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Design of Operating Routes of Wave Energy Powered Electric Cargo Ships in Red Sea

Mohammed Osman Elsadig [1]*+, Mahmoud Hassan Onsa

[1]University of Khartoum, Faculty of Engineering, PO Box: 321, zip code 11115, Khartoum, Sudan
*Corresponding Author and +Speaker: mohammedosmanmog@hotmail.com

Abstract- A theoretical design assessment performed here to evaluate the idea of utilizing wave energy in the Red sea to power electric-cargo ships, in the route between Port Sudan and Jeddah Islamic port. The calculated mean wave power in 2018 was (1.4 MW), five wave power stations was determined in the field depending on the travelling distance of ships batteries with depth of discharge 90% (75.01) km. The assessment used nine ships according to weekly-generated energy and suggested trips schedule (two trips per week). The battery-replacing technique used to exchange ships empty batteries with charged one to save the trip time, and a bunker fuel ship was assigned for batteries transporting between stations according to demand. The electric generation was individual without interconnecting cable between stations due to massive loss of that (16 MW). The calculated annual transported dry goods using this clean energy was 1.72 million ton. A brief economic analysis performed and concluded to start the project after 2020 with estimated annual profits 4.25 million dollar. The design found that it is promising to depend on wave power for supplying electric ships with energy, especially with the development in energy generation and storage technologies.

Keywords-*Renewable energy, wave energy, electric ship, red sea, lithium battery, Pelamis*

1 Introduction

As the modern technologies progress and develop, the world depends more on the electric energy. That due to its feature as the most efficient type of energy can be convert to another energy forms.

In addition, the electric power has no emissions in the last use as a powering source, and can be fully clean when it generated from a clean energy resource. As a result of that many manufacturer in the transportation sector start to implement their modern innovations depending on the concept of manufacturing partially electric (hybrid) vehicles or totally electric, in order to fulfill the need of the new industrial era which, puts the environment and global emission decreasing as a major issue.

This assessment among many alternatives of clean energy resources selected the wave energy to perform this evaluation. That due to the maturity of wave-energy conversion technologies.

Moreover, the cargo shipping transporting sector chose by this study due to its significant contribution in global emissions as shown in Figure 1.

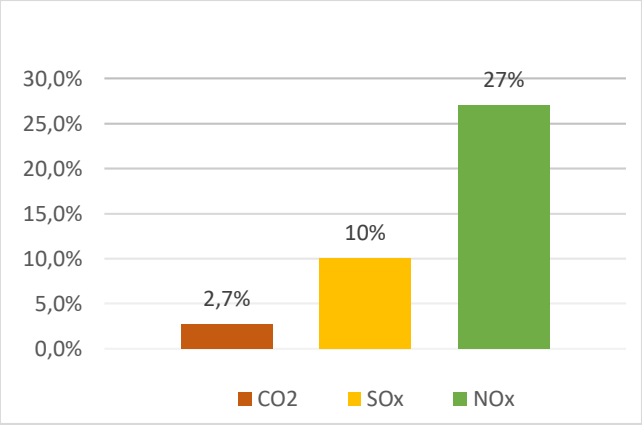


Figure 1. Shipping emissions global share percentage [1]

1.1 The objective of Assessment

This assessment aims to evaluate the idea of utilizing wave energy as a power resource for electric cargo ships. The natural matching between the need to decrease shipping emissions and the appearance of the first electric cargo ship with almost zero emissions [2], in addition to the availability of the wave energy resources and the tremendous development in wave energy conversion technologies made this idea reasonable.

2 Background about Wave energy

Wave energy is a form of ocean energy generated due to forces acting on ocean surface (wind, gravitational force of sun or moon, pressure of the atmosphere…etc.) [3]. Also it defined as a concentrated form of solar energy [4].

The utilization of the potential ocean wave energy has been recognized and established more than 200 years ago, when Monsieur Girard and his son invented the first patent of wave energy convertor (WEC) in 1799 [5].

The wave behavior can be represent in a simple shape by using the linear wave theory that developed by the English mathematician and astronomer George Airy (1801–1892) [6].

The general terminologies and shape of linear wave shown in Figure 2:

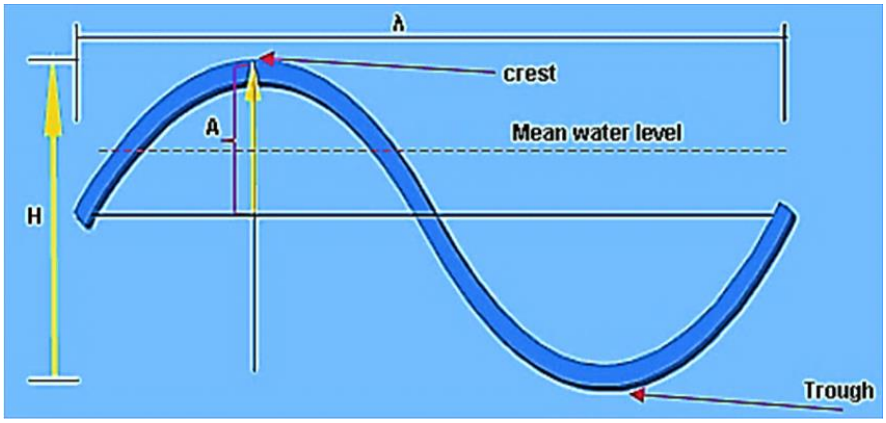


Figure 2. Linear wave

Where

A: the amplitude
H: height between crest and trough
λ: wavelength

The sinusoidal linear wave is compatible to describe the wave behavior in deep water, or when the wave height is smaller than wavelength [6]

In the realistic behavior of wave the wave height is always disturbance so, it becomes inaccurate to represent that behavior by the linear shape, regarding that the random wave shape is used.

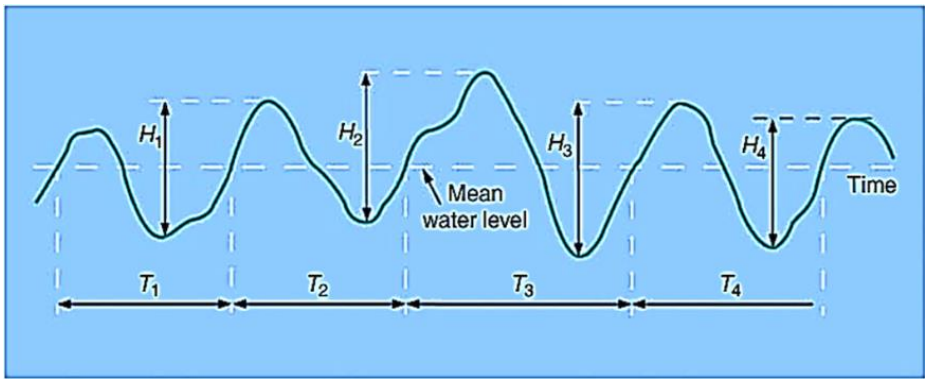


Figure 3. Random wave [6]

In this type of waves, the wave height calculated by taking the average height of the highest third of waves from the data in the probability distribution, that called the significant wave height and it represent with the wave period the most important wave power characteristics.

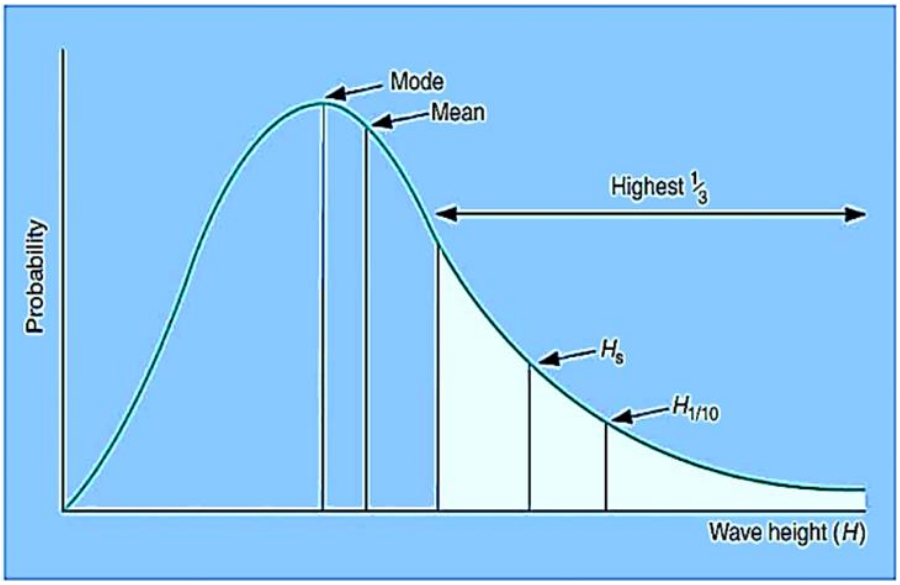


Figure 4. The probability distribution [6]

The wave power mathematical formula for linear wave:

$J = \rho g^2 T H^2 / 32\pi = 0.986\ T\ H^2$ kW/m **(1)** [6]

Where

T or T_e : the wave period (s)
J kW/m: the power per wave width or crest length.

The wave power mathematical formula for random wave:

$$J = \frac{\rho g 2}{64\Pi} H^{2}_{m0} Te \quad kW/m \qquad \textbf{(2)} [7]$$

H_{mo} is the significant wave height (m)

2.1 Global wave energy potential power estimation

In 1973, study done by Isaacs and Seymour estimated that "the global wave power potential to be of the order of 1-10 TW" [8].

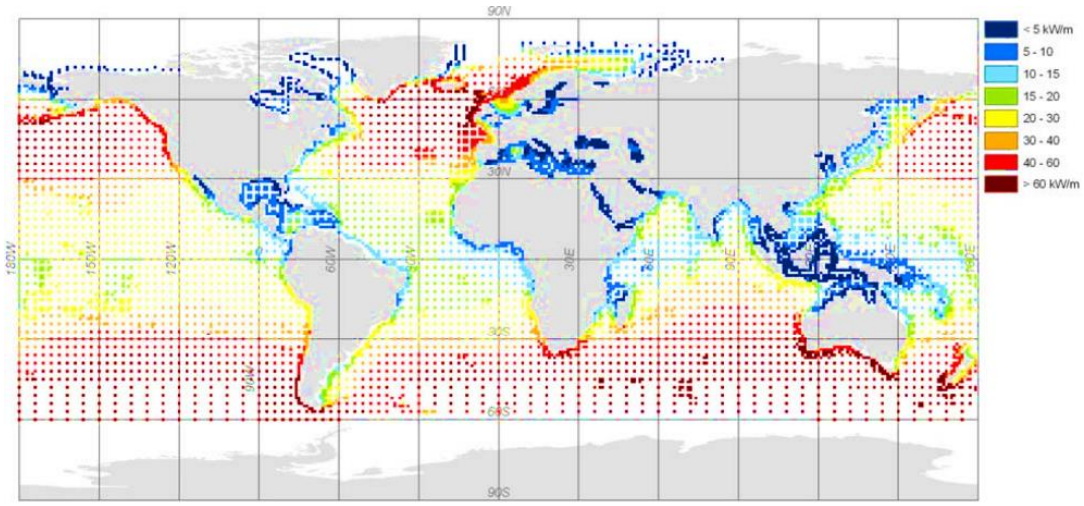


Figure 5. Annual global gross theoretical wave power for all World Waves grid

Points worldwide [7] [8]

3 The methodology and the suggested system components

The main system components are:

1. Wave energy resource (the field of assessment).
2. The electric cargo ship.
3. The wave energy stations.

3.1 The field of assessment

Among many alternatives, the red sea was the applied field for these reasons:

1. The availability of potential wave-energy assessment data.
2. It represent a relatively short trade path between the selected ports.

3. It has the feature of low chance of storms, and suitable temperature range for Li-ion batteries used in the suggested ships [9], so that the devices of stations and ships would have low maintenance rate and cost.
4. It represent very promising gate to connect Asia and Middle East with Africa.

The potential power in the field calculated depending on the results of research paper referenced in [10], done by (V.M. Aboobacker, et al) in King Abdul-Aziz University, Faculty of Marine Sciences. That paper assessed wave energy resources in the Red Sea, by numerical modelling for long period (1979 to 2010), using a third generation-ocean wave model, WAVEWATCH-III. The validity of the results tested through that paper by comparing the numerical results with the measured from a met-ocean data buoy (23020) located at 22.162° north 38.50° east, for the period (2008-2010). The error limits was between (5.9 % -9.5 %) in the significance height and period of wave [10], that error is negligible because the calculation used the averages.

The mean wave power per wave width from paper [10] shown in Figure 6:

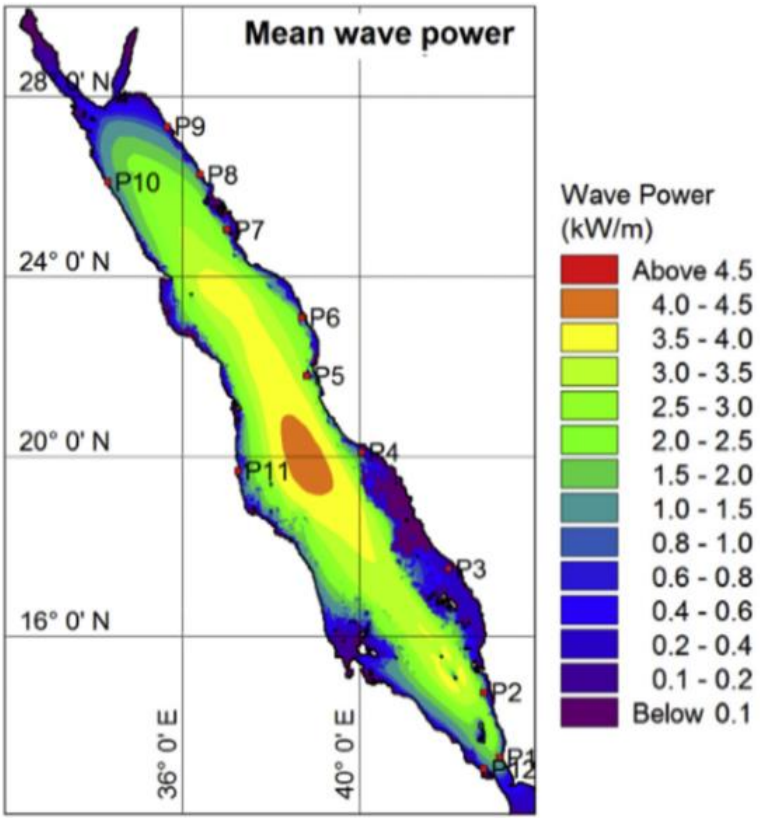


Figure 6. Red sea mean wave power [10]

3.2 The Chinese electric cargo ship

This assessment built its calculations depending on the specifications of the first full electric cargo ship shown in Figure 7, which appeared in November 2017 [11]. It designed by (Hangzhou Modern Ship Design & Research Co) in china [12].



Figure 7. The Chinese electric cargo ship[11]

Design details of the ship

Table 1 display the design specification of the first full electric cargo ship:

Table 1. The Chinese electric cargo ship specifications

Specification	**Magnitude**	**Source**
Travel speed	12.8 Km (6.9 Knot)	[2][11][12][13] [14]
Length	70.5	
Width	13.9	
Depth	4.5	
Draft design	3.3	
Cargo capacity	2000 ton	
Two electric propellers	160 kW	
lithium-ion batteries	2.4 MWh	
Lithium-ion battery weighing	26 ton	[14]
Distance per charge	80 Km	[2]
Charging time	2 hours	[13]

Because this ship works in river water [12], it need small modification in the outer body to satisfy the seawater shipping.

Assumptions used to build reasonable calculations:

- The electric cargo ship is compatible with seawater shipping, to accomplish that the assessment treated the electric ship as the bunker-fuel cargo ships in cost and construction. And regarding the cost, the electric ship construction cost estimated as

23,065.11$ per TEU (Twenty foot Equivalent Unit), because its cargo capacity 2000-ton similar to 83 TEU which located in the mentioned price range (0-999 TEU) [15].

- The batteries of the ship are replaceable, according to Chen Ji, general manager of Guangzhou Shipyard International (the ship manufacturing company) that the cargo capacity could increase proportionally with batteries capacity [2].

3.3 The wave energy stations

The reason for the stations is the need to recharge and exchange the ships batteries, which work for limited distance. In addition, the stations are responsible of controlling and storing electric energy that generated from the nearby wave farm.

The stations are Tension leg plate form (TLP), and consist of:

1. Convertor to transform electric AC current generated from wave energy convertor (WEC) device to DC.
2. Charging control unit to control the delivered electric energy to batteries.
3. Wave energy farm, which contain WECs (Wave Energy Convertors) devices, located nearby stations.
4. Electric winch for lifting the batteries.

Wave energy farm

The farm contain the WEC devices, which generate electric power from the wave motion. The suggested WEC devices is the Pelamis P2.

The Pelamis P2

A semi-submerged system (2/3 of diameter [18]) composed of cylindrical sections linked by hinged joints, which convert the ocean wave energy into hydraulic energy and then to electric energy [16].

Pelamis Wave Power Ltd Company, in Edinburgh in 1998, founds the Pelamis WEC. Since then it became one of the most mature researched and tested WECs [6].The P2 device is 180m long, ,4 meters in diameter, Weights approximately 1,350 tons, and consist of five sections and 750 kW install capacity [6] [17] [18] [19].



Figure 8. Pelamis P2 WEC device [6]

The Pelamis P2 specification:

This device preferred for these reasons:

- It is the most developed device of WECS recently.
- It is safe and clean for environment [17], well covered device so that no hydraulic oil leaks (almost zero sea pollution).
- It does not has any social consequences [17].
- Ability to operate in water depth greater than 50 m [19].
- Typically installed 2-10 km from cost line [19] ,in this assessment the middle devices suggested to fix well with the offshore TLP stations.
- The force generated in one cylinder or section delivered to its neighbor.
- Low cut in wave height (1m H_s) which made it suitable for small seas [20].

Pelamis P2 efficiency and capacity factor

The minimum Pelamis P2 device efficiency from wave to wire approximately 70% [20] and increases according to electric output power.

Regarding the capacity factor, it is reported that wave power devices generate power up to 90% of the time [17].

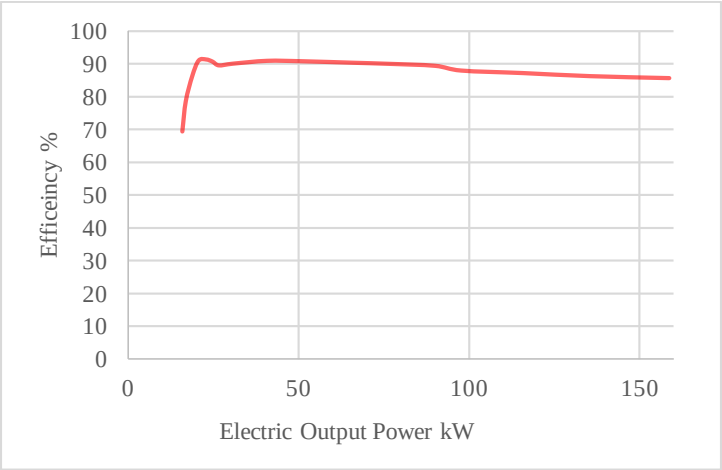


Figure 9 Pelamis P2 efficiency [20]

How the Pelamis work

The movement of waves drives the articulated cylinders to move (heave and sway). Which, create a high pressure in hydraulic arms due to pistons reciprocating movement, that pressure pumps the hydraulic fluid to the high-pressure accumulator, which regulate and control the rate at which the fluid enters the motor/generator to produce the electric power and that depends on sea condition [17].

This system designed to get the maximum utilization, when the waves are small. And minimizes the response in storms to save the device.

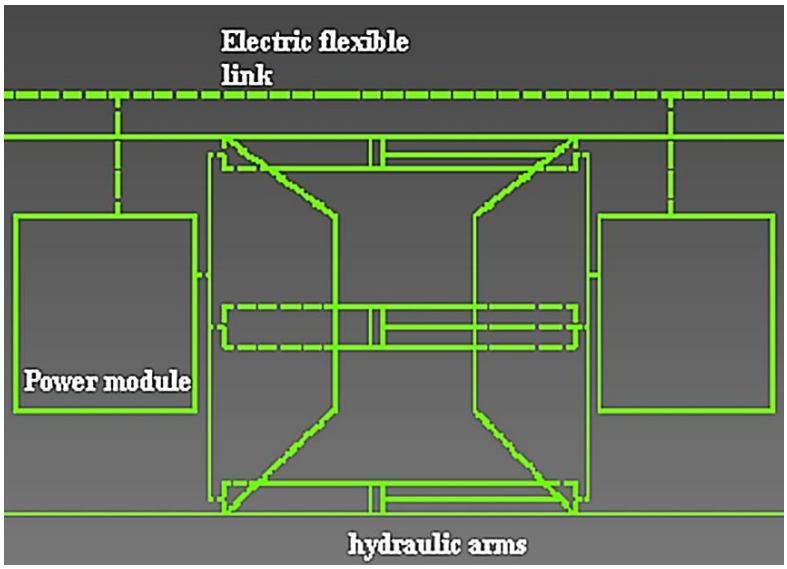


Figure 10. Hydraulic arms between the articulated cylinders sketch

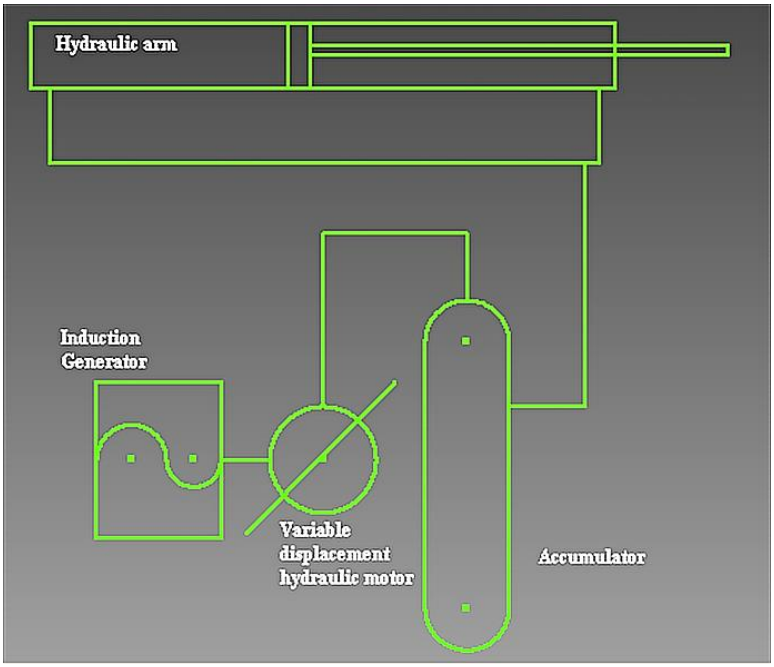


Figure 11. Power module sketch

The mechanical power extracted from wave motion:

$$E_1 = 2F_1v = 2A_1pr\omega = \frac{Q1 * P}{\text{efficiency 1}} \quad \textbf{(3)} \text{ [19]}$$

Where:

E_1: input mechanical power
F_1: reaction force
A_1: piston area
ω: angular frequency of wave

Q_1: total hydraulic flow
P: output pressure
h: efficiency of double rod cylinders
v: the velocity of double rod cylinders [19]

The Pelamis device typically semi-submerged (2/3 diameter is under the water), so the buoyant force represent the total weight of the submerged volume of the device. That force transfer through the hydraulic arms towards power module.

The Pelamis farm typical shape

The farm typically consist of 39 P2 device with approximately 30 MW install capacity. The distribution of Pelamis wave farm is similar to offshore wind farm as shown in figure 12.

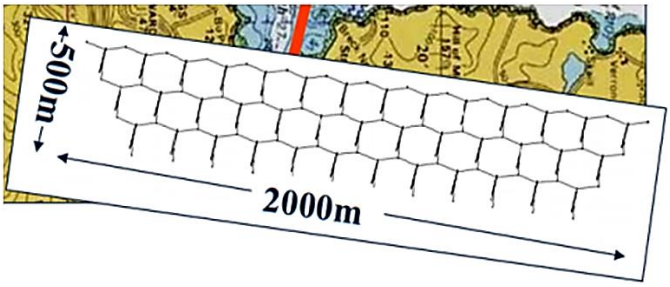


Figure 12. Typical distribution of Pelamis farm [17]

The specific power of the P2 system

The power per km^2

Power/km^2 = (no of Pelamis devices/km^2)*(install power of single Pelamis unit)

= 39*750 = 29.25 MW/km^2

The power per kg

The single unit of Pelamis device weight is 1350 tons

The specific power = $\frac{\text{power}}{\text{weight}}$ W/kg

= $\frac{750 * 10\text{^}3(\text{w})}{1350 * 10\text{^}3(\text{kg})}$ = 0.56 w/kg

The under-study route description

Located Between Port Sudan and Jeddah Islamic port, and has a length of 294.47 Km [21].

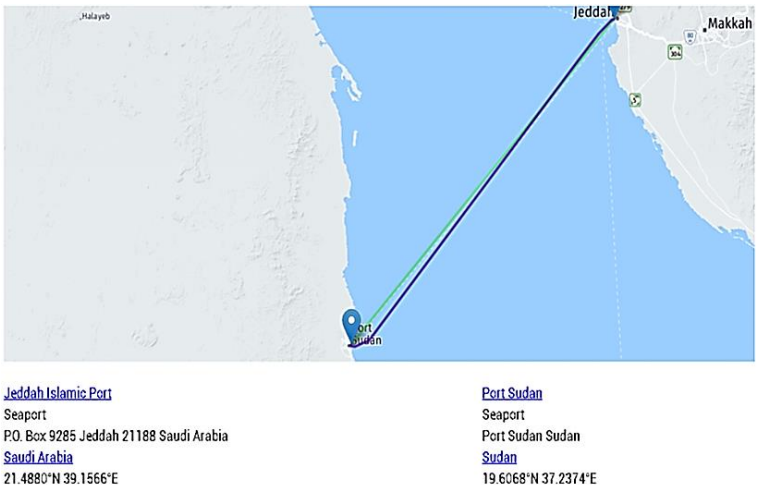


Figure 13. Suggested sea route [21]

4 Results and Discussion

This assessment perform the next calculation to find out , the number of station in the route of ships, the mean wave power in the selected field in 2018, the number of ships could work in the route and the operation scenario of the project.

4.1 Number of stations

The number of station depends on the battery capacity, and how far it could serve in the term of distance, by using the available battery capacity with DOD 90 %(to increase the batteries cycle life [18]), it could run 75.01 km (with travel speed 6 knot).

$$\text{Number of stations} = \left(\frac{\text{the length of the path (km)}}{\text{the traveled distance per charge(km)}}\right) + 1$$

Table 2 number of station and the distance between

the distance between the ports in km	294.47
the travel distance of the electric ship per charge in Km	75.01
length of single path in Km	73.62
the number of station required	5

Therefore, we have five stations with approximately (5 Km^2) total area, which is 0.001% of red sea area (438,000Km^2) [10].

Table 3, Figure 14 and Figure 15 shows the geographical description of the stations:

Table 3. The stations location and bathymetry

Station	Longitude	Latitude	Depth (m)
1	37.2374	19.6068	28.8
2	37.72	20.08	682
3	38.20	20.55	1356
4	38.68	21.02	594
5	39.1566	21.488	20.4

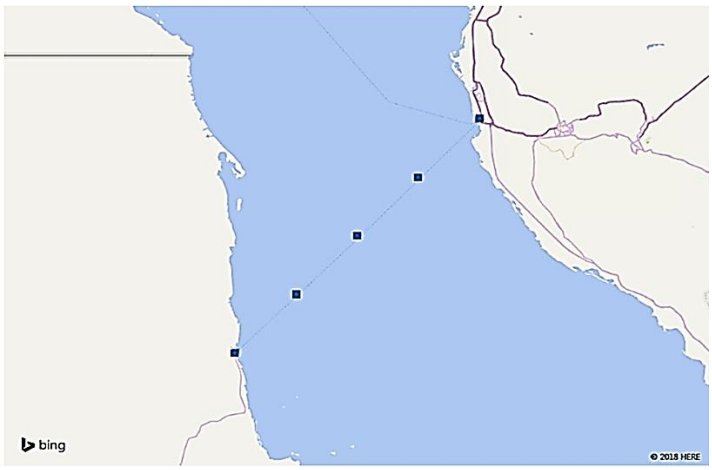


Figure 14. Stations location



Figure 15. Stations bathymetry [22]

Stations types

The suggested station type is the tension leg platform (TLP) [23], which is used in wind offshore NREL[24], and oil drilling. The construction depth of this type of stations reaches 1463 meter [23].



Figure 16. Tension leg platform stations [23] [24]

4.2 Power and energy calculation

Parameters of calculating the mean wave power in the selected field:

Table (4). Power and energy calculating parameters

Number of Pelamis Devices	39
Pelamis P2 width (m)	4
Annual % of increase in mean wave power	0.55%
Efficiency from wave to wire	70%
Capacity factor of wave energy	90%

The annual increase in mean wave power calculated from paper referenced in [10]. The minimum efficiency of P2 device used as a safety factor for calculations. In addition, the P2 device width is important, because it represent the dimension that faces the wave crest and captures the power.

Figure 17 shows the wave power map, which extracted from study [10] in order to estimate the power and energy in 2018.

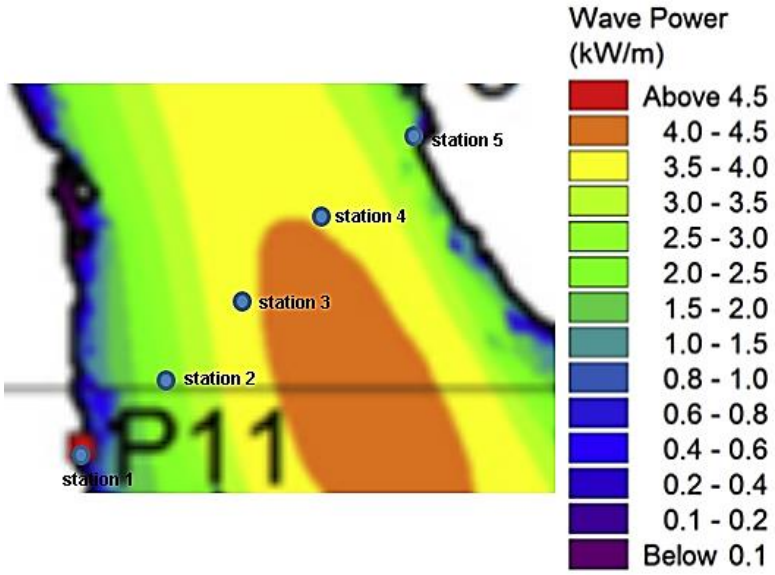


Figure 17. Stations location on the wave power map [10]

From Figure 17, this assessment estimate the maximum power of the stations domain for stations two, three and four. And for stations 1 and 2 it took the values measured from paper [10].

The reason for using the maximum power of the domain is the negligible power difference compared to the minimum (2.7%) power decrease and that did not effect on the number of ships used in this study.

By using the parameters from Table (4 to calculate the power and annual energy in 2018, this assessment got the results as shown in Table 5 and Table 6.

Table 5. Wave power calculation (2018)

Station	Wave power 2010 kW/m	Wave power 2018 kW/m
1	0.62	0.65
2	3	3.13
3	4	4.18
4	4	4.18
5	0.74	0.77
Total	12.36	12.91

- The mean wave power (2018) =

The mean wave power (2010) + {the mean wave power (2010)* (0.55%) * no of years since last measurement (8 years)}

Table 6. Calculated annual electric energy from the wave stations

Station	Generated power per farm kW	Electric power kW	Annual energy generated kWh
1	101	71	557,336
2	489	342	2,696,786
3	652	456	3,595,715
4	652	456	3,595,715
5	121	84	665,207
Total	2,013	1,409	11,110,758

- Power of farm (KW) =

Mean wave power * Pelamis device width*no of devices in the farm

- Electric power (KW) =

Power of farm (KW) * efficiency

- Annual Electric energy (KWh) =

Electric power (KW) * 365(day) * 24(hour) * capacity factor

That generated energy if totally stored could supply 13 ship with annual 96 trip.

No of ships = $\frac{11,110,758}{4*2400*0.9*96}$ = 13.39= 13 ships

4.3 Number of ships and operation scenario

According to battery capacity with 90% DOD, the ship electric propellers power and the distance of the route. The electric cargo-ship need to recharge its battery every 75.01 Km. This

assessment suggested to replace the empty batteries with charged one in the stations using electric winch for lifting, because that could save charging time, from 2 hours to almost thirty minutes.

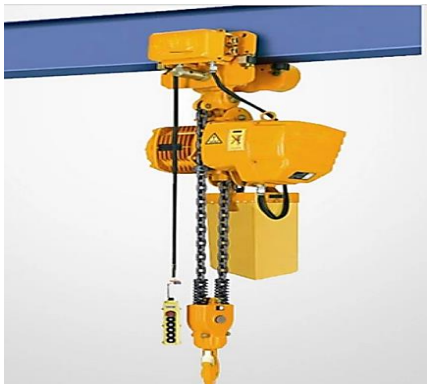


Figure 18. Electric Hoist Winch [25]

This electric winch has loading capacity reaches to 50 ton, and lifting speed up to 11.8 m/min [25] that means it could lift the battery by 354 m in half hour. Also has 3KW motor power [25], which consume 0.064% of the total generated energy of this assessment annually.

Therefore, depending on above information this study made the operation scenario of the ships.

4.3.1 Number of ships in the field

Calculated depending on the suggested trip schedule (two trips weekly per ship). For that, the study calculated the total number of batteries could be charged weekly by the stations, and divided that number by five to get the even distribution number of batteries in every station. Then the study divided the even distribution number of batteries by two which is the number of weekly trips per ship (back and forth) in order to get the number of ships could work weekly in the field.

Table 7. Weekly charging capacity of batteries for stations

station	no of batteries could be charged weekly
1	4.9
2	23.9
3	31.9
4	31.9
5	5.9
Total	98.6

$$\text{The weekly charged no of batteries} = \frac{\text{energy generated per week}}{\text{capacity of battery}}$$

$$= \frac{\text{station power} * 7(\text{days}) * 24(\text{hours}) * \text{capacity factor}}{2400(\text{kwh}) * 0.9(\text{DOD})}$$

$$\text{The even distribution number of batteries} = \frac{\text{total no of weekly charged batteries}}{\text{no of stations}}$$

$$= \frac{98.6}{5} = 19.72 \text{ battery}$$

This study used 18 batteries as an even distribution number in order to avoid fractions in the number of ships.

$$\text{The number of ships} = \frac{18}{2} = 9 \text{ ships}$$

Total no of batteries in the project = Even distribution number of batteries* no of stations in the project

$$= 18 * 5 = 90 \text{ battery}$$

4.3.2 Operation scenario

When the stations are ready to generate energy, the study suggest to use bunker fuel ship in the first week, to distribute the charged batteries between station to fulfill the even battery number per station.

By the end of the first week, every station should contain 18 charged battery. Therefore, in the second week the battery demand of every ship is already satisfied, so the trips could start according to the weekly trips schedule. During that, the bunker fuel ship continue its duty of transporting the empty and charged batteries between stations to fulfill the even distribution no of batteries for the next week.

4.4 Economic analysis

The assessment made an approximated economic analysis depending on the available cost information about some system components.

For the lack of information about some other components cost, these assumptions applied:

- Regarding the ship cost, the construction price of cargo ships calculated depending on its cargo capacity (83 TEU), which is 23,065.11$ per TEU [15].

  The estimated cost of constructing the electric ship
  = the cost per TEU *ship cargo capacity in TEU
  = 23,065.11$ *83
  = 1,914,404.13 $

  By using 10 ships (nine electric and one bunker fuel ship) according to assessment, the total cost is 19,144,041.3$.
- Regarding the stations cost, the assessment used the available price of wind offshore TLP, which is 6.5 million $ [26] for the near shore stations one and five. For the rest offshore stations, the assessment doubled the price of construction due to the increasing in the depth.

The estimated lifetime of project is 24, according to cargo ships calendar life (Wikipedia), and regarding the Lithium batteries the calendar life is 8 years [9], so it need to replace two times during the project life.

The calculations used a discount rate of 1% and applied it on all annual profits and costs, that discount rate used to represent the inflation, in order to take in account the decreasing in money buying power, and not for interest. Because the interest is prohibited according to Religion of Islam, which is governing the selected countries of the route. In addition, this project does not aim to profit rather than decreasing emissions and evaluating wave energy utilizing idea as an alternative clean power source for cargo shipping transportation.

In addition, this idea represent an international project therefore, the contribution of the fund could include the united nation and the countries of selected ports, and every country has the benefit of using this path.

Using the uniform series compound amount taking the discount rate as 1% to calculate the total lifetime profits and cost (for 24 years)

$F = A*\{[(1+I)\ n-1]/I\}$ **(4)** [27]

Where:
F: the future value
A: annual uniform amount
I: the discount rate

4.4.1 The cost calculation

For the wave farm, the assessment depended on information in assessment [16] and euro to dollar price 2018 [28].

Table 8. Total cost of P2 wave farms

The description	The cost in $
Pelamis cost per kW	856.64
Cost of devices in the project	125,283,600
Securing the site cost 2% of devices cost	2,505,672
Installation of array 3% of devices cost	3,758,508
Installation of electric interconnections and tie back 8% of Devices cost	10,022,688
O&M 2% of devices cost annually	2,505,672
O&M 2% for project life	67,586,655.63
Mid-life re fit 13% of devices cost	16,286,868
Un schedule maintenance 6% of devices cost	7,517,016
Mid-life electrical inter-connection maintenance 2% of devices cost	2,505,672
Site lease 2% of devices cost annually	2,505,672
Site lease 2% of project life	67,586,655.63
Insurance 2% of devices cost annually	2,505,672
Insurance 2% of project life	67,586,655.63
Total cost of Pelamis farms for project life	370,639,990.88

4.4.2 The annual income

The estimated cost of freight per TEU is 1300SAR /TEU [29], which equals in USD 351$/TEU (august 2018 USD price) [30].

Annual income = no of working ships*cargo capacity in TEU per ship*annual trips per ship* price of transporting per TEU

= 9 *83 *96 * 351

Annual income = 25,170,912 $

Two options calculated for project cost according to stating time:

- **Option 1**: Before 2020 (Li-batteries cost 600$/kWh) [9] [31]
- **Option 2**: After 2020 (Li-batteries cost 200$/kWh) [31]

Table 9. Total cost and profits of the project

Term	No	calendar life in years	cost in $
Ships	10	24	19,144,041.30
Batteries (2018) option 1	48	8 years * 3	216,000,000
Batteries (2020) option 2	48	8 years * 3	129,600,000
Near shore stations facilities and equipment's	2	_	13,000,000
Offshore stations facilities and equipment's	3	_	39,000,000
Farms of Pelamis P2 devices including installation and O&M and insurance	5	24	370,639,991
The total cost using batteries 2018 option 1			657,784,032.18
The total cost using batteries 2020 option 2			571,384,032
Annual Bunker fuel cost of battery transporting ship			224,672
Annual expected income			25,170,912
Total life time profits			678,946,710
Net profits option 1			21,162,677.98
Annual profits = net profits / project life option 1			657,106.57
Net profits option 2			107,562,677.98
Annual profits = net profits / project life option 2			4,257,106.57

The assessment preferred to start the project after 2020 with annual profits of 4.2 million dollar.

4.5 Annual dry goods could be transport using this clean energy

Calculated using this formula:

Annual goods transporting (ton) = No of working ships * cargo capacity of ship * annual trips per ship

= 9 * 2000 * 96 = 1,728,000 = 1.728 million ton

4.6 Inter connecting electric undersea-cable

The assessment calculated this suggestion, in order to rabidly transfer energy between station according to demand, to compensate the variation of stations electric power generation. But according to available cables technology there was a massive power loss 55 W/m [32] and we have a distance of 294.47 Km that made the power loss (16 MW).

Therefore, the assessment used individual generation and specialized a bunker fuel ship to distribute the batteries between stations according to demand.

4.7 Suggestions for further work

Using LFP or LiNCM lithium batteries could decrease the electric ship batteries weight (to 64% for LiNCM and 27.8% for LFP type) and also could increase the travelling distance if we use the same existing ship battery weight because these types has more specific energy (256Wh/kg for LiNCM and 128Wh/kg for LFP type [9])

The development in ship manufacturing and batteries capacity could allow the ships to use one battery to travel between the selected ports, and that could make it possible to construct the wave power stations and farms concentrated in the highest wave energy potential locations, and could allow using electric ships to deliver the charged batteries to ports.

Applying this assessment in the high potential wave-energy locations such as (Atlantic Ocean, North Sea) where also, the undersea cables are available and due to the large potential power, the cable losses could be acceptable.

The idea of building offshore station for wave energy, with enhanced and developed cables connections, with minimum energy losses, could be the only way to enjoy that tremendous potential power, which concentrated in the middle far location from oceans and seas coasts.

Combined wind and wave energy farms that could increase the produced energy for the same area (increasing energy density), because the wave energy extracted in the bottom of the same constructed station where the wind turbine extract energy from the top, and the shared facilities could also decrease the cost of using them individual.

Using grid connected electric power from another clean energy source for charging batteries in ports in order to cancel the construction cost of port stations (1&5).

The idea of using hybrid ships need to be investigate.

Such projects should be partnership between countries and UN and private sector because it has common effect on their strategic, life and economy.

5 Conclusion

The expected wave power in 2018 calculated to be about 1.4 MW. Five stations suggested on the specified route to cover the consumption of nine ships. The number of ships calculated according to trips schedule (back and forth) and the weekly-generated energy.

Although the cost of utilizing the wave energy in the selected location is high. However, there is a significant profits 4.25 m$ annually. Without forgetting that, the aim of the assessment is to evaluate the idea of utilizing wave energy in ship transportation, in order to generalize and encourage the electric ships manufacturing, and that could satisfy the core aim of decreasing pollutant and dangerous ship emissions. According to this assessment, we can transport 1.728 million ton of dry goods annually without emissions.

The assessment found that, the utilizing of wave power stations to supply electric ship with energy is a very promising idea. Moreover, with the researches and progress in energy capture and storage technologies, many constrains could vanish hopefully in the near future.

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References

[1] O. Merk, Shipping Emissions in Ports, Paris, France: International Transport Forum, Discussion Paper published 2014.

[2] Q. Quanlin, "China Daily.com fully electric cargo ship launched in Guangzhou," China Daily, 14 11 2017. [Online]. Available: http://www.chinadaily.com.cn/business/2017-11/14/content_34511312 . [Accessed July 2018].

[3] A. M. E. Saad, Wave and wind conditions in the Red Sea a numerical assessment using a third generation wave model, Bergen: A thesis submitted in partial fulfillment for the degree of Master in Physical Oceanography, Geophysical Institute University of Bergen, June 2010.

[4] Cruz, J. (Ed.), Ocean Wave Energy. Current Status and Future Perspectives, Springer, 2008.

[5] M. FOLLEY, Numerical Modelling of Wave Energy Converters State-of-the-Art Techniques for Single Devices and Arrays, Elsevier Inc, 2016.

[6] P. A. Lynn, Electricity from Wave and Tide an Introduction to Marine Energy, John Wiley & Sons Ltd, 2014.

[7] Arthur Pecher, Jens Peter Kofoed, Handbook of Ocean Wave Energy, Switzerland: Springer Nature the registered company is Springer International Publishing AG, 2017.

[8] Mork, Gunnar & Barstow, Steve & Kabuth, Alina & Teresa Pontes, Assessing the Global Wave Energy Potential, Arctic Engineering, 3. 10.1115/OMAE2010-20473, 2010.

[9] Greg Albright, Jake Edie, Said Al-Hallaj, A Comparison of Lead Acid to Lithium-ion in Stationary Storage Applications, AllCell Technologies LLC, March 2012.

[10] V.M. Aboobacker, et al, Wave energy resource assessment for Red Sea, Renewable Energy and Hybrid Marine http://dx.doi.org/10.1016/j.renene.2016.09.073 , 2016.

[11] K. Leary, "sciencealert.com," futurism, 6 DEC 2017. [Online]. Available: https://www.sciencealert.com/world-first-completely-electric-cargo-ship-china . [Accessed 10 July 2018].

[12] K. Leary, "futurism.com Advanced Transport," 5 December 2017. [Online]. Available: https://futurism.com/china-launched-worlds-first-all-electric-cargo-ship . [Accessed August 2018].

[13] F. Lambert, "ET @FredericLambert," electrek.co, 4 Dec 2017. [Online]. Available: https://electrek.co/2017/12/04/all-electric-cargo-ship-battery-china . [Accessed 10 July 2018].

[14] M. Cruickshank, "themanufacturer.com, China launches first ever electric cargo ship," the manufacturer, 4 Dec 2017. [Online]. Available: https://www.themanufacturer.com/articles/china-launches-first-ever-electric-cargo-ship . [Accessed 10 July 2018].

[15] M. W. Murray, "Economies of Scale in Container Ship Costs," usmma.edu. [Online].Available:https://www.usmma.edu/sites/usmma.edu/files/docs/CMA%20Paper%20Murray%201%20%282%29.pdf, [Accessed 6 August 2018].

[16] Industry, Energy Technology Support Unit (ETSU) on behalf of the Department of Trade and, "PELAMIS WEC -CONCLUSION OF PRIMARY R&D FINAL REPORT," Ocean Power Delivery Ltd, ETSU V/06/00181/REP, 2006.

[17] Ricardo Gobato, Alekssander Gobato, and Desire Francine Gobato Fedrigo, Assessment Pelamis system to capture energy of ocean wave, Corresponding authors, ricardogobato@seed.pr.gov.br,alekssandergobato@hotmail.com,desirefg@bol.com.br , August 6, 2015.

[18] L. Rodrigues, Devices for Sea Wave Power Extraction to Electrical Energy Conversion, Lisbon: Lusaka University, pp. 193-210.
[19] Hongzhou He, Quanyou Qu and Juyue Li, Numerical Simulation of Section Systems in the Pelamis Wave Energy Converter, Hindawi Publishing Corporation, Advances in Mechanical Engineering, Volume 2013, Article ID 186056, http://dx.doi.org/10.1155/2013/186056, 8 pages.
[20] Richard Yemm, David Pizer*, Chris Retzler and Ross Henderson, Pelamis: experience from concept to connection, 31 Bath Road, Edinburgh, UK: Pelamis Wave Power Ltd, Downloaded from http://rsta.royalsocietypublishing.org , on July 24, 2018, April 2012.
[21] "searoutes.com," [Online]. Available: https://www.searoutes.com/portdistance?fromName=Jeddah%20Islamic%20Port&fromLocode=SAJED&toName=Port . [Accessed May 2018].
[22] "I boating free Marin navigation online map," fishingapp.gps nautical charts, [Online]. Available: http://fishingapp.gpsnauticalcharts.com/i-boating-fishing-web-app/fishing-marine-chartsnavigation.html?title=Red+Sea+boating+app#7/20.486/38.309 . [Accessed 16 July 2018].
[23] S. Tanaka, Y. Okada, Y. Ichikawa, Offshore Drilling and Production Equipment, Civil Engineering, [Eds. Kiyoshi Horikawa, and Qizhong Guo] Encyclopedia of Life Support Systems (EOLSS) Developed under the Auspices of the UNESCO,Eolss,Oxford, UK, [http://www.eolss.net], 2005.
[24] Prymian group, "66KV submarine cable systems for offshore wind," www.prysmiangroup.com , visited on August 2018.
[25] "Aliabad web site," alibaba.com, [Online]. Available: https://www.alibaba.com/product-detail/Electric-HoistWinchforTruckto_60578087219.html?spm=a2700.7724857.main07.23.6e3023cdtuekUD&s=p . [Accessed 25 July 2018].
[26] W. Musial, S. Butterfield, and A. Boone, Feasibility of Floating Platform Systems for Wind Turbines, National Renewable Energy Laboratory (NREL), November 2003.
[27] Donald G Newnan, Ted G Eschenbach, and Jerome P.Lavelle, ENGINEERING ECONOMIC ANALYSIS nine edition, Oxford University press, 2004.
[28] ["Google-finance," google.com, [Online]. Available: https://www.google.com/intl/en/googlefinance . [Accessed 13 August 2018].
[29] "Middle East, Red Sea and Indian subcontinent to Port Sudan - Peak Season Surcharge (PSS)," MAERSK, 16 August 2017. [Online].Available: https://www.maersk.com/en/news/2017/08/16/middle-east-red-sea-and-indian-subcontinent-to-port-sudan-pss . [Accessed 14 August 2018].
[30] "Google-finance," google.com,[Online]. Available: https://www.google.com/intl/en/googlefinance . [Accessed 14 August 2018].
[31] D. Deng, Li-ion batteries basics,progress, and challenges, Detroit, Michigan 48202: Energy Science and Engineering Department of Chemical Engineering and Materials Science, Wayne State University, 2015.
[32] "Submarine Power Cables, Nexans Deutschland and GmbHKabelkamp," Nexans plant Hanover, 20 • 30179 Hannover Tel.: +49 511 676-1 • Fax: +49 511 676-2444, www.nexans.de , 2013.