Valuation of Electric Power Amount Produced by Estimation Tidal Energy in Umm-Qasr Region in Regard to Atmospheric Effects

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ABSTRACT

A mathematical model has been used to estimate the tidal energy and calculate the amount of electric power that can be produced from this energy in Umm-Qasr sea port (southern Iraq).The results of this study show that the estimated tidal energy without atmospheric effect in the sea port, are about 405MW/h and the electric power that can produced from this energy are about 89.1MW/h. Entering the atmospheric effects (pressure and wind speed) on estimated tidal energy in Umm-Qasr port makes this energy reduced to 360.69MW/h and electric power to 79.35MW/h. In compared with results of some researches that estimated tidal energy in the other Iraqi's waters, the tidal energy in Umm-Qasr is convergence with Khor Al-Zubair 400MW/h and Khor Abdullah 425MW/h, because of the convergent in their water depths 8-12 m, and differs vastly from Shatt al Arab 100MW/h due to the shallow depth of it. The depth of water is the main factor in this model, so increasing the current depth of the harbor from 12 m to 50 m reach with tidal energy to 1687.78 MW/h.

INTRODUCTION

Tidal power, also called tidal energy, is a form of hydropower that converts the energy of tides into useful forms of power - mainly electricity; tides are more predictable than wind energy and solar power [1]. Although not yet widely used, tidal power has potential for future electricity generation among sources of renewable energy [2]. Tidal power has traditionally suffered from relatively high cost and limited availability of sites with sufficiently high tidal ranges or flow velocities and this constrict its total availability. However, many recent technological developments and improvements, both in design (e.g. dynamic tidal power, tidal lagoons) and turbine technology (e.g. new axial turbines, cross flow turbines) [1] , indicate that the total availability of tidal power may be much higher than previously assumed, and that economic and environmental costs may be brought down to competitive levels. Many of the coastal States began to take advantage of this kinetic energy to generate electric power and thus relieve the pressure on thermal power stations, and the result of pollution reduction for thermal coal-fired or oil [4].

Area of study: Umm-Qasr is the only deep water port in Iraq, located on the western edge of Al-Faw peninsula in the southern end of the Khor al-Zubair when it's confluence with Khor Abdullah, a way

66km from the entrance of Al-Basra city north the Gulf at 30°1´40´´ N , 47°57´12´´E, as shown in figure (1) [5].

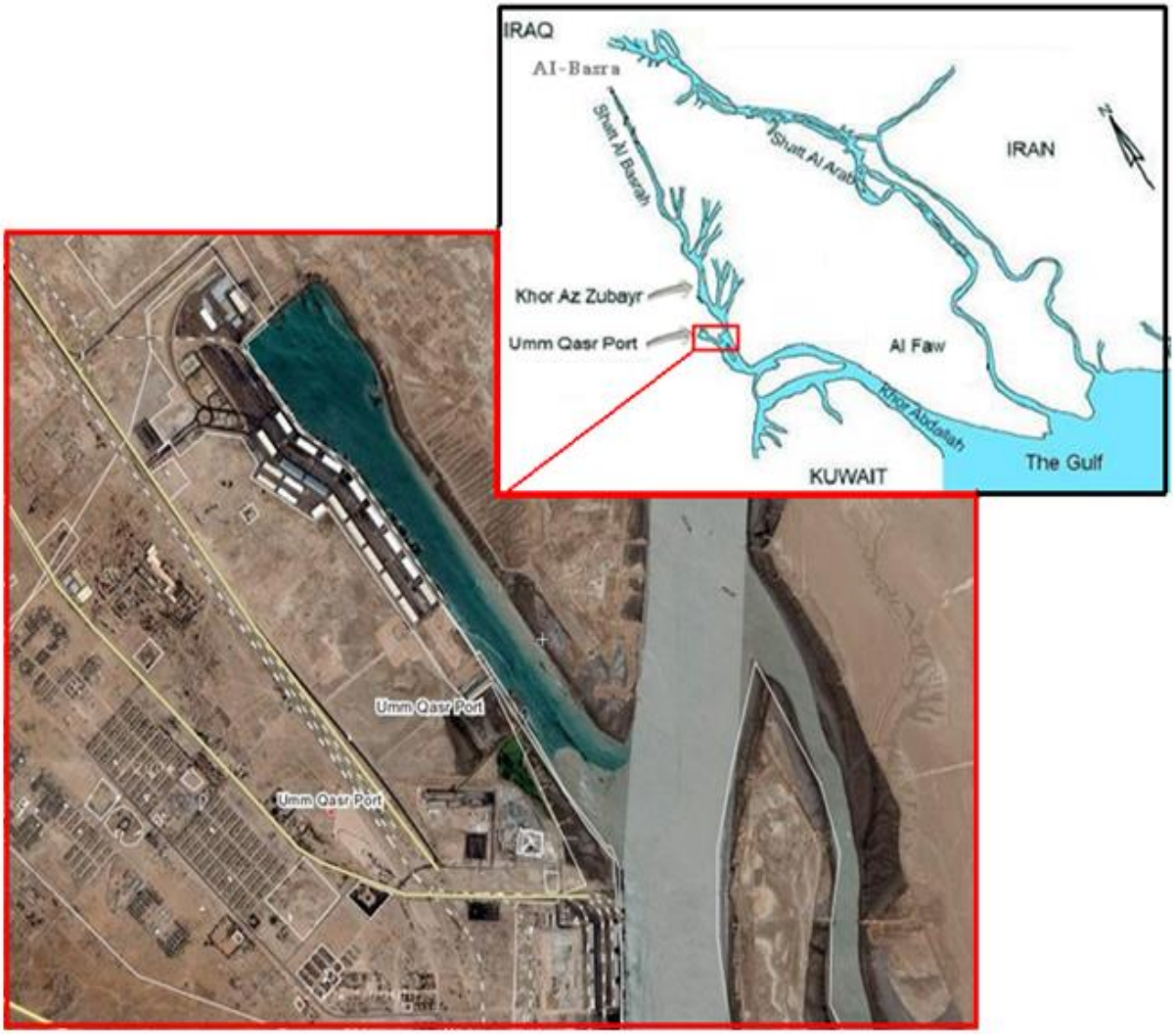

Figure-1: Umm-Qasr port

MATERIALS AND METHOD

The water has depth **d**. Crests and troughs of water are injected from the left hand side by the 12-hourly ocean tides as shown in figure (2) [7].

The crests and troughs move with velocity [8]:

$$\mathbf{v} = \sqrt{\mathbf{g\,d}} \qquad \textbf{(1)}$$

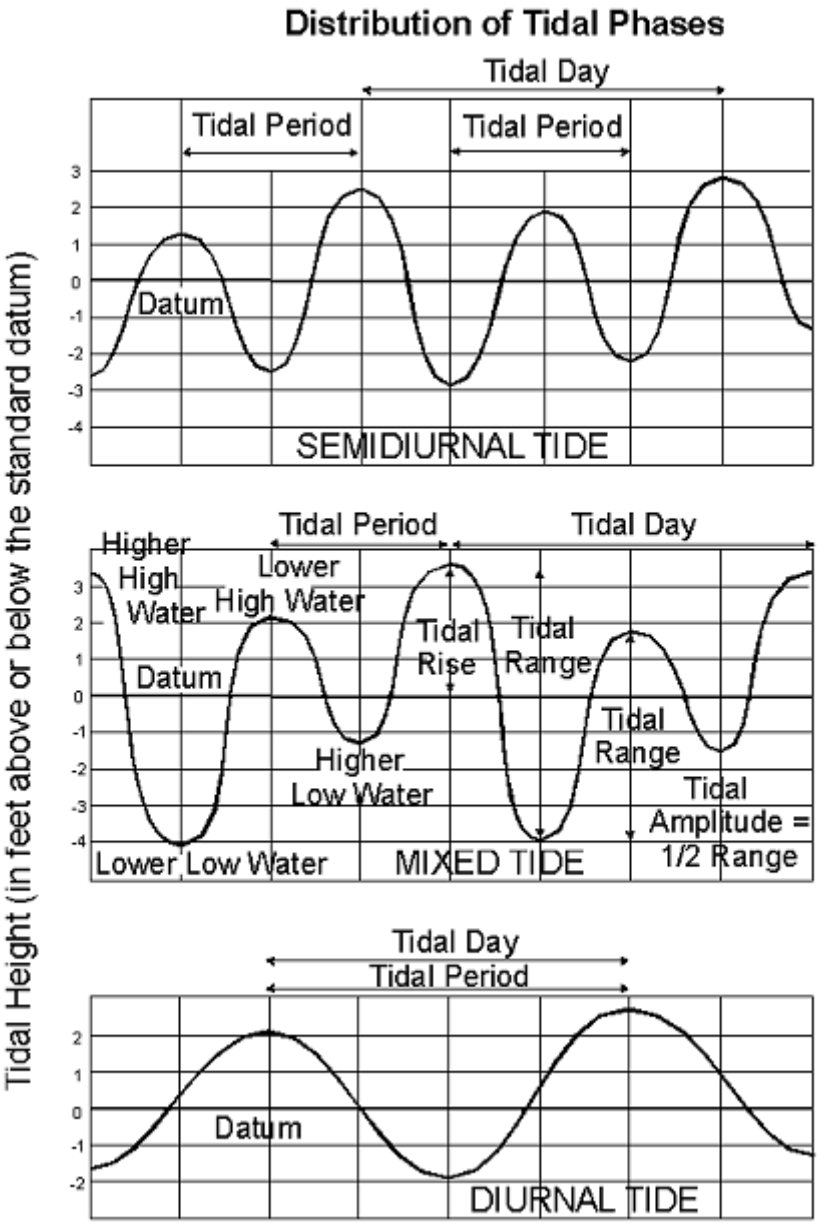

Figure -2: Variation of tides over a day

This model assumes that the wavelength is much bigger than the depth. It call's the vertical amplitude of the tide **h**. For the standard assumption of nearly-vorticity-free flow, the horizontal velocity is near-constant with depth. The velocity is proportional to the surface displacement and has amplitude **U**, which can be found by conservation of mass:

$$\mathbf{U = vh/d} \qquad \textbf{(2)}$$

The peak kinetic-energy flux at any section is:

$$\mathbf{K_{BV} = \tfrac{1}{2}\, \rho\, A\, U^3} \qquad \textbf{(3)}$$

Where **A** is the cross-sectional area

The true total incident power is a standard textbook calculation, one

way to get it is to find the total energy present in one wavelength and divide by the period; another option is to imagine replacing a vertical section by an appropriately compliant piston and computing the average work done on the piston. We'll do the calculation both ways. The potential energy of a wave (per wave- length and per unit width of wave front) is [9]:

$$\tfrac{1}{4}\, g\rho\, h^2\lambda \qquad (4)$$

The kinetic energy (per wavelength and per unit width of wave-front) is identical to the potential energy .So the true power of this model shallow-water tidal wave is:

$$\textbf{Power} = \tfrac{1}{2}\,(\rho\, g\, h^2\lambda)\, w/T = \tfrac{1}{2}\,\rho g\, v\, w \qquad (5)$$

Where w is the width of the wave front. Substituting $\mathbf{v} = \sqrt{gd}$

$$\textbf{Power} = \rho g\, h^2\sqrt{gd}\, w/2 = \rho\, g^{3/2}\sqrt{d}\, h^2\, w/2 \qquad (6)$$

Let's compare this power with the kinetic-energy flux **KBV**. Strikingly, the two expressions scale differently with amplitude. Using the amplitude conversion relation (2), the crest velocity (1), and **A = wd**, we can re-express the kinetic-energy flux as [10]:

$$KBV = \tfrac{1}{2}\,\rho A\, U^3 = \tfrac{1}{2}\,\rho\, w\, d\, (vh/d)^3 = \tfrac{1}{2}\,\rho\, w\, (g^{3/2}/\sqrt{d}\,)\, h^3 \qquad (7)$$

The kinetic-energy-flux method is not always wrong. In the special case of tidal flow through a narrow cleft connecting two immense reservoirs, imagine that at high water there is a height drop of h between stationary waters on the two sides. Assuming vorticity-free flow from the high side up to the outlet, the velocity **U** of water at the outlet of the cleft (at any depth) can be estimated by applying Bernoulli's formula along a streamline connecting that water to a virtually-stationary upstream origin:

$$\tfrac{1}{2}\,\rho\, U^2 = \rho g h \qquad (8)$$

$$U = \sqrt{2gh} \qquad (9)$$

The kinetic-energy flux (KBV) is:

$$\tfrac{1}{2}\,\rho\, A\, U^3 = \tfrac{1}{2}\,\rho\, A\, (\sqrt{2hg}\,)^3 = \rho\, A\sqrt{2}\, g^{3/2} h^{3/2} \qquad (10)$$

For this formula, the extractable power by stream-turbines in this situation has been shown by Garrett and Cummins to be roughly 0.22 times the total power [6].

The amount of Electricity from tidal power = 0.22 KBV (11)

RESULTS AND CONCLUSION

1. Estimated Tidal energy and Electric Power:

By applying this model to account tidal energy on the speculative area of Umm-Qasr port to the current depth 12 m by using MATLAB

programming to solve eq. 10, depending on the tide tables for the entire year 1988[11], it appears that the total summation of 12 month of tidal energy about 405 MW/h, as shown in the diagram in figure (3).

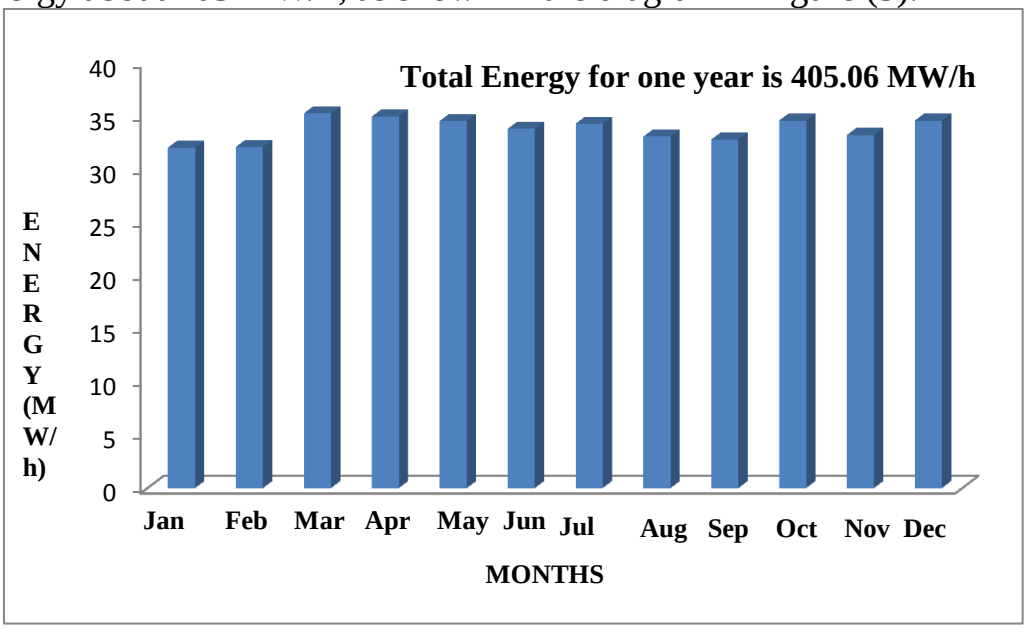

Figure -3: Tidal Energy in Umm-Qasr for one year

From this result and by using eq.11, the estimated the electric power that can be produced in the port of Umm-Qasr is 89.1 MW/h.

2. Compere Tidal Energy:

In comparison with the tidal energy in Khor Al-Zubair, Khor Abd Allah and Shatt al-Arab regions [12], Umm-Qasr port is close to the amount of tidal power speculative for Khor Al-Zubair and Khor Abdullah (average produce 400 MW/h at Khor Al-Zubair and 425 MW/h in the Khor Abdullah) and differs vastly from Shatt al-Arab (average produce 100 MW/h), as shown in the diagram in figure (4). The reason behind this is that the depth in Khor Al-Zubair and Khor Abdullah is (8-12) m which is very close to Umm-Qasr, while the value of tidal energy is very little by a quarter in Shatt al-Arab because of the shallow depth and water flow in it.

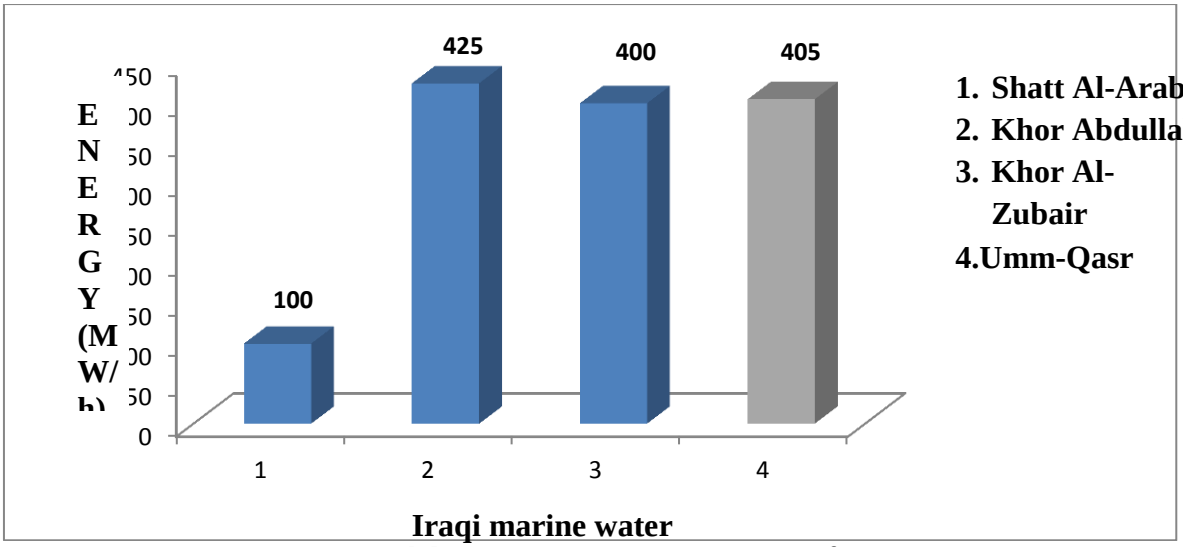

Figure -4: Compare Tidal Energy in Iraqi marine water for one year

3. Increasing Electric Power:

To increase the amount of electric power produced from tidal energy in Umm-Qasr port, the modal is applied for a second time using MATLAB program to various depths because that the depth in sea port is the main factor in increasing the electric power produced by tidal energy, to see this effect, the virtual depth of the sea port of Umm-Qasr has been increased from 10m to 50m, and this lead to an increase in the amount of production electrical energy at the port four times in compere with the power that can be obtained from the value of current depth, as shown in table (1).

Table -1: tidal energy and Electric power produced from this energy For one year in Umm-Qasr port to variation water depth (10-50) m

Depth(m)	Tidal Energy (MW/h)	Electric power (MW/h)
10	337.55	74.26
15	506.33	111.39
20	675.11	148.52
25	843.89	185.65
30	1012.67	222.79
35	1181.44	259.92
40	1350.22	297.05
45	1519	334.18
50	1687.78	371.31

4. Meteorological Effects on Tides Energy:

Meteorological conditions which differ from the average will cause corresponding differences between the predicted and the actual tides. Variations from predicted heights are caused mainly by strong or

prolonged winds, and by unusually high or low barometric pressure. Differences between predicted and actual times of high and low water are caused mainly by the wind.

a. Pressure effect. Tidal predictions are computed for average barometric pressure. A difference of 10 hecto Pascal (hPa) from the average can cause a difference in sea level of about 0.1m. This depression of the water surface under high atmospheric pressure, and its rising under low atmospheric pressure, is often described as the inverted barometer effect. The water level does not adjust itself immediately to a change of pressure and it responds moreover to the average change in pressure over a considerable area. The average barometric pressure and information, in some instances, concerning changes in level which can be expected under different conditions for certain places, is given in Sailing Directions. Changes in sea level due to barometric pressure seldom exceed 0.3m but their effect can be important as they are usually associated with those caused by wind set-up since winds are driven by the pressure gradient [13].

The average value of non-tidal residual for Umm-Qasr from effects of barometric pressure is shown in the table (2) [11].

Table -2: the effects of the barometric pressure on the actual tide in Umm-Qasr

			The positives non-tidal residual		The negatives non-tidal residual	
Barometric pressure(hPa)	Iterations	Percentage %	Non- tidal residual flow (m)	Non- tidal Residual ebb (m)	Non- tidal residual flow (m)	Non- tidal Residual ebb (m)
990-999.5	61	16.67	0.687	0.94	0.687	0.94
1000-1009.5	117	31.97	0.494	1.253	0.494	1.253
1010-1019.5	147	40.16	0.643	0.881	0.643	0.881
1020-1030	41	11.20	0.583	0.02	0.583	0.02
Total	366					

Appling the model account tidal energy for the 3rd time on the speculative area of Umm- Qasr port using MATLAB program depending on the non-tidal residual tables result from the effect of barometric pressure in table (2), gave us a summation of 12 month of tidal energy about 397.84 MW/h, as shown in the diagram in figure (6).

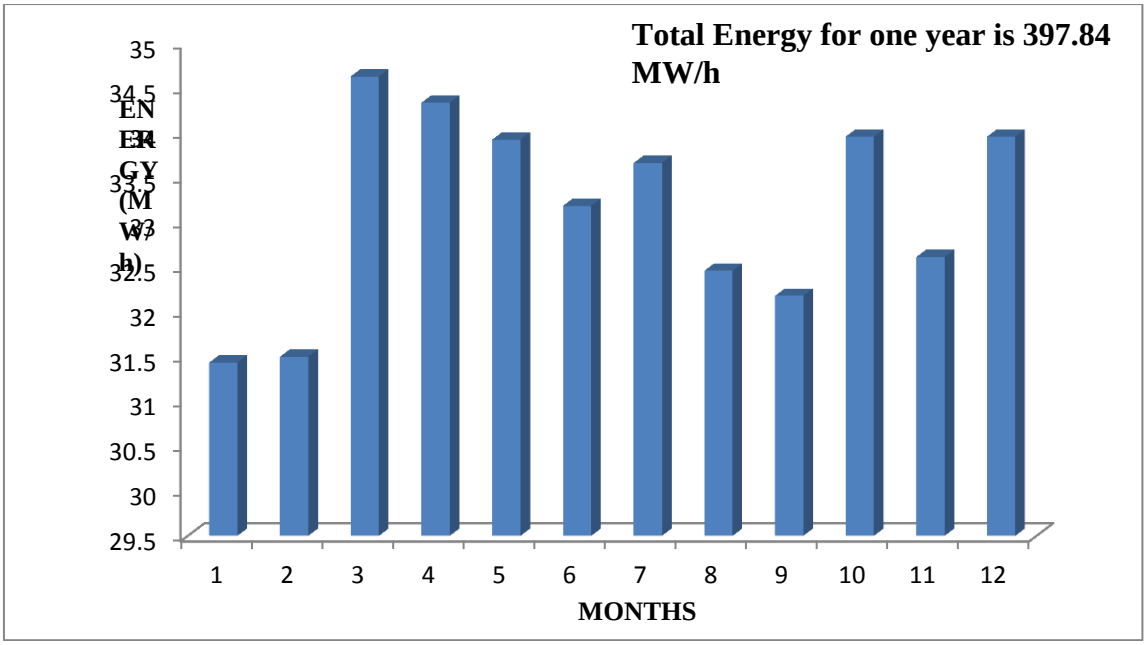

Figure -6: Estimation of tidal energy in Umm-Qasr with effects of barometric pressure.

b. The effect of wind. The effect of wind stresses on sea level and hence on tidal heights and times is very variable and depends largely on the topography of the area. In general, it can be said that wind will raise sea level in the direction towards which it is blowing, this effect is often called wind setup. A strong wind blowing onshore will pile up the water and cause high waters to be higher than predicted, while winds blowing off the land will have the reverse effect. In addition, winds blowing along a coast tend to set up long waves which travel along the coast, raising the sea level at the crest and lowering it in the trough.

The average value of non-tidal residual for Umm-Qasr from effects of winds is shown in the table (3) [11].

Table -3: the effects of the winds on the actual tide in Umm-Qasr

			The positives non-tidal residual		The negatives non-tidal residual	
Direction of wind	Speed m/s	Iterations speed	Non- tidal residual flow (m)	Non- tidal Residual ebb (m)	Non- tidal residual flow (m)	Non- tidal Residual ebb (m)
N,NW	15.6	15	0.653	1.143	0.568	0.639
S,SE	15.05	3	0.619	0.983	0.5299	0.868
E,NE	3.5	0	0.274	1.317	0.586	0.718
W,SW	10	2	0.465	0.881	0.827	0.818
Total	366					

Appling the model account tidal energy for the 4ht time on the speculative area of Umm- Qasr port using MATLAB program depending on the non-tidal residual tables result from the effect of wind in table (3), give us a total summation of 12 month of tidal energy about 324.78 MW/h, as shown in the diagram in figure (7).

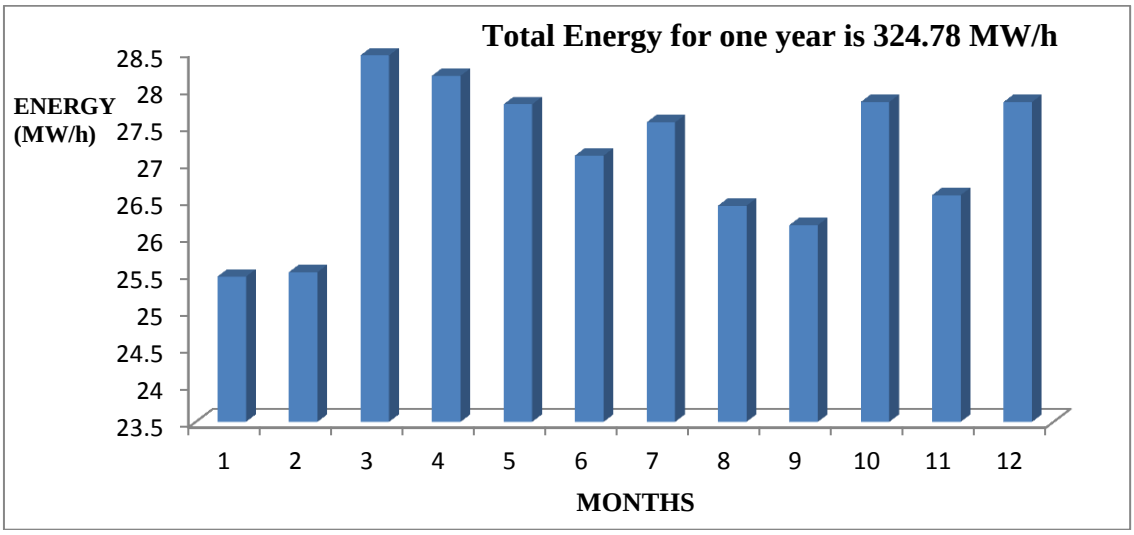

Figure -7: Estimation of tidal energy in Umm-Qasr with effects of winds.

c. Storm surges. The combination of wind setup and the inverted barometer effect associated with storms can create a pronounced increase in the sea level. This is often called a storm surge. An additional process in the form of a long surface wave travelling with the storm depression can further exaggerate this sea level increase. A negative surge is the opposite effect, generally associated with high pressure systems and offshore winds, and can create unusually shallow water. This effect is of great importance to very large vessels which may be navigating with small under-keel clearances [13], with the two effects of atmosphere from table (2) and table (3), the amount of energy tide calculated in this study. The result of this model under these effects for the total summation of 12 month of tidal energy is about 360.69 MW/h, as shown in the diagram in figure (8).

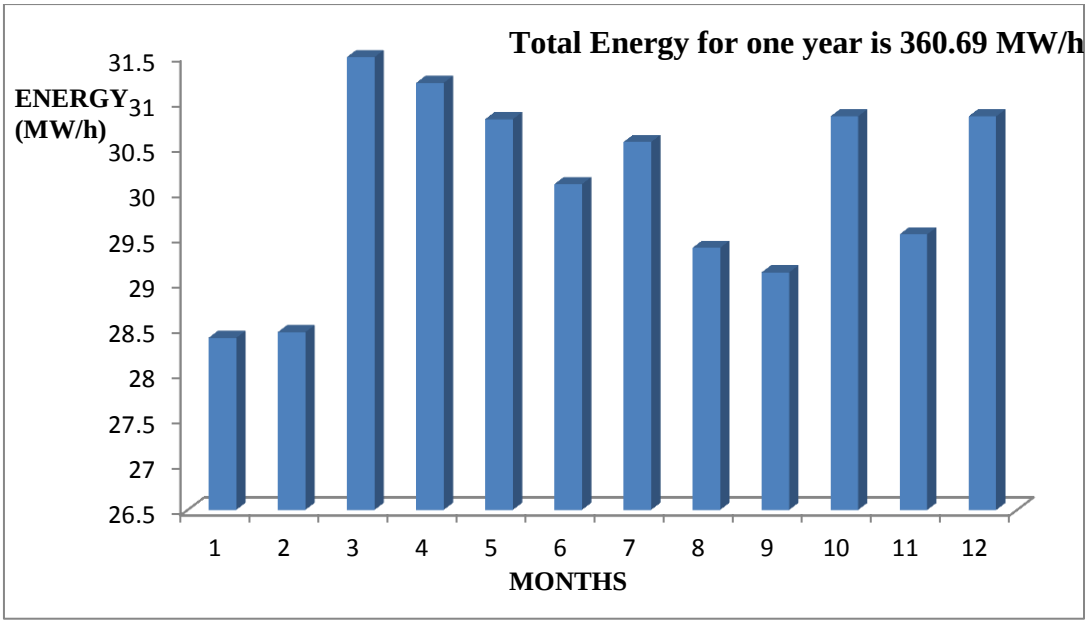

Figure -8:Estimation of tidal energy in Umm-Qasr with effects of barometric pressure and winds which is the meteorological effect on Tidal Energy.

5. Comparison between output energy with and without atmospheric effect:

The effect of the atmosphere on tidal energy and electric power can be clear by comparing estimated tidal energy and electrical power that can produced from it with and without effects of meteorological parameters, as shown in figure (9).Which shows that the atmospheric pressure effect reduced estimated tidal energy from 405.06 MW/h to 397.84 MW/h and reduced electric power that can produce from this tidal energy from 89.1132 MW/h to 78.5248 MW/h. Wind speed effect reduced estimated tidal energy to 324.78 MW/h and electric power to 74.4516 MW/h, while the total effect of these meteorological parameter are reduced this energy to 360.69 MW/h and reduced the electric power to 79.3518 MW/h.

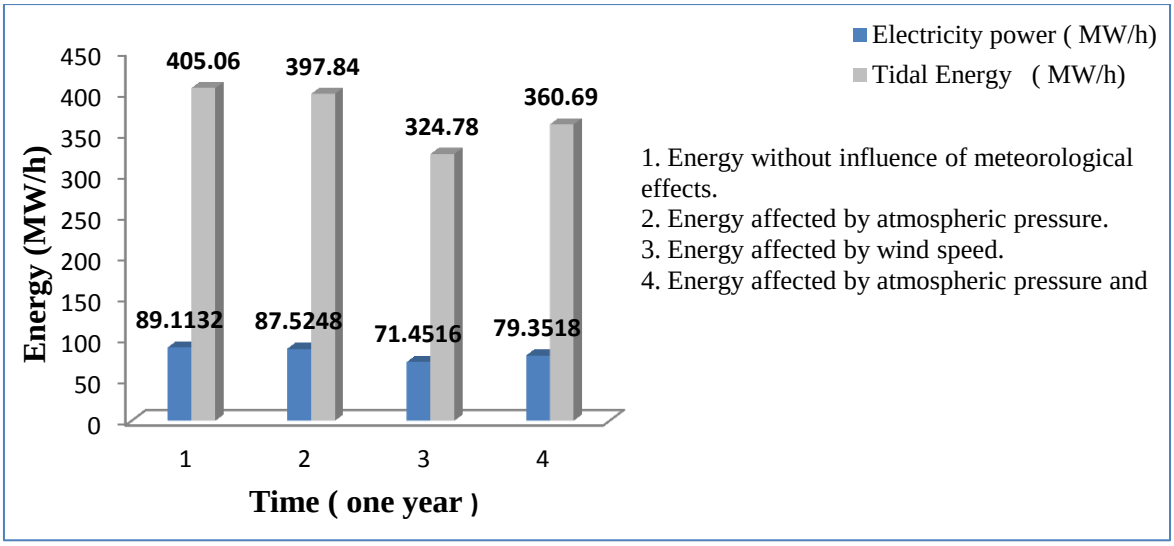

Figure -9: Amount of Energy in MW/h in Umm-Qasr compare with meteorological effects

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