An Initial Tidal Power Resource Estimation at Jhari Creek of Indus Delta, Sindh, Pakistan

Mirza Salman Baig[a,*], Zaheer Uddin[b] and Ambreen Insaf[a]

[a]*Department of Applied Physics, University of Karachi, Karachi, Pakistan*

[b]*Department of Physics, University of Karachi, Karachi, Pakistan*

Abstract: Energy crisis in Pakistan is one of the severe challenges the country is facing today. Electricity is essential part of our daily life and its shortage has severely affected the economy and the other segments of society. This shortfall of electricity is increasing day by day and situation becomes worst especially in summer. The energy crisis are caused due to disproportionate dependence on non-renewable energy resources. The most effective solution that has been found to overcome such crisis is the use of tidal energy, because tidal energy has a significant advantage over many other forms of renewable energy as it is almost perfectly predicted over long time horizons. Therefore, first time an attempt has been made to estimate the tidal energy resources at Jhari creek of Indus Delta, Sindh, Pakistan. For this purpose real time tidal data is acquired from Pakistan Navy and tidal resources are estimated. Potential power density is calculated for the duration of four months May-August 2013 and found that highest potential mean spring power density was observed in June 2013 that was 1.67 W/m^2.

Keywords: Tidal energy, harmonic constituents, tidal range, power density and creek.

1. INTRODUCTION

Pakistan is a developing and energy deficient country. Despite its hydel, rich coal and natural gas reserves, Pakistan, like other countries of the region, is facing a serious challenge of energy crisis.

One of the major sources for producing electricity in Pakistan is from fossil fuels, demand and price of which is continuously increasing with time. Despite demand and price, fossil fuel reserves are also depleting with time and situation is arrived where Pakistan has to import fossil fuel to overcome this shortfall of electricity.

This energy deficiency will increase in coming years and a serious demand and supply in energy scenario will be predicted. Moreover, the burning of fossil fuel releases CO_2 and other harmful gasses which gives environmental problems such as global warming, ozone layer depletion and acid rains etc. The solution to these problems is the use of renewable energy resources in the energy mix of the country.

The renewable energy resource gives many environmental and economical benefits in contrast to conventional energy sources. In recent years, tidal energy is widely utilized to produce electricity in many countries such as Canada, China, United Kingdom, France etc. [1] and will be expected same for Pakistan energy mix.

Pakistan has about 1000 km long coastline with complex network of creeks in the Indus deltaic area. The creek system of Indus delta extends over an area of 1900 Km^2 [2]. The power resource potential of the Indus Deltaic Creek System is a great asset for future energy supply in Sindh, Pakistan and needed to be estimated and exploited.

On the basis of limited surveys carried out by the National Institute of Oceanography (NIO), the Indus deltaic region where seawater inundates up to 80 km inland at some places due to the tidal fluctuation [3]. These surveys and investigations show encouraging results regarding tidal potential.

The Indus creek system extends from Korangi Creek near Karachi to Kajhar Creek near the Pak India border [3].

It is highlighted that, there was no study found investigating real time tidal data to explore tidal energy resources at Jhari creek. According to [4] 10m tidal range were assumed in creek areas of Pakistan, however 10m tidal range was not observed within the creek areas. This research is carried out for the first time to estimate tidal power resources at Jhari creek using real time tidal data.

1.1. Study Area

This research was carried out at Jhari creek (67^{0}19' E 24^{0}44' N) located within the creek system of Indus Delta, District Thatta, Sindh province of Pakistan, shown in Figure **1**. Jhari creek is surrounded by Bundle Island, Port Bin Qasim and Hafeez Island. This map of

*Address correspondence to this author at the Department of Applied Physics, University of Karachi, Karachi, Pakistan; Tel: +923452847048;
E-mail: mirza_salmanbaig@hotmail.com

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study area is developed in Arc-GIS 10.2 (Geographical Information System) environment.

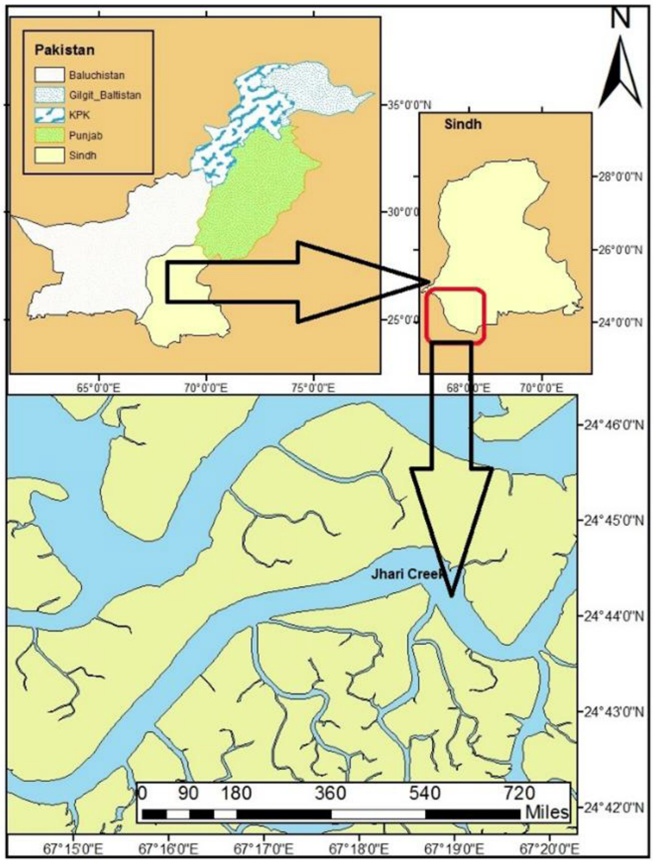

Figure 1: Map of study area.

2. MATERIAL AND METHODS

Hourly tidal data of study area for the duration of four months (May-Aug 2013) was acquired from hydrographic department, Pakistan Navy (Figure **2**). Automatic tidal gauge and tidal pole installed by Hydrographic department were used to collect tidal data. The data was processed to filter the daily high and low levels of sea water. To estimate the tidal resources at study area, different parameters including mean tidal range and mean spring tidal range were calculated.

2.1. Tidal Constituents

The tide in influenced by around 390 tidal constituents, each directly tied in with astronomical influences on the tide and having periods between 8 hours to 18.6 years. These constituents have an amplitude, phase angle and period that are added together to calculate the overall tide. Every location has a unique set of tidal constituents which are derived from tidal analysis of observations for that location. For practical tide prediction, mostly tidal constituents can be neglected that are relatively small. The relative strength of four major harmonic tidal constituents of study area and their details are listed in Table **1**.

2.2. Types of tides

There are four different types of tidal phenomena at different locations of the earth [5], which can be determined from following ratio of diurnal and semi-diurnal harmonics i.e.

$$T = \frac{O_1 + K_1}{M_2 + S_2}$$

The types of tides classified as [6]:

1. T= 0.00-0.25 (semi-diurnal form). Two high and low waters of approximately the same height.

2. T= 0.25-1.50 (mixed, predominantly semi-diurnal). Two high and low waters daily.

3. T = 1.50-3.00 (mixed, predominantly diurnal). One or two high water per day.

4. T> 3.00 (diurnal form). One high water per day.

The ratio T for the study area was calculated as 0.469 and the type of tides found at study area were mixed with predominantly semi-diurnal.

2.3. Methods for Harnessing Tidal Energy

There are basically two different methods to extract tidal energy:

1. Using marine current turbines, which harness the kinetic energy of water (roughly horizontal water motions termed as tidal currents).

2. Using barrage, which harness potential energy of water (the vertical water movements associated with the rise and fall of the tides).

In this research potential energy harnessing technique is applied for the estimation of tidal power density at study area for the duration of four months (May-Aug 2013). The tidal power model depends on the structure of barrage which comprises of gated sluices and low-head hydro turbines to maintain height difference in level of water. Such type of barrage structure can also be built by bridging two sides of creek, the purpose is to fill the basin with water during flood tide and allow to flow out from the basin during

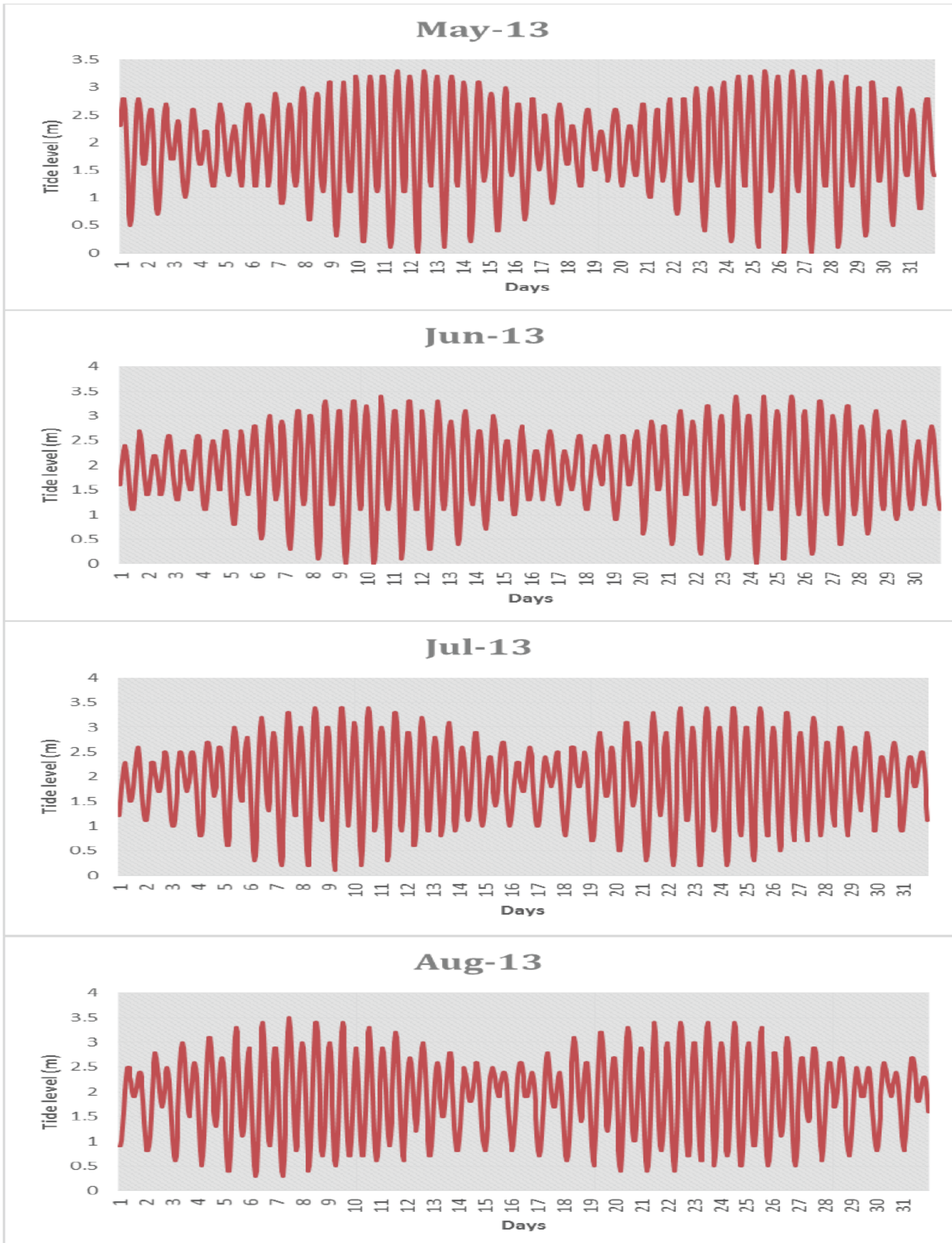

Figure 2: Tide levels at Jhari creek for different months.

Table 1: Tidal Constituents of Study Area

Symbol	Period (hours)	Frequency (rad/hour)	Relative strength	Description
M2	12.42	0.5059	100	Main lunar semidiurnal constituent
S2	12.00	0.5236	45.05	Main solar semidiurnal constituent
K1	23.93	0.2626	45.05	Luni-Solar diurnal
O1	25.82	0.2433	23.07	Main lunar diurnal constituents

Table 2: Major Sites for Tidal Power Plants

Location	Mean range (m)	Basin area (km^2)	Potential mean power (MW)	Potential annual production ($GWhy^{-1}$)	Actual installed capacity (MW)
North America					
Passamaquoddy	5.5	262	1800	15800	-
Coboscook	5.5	106	722	6330	-
Bay of Fundy	6.4	83	765	6710	17.8
Minas- Cobequid	10.7	777	19900	175000	-
Amherst Point	10.7	10	256	2250	-
Shepody	9.8	117	520	22100	-
Cumberland	10.1	73	1680	14700	-
Petitcodiac	10.7	31	794	6960	-
Memramcook	10.7	23	590	5170	-
South America					
San Jose	5.9	750	5870	51500	-
UK					
Severn	9.8	70	1680	15000	-
Mersey	6.5	~7	130	1300	
Solway Firth	5.5	~60	1200	10000	
Thames	4.2	~40	230	1400	
France					
Aber-Benoit	5.2	2.9	18	158	-
Aber-Wrac'h	5	1.1	6	53	-
Arguenon	8.4	28	446	3910	-
Frenaye	7.4	12	148	1300	-
La Rance	8.4	22	349	3060	240
Rotheneuf	8	1.1	16	140	-
Mont St Michel	8.4	610	9700	85100	-
Somme	6.5	49	466	4090	-
Ireland					
Strangford Lough	3.6	125	350	3070	-
Former Soviet Union					
Kislaya	2.4	2	2	22	0.4
Lumbouskii Bay	4.2	70	277	2430	-
White sea	4.65	2000	14400	126000	-
Mezen Estuary	6.6	140	370	12000	-
Australia					
Kimberley	6.4	600	630	5600	-
China					
Baishakou	2.4				0.64
Jiangxia	7.1	2			3.2
Xinfuyang	4.5				1.3
About five other small sites	~5				0.53
Total			~63000	~570000	~1000

the ebb tide. Difference in water level across turbines tends to rotate the turbine for power generation. Characteristics of tidal power plants currently exist are shown in the Table **2** [7]. Table **2** indicates important locations where tidal power stations were constructed with their potential mean power.

2.4. Mathematical Model for Calculating Tidal Energy

The mathematical model for calculating tidal energy per tide using barrage method is as follows [7]:

$$E = 1/2A\rho g h^2 \quad (1)$$

Where,

h is the mean tidal range

A is the horizontal area of the barrage basin

ρ is the density of water = 1025 kg per cubic meter (seawater density varies between 1021 and 1030 kg per cubic meter)

g is the acceleration due to the Earth's gravity = 9.81 m/s^2

The potential mean power for one tidal period t, equation (1) becomes:

$$P\ (mean) = A\rho g h^2/2t \quad (2)$$

Therefore, the potential mean power density = $\rho g h^2/2t$

Since we have semi-diurnal tides at study area. Therefore the total potential mean power density in a day = $(\rho g h^2/2t) \times 2$

$$PD = 1025 \times 9.81 \times h^2 / 44700\ s$$

$$= 0.225 \times h^2\ W/m^2 \quad (3)$$

Power density per tide is expressed as:

$$PD = \rho g h^2/6\ hours \quad (4)$$

3. RESULT AND DISCUSSION

This research work is an initial assessment of tidal resources at one of the creek areas of Indus Delta (i.e. at Jhari creek) using tidal barrage model method.

Hourly tidal heights were used to calculate daily high and low levels of water. Daily two ranges of sea water were extracted from these high and low levels. Mean range for each month (i.e. from May – August 2013) is determined for the study area and presented in Table **3**. Spring tides have a larger than average tidal ranges and usually occur one or two days after new and full moon. There are usually two spring tides in a month. Mean spring tide for each month is also calculated and shown in Table **3**. In barrage model, higher water head will produce greater power and therefore mean spring range would result in higher power density. Among these four months from May-August 2013, largest mean range and largest mean spring range were obtained for the month of June 2013.

Table 3: Tidal Parameters Calculated for Four Months

Duration	Mean range (m)	Mean spring range (m)
May 2013	1.951667	2.675
Jun 2013	1.967241	2.725
Jul 2013	1.94	2.7
Aug 2013	1.985965	2.625

Mathematical model for calculating tidal power density, described in section 2.4. is utilized to determined mean power density and mean spring power density for four months (Table **4**). Since spring ranges were larger than mean tidal ranges therefore mean spring power densities are also greater than mean power densities. It was found that maximum power density was observed for the month of June 2013.

Table 4: Power Density Computed from Tides

Duration	Potential mean power density (W/m^2)	Potential mean spring power density (W/m^2)
May 2013	0.856834	1.609655
June 2013	0.870564	1.670392
July 2013	0.846621	1.639883
August 2013	0.887214	1.550044

Mean tidal ranges, mean spring tidal ranges, potential mean power density and potential mean spring power density shown in Table **3** and 4 shows good results for installation tidal power plants for harnessing potential energy from tides. These results were also compared with some installed tidal power plant (shown in Table **2**) and found that tidal heights are comparable with two tidal power plants: The

Kislaya Guba Power Plant, Russia [8] and BaiShakou Power Station, China [9].

4. CONCLUSION

In this research study, an effort is made for the first time to estimate tidal energy resources at Jhari creek, Indus Delta, Sindh province of Pakistan by utilizing real time tidal data for the duration of May-August 2013. It is revealed from section 2.1 and 2.2 that type of tides are mixed with predominantly semi-diurnal at study area. It is concluded from processed tidal data (Table **3**) that tidal ranges at study area are comparable to other operational tidal power plants (described in section 3) and also mean spring power densities (Table **4**) shows significant results for harnessing tidal energy. It is also concluded that by exploiting clean tidal energy resources of creek network of Indus Delta, electricity crises and environmental pollution could be overcome.

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REFERENCE

[1] Ahmed MA, Ahmed F, Akhtar W. Wind characteristics and wind power potential for southern coasts of Sindh, Pakistan. Journal of Basic and Applied Sciences 2010; 6(2): 163-168.

[2] Mahar GA, Zaigham NA. Identification of climate changes in the lower indus basin, sindh, pakistan. Journal of Basic & Applied Sciences 2010; 6(2).

[3] Zaigham NA, Nayyar Z. Prospects of renewable energy sources in Pakistan. Renewable-Energy Technologies and Sustainable Development. Islamabad: Comsats 2005; p. 65-86.

[4] Waheed-uz-Zaman M, Saif N. To Study Feasibility of the Generation of Tidal Power Energy at Pakistan Creek Areas. Journal of American Science 2014; 10(10).

[5] Montllonch Araquistain T. Tidal power: Economic and Technological Assessment 2010.

[6] Aziz NS. Tidal energy resources assessment in Indonesia 2009.

[7] Twidell J, Weir AD. Renewable energy resources. Taylor & Francis 2006.

[8] Rourke FO, Boyle F, Reynolds A. Tidal energy update 2009. Applied Energy 2010; 87(2): 398-409. https://doi.org/10.1016/j.apenergy.2009.08.014

[9] Chang J, *et al*. A review on the energy production, consumption, and prospect of renewable energy in China. Renewable and Sustainable Energy Reviews 2003; 7(5): 453-468. https://doi.org/10.1016/S1364-0321(03)00065-0

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