J. Basic. Appl. Sci. Res., 2(1)449-460, 2012
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ISSN 2090-4304
Journal of Basic and Applied Scientific Research
www.textroad.com

Distribution Tidal Wave Energy and its Applications in Coasts of Iran

K. Lari[1], H. Rahmani[2,*]

[1]Department of physical oceanography, Islamic Azad University, Tehran-North branch, Tehran, Iran
[2]Department of physical oceanography , American World University, Tarzana CA, United States of America

ABSTRACT

Tidal energy is a clean, reliable and available energy that exits vastly. Moreover, it can be offered to most of coastal regions and cities. This clean energy can be used in littoral zones worldwide, together with islands and coasts of Iran such as Chabahar. Furthermore, from ecosystem point of view, this energy is useful for increasing coral reefs and also using organic materials in different applications. Via different turbines, tidal kinetic energy is transformed into electric energy. In this article, different methods of acquiring energy from tidal flows, as well as their economic feasibility, are evaluated and compared. In addition, tidal energy was considered in southern coasts of Iran. The results indicate that helical turbines have great efficiency and construction of electrical production station in Persian gulf is mandatory.
KEY WORDS: Wave; Tidal; Renewable Energy; Turbine; coasts of Iran.

1. INTRODUCTION

Renewable energies, such as energies of wind and river flow, are systems originating intermittently from solar energy and are generally considered as nonpolluting fuels. It should be mentioned that these energies are renewed by sun and are unlimited. This makes them different from storable energies which are obtained from fossils. A novel strategy for developing clean energies is to use wave and tidal energy and is accepted greatly as one of the energy resources. Developing countries located in Asia, southern and central America، Europe, or those located near Indian ocean together with Pacific and Atlantic oceans, can make use of the advantage of tidal energy. In comparison with solar stations and diesel systems, the cost of equipments and their installation is decreased about 50%.

Tidal energy is exploited by horizontal- and vertical-axis turbines. Regarding efficiency, simplicity and economical issues, the best turbines are helical and vertical. Tidal energy is used in some applications such as electricity generation for regions far from energy generators (small scale), as well as generating energy for networks and power stations (large scale), and this energy is also useful in the field of ecosystem, for increasing coral reefs and making use of organic materials for various activities . Based on these advantages, it is a favorable alternative for oil imports and electricity generation.

The tidal flows are favorable in southern coasts of Iran such as Chabahar, due to the bay form of the region. Additionally, electricity can be generated from tidal flows and their kinetic energy by helical turbines in some parts of Chabahar bay such as “Teiss port”, “Ab-Shirinkon” and “Kenarak port”, and as mentioned above, the generated electricity has diverse usages. Furthermore, it is possible in Chabahar bay to develop the fishery industry with Mashta method making use of the tides. Obtaining energy in a traditional way from tides was initially achieved in Germany in 1580 where using barrages and height difference of the tide, they stirred large water wheels. In its advanced form, acquiring energy from tidal flows has been studied in many countries since 2000. However, no complete and applied research has been carried out in Iran regarding this subject.

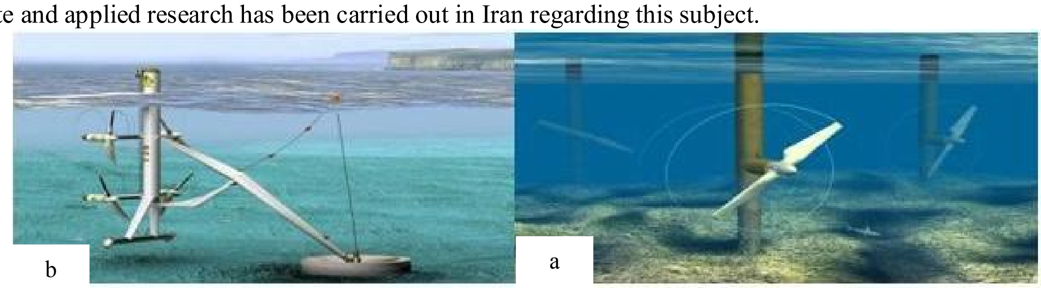


Fig. 1.a: The figure is a sample of horizontal turbine fixed over sea basin.
b:a sample of horizontal turbine is observed which is not fixed over sea basin[9].

***Correspondence Author:** Hamid Rahmani, Department of physics of sea, American World University, Tarzana CA, United States of America *Tel.*: (+98912) 233 97 95, *E-mail*: rahmany_h@yahoo.com

2. MATERIALS AND METHODS

2.1. Calculation formulas of tidal energy

Tidal energy is vastly distributed all over the world, such as Rance River in France and Fundy Bay in Canada. Southern coasts of Iran are among those zones which have considerable tidal energy.

Since 1966, 24 turbines with 10 megawatt power have been installed in Rance River in France, which generate 240 megawatt electricity. The average tide height in this region is 28 feet and the area of the river is approximately 8.5 square miles. Its approximate flow is 6.64 billion cubic feet and the predicted maximum energy is 7734 million kilowatt/hour per year, while in practice 6% of it is obtained. With minimum and maximum tides, 80000 and 1450000 kilowatt/hour energy are generated in a day, respectively. So, the ratio of maximum to minimum tide is 18 to 1. The average of both cases is 500 million kilowatt/hour per year. In France, generating electricity in this way is costs less than oil, pit coal or even nuclear energy.

A significant area for obtaining energy from tides is Passamaquoddy in lower part of Fundy Bay in New Brunswick in Canada with average tide height equal to 18.1 feet. There, the tidal flow is roughly 70 billion cubic feet in each cycle. The area of this bay is about 142 square mile and approximately 3.5% of the estimated maximum energy is exploited. The respective plan was studied and made during 1956 to 1961 and since then, the economical status has consequently changed.

A kind of tidal flow is the one capable of generating electricity with no need to a dam. Another kind of these flows is utilized through harnessing the tidal flows by dam construction over inlet of the bay when immense tidal flow occurs. The turbines are stirred with high speed due to level difference. These so-called high-speed turbines have two kinds of axes, namely vertical and horizontal axes. A drawback of such a method is contamination of ecosystem.

The maximum tidal energy is determined as follows [1]:

$$E = 266 \times 10^{-6} HQ \qquad (1)$$

where E is calculated in terms of kWh/yr, H is the tide range in terms of M, and Q is the amount of tidal flow in terms of Watt (j/s).

When a tide occurs, the maximum energy is calculated as follows:

$$E = 2HQ \qquad (2)$$

$$E = 416 \times 10^{-4} HV \qquad (3)$$

In this formula, V is calculated in terms of cubic meter.

$$Potential\ Energy = s \int_0^{2h} \rho g h d_z \Rightarrow Potential\ Energy = 2 s \rho g h^2 \qquad (4)$$

where S is the area of the region, g is the acceleration of gravity, and ρ is water density.

The average of potential energy is calculated as follows; the above formula is better for half daily tide than the other tides.

$$Mean\ Power = \frac{2 s \rho g h^2}{Tidal\ Period} \qquad (5)$$

b Fig. 2.a: The figure is a bound horizontal turbine. b: a free horizontal turbine is illustrated [9]. a

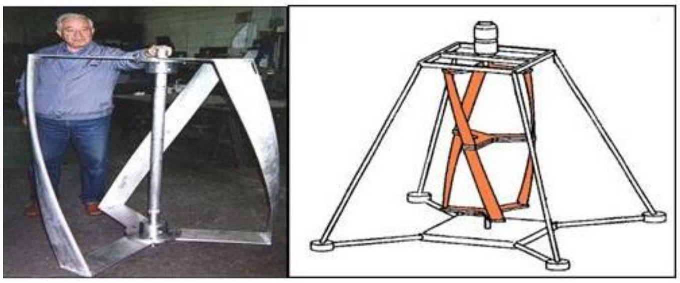


Fig. 3. A picture of helical turbine in a frame and its inventor [7].

2.2 Turbine Types:

Horizontal turbine is a technology being used from 30 years ago to obtain wind energy and it is currently employed for acquiring tidal energy. The horizontal turbine for tidal flows is similar to wind turbine; the only difference is that a tidal turbine is located under water. Regarding the density of water being 800 times greater than the air's density, and the ratio of water speed to air speed, which is approximately 1 to 5, the propellers of a tidal turbine must therefore be about half of a wind-turbine's propellers to generate the same energy. Maintaining the axis of such turbines is simple and has lower costs, thus it is accepted widely. In deep places, these turbines are installed in floating form since they cannot be fixed over sea basin. This procedure is carried out in order to avoid storm damage.

There exist two kinds of horizontal turbines:

- Bound horizontal turbines
- Free horizontal turbines

Vertical turbines have two types: In one type, the blades are parallel to each other and perpendicular to the turbine's plate, while in the second type, blades have an angle other than 90 degrees to the turbine's plate. These kinds of turbines are helical ones and have the highest efficiency. Professor Alexander Gorlov is the inventor of helical turbines. Utilization of such turbines in harnessing tidal energy is very suitable and has a low cost.

This machine is supposed to be used in generating hydroelectric power from water. This turbine is run by tidal flows in oceans and rivers, hence there is no need to construct expensive dams and destroy the ecosystem.

Helical turbine runs by a water flow about 1 m/s speed. Disregarding the flow route, turbine's direction of rotation is in accordance with tide's functionality. It means that turbine rotation is only in one direction disregarding flow direction.

Table 1. daily tidal in Chabahar gulf in 15th March 2009.

Tidal height , Chabahar, 15 March 2009												
Time	00 min	05 min	10 min	15 min	20 min	25 min	30 min	35 min	40 min	45 min	50 min	55 min
00 hour	2.39 m	2.36 m	2.34 m	2.32 m	2.29 m	2.27 m	2.24 m	2.21 m	2.18 m	2.15 m	2.12 m	2.08 m
01 hour	2.05 m	2.01 m	1.98 m	1.94 m	1.90 m	1.87 m	1.83 m	1.79 m	1.75 m	1.71 m	1.67 m	1.63 m
02 hour	1.59 m	1.55 m	1.50 m	1.46 m	1.42 m	1.38 m	1.34 m	1.30 m	1.26 m	1.21 m	1.17 m	1.13 m
03 hour	1.09 m	1.06 m	1.02 m	0.98 m	0.94 m	0.90 m	0.87 m	0.83 m	0.80 m	0.77 m	0.73 m	0.70 m
04 hour	0.67 m	0.64 m	0.61 m	0.59 m	0.56 m	0.54 m	0.51 m	0.49 m	0.47 m	0.45 m	0.43 m	0.42 m
05 hour	0.40 m	0.39 m	0.38 m	0.37 m	0.36 m	0.35 m	0.35 m	0.35 m	0.35 m	0.35 m	0.35 m	0.35 m
06 hour	0.36 m	0.37 m	0.37 m	0.39 m	0.40 m	0.41 m	0.43 m	0.44 m	0.46 m	0.48 m	0.50 m	0.53 m
07 hour	0.55 m	0.58 m	0.60 m	0.63 m	0.66 m	0.69 m	0.72 m	0.76 m	0.79 m	0.82 m	0.86 m	0.89 m
08 hour	0.93 m	0.97 m	1.00 m	1.04 m	1.08 m	1.12 m	1.15 m	1.19 m	1.23 m	1.27 m	1.31 m	1.35 m
09 hour	1.39 m	1.42 m	1.46 m	1.50 m	1.54 m	1.57 m	1.61 m	1.65 m	1.68 m	1.72 m	1.75 m	1.78 m
10 hour	1.81 m	1.85 m	1.88 m	1.91 m	1.93 m	1.96 m	1.99 m	2.01 m	2.04 m	2.06 m	2.08 m	2.10 m
11 hour	2.12 m	2.14 m	2.16 m	2.17 m	2.19 m	2.20 m	2.21 m	2.22 m	2.23 m	2.24 m	2.24 m	2.25 m
12 hour	2.25 m	2.25 m	2.25 m	2.25 m	2.25 m	2.25 m	2.24 m	2.24 m	2.23 m	2.23 m	2.22 m	2.21 m
13 hour	2.20 m	2.19 m	2.17 m	2.16 m	2.15 m	2.13 m	2.12 m	2.10 m	2.08 m	2.07 m	2.05 m	2.03 m
14 hour	2.01 m	1.99 m	1.97 m	1.95 m	1.93 m	1.91 m	1.89 m	1.87 m	1.85 m	1.83 m	1.81 m	1.79 m
15 hour	1.77 m	1.75 m	1.73 m	1.71 m	1.68 m	1.66 m	1.64 m	1.63 m	1.61 m	1.59 m	1.57 m	1.55 m
16 hour	1.53 m	1.52 m	1.50 m	1.48 m	1.47 m	1.45 m	1.44 m	1.42 m	1.41 m	1.40 m	1.39 m	1.38 m
17 hour	1.37 m	1.36 m	1.35 m	1.35 m	1.34 m	1.34 m	1.33 m	1.33 m	1.33 m	1.33 m	1.33 m	1.33 m
18 hour	1.34 m	1.34 m	1.34 m	1.35 m	1.36 m	1.37 m	1.38 m	1.39 m	1.40 m	1.41 m	1.42 m	1.44 m
19 hour	1.45 m	1.47 m	1.49 m	1.50 m	1.52 m	1.54 m	1.56 m	1.58 m	1.60 m	1.63 m	1.65 m	1.67 m
20 hour	1.69 m	1.72 m	1.74 m	1.77 m	1.79 m	1.81 m	1.84 m	1.86 m	1.89 m	1.91 m	1.94 m	1.96 m
21 hour	1.99 m	2.01 m	2.03 m	2.06 m	2.08 m	2.10 m	2.13 m	2.15 m	2.17 m	2.19 m	2.21 m	2.23 m
22 hour	2.24 m	2.26 m	2.28 m	2.29 m	2.31 m	2.32 m	2.33 m	2.34 m	2.35 m	2.36 m	2.37 m	2.38 m
23 hour	2.38 m	2.39 m	2.39 m	2.39 m	2.39 m	2.39 m	2.39 m	2.39 m	2.38 m	2.38 m	2.37 m	2.36 m

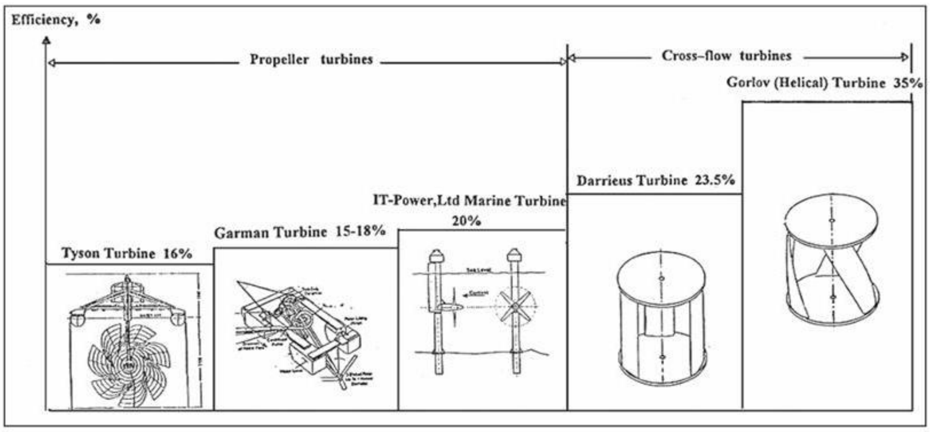
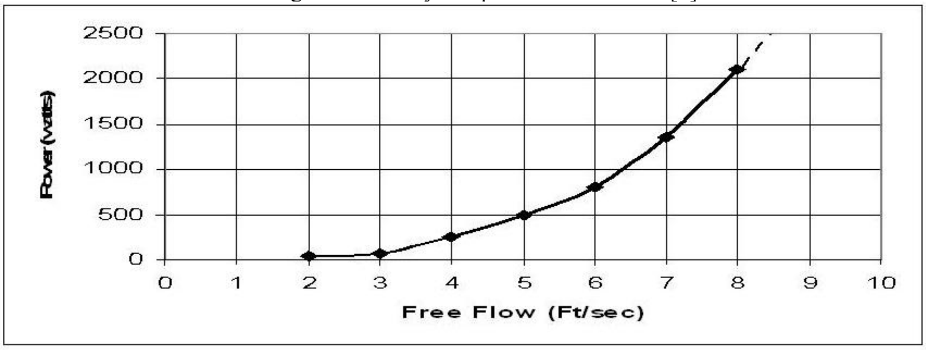


Fig. 4. Efficiency comparison of Turbines [2].



1 m/sec =3.28 ft/sec 1 Knot =1.69 ft/sec

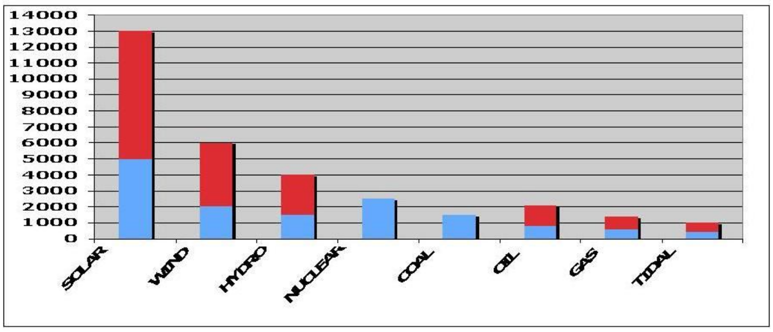
Fig. 5. Diagram illustrating the relationship between power and flow's speed [2].

The efficiency of tidal turbines regarding their types is as follows:
The efficiency of turbines with propeller: 16% to 20%
The efficiency of vertical turbines (normal): 23.5%
The efficiency of vertical turbines (helical): 35%
As observed in Fig. 5, the power of a helical turbine increases 5 to 7 times if the flow's speed doubles.

2.3. Cost comparison of different energy forms in dollars/kW:

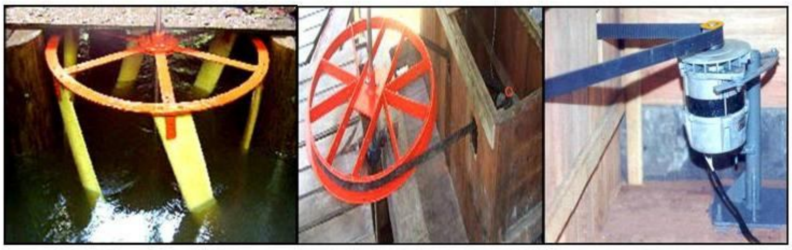
Fig. 6 demonstrates the costs for exploiting different types of renewable and non-renewable energies.

With regard to the above figure, it is obvious that clean tidal energy has the lowest cost compared to other forms of energy.



Blue: low estimate Red: high estimate

Fig. 6. Comparison of spent cost and gained power (Source: GCK Technology, Inc).



(a) (b) (c)

Fig. 7. Electric power generated from tidal flows, (a) Helical turbine with 6-blade, (b) Pulley and belt as the junction between generator and turbine, (c) Generator.

2.4. Applications of tidal energy:

2.4.1. Generating electricity in regions far from energy generators (small scale) [2]:

In a separate part of Amazon River in Brazil, power is obtained from tidal flows and the cost of providing equipments is considerably lower than providing an electrical panel. Furthermore, operating and maintaining these equipments is much easier than a diesel engine. Electric power can be acquired following a simple plan by putting a helical turbine in a place where tidal flows are sufficiently effective. In center of the turbine, there is a vertical axis joined to a bobbin with pulley. As a result, the axis starts rotating after turbine's rotation. Subsequently, the bobbin starts moving. Then, electric power can be obtained by connecting the bobbin to an alternator by a belt.

The mentioned plan is very simple and feasible, with low cost and great competence. The alternator can charge the battery and be utilized when the electric current cuts off. The helical turbine is built by native labor. Additionally, other than its blades which should be supplied from somewhere else, its other parts are simply available. In comparison with solar stations, investment in these equipments and their installations costs 50%. Moreover, compared to diesel stations, the cost factors of tidal energy stations are less than 60%.

Fig. 8. Illustration of turbines installed in Uldolmok strait [4].

Fig. 9. Metallic networks welded in different forms in order to create coral reefs and the way they are placed in shallow water.

2.4.2. Generating energy for power stations (large scale):
Experimental plan in Uldolmok strait in South Korea [7]:

Uldolmok strait in South Korea is located between Jindo Island and the mainland, where tidal flows reach 13 knots. In 2002 South Korea utilized two turbines in Uldolmok strait with following characteristics. Each turbine had a diameter of 1 meter and generated 10 kilowatt power with a flow speed of 4 knots. After the first successful trial with two helical turbines, the Korean government exploited the second phase of megawatts power generation in 2004. In this experiment, each turbine had a diameter of 2.2 meter and length of 2.5 meter. The Korean government has placed approximately 1000 helical turbines in Uldolmok strait after this second successful experiment and exploited approximately 3600 megawatts of energy. This amount is 3 times more than the energy obtained from the dam over world's fourth biggest waterfall, i.e. Nile waterfall, and is equal to the energy of four nuclear power stations.

Approximation of tidal power in some parts of Uldolmok strait:
Uldolmok Strait = 470 MW
Jaing Juk Strait = 1,230 MW
Maeng Gol Strait = 1,910 MW
TOTAL = 3,610 MW

As observed, the total tidal energy in Uldolmok strait is 3610 megawatts, which is roughly 3.5 times compared to the energy obtained from a nuclear power station.

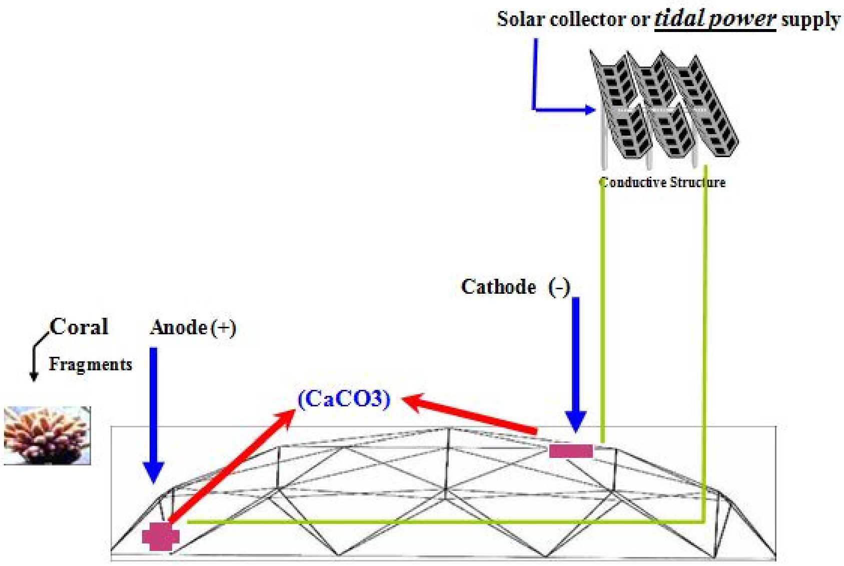


Fig. 10. The procedure of chemical operations in water for generating coral reefs.

2.4.3. Regrowth of coral reefs and subsequent use of organic materials in different applications [5]:

Coral reefs are the ones growing on lime stones in shallow waters and create wonderful scenes. The fishes are attracted by these sceneries and swim around coral reefs. The existence of fishes in coral reefs forms a robust and healthy ecosystem and attracts tourists as well. By passing the time, erosion of such reefs occurs. Thus scientists have reached a new technology, named Biorock's technology, to avoid the erosion or regrowing or producing these reefs.

In order to produce such reefs, a metallic network with patterns and colors consistent with the coast is built. This network is then placed in water and two points of it are connected to a battery or an alternator. Therefore, one side of it takes positive electric charge and the other side becomes negative. Due to a series of chemical processes in water and the originated electric field, carbonate ions in water are absorbed to negative pole (cathode) and calcium ions are absorbed to positive pole (anode).

the number of fishes. In addition, this promotes tourism. This technology has been applied in more than 20 islands in Caribbean Sea, Pacific Ocean, Indian Ocean and Southern countries of Asia.

Fig. 11. A viewpoint of southern coasts of Iran: 1) Chabahar in east $25^{\circ}17'N, 60^{\circ}37'E$, 2) Bandar-e-Abbas in center $27^{\circ}11'N, 56^{\circ}17'E$, 3) Khorramshahr (Khoor-Musa) in west of southern coastal line $29^{\circ}36'N, 49^{\circ}35'E$, 4) Oman sea, 5) Persian gulf.

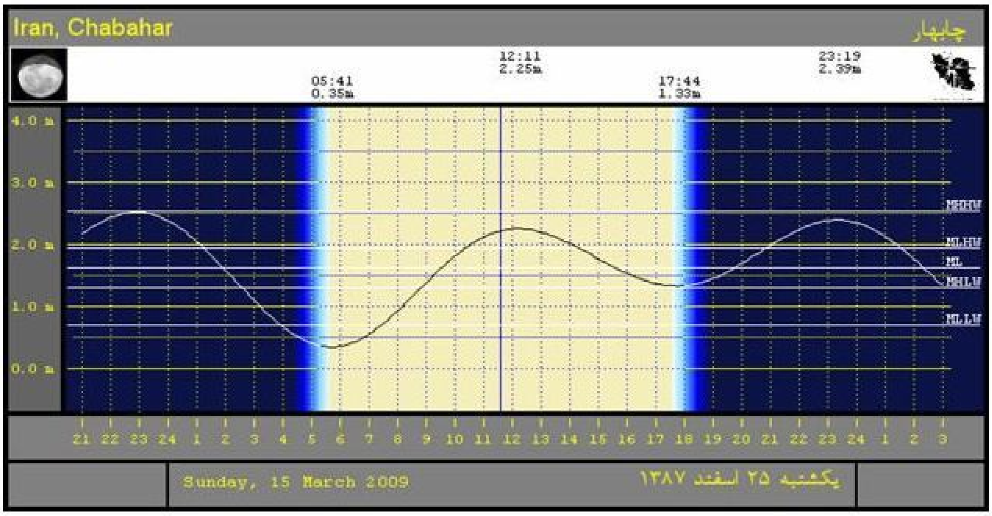


Fig. 12. Diagram of daily tidal in Chabahar gulf in 15th March 2009.

3. RESULTS

Southern coasts of Iran have high tidal energy capacities. Therefore, and based on this paper, these coasts have capability of installation of electricity making.

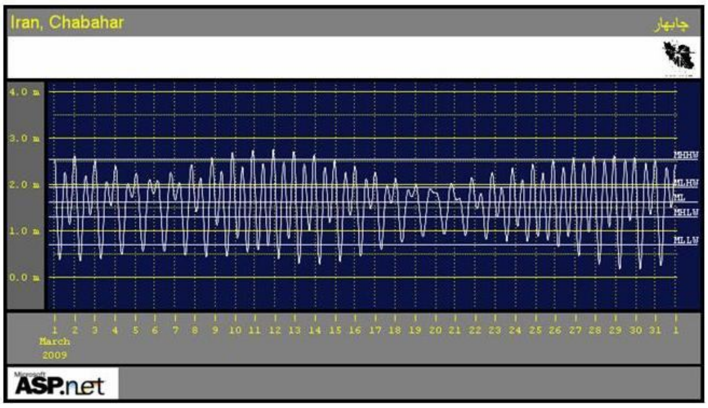


Fig. 13. Monthly tidal in Persian gulf, March 2009.

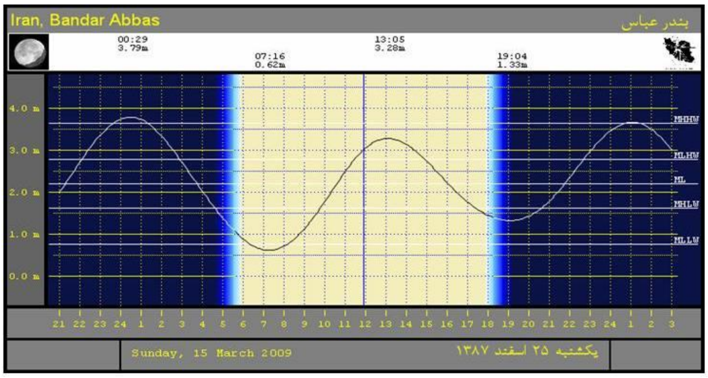


Fig. 14. Diagram of daily tidal in Bandar-e-Abbas gulf in 15th March 2009.

In this section we consider tide type and its height that come from horizontal tidal flows in three regions: east, center and west of southern coasts of Iran. Westernmost coastal city of Iran is Khorramshahr and easternmost coastal city of Iran is Chabahar. Bandar-e-Abbas in Hormozgan state is in first of Persian gulf and is located nearly in the middle of southern cost of Iran. In fact, Chabahar is a part of northern coasts of Oman Sea. The Chabahar geographical location is $25^{\circ}17'N, 60^{\circ}37'E$. Chabahar has shallow waters on its coasts, and there is considerable amount of tide there. In Chabahar, the average of tide's limit is 2 meters. The maximum and minimum flows there are 3 meters 20 centimeters, respectively. Chabahar's tide is half-daily, in other words, tides occur twice in each day (24 hours). The maximum difference in tidal height takes place during 10 AM to 6 PM.

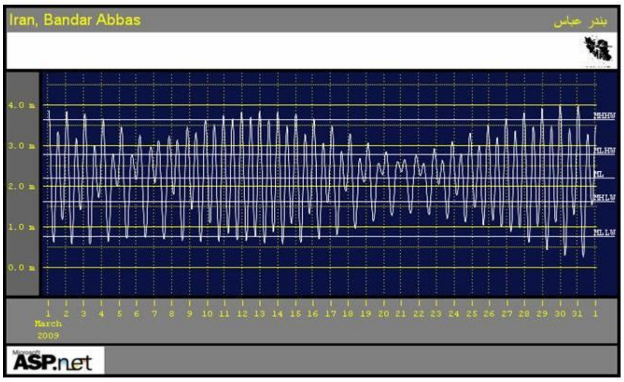


Fig. 15 Monthly tidal in Bandar-e-Abbas, March 2009.

Chabahar has two bays, named Kenarak and Ab-Shirinkon.

Height difference of tide in these two places is 50 centimeters more than that in Chabahar. The following diagram and table show the details of five minutes tide period in 24 h of 15th March of 2009 in Chabahar. The shiny area of diagram shows day and dark area shows night.

Fig. 14 indicates chabahar's tidal in March 2009.

After tidal study in chabahar, we consider the tidal in Bandar-e-Abbas (in middle of southern costal line and above Hormoz neck). Its geographical location is $27^{\circ}11'N, 56^{\circ}17'E$, mean head tidal in Bandar-e-Abbas is about 3.5 m. maximum of high tide and low tide is about 4 and 0.5 m, respectively. Bandar-e-Abbas tide is half-daily. Below figure shows preview of Bandar-e-Abbas location.

Fig. 16 and table 2 show the details of five minutes tide period in 24 h of 15th March of 2009 in Bandar-e-Abbas.

Fig. 17 indicates Bandar-e-Abbas's tidal in March 2009.

Table 2. daily tidal in Bandar-e-Abbas gulf in 15th March 2009.

Tidal height , Bandar Abbas, 15 March 2009												
Time	**00 min**	**05 min**	**10 min**	**15 min**	**20 min**	**25 min**	**30 min**	**35 min**	**40 min**	**45 min**	**50 min**	**55 min**
00 hour	3.74 m	3.75 m	3.77 m	3.78 m	3.78 m	3.79 m	3.79 m	3.78 m	3.78 m	3.77 m	3.76 m	3.75 m
01 hour	3.73 m	3.71 m	3.69 m	3.67 m	3.64 m	3.61 m	3.58 m	3.54 m	3.51 m	3.47 m	3.43 m	3.39 m
02 hour	3.34 m	3.30 m	3.25 m	3.20 m	3.15 m	3.10 m	3.05 m	2.99 m	2.94 m	2.88 m	2.83 m	2.77 m
03 hour	2.71 m	2.65 m	2.60 m	2.54 m	2.48 m	2.42 m	2.37 m	2.31 m	2.25 m	2.19 m	2.14 m	2.08 m
04 hour	2.02 m	1.97 m	1.91 m	1.86 m	1.80 m	1.75 m	1.70 m	1.64 m	1.59 m	1.54 m	1.49 m	1.44 m
05 hour	1.39 m	1.34 m	1.29 m	1.25 m	1.20 m	1.16 m	1.12 m	1.07 m	1.03 m	0.99 m	0.96 m	0.92 m
06 hour	0.89 m	0.85 m	0.82 m	0.79 m	0.77 m	0.74 m	0.72 m	0.70 m	0.68 m	0.66 m	0.65 m	0.64 m
07 hour	0.63 m	0.62 m	0.62 m	0.62 m	0.62 m	0.62 m	0.63 m	0.63 m	0.64 m	0.66 m	0.67 m	0.69 m
08 hour	0.71 m	0.73 m	0.76 m	0.79 m	0.82 m	0.85 m	0.88 m	0.92 m	0.96 m	1.00 m	1.04 m	1.08 m
09 hour	1.13 m	1.18 m	1.22 m	1.27 m	1.33 m	1.38 m	1.43 m	1.49 m	1.55 m	1.60 m	1.66 m	1.72 m
10 hour	1.78 m	1.84 m	1.90 m	1.96 m	2.02 m	2.08 m	2.15 m	2.21 m	2.27 m	2.32 m	2.38 m	2.44 m
11 hour	2.50 m	2.55 m	2.61 m	2.66 m	2.71 m	2.76 m	2.81 m	2.86 m	2.90 m	2.94 m	2.98 m	3.02 m
12 hour	3.06 m	3.09 m	3.12 m	3.15 m	3.17 m	3.20 m	3.22 m	3.23 m	3.25 m	3.26 m	3.27 m	3.28 m
13 hour	3.28 m	3.28 m	3.28 m	3.28 m	3.27 m	3.26 m	3.25 m	3.24 m	3.22 m	3.20 m	3.18 m	3.16 m
14 hour	3.14 m	3.11 m	3.08 m	3.05 m	3.02 m	2.99 m	2.96 m	2.92 m	2.89 m	2.85 m	2.81 m	2.77 m
15 hour	2.73 m	2.69 m	2.65 m	2.61 m	2.57 m	2.53 m	2.48 m	2.44 m	2.40 m	2.35 m	2.31 m	2.27 m
16 hour	2.23 m	2.18 m	2.14 m	2.10 m	2.06 m	2.02 m	1.98 m	1.94 m	1.91 m	1.87 m	1.83 m	1.80 m
17 hour	1.76 m	1.73 m	1.70 m	1.67 m	1.64 m	1.61 m	1.58 m	1.56 m	1.53 m	1.51 m	1.49 m	1.47 m
18 hour	1.45 m	1.43 m	1.41 m	1.40 m	1.39 m	1.37 m	1.36 m	1.35 m	1.34 m	1.34 m	1.33 m	1.33 m
19 hour	1.33 m	1.33 m	1.33 m	1.33 m	1.33 m	1.34 m	1.35 m	1.36 m	1.37 m	1.38 m	1.39 m	1.41 m
20 hour	1.43 m	1.45 m	1.47 m	1.49 m	1.52 m	1.55 m	1.57 m	1.61 m	1.64 m	1.67 m	1.71 m	1.75 m
21 hour	1.78 m	1.83 m	1.87 m	1.91 m	1.96 m	2.00 m	2.05 m	2.10 m	2.15 m	2.20 m	2.25 m	2.30 m
22 hour	2.35 m	2.40 m	2.46 m	2.51 m	2.56 m	2.61 m	2.67 m	2.72 m	2.77 m	2.82 m	2.87 m	2.92 m
23 hour	2.97 m	3.02 m	3.07 m	3.12 m	3.16 m	3.20 m	3.25 m	3.29 m	3.33 m	3.36 m	3.40 m	3.43 m

Table 3. daily tidal in Khoor-musa gulf in 15th March 2009.

Tidal height , Khowr-e Musa, 15 March 2009												
Time	**00 min**	**05 min**	**10 min**	**15 min**	**20 min**	**25 min**	**30 min**	**35 min**	**40 min**	**45 min**	**50 min**	**55 min**
00 hour	**2.53 m**	**2.56 m**	**2.59 m**	**2.62 m**	**2.65 m**	**2.67 m**	**2.70 m**	**2.72 m**	**2.74 m**	**2.76 m**	**2.78 m**	**2.79 m**
01 hour	**2.80 m**	**2.82 m**	**2.83 m**	**2.84 m**	**2.84 m**	**2.85 m**	**2.85 m**	**2.85 m**	**2.85 m**	**2.85 m**	**2.85 m**	**2.84 m**
02 hour	**2.84 m**	**2.83 m**	**2.82 m**	**2.81 m**	**2.80 m**	**2.78 m**	**2.77 m**	**2.75 m**	**2.73 m**	**2.71 m**	**2.69 m**	**2.67 m**
03 hour	**2.65 m**	**2.63 m**	**2.60 m**	**2.58 m**	**2.55 m**	**2.53 m**	**2.50 m**	**2.47 m**	**2.45 m**	**2.42 m**	**2.39 m**	**2.36 m**
04 hour	**2.33 m**	**2.30 m**	**2.27 m**	**2.24 m**	**2.21 m**	**2.18 m**	**2.15 m**	**2.12 m**	**2.09 m**	**2.06 m**	**2.03 m**	**2.01 m**
05 hour	**1.98 m**	**1.95 m**	**1.92 m**	**1.89 m**	**1.87 m**	**1.84 m**	**1.81 m**	**1.79 m**	**1.77 m**	**1.74 m**	**1.72 m**	**1.70 m**
06 hour	**1.68 m**	**1.66 m**	**1.64 m**	**1.63 m**	**1.61 m**	**1.60 m**	**1.58 m**	**1.57 m**	**1.56 m**	**1.55 m**	**1.55 m**	**1.54 m**
07 hour	**1.54 m**	**1.54 m**	**1.54 m**	**1.54 m**	**1.54 m**	**1.55 m**	**1.55 m**	**1.56 m**	**1.57 m**	**1.58 m**	**1.60 m**	**1.61 m**
08 hour	**1.63 m**	**1.65 m**	**1.67 m**	**1.69 m**	**1.71 m**	**1.74 m**	**1.76 m**	**1.79 m**	**1.82 m**	**1.85 m**	**1.88 m**	**1.91 m**
09 hour	**1.95 m**	**1.99 m**	**2.02 m**	**2.06 m**	**2.10 m**	**2.14 m**	**2.18 m**	**2.22 m**	**2.27 m**	**2.31 m**	**2.36 m**	**2.40 m**
10 hour	**2.45 m**	**2.50 m**	**2.54 m**	**2.59 m**	**2.64 m**	**2.69 m**	**2.74 m**	**2.79 m**	**2.83 m**	**2.88 m**	**2.93 m**	**2.98 m**
11 hour	**3.03 m**	**3.08 m**	**3.12 m**	**3.17 m**	**3.21 m**	**3.26 m**	**3.30 m**	**3.34 m**	**3.38 m**	**3.42 m**	**3.46 m**	**3.49 m**
12 hour	**3.53 m**	**3.56 m**	**3.59 m**	**3.62 m**	**3.64 m**	**3.67 m**	**3.69 m**	**3.71 m**	**3.73 m**	**3.75 m**	**3.76 m**	**3.78 m**
13 hour	**3.79 m**	**3.79 m**	**3.80 m**	**3.80 m**	**3.81 m**	**3.81 m**	**3.80 m**	**3.80 m**	**3.79 m**	**3.78 m**	**3.77 m**	**3.76 m**
14 hour	**3.75 m**	**3.73 m**	**3.71 m**	**3.70 m**	**3.67 m**	**3.65 m**	**3.63 m**	**3.60 m**	**3.57 m**	**3.55 m**	**3.52 m**	**3.49 m**
15 hour	**3.45 m**	**3.42 m**	**3.38 m**	**3.35 m**	**3.31 m**	**3.27 m**	**3.23 m**	**3.19 m**	**3.15 m**	**3.11 m**	**3.07 m**	**3.02 m**
16 hour	**2.98 m**	**2.93 m**	**2.89 m**	**2.84 m**	**2.80 m**	**2.75 m**	**2.71 m**	**2.66 m**	**2.61 m**	**2.57 m**	**2.52 m**	**2.47 m**
17 hour	**2.43 m**	**2.38 m**	**2.33 m**	**2.29 m**	**2.24 m**	**2.19 m**	**2.15 m**	**2.10 m**	**2.06 m**	**2.02 m**	**1.97 m**	**1.93 m**
18 hour	**1.89 m**	**1.85 m**	**1.81 m**	**1.76 m**	**1.73 m**	**1.69 m**	**1.65 m**	**1.61 m**	**1.58 m**	**1.54 m**	**1.51 m**	**1.47 m**
19 hour	**1.44 m**	**1.41 m**	**1.38 m**	**1.35 m**	**1.32 m**	**1.30 m**	**1.27 m**	**1.25 m**	**1.22 m**	**1.20 m**	**1.18 m**	**1.16 m**
20 hour	**1.15 m**	**1.13 m**	**1.12 m**	**1.10 m**	**1.09 m**	**1.08 m**	**1.07 m**	**1.07 m**	**1.06 m**	**1.06 m**	**1.06 m**	**1.06 m**
21 hour	**1.06 m**	**1.06 m**	**1.07 m**	**1.07 m**	**1.08 m**	**1.09 m**	**1.10 m**	**1.12 m**	**1.13 m**	**1.15 m**	**1.17 m**	**1.19 m**
22 hour	**1.21 m**	**1.24 m**	**1.26 m**	**1.29 m**	**1.32 m**	**1.35 m**	**1.38 m**	**1.41 m**	**1.44 m**	**1.48 m**	**1.51 m**	**1.55 m**
23 hour	**1.58 m**	**1.62 m**	**1.66 m**	**1.70 m**	**1.74 m**	**1.77 m**	**1.81 m**	**1.85 m**	**1.89 m**	**1.93 m**	**1.97 m**	**2.01 m**

We consider tidal in final point of southern coasts of Iran and Persian Gulf, ultimately. End point city of this region is Khorramshahr. Because of existence of Khoor-musa gulf in this region and its strong effect on tidal, we consider tidal in Khoor-musa region. Khoor-musa is in end of North-West of Persian gulf and its geographical location is $29^{\circ}36'N, 49^{\circ}35'E$. Khoor-musa depth is 20-50 m and in some regions it reaches to 73 m. Figure 18 shows preview of Khoor-musa region.

Mean head tidal in Khoor-musa is about 3.5 m and maximum of high and low tidal is about 4.5 and 0.5 m, respectively. Fig. 19 and table 3 show the details of five minutes tide period in 24 h of 15th March of 2009 in Khoor-musa.

Fig. 20 indicates Khoor-musa's tidal in March 2009.

With consideration of tidal energy in three point of southern coastal line of Iran, it concluded that tidal flow speed in Persian gulf specially in its end is about 1.5 times bigger than east points of southern coasts. Therefore, with consideration of positions and shape of Persian gulf coasts and with attention to the capacity of these regions, we could prioritize foundation of energy making in Persian gulf.

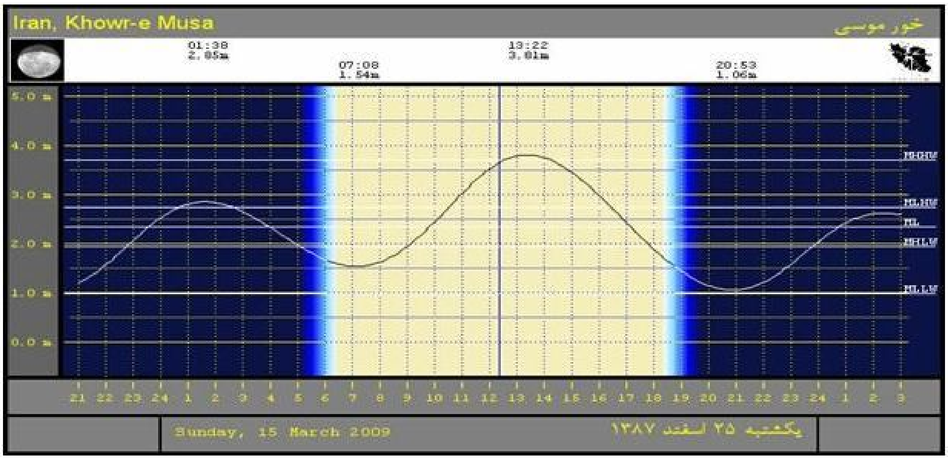


Fig. 16. Diagram of daily tidal in Khoor-musa gulf in 15th March 2009.

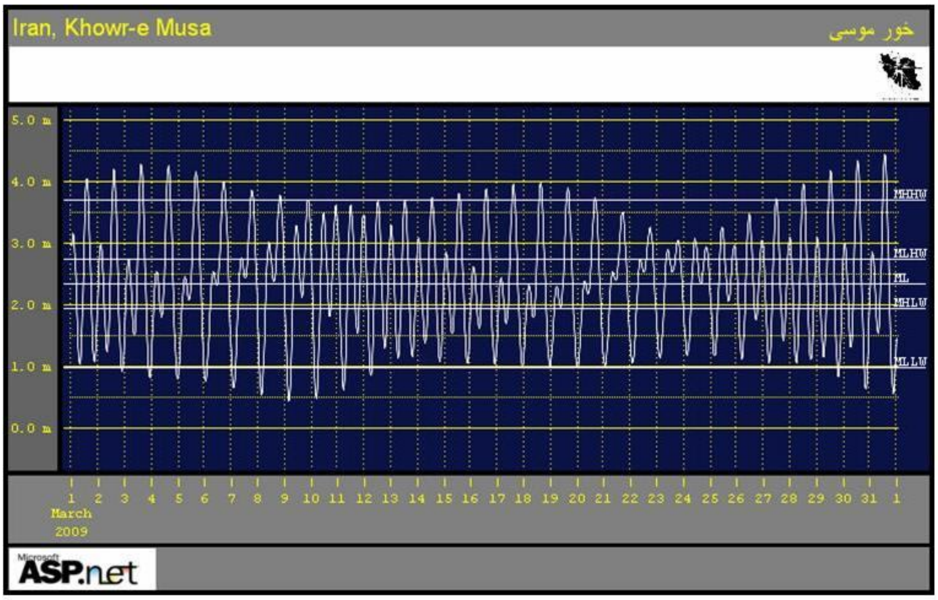


Fig. 17 Monthly tidal in Khoor-musa, March 2009.

Fig. 18 Fishing by Mashta method using tidal flows.

In some southern coasts of Iran, tidal flows are used for fishing. This method is locally called Mashta. Mashta is a method in which a net is used to build vertical partitions near the coast. Fish come into this enclosed area from its only entrance, unable to find their way back. The fishermen collect fishes when the water descents.

4. Conclusion

1- Comparing different methods of obtaining energy from tidal flows indicates that utilization of helical turbines is the best method.
2- Using tidal energy for electricity generation is economical for small regions far from power generators (small scale) and generating plants (large scale).
3- Using tidal energy, artificial coral reefs can be built by Biorock's technology, and the reefs in the danger of destruction can be repaired, in order to protect the ecosystem and developing tourism.
4- Regarding the high importance of new and renewable energies and their production importance, spending for construction of power plant and its feasibility assessment in Persian gulf seems necessary.
5- The fishery can be developed in regions such as Persian gulf by Mashta method (hunting fish using tidal force).
6- Maximum cost of generating one KW-hour energy by tidal power is approximately 1000 dollars, which is lower compared to other energies such as oil and gas.

REFERENCES

[1] Sorensen, B. 2000,Renewable energy. Second Edition. San Diego: Academic Press, 911 pp. ISBN 0-12-656152-4,.
[2] Anderson, S.2006, The tide-energy project near the mouth of the amazon.
[3] Davis, J. 2005,, Alexander's wonderful machine, Onearth
[4] Gorlov, A.M. 2001. Tidal energy. Northeastern University, Boston Massachusetts, USA Academic Press Copyright,
[5] Goreau, T.J. 2003, Global coral reef alliance. Cambridge, MA 02139, USA.

[6] Goreau, Thomas J. 2004, Global Coral Reef Alliance UN Expert Meeting on Ocean Management in Small Island Developing States, Suva, Fiji.
[7] Gorlov A M. 2004,Harnessing power from ocean currents and tides, Sea Technology, pp 40-43.
[8] Http://www.unep.or.kr/energy/ocean/oc_info.html
[9] Http://www.bluenergy.com/technology/prototypes.html