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INVESTIGATION OF THE POTENTIAL HARNESSING TIDAL ENERGY IN MALAYSIA

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ABSTRACT

Tidal energy has been recognized as one of the promising technologies for future electricity generation for its predictability as compared to solar and wind energy, yet traditionally it has been renowned as a technology that's relatively needed detail analysis for availability sites identification and cost. This paper presents an analysis of potential harnessing tidal energy for a country that has low tidal ranges like Malaysia. Tides Table Malaysia 2014 published by National Hydrographic Centre Malaysia has been used in identifying potential sites for harnessing tidal energy in Malaysia. The data are tabulated in monthly and the most potential site for harness tidal energy is presented in hourly versus the height of water for every each of coastal area in Malaysia for better comparison with the results shown.

Keywords: renewable energy, tidal energy.

INTRODUCTION

In the past few decades, there has been a constant global increase in the demand for energy. According to the projections of the International Energy Agency (IEA) [1], the global energy demand has risen by about 40% since 1990, and a 53% increase is expected by 2030. Due to the high demand of electricity throughout the country, various energy sources needed to meet its energy consumption. Therefore, the renewable energy sources were verified to accommodate the demand of electricity.

The majority of the global energy demand is still highly depends on fossil fuels. Therefore, it will contributed to the emission of greenhouse gases, including carbon dioxide, and it is one of the causes of global warming to the world [2]. Consequently, fossil fuels comprise 93% of Malaysia's electricity generation and account for 36% of the country's 2010 Greenhouse Gas (GHG) emissions [3]. Not only that, the price of fossil fuels is also increasing day by day and this will lead to declining state revenues.

One of renewable energy that contributed to the energy sources is ocean energy. Lee *et al.* and Seng *et al.* [4] agree that the potential and commercial viability of harnessing ocean energy in Malaysia were not study thoroughly. Therefore, this paper provides a general view on the potential of harnessing tidal energy in Malaysia. Almost 75% from the earth is water and it is conceivable that tides based on this pollution free source of energy would be very cost-effective for generating electricity.

TIDAL ENERGY

Tidal energy [5] is derived from the gravitational force of attraction that operated between a molecule on the earth and the moon and between a molecule of the earth and the sun. Tidal energy exploits the natural rise and fall of coastal tidal waters caused mainly due to interaction of gravitational fields of the sun and the moon [6]. The effect of the moon and the sun is shown in Figure-1. This is because of the revolution of the earth; the lumps of tides are constantly in front of the position on earth directly under the moon. The gravitational compel between this allotment of water and moon creates a torque that decelerates the pivot of earth. Then again, this power serves to quicken the orbital development of moon around earth. As a result, without other impedance, the rotational time of earth will at last be equivalent to the orbital time of moon.

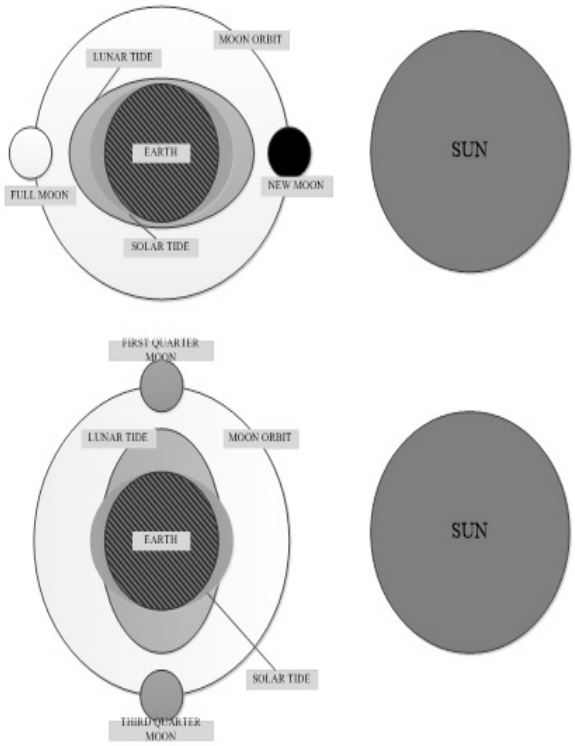


Figure-1. The effect of the moon and the sun on tidal range.

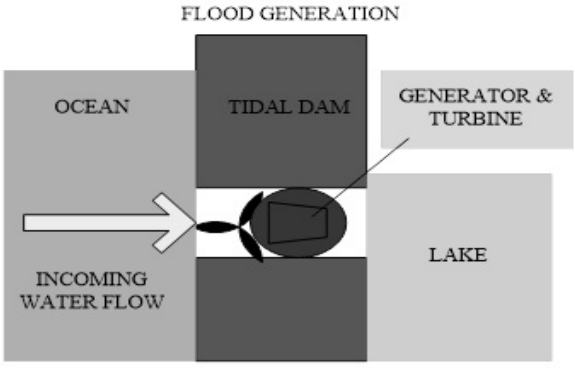
Tidal energy is the one of renewable energy sources and it is defined as a clean energy. The tidal energy also is more predictability other than other renewable energy sources. This is because it is able to produce energy twice a day for every day of the year [7]. Furthermore, tidal energy system also has a potential to generate large amounts of electricity. The usage of tidal vitality, which will inexorably lessen the tidal flows, exploits the rakish element vitality of earth in the comparative way. Notwithstanding, the procedure of tidal quickening is to a great degree moderate, and the phenomena of tides can be required to last until the vaporization of the sea on earth billions of years later [6]. Subsequently, the tidal energy can be delegated renewable energy. Ocean energy has been classified into three types consist of tidal energy, wave energy, and thermal energy [8-10].

TIDAL POWER SCHEME

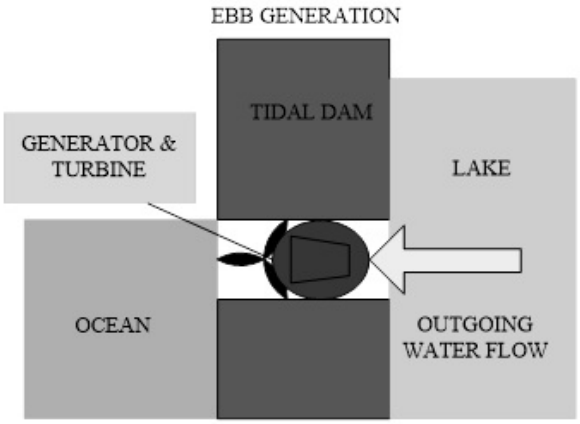
The phrase of a tidal power scheme is used to refer to a particular method of harnessing energy from the tides. By and large, there are four strategies or methodology that was regularly utilized as a part of the request to harnessing the energy and create power from the ocean sources [7], which are tidal flood, tidal stream, tidal lagoon and dynamic tidal power.

Tidal barrage

Rourke *et al.* [11] and Araquistain [12] has defined that the barrage system is a dam and it work by trapping water at high tides and then releasing it through defined channels that carry it through a turbine. A tidal barrage is usually made of reinforced concrete and spans an estuary, bay, river, or other ocean inlet. The hindrance contains doors called floodgates that can open and close. At low tides, the doors open and permit the tides to stream into the waterway as ordinary as the tides climbs. At the point when high tides are arrived at, the doors are shut and keep the water from withdrawing over to the sea as it ordinarily would. Rather than the water is constrained through particular channels that direct it through turbines to create power.



(a)



(b)

Figure-2. Tidal barrage method to harnessing power: (a) Flood generation type and (b) Ebb generation type.

Figure-2 shows the flow tidal barrage system to harness the energy from the ocean. A tidal barrage usually consists four main components that are embankment, turbine, sluice gate, and lock. The energy accessible from a barrage is reliant on the volume of water [12]. The potential energy contained in a volume of water is:

$$E = \frac{1}{2} A \rho h^2 \quad (1)$$

where:

h is the vertical tidal range,
A is the horizontal area of the barrage basin,
ρ is the density of water = 1025 kg per cubic meter (seawater varies between 1021 and 1030 kg per cubic meter),
g is the acceleration due to the Earth's gravity = 9.81 meters per second squared.

The factor half is due to the fact, that as the basin flow empty through the turbines, the hydraulic head over the dam reduces. The maximum head is only available at the moment of low water, assuming the high water level is still present in the basin.

Table-1. Major world tidal barrage sites according to the output power of the year [7].

Site (Place)	Year	Output Power Per Year
La Rance, France	1961-1967	3060GWh
Annapolis, United State	1980-1984	50GWh
Kislaya Guba, Russia	1968	22GWh
Jang Xia Greek, China	1961-1967	650GWh
Sihwa Lake, Korea	2010	552.7GWh

Tidal stream

Tidal stream [13] is the one of tidal that work much like wind turbines, but they use water rather than wind. As the tides flows in and out, it pushes the rotors of a turbine. Tidal stream turbines are appliances that can extract the kinetic energy from the tidal stream and convert the energy into electric power. The Figure-3 shows the types of tidal stream in the system. This method no need dam to harnessing energy such as tidal barrage.

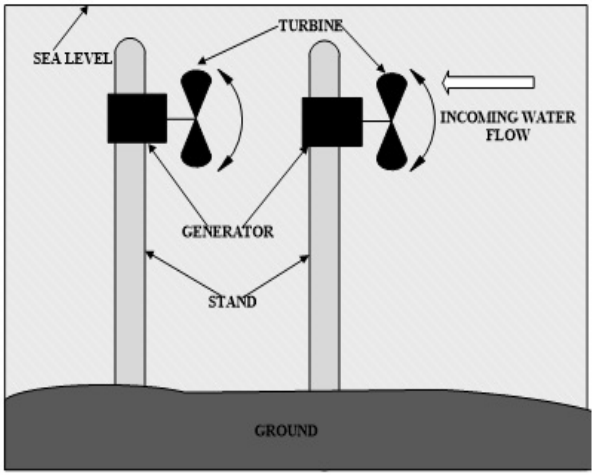


Figure-3. Tidal stream method to harnessing power.

Tidal energy converters can have fluctuating modes of working and therefore varying power output. If the power coefficient of the device " CP" is known, the mathematical statement beneath can be utilized to focus the output power for the tidal stream system[14]. The energy available from these kinetic systems can be expressed as:

$$P = \frac{\rho A V^3}{2} Cp \quad (2)$$

where:

CP is the turbine power coefficient,
P is the power generated (in watts),
ρ is the density of the water (seawater is 1025 kg/m³),
A is the sweep area of the turbine (in m²),
V is the velocity of the flow.

In respect to an open turbine in free stream, ducted turbines are equipped for as much as 3 to 4 times the force of the same turbine rotor in open stream.

Tidal lagoon

The tidal lagoon scheme was been describe in [15] is very much alike to the tidal barrage method for utilizing tides to produce power, except the damn is replaced by a 360 degree enclosure that creates a pool. Indeed, the main genuine distinction between the two is that the tidal lagoon does not close off a whole estuary, but rather makes utilization of just a piece of it.

The idea is moderately straightforward and substantial encased structure is implicit the estuary or anyplace that tidal powers are satisfactory [16]. As high tides come in, the lagoon is filled. At low tides, the lagoon is allowed to empty through a turbine to generate power. The diagrams below show the differences and similarities between a tidal barrage and a tidal lagoon. The Figure-4 shows the tidal lagoon method for harnessing power, but this method still under study. The real application does not exist yet.

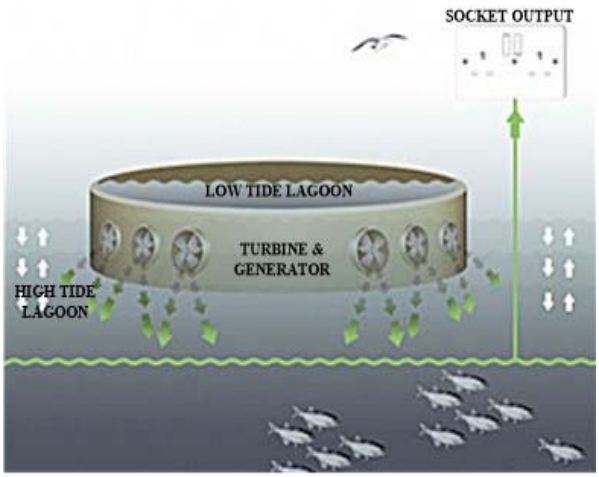


Figure-4. Tidal lagoon method to harnessing power still in under study [16].

Dynamic tidal power

Dynamic tidal power is strategically uses long walls the jut out perpendicular to the shore. As the tides pass the wall, it is trapped on one side or the other, creating a head. This high water is only allowed to flow past the wall by flowing through defining paths that carry it past generators. The system only works if the barrage is at least 30 kilometers long and only if the turbines work in both directions. So far, the system is 100% theory and has never been put to the test. The science and math are sound, but without experiment there is no way to be certain the scheme will really work.

Table-2. Advantages and disadvantages types of tidal power scheme.

Scheme	Advantages	Disadvantages
Tidal Barrage	➢ High power generation ➢ Proven design ➢ Long life span ➢ Low maintenance ➢ Can provide flood control	➢ Requires high tidal flows ➢ Most environmental impact ➢ Expensive to build
Tidal Lagoon	➢ High power generation ➢ Proven design ➢ Less ecological impact than barrage ➢ Low maintenance	➢ Requires high tidal flows ➢ Expensive ➢ Generates less power than barrages ➢ No assistance in flood control
Tidal Stream Generator	➢ Moderate power generation ➢ Modular ➢ Low cost ➢ Less environmental impact	➢ Difficult maintenance ➢ Corrosion more problematic ➢ Requires flow of 2.0 m/s or greater
Dynamic Tidal Power	➢ Huge power generation capability ➢ A single installation	➢ Unproven, untested design ➢ Extremely expensive ➢ Massive engineering feat ➢ Limited available sites

AVAILABLE TIDES IN MALAYSIA

The tides are a periodic phenomenon. The periodic nature of the reaction varies depending on the interaction between the gravitational effects of the moon and sun, each movement of the moon and the sun, and other unique geography. There are three main types of tides phenomenon that are consisted of diurnal, semi-diurnal, and mixed tides as shown in Figure-5.

Diurnal Tides are the one sort of tides has a period relates to a full transformation of the moon with respect to the earth (24 hour 50 minutes) [17]. Such a tides has one high tides every day. Semi-diurnal tides are liable to varieties emerging from the hub of revolution of the earth being slanted to the planes of the circle of the moon around the earth and the earth around the sun [11].

Semi-diurnal Tides was describe in [18] as the one kind of tides has a period that matches the key time of the moon (12 hour 25 minutes). Any sea with such tides will have two high tides every day. Gorji et. al [19] was describe that the amplitude of the tides shifts through the lunar month, with tidal extent being most prominent at full moon or new moon (spring tides) when the moon, earth, and sun are adjusted. Reverberation phenomena in connection to the 12 hours 25 minute period portray tidal reach.

Mixed tides are the combination between the characteristics of semi-diurnal and diurnal tides. They might likewise show month to month and bimonthly variety. When the semi-diurnal is dominant in mixed tides, the highest tidal current will occur at spring tides and the lowest tidal current will occur at the neap tides. When the diurnal is dominant in mixes tides, the highest current will occur at the extreme declination of the moon and the lowest current will occur at the zero declination [4].

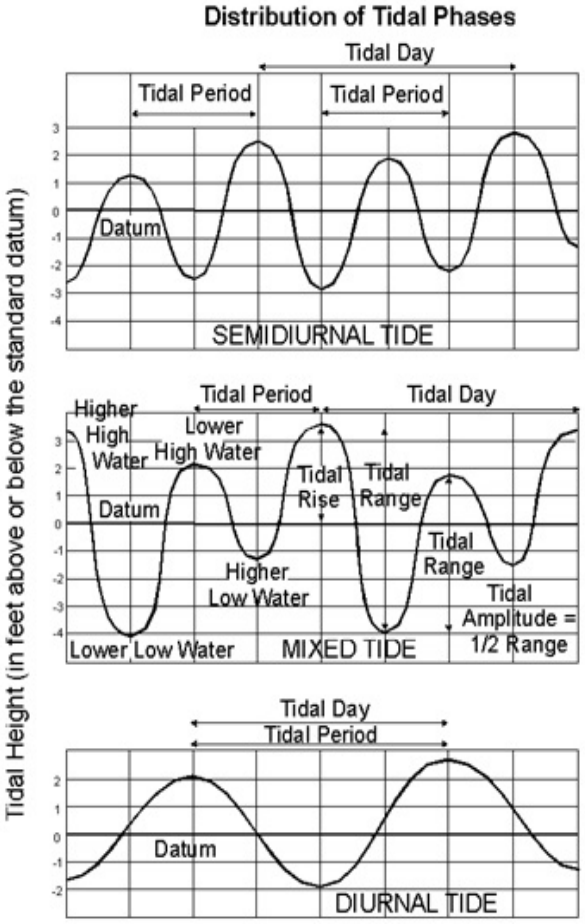


Figure-5. Types of tides [12]: (a) Semidiurnal tides; (b) Mixed tides; (c) Diurnal tides.

The Figure-6 shows that the area of tides that available in Malaysia consist of semidiurnal, mixed tides with dominant semidiurnal and mixed tides with dominant diurnal. There is no diurnal tides in Malaysia has been support by [4][20]. North and West of the Peninsula have been spearheaded by the semidiurnal tides. Among these are Kedah, Perak, Penang and Selangor. While the area South and East of the Peninsula have been spearheaded by mixed tides with dominant semidiurnal. Among these are Johor, Pahang, Kelantan, and one-third of the state Terengganu, Sabah and Sarawak. Rest area for Malaysia, spearheaded by mixed tides with dominant diurnal.

Figure-1. Types of tides available in Malaysia[4].

ANALYSIS OF TIDES DATA IN MALAYSIA

This analysis was conducted according to the tides table Malaysia 2014. This Tides Table has been prepared by the National Hydrographic Centre. The tides event is divided into two parts, spring tides and neap tides. Spring tides are semi-diurnal tides of increased range, which occur approximately twice a month at the time when the moon is either new or full. While, the neap tides are semi-diurnal tides of small range which occur approximately twice a month near the time of the first and the last lunar quarters.

The symbol for the position of the moon when the spring tides and neap tides were occurring has been shown in Figure-7. It includes the prediction of times and heights and the tidal streams data. For this analysis are required to use height in meters, and time in hour to determine the most suitable place for tidal energy in Malaysia.

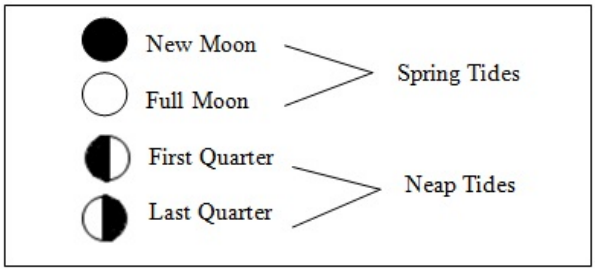


Figure-7. Symbol for the position of the moon.

Error! Reference source not found. shows the graph of tides in Northern Peninsular Malaysia that encompasses the states of Kedah, Perak, and Penang that obtain from Tides Tables Malaysia 2014. The height range for the three regions is between 0.2 meters to 3.1 meters. From this analysis in the northern piece of Peninsular Malaysia, it can prove that the theory of tidal occasions happen twice a day. Based on Figure-6, the tides phenomenon of Figure-9 is semidiurnal tides. The conclusion that can be made based on the graph above; Perak has the highest tides range compared to Kedah and Penang.

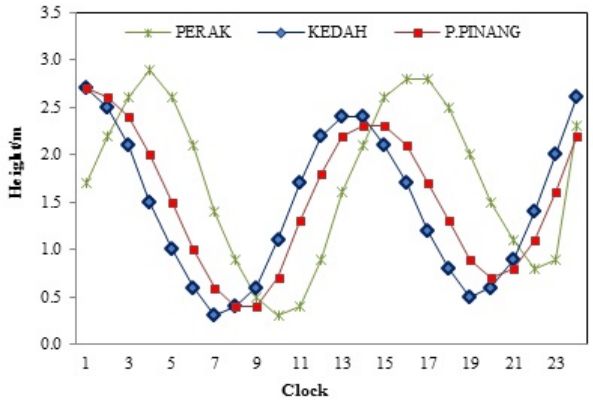


Figure-8. Reading of tides at northern peninsular Malaysia including Perak, Kedah, and Pulau Pinang.

The reading of tides at Southern Peninsular Malaysia focus in Johor has been illustrated in the graph in Figure-9. This reading has been obtained from Tides Tables Malaysia 2014. The height range for this state is between 0.3 meters to 3.6 meters. From this analysis in the south Peninsular Malaysia, the sequence of tides is not clearly showing the tidal occasions happen twice a day because it depends on the motion reflects the changing positions of the Moon and Sun relative to the Earth[21]. According to Figure-6, the phenomenon of the tides in the Figure-10 is a mixed diurnal tide.

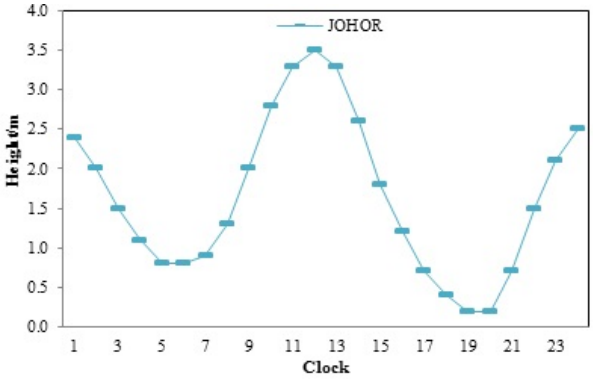


Figure-9. Reading of tides at southern peninsular Malaysia focus in Johor.

Figure-10 interpreted the graph of tides at West Coast Peninsular Malaysia that is Selangor. This reading has been obtained from Tides Tables Malaysia 2014 and the location is Pelabuhan Klang. The height range for this region is between 0.4 meters to 5.3 meters. From the analysis in region of West Coast Peninsular Malaysia, it can prove that the theory of tidal occasions happens twice a day and it is a semidiurnal tide phenomenon.

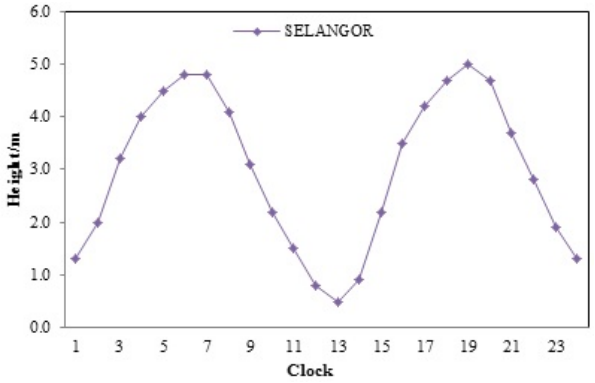


Figure-10. Reading of tides at west coast peninsular Malaysia focus in Pelabuhan Klang, Selangor.

The Figure-11 portrays the graph of tides at East Coast Peninsular Malaysia that covering the states of Kelantan, Pahang, and Terengganu that obtain from Tides Tables Malaysia 2014. The height range for this session is between 0.6 meters to 3.7 meters From the analysis in East Coast Peninsular Malaysia, the sequences of tides not clearly shows the tidal occasions happen twice a day because it depend on the motion reflects the changing positions of the Moon and Sun relative to the Earth[21]. Based on Figure-6, the tides phenomenon of Figure-12 is mixed tides diurnal. As a conclusion, Pahang have the most high tides range compared to Kelantan and Terengganu.

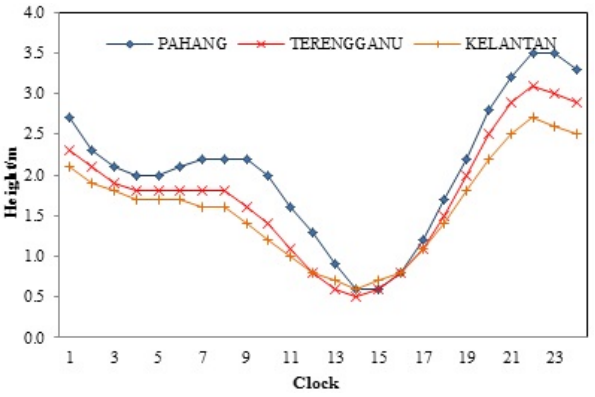


Figure-2. Reading of tides at east coast peninsular Malaysia including Pahang, Kelantan, Terengganu.

From Figure-12, it shows the graph of tides at East Malaysia that including the states of Sabah and Sarawak that obtain from Tides Tables Malaysia 2014. Sarawak consists of three places for this analysis that are Mukah, Miri, and Bintulu. Whereas, in the state of Sabah where were Kota Kinabalu. The height range for this session is between 0.2 meters to 2.7 meters. Based on the analysis that has been carried out in the region of East Malaysia, the tide does not clearly show the times of the tides occur twice a day because it depend on [21][22] the motion reflects the changing positions of the Moon and Sun relative to the Earth. Based on Figure-6, the tides phenomenon of Figure-13 is mixed tides. The conclusion can be made based on the graph above, Mukah are the most high tides range compared Miri, Bintulu and Kota Kinabalu.

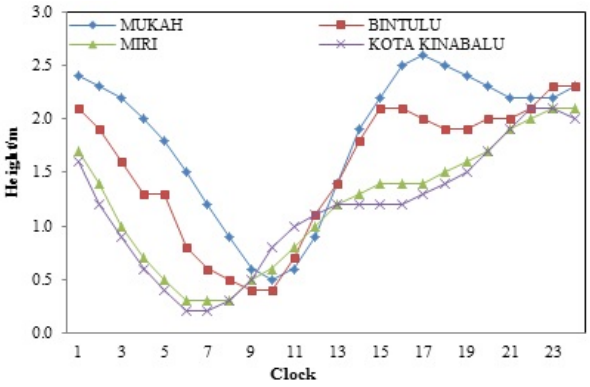


Figure-12. Reading of tides at east Malaysia including.

CONCLUSIONS

The height of the water level for tidal energy will always be influenced by gravity and axial position of the moon and the sun. Based on the analysis carried out in the coastal areas of Malaysia, the tides differ during each month and tide locations must be considered. Tidal has more advantage than solar and wind energy because it is a more predictable nature as it occur twice in a day with the high availability and environmental benefits of the power. The purpose of this paper is to analyze the state of the tides in the coastal area of Malaysia and identify potential locations to harness energy. Depend on the data analysis that has been done, Selangor is a very high potential location of harnessing tidal energy compared to other locations.

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