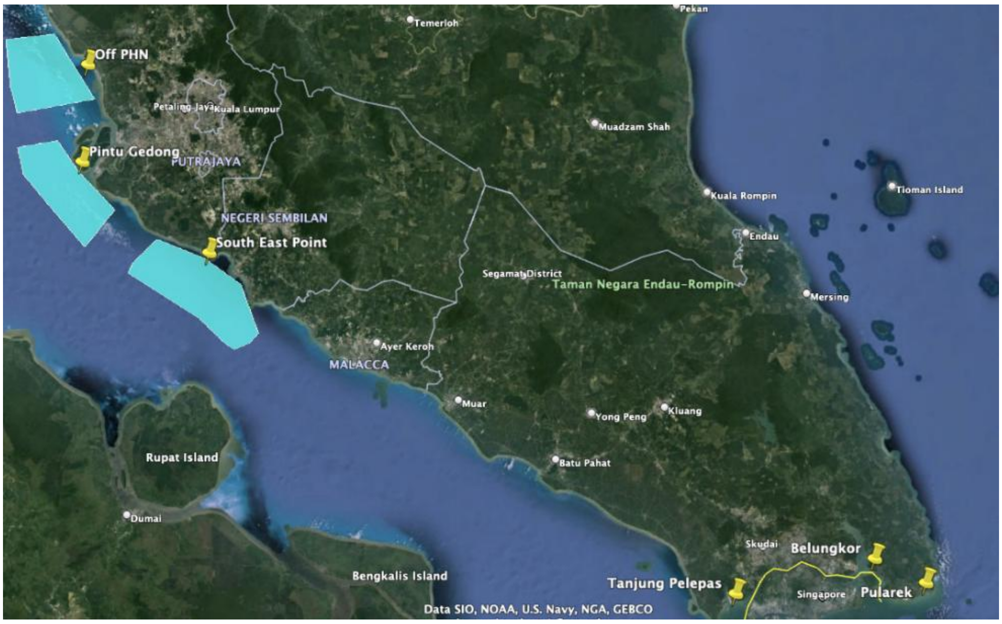

Fig. 3 Suitable installation locations for MHKT system based on current speed.

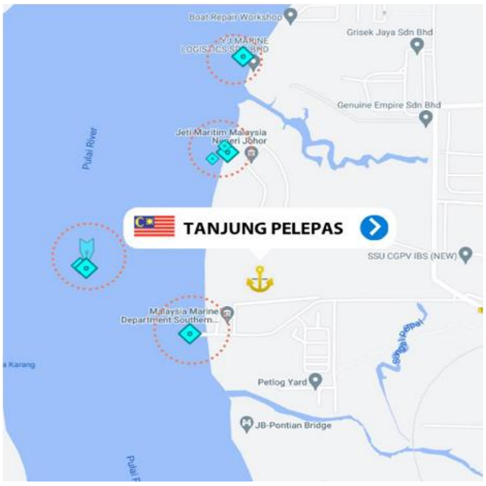

Fig. 4 Shipping route near Tanjung Pelepas.

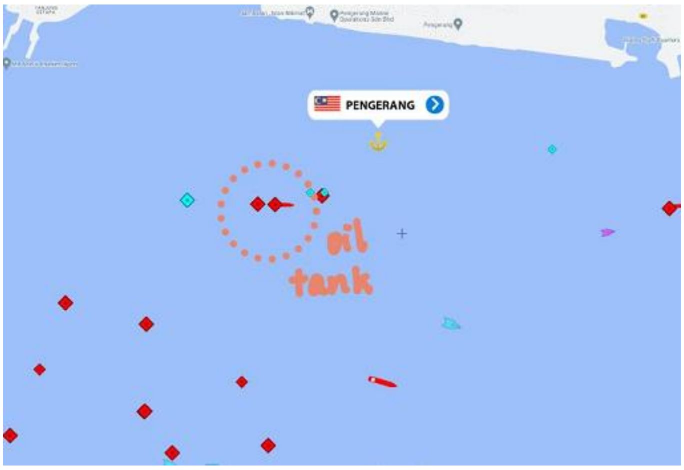

Fig. 5 Shipping route near Pularek, Pengerang, Johor.

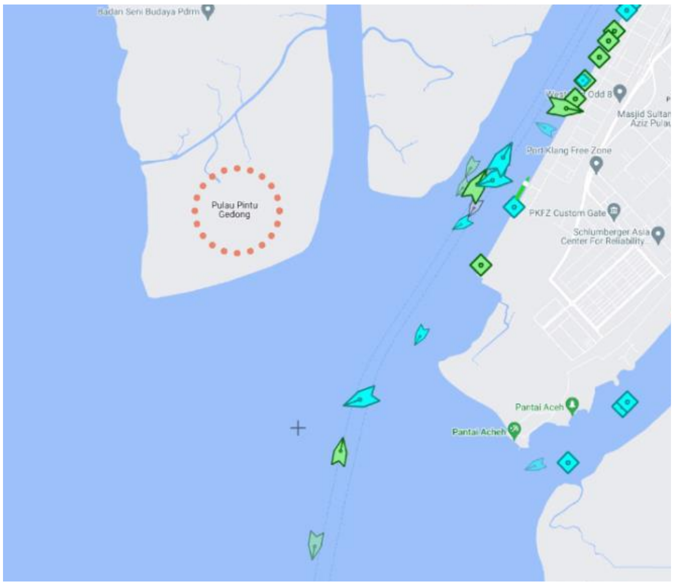

Fig. 6 Shipping route near Pulau Pintu Gedong, Klang.

Following that, this paper is investigating the pipelines and underwater or underground cables, as illustrated in Fig. 7. Pipelines and cables must be protected from potential damage resulting from the deployment of HKT in both the short and long term. Mariners must refrain from anchoring, dredging, or trawling within 500 meters of submarine cables and natural gas pipelines, as it is both prohibited and hazardous. The majority of natural gas and petroleum pipelines in Malaysia traverse the deep sea, with relatively few located along the coastline. Based on our observations from the maps, there are generally no pipelines or underground cables near the proposed coastal regions, except in the Tanjung Pelepas region, Johor, and the Belungkor region, Johor.

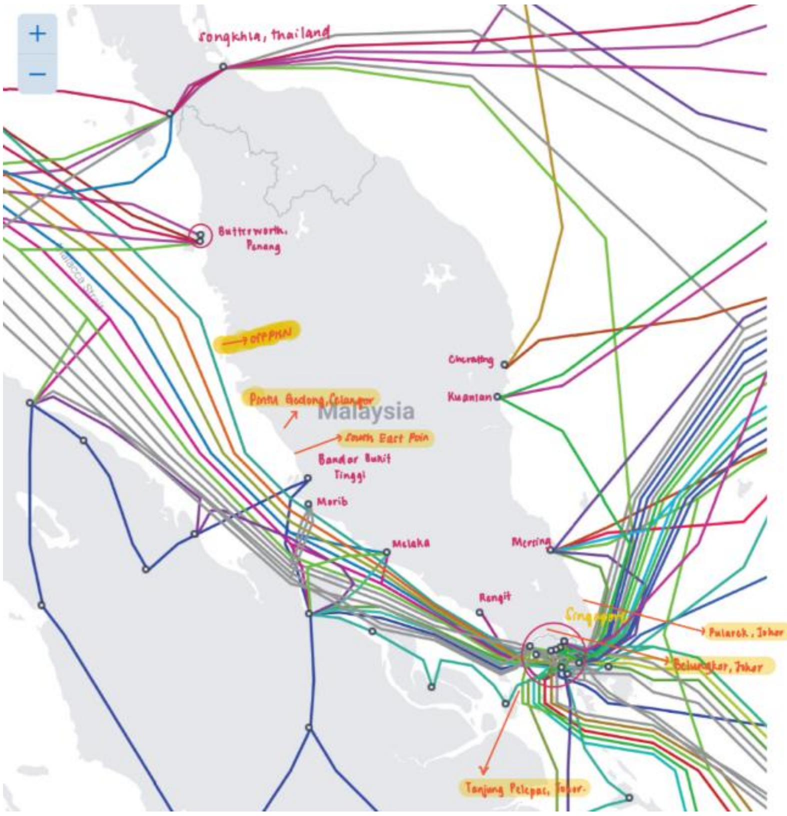

Fig. 7 Labelled regions of submarine cable.

Next, an analysis is conducted to investigate the territorial waters. In general, the selected regions do not have territorial disputes, as they possess extensive territorial waters shared with neighboring countries. Therefore, in terms of territorial waters, all the proposed regions can be considered for the deployment of MHKT. Territorial waters were analyzed by obtaining the coordinates of each region from the Marine Regions website during desk study. The boundary regions were then plotted in Google Earth Pro and the size of the regions is observed for each region. The detailed analysis of these six regions revealed that Belungkor and Tanjung Pelepas offer a relatively smaller area for MHKT installation due to their proximity to neighboring country, Singapore. Nevertheless, Belungkor and Tanjung Pelepas are deemed suitable for hydrokinetic turbine installation, although the available area is limited, resulting in lower power production.

3.3 Sitting analysis for selected regions

Table 1 summarizes the analysis of the hybrid site selection for the deployment of HKT in Malaysia. The selected areas were then undergoing the sitting analysis. In the sitting analysis, the optimized design HKT with a diameter of 1 m is considered. The distances between the turbines and the available surface area are set to be 5 m^2 apart from each turbine. Based on the sitting arrangement, it can be observed that the greatest number of turbines can be deployed at Southeast Point, Johor with a total number of 109 turbines can be placed. The region has the most areas that are not interfered by the territorial water, which allows it to have the highest volume of installation of hydrokinetic turbine. However, the shipping route analyzed before has raised a problem, making this location not suitable for HKT installations. Following that, the total number of turbines for Off PHN in Sepang is found fitting 82 unit of HKT, which can generate a maximum power of 26.404 kW. However, similar with Southeast Point, Off PHN is also suitable as shipping route will caused further issues after installation. Pintu Gedong, Selangor is found to be suitable for the installation of the turbine. t passes all the site criteria and produces a maximum amount of 27.840kW of power with 80 units of MHKT. Fig 8 to Fig. 10 illustrates the turbine sitting analysis for Tanjung Pelepas, Belungkor and Pularek, respectively.

Table 1 Hybrid-criteria site selection outcome for MHKT deployment in Malaysia.

Potential site	Current speed (m/s)	Territorial waters	Shipping routes	Pipelines	Area (m^2)	Spacing between rows (m)	No. Of turbine	Total power output, p
Southeast point	1.0	√	X	√	10840	25	109	268w x 109 = 29212w
Off PHN	1.2	√	P	√	8190	25	82	322w x 82 = 26404w
Pintu Gedong	1.3	√	√	√	7935	25	80	348w x 80 = 27840w
Belungkor	1.5	X	P	X	477	25	5	402w x 5 = 2010w
Pularek	1.6	P	P	P	300	25	3	429w x 3 = 1287w
Tanjung Pelepas	1.1	P	P	X	295	25	2	294w x 2 = 588w

Fig. 8 The sitting analysis outcome for MHKT deployment at Tanjung Pelepas.

Fig. 9 The sitting analysis outcome for MHKT deployment at Belungkor.

Fig. 10 The sitting analysis outcome for MHKT deployment at Pularek, Pengerang.

4 Conclusions

This paper explores offshore current site locations in Malaysia through an assessment of the energy potential in 11 regions. First, the suitability of regions with an average current speed of over 1 m/s are assessed. Then, a site selection method is adopted to identify the most suitable locations for HKT installation. Finally, a statistical analysis of current speeds for the locations meeting the site selection criteria using Google Earth Pro. This study also determines the micro-siting configuration of current turbines by taking into account territorial waters and the selected regions' areas. Although Malaysia is surrounded by sea, only 6 out of the 11 proposed regions, including Southeast Point, Off PHN, Pintu Gedong, Belungkor, Pularek, and Tanjung Pelepas, are considerably suitable for offshore hydrokinetic turbine installation, as the mean current speeds at these selected sites exceed 1 m/s.

Declaration of Conflict of Interest

The authors declared that there is no conflict of interest with any other party on the publication of the current work.

ORCID

Nauman Riyaz Maldar https://orcid.org/0000-0001-5788-7739
Fatin Khalida Abd Khadir https://orcid.org/0000-0001-8323-1928

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